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THE ROLE OF FIRE IN THE REGENERATION OF TABLE MOUNTAIN PINE IN THE SOUTHERN APPALACHIAN MOUNTAINS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gregory L. Sanders

August 1992

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ABSTRACT

Table Mountain pine (*Pinus pungens* Lam.) is a highly intolerant, serotinous-coned species endemic to the Appalachian Mountains. Before it can successfully be regenerated, three conditions must occur--(1) heat must be present to open its serotinous cones, (2) seed must fall on mineral soil, and (3) the existing forest canopy must be removed in to expose seedlings to full sunlight. These conditions are only met in the advent of fire.

This study was conducted in stands of Table Mountain pine that were burned by wildfires to see which burning conditions best regenerate the species. It showed that the best regeneration occurred in areas burned by crown fires. While regeneration was found in areas burned by hot surface fires that removed some overstory vegetation, very little regeneration was found where light surface fires had burned.

This study showed that adequate regeneration of Table Mountain pine had occurred following a fire in a 20 year-old stand. However, an 11 year-old stand sampled had produced very few cones, and it is doubtful that enough seed was being produced to regenerate that stand should it burn now.

This study also raised questions concerning the need for fire management programs to perpetuate this fire-dependent species.

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CHAPTER I

INTRODUCTION

Table Mountain pine (*Pinus pungens* Lam.), shortleaf pine (*Pinus echinata* Lam.), Virginia pine (*Pinus virginiana* Mill.), and pitch pine (*Pinus rigida* Mill.) are the yellow pines native to the southern Appalachian Mountains. All are pioneer species that become established and develop as stands only following disturbances that provide open conditions (Harlow et al., 1979). Without disturbance all are replaced in natural forest succession by hardwoods that are more shade tolerant (Spurr and Barnes, 1980).

The yellow pines have two site requirements that must be created by disturbance before stand establishment and development can occur: (1) a seedbed of exposed mineral soil for seed germination and (2) exposure of the site to full sunlight (Spurr and Barnes, 1980). Table Mountain pine, the only Southern Appalachian pine having a serotinous cone, also requires a third condition: temperatures high enough to open the serotinous cones.

While farming, grazing, logging and fire have provided the needed site requirements for natural regeneration of shortleaf, Virginia, and pitch pines, only fire will perpetuate stands of Table Mountain pine. In prehistoric times it was likely fire alone that "kept pine on the ridges" in Southern Appalachian forests (Whittaker, 1956). While several authors state that Table Mountain pine requires fire (Whittaker, 1956; Spurr and Barnes, 1980), little is said about the "type" of fire that is required.

Fires burn the forest in many different ways. They burn with varying intensities, durations, and frequencies, all of which are affected by weather conditions, topography, and fuel types and amounts. A fire may scarcely scorch the surface fuels in one part of a stand, and completely burn out the crowns in another. The wide variation in fire characteristics results in varying effects on the stands in which they burn.

The goal of this study was to identify and evaluate the characteristics of fire that are important in regenerating Table Mountain pine in the Southern Appalachians.

CHAPTER II

REVIEW OF SELECTED LITERATURE

A. The Yellow Pines

Table Mountain pine, shortleaf pine, Virginia pine, and pitch pine belong to the Section Diploxylon, the yellow or hard pines (Mirov, 1967). They are the yellow pines native to the Southern Appalachians and have traits that make them adept as pioneer trees. These include their winged seeds borne in cones that are highly hygroscopic; thus they open and release seeds when humidity is low but remain closed when it is high. The winds that shake seeds from cones during dry periods generally carry them some distance from the parent tree, increasing the likelihood that they will find a suitable seedbed for germination and growth. Seed release is in the fall, except for Table Mountain pine with its serotinous cone. Shortleaf and pitch pine have the ability to sprout from epicormic buds when all or a portion of the stem is killed.

Some of the more common disturbances in the area that create conditions favorable for yellow pine reproduction include: (1) land clearing for farming, (2) grazing, (3) logging, and (4) fire. While other disturbances such as landslides and blow-down by wind storms are common to the area (White, 1987), they occur too infrequently to have played a major role in maintaining a pine component in the Southern Appalachian ecosystem.

Farming

Pre-Columbian Indians in the region cleared areas in the forests for farming (Davidson, 1983). This practice continued following European settlement and peaked around the turn of this century. In recent decades, the practice has become much more restricted as virgin lands suited for agriculture are no longer available.

As cultivated fields are abandoned, they often regenerate to various pioneer tree species. On the drier sites, yellow pines, particularly Virginia and shortleaf, are prominent. In more mesic areas, other pioneer species such as yellow-poplar and black locust are more prevalent. Ayres and Ashe (1902) noted that while bottomlands were the first to be cleared and cultivated in the Southern Appalachians, later population pressure pushed cultivation onto the higher slopes. They also observed young pine regeneration on some of these abandoned sites.

Without further disturbance, the sites are eventually taken over by more tolerant species. This situation is often termed "old field succession" in its early stages, and known simply as forest succession as the later seral stages develop (Spurr and Barnes, 1980). Periodic outbreaks of the southern pine beetle (Dendroctonous frontalis Zimm.) speeds succession by releasing the replacement hardwoods that are generally present beneath the pine canopy (Kuykendall, 1978).

Grazing

"Open" grazing of livestock was practiced well into the twentieth century, although Tennessee passed a fencing law in 1913. Cattle, sheep and hogs were allowed to roam free until around World War II when land ownerships became more clearly defined and such "encroachment" became illegal (Pyle, 1988). Grazing had a detrimental impact on young hardwoods (Day and DenUyl, 1932; DenUyl and Day, 1934), and favored pine regeneration. A New England study found that grazing may have provided a method of hardwood control, especially on old field sites being managed for conifers (Behre et al., 1929).

Logging

While the Indians cut trees from the forests for numerous uses, such as home construction, palisades, etc., they did not have the tools to remove large amounts of timber from the forest. Large scale timber harvesting did not occur until after European settlement. The white settlers brought with them the technology to harvest and process forest products. As white settlement expanded, so did the demand for timber, and harvesting and milling technology advanced to keep up with this demand. This trend continued through the nineteenth century and peaked in this region in the early part of the twentieth century.

In the late 1920's, the last logging operation in the Great Smoky Mountains National Park (GSMNP) began on the Middle Prong of the Little River. While early logging in the area was generally small-scale, "selective" harvesting, it became predominantly large scale, industrial logging after the turn of the century (Lambert, 1961a, 1961b; Pyle, 1988). Logs were being moved to landings by steam and gasoline powered skidders, loaded onto railroad cars, and shipped to the mill at a record pace. By 1939, when logging operations in the park ceased, an estimated one billion board feet of timber had been removed (Lambert, 1961b).

Cut-over areas were left primarily treeless, with heavy accumulations of logging slash. Only small pockets of timber that were not economically harvestable were left uncut. The soil was often scarred from the skidding operations, exposing mineral soil (Pyle, 1988). This practice of "cut out and get out" left sites conducive to natural regeneration by the pioneer yellow pines and yellow-poplar, especially where fires consumed the logging debris. In many instances, however, this was not the case, especially on good sites that supported mixed mesophytic forests before harvesting (McCracken 1978). Reproduction on those sites was primarily from hardwood sprouts, especially on sites that were burned (Frothingham, 1931).

While farming, grazing, and logging may provide areas suitable for regeneration of all of the yellow pines, stands of Table Mountain pine are unlikely to form as a result of these conditions due to the need for high temperatures to open serotinous cones for seed release. Regeneration requirements for this species are best met where fires burn Table Mountain pine stands. While fire also promotes regeneration of Virginia, pitch, and shortleaf pines, it is most important in the perpetuation of Table Mountain pine.

B. Pinus pungens

Pinus pungens was first collected sometime before 1794 by Andre Michaux near Tablerock Mountain in Burke Co., N.C. (Michaux, 1889), who at that time referred to it as "Table Mountain pine" (Michaux, 1810; in Zobel, 1969). Lambert (1803, 1805) diagrammed, figured, named, and described it from a collection taken in the "Blue Mountains" of Virginia. McIntyre (1929) called it "Mountain Pine," and noted that it was also called at that time Poverty Pine, Hickory Pine, Prickly Pine, Black Pine, Southern Mountain Pine, and Ridge Pine. It has been also been called "Table-Mountain pine"

(Brockman, 1968), "Table-mountain pine" (Barrett, 1980), "table mountain pine" (Barden, 1978), and "table-mountain pine" (Harlow et al, 1979). It will be referred to in this writing as "Table Mountain pine" following Little (1979).

Geographic Range

Table Mountain pine is endemic to the Appalachian Mountains and grows in unevenly distributed stands from Pennsylvania to Georgia. Its range is almost entirely within those of pitch and Virginia pines, and it is by far the rarest of the three. Although it commonly occurs in small, dense stands, such stands are widely scattered throughout its range, within which are large areas in which its existence has not been reported. In areas where it does occur, it is usually found on xeric, infertile sites that are the least favorable for tree growth (Zobel, 1969).

Most populations of Table Mountain pine are found in the Blue Ridge and Valley-and-Ridge provinces of the Appalachian Highlands (Fenneman and Johnson, 1946; in Zobel, 1969). Some outlying populations have been found outside of this region, but may not have originated by natural means. These areas include the easternmost record of Table Mountain pine in Hunterdon Co., N.J. Other locations to the east of the primary range include sites near Newark, Delaware, Washington D.C., central Virginia, and central North

Carolina. In these areas, Table Mountain pine is apparently not reproducing, and would do so only with the occurrence of man-made disturbances (Zobel, 1969). To the west of the main range, the pine has been located in Hawkins Co., Tennessee, and in Summers, Pocahantas, and Randolph Counties in West Virginia (Allard and Leonard, 1952; Zobel, 1969).

Elevational Range

Table Mountain pine is primarily found at elevations between 300 m[a] and 1220 m, exceeding the 1220 m elevation only in Tennessee and North Carolina (Zobel, 1969). Stupka (1964) reported Table Mountain pine, in limited numbers, at several locations over 1675 m in the GSMNP, with a lone, stunted specimen on Andrews Bald at 1767 m. Most specimens growing below the 300 m level are found in the northern part of its range, and in several locations in North Carolina and Virginia (Zobel, 1969).

Aspect and Topography

It has been well documented that the sites on which Table Mountain pine commonly occurs are dry and well drained, often with shallow, rocky soils, having south- to west-facing aspects (Racine, 1966; Whittaker, 1956; Zobel,

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[a]All data measurements were recorded and computed in metric. Factors for converting to English measurements are listed in Table 1 in the Appendix.

1969;). Its ability to survive on these droughty sites can be attributed to minimal interference from other, less drought resistant species. Adaptations such as larger seeds (which allow for heavier seedlings with longer root systems), more lateral roots, and more branches than pitch or Virginia pines (Zobel, 1969) increase the chances of survival.

Table Mountain pine is very shade-intolerant (Barrett, 1980), a factor that also adapts it to the upper-slope positions on south- and west-facing slopes where it receives the most intense sunlight. This situation is true throughout its range, and the correlation of the presence of pine with aspect has been well documented in the GSMNP (Stupka, 1964; Whittaker, 1956). Perhaps one of the best documentations was done by Zobel (1969), where 34 of 47 stands studied had aspects ranging between due south (180 degree azimuth) and due west (270 degree azimuth). Only one stand was found on a north facing slope, but was found in an old field with an 18 percent slope. In that study, stands with slopes less than 15 percent were not plotted, as on such gentle slopes "aspect makes a minimal difference and is difficult to determine."

Cone Serotiny

The serotinous cone of the Table Mountain pine is a characteristic that makes it unique among the native yellow pines in the Southern Appalachians. Cone serotiny is a characteristic that can be found in several pines growing in different parts of the country, generally in high fire-occurrence areas.

Other serotinous species include Jack pine (*Pinus banksiana* L.) in the northern U.S. and Canada; pond pine (*Pinus serotina* Michx.), which grows in the Coastal Plain from New Jersey to Florida and Alabama; sand pine (*Pinus clausa* (Chapm.) Vasey) which grows primarily in central Florida; knobcone pine (*Pinus attenuata* Lemm.), which has a range from southwestern Oregon to southern California; and lodgepole pine (*Pinus contorta* Dougl.), which can be found over much of the western U. S. (Harlow et al., 1979; Zobel, 1969).

The serotiny of Table Mountain pine may vary from stand to stand, and even from tree to tree within a stand. Cones on Table Mountain pine have been known to remained closed for up to about 25 years and still contain viable seed (Lamb, 1937). Most usually open much earlier (Zobel, 1969). Different levels of serotiny seem to be common with other serotinous species as well, where the more serotinous stands tend to be found where fire is more frequent. A good example is with lodgepole pine, which is highly serotinous in much of the Rocky Mountains, and generally non-serotinous in other areas, such as the Sierra Nevada range, where fire is not as prevalent (Critchfield, 1957). Even pitch pine, which is not generally considered to be a serotinous species, has been found to show serotinous traits in areas with frequent fire occurrence (Fowells, 1965).

McIntyre (1929), in a study on Table Mountain pine in Pennsylvania, found differences in serotiny depending on aspect, stand density, and shading of cones. Shaded cones, especially those in dense stands, tended to be more serotinous than unshaded cones in more open stands. He suggested that temperatures as low as 95 degrees F could open cones in these open stands.

Zobel (1969) noticed similar environmental differences in serotiny, and suggested that this variation is genetic. He found that stands in which cones opened within the first two years after maturity were in the northern part of the range. When and he correlated serotiny with several site factors, he found significant correlations showing increases in serotiny with decreases in latitude.

In a study on cones of Table Mountain pine ranging in age from 0-11 years, Barden (1978) found that most cones remained unopened for the first two years, then about 40 percent eventually opened in the absence of fire. The other 60 percent remained closed for a decade or more, and appeared to be "permanently serotinous."

In the same study, Barden also tested the time required for cones to open when placed in an oven maintained at 100 degrees C. Only nine percent opened in the first two minutes, but 78 percent opened before four minutes. All had opened by 7.5 minutes. This, he stated, suggested a strategy of "wait, but don't wait too long," for the cones to open in a fire. This wait, he felt, allowed time for the most intense flames of a fire to pass before the scales of the cones opened and exposed the seed.

While it is evident that cones on Table Mountain pine may open without fire, it is also evident that an abundance of cones remain closed, providing an immediate supply of seed following a fire of sufficient intensity to open the cones, regardless of the time of year. Further, those seed that do fall without fire generally find an environment unsuitable for germination and growth.

Permanence

Because Table Mountain pine is a very shade intolerant, pioneer species, it is usually replaced by more tolerant hardwoods in later seral stages in the absence of disturbance. While it is evident that Table Mountain pine does release some seed on an annual basis even in the absence of fire, it is unlikely that that seed will result in substantial regeneration due to the lack of the other basic regeneration requirements; a mineral soil seedbed and full sunlight. There are some isolated exceptions to this, however, and self-maintaining stands of Table Mountain pine have been found only on sites too severe for most competing vegetation.

In an earlier study done at Looking Glass Rock, Barden (1977) described a stand of Table Mountain pine that appeared to be self-maintaining. The sites he studied totaled 0.27 ha., were on southwest facing slopes, and had shallow soils with much exposed rock. Mountain laurel (Kalmia latifolia L.) was absent or occurred as isolated plants. A total of 155 Table Mountain pines comprised 67 percent of the basal area on the sites. One chestnut oak (Quercus prinus L.) and five small red maples (Acer rubrum L.) in the study area accounted for three percent of the basal area. The remainder of the basal area was comprised of eastern redcedar (Juniperus virginiana L.). The area had not been burned since 1889, but stems of Table Mountain pine were found in all age classes, the majority (62 percent) in the 0-39 year age class. Only five trees were found in the 80-99 year age class. Barden noted nine instances where older trees fell between 1950 and 1975, and nine trees regenerated on the new growing sites made available.

Barden termed this as a "hen-chick" relationship, where a large "hen" tree had a "chick" seedling underneath it. As long as the "hen" tree survived, it suppressed any "chicks" below it. If the "hen" tree had died, then the "chick" tree grew rapidly, taking advantage of the increased amounts of available nutrients and moisture. Light did not seem to be a limiting factor as the "hen" trees were widely spaced, and shading actually seemed to have been beneficial on these extremely dry sites.

In a follow-up study ten years later at the same site, Barden (1988) found that this stand may not be as permanent as it first appeared. In this study he found that high mortality had occurred in the youngest age classes. Only 37 percent of the population in the 10-30 year age class had survived. In 1976 there were 86 Table Mountain pines in the 0-9 year age class. By 1986, all but 17 had died. In addition, there were only 11 stems in the "new" 0-9 year class. He attributed the mortality of the younger stems to drought, particularly a 29-day rainless period in 1984. All trees older than 40 years survived this drought, suggesting that they were more vigorous and deeper rooted than their younger counterparts. Barden concluded that "The question of whether this population is in equilibrium in the sense of equal mortality and recruitment rates must be answered negatively."

Zobel (1969) stated that stands of Table Mountain pine appearing to be "permanent" were associated with having a shallower litter layer, more rock outcrops, and less basal area than stands that were more obviously successional. He also suggested that the amount and type of competing vegetation influence "permanence," and that "... a severe fire is necessary to successfully regenerate Table Mountain pine on sites with a well-developed shrub layer."

These arguments suggest that Table Mountain pine can maintain itself in small isolated stands or as individual trees on very severe sites in the absence of disturbance. Because lightning fires in the Southern Appalachians are neither frequent nor intense enough to have a major effect on maintaining extensive areas of pine forests (Barden and Woods, 1974, 1976), it has been hypothesized that in pre-Columbian times, yellow pines were restricted to the most severe sites, and expanded their range only after disturbance created by Euro-American settlers (Harmon, 1982). However, it has recently been argued that the pre-Columbian landscape was shaped by disturbance, primarily by aboriginal burning (Keel, 1976; Davidson, 1983; Criddlebaugh, 1984). Therefore, it is most likely that stands of Table Mountain pine have remained in the Southern Appalachian landscape only because of anthropogenic disturbances that date back thousands of years.

C. The Role of Fire in the Yellow Pine Ecosystem

The forests in the Southern Appalachian region are very susceptible to being burned by forest fires, most of which are human-caused (USDA, 1989). Forests in the region are generally more vulnerable in the fall and spring months. When the hardwoods drop their leaves, a new supply of fuel is deposited to the forest floor. Upon ignition, a fire can spread quickly through this bed of light, flashy fuel, especially when aided by warm, dry, and windy weather conditions. Even after periods of precipitation, these leaves can dry out quickly in sunny, windy weather. Fire occurrence is most probable from leaf-fall until spring green-up. Very few fires occur during the summer months as green-up reduces the combustibility of many fuels, and decomposition is breaking down much of the light fuel. Also, when hardwoods are a significant component, the closing forest canopy blocks much of the sun's drying capability. Historically, the highest fire occurrence months are March, April, October, and November (USDA, 1989).

In the Southern Appalachian region, the major ignition source of forest fires is human--either by accidental or intentional means. Unlike the American West, in the Southern Appalachians lightning plays an insignificant role in causing forest fires. Less than three percent of all fires in the region are caused by lightning, while nearly half are caused by arsonists (USDA, 1989).

Forest fires in this region reach their greatest intensity on upper slope positions on south- and west-facing slopes (Barden & Woods, 1976). These sites tend to be dry due to exposure to high insolation and wind; thus they burn more frequently and with greater intensity. Their flammability is further increased by the tendency of fire to maintain pine-dominated ecosystems; pine litter is generally deeper and more flammable than that of later seral stages. The flammability of the more extreme sites is probably responsible for the evolution of the serotinous-cone habit in Table Mountain pine. Yellow pines are generally more productive on these droughty sites as adapted hardwoods are slow growing and of poor form and quality (Spurr & Barnes, 1980).

Harmon (1982) showed from fire scars in cross-sections of old trees, that the fire return interval in the western end of the GSMNP averaged 12.7 years. While he could document this for only the past 130 years from living trees, frequent fires have likely been common for several thousand years as use of this area by Indians back to the Archaic period (8,000 to 1,000 years B.C.) is now well established (Keel, 1976). Since Woodland times prehistoric Indians were largely sedentary and agriculture was their primary means of livelihood. Widespread woods burning during the settlement period is well documented (Pyne, 1983; Stewart, 1963; Leyburn, 1962).

Since lightning fires are generally neither of sufficient frequency nor intensity to result in stand replacement (Barden and Woods, 1974, 1976), fires of anthropogenic origin were probably the primary perpetuators of yellow pine communities in the Southern Appalachians. Davidson (1983) found that peak charcoal and pine pollen levels occurred in sediment cores taken from Lake-of-the-Woods in Cades Cove at between 1900 and 165 years BP (before present). She suggested that activities of pre-Columbian Indians may have been the cause. Based on charcoal and pollen analysis in the Tellico region of the Southern Appalachians, Criddlebaugh (1984) claims that fires of anthropogenic origin have been common in this region for at least 3000 years.

Although fires of anthropogenic origin likely started on the lower, flatter lands that were conducive to farming, there is no apparent reason to believe that they did not carry onto the slopes of surrounding mountains. These fires were most likely to reach their greatest intensity on the drier south- to southwest-facing slopes where the pines are more prevalent.

The essential role that fire has played in maintaining yellow pine ecosystems in Eastern North America has been clearly documented (Spurr and Barnes 1980; Pyne 1982). Early researchers, observing the preponderance of yellow pine stands on south- and west-facing slopes, speculated as to their stability on these sites (Whittaker 1956). During the past decade there appears to be general agreement that, except possibly on "new" soils forming on rock outcrops, yellow pine stands are not stable and will be replaced by hardwoods (Barden 1977).

Conditions in the Southern Appalachians have changed dramatically over the past several decades. Abandoned farmland that once provided excellent seedbeds for the winged seeds of the yellow pines is no longer common and the "open range" grazing policy is no longer in effect. Logging is more likely to be controlled by forest management objectives, especially on public lands, such that yellow pine stands occur primarily where they are planted "by prescription." In primitive and natural areas there is little disturbance except for the few fires that "get away."

Effective fire prevention and control have greatly reduced the acreage burned by wildfire in recent decades. It is now unlikely that a pioneer stand will burn during the life-span of the pioneer species present, in contrast to Lambert's (1958) claim that 30-50 percent of Swain County, North Carolina burned every year and every acre burned within a 5-year period during pre-Park days. While such fire protection is essential in modern forestry practice, it is resulting in the replacement of pioneer stands by later seral stages in which yellow pines are not a significant component.

Observations in the GSMNP over the past 3 decades confirm this trend. Stands of Table Mountain pine that were once used in teaching dendrology to forestry students are now classified as hardwood stands. In at least two instances the conversion was abrupt as the pine stands were killed by bark beetles, releasing the understory hardwoods. On many sites succession has progressed to the point that complete elimination of a pine seed source is threatened, which could result in the permanent loss of the pine component unless artificial regeneration techniques are used.

This successional process is especially important in the decline of Table Mountain pine in the region. The other native yellow pines are both more widely distributed and commercially important. They are perpetuated by the abandonment of agricultural lands and by forest management activities. In contrast, Table Mountain pine is restricted to higher, drier sites and is of little commercial value because of inaccessibility and poor growth form. Since most of its native habitat is in public ownerships on which fire prevention/suppression efforts have been reasonably effective for the past several decades, natural forest succession and periodic outbreaks of the southern pine beetle are rapidly eliminating these stands in the Southern Appalachians.

Cone serotiny in Table Mountain pine provides a large bank of seed stored on trees, allowing for seed dispersal immediately following fire, regardless of the time of the year they occur. In the event of fire, Table Mountain pine has unique regeneration advantage over other native yellow pines. As seed from the other pines is dispersed annually during the fall, fires occurring after seedfall will consume seed and any regeneration. Only when seed is dispersed after a fire can successful regeneration occur.

The regeneration advantage of Table Mountain Pine was documented in a report done for the National Park Service (Buckner et al., 1987). In April, 1986 two fires burned in the GSMNP; the Hickory Fire on Bote Mountain on the Tennessee side of the park and the Peachtree Fire on the North Carolina side. The two fires burned areas with similar site-situations, both of which contained various mixtures of yellow pines and hardwoods. In the area burned by the fire on Bote Mountain, Table Mountain pine was the dominant yellow pine present, while in the area of the Peachtree Fire it was absent. Virginia, shortleaf and pitch were the yellow pines present. In the first growing season following the fires, seedlings of Table Mountain pine established in burned areas of the Bote Mountain fire. The extent of this regeneration is discussed in detail in Chapter V.

In the area burned by the Peachtree Fire, however, there was no pine regeneration from seed during the 1986 growing season as these yellow pines (Virginia, shortleaf, and pitch) had all released their seed the previous fall and it was consumed by the fire.

D. Forest Fire Behavior[a]

Environmental Factors

There are many different ways fires burn through the forest. Some barely burn across the surface of the ground while others rage through the crowns consuming large areas in short periods of time.

In any forest fire situation, there are always three environmental factors influencing that fire's behavior. These factors are topography, weather, and fuel. Each of these factors has different components as well that affect fire behavior.

Topography, for example, includes such components as steepness, length of slope, slope aspect, elevation, and natural barriers. Fires tend to burn faster moving up a slope than down, and the steeper the slope, the faster the uphill spread. The longer a slope is, the more momentum a fire can build as it spreads up it. Fires also burn more

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[a]This section was written based on the working knowledge of the author who has over a decade of experience in wildfire suppression. This experience includes training in forest fire behavior (Nation Wildfire Coordinating Group, 1981, 1983), which the author has both completed and instructed.

intensely up dry canyons or hollows than on paralleling ridges, as the flow of air out of the head of these drainages creates what is commonly called a "chimney effect." Natural barriers such as streams and rock bluffs can slow or stop the spread of a fire. Unnatural barriers such as roads can do the same.

Weather components include temperature, relative humidity, wind, and precipitation. Wind can cause a fire to spread faster and/or change direction. Fires burn more intensely on warm days with low humidities than they do on cool, damp days. Rain, obviously, can put a fire out.

Fuels probably influence fire behavior the most. Without fuel, a fire cannot burn. Aspects of fuel include density (fuel load), compaction, horizontal continuity, vertical continuity, size, moisture, and chemical make-up. The heavier a fuel load is, the greater the potential is for a hotter fire. However, if the fuel is compacted, then it may be harder for a flow of oxygen to "fan" the fire. Any breaks in horizontal continuity, such as the topographic barriers mentioned above, can slow or stop a fire. Vertical continuity of fuel describes the presence of fuel from the surface of the forest floor, through the midstory, up to the canopy. The presence (or absence) of these "ladder" fuels can determine how high up into the canopy a fire can burn.

Small-sized, "flashy" fuels, such as grass, allow a fire to spread more rapidly than do larger-sized fuels such as fallen logs. However, the larger fuels can burn longer and with more intensity once ignited. The amount of moisture available in a fuel determines how quickly a fire will ignite and consume the fuel. The chemical make-up of the fuel will vary from species to species. Pines, for example, have needles that contain saps and resins that are more flammable than saps and resins in leaves of most hardwood species.

Topography, weather, and fuel also have influences on each other that affect fire behavior. For instance, warm temperatures, wind, and low relative humidities can lower fuel moisture while precipitation and high relative humidities can raise it. Higher elevations tend to get more precipitation and have cooler temperatures than lower elevations, and the fuels there may not be as dry. Species composition often changes with differences in elevation as well. South and west facing slopes tend to get more direct sunlight than north and east facing slopes, and fuels there will likely dry faster. Also, different species composition is often found on south and north slopes. Mountainous terrain can cause changes in wind speed and direction by restricting the air flow through an area and by diurnal warming and cooling.

The interactions seem endless, and many are present on any given forest fire. Therefore, it is sometimes difficult to go back to a burned area and determine exactly what the fire did and why. Some things may seem obvious, such as being able to see where a crown fire ran up a steep south slope through a dense pine stand. But why did the fire only burn over the surface on an adjacent ridge that also had a steep south slope and a dense stand of pine? Did it burn when the humidity was higher? Did it rain? Sometimes you have to be there to see what happened. And even then, it sometimes is not easy to understand why it happened as it did.

Types of Forest Fires

The way a forest fire burns is usually described as being either ground fire, surface fire, or crown fire. Depending on the environmental conditions present, a fire may burn a forest in one, two, or all three ways.

The most common type of fire is a surface fire, in which the fire primarily burns fuels such as leaf litter, grass, dead logs, tree branches, and small shrubs that lie on the forest floor. Surface fires may be slow and creeping or fast-spreading and intense, depending on the fuel loading, fuel type, and environmental conditions present.

Ground fires occur when the organic humus layer in the soil is dry enough to burn. When the humus layer is damp, surface fuels may still be dry enough to carry a hot fire while leaving the humus layer intact. However, when the humus layer dries, a fire may burn deep down into it, creeping and smoldering for days. Some ground fires may burn underneath the surface far enough that it is not visible on the surface. A ground fire sometimes appears to be burning in pure soil, but is actually burning in humus and fine root hairs. Ground fires in the Southern Appalachians can occur during droughty periods, but are most common in peat bogs and swampy areas where mineral soil may be buried under several feet of organic matter.

Several conditions must be present for a crown fire to occur. First, there must be enough intensity in a surface fire to heat the vegetation in the forest canopy overhead and/or up-slope. Secondly, there must be adequate ladder fuels to carry the fire from the surface to the crown. And finally, the canopy must be closed enough for the fire to spread from crown to crown. After a crown fire gets started, the fire in the crown will often spread faster than the surface fire below. Crown fires are more likely to occur in coniferous forests than in hardwood forests, and are more likely to occur in mountainous terrain than in flatlands because heat, as released, pre-heats fuels up-slope, making them more combustible.

On some fires, all three types of fire may occur. On others, there may just be a ground fire or surface fire. As stated, how the fire burns depends on the combination of environmental factors involved.

CHAPTER III

OBJECTIVES AND STUDY AREAS

A. Objectives

The objectives of this study were to evaluate fire effects on stands of Table Mountain pine in the Southern Appalachians by: 1) demonstrating that fire is the component that maintains Table Mountain pine in the region, and 2) identifying the types of burn effects that are most successful in regenerating and perpetuating stands of Table Mountain pine.

To meet the objectives of this study, stands of Table Mountain pine had to be located that had recently burned. The fires that burned these stands had to be large and severe enough that effects of varying fire intensities on the stands and any regeneration could be studied. Due to the limited occurrence of Table Mountain pine, and because effective fire suppression efforts allow for few large fires in the Southern Appalachians, areas where this interaction occurred were extremely limited.

B. Study Areas

Suitable study sites were located with the assistance of personnel from the GSMNP and U. S. Forest Service. There were two basic criteria used in selecting the sites--(1) a pure to nearly pure stand of Table Mountain pine had recently burned, and (2) fire intensities varied from creeping surface fires to running crown fires. Three sites met these criteria and were selected for this study. Most of the field research was done on Bote Mountain on the Tennessee side of the Great Smoky Mountains National Park. Additional research was done in the Horsehitch Gap and Greystone Mountain areas of the Cherokee National Forest in Greene County, Tennessee (Figure 1). Stand characteristics varied by and within locations; thus several different kinds of fire effects were studied.

Observations were also made on a locale near Old Fort, McDowell County, North Carolina on the Pisgah National Forest. However, stand characteristics at Old Fort did not warrant extensive sampling, and discussion of findings there will only be used to support findings at other locations.

Regional Characteristics.

Climate. The nearest National Weather Service weather stations to the study areas are located at McGhee-Tyson Airport in Alcoa (Bote Mountain site) and at the Greeneville

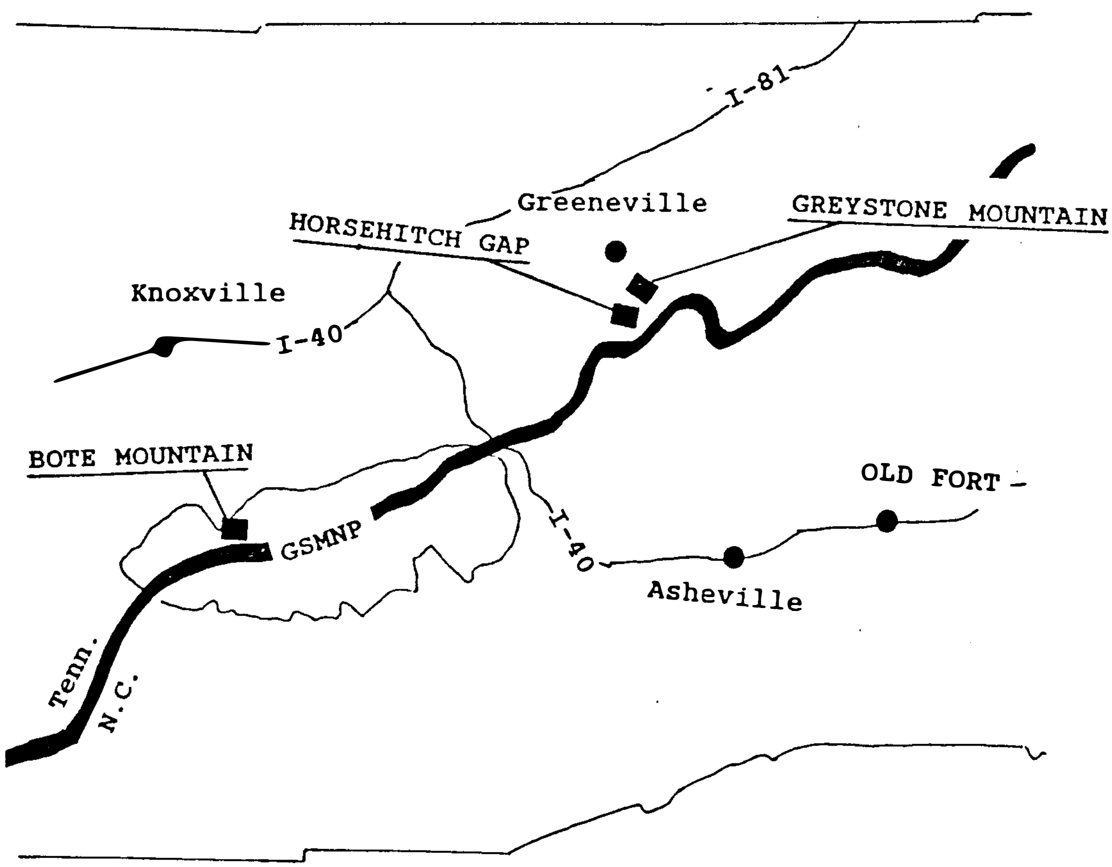

Figure 1. Location of Study Areas.

Experiment Station (Horsehitch Gap and Greystone Mountain sites). As climate in the mountains of East Tennessee is greatly influenced by changes in topography and elevation, the climates at the study sites, which are at higher elevations in mountainous topography, are probably somewhat cooler and wetter than the lower-elevation valley sites where the above weather stations are located. Shanks (1954) noted temperature decreases of 2.23 degrees F (1.24 degrees C) for every increase in elevation of 305 m in the Great Smoky Mountains. Precipitation is influenced as well, and increases as elevation increases. Over a thirty year period, the difference in averages from Gatlinburg to Clingmans Dome was 67.8 cm, or an increase of 13.08 cm per 305 m (Tennessee Valley Authority, 1968). In another study, Smallshaw (1953) found the precipitation increase to be 22.9 cm per 305 m.

The climates of the study areas are generally warm and wet. U.S. Department of Commerce records (1989) showed the average mean temperature at the weather station at McGhee-Tyson Airport (elevation 281.6 m) is 58.7 degrees Fahrenheit (14.8 degrees Celsius). July is the warmest month of the year with an average temperature of 77.6 degrees F (25.3 degrees C), and January is the coolest with an average temperature of 38.2 degrees F (3.4 degrees C). The average annual precipitation is 120.12 cm. While the precipitation is well distributed throughout the year, March is historically the wettest month with an average of 16.05 cm of precipitation, while October is the driest with an average of 6.93 cm.

At the Greeneville Experiment Station (elevation 402.3 m), the average annual temperature is 57.0 degrees F (13.8 degrees C), with July being the warmest month (75.9 degrees F or 24.4 degrees C) and January the coolest (36.8 degrees F or 2.7 degrees C). The average annual precipitation at Greeneville is 107.31 cm. July has the wettest monthly average with 11.76 cm, and October has the lowest (6.48 cm) (U.S. Dept. of Commerce, 1989).

Vegetation. Botanically, the Southern Appalachian Mountain region is one of the most diverse areas in North America. There are 131 native trees in the GSMNP alone, which is more than in all of Europe (King and Stupka, 1950). There are approximately 1450 species of vascular plants (Hoffman, 1966), and over 2500 nonvascular species (King and Stupka, 1950) found in the area. This diversity is not limited to the GSMNP, but is prevalent throughout much of the Southern Appalachians. Stupka (1964) noted a collection of over 4000 species collected by Dr. A. Gattinger in East Tennessee during the mid-1800's. It is not known how many, if any, of those collections were made inside the area that is now the GSMNP. Due to inaccessibility, the GSMNP area had largely been bypassed by botanists until after 1925.

According to King and Stupka (1950), the plant life of the area today represents the vegetation that existed in North America during the Tertiary Period. The successive ice ages of the Pleistocene time, however, created unfavorable growing conditions in the North and West, eliminating many species (Delcourt and Delcourt, 1987). It was during these ice ages that spruce and fir forests spread southward onto the high ridges of the Southern Appalachians, where conditions were so severe that few other species could survive. These species, Fraser fir (Abies fraseri (Pursh) Poir.) and red spruce (Picea rubens Sarg.) still dominate mountain slopes in the eastern half of the GSMNP above elevations of 1500 m. The southernmost extent of the ranges of these two species is near Clingmans Dome.

Both of these conifer populations are currently being altered by factors that are not fully understood. Atmospheric deposition, climatic warming, and other exogenous factors are possible causes. The balsam woolly adelgid (Adelges piceae Ratz.), and aphid introduced from Europe around the turn of the century, entered the Park around 1957 and is currently killing the last remaining mature Fraser fir in the Park. While there is abundant fir regeneration, its future as a forest type in the Southern Appalachians is unknown (Eagar, 1978).

Bote Mountain Site.

Physical features. Bote Mountain lies between the West Prong of the Little River and Laurel Creek in the western portion of the GSMNP, approximately 8 km east of Cades Cove in Blount County, Tennessee. The GSMNP encompasses the Great Smoky Mountains, a segment of the Unaka Mountains in the Blue Ridge Province (Fenneman, 1938).

Bote Mountain was burned by a 273 ha fire in April, 1986. Prior to burning, that site contained several small Table Mountain pine stands with stand ages ranging from approximately 50 to 80 years as determined from increment cores. These stands were growing on upper slope positions on south to west aspects at elevations ranging from 658 m to 896 m. Slopes ranged from relatively flat ridgetops to over 60 percent.

The younger stands (50 - 55 years old) of Table Mountain pine on Bote Mountain were found where, according to GSMNP fire records, a 40-acre fire burned in 1931. The older stands probably originated from fires that occurred before Park Service acquisition that began in 1928, as fire records showed no other fires on Bote Mountain. Severe fires were common in pre-Park days, especially in areas covered with logging slash (Pyle, 1988). An early Park Ranger, Charlie Dunn, recalled that a large fire in 1910 burned the entire West Prong, as well as Laurel Creek (McCracken, 1974-1975; in Pyle, 1988). The present age of the older stands (approximately 80 years) of Table Mountain pine on Bote Mountain indicates that they likely regenerated as a result of this 1910 burn.

Substrate. The complex geology of the Great Smoky Mountains has been described by King et al., 1968, and King and Stupka, 1950. The entire study site on Bote Mountain lies on Elkmont sandstone, a member of the Great Smoky Group. It is a feldspathic sandstone which contains blue quartz and is interbedded with many thin to thick layers of dark argrillaceous and silty rocks. This substrate is Precambrian sedimentary rock of the Ocoee Series, which has been greatly affected by folding, faulting, weathering, and metamorphism (King et al., 1968).

The soils at the Bote Mountain sites belong to the Ramsey Series. These soils are slaty silt loams of the steep and very steep phases, and were derived from acid sandstones, quartzites, shales, and slates. They are very shallow without, well-developed profiles, and are strongly acid and low in fertility (Elder, et al 1959).

Horsehitch Gap Site.

Physical features. Horsehitch Gap is located on Short Mountain, which is found north of Greene Mountain in the southern portion of Greene County near the North Carolina border. Short Mountain and Greene Mountain are segments of the Unaka Mountains.

The study sites at Horsehitch Gap are located on a 54 ha tract proposed in 1976 as the Horsehitch Gap Research Natural Area. Final approval on this designation is still pending. The Horsehitch Gap sites have southeast to southwest exposure on slopes as steep as 50 percent. Elevation ranges from 634 m to 835 m.

The Horsehitch Gap site contained two distinctly different stands of Table Mountain pine--an older stand that originated from an April, 1941 fire that burned 1200 ha, and a younger, dense stand that originated from an 800 ha fire in May, 1981, that burned through the older stand.

Substrate. The geology at Horsehitch Gap is that of the Unicoi and Ocoee Supergroup formations. The Unicoi formation is made up of a mass of sedimentary rocks, which are primarily coarse-grained and conglomeratic sandstone and shale, with smaller amounts of quartzite. The Ocoee Supergroup formation is made up of undifferentiated metasedimenatary rocks, primarily phyllite, siltstone, arkose, graywacke, and conglomerate, with small amounts of quartzite and slate (Griffith, et al 1976).

The soils at Horsehitch Gap belong to the Ramsey series, and are stony loams of the very steep phase. These soils are similar to those at Bote Mountain as they are medium to strongly acid, poorly developed, and low in fertility. Depth to bedrock ranges from 15 cm to 60 cm, and rock outcrops are common (Edwards, et al 1958).

Greystone Mountain Site.

Physical features. Greystone Mountain is located in the Unaka Mountains approximately 8 km north of Short Mountain. The study site, which is located on the east end of Greystone Mountain, has primarily a west-facing aspect on slopes ranging from 40 percent to 60 percent at elevations ranging from 730 m to 790 m. The site contained a 1.5 ha stand of 20 year-old Table Mountain pine that regenerated following an April 22, 1968 fire that burned again on, oddly enough, April 22, 1988.[a] Both fires were arson-caused.

Substrate. The geology of Greystone Mountain is that of the Unicoi formation, which contains Cambrian rocks of the Chilhowee group. The Unicoi formation is made up of feldspathic sandstones and conglomerates, with some siltstone and shale (Rodgers, 1956).

The soils at Greystone Mountain belong to the Ramsey series (Edwards, et al, 1958), the same as those found at Horsehitch Gap.

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[a]Personal communication with Reed Jennings, Forest Technician, Nolichucky Ranger District, Cherokee National Forest. 1988.

CHAPTER IV

METHODS

A. Bote Mountain Site

The Bote Mountain site was sampled in the fall of 1988, three growing seasons after the April, 1986 fire. The fire burned at varying intensities through several stands of nearly pure Table Mountain pine. These stands covered approximately 70 ha of the burned area. Twenty-eight 20x20 m (0.04 ha) plots were established in the summer of 1986 for a post-fire report to the GSMNP of fire damage and the need for rehabilitation (Buckner, et al 1987). For this study, 18 of those plots were located and sampled. The total sample area of the plots was 0.72 ha, which amounts to slightly more than a one percent sample.

Through aerial photo interpretation and ground reconnaissance, the fire was stratified into three levels of burn intensity, categorized as follows:

LOW: Areas burned by light surface fire that scorched little or none of the crowns of mature trees.

MEDIUM: Areas where hot surface fire scorched the crowns of most mature trees and torched individual trees, but did not support a running crown fire.

HIGH: Areas where sustained crown fire occurred.

Six plots were selected from each of these burn levels for study.

Within each plot, a stem count of trees greater than 7.5 cm in diameter at breast height (DBH) was made to reconstruct the pre-fire overstory. Trees were recorded by species and diameter (nearest 2 cm DBH). An assessment of fire damage was made as well, with each tree being rated as "killed," "killed-back," "damaged," or "none." ("Killed-back" was assigned to stems of species that can sprout from adventitious buds following stem damage, such as most hardwoods and pitch pine. Table Mountain pine was the only species sampled that does not sprout from adventitious buds; thus they were recorded as "killed" rather than "killed-back.")

While it was not difficult to determine which trees were either killed or killed-back, other damage values were not as easy to assess. Nearly all of the surviving trees within the burned area showed evidence of being burned, such as a charred stem or scorched needles. However, it may be years before the total impact of the fire on these trees can be assessed. Therefore, only obvious damage was noted. If the fire burned the bark of a tree badly enough to damage the cambium layer and leave a scar, or "cat face," it was recorded as "damaged." Pines with much of the crown scorched or consumed, but still having green tops, were also called "damaged." Trees without obvious fire effects were recorded as "none."

Stems comprising the pre-fire stand that were smaller than 7.5 cm DBH, but taller than 2 m in height, were recorded as saplings and tallied by species. In addition, stem mortality from the fire and any post-fire stem sprouting were recorded.

Each Table Mountain pine was rated on the probability that enough heat was available to open its serotinous cones. This was done by observing the amount of the crown of each tree that had been either consumed or scorched by the fire, and by observing the number of open and closed cones remaining on the tree. A tree with 50 percent or more of its crown consumed or scorched, and with most or all residual cones open, was placed in a "high" probability class. If a tree's crown was less than 50 percent scorched, and only about half of the cones appeared open, then a "moderate" rating was assigned. If the fire had not scorched the crown and the majority of cones remained closed, a rating of "low" was assigned.

Each of the 18 plots was divided into four 10x10 m quadrats for sampling purposes. In each quadrat, 16 sample points were randomly located using a grid giving 64 sample points per plot. At each sample point, the thickness of residual organic matter (ROM) to mineral soil was measured to determine the effect of organic matter on Table Mountain pine regeneration. These ROM depths were recorded into five depth classes as follows: 1) less than 1 cm thick, 2) between 1 cm and 5 cm thick, 3) between 6 cm and 10 cm thick, and 4) between 11 cm and 15 cm thick, and 5) greater than 15 cm thick.

A circular miniplot (area = 0.25 m^2) was established in which the number of seedlings of Table Mountain pine was recorded. The height of each seedling was recorded to the nearest 5 cm. For each of these highly intolerant seedlings, the likelihood that it would be over-topped, suppressed and killed by competing vegetation was estimated by classifying each as "free-to-grow," "not free-to-grow," or "not yet able to determine." Seedlings that were already dead were not tallied.

Also recorded for each miniplot was the presence of other woody species. Since most were of sprout origin and occurred in clusters, the presence of any cluster or sprout in a miniplot was recorded as "1." The height of the tallest sprout was recorded to the nearest 10 cm.

B. Horsehitch Gap Site

The Horsehitch Gap area was burned by hot fires in 1941 and again in 1981. Stands of nearly pure Table Mountain pine regenerated following the 1941 fire. The 1981 fire burned through these 40 year-old stands at varying intensities. Table Mountain pine again regenerated following the 1981 fire, primarily in the hottest-burned areas.

The 1981 fire "crowned out" in several places. One very evident crown fire area is on the south-southwest slopes of Short Mountain, where a large area (approximately 20 ha) of the forest canopy was completely consumed. According to Reed Jennings, who fought the 1981 blaze, fire intensities in this area were so high that some trees were actually burned off at the stump.[a] This opening in the stand, which somewhat resembles a large clearcut, is now covered with a thicket of dense Table Mountain pine regeneration. In this area, only a very few individual stems survived the 1981 fire. These trees can be seen in and above this thicket of regeneration.

Adjacent to where the crown fire made its uphill run, a surface fire burned through the stand, leaving the overstory intact. There is now a jagged, but abrupt "edge" between where the 1941 stand crowned and where it did not. Some regeneration of Table Mountain pine has occurred under this overstory as well, but it is sparse and less vigorous than regeneration in the area where the canopy was removed.

[a]Personal communication, 1988.

Sampling transects were established to show differences in regeneration density and vigor between areas where the fire crowned and where it did not. Twenty-five sample points were located at 25 m intervals in five transect lines established perpendicular to the slope. Transect line A was located in the area completely crowned out by the 1981 fire, 20 m from the edge of the canopy of the 1941 stand (Figure 2). This was done to sample seedlings that were not shaded by the residual stand. As this canopy was to the east of this "crowned" area, any shading received would occur only in early morning. Line B was located 10 m inside of the canopy, while Lines C, D, and E were located 30 m, 50 m, and 70 m inside of the stand edge respectively. Thus, Line A was located where fire intensities appeared to be the highest, and Line E was where they were the lowest.

At each sample point, a 50 m^2 circular plot was established to record the density of the 1941 stand. Each stem in the overstory was recorded by species and measured to the nearest 2 cm DBH.

A 5 m^2 subplot was sampled at each point as well. In these subplots, regeneration was recorded by species. The height of each stem in these subplots was measured and recorded in the following height classes: (1) less than 0.5 m, (2) 0.5 to 0.99 m, (3) 1 to 1.99 m, (4) 2 to 2.99 m, and (5) 3 m or greater. The number of seedlings of Table Mountain pine with at least one cone was also recorded.

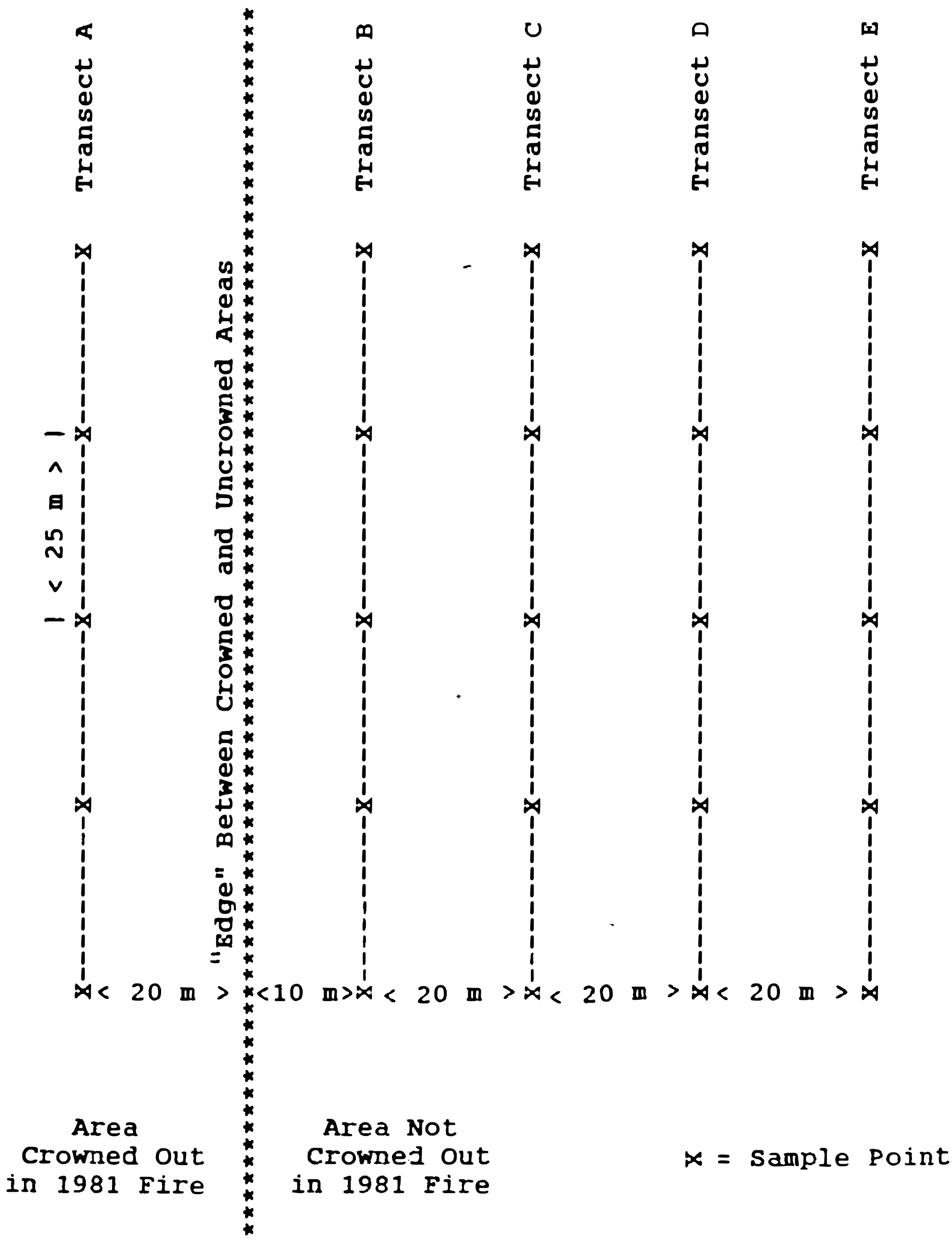


Figure 2. Layout of Sample Points at Horsehitch Gap.

C. Greystone Mountain Site

The 1988 Greystone Mountain fire, which burned approximately 15 ha, swept uphill through a dense, 1.5 ha stand of Table Mountain pine that regenerated after the 1968 fire. A crown fire burned nearly all of this dense, 20 year-old stand.

An initial visit to the site in October 1988 revealed that mortality was virtually 100 percent. Mineral soil was exposed on the entire site. Cones were present in many of the killed Table Mountain pine stems, the tallest of which were 4-5 m. Regeneration, however, was almost non-existent. Only 1 seedling was present in 30 5 m^2 circular plots sampled. In a nearby stand of older Table Mountain pine that burned, regeneration was abundant, but only where mineral soil was exposed. Pitch pines and hardwoods in the stand were sprouting.

In May, 1992, the site was revisited, and 30 5 m^2 circular plots were again sampled. These plots were located at 10 m intervals on transect lines parallel to the slope. Distance between transect lines was 10 m.

In each plot, the number of stems in the pre-fire stand was tallied by species to reconstruct the pre-fire stand. For each pre-fire stem of Table Mountain pine tallied, the presence of cones was recorded as "present" or "not present."

In each plot, regeneration was recorded by species in the following height classes: (1) less than 0.5 m, (2) 0.5 to 0.99 m, (3) 1 to 1.99 m, (4) 2 to 2.99 m, and (5) 3 m or greater. The number of pitch pine and hardwood stumps sprouting in each plot was tallied, with the height of the tallest sprout recorded. The occurrence of regeneration of mountain laurel, blueberries, and other shrubs was also recorded.

D. Statistical Analysis

To test the significance of data found in this study, the Kolmogorov-Smirnov one-sample test (Siegel, 1956) was used. This is a non-parametric test of goodness-of-fit, but unlike the Chi-square test, the Kolmogorov-Smirnov test also gives the break in trended data of significant samples.

The Kolmogorov-Smirnov test compares observed cumulative frequency distribution against a theoretical cumulative frequency distribution to determine the point that these two distributions show the greatest deviation. This point is called the maximum deviation. The theoretical distribution represents the results that would be expected under the null hypothesis that there is no difference between the expected and observed results and observed differences are merely chance variations expected in a random sample. For example, the results found in HIGH-intensity plots at Bote Mountain were tested against results from all plots (which included the results of the HIGH-intensity plots) to see if differences in the observations of the HIGH-intensity-burn plots were significant, or if those differences simply occurred by chance.

To test the null hypothesis, the maximum deviation is determined and compared to the sampling distribution of maximum deviations under the null hypothesis at a desired probability, from which critical values have been determined (Siegel, 1956:251). Any maximum deviation that is found to be greater than or equal to the critical value of the maximum deviation at the desired probability level is significant and the null hypothesis is rejected. The significance of any given value of the maximum deviation depends on sample size.

For example, if the maximum deviation were found to be 0.360 and the sample size was 20, the critical value of the maximum deviation at the .01 level is 0.356 (Siegel, 1956:251). The maximum deviation (0.360) is greater-than 0.356; thus significant at the .01 level, and the null hypothesis is rejected.

In this study, differences were considered significant when the null hypothesis was rejected at the .05 level, and highly significant when the null hypothesis was rejected at the .01 level.

Chapter V

RESULTS AND DISCUSSION

A. Bote Mountain Site

Pre-fire Stand Composition and the Impacts of Burning.

Overstory composition. Tables A-2[a] and A-3 show the reconstructed pre-fire overstory stem count and basal area by species of the 18 plots sampled on Bote Mountain. Tables 1 and 2 summarize those plot data into the LOW-, MEDIUM-, and HIGH-intensity burn levels. There were a total of 468 stems with DBHs greater than 7.5 cm counted in the 18 plots that had a total basal area of 14.59 m^2 (650.00 stems/ha and 20.26 m^2/ha, respectively). The composition and fire damage of the pines and hardwoods will be discussed separately.

Pines. Table Mountain pine accounted for 63.89 percent of the overstory stems sampled and 67.58 percent of the basal area. There were 299 Table Mountain pines for an average of 16.61 stems per plot (415.27 stems/ha). The average Table Mountain pine stem count for the LOW-intensity plots was 11.50 stems/plot (287.50 stems/ha), 15.33

[a]Appendix Tables are numbered A-1, A-2, A-3, etc. Text Tables are numbered 1, 2, 3, etc.

Table 1. Stem Density of Pre-fire Overstory at Bote Mountain (stem DBH 7.5 cm and greater).

Plot Intensity Level	Table Mtn. Pine	Pitch Pine	Chestnut Oak	Scarlet Oak	Red Maple	Other Hdwds.
			Total Number of Stems Sampled			
LOW	69	29	4	17	9	6
MEDIUM	92	19	11	19	9	3
HIGH	138	4	3	28	8	1
Total	299	52	18	64	26	10
			Average Number of Stems Per Plot			
LOW	11.50[a]	4.83	0.67	2.83	1.50	1.00
MEDIUM	15.33	3.17	1.83	3.17	1.50	0.50
HIGH	23.00	0.67	0.50	4.67	1.33	1.67
Total	16.11	2.89	1.00	3.56	1.44	0.56
			Standard Deviation Per Plot			
LOW	4.76	5.27	1.12	1.72	1.05	1.10
MEDIUM	11.78	3.87	3.13	1.72	2.24	0.84
HIGH	15.54	0.82	0.84	2.67	1.86	0.41
Total	11.95	3.98	1.97	2.12	1.69	0.86
			Average Number of Stems Per Hectare			
LOW	287.50	120.83	16.67	70.83	37.50	25.00
MEDIUM	383.33	79.17	45.83	79.17	37.50	12.50
HIGH	575.00	16.67	12.50	116.67	33.33	4.17
Total	415.27	72.22	25.00	88.89	36.11	13.89

[a]All figures rounded to the nearest 0.01.

Table 2. Basal Area (m^2) of Pre-fire Overstory at Bote Mountain (stem DBH 7.5 cm and greater).

Plot Intensity Level	Table Mtn. Pine	Pitch Pine	Chestnut Oak	Scarlet Oak	Red Maple	Other Hdwds.
			Total Basal Area			
LOW	2.81[a]	1.03	0.24	0.46	0.17	0.19
MEDIUM	2.79	0.84	0.28	0.40	0.09	0.02
HIGH	4.26	0.25	0.04	0.67	0.19	0.01
Total	9.86	2.12	0.56	1.53	0.45	0.22
			Average Basal Area Per Plot			
LOW	0.47	0.17	0.04	0.08	0.03	0.03
MEDIUM	0.46	0.14	0.45	0.07	0.02	0.00
HIGH	0.71	0.04	0.01	0.11	0.03	0.00
Total	0.55	0.12	0.03	0.09	0.03	0.01
			Standard Deviation Per Plot			
LOW	0.34	0.16	0.09	0.07	0.36	0.04
MEDIUM	0.29	0.16	0.07	0.06	0.01	0.01
HIGH	0.39	0.07	0.01	0.08	0.04	0.00
Total	0.34	0.14	0.06	0.07	0.03	0.03
			Average Basal Area Per Hectare			
LOW	11.71	4.33	0.99	1.93	0.72	0.80
MEDIUM	11.60	3.51	1.17	1.67	0.38	0.08
HIGH	17.76	1.04	0.18	2.79	0.79	0.03
Total	13.69	2.95	0.78	2.13	0.63	0.31
			Average DBH (cm) Per Stem			
LOW	22.77	21.29	27.52	18.64	15.60	20.24
MEDIUM	19.63	23.76	18.05	16.41	11.32	9.00
HIGH	19.83	28.19	13.54	17.45	17.33	9.96
Total	20.49	23.81	19.95	17.48	14.86	16.73

[a]All figures rounded to the nearest 0.01.

stems/plot (383.33 stems/ha) in the MEDIUM-intensity plots, and 23.00 stems/plot (575.00 stems/ha) in the HIGH-intensity plots. The number of stems per plot ranged from four to 54 (Table A-2). This wide range likely accounts for the high standard deviation (11.95 stems/plot) in the sample, especially among the MEDIUM- and HIGH-intensity plots (11.78 stems/plot and 15.54 stems/plot, respectively) where the widest ranges were observed (4-38 and 13-54, respectively). While these ranges are quite wide, 11 of the 18 plots had stems counts between 12 and 19, which is more reflective of the sample average (16.61 stems/plot).

The basal area of Table Mountain pine averaged 0.55 m^2/plot (13.69 m^2/ha) in the sample. The average basal area in the LOW-intensity plots was 0.47 m^2/plot (11.71 m^2/ha), while it was slightly less in the MEDIUM-intensity plots--0.46 m^2/plot (11.60 m^2/ha). The HIGH-intensity plots averaged considerably more with 0.71 m^2/plot (17.76 m^2/ha). Average DBH for Table Mountain pine in the sample was 20.49 cm, or 22.77 cm, 19.63 cm, and 19.83 cm for the LOW-, MEDIUM-, and HIGH-intensity plots, respectively.

As with stem count, there was a wide range in basal areas observed among the 18 plots (0.07 m^2/plot to 1.31 m^2/plot), which likely accounts for much of the standard deviation shown (0.34 m^2/plot). The wide ranges and high standard deviations in stem count and basal area reflect a very heterogeneous population of Table Mountain pine, which could be expected in these old stands.

Pitch pine was found in the overstory of 11 plots, with a total of 52 stems for an average of 2.89 stems/plot (72.22 stems/ha). Their average DBH was 22.81 cm, and the average basal area was 0.12 m^2/plot (2.95 m^2/ha). Pitch pines were not as widely distributed as the stem count suggests, as 15 pitch pines were tallied in one plot. This accounts for 28.85 percent of the stem count and 20.75 percent of the basal area, and contributes to the high standard deviations shown (3.98 stems/plot and 0.14 m^2/plot, respectively).

Fire damage to Table Mountain pine in overstory. Table A-4 shows the damage to the overstory Table Mountain pine in each of the 18 plots. All but four of the 138 Table Mountain pines in the HIGH-intensity plots were killed (Table 3). The four surviving Table Mountain pines were in the same plot and were found on the fringe of a crowned-out area where they escaped the intense fire. Although the MEDIUM-intensity plots were not located in areas that experienced a running crown fire, 66 of the 92 Table Mountain pines (71.74 percent) were burned badly enough to be killed. This compares to just 8 of 69 (11.59 percent) killed in the LOW-intensity plots. Of the surviving stems, four stems in the LOW-intensity plots and three in the MEDIUM-intensity plots were classified as "damaged."

Table 3. Summary of Fire Damage to Overstory Table Mountain Pine at Bote Mountain (stem DBH 7.5 cm and greater).

Plot Intensity Level	Total Number Stems	Damage to Tree: None	Damage to Tree: Charred/ Scorched	Damage to Tree: Killed	Heat Sustained by Canopy/Cones: Low	Heat Sustained by Canopy/Cones: Mod.	Heat Sustained by Canopy/Cones: High
			Totals				
LOW	69	57	4	8	55	10	4
MEDIUM	92	23	3	66	0	67	25
HIGH	138	4	0	134	0	6	132
Total	299	84	7	208	55	83	161
			Average DBH (cm) Per Stem				
LOW	22.77	24.62	15.13	14.10	24.25	13.28	14.38
MEDIUM	19.63	20.31	33.71	18.49	-	19.54	19.87
HIGH	19.83	20.73	-	19.80		19.29	19.86
Total	20.49	23.34	24.85	19.20	24.25	18.88	19.74

[a]Rating of the amount of heat sustained to open serotinous cones in the crown of the tree.

In the LOW-intensity plots, stem diameter appeared to have had an effect on survivability. The average DBH of all 69 Table Mountain pines in the LOW plots was 22.77 cm. The undamaged stems had an average DBH of 24.62 cm, while the eight that were killed averaged 14.10 cm DBH. However, under the Kolmogorov-Smirnov test, these differences in DBHs were not significant.

Table Mountain pines surviving the fire were larger than those killed. Large diameter trees have thicker bark, providing more protection to the cambium. In a regression of bark thickness on tree diameter, Zobel (1969) found that the bark layer of small Table Mountain pine (10 cm DBH) is thin (9 mm on bark ridges), similar to that of Virginia pine. At larger diameters (41 cm), however, the bark becomes significantly thicker (25 mm), reaching the thickness of pitch pine bark. Another reason for the increased survival in the larger diameter stems may be that they will generally be taller than smaller stems, with more of their crowns above the heat of a surface fire.

As fire intensity increases above the cool surface fire stage to the hot, surface fire and crown fire stages, stem size probably has a much smaller effect on a tree's chance of survival. This is because fire damage to the tree's crown becomes much more detrimental than in a low-intense burn. For example, the four surviving trees in plot number 13 had a slightly higher average DBH than those killed in the six HIGH-intensity plots (20.73 cm and 19.80 cm respectively). However, their survival can more likely be attributed to their location on the edge of the crown fire area than their to size. The same is likely true with the trees in the MEDIUM-intensity plots. While the undamaged stems had a larger average diameter (20.31 cm) than those that were killed (18.49 cm), these differences were not significant under the Kolmogorov-Smirnov test.

The probability that the serotinous cones of the Table Mountain pines received enough heat to open was highest in the HIGH-intensity plots. Of the 138 stems in those plots, 132 were in the "high" probability category and highly significant according to the Kolmogorov-Smirnov test. None were ranked as "low." In the MEDIUM-intensity plots, 25 of the 92 stems were ranked as "high" and the remainder as "moderate". Only four of the 69 Table Mountain pines in the LOW-intensity plots were ranked as "high," with 10 ranked as "moderate." The majority (55) were ranked as "low," which is highly significant according to the Kolmogorov-Smirnov test. On the "low" trees, only a few cones on the lowest branches were observed to be opened, while the cones in the upper part of the crown appeared unaffected by the fire.

Fire damage to pitch pine in overstory. Table A-5 is a summary of damage to the pitch pine stems in the overstory. Like Table Mountain pine, most of the pitch pine trees in the MEDIUM- and HIGH-intensity plots were killed-back by the fire.

In the MEDIUM-intensity plots 10 of the 19 pitch pine trees (52.63 percent) were killed-back, as were three of the four counted in the HIGH-intensity plots (Table 4). Only one of the 29 pitch pines (3.45 percent) in the LOW-intensity plots was killed-back. Of the surviving stems,

Table 4. Summary of Fire Damage to Overstory Pitch Pine at Bote Mountain (stem DBH 7.5 cm and greater).

Plot Intensity Level	Total Number Stems	Damage to Tree: None	Damage to Tree: Charred/ Scorched	Damage to Tree: Killed Back
		Totals		
LOW	29	26	2	1
MEDIUM	19	3	6	10
HIGH	4	1	0	3
Total	50	30	8	14
		Average Stem DBH (cm)		
LOW	21.29	21.75	19.24	10.00
MEDIUM	23.78	32.76	21.31	21.86
HIGH	28.20	46.00	-	18.83
Total	22.81	24.25	20.81	20.61

six pitch pines in the MEDIUM plots and two in the LOW plots were recorded as damaged, primarily by butt-char wounds.

As with Table Mountain pine, the pitch pine stems surviving the fire had a larger average DBH than those killed-back. The single pitch pine killed-back in the LOW plots had a DBH of 10 cm, while the average DBH of all LOW plot pitch pines was 21.29 cm. In the MEDIUM plots, the nine surviving stems averaged 25.69 cm DBH, while those killed-back averaged 21.86 cm DBH. However, these differences in diameters were not significant according to the Kolmogorov-Smirnov test. The one survivor of the four pitch pines in the HIGH plots was a 42 cm DBH specimen located in the same area of the plot that the four surviving Table Mountain pines.

Of the 22 pitch pines that were damaged or killed-back, 15 of them (68.18 percent) had epicormic and/or basal sprouts. Three growing seasons after the fire, some of the pitch pines that had been completely crowned out had sprouted epicormically with such vigor that they appeared undamaged from a distance.

Hardwood overstory composition and fire damage. Table 5 shows the damage the hardwoods in the overstory sustained from the fire. As a whole, the hardwoods did not fare as well in the fire as did the pines. In the LOW-intensity plots, 13 of the 36 hardwoods were killed-back while six suffered severe bark char wounds. All of the 82 hardwoods found in the MEDIUM and HIGH plots were killed-back.

As with the pines, the surviving hardwood stems were larger in diameter than those killed-back. In the LOW-intensity plots, the 23 surviving hardwoods averaged 21.20 cm DBH, while the thirteen killed-back averaged 15.92 cm DBH. The average DBH of all hardwoods that were killed-back was 16.22 cm.

The most abundant overstory hardwood species was scarlet oak (<u>Quercus coccinea</u> Muenchh.) with a total of 64

Table 5. Fire Damage to Overstory Hardwoods at Bote Mountain (stem DBH 7.5 cm and greater).

Plot Intensity Level	Total Number Stems	Damage to Tree: None	Damage to Tree: Charred/ Scorched	Damage to Tree: Killed Back
Chestnut Oak				
LOW	4	1	1	2
MEDIUM	11	0	0	11
HIGH	3	0	0	3
Total	18	1	1	16
Avg. DBH	19.95	40.00	18.00	18.10
Scarlet Oak				
LOW	17	10	2	5
MEDIUM	19	0	0	19
HIGH	28	0	0	28
Total	64	10	2	52
Avg. DBH	17.48	20.45	20.00	16.74
Red Maple				
LOW	9	5	1	3
MEDIUM	9	0	0	9
HIGH	8	0	0	8
Total	26	5	1	20
Avg. DBH	14.86	17.44	18.00	13.97
Other Hardwoods				
LOW	6	1	2	3
MEDIUM	3	0	0	3
HIGH	1	0	0	1
Total	10	1	2	7
Avg. DBH	16.73	36.00	11.05	13.52
All Hardwoods				
LOW	36	17	6	13
MEDIUM	42	0	0	42
HIGH	40	0	0	40
Total	118	17	6	95
Avg. DBH	17.30	22.49	16.79	16.22

stems tallied in the sample. Scarlet oak averaged 3.56 stems/plot (89.00 stems/ha) and 0.09 m^2/plot basal area (2.13 m^2/ha). The average DBH was 17.48 cm. Fifty-two of the scarlet oak stems were killed-back, while two were charred at the butt, but survived. The only stems surviving the fire were in the LOW-intensity plots. Forty-six of the stems that were damaged or killed-back (85.19 percent) were sprouting at the stump.

Red maple (*Acer rubrum* L.) and chestnut oak (*Quercus prinus* L.) were found in the overstory of 13 and seven plots, respectively, of the 18 plots sampled. Of 26 red maples, 20 had been killed-back, all of which were sprouting vigorously at the stump. Some red maple sprouts were as tall as five meters. The only red maple stems surviving the fire were found in the LOW-intensity plots. The same was true for the chestnut oaks, of which 16 of the 18 stems counted had been killed-back, 12 of which were sprouting.

Other hardwood species counted in the sample included black oak (*Quercus velutina* Lam.), southern red oak (*Quercus falcata* Michx.), sourwood (*Oxydendrum arboreum* L.), black gum (*Nyssa sylvatica* Marsh.), black cherry (*Prunus serotina* Ehrh.), and sweetgum (*Liquidambar styraciflua* L.). These species accounted for only 10 stems, seven of which were killed-back and sprouting. Again, the only hardwood stems surviving the fire were found in the LOW-intensity plots.

Understory composition. The understory saplings (stems with less than 7.5 cm DBH and at least 2 m high) were primarily hardwoods (Table 6). Of the 306 understory saplings tallied, only 48 (15.69 percent) were Table Mountain pine. However, 36 of these pine saplings had been suppressed by the overstory, and all but four of those were killed by the fire. There were 17 pitch pine saplings counted in the sample, 14 of which were killed-back by the fire. Nine of those killed-back were sprouting. Table 7 summarizes fire damage to the understory pines.

Table 8 summarizes damage to the hardwoods in the understory. Red maple was the primary understory species, with 111 saplings tallied (154.16 per ha). Of these, 108 were killed-back, and 103 were sprouting. Some of these sprouts were already over three meters high, but most were between one and two meters high. The three surviving stems were in the LOW-intensity plots.

Scarlet oak, chestnut oak, and blackgum were the other common species found in the understory, with total stem counts of 48, 27, and 25, respectively. Other species found in the understory were sugar maple (Acer saccharum Marsh.), southern red oak, black locust (Robinia psuedoacacia L.), sourwood, black cherry, American chestnut (Castanea dentata (Marsh.) Borkh.), and sweetgum. Of these, 112 out of 130 (86.15 percent) were killed-back, with 106 (94.64 percent) sprouting. While most sprouts ranged

Table 6. Stem Count of Pre-fire Understory at Bote Mountain (stem DBH less than 7.5 cm and height greater than 2 m).

Plot Intensity Level	Table Mtn. Pine	Pitch Pine	Chestnut Oak	Scarlet Oak	Red Maple	Other Hdwds.
			Total Stems			
LOW	14	10	11	22	51	35
MEDIUM	23	5	7	14	25	15
HIGH	11	2	9	12	25	5
Total	48	17	27	48	111	55
			Average Stems Per Plot			
LOW	2.33	1.67	1.83	3.67	8.50	5.83
MEDIUM	3.83	0.83	1.67	2.33	5.83	2.50
HIGH	1.83	0.33	1.50	2.00	4.17	0.83
Total	2.67	0.94	1.50	2.67	6.17	3.06
			Standard Deviation Per Plot			
LOW	3.67	2.25	1.94	3.01	7.71	5.98
MEDIUM	5.12	0.75	1.17	1.86	4.36	3.33
HIGH	2.86	0.51	1.38	1.90	2.45	0.98
Total	3.85	1.43	1.47	2.30	5.32	4.32
			Average Stems Per Hectare			
LOW	58.33	41.67	45.83	91.67	212.50	145.83
MEDIUM	95.83	20.83	29.17	58.33	145.83	62.50
HIGH	45.83	8.33	37.50	50.00	104.16	20.83
Total	66.67	23.61	37.50	66.67	154.16	76.39

Table 7. Fire Damage to Pine Stems in Understory at Bote Mountain (stem DBH less than 7.5 cm and height greater than 2 m).

Plot Intensity Level	Total Number Stems	Number Killed/ Killed Back	Percent Killed/ Killed Back
	Table Mountain Pine		
LOW	14	10	71.43
MEDIUM	23	23	100.00
HIGH	11	11	100.00
Total	48	44	91.67
	Pitch Pine		
LOW	10	7	70.00
MEDIUM	5	5	100.00
HIGH	2	2	100.00
Total	17	14	82.35

Table 8. Fire Damage to Hardwood Stems in Understory at Bote Mountain (stem DBH less than 7.5 cm and height greater than 2 m).

Plot Intensity Level	Total Number Stems	Number Killed/ Killed Back	Percent Killed/ Killed Back
	Chestnut Oak		
LOW	11	7	63.63
MEDIUM	7	7	100.00
HIGH	9	9	100.00
Total	27	23	85.19
	Scarlet Oak		
LOW	22	11	50.00
MEDIUM	14	14	100.00
HIGH	12	12	100.00
Total	48	37	77.08
	Red Maple		
LOW	51	48	94.12
MEDIUM	35	35	100.00
HIGH	25	25	100.00
Total	111	108	97.30
	Other Hardwoods		
LOW	35	32	91.43
MEDIUM	15	15	100.00
HIGH	5	5	100.00
Total	55	52	94.55
	All Hardwoods		
LOW	119	98	82.35
MEDIUM	71	71	100.00
HIGH	51	51	100.00
Total	241	220	91.29

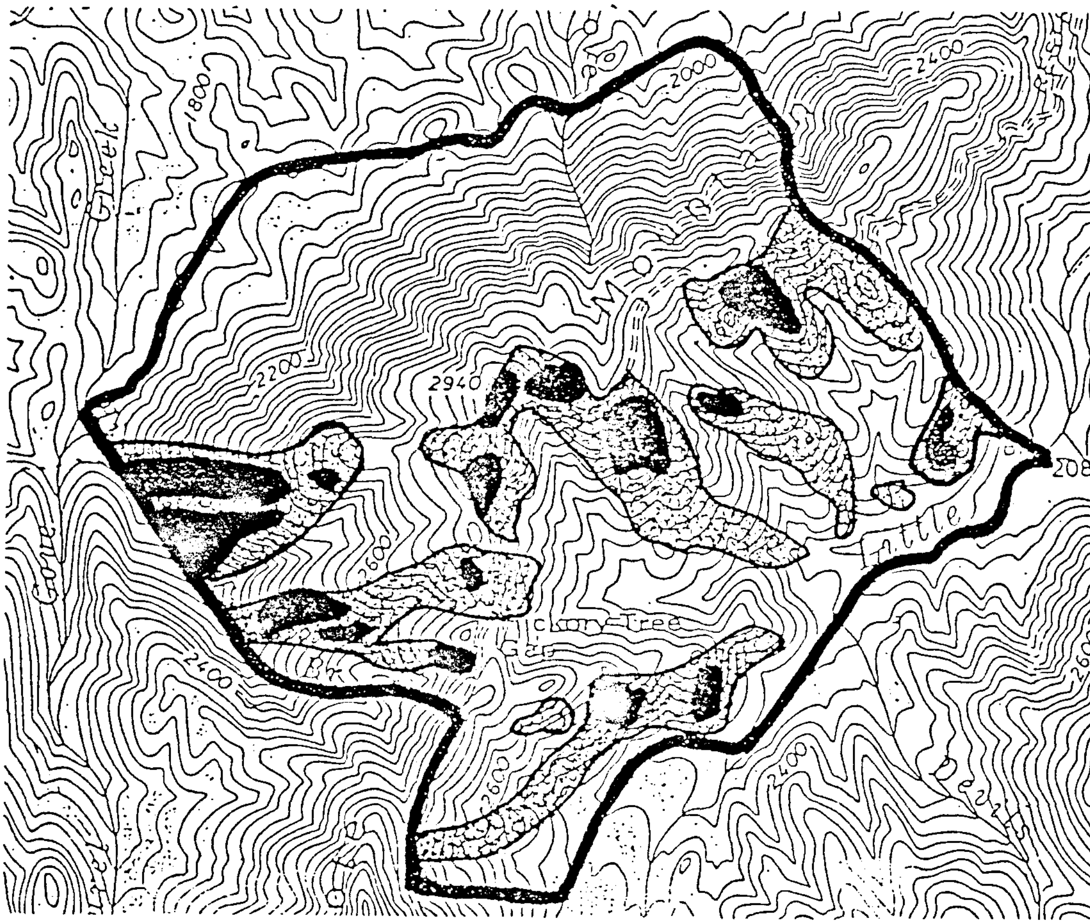
between 1-3 meters in height, several black locusts were taller than three meters.

Mountain laurel was the primary shrub species in the understory and was abundant in every plot on Bote Mountain. Judging from charred stems in the burn area, it had formed a closed understory canopy approximately one-to-two meters high. Almost without exception, every burned clump was resprouting, with sprouts averaging just over 50 cm high.

Burn patterns. Figure 3 is a map showing the burn patterns of the Bote Mountain fire. On the Hickory Fire, the areas that supported the hottest fire were those that contained the most pine stems. Combining pitch and Table Mountain pines, the LOW-intensity plots averaged 408.32 stems/ha, while the MEDIUM-intensity plots averaged 454.18 stems/ha. The HIGH-intensity plots, however, averaged 591.68 stems/ha, which is 45 percent more stems than the LOW-intensity plots and 30 percent more than the MEDIUM-intensity plots.

Mountain laurel was the "ladder fuel" present throughout the understory, providing fire with continuous vertical fuel capable of carrying fire from the ground to the pine canopy. Without mountain laurel in the understory, there would likely have been less crown fire.

Another factor affecting fire intensity was slope position. Four of the LOW-intensity plots were on ridge-



N

LEGEND

Fire Perimeter

LOW-intensity Burn

MEDIUM-intensity Burn

HIGH-intensity Burn

Scale = 1:16,875

Contour Interval = 40 ft.

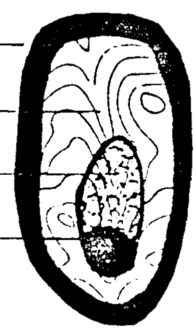


Figure 3. Burn Patterns of the Bote Mountain Fire.

tops, rather than on steeper side slopes. Fires, especially crown fires, generally lose intensity when they "top out" on a ridge because slope steepness is reduced. Many wildfires in the southeast are contained at ridgetops, rather than midslope, because of this decrease in fire intensity.

Examining of the fire suppression report revealed that the sites in which most of the plots fell were burned from a backfire set by suppression crews from the bottom of the west side of the mountain along Hickory Tree Branch. The original fire was human-caused (escaped camp fire) and originated from the West Prong of the Little River on the east side of the mountain.

Regeneration of Table Mountain Pine.

Seedbed and seedling occurrence. Of the 1152 miniplots sampled (64 per plot), the depth of residual organic matter (ROM) recorded ranged from none to over 16 cm. Table 9 lists the number of miniplots recorded in ROM depth classes.

The majority of the miniplots with ROM depths less than 1 cm were found in the HIGH-intensity plots (Figure 4). Most of the miniplots in this class actually had no surface ROM at all, leaving mineral soil exposed. In the HIGH plots, 232 of the 384 (60.42 percent) miniplots sampled had ROM depths less than 1 cm. The large number of miniplots in the ROM < 1 cm depth class was found to be highly

Table 9. Number of Miniplots in Each ROM Depth Class in Bote Mountain Plots (64 miniplots per plot).

Plot Number	Residual Organic matter Depth Class (cm) 0-1	1-5	6-10	11-15	16+
			LOW-Intensity Plots		
1	1	16	28	6	2
2	14	8	30	11	1
3	6	16	34	7	1
4	8	10	30	13	3
15	13	22	24	5	0
16	16	19	20	8	1
Total	58	101	167	50	8
Percent	15.10	26.30	43.49	13.02	2.08
			MEDIUM-Intensity Plots		
5	20	10	23	10	1
6	26	16	12	2	8
9	22	36	6	0	0
10	23	7	24	9	1
12	25	36	1	1	1
14	13	49	2	0	0
Total	129	154	68	22	11
Percent	33.59	40.10	17.71	5.73	2.86
			HIGH-Intensity Plots		
7	26	22	8	5	3
8	40	20	4	0	0
11	51	8	5	0	0
13	46	18	0	0	0
17	36	26	2	0	0
18	33	20	11	0	0
Total	232	114	30	5	3
Percent	60.42	29.69	7.81	1.30	0.78
Grand Total	419	369	265	77	22
Percent	36.37	32.03	23.00	6.68	1.91

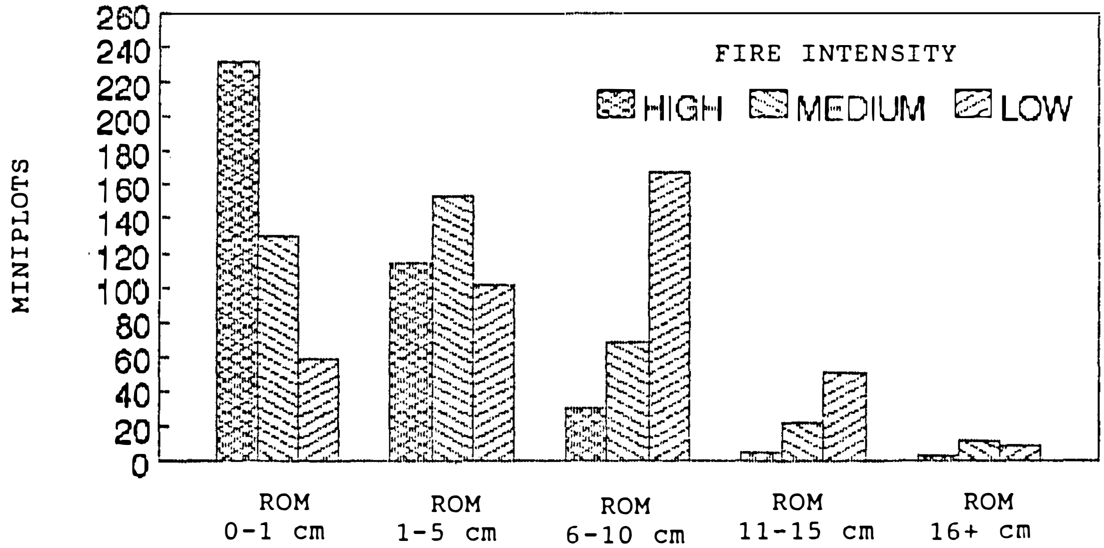


Figure 4. Number of Miniplots per ROM Depth Class.

significant at the .01 level. This indicates that the higher number of miniplots in this depth class found in the HIGH-intensity plots can be attributed to high fire intensities rather than coincidence. Only 38 miniplots (9.90 percent) had ROM depths greater than 6 cm.

The reverse was true for the LOW-intensity plots where 225 miniplots (58.59 percent) had ROM depths greater than 6 cm, and only 58 (15.10 percent) had ROM depths less than 1 cm. These results, too, were highly significant according to the Kolmogorov-Smirnov test.

Since one of the requirements for successful regeenration of Table Mountain pine is a mineral soil seedbed, it should not be surprising that the majority of the regeneration at Bote Mountain occurred in areas where the ROM depth was less than 1 cm. Table A-6 shows, by plot, the number of miniplots per ROM depth class with at least one seedling of Table Mountain pine present. Table 10 compares the number of miniplots in each ROM depth class (Table 9) with those containing at least one seedling (Table A-6). Nearly half (185 of 419) of the miniplots with ROM 1 cm or less had at least one seedling present. Seedling occurrence decreased dramatically as ROM depth increased. Only 70 of 369 miniplots (18.97 percent) in the 1-5 cm ROM depth class had a seedling present, while just four of the 265 miniplots in the 6-10 cm depth class contained a seedling. No seedlings were found in miniplots with ROM depths 11+ cm or greater.

Seedling density. There were 353 seedlings of Table Mountain pine in the 1152 miniplots giving an average of 19.61 seedlings/plot (1.23 seedlings/m^2, or 12,256.18 seedlings/ha). Several miniplots had more than one seedling, and the count per plot (64 miniplots) ranged from none to 70 (Table A-7).

The majority of the seedlings counted (192, or 54.39 percent; density of 20,000/ha) were found in the HIGH-intensity plots. Most of those seedlings (170, or 88.54 percent) were found in miniplots with ROM depths less than 1 cm (Table 11), a highly significant relationship according to the Kolmogorov-Smirnov test.

Table 10. Number of Miniplots in Each ROM Depth Class with the Number of Miniplots Containing at Least One Seedling of Table Mountain Pine at Bote Mountain.

	Residual Organic Matter Depth Class (cm)				
	0-1	1-5	6-10	11-15	16+
			LOW-intensity Plots		
# Miniplots[a]	58	101	167	50	8
# With TMP[b]	11	1	2	0	0
% With TMP[c]	18.97	0.99	1.20	0.00	0.00
			MEDIUM-intensity Plots		
# Miniplots	129	154	68	22	11
# With TMP	66	49	1	0	0
% With TMP	51.16	31.82	1.47	0.00	0.00
			HIGH-intensity Plots		
# Miniplots	232	114	30	5	3
# With TMP	108	20	1	0	0
% With TMP	46.55	17.54	3.33	0.00	0.00
			All Plots		
# Miniplots[d]	419	369	265	77	22
# With TMP	185	70	4	0	0
% With TMP	44.15	18.97	1.51	0.00	0.00

[a]Number per depth class (total miniplots = 384).

[b]Number of miniplots in ROM depth class with Table Mountain pine seedling(s) present.

[c]Percent of miniplots in ROM depth class with Table Mountain pine seedling(s) present.

[d]Total miniplots = 1152.

Table 11. Seedling Count of Table Mountain Pine in Miniplots by ROM Depth Class at Bote Mountain (Total of 1152 Miniplots).

	ROM Depth Class (cm)				
	0-1	1-5	6-10	11+	Totals
		LOW-intensity Plots			
Seedlings	11	1	2	0	14
Percent	78.57	7.14	14.29	0	100
		MEDIUM-intensity Plots			
Seedlings	81	65	1	0	147
Percent	55.10	44.22	0.68	0	100
		HIGH-intensity Plots			
Seedlings	170	21	1	0	192
Percent	88.54	10.94	0.52	0	100
		All Plots			
Seedlings	262	87	4	0	353
Percent	74.22	24.65	1.13	0	100

In the MEDIUM-intensity plots regeneration was slightly less with 147 seedlings counted (15,312.50/ha), 81 of which (55.10 percent) were in miniplots where ROM was less than 1 cm. This relationship was highly significant according to the Kolmogorov-Smirnov test.

Regeneration in the LOW-intensity plots was very low, as only 14 seedlings were tallied (1458.33/ha). Of these, 11 were in the "ROM < 1 cm" depth class.

In all, 262 seedlings were counted in miniplots with ROM depths less than 1 cm, which is 74.22 percent of all seedlings of Table Mountain pine that were tallied (Figure 5). Seedling density was much lower where ROM layers were thicker. Only 94 seedlings (26.26 percent) were counted in

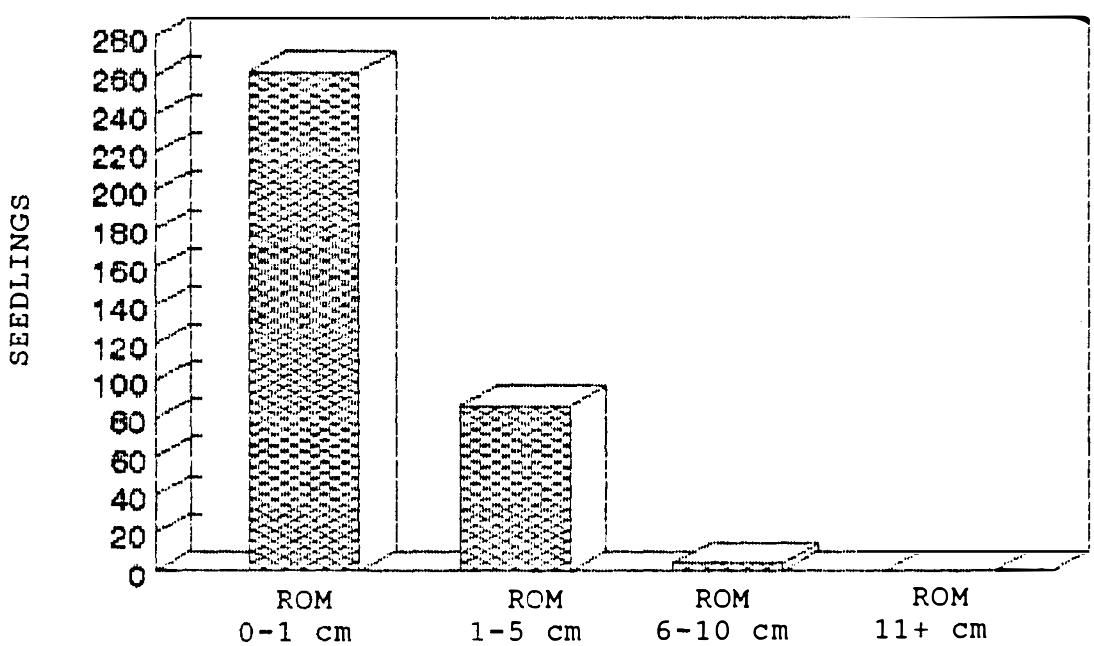


Figure 5. Seedling Density by ROM Depth.

miniplots in the 1-5 cm ROM depth class, while only four were found in the 6-10 cm class. Again, no seedlings were found where ROM depth exceeded 11 cm.

Two relationships pertinent to the site preparation necessary for regeneration of Table Mountain pine become apparent from these observations--(1) sites that burned the hottest had the least amount of residual organic matter and more mineral soil exposed, and (2) pine regeneration was most successful on sites where mineral soil was exposed. It was impossible to determine the exact depth of the organic layer and the amount of surface fuels that were present before the fire. However, the organic matter depths were checked at several similar sites that were adjacent to the fire, and although a wide variation was found, there were no areas where mineral soil was exposed except in a few "spots" where trees had "uprooted."

Regardless of how much of the organic layer was removed, the data suggest that successful regeneration of Table Mountain pine will not occur unless essentially all is removed. Even in some of the areas where the fire intensity was low, seedlings germinated in small microsites created where a log had been completely burned up, leaving a small area of exposed mineral soil where surrounding organic matter was much thicker.

Vigor. In the three growing seasons following the Bote Mountain fire, some seedlings of Table Mountain pine had already grown to over a meter in height. Others, however, appeared to have just germinated. The heights of seedlings found in the miniplots in the LOW-, MEDIUM-, and HIGH-intensity plots are summarized in Table 12.

Nearly two-thirds of the seedlings tallied were between 25 cm and 75 cm high. The majority of seedlings in the "75+cm" height class were found in HIGH-intensity plots, where the overstory canopy was completely removed, allowing maximum exposure to sunlight. However, this relationship was not statistically significant according to the Kolmogorov-Smirnov test.

Although the MEDIUM-intensity plots were located in areas where the fire did not crown out, it appears as though

Table 12. Summary of Seedling Heights at Bote Mountain

	Height Class				
Plots	0-5 cm	6-25 cm	26-50 cm	50-75 cm	75+ cm
LOW	1	10	3	0	0
MED	5	27	69	37	9
HIGH	2	59	83	32	16
TOTAL	8	96	155	69	25

the fire still created openings in the overstory sufficient to provide seedlings with enough sunlight for satisfactory growth. Both shading and root competition are likely affecting the few seedlings in the LOW-intensity plots, causing their shorter heights.

Of the 355 seedlings counted, 305 (86.40 percent) were not in immediate danger of being overtopped and suppressed by other, competing species and were judged to be "free-to-grow." Five seedlings were rated as "not free-to-grow." It was not yet possible to determine the "fate" of the other 43 seedlings, most of which were less than 25 cm in height.

Sprouting clumps of mountain laurel were tallied in 200 miniplots (17.36 percent) with an average height of just over 50 cm. In most cases, however, pine seedlings had already exceeded the height of mountain laurel, eliminating any threat of being overtopped.

The biggest suppression threat to pine seedlings appeared to be from hardwood sprouts, which, in some cases, had already grown to 3 m in height. Initial growth of hardwood sprouts is often rapid due to availability of food and nutrient reserves in an already-established root system. This rapid growth soon declines, however, once the reserve is depleted. In addition, as hardwood stems were not abundant in the original stand, the taller "clumps" of hardwood sprouts were scattered, leaving most of the pine seedlings in the stand exposed to full sunlight.

Other Regeneration.

Pitch pine. Pitch pine regeneration was primarily by epicormic sprouting. Fifteen of the 22 pitch pines in the overstory that were damaged or killed-back were sprouting. Nine of the 14 saplings that were killed-back were sprouting as well. Most of the sprouts were over 1 m high, with some higher than 2 m. Only three pitch pine seedlings were tallied in the miniplots, the tallest being 60 cm. As the Hickory Fire burned in the spring, any pitch pine seed released the previous autumn was likely destroyed. This supports the observations of Buckner et al (1987) in studies of the Peachtree Fire that no pine seedling regeneration will be found in stands of pitch, Virginia, and shortleaf pines when intense burning occurs after seedfall. The abundant regeneration of Table Mountain pine following the Hickory Fire was possible because pine seeds were protected from the fire by the closed cones and released shortly after fire opened the cones.

Hardwoods. Table 13 summarizes the hardwood regeneration found in miniplots. Most of the hardwoods that were killed-back or damaged were sprouting, accounting for the majority of hardwood regeneration. Although some hardwood seedlings were found (primarily red maple), regeneration from seed was negligible.

Table 13. Hardwood Regeneration From Stump Sprouting Following the Bote Mountain Fire.

Species	# Stems Damaged & Killed Back	Number Sprouting	Number Sprouting Per Hectare	Avg. Ht. Tallest Sprout (cm)[a]
Chestnut Oak	40[b]	35	48.61	174.44
Scarlet Oak	91	81	112.50	107.94
Red Maple	129	124	172.22	130.63
Other Hardwoods	61	56	77.78	74.29
Total Hardwoods	321	296	411.11	102.96

[a]Average height of the tallest sprout in stump clusters found in miniplots measured to the nearest 10 cm.

[b]Number of overstory and understory stems counted in the 18 plots.

Red maple was the most abundant hardwood regenerating, with 124 of the damaged and killed-back overstory and understory stems sprouting in the 18 plots (172.22 sprout-clusters/ha). The average height of the tallest sprout in the cluster (measured from a subsample taken in the miniplots to the nearest 10 cm) was 131 cm. Some of these sprouts had already grown higher than 3 m.

Scarlet and chestnut oaks appear to be the climax vegetation for these upper south-to-west exposures. Sprouting scarlet oak stumps totaled 91 (112.5 per ha), while there were 40 sprouting chestnut oak stumps (48.61 per ha). The average heights of the tallest sprouts for the two oaks were 107.94 cm and 174.44 cm, respectively. Other hardwood species accounted for 61 sprout clumps (77.78 per ha) with an average height of 74.29 cm. Black gum was the primary species of these other hardwoods.

Shrubs. Mountain laurel was the primary shrub species regenerating on this site. Other woody plants commonly found were blueberries (Vaccinium) and greenbriars (Smilax).

Blueberries were found in 629 of the 1152 miniplots (54.60 percent). They were most abundant in areas where the residual organic matter was the thickest. In the LOW-intensity plots, where the most miniplots had ROM depths greater than 6 cm, blueberries were found in 313 of the 384 miniplots (81.51 percent). In the MEDIUM-intensity plots, blueberries were found in 174 of the miniplots (45.31 percent), while they were growing in just 142 (36.98 percent) of the HIGH-intensity miniplots. It was noted during sampling that, when approaching an area where blueberries were abundant, regeneration of Table Mountain pine was scarce. Upon examination, it was noted that a large portion of the blueberry root system was in the organic layer. It was apparent that where the fire removed the organic layer, creating a suitable seedbed for Table Mountain pine, it also removed much of the root mass of the blueberries.

Greenbriar was found in 246 of the miniplots sampled (21.35 percent). They too, were most abundant in the LOW-intensity miniplots (93, or 24.22 percent). Occurrence in the MEDIUM- and HIGH-intensity plots was slightly less--77 (20.05 percent) and 76 (19.79 percent), respectively.

Galax, a small evergreen ground-cover plant, was found regenerating in 41 miniplots (3.56 percent). Its occurrence was highest in the LOW-intensity plots, where it was found in 19 miniplots, versus 14 and 8 in the MEDIUM- and HIGH-intensity plots, respectively. Although galax regeneration in the burned area was not abundant, in nearby, unburned pine stands it was a common understory species. The galax in these stands often supported a layer of fallen pine needles, suspending them in a network that is well aerated and dries rapidly. This combination of waxy, flammable galax leaves and dry pine needles forms a highly combustible "bed" that allows fires to burn rapidly and with high intensities. Where galax was abundant in the pre-fire understory, it is probable that it, in conjunction with mountain laurel, contributed to crowning and high fire intensities.

Other Fire Effects.

There was no evidence of significant soil erosion on the areas burned by the Bote Mountain fire. In areas burned to mineral soil, some minor, on-site soil movement was observed.

A field trip to Bote Mountain in October 1990 revealed that many of the stems that were killed or killed-back by the fire were beginning to fall, especially on higher ridges most exposed to winds. This, in conjunction with sprouting mountain laurel and greenbriars, made foot travel in these areas very difficult. The fallen stems and sprouting mountain laurel also compose a new accumulation of surface fuel, which would at first appear to be very conducive to supporting a hot fire. However, there was very little light, flashy surface fuel, such as hardwood litter and pine needles, available to carry a fire. The areas with the most exposed mineral soil, which supported the most abundant Table Mountain pine regeneration, were also the areas with the least amount of light surface fuel. Thus, areas burned by hot fire not only produced the most regeneration, but were essentially "fireproofed" as well.

Summary: Bote Mountain.

The Bote Mountain fire burned through several stands of nearly pure Table Mountain pine at intensities ranging from light surface fire to running crown fire. Fire intensities were highest in areas with the most pine in the overstory. Galax and mountain laurel in the understory appeared to be the primary ladder fuels contributing to high fire intensities.

The Bote Mountain fire had two primary effects on stands of Table Mountain pine. In lightly burned areas, it killed-back most competing vegetation, probably prolonging the life of pine stands there. In areas burned by more intense fires, older stands were replaced by a new crop of seedlings, and developing hardwood competition that would eventually replace Table Mountain pine in later seral stages was killed-back.

The three requirements for successful regeneration of Table Mountain pine--(1) sufficient heat to open serotinous cones, (2) a seedbed of exposed mineral soil, and (3) exposure of seedlings to full sunlight--were best met in areas burned by crown fire (HIGH-intensity plots), where the most regeneration was occurring.

Where hot surface fire burned (MEDIUM-intensity plots), heat was still intense enough to open most serotinous cones, kill back much of the overstory, and expose enough mineral soil to result in ample regeneration of Table Mountain pine.

In areas burned by light surface fires (LOW-intensity plots), much of the surface organic layer was generally left intact with very little mineral soil exposed. The crowns of Table Mountain pines in these areas were largely unaffected by the fire and most of their serotinous cones remained closed. Very few openings were made in the canopy, which is shading the small number of seedlings that regenerated.

In the lightly burned areas, most of the competing hardwoods were killed-back, while most Table Mountain pines were undamaged. As Table Mountain pine can attain ages of over 200 years (Zobel, 1969), this may prolong the longevity of pine stands in these areas. However, if these stands are never burned by hot fire, they will eventually convert to hardwoods because regeneration in these areas was primarily by hardwood sprouts. Pine mortality from southern pine beetle, which was present in areas on Bote Mountain, will accelerate this process.

Most seedlings of Table Mountain pine regenerating after the fire were between 25 and 75 cm in height after three growing seasons. While some seedlings had already exceeded 100 cm in height, others had just germinated, indicating that regeneration may continue to occur for several years following a fire.

While Table Mountain pine dominated the overstory of the areas sampled, hardwoods (primarily red maple, scarlet oak, and chestnut oak) dominated the understory. Most of the hardwoods in both the overstory and understory were killed-back by even light surface fire, and most stems killed-back were sprouting vigorously. Although these sprouts were generally taller than most seedlings of Table Mountain pine, there appeared to be no immediate threat that these hardwood sprouts would suppress the pine regeneration since clusters of stump sprouts were usually scattered widely in the stand, leaving most seedling in full sunlight. Regeneration of hardwoods by seeding was rare.

Pitch pine was present in much of the study area and appeared to be more resilient to surface fires than any other species. Although regeneration of pitch pine from seeding was uncommon, two-thirds of damaged and killed-back stems were sprouting vigorously.

Mountain laurel was the primary shrub species in the pine stands burned, and was sprouting vigorously from stems killed-back by fire. Blueberries, greenbriars, and galax accounted for most of the ground vegetation regenerating. All three species were coming back most abundantly in the areas burned the lightest. Although the occurrence of galax regeneration was light, similar unburned sites in the area indicate it was probably more abundant before the fire and contributed to high fire intensities.

While the Bote Mountain fire appears to have benefited Table Mountain pine, a fire in the near future could have an adverse effect. In areas that burned the hottest, the seed source has been depleted. While regeneration of Table Mountain pine there is plentiful, even a light surface fire could wipe it out, causing the stand to be replaced by sprouting hardwoods and pitch pine. However, in areas burned the hottest, where most regeneration occurred, there was virtually no light, flashy surface fuel present to carry such a fire, leaving these areas essentially "fireproof."

How long, then, will these areas remain "fireproofed?" How long must fire be absent in these newly regenerated areas before a seed source is again available to perpetuate the stand? While saplings as young as eight years produce cones with viable seed (McIntyre, 1929), will there be enough seed available to ensure adequate regeneration if a stand burns at that age?

What will the site look like in the near future? Regeneration in the HIGH-intensity plots averaged 20,000 stems per ha. How long will this density be maintained before less vigorous stems are suppressed by faster-growing specimens?

The results from sites studied at the Horsehitch Gap and Greystone Mountain, where fires burned stands of 40 and 20 year-old respectively, will help answer these questions.

B. Horsehitch Gap Site

Composition of 1941 Stand.

The stand originating from the 1941 fire (overstory stand) was nearly pure Table Mountain pine. There were no overstory stems in the five plots in Transect Line A, which was purposely located where the overstory had boen removed by the 1981 fire. In the other four transect lines, overstory Table Mountain pines occurred at an average of 1320 stems/ha with an average basal area of 20.61 m^2/ha (Table 14). The average DBH of Table Mountain pine in these plots was 14.09 cm, indicating a very slow growth rate.

Assuming that there were no significant differences in stand composition among the sampled areas previous to the 1981 fire, it is evident that the survival rate of Table Mountain pine increased as fire intensity decreased. Although a crown fire did not run through the area where Transect B and C were located, the lower stem counts indicate that fire intensities were still high enough to kill individual stems, much like the intensities in the MEDIUM-intensity plots in the Bote Mountain study. Fire char on stems here often reached higher than 5 m, while it

Table 14. Density and Basal Area of Table Mountain Pine in 1941 Stand at Horsehitch Gap.

Transect Line	Stems Per Ha	Basal Area Per Ha (m^2)	Average DBH (cm)
B[a]	960	15.38	14.28
C	1040	17.83	14.78
D	1640	26.60	14.37
E	1640	22.61	13.25
Totals	1340	20.65	14.09

[a]Transect Line A was not located in 1941 stand.

reached only approximately 2 m in the part of the stand where Transects D and E were located. In addition, fallen, dead stems of Table Mountain pine were more abundant in the areas of Transects A, B, and C than in areas of Transects D and E, where there were very few. Fire intensity in the areas where Transects D and E were located probably were similar to those in the LOW-intensity plots at Bote Mountain.

Of the 132 Table Mountain pines counted in the sample, 32 had DBHs of 10 cm or less, 20 of which were suppressed by more dominant stems. Most of these stems were found in Transect E plots (13 stems) and Transect D plots (11 stems), while the occurrence decreased to five stems in Transect C plots and just three in Transect B plots. It is probable that most of the smaller-diameter stems in the areas of Transects B and C were killed in 1981, while more were able to survive the lower fire intensities where Transects D and E were located.

There were 22 pitch pines in the sample, providing an average of 220 stems/ha with an average basal area of 3.34 m^2/ha. The average DBH of pitch pine was 13.90 cm. Only one hardwood tree was found in the sample that had survived the 1981 fire. This was a 12 cm blackjack oak (*Quercus marilandica* Muenchh.) that was fire-scarred and in poor condition. The existence of sprouting stumps and decaying logs indicated that hardwoods had been more abundant in this stand before the 1981 fire that killed them back, leaving a nearly pure pine overstory.

Regeneration of Table Mountain Pine Following the 1981 Fire.

Density and vigor. Table 15 shows the regeneration density of Table Mountain pine, by height class, following the 1981 fire. Regeneration was concentrated most heavily along the edge created by the crowned and uncrowned portions of the 1941 stand (where Transects B and C were located) rather than in the area exposed to full sunlight (Transect A). These observations are contrary to findings at Bote Mountain, where the most abundant regeneration was found in areas where the fire crowned. However, the most vigorous growth at Horsehitch Gap (as indicated by stem height) was

Table 15. Regeneration Density of Table Mountain Pine by Height Class at Horsehitch Gap.

Transect Line	Height Class 0 - 0.5 m	0.5 - 1 m	1 - 2 m	2+m	Total	Seedlings Per Ha
A	1	4	23	38	66	26,400
B	38	40	34	0	112	44,800
C	51	31	1	0	83	33,200
D	24	6	1	0	31	12,400
E	7	2	0	0	9	3,600
Totals	121	83	59	38	301	24,080

occurring in the completely crowned area where the young stand was in full sunlight. While regeneration in Transect A plots (full sun) was not as dense as it was in Transect B and C plots, it was much faster growing. Over half of the stems (38 of 66) in Transect A plots were taller than 2 m (eight were actually 3 m or taller), which was highly significant according to the Kolmogorov-Smirnov test. None of the stems tallied in plots in Transects B, C, D, or E exceeded 2 m. Stem height decreased as the distance into the 1941 canopy increased, and the majority of the stems in Transects C, D, and E were less than a half-meter tall.

Since regeneration Table Mountain pine following the 1981 fire was most vigorous in the area exposed to full sunlight, why then was it more dense in areas along the edge receiving some shading from the canopy of the 1941 stand? One explanation could be that the faster-growing specimens in the full sun area resulted in stand closure earlier than those in the "edge" area, shading out less vigorous or any late germinating seedlings. The data support this explanation, as only five of the 66 stems tallied in the Line A plots were less than 1 m in height.

Another explanation for the higher stem density in the "edge" could be due to continued seeding from the 1941 overstory. As 40 percent of serotinous cones on Table Mountain pine will open without fire (Barden, 1977), overstory trees along the edge of the crowned area likely continued to drop seed that will germinate on exposed mineral soil. Ages determined from cross-sections of some smaller stems in this "edge" area showed that some had germinated as long as five years after the fire. Although seedlings germinating in the edge of the 1941 stand receive shading from the overstory canopy, this canopy is not completely closed since some thinning occurred as a result of the 1981 fire. Also, afternoon sunlight penetrates this south-facing edge from the side. The effect of this side-lighting decreases with distance into the canopy from the edge.

Seedlings tallied in the Transect D and E plots were exposed to virtually no direct sunlight, and as a result were sparse and slow-growing. Most were less than a half-meter tall, and, unlike the shorter, younger specimens found along the edge, these were not new germinants. Cross-sections made from stems in these areas showed that most had germinated within three years following the 1981 fire. It is highly unlikely that these "older" seedlings will survive many more years, as they were merely existing in the stand and did not exhibit a growth rate satisfactory for survival. Specimens that had recently died could be seen scattered throughout the understory, and were easily located by their dead, red needles.

Cone production. Only eight of the 301 stems regenerating from the 1981 fire had mature cones, and only one had more than one cone. All eight stems were in Transect A plots, and all were on stems at least 2 m tall.

Other Regeneration

Regeneration by other species was sparse. Although a few pitch pine saplings from sprout origin were found in the stand, none were in the plots. The hardwood regeneration tallied was from sprouting stumps of chestnut, scarlet, and blackjack oaks (Table 16). Most sprouts were still relatively short, and only a few could be called "saplings," the tallest of which was in the 2-3 m range. The number of sprouting oak stumps averaged 1280/ha.

Table 16. Number of Sprouting Oak Stumps in Horsehitch Gap Sample Plots.

Transect Line	Scarlet Oak	Chestnut Oak	Blackjack Oak	Total Oaks
A	2	0	4	6
B	2	1	0	3
C	0	4	0	4
D	2	0	0	2
E	0	0	1	1
Totals	6	5	5	16
Oaks/ha	480	400	400	1280

It is unknown how much oak was present in the stand at Horsehitch Gap before the 1941 fire. Judging from the small number of sprouting stumps, it was not likely a predominant component, and was not a serious competitor to the crop of young pines regenerating from the 1981 fire.

In 1982, Virginia pine was planted by the Forest Service on 38 acres of the area that crowned out. Although plots in Line A were located in this planted area, no Virginia pine was found. Neither planting density nor survival rate could be determined from Forest Service records, although a Forest Service silviculturist recalled that survival rates were not high.[a] It is likely, however,

[a]Personal communication with Pete Irvine. 1991.

that some Virginia pine from the 1982 planting did survive and may make up a small component in the stand.

Blueberries were found in every plot at Horsehitch Gap and accounted for the primary understory vegetation present. Mountain laurel was tallied in only one plot. No galax was found in the study plots, but a few small, dense patches of this plant were observed on the site.

Summary: Horsehitch Gap

The fires at Horsehitch Gap in 1941 and 1981 resulted in two dense stands of pure Table Mountain pine. The portion of the 1941 stand that survived the 1981 fire is very slow-growing, and may be approaching a stagnant condition. The portion of this stand that was burned by crown fire in 1981 regenerated to a dense stand of Table Mountain pine. There is now a relatively abrupt edge between the 1941 and 1981 stands.

Regeneration of Table Mountain pine was densest along the edge of the 1941 stand, but was faster growing away from the edge where full sunlight was available. While regeneration occurred beneath inside the canopy of the 1941 stand (where only a surface fire burned), it was receiving very little, if any, direct sunlight. Seedlings were obviously suffering continued mortality. This regeneration will not likely survive much longer.

Cones had developed on a few of the taller stems in the 1981 stand. However, it is unlikely that an abundant seed source was available to perpetuate the stand should it be killed by fire. While the young stands at Bote Mountain were, for the time being, "fireproofed" because of the low amount of surface fuel available to carry a fire, the young stand at Horsehitch gap is more vulnerable. Although areas of mineral soil are still exposed, fallen needles from the young saplings have covered the ground in much of the area. Under the right weather conditions, a fire running up the steep, south- and southwest-facing slopes through this regeneration thicket could reach high intensities.

In 1988, when searching for suitable study areas, a site on the Pisgah National Forest near Old Fort, North Carolina was found where this had happened. A fire in 1984 burned up a steep west slope through a young stand of Table Mountain pine that had regenerated from a 1970 fire. Four years after this fire cones could still be seen on stems killed by the fire. While cones were not abundant (most stems had no more than a half-dozen cones) they were more abundant than in the young Horsehitch Gap stand. Table Mountain pine regeneration, however, was sparse. Only six seedlings were found in 20 5 m^2 circular plots sampled there (600/ha). Meanwhile, pitch pine that had been scattered throughout the stand, had sprouted vigorously--many sprouts were already 2 m tall. The few hardwoods in the stand had done the same.

Judging from the way the Old Fort site burned, it is likely that the young stand of Table Mountain pine at Horsehitch Gap could carry a similar fire. And, judging by the small amount of regeneration of Table Mountain pine that occurred following the fire at Old Fort, it is unlikely that enough seed would be available at Horsehitch Gap to perpetuate that young stand should it burn in its current state. The new stand at the Old Fort site is probably going to be predominantly pitch pine and hardwood. If the 1981 stand at Horsehitch Gap burned now, regeneration would likely be predominantly stump sprouts from the few pitch pines and/or hardwoods present.

C. Greystone Mountain Site

Composition of the Pre-fire Stand.

The stand that burned in the 1988 fire was virtually pure Table Mountain pine, accounting for 133 of 146 (91.10 percent) of stems tallied in the 30 sample plots established. Average density of Table Mountain pine in the pre-fire stand was 8867 tree/ha (Table 17).

Over one-third of the pre-fire Table Mountain pines tallied (55 of 133) had cones, most of which were attached directly to the main stem. It is probable that some cones

Table 17. Table Mountain Pine Density of the Pre-fire Stand at Greystone Mountain.

Stem Count[a]	Stems Per Ha	Stems With Cone(s)	Stems With Cone(s) Per Ha
133	8866.67	55	3666.67

[a]Total in 30 plots, each 5 m^2.

had fallen off these dead trees in the four years following the fire, especially those that may have been attached to small branches. Therefore, the number of trees that had cones at the time of the fire was likely higher than the number observed in the sample. Although 12 cones were observed on one stem, most had fewer than a half-dozen, and many had just one.

In addition to Table Mountain pine, there were also 12 pitch pines (800 stems/ha) and one blackgum (66.67 stem/ha). Although none were tallied, a few red maples were observed on the site. Mountain laurel was tallied in 24 of the 30 plots, and had been approximately 1 m high when burned. It was therefore a likely contributor to the high fire intensity that occurred on this site.

Post-fire Regeneration.

When this site was first visited one growing season following the fire, regeneration of Table Mountain pine was almost non-existent. However, after four growing seasons, regeneration was much more abundant. In all, 87 seedlings were tallied in the 30 plots (5800 seedling/ha).

Only one seedling of Table Mountain pine was taller than a half-meter in height. These seedlings had not grown as fast as those at Bote Mountain, where approximately one-fourth had reach heights of a half-meter after three growing season. Although some appeared to have germinated the previous season, all were free-to-grow and none were being shaded out by the abundant, sprouting mountain laurel. While other sprouting species on the site--namely pitch pine, red maple, and blackgum--had sprouts over 2 m tall, they were too scattered to pose a threat to regenerating Table Mountain pines. Only eight pitch pine sprout clumps were tallied, five of which were between 1-2 m high, with two others over 2 m high.

Eighteen blackgum sprouts were tallied, seven of which were over 1 m high. Most blackgum sprouts tallied were sprouting individually, rather than in clumps. As only one blackgum stem was tallied in the pre-fire stem count, most of these sprouts must have sprouted from very small stems that had completely decayed in the four years following the fire.

Blueberries were abundant on the site, and were present in every plot. This is contrary to findings at Bote Mountain where blueberries were abundant only where fire intensities were the lowest. Clumps of grass were scattered across the site, as were various other herbaceous plants.

Summary: Greystone Mountain.

The fire on Greystone Mountain in April, 1988 crowned out in a small stand of Table Mountain pine that had regenerated following an April, 1968 fire. Although the 1988 fire left mineral soil exposed throughout the site, and cones were present on over one-third of the stems throughout the young stand, regeneration was almost non-existent after one growing season. Because more abundant regeneration was observed in an older stand of Table Mountain pine burned by the same fire, indications were that this 20 year-old stand had not yet produced enough seed to successfully regenerate the stand following the fire.

While no Table Mountain pine had regenerated on the site during the first growing season, regeneration did occur in the subsequent three years. It is uncertain as to why regeneration was not abundant after the first year, as it was at Bote Mountain. Although both sites burned when the region was experiencing an extended drought, that drought peaked in the summer of 1988. Therefore, seedlings germinating on the Greystone Mountain site may have faced harsher growing conditions than those at Bote Mountain and did not survive.

While seedling density (5800 seedlings/ha) at Greystone Mountain was less than the previous stand density (8867 stems/ha) and seedling density observed at Bote Mountain (12,326 seedlings/ha), it is still abundant enough to result in a dense stand of Table Mountain pine. Although competing pitch pines and hardwoods have shown faster initial growth rates, these species were not abundant on the site and will not likely be a big component in the future stand.

The regeneration of Table Mountain pine at Greystone Mountain is also much more abundant than regeneration observed (600 seedlings/ha after four growing seasons) where the 14 year-old stand burned at Old Fort, NC. This suggests that 15-20 years is the minimum time needed between fires to allow for adequate cone and seed production.

At Bote Mountain, the areas with the most regeneration were those that burned the hottest, and those areas were essentially "fireproof" for the time being because most fine fuel had been removed from the site. The same was true at Greystone Mountain where the only fine fuel "abundant" on the site was grass, and it only occurred in scattered clumps. Although mountain laurel and fallen, dead tree stems covered much of the area, there was virtually no fine fuel to carry fire through this heavier fuel.

CHAPTER VI

SUMMARY AND CONCLUSIONS

A. Summary

Fire is the component that has perpetuated stands Table Mountain pine in the Southern Appalachian Mountains. Fire is the only disturbance that creates the three conditions necessary for successful regeneration of this highly intolerant species--(1) heat to open serotinous cones, (2) a seedbed of mineral soil, and (3) removal of competing vegetation so the exposure to sunlight can be maximized. While some small, isolated stands of Table Mountain pine have been found on extremely poor sites that appear to be self-maintaining, most stands, in the absence if fire, will eventually break up and be replaced in succession by more tolerant hardwood species.

In order for a fire to result in the regeneration of a Table Mountain pine stand, high fire intensities must be obtained. Only hot fires will open serotinous cones, remove the entire canopy to open the stand to full sunlight, and remove surface litter so mineral soil is exposed.

On the sites examined in this study, the most vigorous regeneration occurred primarily where crown fires had burned. At the Bote Mountain site, nearly 75 percent of regenerating Table Mountain pine was found at sample points where mineral soil was exposed, and the most sample points with mineral soil exposed were found where crown fire burned.

While ample regeneration had occurred in areas burned by hot surface fires that had removed part of the canopy, shading from the residual canopy appeared to be retarding growth. At both Bote Mountain and Horsehitch Gap, the fastest growth of regeneration was occurring where crown fire had occurred. Even though the most abundant regeneration at Horsehitch Gap was actually found along an edge where a hot surface fire burned, stem height was significantly greater in the crown fire area.

In areas where light surface fires burned, much of the hardwood competition was killed-back, but regeneration of Table Mountain pine was negligible. Most cones did not receive enough heat to open, and very little mineral soil was exposed. Seedlings that did germinate are receiving very little sunlight, and will likely fail to survive.

Areas burned the hottest are not likely going to be able to burn again for several years due to the low level of light surface fuel available that is needed to carry a fire. The duration of this "fireproof" condition is probably less than 10 years, which is indicated by the 11 year-old stand at Horsehitch Gap, where fallen needles and other fine fuels appear to have accumulated sufficiently to carry a fire through much of the stand. Since the hottest fires that kill the existing stand are the ones that establish the most vigorous regeneration, exclusion of fire is critical until the regenerated stand has produced enough seed to once again perpetuate itself.

Although cones were observed on stems in the 11 year-old stand at Horsehitch Gap, they were only found on stems growing in the area burned by crown fire. Even then, only 8 of 66 stems had at least one cone, and only stem one had more than one cone. Therefore, it is unlikely that enough seed has been produced to regenerate the stand if it were burned now. This assumption is supported by observations made at the 14 year-old stand of Table Mountain pine that burned near Old Fort, North Carolina, where regeneration of the species was sparse (600 seedlings/ha).

On Greystone Mountain, however, where fire burned through a 20 year-old stand, ample regeneration did occur. Over one-third of the 20 year-old stems there had cones, and multiple cones were not uncommon. Although regeneration there (5800 seedlings/ha) was not as dense as that found where older stands burned at Bote Mountain and Horsehitch Gap (20,000+/ha), it is likely sufficient for the composition of the next stand to be dominated by Table Mountain pine.

A review of literature shows that fire has been affecting the landscape of the Southern Appalachians for thousands of years (Criddlebaugh, 1984; Davidson, 1983; Keel, 1976). Pollen and charcoal analysis, along with accounts written by European explorers, show that aboriginal burning of the forest was common. Indians burned the land for various reasons. White settlers caused frequent fires as well, often to clear land for farming. While fires used for land clearing probably originated on lower, flatter areas more suitable for cultivation, they likely spread onto adjacent mountains, where they would attain their highest intensities on the drier, south- to west- facing slopes where the pine component is most prevalent. Because lightning fires in the Southern Appalachians are infrequent, it has likely been these "human-caused" fires that have perpetuated the yellow pine communities (especially Table Mountain pine) in the Southern Appalachians. All of the stands of Table Mountain pine sampled in this study are documented to have originated following human-caused fires.

With exclusion of fire, stands of Table Mountain pine will slowly break up and be replaced by more tolerant hardwoods. Eventually such stands will disappear from the landscape. This successional process is accelerated by infestations of the southern pine beetle. Where uncontrolled human-caused fires have perpetuated stands of Table Mountain pine in the past, controlled human-caused fires must be used to perpetuate them in the future.

B. Conclusions

1. The stands of Table Mountain pine studied in this paper were documented to have originated following hot fires, all of which were human-caused.

2. Crown fires best create the conditions required for successful regeneration of Table Mountain pine: (1) heat to open serotinous cones, (2) a seedbed of mineral soil, and (3) exposure of seedlings to full sunlight for maximum growth.

3. Where hot surface fires expose mineral soil and only thin the canopy, regeneration of Table Mountain pine will likely occur, but seedling growth rates will be retarded by shading from the residual canopy.

4. Where fire intensities are low, regeneration of Table Mountain pine will be negligible, but hardwood competition may be reduced.

5. Although cones develop on stems of Table Mountain pine that are less than ten years old, it may take as many as 20 years before enough cones are

produced by the stand for successful regeneration to occur following a fire.

6. In the stand of Table Mountain pine studied at Bote Mountain, the pre-fire understory was dominated by hardwoods. Although some Table Mountain pine was found in the understory, most was suppressed. In the absence of fire, hardwoods would likely dominate later seral stages.

CHAPTER VII

INFERENCES AND RECOMMENDATIONS FOR FUTURE STUDY

A. Inferences

Fire, and fire alone, has perpetuated stands of Table Mountain pine in the Southern Appalachian landscape. Table Mountain pine is a highly-intolerant pioneer species that regenerates only after severe disturbance, and fire is the only disturbance that creates the three conditions required for successful regeneration: heat to open serotinous cones, a mineral soil seedbed, and exposure to full sunlight.

The fires that have perpetuated Table Mountain pine have largely been human-caused. That Native Americans burned the landscape in pre-Columbian times for various reasons is well documented. White settlers burned the landscape as well, often for the same reasons as the Indians. Nearly all of the fires that burn in Southern Appalachian forests today are still human-caused, the majority being set by arsonists. Lighting fires are rare. Those that do occur usually do not get large enough to have a significant impact on the landscape--partially because rain is generally associated with lightning storms, and mainly because of fire suppression.

Fire prevention and suppression activities in this century have greatly reduced the number and size of fires that burn in the Southern Appalachians. Currently, the only times that stands of Table Mountain pine in the region are burned are when wildfires occur, and the only time that these fires can reach intensities high enough to regenerate a stand is when they exceed initial suppression efforts of firefighters. Such were the cases with all of the stands examined in this study. While these fires may perpetuate an occasional stand of Table Mountain pine, they cannot be depended on to maintain a significant population. Total exclusion of fire from the Southern Appalachian environment will have detrimental effects on the species.

Unless public land managers in the Southern Appalachians adopt a prescribed fire program to intensely burn old, decadent stands of Table Mountain pine for regeneration purposes, Table Mountain pine will eventually disappear from much of the landscape. This replacement process is accelerated in areas infested by southern pine beetles.

Fires used to burn stands Table Mountain pine will need to be hot if successful regeneration is to occur. To gain the desired high intensities, a head-fire will probably have to burn upslope through a stand under warm, dry climatic conditions. This, obviously, may make control efforts more difficult and more labor-intensive than with prescribed burns using low-intensity, backing-fire methods.

B. Recommendations for Future Study

Stand conditions prior to the fires critical to this study were not fully known because the fires that burned the study areas were wildfires and not planned events. While it was possible to evaluate site conditions after each fire, pre-fire conditions could only be partially reconstructed. Although stems of trees could be counted and measured in an area consumed by crown fire, other vegetation may have been entirely consumed. While residual organic matter (ROM) could be measured, it was not known how much had been there to begin with.

Another limiting factor was the time that had elapsed between the occurrence of a fire and first examination of the fire area by the author, the least of which was six months. Most of the sites were sampled several years following the fires. Therefore, some fire effects may not have been as evident as they would have been immediately following the fire. One prime example of this was found when measurements of ROM were made at Bote Mountain. It was first attempted to distinguish sample points on bare mineral soil from those with ROM depths of less than 1 cm. However, it was soon discovered that this differentiation between "none" and "a little" organic matter was hard to accurately distinguish. This was primarily due to the fact that some of organic matter observed was thought to have accumulated after the fire. Therefore, sample points with bare mineral soil exposed were included in with those having less than 1 cm of residual organic matter.

Statistical analysis showed high significance in the number of sample points and amount of regeneration in the ROM < 1 cm depth class, indicating that a further breakdown of the class (i.e., 0-0.5 cm and 0.6-1 cm) may give a better indication of the "best" seedbed conditions.

The best way to further study the effects that fire has on Table Mountain pine is to plan and conduct controlled burns. Only then would it be possible to determine pre-fire stand conditions to which post-fire stand conditions could be compared. Burns could be conducted under varying climatic conditions in stands with varying ages and densities on sites with varying aspects, steepnesses, and fuel loadings to better determine conditions in which Table Mountain pine can be regenerated. Pre-fire analysis should include an accurate analysis of all vegetation on the site. The depths of organic matter should be measured at various points throughout the proposed burn area to be compared with post-fire depths. Fuel moistures and loadings, as well as weather conditions, should be well documented for each burn.

During a burn, firing techniques and fire behavior should be documented. Temperatures could be measured at various places within the stand, both horizontally and vertically (i.e., at ground level, mid-crown, and upper-crown).

Post-fire analysis could include methods used in this study and refined as needed. Seed traps could be used to measure seedfall. Permanent plots should be established to monitor stand development over time.

The possibilities for studying effects of fire on Table Mountain Pine are many. However, most rely on the chance occurrence of a fire. While some effects can be studied through post-fire analysis of wildfires, only with planned, controlled fires can a management scheme for perpetuating Table Mountain pine in the Southern Appalachians be developed.

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APPENDIX

Table A-1. Selected Multipliers for Metric to English Conversions.

Conversion	Multiplier
Length or Distance	
Millimeters to inches	0.0394
Centimeters to inches	0.3937
Meters to feet	3.2808
Meters to yards	1.0936
Kilometers to miles	0.6214
Area	
Square meters to square feet	10.7636
Hectares to acres	2.4710
Square meters/hectare to square feet/acre	4.3560

Source: Paine, D. P. 1981. Aerial [illegible]
interpretat[illegible]
Wiley an[illegible]

Table A-2. Stem Count of Pre-fire Overstory of Bote Mountain Plots (stem DBH 7.5 cm and greater).

Plot Number	Table Mtn. Pine	Pitch Pine	Chestnut Oak	Scarlet Oak	Red Maple	Other Hdwds.
LOW-intensity Plots						
1	16	0	3	3	0	2
2	17	15	0	3	2	2
3	7	4	0	2	1	2
4	5	5	0	0	1	0
15	12	2	1	4	3	0
16	12	3	0	5	2	0
MEDIUM-intensity Plots						
5	13	1	0	0	0	0
6	15	3	2	5	1	2
9	4	0	8	4	6	0
10	9	5	0	3	1	0
12	13	10	0	4	1	0
14	38	0	1	3	0	1
HIGH-intensity Plots						
7	13	2	0	8	5	0
8	14	1	2	5	1	1
11	54	0	0	0	0	0
13	19	1	0	6	0	0
17	16	0	1	5	1	0
18	22	0	0	4	1	0
Total Stems						
LOW	69	29	4	17	9	6
MEDIUM	92	19	11	19	9	3
HIGH	138	4	3	28	8	1
Total	299	52	18	64	26	10

Table A-3. Basal Area[a] of Pre-fire Overstory of Bote Mountain Plots (stem DBH 7.5 cm and greater).

Plot Number	Table Mtn. Pine	Pitch Pine	Chestnut Oak	Scarlet Oak	Red Maple	Other Hdwds.
			LOW-intensity Plots			
1	0.76[b]	0.00	0.21	0.02	0.00	0.11
2	0.95	0.44	0.00	0.19	0.04	0.06
3	0.19	0.09	0.00	0.05	0.01	0.03
4	0.07	0.15	0.00	0.00	0.01	0.00
15	0.45	0.08	0.03	0.11	0.10	0.00
16	0.38	0.28	0.00	0.09	0.02	0.00
			MEDIUM-intensity Plots			
5	0.41	0.05	0.00	0.00	0.00	0.00
6	0.58	0.20	0.07	0.11	0.01	0.02
9	0.19	0.00	0.17	0.05	0.04	0.00
10	0.33	0.20	0.00	0.15	0.03	0.00
12	0.28	0.40	0.00	0.07	0.01	0.00
14	0.99	0.00	0.05	0.02	0.01	0.00
			HIGH-intensity Plots			
7	0.28	0.06	0.00	0.23	0.05	0.00
8	0.66	0.01	0.03	0.11	0.01	0.01
11	1.31	0.00	0.00	0.00	0.00	0.00
13	0.49	0.17	0.17	0.15	0.00	0.00
17	0.48	0.00	0.00	0.09	0.11	0.00
18	1.03	0.00	0.00	0.08	0.02	0.00
			Totals			
LOW	2.81	1.03	0.24	0.46	0.17	0.19
MEDIUM	2.79	0.84	0.28	0.40	0.09	0.02
HIGH	4.26	0.25	0.04	0.67	0.19	0.01
Total	9.86	2.12	0.56	1.53	0.45	0.22

[a]Basal area in square meters.

[b]All figures rounded to the nearest 0.01.

Table A-4. Fire Damage to Table Mountain Pine in Overstory of Bote Mountain Plots (stem DBH 7.5 cm and greater).

Plot Number	Total Number Stems	Damage to Tree: None	Damage to Tree: Charred/ Scorched	Damage to Tree: Killed	Heat Sustained by Canopy/Cones[a]: Low	Heat Sustained by Canopy/Cones[a]: Mod.	Heat Sustained by Canopy/Cones[a]: High
			LOW-intensity Plots				
1	16	15	0	1	16	0	0
2	17	17	0	0	17	0	0
3	7	4	0	3	0	5	2
4	5	1	0	4	1	2	2
15	12	12	0	0	12	0	0
16	12	8	4	0	9	3	0
			MEDIUM-intensity Plots				
5	13	5	0	8	0	5	8
6	15	0	1	14	4	11	0
9	4	0	0	4	0	0	4
10	9	0	0	9	0	0	9
12	13	1	0	12	0	13	0
14	38	17	2	19	0	38	0
			HIGH-intensity Plots				
7	13	0	0	13	0	0	13
8	14	0	0	14	0	0	14
11	54	0	0	54	0	0	54
13	19	4	0	15	0	6	13
17	16	0	0	16	0	0	16
18	22	0	0	22	0	0	22
			Totals				
LOW	69	57	4	8	55	10	4
MEDIUM	92	23	3	66	0	67	25
HIGH	138	4	0	134	0	6	132
Total	299	84	7	208	55	83	161

[a]Rating of the amount of heat sustained to open serotinous cones in the crown of the tree.

Table A-5. Fire Damage to Pitch Pine in Overstory of Bote Mountain Plots (stem DBH 7.5 cm and greater).

Plot Number	Total Number Stems	Damage to Tree: None	Damage to Tree: Charred/ Scorched	Damage to Tree: Killed Back
LOW-intensity Plots				
1	0	-	-	-
2	15	15	0	0
3	4	3	0	1
4	5	3	2	0
15	2	2	0	0
16	3	3	0	0
MEDIUM-intensity Plots				
5	1	0	1	0
6	3	0	1	2
9	0	-	-	-
10	5	0	0	5
12	10	3	4	3
14	0	-	-	-
HIGH-intensity Plots				
7	2	0	0	2
8	1	0	0	1
11	0	-	-	-
13	1	1	0	0
17	0	-	-	-
18	0	-	-	-
Totals				
LOW	29	26	2	1
MEDIUM	19	3	6	10
HIGH	4	1	0	3
Total	50	30	8	12

Table A-6. Number of Miniplots in Each ROM Depth Class with Seedling(s) of Table Mountain Pine Present at Bote Mountain (64 miniplots per plot).

Plot Number	Residual Organic Matter Depth Class (cm) 0-1	1-5	6-10	11-15	16+
		LOW-intensity Plots			
1	0	0	0	0	0
2	1	0	0	0	0
3	1	0	0	0	0
4	2	0	1	0	0
15	3	0	1	0	N/A[a]
16	4	1	4	0	0
Total LOW	11	1	2	0	0
		MEDIUM-intensity Plots			
5	7	3	1	0	0
6	19	3	0	0	0
9	8	7	0	N/A	N/A
10	7	0	0	0	0
12	13	6	0	0	0
14	12	30	0	N/A	N/A
Total MED	66	49	1	0	0
		HIGH-intensity Plots			
7	10	2	0	0	0
8	8	3	1	N/A	N/A
11	32	1	0	N/A	N/A
13	34	7	N/A	N/A	N/A
17	8	2	0	N/A	N/A
18	16	5	0	N/A	N/A
Total HIGH	108	20	1	0	0
		All Plots			
Total	185	70	4	0	0

[a]No miniplots recorded in this depth class.

Table A-7. Number of Seedlings of Table Mountain Pine in Each Miniplot by ROM Depth Class at Bote Mountain (64 Miniplots per Plot).

Plot Number	Residual Organic matter Depth Class (cm) 0-1	1-5	6-10	11-15	16+
		LOW-intensity Plots			
1	0	0	0	0	0
2	1	0	0	0	0
3	1	0	0	0	0
4	2	0	1	0	0
15	3	0	1	0	N/A[a]
16	4	1	4	0	0
Total LOW	11	1	2	0	0
		MEDIUM-intensity Plots			
5	8	3	1	0	0
6	25	3	0	0	0
9	8	7	0	N/A	N/A
10	7	0	0	0	0
12	14	7	0	0	0
14	19	45	0	N/A	N/A
Total MED	81	65	1	0	0
		HIGH-intensity Plots			
7	12	[illegible]	0	0	0
8	8	[illegible]	1	N/A	N/A
11	69	1	0	N/A	N/A
13	54	8	N/A	N/A	N/A
17	8	2	0	N/A	N/A
18	19	5	0	N/A	N/A
Total HIGH	170	21	1	0	0
		All Plots			
Grand Total	262	87	4	0	0

[a]No miniplots recorded in this depth class.

VITA

Gregory Lynn Sanders was born in Knoxville, Tennessee on March 12, 1962. He was raised in Harper, Oregon where attended elementary school and graduated from Harper High School in May, 1980. In September, 1980 he entered Treasure Valley Community College in Ontario, Oregon, and in June, 1982 received an Associate of Science degree. He entered Oregon State University Corvallis in September, 1982 where he received a Bachelor of Science degree in Forest Management in June, 1985. He enrolled the University of Tennessee, Knoxville in September, 1986 and in August, 1992, received a Master of Science degree in Forestry.

He has been employed as a Fire Prevention Forester with the Tennessee Department of Agriculture, Division of Forestry in Knoxville since December, 1988.