FINAL REPORT

Low-intensity fires may be adequate for stand replacement of Table Mountain Pine (*Pinus pungens* Lamb.) in the Southern Appalachian Mountains

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Abstract

Previous management recommendations for stand replacement of Table Mountain/pitch pine communities were based on differences observed one year after prescribed burning. Fires reaching into the crowns of trees were recommended to kill all overstory trees and leave adequate pine regeneration. Cooler fires did not kill overstory trees and hotter fires reduced pine germination. However, measurements taken in one of the original six burn units showed delayed overstory mortality for several years after burning, regardless of fire intensity, and pine seedlings survived. Stand replacement on that unit was achieved with fires of relatively low intensity. Therefore, low intensity fires may be adequate for stand replacement while achieving safety goals. This project re-measured study plots in all burn units to examine delayed overstory mortality and early stand dynamics in areas burned at each of four fire intensity levels. We measured 6 burn units in Georgia and South Carolina for up to 11 years after burning. Burns with flame heights of 6 to 8 feet or higher successfully killed overstory trees and allowed adequate pine regeneration. Lower intensity flames killed some overstory trees but left 60 ft^2/ac of basal area. Shade from residual overstory did not severely impact pine regeneration density but it did slow height growth. Competition from sprouts of hardwoods and shrubs did not impact pine density differently among areas burned at differing intensities. Stand replacement was not achieved by low intensity fires but complete mortality of overstory trees was not necessary to regenerate Table Mountain pine.

Data collected for this study, along with data from another project funded by JFSP, were used for a third and corollary study. Two existing theoretical models of the temporal abundance of Table Mountain pine were tested using dendrochronological techniques. Four Table Mountain pine communities in Georgia, South Carolina, and Tennessee were analyzed for species recruitment trends, radial growth patterns, and known disturbance histories. A temporal abundance model was entirely validated. In all stands, pines reproduced for a century or more before large surges in regeneration occurred during the early to mid 20th century. After that, pine regeneration declined sharply before ceasing several decades ago. A disturbance – succession dynamics model was partially validated. Generally, pine regeneration followed fires while bark beetle infestations, storm damage, and other canopy disturbances favored hardwoods. However, these stands are not succeeding to oak. Rather, mountain laurel is replacing both pines and oaks. In the absence of periodic fire, these stands will convert to heath shrublands.

Background and Purpose

Table Mountain pine (*Pinus pungens* Lamb.) is a species in decline in the Appalachian Mountains due to changes in land use. Stands occur from central Pennsylvania to northeast Georgia on shallow, dry soils with southern and western aspects (Zobel 1969). Throughout the region, stands in which this species occurs are entering later seral stages where pines are beginning to be dominated by oaks (particularly chestnut oak, *Quercus prinus* L.) and hickories (*Carya* spp.) (Zobel 1969, Turrill and others 1997). This pattern indicates that the short-lived, shade-intolerant pines are being replaced by the longer-lived, shade tolerant hardwoods. Table Mountain pines have serotinous cones and this suggests that fire may be needed to regenerate this species. Microsite conditions needed for seedling establishment are similar to those created by fire. Williams (1998) stated that Table Mountain/pitch pine stands are in decline as a result of fire suppression and inadequate understanding of regeneration biology.

Fire exclusion policies in the Southern Appalachian Mountains have reduced the abundance of fire dependent species such as Table Mountain pine (Zobel 1969). High-intensity, stand-replacement prescribed burning has been suggested as a tool to reverse the decline but accomplishing these burns is difficult (Welch and others 2001). Few studies have used prescribed fire for stand replacement of Table Mountain pine. Turrill (1998) planned ten fires on federal lands throughout the Southern Appalachian Region. Only four of the burns were conducted during the 3-year study period. Of those, only one burn produced Table Mountain pine regeneration, emphasizing the difficulty of using stand-replacement fire. The burning window is extremely limited, and safety of personnel and smoke management considerations are of primary concern. Prescriptions calling for intense crown fires effectively narrow the burning window and raise questions about worker safety and smoke management. If Table Mountain pine can be regenerated without crown fires, then some of these problems could be diminished or eliminated.

Waldrop and others (1999, 2000, 2002) compared regeneration success in six burn units after prescribed fires of varying intensity. High- and medium-high intensity fires killed most overstory trees and provided adequate sunlight for pine seedlings, with sufficient seedling densities to restore pine-dominated stands (< 22,000 per ac) after all but the highest intensity fires. Poor regeneration after high-intensity fires was unexpected and ran counter to what previous research suggested.

Further examination suggested that high intensity fires reduced seedbed habitat quality by drying the site (Mohr and others 2002). In that study, pine seedlings had better survival under low shade with a thin duff layer than in full sunlight with exposed mineral soil. A study of seed biology (Gray and others 2002), showed that poor regeneration after high-intensity fires was not due to a poor seed source. Rather, the fires probably consumed the cones or killed the seeds within. Another study showed that high-intensity fires reduced mycorrhizal abundance, which also limited moisture availability for the newly germinated pine seedlings (Ellis and others 2002). These studies suggested that medium-low (subcanopy flames with hot spots) and low intensity (subcanopy flames) fires were not the answer as they did not kill overstory trees and left too much shade on the forest floor.

Other work, demonstrated that ridgetop pine communities in GA and SC historically were created and maintained by multiple low-intensity fires rather than a single stand-replacement fire. In a dendrochronology study, Brose and others (2002) and Brose and Waldrop (2006) showed that Table Mountain pine stands are uneven-aged; trees ranged from 50- to 150-years-old. Pines regenerated frequently from approximately 1850 to 1950, probably due to open conditions maintained by low-intensity fires. Mountain laurel (*Kalmia latifolia* L.) became more common after 1950, probably due to fire exclusion. These results agree with similar studies done in Virginia (Sutherland and others 1995) and Tennessee (Armbrister 2002).

Waldrop and others (2006) re-measured study plots in one of the six original burn units to examine early stand dynamics as impacted by fire intensity. Results suggested that their earlier recommendations were premature. Fires of all intensities created successful stand replacement of Table Mountain pine. All overstory hardwoods died and pine regeneration increased in density over time. Hardwood mortality was not immediate; it occurred over a three- to six-year period. The cause of delayed hardwood mortality was unknown. In that study, both pine seedlings and hardwood sprouts were abundant and competition varied among plots burned at different intensities. High intensity fires may have dried these already xeric sites, thus impacting early stand development. Competition between pine seedlings and hardwood sprouts in young stands was shown to impact later stand composition in the Piedmont region (Lloyd and others 1993, Waldrop 1997). However, successful regeneration of Table Mountain pine has been too limited to allow a study of early stand dynamics in this type. In this study, previously-sampled plots in stands burned 6 to 11 years ago were followed to (1) examine overstory mortality over time as impacted by fires of differing intensity and (2) to determine if observed differences in growth of regenerated pines and hardwoods are a result of fire intensity.

Study Description and Location

A total of 177 study plots, 0.05 ac in size, were established in five burn units in the mountains of Georgia and South Carolina. Burn units are located on the Chattooga River Ranger District of the Chattahoochee National Forest in Georgia and the Andrew Pickens Ranger District of the Sumter National Forest in South Carolina. Units on the Chattooga River Ranger District are known as upper Tallulah (n=60), Big Ridge (n=14), and Roach Mill (n=50). Those on the Andrew Pickens Ranger District are known as Poor Mountain (n=39) and Toxaway Ridge (n=14). Each site was selected because it was dominated by Table Mountain pine and was scheduled for stand-replacement prescribed burning.

Burns were conducted in the winters of 1998 through 2004; each burn unit was a minimum of 500 acres in size. All burns were conducted in winter and all but Toxaway Ridge were ignited by helicopter using a plastic sphere dispenser. Fire behavior ranged from subcanopy ground fires to crown fires reaching above the stand canopy and carrying through canopies. Fire intensity category was inferred for each plot using fire severity variables in a discriminant function (Waldrop and Brose 1999) and described as low, medium-low, medium-high, and high. Energy release for each intensity category was estimated from observed flame lengths using Byram's flame length index (Brown and Davis 1973). Maximum energy release was estimated to be 300 BTU/sec/ft for low intensity fires, 1,200 BTU/sec/ft for medium-low intensity fires, 13,000 BTU/sec/ft for medium-high intensity fires, and 40,000 BTU/sec/ft for high intensity fires. Observed fire behavior for each category was described as subcanopy ground fires (low), subcanopy ground fires with hot spots where jackpot fuels occurred (medium low), flames reaching into overstory tree crowns (medium high), and flames equal to or exceeding tree height (high).

Study plots were established only in the portion of the burn unit occupied by Table Mountain pines, predominantly on the ridges and south-facing slopes. The study had an unbalanced completely random design with fire intensity as the independent variable. Plots were given permanent markers, mapped, and coordinates were measured by a Geographic Positioning System, thus allowing easy reestablishment.

Preburn and first-year post-burn measurements included overstory d.b.h., species, and mortality; hardwood abundance; and species and size of pine regeneration. Regeneration was measured in each of 28 subplots, 6.5 by 6.5 ft in size, spaced systematically throughout the 0.05-ac sample plots. Seven subplots were established along each of four transects so that subplot centers would be at a 10 by 10 ft spacing. At each plot center, two 6.5 ft long PVC pipes were placed at right angles to each other and crossing at their centers. With this placement, the pipes outlined four 3 by 3 ft quadrants. Seedlings and sprouts of hardwoods were counted and recorded by species in one randomly-selected quadrant at each of the 28 subplots. For sprouts, number of sprouting rootstocks and number of sprouts per rootstock were recorded. A complete description of measurements appears in Waldrop and Brose (1999). Study plots were measured periodically in winter through 2008-2009 using identical field procedures. The year(s) of measurement depended on the year of burning so that the resulting measurements would provide data through the sixth growing season after burning for all units (Table 1). Exceptions were the Roach Mill and Toxaway units which were burned a second time after 5 years. Therefore, those units have stand development data for only the first 3 years after the first burn. Statistical analysis of vegetative data was by one-way analysis of variance (ANOVA) or by ANOVA with repeated measures as appropriate. An alpha of 0.05 will be used for the overall study.

Table 1. Stand ages at the time of sampling each Table Mountain pine burn unit.

Sample year	*Upper Tallulah*	*Poor Mountain*	*Big Ridge*	*Roach Mill*	*Toxaway*
Winter 1997-1998	1	-	-	-	-
Winter 1998-1999	2	1	-	-	-
Winter 1999-2000	3	2	-	-	-
Winter 2000-2001	-	-	-	-	-
Winter 2001-2002	-	-	-	-	1
Winter 2002-2003	6	5	-	-	-
Winter 2003-2004	-	-	1	-	3
Winter 2004-2005	-	-	2	1	-
Winter 2005-2006	-	-	3	-	-
Winter 2006-2007	-	-	4	3	-
Winter 2007-2008	11	10	-	-	-
Winter 2008-2009	-	-	6	-	-

Key Findings

OVERSTORY MORTALITY

- Fires of all intensities significantly reduced basal area during the first growing season after burning.

- First-year overstory mortality following the expected pattern of more mortality in areas burned at higher intensities.

- Mortality continued through the third growing season in plots burned at the three higher intensity categories but additional mortality was observed in low intensity plots between year 3 and year 6.

Fire behavior was exceptionally variable among the six burn units and, therefore, data describing changes in overstory survival, pine regeneration, and hardwood competition were equally variable. Analysis of variables measured in each individual burn unit has not yet been completed, but will become an important portion of papers submitted to journals. For the purpose of this report, we will present results of all burn units combined. Also only 2 burn units remained intact (without a second burn) past year 6. Therefore, data from the 2 remaining units, stand ages 10 and 11, were combined as one category.

Stand basal area of all species combined was similar across all fire intensity categories prior to treatment (fig. 1). Basal area ranged from 104 ft^2/ac in areas that eventually burned with high intensity to 129 ft^2/ac in areas that eventually burned at low intensity. Fires of all intensities significantly reduced basal area during the first growing season after burning with the amount of mortality following the expected pattern of more mortality in areas burned at higher intensities. Basal area was significantly different between each combination of intensity level in year 1, ranging from 95 ft^2/ac in areas burned at low intensity to 38 ft^2/ac in areas burned at high intensity.

Mortality of overstory trees continued in all burn units and in areas burned at all fire intensities through year 2 (fig. 1). Basal area reduced in plots burned at low intensity to 78 ft^2/ac. There was no significant difference in basal area between plots burned at the two medium intensity categories; both had 43 ft^2/ac. Plots burned at high intensity had only 15 ft^2/ac of surviving trees in the second year.

Mortality continued through the third growing season in plots burned at the three higher intensity categories, with basal area of surviving trees ranging from 27 ft^2/ac in plots burned at medium low intensity to only 1 ft^2/ac in plots burned at high intensity. There was no additional mortality in plots burned at low intensity between the second and third growing seasons. However, additional mortality was observed in low intensity plots between year 3 and year 6. Basal area in plots burned at the three higher intensity categories began to increase between the third and sixth growing seasons, possibly due to regeneration growing into the minimum size class to be included in basal area calculations. This increase was also observed in the plots burned at low intensity between the sixth year and the final measurement of the study (years 10-11 depending on location). Although unmeasured, this increase could be a combination of ingrowth of regeneration and diameter growth of surviving trees.

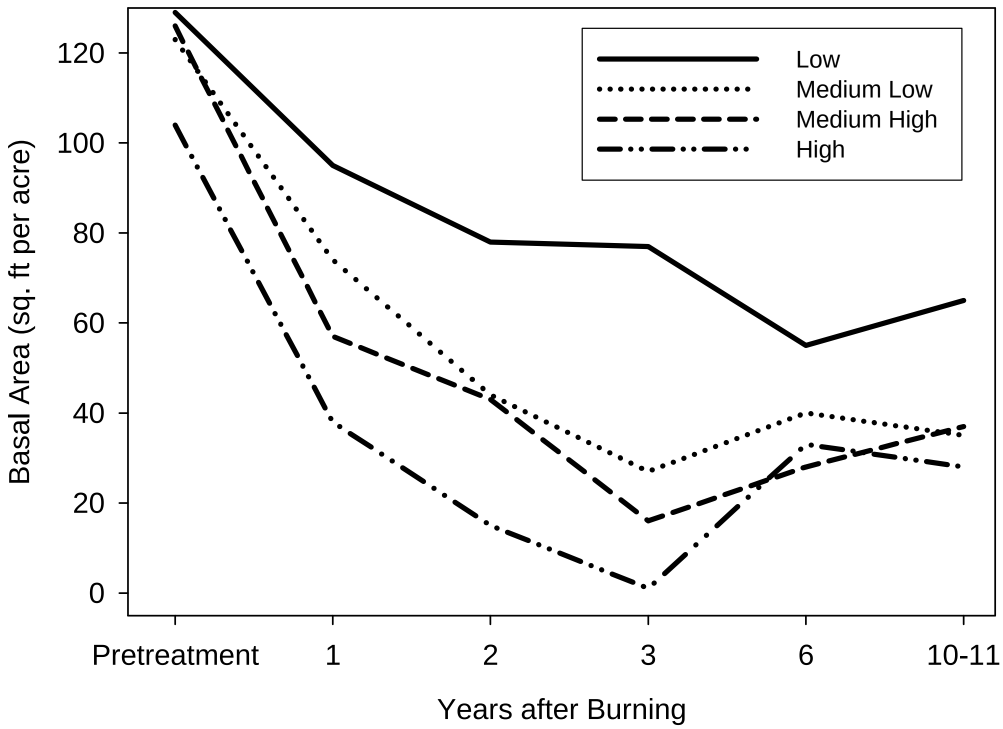

Figure 1. Basal area of surviving trees after prescribed burning by intensity category and year.

PINE REGENERATION

- Pine regeneration was abundant in plots burned at almost every intensity category and in almost every year. Shading from residual overstory trees did not eliminate pine regeneration.

- Pine numbers varied from year to year but remained significantly higher in each of the three highest intensity categories during most years.

- Low intensity burning produced significantly fewer pine seedlings per acre than most other intensity categories in years 1, 2, and 10-11.

- We consider that the density of pines was successful for all fire intensity categories.

Pine regeneration was abundant in plots burned at almost every intensity category and in almost every year (fig. 2). The most common pine species was Table Mountain pine but pitch pine (*Pinus rigida* Mill.) and white pine (*Pinus strobus* P.) were present in small numbers in some burn units. Plots burned at the three highest categories had no fewer that 454 stems per acre, a threshold value that we consider to represent successful regeneration based on a 10 by 10 foot spacing (Waldrop and Brose 1999), at any time during the 11-year study. Pine numbers varied from year to year but remained significantly higher in each of the three highest intensity categories during most years. During the first 6 years, numbers in three highest categories ranged from a low of 1,402 stems per acre in year 3 to a high of 10,552 in year 6. The lowest number of pines was in plots burned at the high intensity category during the 10- to 11-year period. There, 898 pines per acre had survived early stand competition and self thinning, well above the threshold to be considered successful.

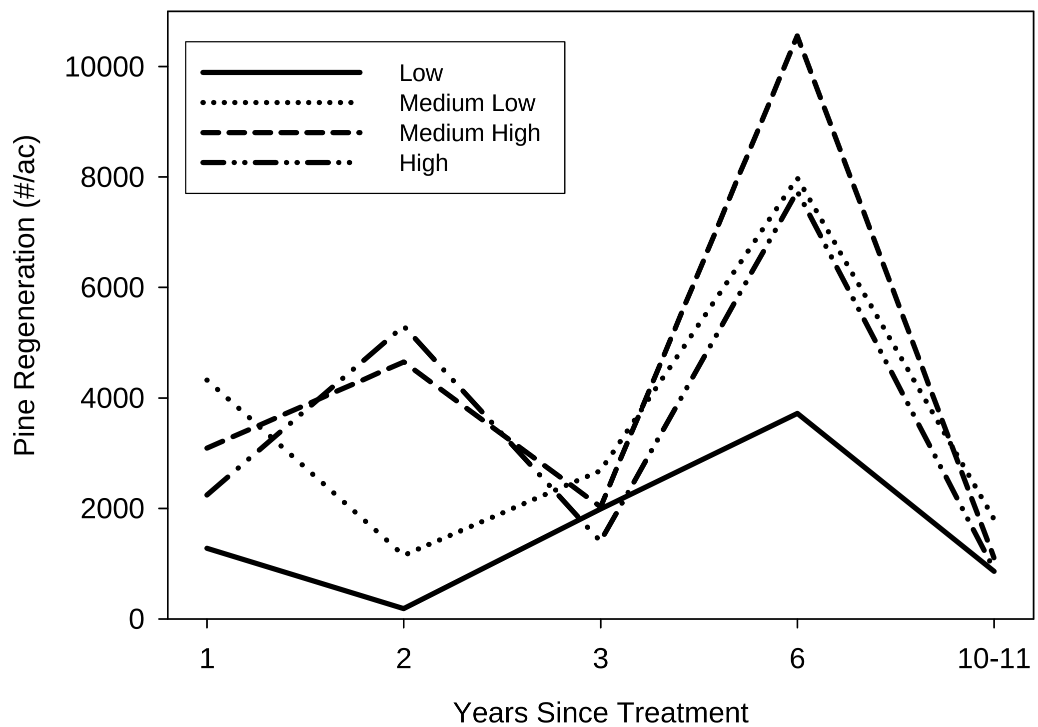

Figure 2. Pine regeneration by intensity category and year since burning.

Low intensity burning produced significantly fewer pine seedlings per acre than most other intensity categories in years 1, 2, and 10-11. These plots had 1,278 pine seedlings per acre the first growing season after burning but only 100 per acre during the second year, suggesting that overstory shading may be killing regeneration. However, pine regeneration numbers in these plots increased to over 3,700 per acre in year 6 as overstory trees continued to die. A total of 859 pines per acre survived until the 10 to 11-year period. Even though pine regeneration numbers varied greatly and were below threshold levels in some years, we consider that the density of pines was successful for all fire intensity categories.

COMPETITION

- Sprouts overtopped young pines during year 1 and continued to be strong competitors throughout the study.

- Plots burned at medium high and high intensities had significantly higher numbers of hardwood sprouts than did plots burned at lower intensities, largely because shrubs were abundant prior to burning and caused the high intensity.

- At stand ages 10 to 11, hardwood and shrub density was considerably lower at all intensity levels as sprouts and pine regeneration grew and approached crown closure.

- Hardwood sprouts overtopped pines regardless of fire intensity level through year 6 but, then, Table Mountain pines grew more quickly than did hardwoods so that by stand ages 10 to 11, Table Mountain pine had overtopped hardwoods and shrubs in plots burned at almost all intensities.

A continuing concern for pine survival is competition from hardwood and shrub spouts. These sprouts overtopped young pines during year 1 and 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. During the first year after burning, plots burned at medium high and high intensities had significantly higher numbers of hardwood sprouts than did plots burned at lower intensities. Numbers of shrub sprouts were essentially double in plots burned at high intensity than in all other plots. These differences should not be considered a treatment effect, however, because the difference was due to density prior to burning. Hardwoods and shrubs had heavy cover in these plots before burning, thus providing the vertical fuels to create the high intensity fires. Numbers of hardwood sprouts decreased somewhat the second year after burning but increased again by the third year. Significant differences occurred again only in the higher intensity plots where preburn density was high. The total number of hardwood sprouts was significantly higher in plots burned at medium-high and high intensity in year 2 but there were no differences in year 3. Shrub density remained significantly higher in plots burned at high intensity through the first 3 years.

By year 6, mountain laurel sprouts were exceptionally dense in plots burned at medium high and high intensities. Sprouts of all hardwood species were dense and significantly greater in number in plots burned at medium low intensity than those burned at low intensity. There was no significant difference in hardwood sprout density in plots burned at medium high and high intensity but both intensities had significantly higher numbers of hardwood sprouts than did plots burned at the two lower intensities.

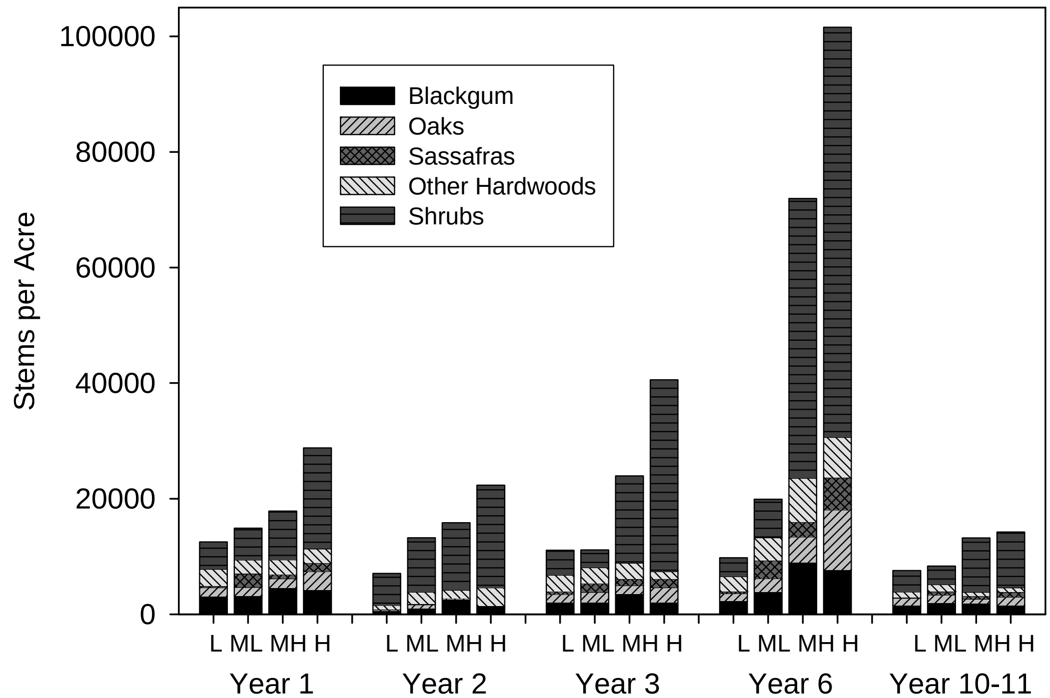

Figure 3. Number of hardwood and shrub sprouts by intensity category and year since burning, L=low, ML=medium low, MH=medium high, H=high.

During the 10- to 11-year period, hardwood and shrub density was considerably lower at all intensity levels as sprouts and pine regeneration grew and approached crown closure. Hardwood density during this last period was significantly lower in plots burned at low intensity than in all other plots. Shrub density remained significantly higher in plots burned at the two high intensities. Even though shrub and hardwood sprout density remained high, competition did not seem to greatly impact pine survival.

During year 6, hardwood sprouts overtopped pines regardless of fire intensity level (fig 4). Hardwoods were approximately 7 feet tall, while Table Mountain pines were 3 to 4 feet tall and pitch pines were 2 to 3 feet tall. Table Mountain pine overtopped shrubs in the high intensity category but remained shorter than shrubs in all other categories. Pitch pine remained overtopped by all other vegetation through year 6.

Table Mountain pines grew more quickly than did hardwoods between the time they were measured in year 6 and measurements made for the 10- to 11-year category. By the last measurement Table Mountain pine had overtopped hardwoods and shrubs in plots burned at all intensities except the medium-high category (fig 5). Pines and hardwoods were generally taller when growing in plots burned at the higher intensity categories, suggesting a shading effect from residual overstory trees left in plots burned at the lower intensity categories. In plots burned at low intensity, Table Mountain pines averaged 7.2 feet tall and hardwoods were 6.9 feet tall. In contrast, Table Mountain pines in plots burned at high intensity were 10.7 feet tall and hardwoods were 10.0 feet tall.

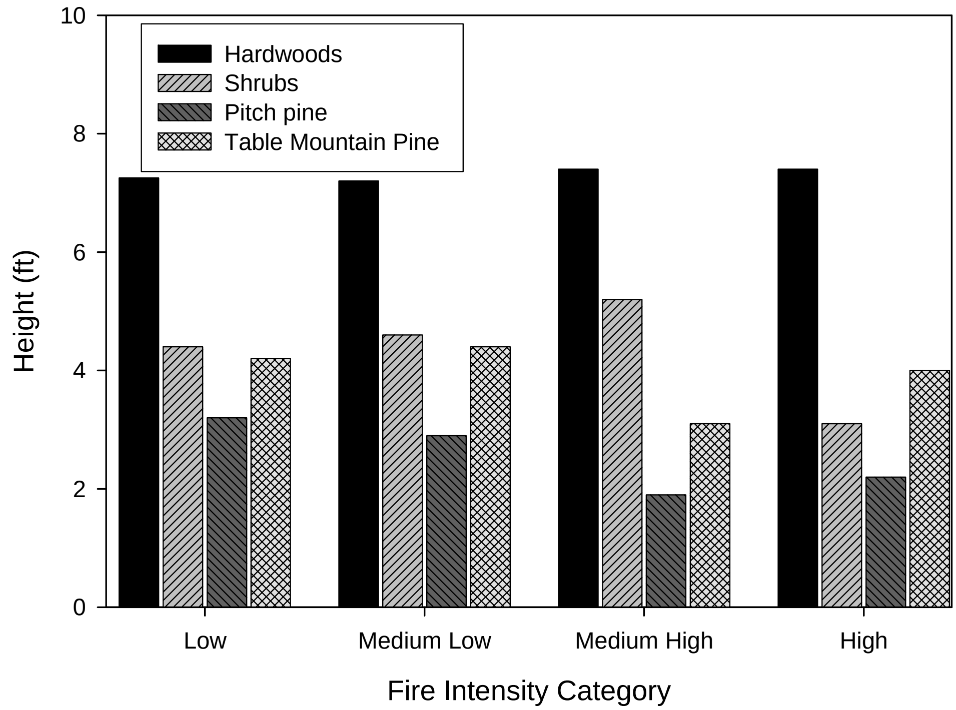

Figure 4. Relative height of pine seedlings with hardwood and shrub sprouts at the end of 6 growing seasons after burning.

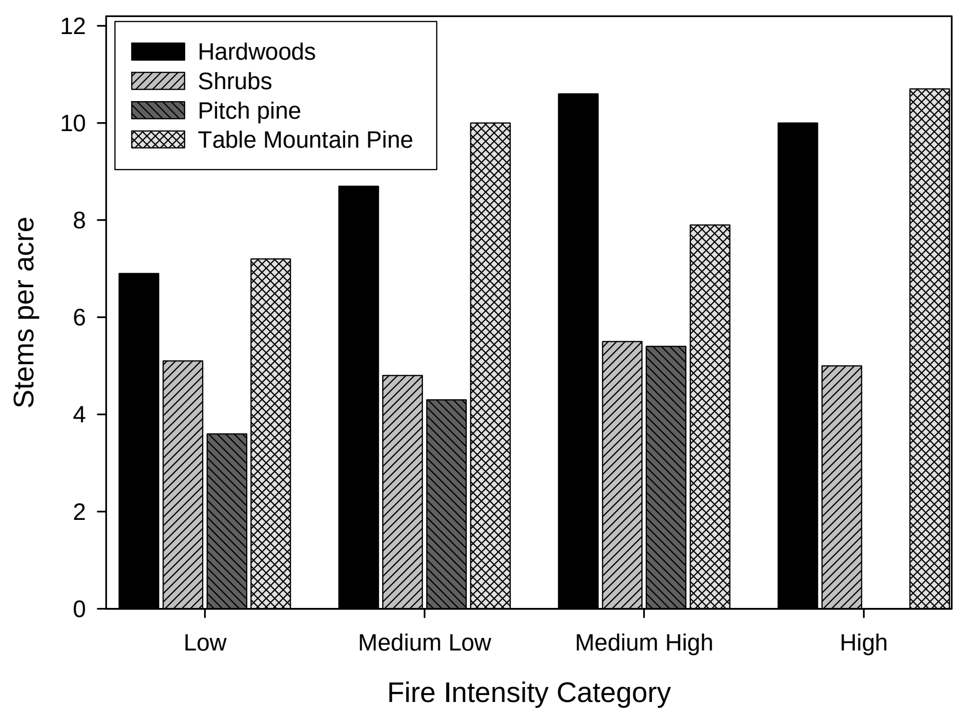

Figure 5. Relative height of pine seedlings with hardwood and shrub sprouts at the end of 10 to 11 growing seasons after burning.

COROLLARY STUDY

- The findings of this study clearly support a temporal abundance model of Table Mountain pine occurrence over several centuries.

The species establishment data from all four sites showed a baseline density of pines (pre-European, frequent low-intensity fire) followed by a marked increase in their abundance (post-European, logging, fire and disease) then a significant decline (fire exclusion policy). None of the sites has had any successful pine regeneration for several decades. In the temporal abundance model, this pattern adheres to the pre-European settlement, expansion, and decline phases.

- The successional stability model is partially supported.

This model proposes that Table Mountain pine communities convert to stable (self-perpetuating) oak forests in the absence of fire and the persistence of canopy-level disturbances. The structure of these communities gives that impression; dominant pines and intermediate oaks. However, our species establishment data indicate that Table Mountain pine communities are not converting to mixed-oak forests. Rather, oak has always been a part of these ecosystems. Oaks and pines are the same age despite their size differences. Oak regeneration rose and fell at the same time as the pine establishment and to the same degree. Oaks did not continue regenerating successfully after pine reproduction had ceased. Instead of converting to stable mixed-oak forests, Table Mountain pine ecosystems temporally transition to them before ultimately succeeding to mountain laurel thickets.

- Study results add new knowledge to our understanding about the regeneration ecology of Table Mountain pine communities and of the roles of fire, canopy disturbance events, and their interaction in the maintenance of these ecosystems.

The majority of the fires were widespread, burning through most or all of a site, but not intense as many small oaks and pines survived. Many of the fires were during the dormant-season, indicating they were likely caused by humans and spread upslope from their origin. This is consistent with findings from fire history studies throughout the Table Mountain pine forest type. However, some small fires in GA and TN started during the growing season, suggesting they were caused by lightning. Such fires are rare in the southern Appalachian Mountains, but when they do occur, it is in this plant community.

Management Implications

- Overstory hardwoods may be killed by prescribed fires of even low intensity (flame heights < 6 feet) but mortality may not occur for 3 or more years.

This fact should be considered when evaluating the success or failure of any prescribed fire. An evaluation done soon after burning might consider a fire a success because most overstory trees survived but that same fire might be considered a failure 4 years later. The opposite is true if the objective was for stand replacement or thinning. Fire intensity does not need to be as high as once thought to reach levels of high mortality. Flame heights of 6 to 8 feet killed many trees and allowed for successful pine regeneration. Even though these are relatively hot fires, they are easier to plan and control than are the crown fires once thought necessary.

- Pine regeneration density was not impacted by fire intensity.

Fires of all intensities had enough pine regeneration to be considered successful through the study period, again, showing that fire intensity can be moderate to regenerate this declining species.

- Pine density was extremely variable among study sites.

There was no clear indication that fire intensity had any impact on the number of seedlings present at any year. This suggests that other factors are more important. Possible considerations are the number of cones present on the trees and if the cones are open. Even though these are serotinous cones, personal observation is that they will open on a hot dry day and drop seed. A survey of cone abundance and degree of openness prior to burning might prevent a burn that is unsuccessful for Table Mountain pine regeneration.

- Low-intensity fires left 60 ft^2/ac of basal area of overstory trees with some Table Mountain pine regeneration.

Some management objectives call for restoration of open woodlands. Although the residual basal area is not defined for this objective, this study indicates and low intensity fires can cause some mortality and begin the process of restoration. A single fire was not successful at restoring sites to the woodland condition because sprouts of hardwoods and shrubs became abundant.

- Pines are strong competitors with hardwood and shrub sprouts.

Fires of varying intensity have little effect on controlling sprout density. Therefore, extreme fire conditions are not needed. Once pines become established, they lag behind sprouts in height growth for a number of years (6-10) but eventually overtop the sprouts. Intermediate treatments such as release or prescribed burning are probably not necessary for survival of some Table Mountain pine trees but may help to improve growth or species composition if a pure Table Mountain pine stand is desired.

- The corollary study validated a model of Table Mountain pine historical abundance.

This information is critical for planning prescribed burning programs that replicate historical conditions. These results show that prior to European contact, Table Mountain pine regenerated frequently and abundantly, possibly due to frequent low-intensity fires. Infrequent conflagrations were certainly a component of this ecosystem but the species was most likely perpetuated by frequent fires.

Bottom Line:
Low-intensity fires are <u>not</u> adequate for stand replacement of Table Mountain Pine in the Southern Appalachian Mountains. However, stand replacement may not be necessary. Single low-intensity fires did not kill all of the overstory but they did allow abundant regeneration of Table Mountain pine. These fires may eventually promote restoration of an open woodland condition which, historically, may have been the most common habitat where the species was found.

Future Work Needed

Intermediate stand management. As designed, this study provides valuable management information for prescription of fires for stand replacement and restoration of Table Mountain pine communities in the Southern Appalachian Mountains. It allows a comparison of early stand dynamics and competition to evaluate the regeneration/ restoration success of stand replacement fires. However, the next step in managing for restoration goals is uncertain. In the stands that we are measuring, pines are dense with over 1,600 stems per acre but hardwoods are extremely thick, with as many as 8,000 stems per acre, and they overtop pines for several years. Prescribed burning or mechanical release may help to ensure the success of the preferred pines but these operations have never been used in young stands such as these. The Chattooga Ranger District of the Chattahoochee National Forest is considering treatments to release Table Mountain pine. However, this practice has never been attempted in this type of stand. Work in the Coastal Plain of SC indicates that the pines may be large enough to withstand a backing fire that would help to top-kill hardwood and shrub sprouts. Mechanical treatments would probably be successful but the cost may be cost prohibitive.

Establishment of an open woodland community. Results of this work indicate that fire can be used to thin overstory trees, thus changing stand structure to resemble the open woodland community that is described as a management objective for many Appalachian forests. However, this study also showed that a single fire, even one that was relatively hot, could not achieve that objective because it did little to control sprouting of hardwoods and shrubs. Very little information is available about the impacts of repeated prescribed burning in the southern Appalachian Mountains but frequent low-intensity fires, with or without mechanical treatments, may help to speed the process. Little is known about the impacts on competitors, such as red maple, yellow-poplar, and invasive plants.

Appendix 1. Crosswalk between proposed and delivered outreach activities.

Proposed	Delivered	Status
Refereed paper - Prescription recommendations for stand replacement	Draft complete. The manuscript makes up the bulk of this final report.	Ready for submission to *Forest Ecology and Management* mid-July 2009.
Manager Workshop - Prescription recommendations for stand replacement	Hosted by the Southern Blue Ridge Fire Learning Network in conjunction with discussions of results from the Fire and Fire Surrogate Study. April 2007.	Completed
Refereed paper - Relative growth of pines and hardwoods as impacted by fire intensity	Negative results of the study will make this paper difficult to publish in a refereed journal. It will be drafted from the current report for the Southern Silvicultural Research Conference.	Analysis complete
Conference presentation and abstract	Restoration of Table Mountain Pine Communities with Prescribed Fire – A Question of Fire Intensity, Seed Availability, or Soil Properties? Conference of Soil Restoration Concepts, Chicago Illinois. December 18, 2006. Presentation and abstract.	Completed
RWU Science Highlights and fact sheets	Low-intensity fires may be adequate for stand replacement of Table Mountain Pine (*Pinus pungens* Lamb.) in the Southern Appalachian Mountains	Completed
Tours -	Stand replacement prescribed fires for regeneration of Table Mountain pine. Two graduate and three undergraduate classes (Clemson University and Haywood College) 2007-2009 Biennial Southern Silvicultural Research Conference (2007)	Completed

Appendix 2. **O**utreach activities in addition to proposed deliverables.

Item	Delivered	Status
Refereed publication	Brose, Patrick H.; Waldrop, Thomas A. Disturbance-succession dynamics of Table Mountain pine communities in the southern Appalachian Mountains. *Canadian Journal of Forest Research*. Submitted March 2009.	In review.
Conference presentation and abstract	Brose, Patrick H.; Waldrop, Thomas A. 2009. A comparison of low and high elevational Table Mountain pine forests in the southern Appalachian Mountains. In: Stanturf, John A. ed. Proceedings of the 14th biennial southern silvicultural research conference. 2007 February 26-28; Athens, GA. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.	Complete
Conference presentation	Brose, Patrick H.; Waldrop, Thomas A. 2006. Changes in the disturbance regime of upland yellow pine stands in the southern Appalachian Mountains during the 20th century. Third International Fire Ecology and Management Congress, San Diego CA, Nov. 13-17, 2006.	Complete
Conference paper and presentation	Brose, Patrick H.; Waldrop, Thomas A. 2006. Changes in the disturbance regime of upland yellow pine stands in the southern Appalachian Mountains during the 20th century. Pp. 467-470. In: Conner, Kristina F., ed. Proceedings 13th biennial southern silvicultural research conference. 2005 March 1-3; Memphis, TN: Gen. Tech. Rep. SRS-92; Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 640pp.	Complete
Conference presentation.	Brose, Patrick; Waldrop, Thomas. Determining a Mixed-Severity Fire Regime for Appalachian Yellow Pine Stands. 2009 North American Forest Ecology Workshop.	Complete

Item	Delivered	Status
Refereed Journal paper	Brose, Patrick; Waldrop, Thomas. Determining a Mixed-Severity Fire Regime for Appalachian Yellow Pine Stands. 2009 North American Forest Ecology Workshop. Submitted to International Journal of Forestry Research, June 2009.	In review.
Station research paper	Mohr, Helen H.; Waldrop, Thomas A. High-intensity fires reduce seedbed quality for Table Mountain pine (*Pinus pungens*). SRS Research paper	In revision.
Fire encyclopedia	Waldrop, Thomas A.; Brose, Patrick H.; Welch, Nicole Turrill. 2007. Fire and the Ecology of Table Mountain Pine. Chapter for internet-based fire encyclopedia. http://fire.forestencyclopedia.net/	Complete
Textbook Chapter	Waldrop, Thomas A.; Phillips, Ross J. Restoring Fire-Adapted Forests in Eastern North America for Biodiversity Conservation and Hazardous Fuels Reduction. Chapter in Stanturf, J.A., P. Madsen, D. Lamb, eds. A Goal-Oriented Approach to Forest Landscape Restoration.	Draft begun
Conference presentation	Yaussy, Daniel A.; Waldrop, Thomas A.; 2006. Delayed mortality of eastern hardwoods – a function of fire behavior, site, or pathology? Third international wildland fire ecology and fire management congress. 2006 November 13-16; San Diego, CA: Washington State University Extension Service.	Complete
Conference presentation and abstract	Yaussy, Daniel A.; Waldrop, Thomas A. 2007. Delayed mortality of eastern hardwoods after prescribed fire. 34TH Annual Natural Areas Conference. October 9-12, 2007, Cleveland, OH. Abstract	Complete
Conference poster and abstract	Waldrop, Thomas A.; Yaussy, Daniel A. Delayed mortality of Eastern hardwoods after prescribed fire. 2nd IAWF meeting, Destin FL	Complete

Item	Delivered	Status
Conference presentation, abstract, and paper.	Yaussy, Daniel A.; Waldrop, Thomas A. 2009. Delayed mortality of eastern hardwoods after prescribed fire. In: Stanturf, John A. ed. Proceedings of the 14th biennial southern silvicultural research conference. 2007 February 26-28; Athens, GA. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.	In press.
Briefing to Chief Dale Bosworth	Fire in the Appalachian Mountains – Restoration and fuel management research May 2006	Complete
Field trip	Restoration and fuel management research in the southern Appalachians JFSP Governing Board May 2006	Complete
Field trip and lecture	Fire to restore Table Mountain pine – NC Chapter Wildlife Society March 2007	Complete
Field trip	Fire to restore Table Mountain pine – Southern Blue Ridge Project April 2007	Complete
Workshop discussion	Restoration activities in the southern Appalachian Mountains – National Forests of NC August 2007	Complete
Field trip	Fire for restoration in the NC mountains – NC Wildlife Resources Commission – November 2007	Complete
Field trip	Fire to restore Table Mountain pine – Southern Blue Ridge Fire Learning Network June 2008	Complete
Panel discussion	Re-introduction of fire into appropriate areas of the southern Appalachian landscape - Second Summit for Planning Restoration on National Forests in southern Appalachians August 2008	Complete
Workshop Leader	Management options to promote smooth coneflower and Table Mountain pine – Southern Blue Ridge Fire Learning Network – October 2008	Complete

Item	Delivered	Status
Seminar	Low-intensity fires may be adequate for stand replacement of Table Mountain Pine (*Pinus pungens* Lamb.) in the Southern Appalachian Mountains – University of Georgia January 2009	Complete
Field trip	Restoration and fuel management research in the southern Appalachians - The Nature Conservancy, April 2009	Complete
Lecture and field trip	Fire history; demonstration installation updates; Tallulah Gorge and Chattahoochee National Forest demonstration sites field tour – Southern Blue Ridge Fire Learning Network June 2009	Complete
Lecture and field trip	Delayed mortality of hardwoods after prescribed fire – Southwide Forest Disease Workshop – July 2009	Complete