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To the Graduate Council:

I am submitting herewith a dissertation written by Nicole Leigh Turrill entitled "Using prescribed fire to regenerate Pinus echinata, P. pungens, and P. rigida communities in the southern Appalachian Mountains." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology and Evolutionary Biology.

Edward R. Buckner, Major Professor

We have read this dissertation and recommend its acceptance:

Sally P. Horn, Stephen C. Nodvin, Thomas A. Waldrop

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Nicole Leigh Turrill entitled "Using Prescribed Fire to Regenerate *Pinus echinata*, *P. pungens* and *P. rigida* Communities in the Southern Appalachian Mountains." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology.

Edward R. Buckner, Major Professor

We have read this dissertation
and recommend its acceptance:

Sally P. Horn

Stephen C. Nodvin

Thomas A. Waldrop

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

USING PRESCRIBED FIRE TO REGENERATE *Pinus echinata, P. pungens, AND P. rigida* COMMUNITIES IN THE SOUTHERN APPALACHIAN MOUNTAINS

A Dissertation
Presented for the
Doctor of Philosophy Degree
The University of Tennessee, Knoxville

Nicole Leigh Turrill
May 1998

DEDICATION

This dissertation is dedicated to my parents

Frank and Shirley Turrill

for their love, support, and words of encouragement

and to

Dr. Edward R. Buckner

for his numerous years of service to the students of

The University of Tennessee and to the forests of the southern Appalachian region.

ABSTRACT

Southern Appalachian yellow pines [shortleaf pine (*Pinus echinata*), table mountain pine (*P. pungens*), and pitch pine (*P. rigida*)] require disturbance for successful regeneration. Cultural burning practices provided the disturbance that prehistorically and historically maintained these forest communities. These practices ceased in the early twentieth century when fire suppression became the primary fire management initiative of federal land managers. The last fifty years of fire suppression have degraded yellow pine habitat to the point that federal fire management plans now call for increased use of prescribed burning to restore these forests. Before fire can be effectively used for this purpose, land managers must understand the ecology of these changed systems. In addition, prescribed fire must become a more accessible management tool. This project evaluated the fire history, current structure, and species composition of selected southern Appalachian yellow pine forests as well as their response to prescribed fire. I examined these factors in seven yellow pine stands on five National Forests in the southern Appalachian region. The presence of macroscopic charcoal in soils indicated that fires burned these stands at some time in their past. Yellow pines remained overstory dominants on all sites but potential overstory dominants [chestnut oak (*Quercus prinus*) scarlet oak (*Q. coccinea*) and red maple (*Acer rubrum*)] predominated both midstory and understory size classes. Pre-burn pine regeneration was absent likely due to shading from a closed canopy as well as deep litter and duff accumulations. Hardwood regeneration was successful. Two of these stands burned with high intensities but four burned at medium to low intensities and two were not burned at all. Prescribed burning did not effect soil pH or soil nutrient content of these acidic, oligotrophic soils. Prescribed burns of moderate intensity and severity opened the forest canopy but encouraged sprouting of understory hardwoods. I observed yellow pine regeneration only following those burns that reduced overstory and

midstory basal area and density as well as litter and duff depth. Future burns to restore yellow pine communities must be of moderate to high intensity and severity not only to open the forest canopy and expose mineral soil, but also to expose regenerative basal buds of hardwoods to lethal temperatures in order to lessen hardwood sprouting. Prescribed burns that do not promote pine regeneration may further encourage succession towards hardwood-dominated stands. Opportunities to conduct burns appropriate to the restoration of yellow pine communities, however, are rare under current prescribed burning guidelines. The number of days meeting required weather parameters are few and occur during late spring and early fall months. Before yellow pine communities can be restored, burning guidelines must change in order to make prescribed burning accessible to ecosystem managers.

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I have so many people to thank for their involvement with this research. First and foremost, I need to acknowledge my doctoral committee for their many hours of hard work. It is because of my advisor, Ed Buckner, that I became interested in the fire dependent vegetation of the southern Appalachian Mountains. In addition to his advice on this research, Ed provided much advice on handling life's little up's and down's. Stephen Nodvin was instrumental in my decision to attend The University of Tennessee and remained helpful from the beginning to the end of my doctoral program. Sally Horn acted as much as a role model as she did a committee member. Sally's balance of an extremely active career and "a normal life" amazes me. Tom Waldrop not only served on my committee, but also helped with the overall design and field sampling of this research. In the end, Tom made sure this dissertation appealed to both the foresters and the ecologists who awaited its completion. For that, I owe him many thanks.

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Thanks to my involvement with this project, I have been able to travel to some of the most beautiful and interesting places throughout the southern Appalachian region. In addition, I have had the pleasure of meeting and working with so many wonderful people. I must thank all of the following: Dave Jensen, Tom Kelly, and Francisco Sanchez of the

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TABLE OF CONTENTS

PAGE

I INTRODUCTION 1

II THE ROLE OF FIRE IN SHAPING THE VEGETATION OF THE SOUTHERN APPALACHIAN MOUNTAINS 5

- Pre-Historic Setting 5
- Historic Setting 8
- Modern Setting 11

III YELLOW PINE COMMUNITIES AND THE SELECTED STUDY SITES 14

- Yellow Pine Habitat 14
  - Shortleaf Pine (*Pinus echinata*) 15
  - Pitch Pine (*P. rigida*) 15
  - Table Mountain Pine (*P. pungens*) 16
- Study Sites 17
  - George Washington and Jefferson National Forest, Warm Springs District 17
  - George Washington and Jefferson National Forest, Wythe District 20
  - Daniel Boone National Forest, Somerset District 20
  - Daniel Boone National Forest, Stearns District 21
  - Cherokee National Forest, Hiwassee District 21
  - Pisgah National Forest, Grandfather District 22
  - Chattahoochee National Forest, Tallulah District 23

IV FIRE HISTORY OF STUDY SITES AS INDICATED BY MACROSCOPIC CHARCOAL 24

- Introduction 24
- Methods 25
  - Field Sampling 25
  - Laboratory Procedures 26
- Results 26
- Discussion 30

V PRESCRIBED BURNING OF SOUTHERN APPALACHIAN YELLOW PINE COMMUNITIES 32

- Introduction 32
- Methods 33
  - Plot Location 33
  - Vegetation Sampling 34
  - Prescribed Burning Schedule 34

TABLE OF CONTENTS (CONTINUED)

PAGE

Burn Measurements 38
Post Burn Sampling 38
Data Analysis 38
Results 40
Fall and Spring Burns on the George Washington and JeffersonNational Forest, Warm Springs Ranger District 40
GWWS Pre-Burn Vegetation 40
GWWS Fall Burn 47
GWWS Spring Burn 49
Spring Burn on the George Washington and Jefferson National Forest, Wythe Ranger District 57
GWWY Pre-Burn Vegetation 57
GWWY Spring Burn 57
Spring Burn on the Daniel Boone National Forest, Somerset Ranger District 64
DBSM Pre-Burn Vegetation 64
DBSM Spring Burn 64
Spring Burn on the Daniel Boone National Forest, Stearns Ranger District 75
DBST Pre-Burn Vegetation 75
DBST Spring Burn 75
Spring and Fall Burns on the Cherokee National Forest, Hiwassee Ranger District 85
CKHW Pre-Burn Vegetation 85
CKHW Spring Burn 90
CKHW Fall Burn 90
Spring and Fall Burns on the Pisgah National Forest, Grandfather Ranger District 93
PSGF Pre-Burn Vegetation 93
PSGF Spring Burn 93
PSGF Fall Burn 101
Spring Burn on the Chattahoochee National Forest, Tallulah Ranger District 102
CHTL Pre-Burn Vegetation 102
CHTL Spring Burn 102
Discussion 108
Recommendations for Future Measurements 114

VI EFFECTS OF PRESCRIBED BURNING ON SOIL NUTRIENT CONTENT 116

Introduction 116
Methods 117
Field Sampling and Chemical Analysis 117
Data Analysis 118
Results 118

TABLE OF CONTENTS (CONTINUED)

PAGE

Discussion 125

VII AVAILABILITY OF PRESCRIBED BURNING CONDITIONS IN THE SOUTHERN APPALACHIAN MOUNTAINS 128

Introduction 128
Methods 129
Results 130
Discussion 130

VIII CONCLUSIONS 134

LITERATURE CITED 138

VITA 148

LIST OF TABLES

TABLE PAGE

1. Presence (+) or absence (-) of macroscopic charcoal from soils supporting yellow pine forests 27

2. Summary of study sites and prescribed burning effects..... 37

3. Overstory (trees ≥10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn..... 41

4. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn 42

5. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn..... 45

6. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn 46

7. Overstory (trees ≥10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn 52

8. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn 53

9. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn 55

10. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn 56

11. Overstory (trees ≥10 cm dbh) species of the George Washington and Jefferson National Forest, Wythe Ranger District 58

12. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Wythe Ranger District 59

13. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Wythe Ranger District 62

LIST OF TABLES (CONTINUED)

TABLE PAGE

14. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Wythe Ranger District 63

15. Overstory (trees ≥10 cm dbh) species of the Daniel Boone National Forest, Somerset Ranger District 65

16. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Daniel Boone National Forest, Somerset Ranger District..... 66

17. Understory (stems <2.5 cm dbh and >1 m in height) species of the Daniel Boone National Forest, Somerset Ranger District, both prior to and following a spring prescribed burn 69

18. Ground layer (vegetation ≤1 m in height) species of the Daniel Boone National Forest, Somerset Ranger District, both prior to and following a spring prescribed burn 71

19. Overstory (trees ≥10 cm dbh) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn 76

20. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn..... 77

21. Understory (stems <2.5 cm dbh and >1 m in height) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn..... 80

22. Ground layer (vegetation ≤1 m in height) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring prescribed burn 82

23. Overstory (trees ≥10 cm dbh) species of the Cherokee National Forest, Hiwassee Ranger District 86

24. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Cherokee National Forest, Hiwassee Ranger District 87

25. Understory (stems <2.5 cm dbh and >1 m in height) species of the Cherokee National Forest, Hiwassee Ranger District 91

26. Ground layer (vegetation ≤1 m in height) species of the Cherokee National Forest, Hiwassee Ranger District 92

LIST OF TABLES (CONTINUED)

TABLE PAGE

27. Overstory (trees ≥10 cm dbh) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn 94

28. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn 95

29. Understory (stems <2.5 cm dbh and >1 m in height) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn 98

30. Ground layer (vegetation ≤1 m in height) species of Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn..... 99

31. Overstory (trees ≥10 cm dbh) species of the Chattahoochee National Forest, Tallulah Ranger District..... 103

32. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Chattahoochee National Forest, Tallulah Ranger District 104

33. Ground layer (vegetation ≤1 m in height) species of the Chattahoochee National Forest, Tallulah Ranger District 107

34. Chemical properties of pre-burn and post-burn soils..... 119

35. Correlations of pre-burn and post-burn soil variables..... 122

36. Number of days meeting prescribed burning parameters for the 1995 and 1996 burning seasons 131

LIST OF FIGURES

FIGURE PAGE

1. Participating National Forests of the southern Appalachian region 19

2. Sample plot design.... 36

3. Pre- and post-fall-burn distributions of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Warm Springs Ranger District 44

4. Pre- and post-spring-burn distributions of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Warm Springs Ranger District 51

5. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Wythe Ranger District 61

6. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Daniel Boone National Forest, Somerset Ranger District..... 68

7. Pre- and post-cut/burn distribution of the three most important canopy species (combined overstory and midstory size classes) of the Daniel Boone National Forest, Stearns Ranger District 79

8. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Cherokee National Forest, Hiwassee Ranger District 89

9. Pre- and post-burn distributions of the three most important canopy species (combined overstory and midstory size classes) of the Pisgah National Forest, Grandfather Ranger District..... 97

10. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Chattahoochee National Forest, Tallulah Ranger District.....106

CHAPTER I

INTRODUCTION

Pre-historic and historic cultural burning maintained southern Appalachian shortleaf pine (*Pinus echinata*), table mountain pine (*P. pungens*) and pitch pine (*P. rigida*) forest communities. Native American and European settler burning provided suitable habitat on upper southwest-facing slopes for the regeneration of these species (Buckner 1989). Fire frequencies and intensities peaked during destructive logging and slash burning operations in the early twentieth century. Over time, declines in Indian populations, establishment of USDA Forest Service and USDI National Park Service fire policies, and public fear of fire resulted in widespread fire suppression in the southern Appalachian Mountains (Pyne 1982). Over fifty years of suppression efforts have reduced the availability of regeneration niches for yellow pines and most suitable sites either have converted to, or are in various stages of succession towards, hardwood dominance (Cain and Shelton 1995; Sutherland et al. 1995; Waterman et al. 1995; Abrams and Nowacki 1992; Williams and Johnson 1990; 1992; Collins and Good 1987).

Today, the USDA Forest Service manages the vast majority of southern Appalachian yellow pine forests. Ecosystem management plans for these degraded forests may need to include prescribed burning to reduce hardwood competition and restore yellow pine communities. Similar proactive fire management programs already are successful in regions of the Atlantic Coastal Plain and western United States. Fire-dependent species of these areas include longleaf pine (*P. palustris*) (Brennan and Hermann 1994; Christensen 1988), pitch pine (Good and Good 1984), ponderosa pine (*P. ponderosa*) (Arno 1996; Harrington 1996; Kurth 1996; Leuschen 1996), whitebark pine (*P. albicaulis*) (Keane and

Arno 1996), black spruce (*Picea mariana*) (Vanderlinden 1996), and giant sequoia (*Sequoia gigantea*) (Barbour 1988). The fire ecology of these systems is understood. Fire is vital to maintaining forest health (McLean 1995; Kolb et al. 1994; Mutch 1994) by promoting forest regeneration and controlling forest pests (Brennan and Hermann 1994). Residents of these fire-prone areas generally accept prescribed burning since it reduces the risk of wildfires (McLean 1995; Mandredo et al. 1990).

Although some USDA Forest Service Ranger Districts in the southern Appalachian region include fire in their management plans for yellow pine forests, implementing such initiatives often is difficult. Successful ecosystem management requires an ecological approach; management based on sound science; partnerships between ecologists, land managers, and policy makers; and public involvement (Thomas and Huke 1996). Not all of these factors are understood or are in place for managing southern Appalachian yellow pine forests. That fire established these yellow pine forests is unquestioned, but details of the frequencies, intensities, and severities of those fires remain uncertain. Instabilities in policy and funding (Irland 1994), as well as a lack of coordination across time horizons and land owners (Gerlach and Bengston 1994), also hamper fire management programs.

Public understanding and acceptance of fire is lacking in the southern Appalachian region. Ecologists and land managers find it difficult to convince most citizens that human-ignited fires, not lightning-ignited fires, established yellow pine forests. Such notions conflict with the messages of successful fire prevention programs (Sedjo 1996; Sampson 1995; Reeves 1989; Taylor and Daniel 1984) and feelings that nature should dictate which forests thrive, not humans (Huck 1985). Many retirees and employees in service industries reside near southern Appalachian National Forests (SAMAB 1996a). These residents are interested in the scenery and recreation potentials of the forests and do not accept fire as a necessary part of management plans. Indeed, some federal land managers find the role of

fire in forest management confusing. For instance, fire may improve wildlife habitat but degrade water resources, timber production and recreation opportunities (Fedkiw 1997). Furthermore, prescribed burning involves risks. Regulatory constraints, managerial anxieties, professional controversies, and technological ambiguities often prohibit burning operations (Johnson 1984).

This research represents the initial stages of an ongoing, collaborative effort to resolve some of these ecological and managerial issues and to return fire to southern Appalachian yellow pine forests. The framework for this initiative was developed in April 1994 at a round-table discussion hosted by The University of Tennessee, Department of Forestry, Wildlife, and Fisheries, Knoxville, Tennessee. Representatives from academia and southern Appalachian National Forests and National Parks attended and identified the following four questions that must be addressed before effective fire management strategies can be developed for the southern Appalachian Mountains:

1. What do we know of the fire history of the southern Appalachian Mountains?

2. How have yellow pine forests changed, in both species composition and structure, over the last fifty years of fire suppression?

3. How do the vegetation and soils of these forests respond to prescribed burning?

4. Is prescribed burning an accessible management tool under current prescribed burning guidelines?

This dissertation presents the initial research conducted to address these four questions. Chapter II summarizes the literature concerning the fire and vegetation history of the southern Appalachian Mountains. Chapter III describes shortleaf pine, table mountain pine, and pitch pine communities and the field sites studied in this research. Chapter IV illustrates how macroscopic charcoal particles in soils can be used to assess past fire occurrences in individual forest stands. Chapter V compares the current species composition and structure of southern Appalachian yellow pine stands to other stands throughout the geographic distribution of these species as well as to historic accounts of their character. Chapter V and Chapter VI analyze the response of forest vegetation and soils, respectively, to prescribed burning. Chapter VII assesses the availability of prescribed burning opportunities under current prescribed burning guidelines. Finally, Chapter VIII summarizes the conclusions of this research.

CHAPTER II

THE ROLE OF FIRE IN SHAPING THE VEGETATION OF THE SOUTHERN APPALACHIAN MOUNTAINS

Prehistoric Setting

The yellow pine species native to the southern Appalachian region belong to the diploxylon subgenus. Diploxylon pines have two fibrovascular bundles per needle whereas the haploxylon pines have a single bundle (Mirov 1967). This characteristic distinguishes diploxylon pines in the macrofossil record and allows paleoecologists to track the distribution of the subgenus over geologic time.

The fire-adapted diploxylon pines have migrated across several degrees of latitude during the present interglacial interval. During the most recent full glacial period, from 20,000 to 18,000 years before present (BP), these pines resided south of 33°N along the Gulf Coastal Plain. As glaciers retreated, southern diploxylon pines moved northward. By 14,000 BP, some expansion within and west of the Appalachian Mountains had occurred and between 12,000 and 10,000 BP, these pines had advanced northward into the southern Appalachians (Delcourt and Delcourt 1987). Watts (1979) noted the presence of pitch pine macrofossils in central and northern Pennsylvania bog sediments that dated to 9,600 BP. Southern pines occupied areas along the Appalachians and Atlantic Coastal Plain north to approximately 41°N in 8,000 BP. Southern pine forests were not a dominant cover type at this time because they occupied less than 20% of the regional landscape (Delcourt and Delcourt 1987).

The pollen record documents that during the mid-Holocene, approximately 6,000 BP, southern diploxylon pines of the central and southern Appalachians increased in dominance throughout the eastern two-thirds of their geographical distribution. South of 35°N, southern pines increased in dominance and accounted for greater than 40% of forest vegetation by 4,000 BP (Delcourt and Delcourt 1987). Likewise, Watts (1979) recorded a dramatic increase in pine pollen in the central Appalachian region during the late Holocene.

Although southern diploxylon pines migrated great distances during the last 20,000 years, the total area occupied by southern pines remained generally constant. However, the dominance structure markedly changed. Delcourt and Delcourt (1987) estimate that over the last 8,000 years (a period commonly referred to as the "southern pine rise") the total area occupied by southern pines increased by 14%. Accompanying this was a seven-fold increase in area containing greater than 20% southern pines (Delcourt and Delcourt 1987). Watts (1979) stated that the rise in pine pollen occurred in the southern and central regions of the Appalachian Mountains and the Atlantic Coastal Plain from Virginia southward. Pines, oaks, and ericaceous shrubs dominated upland forests of the region at this time (Watts 1979).

Lightning-ignited fires were one factor that shaped prehistoric vegetation patterns in the southeastern United States (Van Lear and Waldrop 1989). During the last full glacial period, when southern pines occupied Gulf Coast refugia, the polar front extended south from the glacial front to the upper Atlantic and Gulf Coastal Plains. Increased storm activity associated with the front (Hidore and Oliver 1994) increased the frequency of lightning strikes in these areas. These lightning-ignited fires reinforced fire-adapted traits in many species, including native southern Appalachian pines.

During the full glacial and glacial retreat, montane forests of the southern Appalachians probably did not burn as frequently as the pine-grasslands in the adjacent

Piedmont region of the Atlantic Coastal Plain (Van Lear and Waldrop 1989). Although considerable lightning was present in these mountainous areas, the likelihood that it caused catastrophic fires over the past 10,000 years was small. In the southern Appalachian region, most lightning strikes occurred during summer thunderstorm events. Moist, humid conditions associated with these events prevented large widespread fires. Lightning strikes and subsequent fires were more common on ridge tops and at higher elevations (Meier and Bratton 1995). When extremely dry conditions prevailed during the mid-Holocene, larger fires occurred. As a result, the overall fire mosaic of the southern Appalachian region was a pattern of small burns interspersed over the landscape at irregular intervals (Komerek 1974) with occasional large fires in more xeric habitats. These lightning fires reinforced fire-adapted traits of southern diploxylon pines and maintained pine communities in xeric ridgetop habitats.

Fire of anthropogenic origin also influenced southern Appalachian pine forests. Modern humans (*Homo sapiens sapiens*) entered the southern Appalachian region over 12,000 years ago (Chapman 1985) and applied cultural burning to a landscape which had been influenced by lightning fires. Both prehistoric cultural fires and lightning-ignited fires reinforced natural selection of fire-adapted traits and deserve equal attention when describing the fire history and fire regime of the southern Appalachian region.

As paleo-Indian tribes spread eastward out of central North America they brought with them the controlled use of fire (Goudsblom 1992). Nomadic tribes used fire in hunting woolly mammoths and mastodons that grazed in the open woodlands of the southern Appalachian region. As the climate warmed and glaciers retreated, forest composition changed as populations of deciduous species increased (Delcourt and Delcourt 1991). As these changes in species composition occurred, forest canopies closed and native Indian tribes likely adjusted their burning practices to maintain open wildlife habitat.

During the Archaic Period, 6,500-2,000 BP, Indian tribes used fire to clear fertile floodplains for agriculture (Delcourt and Delcourt, 1997; Chapman 1985). In addition to these local-scale burns, watershed and regional-scale fires maintained open pine and oak (*Quercus* sp.) forests with herbaceous understories in upland areas (Delcourt and Delcourt 1997). These open, upland forests provided grazing habitat for wildlife, exposed nuts, and encouraged growth of edible berries. Oak, chestnut (*Castanea dentata*), hickory (*Carya* spp.) and pine dominated the area until approximately 2,000 BP (Delcourt and Delcourt 1997; Shafer 1984; Davidson 1983). Pine pollen and charcoal influx peaked around 1,900 to 1,100 BP suggesting heightened burning of the area (Shafer 1984; Davidson 1983). Pollen from fire-intolerant species was absent at this time, suggesting that frequent fires prevented establishment of these species in upland areas (Shafer 1984).

Historic Setting

Most written accounts of cultural burning are second-hand observations. In many cases, the author was an explorer with limited knowledge of regional cultures or plant taxonomy. Forman and Russell (1983) question the reliability of such accounts and warn that historical descriptions of burning practices and vegetation should be interpreted with caution. Ecologists should heed these warnings especially in reference to European accounts of Indian burning. Most early explorers and European settlers viewed Indians as "savages," a perception that would negatively bias their statements towards the purpose and/or extent of Indian burning practices. Russell (1983) believes that some accounts of Indian use of fire are exaggerated yet she recognizes that Indian burning increased the frequency of fires above the low levels caused by lightning, and, therefore, had an effect on regional vegetation.

In 1492, approximately 18 to 20 million Native Americans inhabited the North American landscape (Dobyns 1983). Of the Indian tribes encountered by early European settlers, the Cherokee Indians occupied the greatest proportion of the southern Appalachian region (primarily western North Carolina, east Tennessee, north Georgia, and northwestern South Carolina, with additional land in West Virginia and Kentucky) (Ehle 1988). Their use of fire in hunting, gathering, and agriculture produced a landscape very unlike the presumed "virgin forest" image of the New World. Buckner (1989) pictured this landscape as a "shifting mosaic of open grasslands, woodlands, and closed forests with widely scattered Indian villages." Early accounts by Europeans in eastern North America also emphasized the open character of the forest (Guffey 1977). Maxwell (1910) quoted the Discoveries of John Lederer (1891) concerning the burning practices of Virginia's Indian tribes as follows:

> "Virginia, . . . , was passing through its fiery ordeal, and was approaching a crisis, at the time the colonists snatched the fagot from the Indian's hand. The tribes were burning everything that would burn, . . . , if the discovery of America had been postponed 500 years, Virginia would have been a pasture land or desert."

DeVivo (1991) claimed that DeSoto's chronicles of 1540 alluded to a treeless French Broad Valley in western North Carolina up to the 900 m contour (600 m is the approximate elevation of the valley floor). Furthermore, Maxwell (1910) stated that the Shenandoah Valley of Virginia, when first seen by Europeans, was treeless its entire length.

A land-lottery survey in Rabun County, GA (near the southern terminus of the Appalachian Mountains) suggested that southern Appalachian forests were approximately 42% oak, 25.5% pine, 19.5% hickory and 2% chestnut at the time of European settlement

in 1811 AD (Meier and Bratton 1995). At this time, European settlers adopted some of the firing practices of the Indians and introduced some of their own (Pyne 1982). Europeans quickly settled rich bottomlands along major streams as settler populations increased. As settlement continued, farming and early logging (and associated burning) practices moved upslope into steeper areas (Van Lear and Waldrop 1989). A mixture of European and Indian burning, one for farming in the lowlands and the other for hunting and ranging in the uplands, maintained southern Appalachian landscape patterns (Pyne 1982).

European settlers and early explorers introduced smallpox, and other diseases, that reduced Indian populations and decreased fire frequencies (Van Lear and Waldrop 1989). Over 10,000 Cherokee Indians alone died in smallpox epidemics (Ehle 1988). This reduction in cultural pressure promoted the development of closed, hardwood forests over vast areas that had been kept open for thousands of years by frequent cultural fires. Eventually, over the next 200 to 250 years, dense, closed-canopy forests became established. During this period, yellow pine populations retreated to xeric ridgetops (Williams in press) while scattered large pine trees remained in mid-slope forests.

Around 1880, railroads constructed along both sides of the Appalachian Mountains made their rich timber resources accessible to national and world markets. Logging without regard for forest restoration occurred throughout the southern Appalachian Mountains. Utilization standards of the time were such that most of each tree was left in the woods and, upon drying, the logging slash became highly flammable fuel. The resulting slash fires returned pine dominance in upland forests as pines were often the main seed source available to recolonize areas following burning (Williams in press). Palynological studies by Davidson (1983), Shafer (1984) and Delcourt and Delcourt (1997) documented increased pine pollen and charcoal associated with clearing and burning beginning in the 1820's.

Modern Setting

Continued use of fire in clearing and maintaining agricultural lands persisted through the late 1800's and early 1900's. At the same time, attitudes towards fire changed. Federal land acquisition in the southern Appalachian region began in the early 1900's with the purchase of headwater areas in the Appalachian Mountains as allowed by the Weeks Act of 1911 and the Clark McNairy Act of 1924. Eventually, New Deal Programs during the administration of Franklin Delanor Roosevelt, such as the Civilian Conservation Corps, ushered in an era of fire suppression and prevention on public lands.

Eliminating fire from public lands was the official stance of federal agencies when land acquisition began and the USDA Forest Service was established. In the 1920's the Forest Service opposed any use of fire in forests (Pyne 1982). At this time, policy prohibited even light burning in the newly established National Forests. Foresters of that time did not realize the benefits of fire or the ecological role that fire had played in the evolution and maintenance of the ecosystems they were trying to protect (Van Lear and Waldrop 1989).

Highly effective fire suppression and fire prevention practices, spear-headed by the Smokey Bear campaign that began in the 1940's, essentially eliminated fire as a factor in shaping the southern Appalachian landscape. During the period of heightened Native American and European settlement (1856-1940), fires in the westernmost portion of the Great Smoky Mountains National Park were more frequent at lower elevations where they occurred every 10-40 years (Harmon 1982). This fire rotation increased when the National Park Service acquired the land and initiated fire suppression practices in the 1930's. By comparing the combined area burned by lightning and man-caused fires between 1940 and

1979 to the total area of this region of the Park, Harmon (1982) predicted that continued fire suppression practices would increase the fire rotation to over 2000 years.

Although modern forest management practices greatly reduced the frequency of fire, it was not eliminated from the southern Appalachian landscape. Data from the Southern Appalachian Assessment (SAMAB 1996b) demonstrated that most fires on National Forest lands are of human origin. Contrary to most prehistoric and historic fires, which arose from the use of fire in maintaining agricultural areas and wildlife habitat, the majority of human-caused fires today are due to carelessness and arson. Records showed that some fires are started by lightning, however, most of those fires are restricted to ridge top areas and rarely exceed 40 ha (SAMAB 1996b).

Today, the role of fire in southern Appalachian forests is coming full circle and the use of prescribed fire on public lands is increasing. Prescribed fire is defined as "fire applied in a knowledgeable manner to forest fuels on a specific land area under selected weather conditions to accomplish predetermined, well-defined management objectives" (USDA Forest Service 1989). Management goals attainable through the use of prescribed fire include reducing hazardous fuels, preparing sites for seeding and planting, disposing of logging debris, improving wildlife habitat, managing competing vegetation, controlling disease, improving forage for grazing, enhancing appearance, improving access, perpetuating fire-dependent species, cycling nutrients, and managing endangered species (USDA Forest Service 1989). Fire is recognized as a component of some ecosystems and, under current ecosystem management guidelines, can be used to obtain one, or any combination, of these objectives.

More and more federal reports call for increased use of prescribed fire on federal lands. The loss of firefighters suppressing fire in areas with tremendous fuel loads from over fifty years of fire exclusion prompted this call for action. The Federal Wildland Fire

Management Policy and Review Program supports prescribed burning as a means of restoring forest health (USDA and USDI 1995). The USDA Forest Service recently developed the "Fire 21: Fire Management in the 21st Century" program which advocates the safe and prudent use of wildland fire (USDA Forest Service 1996). In addition to improving firefighter and public safety, Fire 21 promotes prescribed burning as a means of "restoring, maintaining, and sustaining ecosystem function for healthier forests and rangelands" (USDA Forest Service 1996).

CHAPTER III

YELLOW PINE COMMUNITIES AND THE SELECTED STUDY SITES

Yellow Pine Communities

The yellow pines native to the southern Appalachian Mountains, shortleaf, pitch, table mountain pine and Virginia pine are all pioneer species that establish stands following disturbance. It is thought that the disturbance must expose mineral soil and provide full sunlight for successful regeneration (USDA Forest Service 1965). Whittaker (1956) describes three of these species, shortleaf, pitch, and table mountain pines, as capable of maintaining edaphic climax communities on xeric ridges and southwest-facing slopes. Virginia pine commonly is found as dense, pure, even-aged stands in eroded old-fields on heavy clay soils. Since Virginia pine has no fire-adapted traits (e.g., cone serotiny, epicormic branching, thick bark) and is uncommon in fire-prone regions of the southern Appalachian Mountains, it is not a central focus of this research.

Many animal and plant species depend upon pioneer (pine) and mid-seral (pine/oak) yellow pine forests. Rare wildlife that depend upon yellow pine habitat include the red-cockaded woodpecker (*Picoides borealis*) (endangered), the northern pine snake (*Pituophis melanoleucus melanoleucus*) (species of special concern), and the slender glass lizard (*Ophisaurus attenuatus*) (Langdon pers. com., 1997). Rare plants restricted to xeric pine and pine/oak forests include round-leafed service berry (*Amelanchier sanquinea*), branched whitlow grass (*Draba ramosissima*) and witch-alder (*Fothergilla major*) (species of special concern) (Hessl and Spakman 1996). Hessl and Spakman (1996) also suggest that Heller's blazing star (*Liatris helleri*) (threatened), Peter's Mountain mallow (*Iliamna corei*)

(endangered), white irisette (*Sisyrinchium dichotomum*) (endangered), and running buffalo clover (*Trifolium reflexum*) (endangered) depend upon xeric, montane woods.

Shortleaf Pine (Pinus echinata)

Shortleaf pine is the most widely distributed of the southern Appalachian yellow pines. It is found from dry rocky mountain ridges to sandy loams and silt loams of floodplains, and in old fields. Shortleaf pine is distributed primarily throughout southeastern United States from New York and New Jersey south to north Florida, west to east Texas, and north to southern Missouri. Shortleaf pine occurs both as pure stands and with other yellow pines and oaks. These forest communities are found at elevations up to 1006 m (Sutton and Sutton 1985). Shortleaf pine releases seed during the fall and trees often sprout following fire (Wright and Bailey 1982).

Pitch Pine (Pinus rigida)

Pitch pine generally is found on oligotrophic, shallow, sandy and gravely soils on steep slopes and ridges and can tolerate xeric to slightly mesic conditions (Ledig and Little 1979). The distribution of pitch pine extends southward from southern Maine along the Appalachian Mountains to northeast Georgia (Sutton and Sutton 1985). In the southern Appalachian region, stands are commonly found between 430-1370 m elevation. Pitch pine commonly shares canopy dominance with Virginia pine (*Pinus virginiana*), table mountain pine, chestnut oak (*Quercus prinus*), scarlet oak (*Q. coccinea*) and various hickories. Blackgum (*Nyssa sylvatica)* is common in the midstory and understory. blueberries (*Vaccinium sp.)* and huckleberries (*Gaylussacia sp.*) are common shrubs

(Whittaker 1979). Pitch pine is highly susceptible to southern pine bark beetle infestations (Ledig and Little 1979).

Pitch pine cones in the central regions of the New Jersey Pine Barrens are serotinous. In contrast, pitch pine cones in the southern Appalachian Mountains are non-serotinous. Mature cones are found on trees eight to twelve years old and seed dissemination occurs from late October through late November (Little and Garrett 1990). Vegetative reproduction from basal buds and epicormic branching is common following fire injury (Ledig and Little 1979; Little and Garrett 1990).

Table Mountain Pine (Pinus pungens)

Table mountain pine is an Appalachian endemic distributed along the ridges of the Appalachian Mountains from central Pennsylvania to northern Georgia (Zobel 1969). It occurs on xeric, southwest-facing slopes between 305-1220 m in elevation. Soils supporting table mountain pine are generally shallow, acidic, and oligotrophic. Canopy species most often found with table mountain pine include pitch pine, chestnut oak and scarlet oak. Associated midstory and understory species are blackgum and sourwood (*Oxydendrum arboreum*). Dense thickets of mountain laurel (*Kalmia latifolia*) and species of blueberry and huckleberry comprise the shrub layer with galax (*Galax* sp.) common in the ground layer (Zobel 1969; Barden 1977; Williams and Johnson 1992).

The serotinous cones of some table mountain pines mature when the tree is five years of age (Della-Bianca 1990). Temperatures above 32°C are necessary to melt resins that seal cone scales to release seeds (Barden 1978). In the southern Appalachian region, such temperatures are not uncommon during summer months and some cones open in the absence of fire. However, seeds released by hot summer temperatures do not regenerate

because they fall on deep litter and duff layers under closed forest canopies. Table mountain pine does not reproduce vegetatively (Della-Bianca 1990).

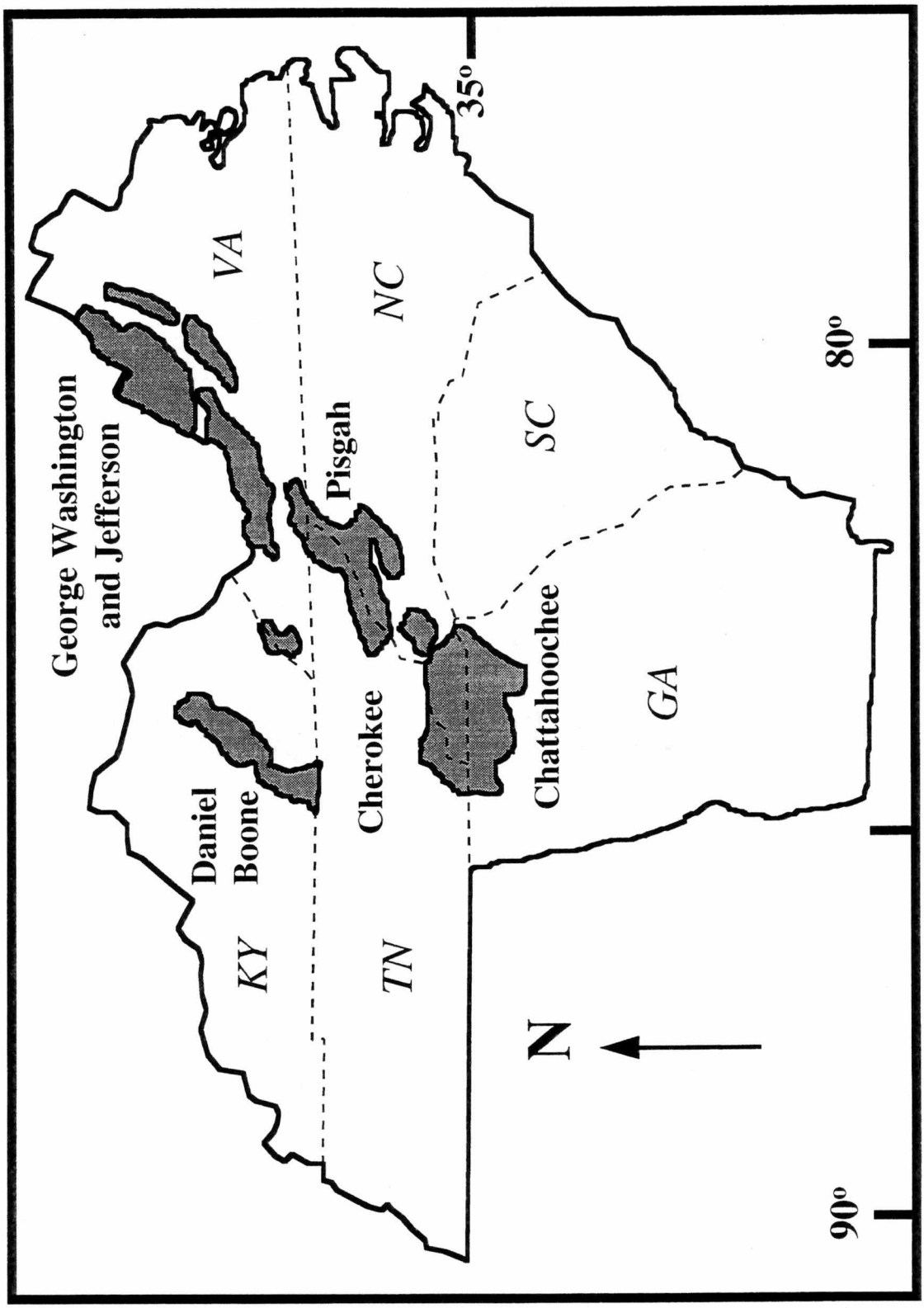
Study Sites

This study integrated research on five National Forests throughout the southern Appalachian region. National Forests participating in the study were (from north to south) the George Washington and Jefferson in Virginia, the Daniel Boone in Kentucky, the Cherokee in Tennessee, the Pisgah in North Carolina, and the Chattahoochee National Forest in Georgia (Figure 1). The southern Appalachian region has a temperate climate with a frost-free period of 150-210 days and precipitation averaging 100-200 cm per year (US Department of Commerce 1968). The area includes much of the Blue Ridge and Ridge and Valley physiographic provinces of the southern Appalachian Mountains (Fenneman 1938). Characteristic soils are Ultisols and Inceptisols (USDA Soil Conservation Service 1975).

George Washington and Jefferson National Forest, Warm Springs Ranger District (GWWS)

We sampled 15 ha of a 60-year-old pitch pine-mixed oak stand on the Warm Springs Ranger District of the George Washington and Jefferson National Forest near Clifton Forge, Virginia. The stand occupied a slope that was flat at the top and of moderate steepness in mid- and lower-slope positions. McClung, Watahala, and Wallen soils (Ultisols) covered brown sandstone and cherty limestone parent materials. The USDA Forest Service purchased the land from the Douthat Land Company in 1937. Previous

Figure 1. Participating National Forests of the southern Appalachian region.


George Washington
and Jefferson
VA
NC
35°
Pisgah
SC
80°
Cherokee
Chattahoochee
GA
Daniel
Boone
KY
TN
N
90°

owners included mining, timbering, and railroading companies. Cutting histories prior to federal land acquisition could not be obtained. Since Forest Service ownership, the site has not been cut or otherwise manipulated. There was no evidence of wildfires or prescribed fires in the written records for this area.

George Washington and Jefferson National Forest, Wythe Ranger District (GWWY)

On the Wythe Ranger District of the George Washington and Jefferson National Forest near Wytheville, Virginia, we sampled a 60 ha, 68-year-old pine-oak stand (Compartment 6080, Stand 5). The rolling topography of the sampled area created three hill and two valley regions. The pine component of this stand included pitch and table mountain pine. Soils of the Berks-Weikert complex and the Gilpin-Berks complex covered slopes underlain by shale bedrock. The family of Robert Norris owned the land from 1795 to 1942. The USDA Forest Service acquired the land in 1942. Timbering has not occurred on the land since 1942 and the cutting history prior to that is unknown. Iron ore mining occurred in the region. Written records contained no references to wildfires or prescribed fires.

Daniel Boone National Forest, Somerset Ranger District (DBSM)

We sampled a 16 ha, 103-year-old shortleaf pine-mixed oak stand (Compartment 5032, Stand 8) on the Somerset Ranger District of the Daniel Boone National Forest, near Somerset, Kentucky. The stand occupied a slope of little relief. Ultisols with Hartsells fine sandy loam covered ridgetop areas and Whitley silt loams topped ridges and sideslopes. The USDA Forest Service acquired the land in the early 1940's from W.S.

Glore. Cutting history prior to federal ownership was unknown. Only occasional single-tree salvages have occurred since acquisition. There were no recorded wildfires for this area. Three prescribed burns for fuel reduction and maintenance of red-cockaded woodpecker habitat (understory reduction) occurred in 1980, 1983, and 1992.

Daniel Boone National Forest, Stearns Ranger District (DBST)

We sampled a portion of a 250 ha, 103-year-old shortleaf pine-mixed oak stand (Compartment 6061, Stand 33), rich in archeological sites, on the Stearns Ranger District of the Daniel Boone National Forest, near Whitley City, Kentucky. The site was of moderate slope. Four series of Ultisols, DeKalb fine sandy loam, DeKalb/Ramsey sandy loam, Muse silt loam, and Tate loam, dominated the area. John Hamlin sold the land to the USDA Forest Service in 1942. No timber cutting has occurred since its purchase. USDA Forest Service crews applied a midstory removal treatment in 1995 to improve red-cockaded woodpecker habitat. Portions of this stand burned in a wildfire during the Spring of 1995. No prescribed burning has occurred in this stand for at least ten years.

Cherokee National Forest, Hiwassee Ranger District (CKHW)

The 12 ha area we sampled included two pine-oak stands (Compartment 104 Stand 16 and Stand 7) of the Hiwassee Ranger District near Etowah, Tennessee. Stand 16, located below a wildlife opening, contained mature sawtimber and had little topographic relief. The USDA Forest Service managed this 80-year-old, shortleaf pine and mixed-oak stand for upland hardwoods and as a potential recreation area. Crews thinned the stand in 1986. There was no documentation of wildfires or prescribed fires for the area. Parent

material was colluvium and soils were of the Jefferson series and described as dry, depositional, sandy loams with moderate erosion potential. Stand 7, located above the same wildlife opening, was 82 years old and was moderate in slope. There were no written records of cutting or fire events for this stand. Soils over the sandstone parent material were of the Ditney series and described as droughty, sandy loams with moderate erosion potential.

Previous owners included the Whitmore Logging Company for Stand 16 and the Tennessee Power Company for Stand 7. Letters obtained by the Hiwassee Ranger District document the observations of George Metcalfe, a surveyor for the Whitmore Logging Company. He described the 1894 composition of the forest as white oak, chestnut oak, poplar, white pine and yellow pine. Letters from 1898 suggested there were several sawmills and iron ore mines in the area. Also, these letters recorded leasee descriptions of old fields as a result of historic Indian burning.

Pisgah National Forest, Grandfather Ranger District (PSGF)

We established sample plots in a 7 ha, 77-year-old pine-oak stand (Compartment 286, Stand 7) on the Grandfather Ranger District of the Pisgah National Forest near Nebo, North Carolina. The slope of area was of moderate steepness. The pine component of this stand included both pitch and table mountain pine. Soils were Ultisols of the Ditney Series and covered regional quartzite and phyllite parent materials. The USDA Forest Service acquired the land in 1938 from the Packer and Harrison Lumber Company. No Forest Service records documenting a cutting history were found. Written records contained no evidence of wildfires or prescribed fires in the area.

Chattahoochee National Forest, Tallulah Ranger District (CHTL)

USDA Forest Service personnel sampled the table mountain pine component of a 150 ha, 68-year-old, white oak-red oak-hickory forest (Compartment 11, Stand 2) on the Tallulah Ranger District of the Chattahoochee National Forest near Clayton, GA. The ridge-top table mountain pine component did not include enough basal area or acreage to be broken out into a separate stand. The slope leading to the ridge was very steep whereas the table mountain pine component had little topographic relief. Stony Ashe soils covered the granite, gneiss and schist parent materials of the area. The Forest Service acquired the stand in 1935 from Three States Lumber Company of Asheville, NC. Ownership previous to that was unknown. Forest Service records showed that the stand was cut over at least twice prior to federal acquisition. After federal purchase of the land, limited cutting for railroad crossties and of higher grade oaks occurred. No commercial timber harvesting has occurred in the sample area since 1973. Although there were no written records of this stand burning prior to a wildfire in 1994, there was evidence that the area burned sometime in the 1950's. In November 1995, there was a 50 ha wildfire in this area but it did not reach the ridge-top table mountain pine stand.

CHAPTER IV

FIRE HISTORY OF STUDY SITES AS INDICATED BY MACROSCOPIC CHARCOAL

Introduction

Charcoal deposits in tree rings and lake sediments have been used as evidence for prehistorical and historical fire events in the southern Appalachian region. Sutherland et al. (1995) used fire scars on trees to record fire occurrences in southwestern Virginia whereas Davidson (1984) and Delcourt and Delcourt (1997) utilized lake and/or bog sediments, respectively, to document fire events in the Cades Cove region of the Great Smoky Mountains National Park, Tennessee and southwestern North Carolina. Methods used in studies such as these are labor intensive. Coring trees demands accuracy in obtaining and preparing cores for interpretation. Analyzing charcoal particles from lake and bog sediments first requires their presence in your study area. Most often, these are not found in areas supporting yellow pine communities. Secondly, sampling lake and bog sediments requires specialized equipment for obtaining the sediment core plus laboratory facilities to extract and examine charcoal fragments. Such time and facilities generally are not available to federal land managers for assessing whether or not a stand has burned in its past. Presented here are data to support using macroscopic charcoal particles, easily extracted from forest soils, as an indicator of past fire occurrences in a forest stand.

Fire intensity, duration and temperature, and taphonomic processes alter the size of charcoal fragments. Fires of great intensity produce finer, microscopic ash particles (Shaefer 1974). Extended fire duration and high temperatures also lead to smaller charcoal

fragments (Patterson et al. 1987). Winds, both atmospheric and convection winds produced by the fire itself, carry some charcoal particles away from the fire site as may overland water flow. Patterson et al. (1987) concluded that larger charcoal fragments are deposited closer to fire sites compared to smaller charcoal particles. Macroscopic charcoal particles thus are interpreted as indicators of local-scale burning whereas microscopic charcoal particles are indicators of regional-scale burning (Clark and Royall 1995; Delcourt and Delcourt 1997).

Horn et al. (1994) and Horn and Sanford (1992) studied macroscopic charcoal fragments in soils to document the occurrence of Holocene fires in Costa Rica. This study applied their methods to southern Appalachian yellow pine forests. In this work, the presence of macroscopic charcoal was used as an indictor of past fires. Because fire-adapted vegetation dominated these yellow pine forests, I hypothesized that macroscopic charcoal fragments were present in their soils. The topography afforded by each site also permitted comparisons between erosional and depositional landscape positions as to their ability to retain charcoal fragments.

Methods

Field Sampling

Sampling crews retrieved eight to ten soil cores from the range of landscape positions (i.e., summit, shoulder, backslope, footslope, and toeslope) available at each of the seven study sites. We collected the soil cores by a modification of the methods outlined in Horn et al. (1994) using a manual soil auger. We extracted each soil core in 10-cm intervals to the depth of unconsolidated bedrock or to an impenetrable clay layer, up to a

maximum of 70 cm as allowed by the length of the soil auger handle. From this point forward in this report, each 10-cm interval is referred to as a soil sample. We collected all soil cores between May-August 1996.

Laboratory Procedures

Following the methods of Horn et al. (1994), I soaked each soil sample first in approximately 1.5 l of water for one to three days to help disaggregate the soil and make sieving easier. I then sieved these soil samples using a 20.5 cm diameter brass screen with 1 mm openings. Finally, I noted the presence or absence of macroscopic charcoal by observing the material caught in the screen with the unaided eye.

Results

Maximum sampling depth varied greatly among and within study sties. Each core consisted of two to seven soil samples. Average sampling depth was 47.7±11.7 cm and ranged from 20.0 to 70.0 cm. I observed macroscopic charcoal particles in all soil cores from all field sites (Table 1). The mean percentage of soil samples containing macroscopic charcoal fragments within a study area was 85.0±12.5% and ranged from 61.3 to 100.0%. Landscape position did not influence maximum sampling depth or occurrence of macroscopic charcoal.

Table 1. Presence (+) or absence (-) of macroscopic charcoal from soils supporting yellow pine forests.

Depth (cm)	Sample Number							
*GWWS**								
	1	2	3	4	5	6	7	8
Lancscape Position	shoulder	shoulder	back-slope	backslope	foot-slope	foot-slope	toeslope	toeslope
0-10	+	+	-	+	+	+	+	-
10-20	+	-	+	+	+	-	-	-
20-30	+	+	+	+	+	-	-	+
30-40	+		+	+	+	+	-	-
40-50	+		-			+	-	-
50-60	+		-			-	+	
60-70	+		-			+	-	

GWWY										
	1	2	3	4	5	6	7	8	9	10
Landscape Position	summit	summit	toe-slope	toe-slope	summit	summit	toe-slope	toe-slope	summit	summit
0-10	+	+	+	+	+	+	+	+	+	+
10-20	+	-	-	+	+	-	-	+	+	+
20-30			+	+	+		+	+	+	
30-40			+	+			+	-		

*DBSM**								
	1	2	3	4	5	6	7	8
Landscape Position	back-slope	foot-slope	toeslope	toeslope	summit	summit	backslope	foot-slope
0-10	+	+	+	+	+	+	+	+
10-20	+	+	+	+	+	+	+	+
20-30	+	+	+		+	+	+	+
30-40	+	+	+		+	+		+
40-50	+	+	+		+	+		+
50-60		+			+	+		
60-70					+	+		

Table 1 (continued).

Depth (cm)	----------Sample Number----------							
*DBST**	1	2	3	4	5	6	7	8
Landscape Position	summit	summit	summit	summit	back-slope	back-slope	foot-slope	foot-slope
0-10	+	+	+	+	+	+	+	+
10-20	+	+	+	+	+	+	+	+
20-30	+	+	+	+	+	+	+	
30-40	+	+	-	+	-	-	+	
40-50	-	+	-	+	+	-	-	
50-60	+	+	+		+	+	-	
60-70	+	+	-		+		-	

CKHW	1	2	3	4	5	6	7	8
Landscape Position	back-slope	back-slope	back-slope	back-slope	foot-slope	foot-slope	toeslope	toeslope
0-10	+	+	+	+	+	+	+	+
10-20	+	+	+	+	+	-	+	+
20-30	+	+	+		+	-	+	+
30-40	+	+	+		+	-	+	+
40-50		+	+		-	-	+	+
50-60		+	+				+	+
60-70			+				-	+

Table 1 (continued).

Depth (cm)	Sample Number							
*PSGF**	1	2	3	4	5	6	7	8
Landscape Position	back-slope	back-slope	back-slope	back-slope	foot-slope	foot-slope	toe-slope	toe-slope
0-10	+	+	+	+	+	+	+	+
10-20	+	+	+	+	+	+	+	+
20-30		+	+	+	+	+	-	+
30-40			+	+				
40-50				-				
*CHTL**	1	2	3	4	5	6	7	8
Landscape Position	shoulder	shoulder	back-slope	back-slope	foot-slope	foot-slope	toe-slope	toe-slope
0-10	+	+	+	+	+	+	-	+
10-20	+	+	+	+	+	+	+	+
20-30	+	+	+	+		+	+	+
30-40	+	+	+	+		+	+	+
40-50	+	+	+	+		+		+
50-60	-	+				+		
60-70	-	+				+		

*Sites where prescribed fires and/or wildfires were known to have occurred prior to sampling.

Discussion

When designing this project I encountered two points of concern. First, are soils of the southern Appalachian region too shallow and rocky for these sampling methods to be successful? An average core depth of nearly 50 cm indicates otherwise. Indeed, the maximum sampling depth was greater than 50 cm for 20 of the 58 collected cores. The second concern was that soils are too sandy in texture for charcoal particles to be retained. The fact that I found macroscopic charcoal in all cores, across seven different field sites, indicates that charcoal particles are retained by these sandy forest soils following fire events.

I expected a greater occurrence of charcoal in soil samples from depositional landscape positions (footslope and toeslope areas) where post-fire erosion carries charcoal particles (Patterson et al. 1987). This prediction held true only for the rolling topography of GWWY (Table 1). When comparing results among other sampling sites, few consistencies existed across landscape positions. In some cases, maximum sampling depth was as great on summits as it was on footslopes and toeslopes. On sites with long, gentle slopes, the presence or absence of macroscopic charcoal did not vary among landscape positions.

Charcoal retained by these forest soils does not appear as distinct layers as charcoal sometimes does in lake and bog sediments. Preservation of charcoal layers is not possible in upland forest soils due to overland flow, soil mixing by organisms and physical processes, and movement of charcoal fragments in the soil solution (Buol et al. 1989). These factors likely explain the inconsistent occurrence of charcoal in soil samples across cores from the same site. The charcoal present in each soil sample could be the result of

one or several fires, unlike lake and bog sediments where distinct layers of macroscopic charcoal sometimes can be traced to a single fire event (Patterson et al. 1987).

I found charcoal fragments in all cores from the five sites where prescribed fires or recorded wildfires had occurred (Table 1). This demonstrates that charcoal particles are retained by these soils following fire events and can serve as indicators of past fires. Of greater interest was the presence of macroscopic charcoal from the two sites where no fires have been recorded since the time of land acquisition by the USDA Forest Service (GWWY and CKHW). Charcoal particles in these soil samples could date to fires that occurred many years prior to USDA Forest Service fire suppression practices. Dating pre-suppression fires, even those as far back as the 1600's, may be impossible since radiocarbon dating has a resolution of 350-400 years (Roberts 1991). Furthermore, radiocarbon dating of soil, or particles contained within soils, is complicated by long-term additions of organic carbon from soil mixing, humic acid filtration and root penetration (Lowe 1984).

In conclusion, this study indicated that fire burned all study sites at some time in their past and that forest soils retained the macroscopic charcoal produced by these fires. These methods provided answers only to questions of past fire occurrences not historic fire frequencies.

CHAPTER V

PRESCRIBED BURNING OF SOUTHERN APPALACHIAN YELLOW PINE COMMUNITIES

Introduction

Fire suppression eliminates a disturbance thought to be essential to regenerate and maintain southern Appalachian yellow pine forests. Self-maintaining stands of yellow pines are the exception instead of the rule. Many studies attribute the lack of pine regeneration to the absence of fire. Cain and Shelton (1995) and Collins and Good (1987) document an absence or low occurrence of shortleaf pine seedlings in Arkansas and New York, respectively. Waterman et al. (1995) report suppressed pitch pine regeneration due to extensive mountain laurel development in the Coweeta Basin of North Carolina. Likewise, table mountain pine is not regenerating in southwestern Virginia (Williams and Johnson 1990; 1992; Sutherland et al. 1995). Harrod et al. (1997) report a decline in density of pitch pine saplings in the western portions of the Great Smoky Mountains National Park, Tennessee, over the past sixty years of fire suppression.

In the absence of fire, closed canopy forests with deep litter and duff layers develop as shade-tolerant hardwoods invade niches once open to yellow pines. The shade-tolerant hardwoods regenerate and eventually become established in the midstory and understory. Shade-tolerant hardwoods in the understory grow into the forest overstory and fragment previously contiguous yellow pine forests (Turrill et al. in press). Such changes in species composition and forest structure are noted for yellow pine forests in Arkansas (Cain and Shelton 1995), North Carolina (Waterman et al. 1995), Virginia (Sutherland et al. 1995;

Williams and Johnson 1992, 1990), Pennsylvania (Abrams and Nowacki 1992), New York (Seischab and Bernard 1991) and New Jersey (Collins and Good 1987).

The extent of hardwood invasion in the understories and overstories of table mountain pine-pitch pine woodlands warrants their designation as one of thirty-one rare communities in the southern Appalachian Mountains (SAMAB 1996b). To prevent the loss of pine woodlands and other early-successional, fire-dependent communities, federal policy that once dictated fire suppression, now encourages ecosystem managers to conduct prescribed burns to regenerate these stands (USDA and USDI 1995). These future prescribed burns must eliminate hardwood competition to regenerate yellow pines (Regelbrugge and Smith 1994; Boggs and Wittwer 1993; Sanders 1992).

The purpose of this chapter is to evaluate the effects of prescribed burning on southern Appalachian yellow pine forests. First, I present the pre-burn structure and species composition of the study sites. Then, I describe the conditions (air temperature, relative humidity, wind speed and fuel moisture) and the characteristics (ignition source, flame height, temperature and bark char) of each prescribed burn. Finally, I determine the effects of burning on species composition and on yellow pine regeneration.

Methods

Plot Location

At DBSM, DBST, GWWY and CHTL, sampling crews located permanent plots within the pine component of the stand in a stratified random manner. USDA Forest Service crews divided each of the remaining pine-oak stands, CKHW, GWWS and PSGF, into two compartments to allow for two burns, of different seasons, at each site. We then

located an equal number of sample plots within each of those compartments. All permanent sample plots were rectangular and 0.02 ha (10 x 20 m) in size (Figure 2).

Vegetation Sampling

Sampling crews tallied all living woody stems ≥2.5 cm diameter breast height (dbh) within each sample plot as to species and dbh. Generally, stems >10 cm dbh were in the overstory and those ≤10 cm dbh were in the midstory. We noted understory stems (all vegetation <2.5 cm dbh and >1 m in height) as to species and placed them in 30 cm height classes. We sampled the understory size class in the outermost quarters of each plot (Figure 2). Sampling crews obtained litter layer depth (cm) from three random measurements within each understory subplot. I measured duff depth (cm) (depth of materials no longer recognizable as litter and not recognizable as soil) at the center of each plot. We located one 1-m^2 subplot at each of the four corners of the sample plot for ground layer sampling. Within these subplots, we visually estimated percent (%) cover for all vascular species, both woody and herbaceous, ≤1 m in height. Nomenclature follows Radford et al. (1968).

Prescribed Burning Schedule

Each Ranger District proposed a target burning season (Table 2). At the initiation of this study, ten burns were planned. The purpose of two of these burns was to reduce understory vegetation in order to improve red-cockaded woodpecker habitat and to regenerate yellow pines. The purpose of the remaining eight burns was for yellow pine regeneration. However, primarily due to weather conditions and extraneous factors

Figure 2. Sample plot design. Total area of plot is 0.02 ha.

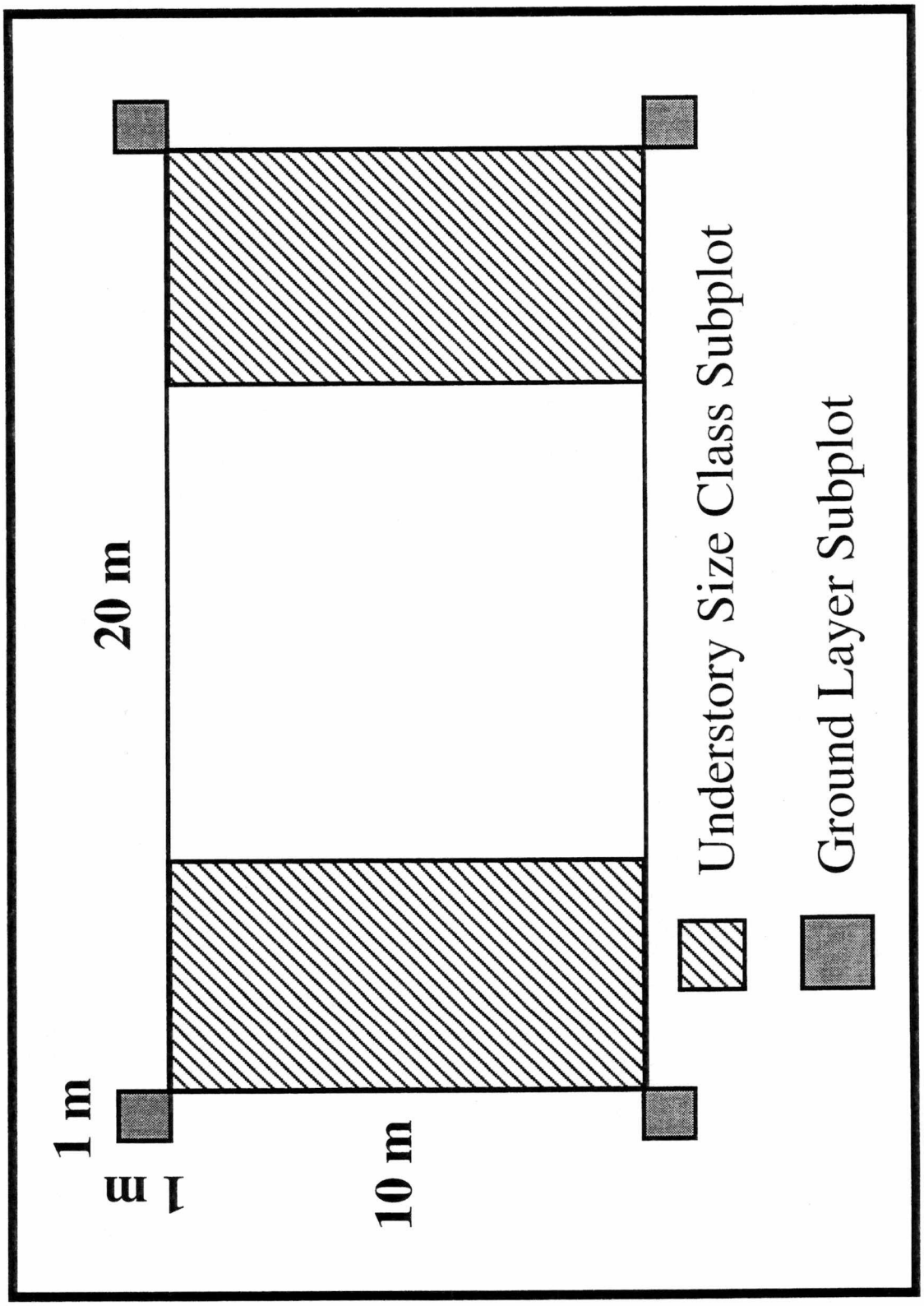

1 m
1 m
10 m
20 m
Understory Size Class Subplot
Ground Layer Subplot

Table 2. Summary of study sites and prescribed burning effects. Abbreviations are as follows: GWWS=George Washington and Jefferson National Forest, Warm Springs Ranger District, DBSM=Daniel Boone National Forest, Somerset Ranger District, DBST=Daniel Boone National Forest, Stearns Ranger District, CKHW=Cherokee National Forest, Hiwassee Ranger District, PSGF=Pisgah National Forest, Grandfather Rager District, CHTL=Chattahoochee National Forest, Tallulah Ranger District, P=pitch pine, S=shortleaf pine, and TMP=table mountain pine.

National Forest	Pine Species	# Plots	Burn Season	Burn Completed	Canopy Reduction	Litter Reduction	Duff Reduction	Pine Regeneration
GWWS	P	8	Fall 1995	yes	yes	yes	yes	yes
GWWS	P	8	Spring 1996	yes	yes	yes	no	no
GWWY	TMP/P	11	Spring 1996	no	-----	-----	-----	-----
DBSM	S	8	Spring 1995	yes	no	no	no	no
DBST	S	10	Spring 1996	yes	no	yes	no	no
CKHW	S	8	Fall 1995	no[1]	-----	-----	-----	-----
CKHW	S	8	Spring 1996	no	-----	-----	-----	-----
PSGF	TMP/P	8	Spring 1996	yes	yes	yes	no	yes
PSGF	TMP/P	8	Fall 1996	no	-----	-----	-----	-----
CHTL	TMP/P	14	Spring 1996	no[2]	-----	-----	-----	-----

[1]USDA Forest Service crews burned both compartments Spring 1997. I did not collect post-burn data because seasonal comparisons could not be made.

[2]USDA Forest Service attempted a Spring 1996 burn but it was unsuccessful. I did not collect post-burn data.

(budget constraints and limitations on available personnel) burning crews completed only five of these burns, two at GWWS and one each at DBSM, DBST and PSGF.

Burn Measurements

No more than two hours before each burn, sampling crews placed one ceramic tile painted with heat sensitive paints 1 m above the ground in each plot. Each Templaq© paint melted at a specific temperature (37.8, 93.3, 148.9, 204.4, 232.2, 260.0, 315.6, 371.1, 426.7, 482.2, or 537.8°C). In addition, sampling crews retrieved one grab-sample of litter from each shrub sub-plot. I determined percent moisture for each grab-sample by comparing field and oven-dried (75°C for 24 hours) weights. In addition, some USDA Forest Service districts used fuel moisture sticks to assess percent moisture of ten-hour fuels.

Post-Burn Sampling

We resampled the burned areas during the first growing season following the burn. Post-burn vegetation sampling included all pre-burn measurements plus three bark char heights taken randomly within each understory sub-plot. Sampling crews also estimated the percent from bottom to top of crown scorched in each plot.

Data Analysis

I obtained mean total basal area (m^2/ha), mean canopy density (# stems/ha) and mean canopy species richness (# species/0.02 ha) values for each sample plot. I calculated

importance values of canopy species by adding relative basal area and relative density. The term relative refers to the percentage of the total basal area or density for each species. I determined frequencies of all canopy stems (overstory and midstory size classes combined) in 5 cm dbh classes for each species and constructed histograms of the three most important canopy species for each study site. I then separated stems into midstory (<10 cm dbh) and overstory (≥10 cm dbh) classes and determined basal area, stem density and species importance values for each class.

I determined mean understory density (# stems/ha), mean understory species richness (# species/0.01 ha), mean ground layer cover (%/m^2) and mean ground layer species richness (# species/m^2) for each plot. I calculated importance values of understory species and ground layer species as relative density plus relative height and relative cover plus relative frequency, respectively. Here, the term relative refers to the percentage of the total basal area, density or cover for each species. I determined relative height by dividing the average height of each species by the total height (sum of all species heights) of understory stems. Furthermore, I obtained mean litter and mean duff depth (cm) values for each sample site. Finally, I compared pre- and post-burn means of vegetation parameters with paired t-tests (SAS 1994; Zar 1973).

Results

Fall and Spring Burns on the George Washington and Jefferson National Forest, Warm Springs Ranger District

GWWS Pre-Burn Vegetation

Pitch pine was the most important overstory species of this stand followed by scarlet oak and blackgum (Table 3). Total density of the overstory size class was 706 stems/ha. Blackjack oak (*Quercus marilandica*), black oak (*Q. velutina*) and blackgum predominated the midstory size class that contained 821 stems/ha (Table 4). Most pitch pine stems exceeded 15 cm dbh whereas most oak stems were smaller than 15 cm dbh (Figure 3). Basal area and canopy density averaged 25.9±1.8 m^2/ha and 1159.5±97.5 stems/ha, respectively, for overstory and midstory size classes combined. Mean species richness was 5.9±0.3 species/0.02 ha for these combined size classes.

Sassafras (*Sassafras albidum*), scarlet oak and mountain laurel predominated the understory size class (Table 5). Mean understory species richness was 2.6±0.2 species/0.01 ha and mean understory density was 95.1±16.3 stems/ha. Huckleberry (*Gaylussacia sp.*) was the most important ground layer species followed by blueberry and bracken fern (*Pteridium aquilinum*) (Table 6). Species richness of this vegetation averaged 2.6±0.2 species/m^2 and cover averaged 68.5±5.5 %/m^2. Hardwood regeneration was occurring prior to burning but pine regeneration was not. Mean litter and duff depths were 4.2±0.3 cm and 4.2±0.7 cm, respectively.

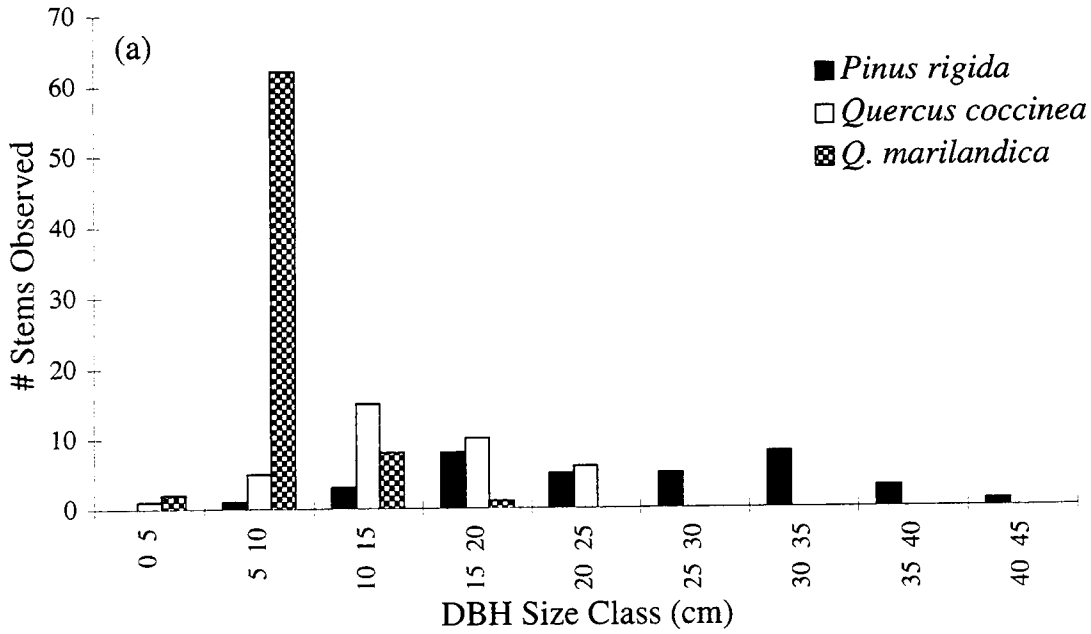
Table 3. Overstory (trees ≥ 10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District prior to and following a fall prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Pinus rigida	11.3	(57.6)	206.3	(29.2)	86.8
Quercus coccinea	3.9	(19.8)	193.8	(27.4)	47.2
Nyssa sylvatica	1.6	(8.1)	93.8	(13.3)	21.4
Q. prinus	1.5	(7.6)	93.8	(13.3)	20.9
Q. velutina	0.8	(3.9)	62.5	(8.9)	12.7
Q. marilandica	0.6	(3.0)	56.3	(8.0)	11.0
Total	19.7		706.5		
Post-Burn					
Pinus rigida	9.6	(58.3)	168.8	(30.7)	89.0
Quercus coccinea	3.8	(22.7)	187.5	(34.1)	56.8
Nyssa sylvatica	1.5	(8.9)	87.5	(15.9)	24.9
Q. prinus	1.2	(7.3)	75.0	(13.6)	20.9
Q. velutina	0.2	(1.2)	12.5	(2.3)	3.4
Q. marilandica	0.2	(1.1)	12.5	(2.3)	3.3
Q. alba	0.1	(0.5)	6.3	(1.1)	1.6
Total	16.6		550.1		

Table 4. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District prior to and following a fall prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Quercus marilandica	1.7	(49.2)	400.0	(48.9)	98.1
Q. velutina	0.6	(16.6)	143.8	(17.6)	34.1
Nyssa sylvatica	0.5	(12.6)	112.5	(13.7)	26.4
Q. prinus	0.4	(9.7)	62.5	(7.6)	17.3
Q. coccinea	0.2	(5.6)	37.5	(4.6)	10.1
Sassafras albidum	0.1	(1.7)	31.3	(3.8)	5.5
Q. alba	0.1	(2.4)	6.3	(0.7)	3.2
Amelanchier arborea	0.1	(1.6)	12.5	(1.5)	3.1
Pinus rigida	0.0	(0.5)	6.3	(0.8)	1.2
Acer rubrum	0.0	(0.2)	6.3	(0.8)	1.0
Total	3.7		819.0		
Post-Burn					
Nyssa sylvatica	0.2	(48.2)	37.5	(50.0)	98.2
Quercus prinus	0.1	(31.1)	18.8	(25.0)	56.1
Q. coccinea	0.1	(20.7)	18.8	(25.0)	45.7
Total	0.4		75.1		

Figure 3. Pre- and post-fall-burn distributions of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Warm Springs Ranger District. The number of stems observed represents the number of trees tallied in 0.16 ha. The prescribed burn occurred in October 1995. Post-burn vegetation sampling took place in August 1996.


(a)
Pinus rigida
Quercus coccinea
Q. marilandica
Stems Observed
70
60
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

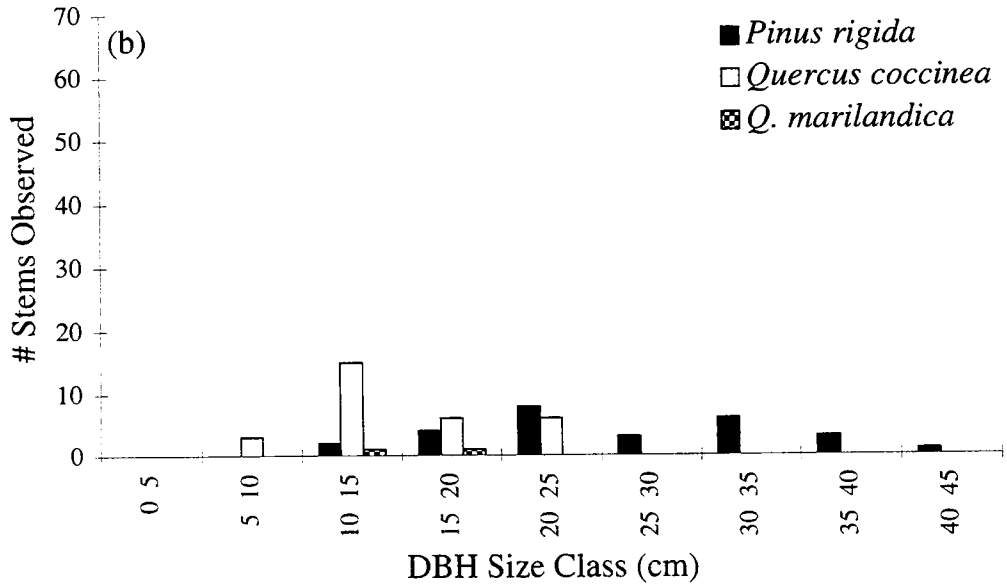

(b)
Pinus rigida
Quercus coccinea
Q. marilandica
Stems Observed
70
60
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

Table 5. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Mean Height (m)		IV
Pre-Burn					
Tree Species					
Sassafras albidum	406.3	(36.3)	2.2	(55.3)	91.6
Quercus coccinea	312.5	(27.9)	1.2	(22.4)	50.3
Q. marilandica	43.8	(3.9)	0.8	(2.2)	6.2
Total	762.6		4.2		
Shrub Species					
Kalmia latifolia	325.0	(29.1)	0.9	(18.2)	47.4
Gaylussacia sp.	18.8	(1.7)	1.0	(1.1)	2.8
Rhododendron sp.	6.3	(0.6)	1.5	(0.6)	1.1
Total	350.1		3..4		
Post-Burn					
Tree Species					
Sassafras albidum	1537.5	(52.7)	0.5	(53.6)	106.3
Quercus velutina	381.3	(13.1)	0.6	(15.9)	29.0
Q. coccinea	193.8	(6.6)	0.5	(6.5)	13.1
Q. marilandica	81.3	(2.8)	0.7	(3.8)	6.6
Nyssa sylvatica	75.0	(2.6)	0.4	(2.2)	4.8
Q. prinus	56.3	(1.9)	0.6	(2.2)	4.1
Acer rubrum	12.5	(0.4)	0.4	(0.3)	0.7
Total	2337.7		3.7		
Shrub Species					
Kalmia latifolia	575.0	(19.7)	0.4	(15.3)	35.0

Table 6. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a fall prescribed burn. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Pre-Burn					
Tree Species					
Sassafras albidum	3.9	(5.1)	28.1	(10.2)	15.3
Quercus marilandica	1.7	(2.2)	12.5	(4.6)	6.8
Q. coccinea	0.3	(0.4)	9.4	(3.4)	3.8
Acer rubrum	0.0	(0.0)	3.1	(1.1)	1.2
Total	5.9				
Shrub Species					
Gaylussacia sp.	45.1	(58.6)	81.3	(29.6)	88.2
Kalmia latifolia	7.9	(10.2)	18.8	(6.8)	17.1
Total	53.0				
Herbaceous Species					
Vaccinium sp.	13.7	(17.8)	62.5	(22.7)	40.6
Pteridium aquilinum	4.0	(5.2)	81.3	(18.2)	23.4
Panicum sp.	0.2	(0.3)	3.1	(1.1)	1.4
Vicia sp.	0.1	(0.1)	3.1	(1.1)	1.3
Smilax rotundifolia	0.0	(0.0)	3.1	(1.1)	1.2
Total	18.0				
Post-Burn					
Tree Species					
Sassafras albidum	3.7	(7.7)	46.9	(14.2)	21.8
Pinus rigida	1.5	(3.1)	3.1	(13.2)	16.3
Quercus velutina	3.9	(8.3)	8.3	(5.7)	13.9
Nyssa sylvatica	0.1	(0.1)	3.1	(0.9)	1.1
Q. coccinea	0.0	(0.1)	3.1	(0.9)	1.0
Total	9.2				
Shrub Species					
Gaylussacia sp.	17.0	(35.7)	56.3	(17.0)	52.6
Kalmia latifolia	3.8	(8.0)	12.5	(3.8)	11.8
Total	20.8				
Herbaceous Species					
Vaccinium sp.	13.5	(28.4)	81.3	(24.5)	52.9
Pteridium aquilinum	3.9	(8.2)	56.3	(17.0)	25.2
Panicum sp.	0.1	(0.2)	3.1	(0.9)	1.1
Iris cristata	0.1	(0.2)	3.1	(0.9)	1.1
Smilax rotundifolia	0.1	(0.1)	3.1	(0.9)	1.1
Total	17.7				

GWWS Fall Burn

USDA Forest Service crews burned this approximately 7 ha pitch pine stand on the GWWS in mid-October 1995. The stated purpose of this burn was to regenerate pitch pine. Burning crews applied a ring firing technique under warm (air temperatures 22°C), relatively dry (relative humidity 30-41%, 10 hour fuels at 10% moisture content) conditions. Litter moisture averaged 47.2%. Flame lengths ranged from 1-3 m and temperatures 1 m above the ground averaged 121°C. We sampled the post-burn vegetation in August 1996.

The fire significantly reduced mean total basal area from 23.3±2.9 to 16.9±2.6 m^2/ha ($P<0.05$) and mean total canopy density from 1525.0±188.0 to 625.0±97.5 stems/ha ($P<0.05$) for the combined overstory and midstory size classes. Bark char averaged 2 m. Canopy scorch could not be estimated because of the length of time between burning and post-burn sampling (ten months). Burning reduced canopy species richness significantly from 5.9±0.6 to 3.6±0.3 species/0.02 ha ($P<0.05$).

Burning did not change the dominance structure of the overstory (Table 3). Pitch pine, scarlet oak and blackgum remained the most important overstory species. Blackjack oak was not present in the overstory following the fire. Blackgum, chestnut oak and scarlet oak comprised the entire midstory following the burn (Table 4). Burning eliminated all trees in the 0 to 5 cm dbh size class and all but two stems in the 5 to 10 cm dbh size class (Figure 3). The majority of stems greater than 10 cm dbh survived the prescribed burn.

Understory stem density doubled following the burn [69.9±11.4 to 168.8±32.2 stems/ha ($P<0.05$)]. In addition, understory species richness increased following the burn [2.6±0.3 to 5.4±0.5 species/0.01 ha ($P<0.05$)]. Sassafras, black oak and mountain laurel

predominated the post-burn understory (Table 5). Many hardwood species in the understory sprouted following the fire and grew into the understory size class. Sprouting species included sassafras, scarlet oak and blackjack oak. In addition, top-killed black oak, blackgum, chestnut oak, and red maple (*Acer rubrum*) stems of the midstory sprouted following the burn, thus increasing the numbers of stems in the understory size class.

Ground layer cover decreased following the burn [76.9±8.1 to 47.0±3.0 %/m^2 ($P<0.05$)]. In contrast, species richness of this vegetation increased [2.8±0.3 to 6.0±0.8 species/m^2 ($P<0.05$)]. Blueberry, huckleberry and bracken fern sprouted after the burn and predominated the ground layer (Table 6). Sprouts of sassafras, black oak and mountain laurel also were present in this layer.

I observed pine regeneration in 3.1% of the ground layer subplots. The density of pitch pine seedlings was 1.5 seedlings/m^2. I did not observe any pitch pine sprouts. The fire significantly reduced mean litter depth [4.0±1.2 to 0.2±0.6 cm ($P<0.05$)] and mean duff depth [4.8±2.1 to 2.3±0.9 cm ($P<0.05$)]. Burning exposed mineral soil in some small areas.

Prior to burning, this stand was characterized by a moderately high basal area and a large number of small stems in the overstory and midstory. The prescription used for burning this stand produced a relatively low intensity fire. Burning created many changes among the species in the ground layer and understory vegetation. However, this low-intensity fire was ineffective for removing midstory and overstory trees. Even though the fire significantly reduced basal area and stem density, the majority of trees in these size classes survived. After burning, pitch pine seedlings were present in insufficient numbers to regenerate the stand. These seedlings are not likely to survive, however, due to shading from taller vegetation and competition from hardwood sprouts.

GWWS Spring Burn

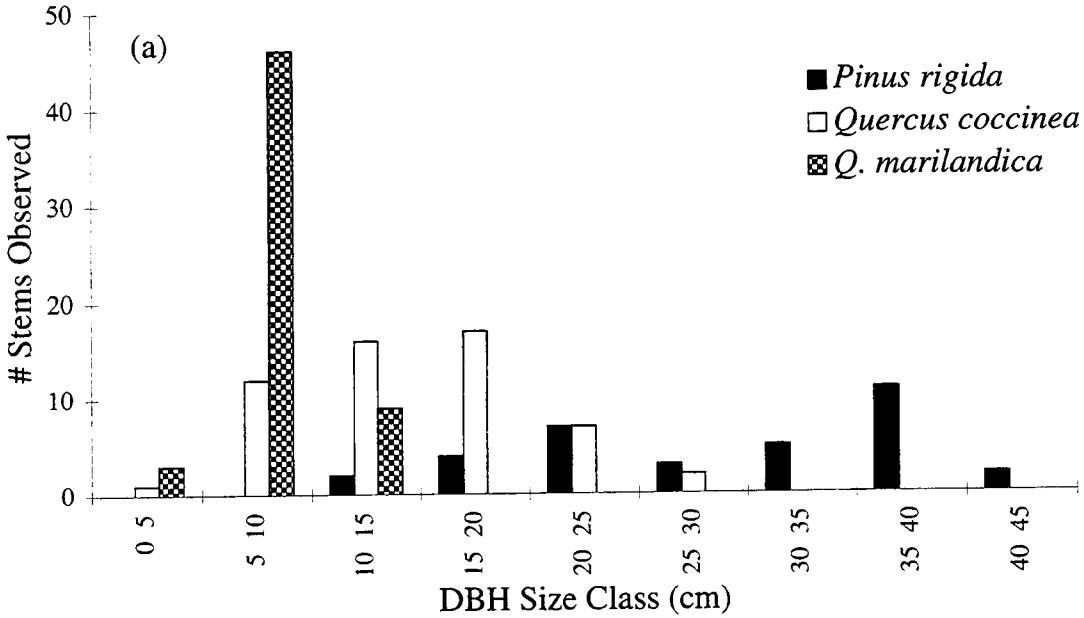
USDA Forest Service personnel burned seven hectares of the same pitch pine stand as the Fall burn in late May 1996 using a ring fire technique. The purpose of the burn was to regenerate pitch pine. Air temperature during the burn was 26°C, relative humidity ranged from 40 to 60%, and the moisture content of 10-hour fuels was 12%. Litter moisture averaged 20.8%. Mean temperatures 1 m above the ground were 86°C and flame lengths ranged from 1 to 6 m. Sampling of post-burn vegetation occurred in August 1996.

This burn reduced the total density of canopy stems by 73% [from 1594.0±163.0 to 431.5±90.5 stems/ha ($P<0.05$)]. I observed a corresponding 32% loss in total basal area as well [from 28.5±2.0 to 19.2±1.7 m^2/ha ($P<0.05$)]. Bark char averaged 2 m. Stems greater than 20 cm dbh survived the fire whereas many stems less than 20 cm dbh were top-killed (Figure 4). Canopy scorch could not be estimated because of the length of time between and burning and post-burn sampling (three months). Canopy species richness decreased significantly [5.9±0.4 to 2.8±0.6 species/0.02 ha ($P<0.05$)].

Overstory dominance changed following the burn. Because overstory stems of chestnut oak, blackjack oak, white oak (*Quercus alba*), sassafras, and red maple were top-killed by the fire, pitch pine, scarlet oak and blackgum dominated the post-burn overstory (Table 7). The burn also top-killed midstory stems of blackjack oak, scarlet oak, black oak, red maple and hickory. Blackgum, chestnut oak and pitch pine predominated the post-burn midstory (Table 8).

Understory stems of sassafras, scarlet oak and red maple sprouted following the fire and grew into the understory size class. Top-killed overstory and midstory chestnut oak, sassafras, black oak, scarlet oak, blackgum and red maple sprouted after the fire. This sprouting significantly increased mean understory density from 120.3±28.9 stems/ha

Figure 4. Pre- and post-spring-burn distributions of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Warm Springs Ranger District. The number of stems observed represents the number of trees tallied in 0.16 ha. The prescribed burn occurred in May 1996. Post-burn vegetation sampling took place in August 1996.


(a)
Pinus rigida
Quercus coccinea
Q. marilandica
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

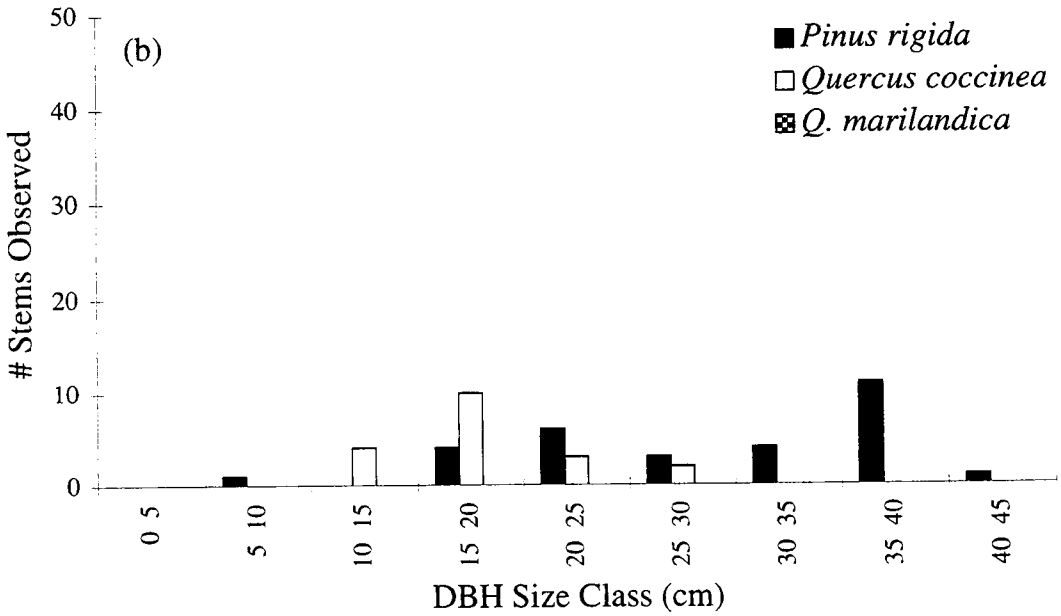

(b)
Pinus rigida
Quercus coccinea
Q. marilandica
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

Table 7. Overstory (trees ≥ 10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District prior to and following a spring prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Pinus rigida	14.4	(57.2)	200.0	(26.9)	84.1
Quercus coccinea	6.5	(25.7)	262.5	(35.3)	61.0
Q. prinus	1.8	(7.3)	112.5	(15.1)	22.4
Q. marilandica	0.6	(2.3)	56.3	(4.6)	9.9
Q. velutina	0.8	(3.4)	43.8	(5.9)	9.2
Nyssa sylvatica	0.3	(1.1)	25.0	(3.4)	4.4
Q. alba	0.3	(1.1)	18.8	(2.5)	3.6
Sassafras albidum	0.2	(0.7)	18.8	(2.5)	3.2
Acer rubrum	0.3	(1.3)	6.3	(0.8)	2.2
Total	25.2		744.0		
Post-Burn					
Pinus rigida	13.9	(88.7)	181.3	(69.1)	157.8
Quercus coccinea	1.4	(8.7)	62.5	(23.8)	32.5
Nyssa sylvatica	0.1	(0.9)	12.5	(4.8)	5.7
Q. velutina	0.3	(1.7)	6.3	(2.4)	4.1
Total	15.7		262.6		

Table 8. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District prior to and following a spring prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Quercus marilandica	1.1	(35.2)	306.3	(36.0)	71.3
Sassafras albidum	0.6	(19.1)	243.8	(28.7)	47.7
Q. prinus	0.5	(14.3)	106.3	(12.5)	26.8
Q. coccinea	0.5	(14.3)	81.3	(9.6)	23.9
Q. velutina	0.3	(8.3)	50.0	(5.9)	14.2
Nyssa sylvatica	0.2	(7.2)	50.0	(5.9)	13.1
Acer rubrum	0.0	(1.0)	6.3	(0.7)	1.7
Carya sp.	0.0	(0.6)	6.3	(0.7)	1.3
Total	3.2		850.3		
Post-Burn					
Nyssa sylvatica	0.1	(42.2)	18.8	(37.5)	79.7
Quercus prinus	0.1	(39.1)	18.8	(37.5)	76.6
Pinus rigida	0.0	(15.4)	6.3	(12.5)	27.9
Sassafras albidum	0.0	(3.3)	6.3	(12.5)	15.8
Total	0.2		50.2		

to 203.1±29.6 stems/ha ($P<0.05$). Sassafras, black oak and mountain laurel predominated the post-burn understory (Table 9). Understory species richness increased from 2.7±4.6 to 3.7±0.3 species/0.01 ha ($P<0.05$).

Ground layer cover declined significantly after the burn [60.1±6.6 to 18.8±2.5 %/m^2 ($P<0.05$)]. Ground layer species richness increased [2.5±0.2 to 4.3±0.4 species/m^2 ($P<0.05$)]. Huckleberry, sassafras, and bracken fern were the most important ground layer species following the burn (Table 10). Sprouts of scarlet oak, black oak, blackgum and mountain laurel were present in the post-burn ground layer as well. Burning significantly reduced mean litter depth [4.4±0.3 to 0.9±0.1 cm ($P<0.05$)] but mean duff depth was unchanged. I did not observe any pitch pine regeneration or sprouting following the burn.

This stand contained a large number of small stems in the overstory and midstory prior to burning. Basal area was moderately high. The prescription used to burn this stand resulted in a relatively low intensity fire. Changes in importance among understory and ground layer species occurred after the burn. Although this fire significantly reduced basal area and stem density, it left the majority (56% of the original basal area) of the midstory and overstory trees alive. I did not expect to see post-burn pitch pine regeneration at the time of post-burn sampling because pitch pine seedfall had not occurred. However, any pitch pine regeneration that occurs is not likely to survive due to shading from taller vegetation and competition from numerous hardwood sprouts.

Table 9. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Mean Height (m)		IV
Pre-Burn					
Tree Species					
Sassafras albidum	537.5	(30.1)	1.0	(31.0)	61.0
Quercus coccinea	31.3	(1.8)	0.7	(1.3)	3.0
Acer rubrum	12.5	(0.7)	0.7	(0.5)	1.2
Q. marilandica	6.3	(0.4)	0.7	(0.3)	0.6
Total	587.6		1.2		
Shrub Species					
Gaylussacia sp.	1006.3	(56.3)	0.8	(42.4)	98.7
Kalmia latifolia	193.8	(10.8)	2.3	(24.6)	35.5
Total	1200.1		3.1		
Post-Burn					
Tree Species					
Sassafras albidum	2675.0	(82.3)	0.5	(85.6)	167.9
Quercus velutina	231.3	(7.1)	0.4	(6.2)	13.4
Q. coccinea	106.3	(3.3)	0.4	(2.8)	6.0
Q. prinus	56.3	(1.7)	0.4	(1.4)	3.1
Nyssa sylvatica	25.0	(0.8)	0.4	(0.6)	1.3
Castanea dentata	6.3	(0.2)	0.4	(0.1)	0.3
Acer rubrum	6.3	(0.2)	0.4	(0.1)	0.3
Total	3106.5		2.9		
Shrub Species					
Kalmia latifolia	143.8	(4.4)	0.4	(3.2)	7.6

Table 10. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Warm Springs Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Pre-Burn					
Tree Species					
Sassafras albidum	6.5	(4.3)	37.5	(15.4)	21.8
Quercus coccinea	0.2	(0.3)	9.4	(3.9)	4.2
Q. marilandica	0.3	(0.5)	2.6	(6.3)	3.0
Acer rubrum	0.1	(0.0)	3.1	(1.3)	1.3
Total	7.1				
Shrub Species					
Gaylussacia sp.	49.2	(73.1)	78.1	(32.1)	105.2
Kalmia latifolia	1.3	(2.0)	15.6	(6.4)	8.4
Total	50.5				
Herbaceous Species					
Vaccinium sp.	10.5	(15.6)	59.4	(24.4)	40.0
Pteridium aquilinum	1.2	(1.8)	28.1	(11.5)	13.4
Gaultheria procumbens	0.1	(0.2)	6.3	(2.6)	2.8
Total	11.8				
Post-Burn					
Tree Species					
Sassafras albidum	5.1	(26.8)	65.6	(28.4)	55.2
Quercus coccinea	0.3	(1.7)	9.4	(4.1)	5.7
Q. velutina	0.1	(0.3)	3.1	(1.4)	1.7
Nyssa sylvatica	0.0	(0.2)	3.1	(1.4)	1.5
Total	5.5				
Shrub Species					
Gaylussacia sp.	11.1	(58.5)	96.9	(41.9)	100.4
Kalmia latifolia	0.8	(4.0)	15.6	(6.8)	10.7
Total	11.9				
Herbaceous Species					
Pteridium aquilinum	1.1	(5.8)	31.3	(13.5)	19.3
Vaccinium sp.	0.5	(2.6)	3.1	(1.4)	4.0
Gaultheria procumbens	0.0	(0.2)	3.1	(1.4)	1.5
Total	1.6				

Spring Burn on the George Washington and Jefferson National Forest, Wythe Ranger District

GWWY Pre-Burn Vegetation

Pitch pine and table mountain pine shared overstory dominance of this stand (Table 11). Blackgum was the most important midstory species (Table 12). Scarlet oak was common in both the overstory and the midstory size classes. Total density of the overstory size class was 950 stems/ha and total density of the midstory size class was 1877 stems/ha. The majority of pitch pine and table mountain pine stems surpassed 15 cm dbh whereas most scarlet oak stems were less than 15 cm dbh (Figure 5). Mean basal area was 30.5 ± 1.9 m^2/ha and mean canopy density was 2850.0 ± 255.5 stems/ha. Canopy species richness averaged 10.1 ± 0.5 species/0.02 ha.

Chinquapin (*Castanea pumila*) was the most important understory species followed by scarlet oak and white pine (*Pinus strobus*) (Table 13). Understory species richness averaged 5.4 ± 0.3 species/0.01 ha and understory density averaged 156.8 ± 16.3 stems/ha. Mean ground layer cover was 55.9 ± 2.8 %/m^2. Mean ground layer species richness was 5.3 ± 0.2 species/m^2 and huckleberry and blueberry predominated this vegetation (Table 14). Mean litter depth and mean duff depth were 3.2 ± 0.3 cm and 1.7 ± 0.5 cm, respectively. I did not observe any table mountain pine or pitch pine regeneration.

GWWY Spring Burn

The USDA Forest Service, Wythe Ranger District did not conduct the planned Spring 1996 burn because the prescribed weather did not occur during the study period.

Table 11. Overstory (trees ≥ 10 cm dbh) species of the George Washington and Jefferson National Forest, Wythe Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pinus rigida	12.1	(45.8)	272.7	(28.7)	74.5
P. pungens	7.2	(27.2)	250.0	(26.3)	53.5
Quercus coccinea	2.2	(8.4)	113.6	(12.0)	20.4
Q. alba	1.9	(7.1)	118.2	(12.4)	19.6
P. strobus	1.0	(3.6)	68.2	(7.2)	10.8
Q. prinus	0.6	(2.3)	45.5	(4.8)	7.0
P. virginiana	0.8	(3.0)	36.4	(3.8)	6.8
Acer rubrum	0.3	(1.0)	22.7	(2.4)	3.4
Nyssa sylvatica	0.2	(0.9)	9.1	(1.0)	1.9
Q. velutina	0.1	(0.4)	4.5	(0.5)	0.9
Oxydendrum arboreum	0.1	(0.2)	4.5	(0.5)	0.7
Amelanchier arborea	0.0	(0.1)	4.5	(0.5)	0.6
Total	26.5		949.9		

Table 12. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the George Washington and Jefferson National Forest, Wythe Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Nyssa sylvatica	1.0	(24.0)	595.4	(31.7)	55.8
Quercus coccinea	0.4	(10.3)	286.1	(15.3)	25.5
Pinus strobus	0.5	(13.3)	213.6	(11.4)	24.7
Q. alba	0.4	(11.2)	118.2	(6.3)	17.5
P. virginiana	0.4	(9.1)	136.4	(7.3)	16.1
Castanea pumila	0.1	(2.7)	127.3	(6.8)	9.5
P. pungens	0.2	(5.9)	68.2	(3.6)	9.5
Cornus florida	0.2	(4.9)	81.8	(4.4)	9.2
Sassafras albidum	0.1	(3.1)	63.6	(3.4)	6.5
Acer rubrum	0.2	(4.0)	40.9	(2.0)	6.1
Amelanchier arborea	0.1	(3.2)	54.6	(2.9)	6.1
P. rigida	0.1	(3.6)	31.8	(1.7)	5.3
Q. velutina	0.1	(2.0)	36.4	(1.9)	3.9
Q. prinus	0.1	(2.5)	18.2	(1.0)	3.5
Carya sp.	0.0	(0.2)	4.6	(0.2)	0.5
Total	3.9		1877.1		

Figure 5. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the George Washington and Jefferson National Forest, Wythe Ranger District. Number stems observed represents the number of trees tallied in 0.22 ha.

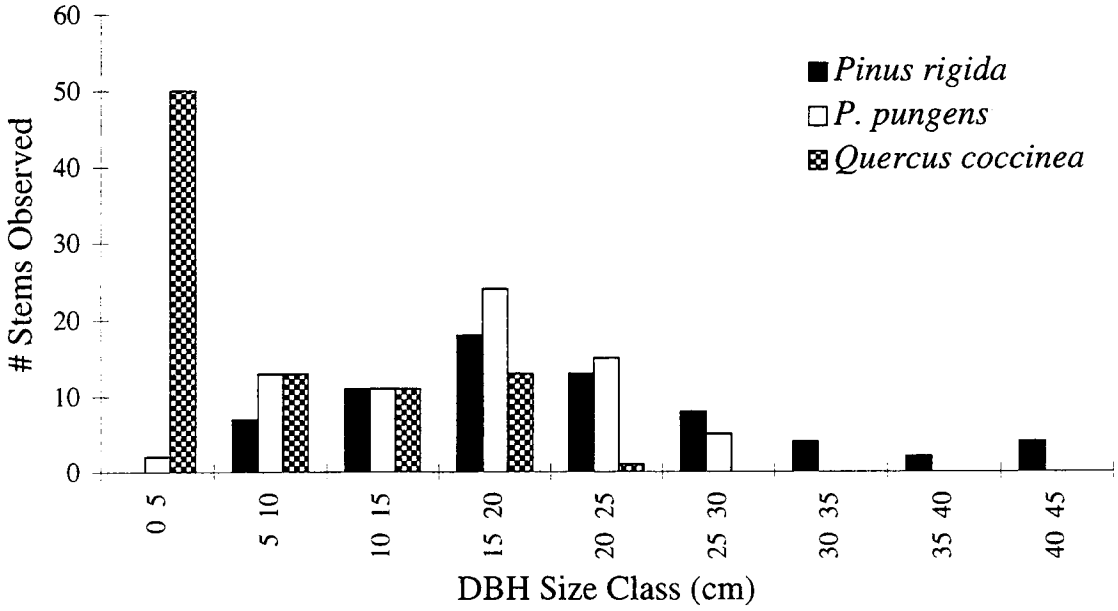

60
50
40
30
20
10
0
Stems Observed
Pinus rigida
P. pungens
Quercus coccinea
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

Table 13. Understory (stems <2.5 cm dbh and >1 m in height) species of the George Washington and Jefferson National Forest, Wythe Ranger District. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Height (m)		IV
Tree Species					
Castanea pumila	791.7	(32.0)	1.2	(34.5)	66.5
Quercus coccinea	423.2	(17.1)	0.9	(14.4)	31.5
Pinus strobus	291.2	(11.8)	1.4	(14.9)	26.7
Q. velutina	277.6	(11.2)	0.8	(7.6)	18.8
Q. marilandica	95.6	(3.9)	0.9	(3.2)	7.1
Nyssa sylvatica	41.0	(1.7)	1.9	(2.9)	4.5
Q. alba	31.9	(1.3)	0.8	(1.0)	2.2
Sassafras albidum	22.8	(0.9)	1.3	(1.0)	2.0
P. virginiana	18.2	(0.7)	1.1	(0.7)	1.5
Robinia pseudoacacia	18.2	(0.7)	0.9	(0.6)	1.3
P. pungens	13.7	(0.6)	1.5	(0.7)	1.3
Amelanchier arborea	9.1	(0.4)	1.5	(0.5)	0.8
Carya sp.	4.6	(0.2)	1.5	(0.2)	0.4
Acer rubrum	4.6	(0.2)	1.5	(0.2)	0.4
Q. prinus	4.6	(0.2)	0.7	(0.1)	0.3
Total	2048.0		17.9		
Shrub Species					
Vaccinium caesium	223.0	(9.0)	1.2	(9.23)	18.3
Kalmia latifolia	191.1	(7.7)	1.1	(7.7)	15.5
Smilax rotundifolia	9.1	(0.4)	1.5	(0.5)	0.8
Total	423.2		3.8		

Table 14. Ground layer (vegetation ≤1 m in height) species of the George Washington and Jefferson National Forest, Wythe Ranger District. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Tree Species					
Quercus coccinea	7.1	(12.9)	47.7	(9.4)	22.3
Q. velutina	4.4	(7.9)	29.6	(5.8)	13.7
Castanea pumila	4.2	(7.6)	27.3	(5.4)	13.0
Pinus strobus	1.8	(3.2)	11.4	(2.2)	5.4
Amelanchier arborea	0.7	(1.2)	15.9	(3.1)	4.3
Sassafras albidum	0.3	(0.5)	13.6	(2.7)	3.2
Acer rubrum	0.6	(1.0)	6.8	(1.4)	2.3
Carya sp.	0.7	(1.2)	2.3	(0.5)	1.7
Q. alba	0.2	(0.4)	4.6	(0.9)	1.3
Robina pseudoacacia	0.3	(0.6)	2.3	(0.5)	1.1
P. rigida	0.1	(0.3)	2.3	(0.5)	0.7
Cornus florida	0.1	(0.1)	2.3	(0.5)	0.5
Total	20.5				
Shrub Species					
Gaylussacia sp.	13.6	(24.6)	70.5	(13.9)	38.5
Kalmia latifolia	4.1	(7.4)	52.3	(10.3)	17.7
Vaccinium caesium	3.0	(5.3)	9.1	(1.8)	7.1
Total	20.7				
Herbaceous Species					
Vaccinium sp.	8.6	(15.5)	81.8	(16.1)	31.6
Tea berry	4.0	(7.2)	72.7	(14.4)	21.5
Pteridium aquilinum	0.9	(1.6)	22.7	(4.5)	6.1
Andropogon scoparius	0.3	(0.5)	9.1	(1.8)	2.2
Rubus sp.	0.2	(0.4)	9.1	(1.8)	2.2
Smilax rotundifolia	0.1	(0.1)	4.6	(0.9)	1.0
Panicum sp.	0.2	(0.4)	2.3	(0.5)	0.9
Galax sp.	0.0	(0.0)	2.3	(0.5)	0.5
Total	14.3				

DBSM Pre-Burn Vegetation

Shortleaf pine dominated the overstory of this stand (Table 15). Total density of the overstory size class was 432 stems/ha. Dogwood (*Cornus florida*) and red maple were the two most important midstory species (Table 16). Total density of the midstory size class was 81 stems/ha. Stems of shortleaf pine most often exceeded 20 cm dbh whereas stems of red maple and scarlet oak generally were below 15 cm dbh (Figure 6). Mean basal area and mean density of the combined overstory and midstory size classes were 30.2±2.7 m^2/ha and 519.0±78.5 stems/ha, respectively. Canopy species richness averaged 3.8±0.4 species/0.02 ha for these combined size classes.

Sassafras and red maple predominated the understory layer (Table 17). Understory density averaged 445.7±32.3 stems/ha and understory species richness averaged 8.7±0.5 species/0.01 ha. Mean ground layer species richness was 3.2±0.5 species/m^2 and blueberry and catbriar (*Smilax rotundifolia*) were the most important ground layer species (Table 18). Ground layer cover averaged 12.5±2.5 %/m^2. Mean litter depth was 6.9±0.6 cm and mean duff depth was 1.7±0.7 cm.

DBSM Spring Burn

In March 1995, the USDA Forest Service burned 960 ha of the DBSM. The stated purpose of the burn was to improve red-cockaded woodpecker habitat by restoring or enhancing the fire-dependent shortleaf pine ecosystem. Burn crews ignited the fire with drip torches along firelines and with a delayed aerial ignition device. During the burn, air

Table 15. Overstory (trees ≥ 10 cm dbh) species of the Daniel Boone National Forest, Somerset Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pinus echinata	25.1	(83.6)	306.3	(71.0)	154.7
Quercus prinus	1.3	(4.4)	31.3	(7.2)	11.6
Cornus florida	0.4	(1.3)	31.3	(7.2)	8.5
Acer rubrum	1.2	(4.0)	18.8	(4.3)	8.3
Q. alba	0.7	(2.4)	12.5	(2.9)	5.3
Carya sp.	0.7	(2.2)	6.3	(1.4)	3.7
Q. velutina	0.3	(1.1)	6.3	(1.4)	2.5
P. virginiana	0.1	(0.5)	6.3	(1.4)	1.9
Oxydendrum arboreum	0.1	(0.4)	6.3	(1.4)	1.8
Q. stellata	0.1	(0.2)	6.3	(1.4)	1.7
Total	30.0		431.7		

Table 16. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Daniel Boone National Forest, Somerset Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Cornus florida	0.1	(57.8)	25.0	(30.8)	88.5
Acer rubrum	0.0	(15.2)	25.0	(30.8)	46.0
Sassafras albidum	0.0	(16.3)	12.5	(15.4)	31.7
Oxydendrum arboreum	0.0	(5.4)	6.3	(7.7)	13.2
Nyssa sylvatica	0.0	(2.8)	6.3	(7.7)	10.5
Quercus velutina	0.0	(2.4)	6.3	(7.7)	10.1
Total	0.1		81.4		

Figure 6. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Daniel Boone National Forest, Somerset Ranger District. The number of stems observed represents the number of trees tallied in 0.16 ha. The prescribed burn occurred in March 1995. Post-burn vegetation sampling took place in May 1995 and May 1996. There was no mortality of overstory or midstory stems following the burn.

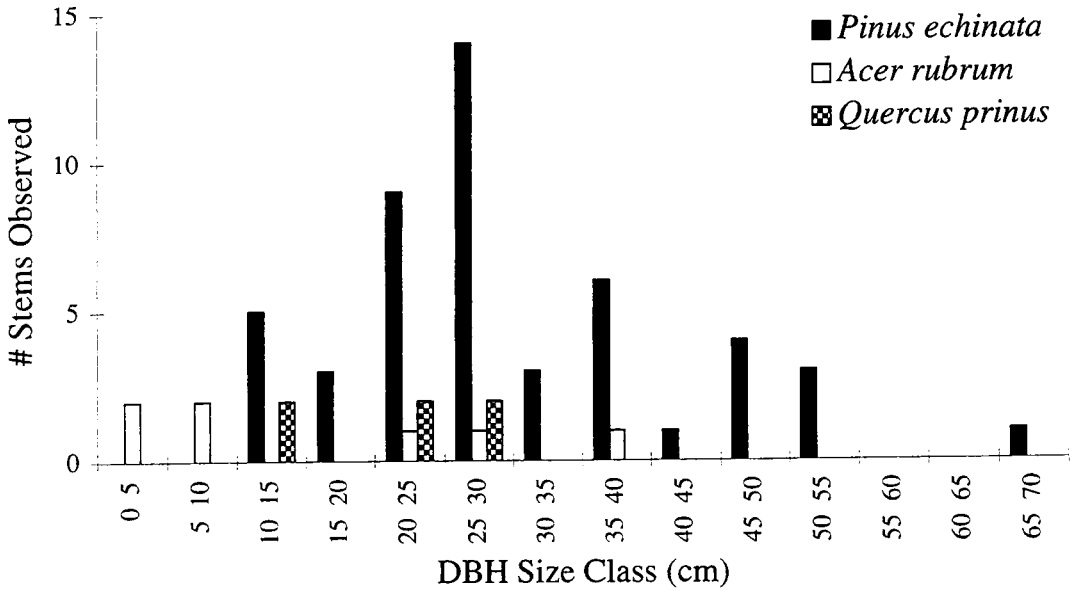

15
10
5
0
Stems Observed
Pinus echinata
Acer rubrum
Quercus prinus
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
45 50
50 55
55 60
60 65
65 70
DBH Size Class (cm)

Table 17. Understory (stems <2.5 cm dbh and >1 m in height) species of the Daniel Boone National Forest, Somerset Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Height (m)		IV
Pre-Burn					
Tree Species					
Sassafras albidum	687.5	(20.4)	2.7	(19.7)	40.1
Acer rubrum	662.5	(19.6)	2.8	(19.5)	39.1
Quercus sp.	537.5	(15.9)	2.7	(15.3)	31.2
Nyssa sylvatica	312.5	(9.3)	3.0	(9.8)	19.1
Oxydendrum arboreum	275.0	(8.2)	3.0	(8.7)	16.9
Carya sp.	168.8	(5.0)	2.9	(5.1)	10.1
Cornus florida	162.5	(4.8)	3.0	(5.1)	9.9
Pinus sp.	25.0	(0.7)	3.6	(1.0)	1.7
Liriodendron tulipifera	18.8	(0.6)	2.7	(0.5)	1.1
P. echinata	18.8	(0.6)	2.4	(0.5)	1.0
Ilex opaca	12.5	(0.4)	1.8	(0.2)	0.6
Fagus grandifolia	6.3	(0.2)	2.2	(0.1)	0.3
P. virginiana	6.3	(0.2)	1.5	(0.1)	0.3
Total	2894.0				
Shrub Species					
Rhus copallina	306.25	(9.1)	3.2	(10.2)	19.3
Vaccinium sp.	62.5	(1.9)	2.8	(1.9)	3.7
Diospyros virginiana	25.0	(0.7)	2.6	(0.7)	1.4
Rubus sp.	25.0	(0.7)	2.0	(0.5)	1.3
Smilax rotundifolia	18.8	(0.6)	1.5	(0.3)	0.8
Vitis sp.	12.5	(0.4)	3.3	(0.4)	0.8
Rubus sp.	12.5	(0.4)	1.8	(0.2)	0.6
Kalmia latifolia	12.5	(0.4)	0.7	(0.1)	0.5
Viburnum acerifolium	6.3	(0.2)	2.2	(0.1)	0.3
Total	481.4				
Post-Burn Year 1					
Tree Species					
Sassafras albidum	3187.5	(14.8)	0.4	(31.6)	46.4
Acer rubrum	1700.0	(7.9)	0.4	(16.7)	24.6
Quercus coccinea	781.3	(3.6)	0.6	(10.9)	14.6
Q. velutina	612.5	(2.8)	0.6	(7.8)	10.6
Nyssa sylvatica	550.0	(2.6)	0.4	(5.5)	8.0
Carya sp.	362.5	(1.7)	0.4	(3.1)	4.8
Oxydendron arboreum	300.0	(1.4)	0.4	(2.6)	4.0
Cornus florida	125.0	(0.6)	1.2	(3.3)	3.9
Q. prinus	275.0	(1.3)	0.4	(2.5)	3.8
Q. alba	175.0	(0.8)	0.4	(1.6)	2.5
Robinea pseudoacacia	43.8	(0.2)	0.4	(0.4)	0.6

Table 17 (continued).

Species	Density (# stems/ha)		Height (m)		IV
Liriodendron tulipifera	37.5	(0.2)	0.4	(0.3)	0.5
Prunus sp.	12.5	(0.1)	0.7	(0.2)	0.3
Ilex opaca	6.3	(0.0)	0.4	(0.1)	0.1
Total	8168.9				
Shrub Species					
Rhus copallina	13231.3	(61.5)	0.0	(12.4)	73.9
Hydrangea sp.	93.8	(0.4)	0.4	(0.8)	1.2
Kalmia latifolia	12.5	(0.1)	0.4	(0.1)	0.2
Vaccinium sp.	12.5	(0.1)	0.4	(0.1)	0.2
Aralia spinosa	6.3	(0.0)	0.4	(0.1)	0.1
Diospyros virginiana	6.3	(0.0)	0.4	(0.1)	0.1
Total	13362.7				
Post-Burn Year 2					
Tree Species					
Acer rubrum	1581.3	(25.5)	2.3	(33.6)	59.1
Sassafras albidum	1400.0	(22.6)	1.5	(19.6)	42.2
Quercus velutina	537.5	(8.7)	1.8	(9.0)	17.6
Oxydendron arboreum	387.5	(6.2)	2.6	(9.1)	15.4
Q. coccinea	350.0	(5.6)	1.6	(5.1)	10.7
Nyssa sylvatica	362.5	(5.8)	1.4	(4.6)	10.4
Cornus florida	175.0	(2.8)	1.4	(2.3)	5.1
Carya sp.	156.3	(2.5)	1.2	(1.8)	4.3
Q. prinus	75.0	(1.2)	1.0	(0.7)	1.9
Robinea pseudoacacia	75.0	(1.2)	0.9	(0.6)	1.8
Q. alba	50.0	(0.8)	1.0	(0.5)	1.3
Pinus echinata	56.25	(0.9)	0.5	(0.3)	1.2
Liriodendron tulipifera	6.3	(0.1)	0.7	(0.0)	1.1
Total	5212.7				
Shrub Species					
Rhus copallina	625.0	(10.1)	1.5	(8.5)	18.6
Rubus sp.	175.0	(2.8)	1.3	(2.0)	4.9
Vaccinium sp.	125.0	(2.0)	0.8	(0.9)	2.9
Vitis sp.	31.3	(0.5)	3.5	(1.0)	1.5
Viburnum acerifolium	12.5	(0.2)	1.5	(0.2)	0.4
Aralia spinosa	12.5	(0.2)	1.1	(0.1)	0.3
Diospyros virginiana	12.5	(0.2)	1.1	(0.1)	0.3
Total	993.8				

Table 18. Ground layer (vegetation ≤1 m in height) species of the Daniel Boone National Forest, Somerset Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Pre-Burn					
Tree Species					
Pinus virginiana	0.8	(11.2)	28.1	(11.7)	22.9
Acer rubrum	0.5	(7.6)	25.0	(10.4)	18.0
Sassafras albidum	0.5	(6.7)	15.6	(6.5)	13.2
Cornus florida	0.6	(9.0)	3.1	(1.3)	10.3
Quercus sp.	0.1	(0.9)	6.3	(2.6)	3.5
Q. alba	0.1	(0.9)	6.3	(2.6)	3.5
Carya sp.	0.0	(0.5)	3.1	(1.3)	1.8
Total	2.6				
Herbaceous Species					
Vaccinium sp.	2.2	(31.8)	78.1	(32.5)	64.3
Smilax rotundifolia	1.3	(17.9)	34.4	(14.3)	32.2
Carex sp.	0.3	(4.9)	15.6	(6.5)	11.4
Panicum sp.	0.3	(4.9)	15.6	(6.5)	11.4
Rubus sp.	0.3	(3.6)	9.4	(3.9)	7.5
Total	4.4				
Post-Burn Year 1					
Tree Species					
Acer rubrum	5.6	(18.0)	75.0	(18.6)	36.6
Sassafras albidum	3.9	(12.8)	53.1	(13.2)	25.9
Quercus coccinea	1.4	(4.7)	15.6	(3.9)	8.5
Nyssa sylvatica	0.8	(2.6)	12.5	(3.1)	5.7
Q. prinus	0.6	(2.0)	9.4	(2.3)	4.4
Q. alba	0.5	(1.7)	6.3	(1.6)	3.3
Pinus echinata	0.4	(1.2)	6.3	(1.6)	2.8
Oxydendron arboreum	0.2	(0.6)	3.1	(0.8)	1.4
Carya sp.	0.1	(0.3)	3.1	(0.8)	1.1
Total	13.5				
Shrub Species					
Rhus copallina	2.2	(7.1)	25.0	(6.2)	13.3
Diospyros virginiana	0.1	(0.3)	3.1	(0.8)	1.1
Total	2.3				
Herbaceous Species					
Vaccinium sp.	5.7	(18.3)	78.1	(19.4)	37.7
Smilax rotundifolia	3.6	(11.6)	40.6	(10.1)	21.6
Rubus sp.	2.8	(9.1)	28.1	(7.0)	16.1
Uvalaria sessilifolia	2.4	(7.8)	25.0	(6.2)	14.0
Rubus sp.	0.4	(1.3)	9.4	(2.3)	3.6
Smilax glauca	0.0	(0.1)	3.1	(0.8)	0.9

Table 18 (continued).

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Viola sp.	0.0	(0.1)	3.1	(0.8)	0.9
Total	14.9				
Post-Burn Year 2					
Tree Species					
Acer rubrum	11.4	(12.2)	71.9	(12.6)	24.8
Sassafras albidum	10.3	(11.1)	68.8	(12.0)	23.1
Nyssa sylvatica	8.6	(9.2)	37.5	(6.6)	15.7
Oxydendron arboreum	9.7	(10.4)	21.9	(3.8)	14.2
Quercus coccinea	3.3	(3.5)	15.6	(2.7)	6.2
Carya sp.	1.8	(1.9)	15.6	(2.7)	4.6
Q. velutina	1.7	(1.8)	15.6	(2.7)	4.5
Cornus florida	1.8	(2.0)	12.5	(2.2)	4.2
Liriodendron tulipifera	1.7	(1.8)	9.4	(1.6)	3.5
Pinus echinata	0.6	(0.6)	15.6	(2.7)	3.3
Robinea pseudoacacia	1.3	(1.4)	9.4	(1.6)	3.1
Q. prinus	0.7	(0.7)	12.5	(2.2)	2.9
Q. stellata	0.9	(1.0)	3.1	(0.6)	1.6
Magnolia sp.	0.3	(0.3)	3.1	(0.6)	0.9
Q. alba	0.2	(0.2)	3.1	(0.6)	0.8
Total	54.3				
Shrub Species					
Rhus copallina	5.8	(6.2)	34.4	(6.0)	12.2
Rhododendron sp.	1.3	(1.3)	6.3	(1.1)	2.4
Viburnum acerifolium	0.9	(1.0)	3.1	(0.6)	1.6
Total	8.0				
Herbaceous Species					
Vaccinium sp.	17.7	(18.9)	62.5	(10.9)	29.9
Rubus sp.	8.3	(8.9)	43.8	(7.7)	16.6
Panicum sp.	0.7	(0.8)	15.6	(2.7)	3.5
Vitis sp.	1.0	(1.1)	12.5	(2.2)	3.3
Smilax rotundifolia	0.4	(0.5)	15.6	(2.7)	3.2
Lysimachia sp.	0.4	(0.4)	12.5	(2.2)	2.6
Potentilla sp.	0.3	(0.3)	6.3	(1.1)	1.4
Aralia spinosa	0.6	(0.7)	3.1	(0.6)	1.2
Rhus radicans	0.1	(0.1)	3.1	(0.6)	0.7
Monotropa uniflora	0.1	(0.1)	3.1	(0.6)	0.7
Osmunda cinnamomea	0.1	(0.1)	3.1	(0.6)	0.7
Total	29.7				

temperature ranged from 7 to 13°C and winds blew from the north and northwest at 1.6 to 3.2 km per hour. Relative humidity was 44% and fuel moisture sticks averaged 16.8%. Mean litter moisture was 29.5% one hour before the burn. The fire was a light, cool burn (<100°C) with low (<2 m)flame heights. Post-burn vegetation sampling occurred during the 1995 and the 1996 growing seasons.

There was no mortality in the overstory and understory size classes in either the first or second growing seasons following the burn. Accordingly, importance values for these size classes did not change. Shortleaf pine remained the dominant canopy species following the burn followed by dogwood, red maple, and chestnut oak, respectively (Table 15). Mean bark char height was 1.2 m.

The three most important understory species in the first years following the burn were winged sumac (*Rhus copallina*), sassafras and red maple (Table 17). First year mean understory density did not differ from pre-burn measurements. Understory species richness increased significantly from 8.7±0.5 to 10.3±0.4 species/0.01 ha ($P<0.05$). Numerous understory hardwoods [sassafras, red maple, blackgum, hickory and yellow poplar (*Liriodendron tulipifera*)] sprouted and grew into the understory size class. Winged sumac produced many post-burn sprouts as well.

Red maple, sassafras and winged sumac, respectively, were the most important species of the understory size class in the second growing season after the burn (Table 17). The number of winged sumac sprouts had decreased by 95% by this second growing season. Likewise, the number of sassafras sprouts had decreased by 50%. The number of red maple sprouts did not change from the first to the second growing season after the burn. The density of understory stems was significantly greater in the second growing season compared to pre-burn measurements (445.7±32.3 to 963.9±55.4 stems/ha

($P<0.05$). Second growing season understory species richness did not differ from the pre-burn value.

Blueberry and red maple were the most important ground layer species in both the first and the second growing seasons after the burn (Table 18). Sprouts of hardwood and herbaceous species comprised much of this vegetation. Ground layer cover was significantly higher in both the first and the second growing seasons after the burn [12.5 ± 2.5 to 30.3 ± 1.9 to 93.9 ± 6.8 %/m^2 ($P<0.05$)]. Ground layer species richness showed no difference in the first growing season but increased significantly during the second growing season [3.2 ± 0.5 to 5.7 ± 0.3 species/m^2 ($P<0.05$)]. I observed no shortleaf pine seedlings in either the first or second growing season after the fire and only a few shortleaf pine sprouts in the first year following the fire (12.5 stems/ha). I recorded no shortleaf pine sprouts in the second growing season. Burning did not significantly reduce litter or duff depth.

Prior to burning, this stand was characterized by a low number of overstory and midstory stems and a moderately high basal area. The understory size class contained a large number of hardwood stems. The prescription used to burn this stand produced a very low intensity fire that did not reduce either the density or the basal area of the overstory and understory size classes. Burning greatly increased the density of understory stems as numerous hardwood sprouts grew into this size class. The ground layer contained many hardwood sprouts as well. Pine regeneration did not occur following this burn.

Spring Burn on the Daniel Boone National Forest, Stearns Ranger District

DBST Pre-Burn Vegetation

Shortleaf pine dominated the overstory of this stand followed decreasingly by chestnut oak and red maple (Table 19). Total density of the overstory size class was 805 stems/ha. Red maple predominated in the midstory (Table 20). Total density of midstory stems was 725 stems/ha. Most shortleaf pine stems were larger than 25 cm dbh whereas all red maple stems were smaller than 25 cm dbh (Figure 7). Mean basal area and mean canopy density were 28.9±2.1 m^2/ha and 1515.0±105.5 stems/ha, respectively, for the combined overstory and midstory size classes. Canopy species richness averaged 6.5±0.5 species/0.02 ha for these combined size classes.

Mean understory species richness was 5.1±0.5 species/0.01 ha and red maple and dogwood were the most important understory species (Table 21). Understory density averaged 276.9±38.3 stems/ha. Blueberry, dogwood and red maple were the three most important ground layer species (Table 22). Mean ground layer species richness was 1.8±0.2 species/m^2 and mean ground layer cover was 29.2±3.7 %/m^2. There were no shortleaf pine sprouts or seedlings in the pre-burn ground layer. Litter depth and duff depth averaged 6.2±0.5 cm and 1.1±0.2 cm, respectively.

DBST Spring Burn

In April 1996, USDA Forest Service personnel burned 253 ha of this shortleaf pine stand on the DBST. The stated purpose of the burn was to improve red-cockaded woodpecker habitat by opening the understory of the stand. I did not receive notification

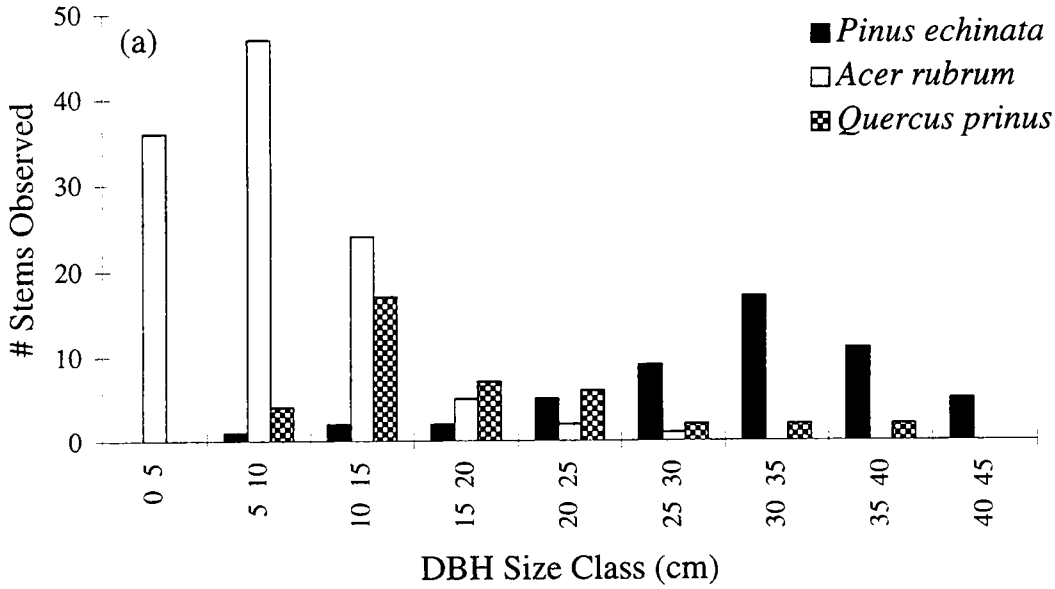
Table 19. Overstory (trees ≥ 10 cm dbh) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Cut/Burn					
Pinus echinata	20.7	(56.7)	255.0	(31.7)	88.3
Quercus prinus	4.9	(13.4)	175.0	(21.7)	35.2
Acer rubrum	2.6	(7.0)	160.0	(19.9)	26.9
Q. alba	2.4	(6.6)	60.0	(7.5)	14.1
Oxydendron arboreum	1.1	(3.1)	60.0	(7.5)	10.5
Q. coccinea	1.7	(4.7)	30.0	(3.7)	8.4
P. virginiana	1.3	(3.5)	35.0	(4.3)	7.9
Nyssa sylvatica	1.1	(3.1)	15.0	(1.9)	4.9
Carya sp.	0.7	(1.9)	15.0	(1.9)	3.8
Total	36.5		805.0		
Post-Cut/Burn					
Pinus echinata	18.6	(58.9)	235.0	(36.7)	95.7
Quercus prinus	4.1	(12.9)	115.0	(18.0)	30.9
Acer rubrum	1.7	(5.4)	85.0	(13.3)	18.6
Q. alba	2.4	(7.7)	60.0	(9.4)	17.1
Nyssa sylvatica	1.4	(4.5)	40.0	(6.3)	10.8
Oxydendron arboreum	1.0	(3.2)	40.0	(6.3)	9.4
Q. coccinea	1.2	(3.8)	25.0	(3.9)	7.6
P. virginiana	0.6	(1.9)	30.0	(4.7)	6.6
Carya sp.	0.6	(1.8)	10.0	(1.6)	3.3
Total	31.6		640.0		

Table 20. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Cut/Burn					
Acer rubrum	1.2	(48.1)	415.0	(57.2)	105.4
Nyssa sylvatica	0.6	(25.0)	140.0	(19.3)	44.3
Cornus florida	0.2	(8.4)	65.0	(9.0)	17.4
Quercus prinus	0.1	(4.4)	20.0	(2.8)	7.2
P. virginiana	0.1	(4.0)	20.0	(2.8)	6.7
Oxydendron arboreum	0.1	(3.8)	15.0	(2.1)	5.9
Carya sp.	0.1	(2.3)	20.0	(2.8)	5.0
Pinus echinata	0.0	(1.3)	5.0	(0.7)	2.0
Q. coccinea	0.0	(1.1)	5.0	(0.7)	1.8
Q. alba	0.0	(0.5)	5.0	(0.7)	1.2
Q. velutina	0.0	(0.5)	5.0	(0.7)	1.2
Sassafras albidum	0.0	(0.4)	5.0	(0.7)	1.1
Amelanchier arborea	0.0	(0.3)	5.0	(0.7)	1.0
Total	2.4		725.0		
Post-Cut/Burn					
Acer rubrum	0.4	(46.8)	175.0	(48.6)	95.4
Nyssa sylvatica	0.2	(17.1)	80.0	(22.2)	39.4
Cornus florida	0.1	(8.3)	35.0	(9.7)	18.0
P. virginiana	0.1	(10.2)	20.0	(5.6)	15.7
Carya sp.	0.1	(5.7)	20.0	(5.6)	11.3
Pinus echinata	0.0	(3.3)	5.0	(1.4)	4.7
Oxydendron arboreum	0.0	(2.9)	5.0	(1.4)	4.3
Quercus prinus	0.0	(2.4)	5.0	(1.4)	3.8
Q. alba	0.0	(1.2)	5.0	(1.4)	2.6
Q. velutina	0.0	(1.2)	5.0	(1.4)	2.6
Sassafras albidum	0.0	(1.0)	5.0	(1.4)	2.3
Total	0.9		360.0		

Figure 7. Pre- and post-cut/burn distribution of the three most important canopy species (combined overstory and midstory size classes) of the Daniel Boone National Forest, Stearns Ranger District. The number of stems observed represents the number of trees tallied in 0.20 ha. The prescribed burn occurred in April 1996. Post-burn vegetation sampling took place in May 1996.


(a)
Pinus echinata
Acer rubrum
Quercus prinus
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

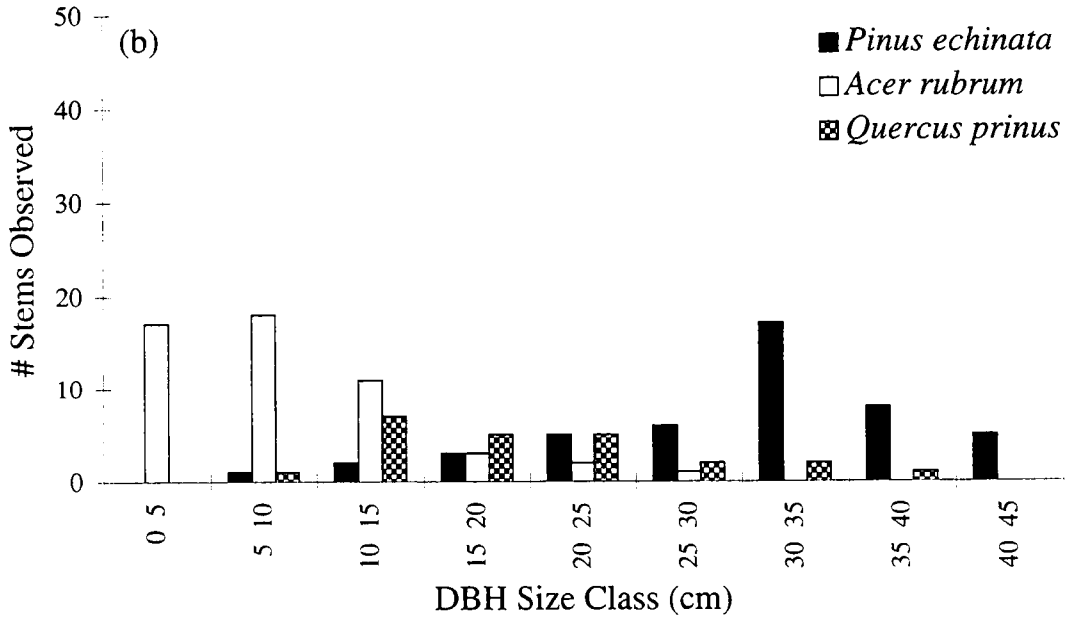

(b)
Pinus echinata
Acer rubrum
Quercus prinus
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

Table 21. Understory (stems <2.5 cm dbh and >1 m in height) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Height (m)		IV
Pre-Cut/Burn					
Tree Species					
Acer ruburm	2260.0	(48.9)	1.7	(59.6)	108.5
Cornus florida	780.0	(16.9)	1.4	(17.2)	34.0
Nyssa sylvatica	215.0	(4.7)	1.4	(4.7)	9.4
Amelanchier arborea	240.0	(5.2)	0.4	(1.4)	6.6
Quercus sp.	115.0	(2.5)	1.1	(2.1)	4.6
Carya sp.	95.0	(2.1)	1.2	(1.7)	3.8
Oxydendron arboreum	20.0	(0.4)	1.8	(0.6)	1.0
Prunus sp.	20.0	(0.4)	1.6	(0.5)	1.0
Ilex opaca	20.0	(0.4)	1.5	(0.5)	0.9
Magnolia sp.	5.0	(0.1)	1.5	(0.1)	0.2
Total	3770.0				
Shrub Species					
Vaccinium sp.	520.0	(11.3)	0.4	(3.0)	14.3
Kalmia latifolia	115.0	(2.5)	1.7	(3.1)	5.6
Smilax rotundifolia	95.0	(2.1)	1.3	(2.0)	4.0
Gaylussacia sp.	40.0	(0.9)	3.4	(2.2)	3.0
Euonymus sp.	45.0	(1.0)	1.1	(0.8)	1.7
Diospyros virginiana	30.0	(0.6)	1.2	(0.6)	1.2
Viburnum acerifolium	5.0	(0.1)	0.7	(0.1)	0.2
Total	850.0				
Post-Cut/Burn					
Tree Species					
Acer rubrum	2415.0	(41.4)	0.6	(37.3)	78.7
Quercus velutina	195.0	(3.3)	4.2	(21.6)	24.9
Cornus florida	455.0	(7.8)	0.4	(5.3)	13.1
Q. rubra	340.0	(5.8)	0.4	(3.8)	9.6
Oxydendron arboreum	145.0	(2.5)	0.9	(3.6)	6.0
Nyssa sylvatica	175.0	(3.0)	0.6	(2.6)	5.6
Carya sp.	165.0	(2.8)	0.5	(2.0)	4.9
Sassafras albidum	155.0	(2.7)	0.4	(1.8)	4.5
Q. alba	115.0	(2.0)	0.4	(1.1)	3.1
Q. coccinea	100.0	(1.7)	0.4	(1.0)	2.7
Q. prinus	20.0	(0.3)	3.4	(1.2)	2.1
Betula lenta	20.0	(0.3)	0.4	(0.2)	0.5
Q. stellata	20.0	(0.3)	0.4	(0.2)	0.5
Ilex opaca	10.0	(0.2)	0.4	(0.1)	0.3
Amelanchier arborea	10.0	(0.2)	0.4	(0.1)	0.3

Table 21 (continued).

Species	Density (# stems/ha)		Height (m)		IV
Castanea dentata	5.0	(0.1)	0.7	(0.1)	0.2
Prunus sp.	5.0	(0.1)	0.4	(0.1)	0.1
Liriodendron tulipifera	5.0	(0.1)	0.4	(0.1)	0.1
Total	4485.0				
Shrub Species					
Vaccinium sp.	950.0	(16.3)	0.4	(9.7)	25.9
Smilax rotundifolia	220.0	(3.8)	0.6	(3.4)	7.1
Kalmia latifolia	130.0	(2.2)	0.7	(2.3)	4.5
Viburnum acerifolium	85.0	(1.5)	0.4	(1.0)	2.4
Rhododendron sp.	55.0	(1.0)	0.4	(0.5)	1.5
Diospyros virginiana	40.0	(0.7)	0.5	(0.6)	1.3
Vitis sp.	5.0	(0.1)	0.4	(0.1)	0.1
Total	1355.0				

Table 22. Ground layer (vegetation ≤1 m in height) species of the Daniel Boone National Forest, Stearns Ranger District, both prior to and following a spring midstory-reduction cut and prescribed burn. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Pre-Cut/Burn					
Tree Species					
Cornus florida	5.2	(17.8)	20.0	(11.4)	29.2
Acer rubrum	3.7	(12.8)	25.0	(14.3)	27.0
Ilex opaca	0.8	(2.6)	2.5	(1.4)	4.0
Carya sp.	0.3	(0.9)	5.0	(2.9)	3.7
Juniperus virginiana	0.5	(1.7)	2.5	(1.4)	3.1
Crataegus sp.	0.2	(0.7)	2.5	(1.4)	2.1
Total	10.7				
Shrub Species					
Kalmia latifolia	4.0	(13.8)	20.0	(11.4)	25.2
Viburnum acerifolium	1.2	(4.0)	7.5	(4.3)	8.3
Total	5.2				
Herbaceous Species					
Vaccinium sp.	10.1	(34.6)	72.5	(41.43)	76.0
Smilax rotundifolia	3.2	(10.9)	12.5	(7.4)	18.0
Chimaphila maculata	0.1	(0.4)	5.0	(2.9)	3.3
Total	13.4				
Post-Cut/Burn					
Tree Species					
Acer rubrum	7.8	(22.4)	65.0	(17.2)	39.6
Cornus florida	3.2	(9.3)	20.0	(5.3)	14.6
Quercus rubra	1.1	(3.3)	25.0	(6.6)	9.9
Q. velutina	0.6	(1.6)	20.0	(5.3)	6.9
Carya sp.	1.2	(3.3)	10.0	(2.7)	6.0
Nyssa sylvatica	0.9	(2.4)	12.5	(3.3)	5.8
Liriodendron tulipifera	0.1	(0.3)	10.0	(2.7)	2.9
Q. prinus	0.3	(0.9)	7.5	(2.0)	2.9
Prunus sp.	0.2	(0.6)	7.5	(2.0)	2.6
Oxydendron arboreum	0.4	(1.2)	5.0	(1.3)	2.5
Q. coccinea	0.3	(0.7)	5.0	(1.3)	2.0
Betula lenta	0.2	(0.4)	5.0	(1.3)	1.8
Ilex opaca	0.4	(1.1)	2.5	(0.7)	1.7
Q. alba	0.1	(0.3)	5.0	(1.3)	1.6
Sassafras albidum	0.0	(0.1)	2.5	(0.7)	0.7
Total	16.8				
Shrub Species					
Kalmia latifolia	1.5	(4.4)	12.5	(3.3)	7.7
Euonymus sp.	0.4	(1.1)	7.5	(2.0)	3.1

Table 22 (continued).

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Viburnum acerifolium	0.5	(1.4)	2.5	(0.7)	2.1
Total	2.4				
Herbaceous Species					
Vaccinium sp.	13.0	(37.1)	75.0	(19.9)	57.0
Smilax rotundifolia	0.7	(2.0)	22.5	(6.0)	8.0
Desmodium sp.	0.9	(2.4)	10.0	(2.7)	5.1
Gaultheria procumbens	0.1	(0.4)	10.0	(2.7)	3.0
Vitis sp	0.3	(0.8)	7.5	(2.0)	2.8
Lysimachia sp.	0.4	(0.7)	7.5	(2.0)	2.7
Viola sp.	0.2	(0.4)	7.5	(2.0)	2.4
Panicum sp.	0.1	(0.4)	5.0	(1.3)	1.7
Gillenia trifoliata	0.4	(0.7)	2.5	(0.7)	1.4
Rhus radicans	0.1	(0.4)	2.5	(0.7)	1.0
Asarum canadensis	0.0	(0.1)	2.5	(0.7)	0.7
Total	16.2				

until the morning of the burn. At that time, I was observing a burn on the CHTL and could not be reached by the DBST. Therefore, I was unable to collect data to measure temperature and litter moisture for this burn. Post-burn sampling occurred in May 1996.

Burning crews ignited the fire using drip torches along firelines and with a delayed aerial ignition device. During the burn, air temperatures ranged from 18 to 27°C and winds blew 16.1 to 24.1 km per hour from the south and southwest. Relative humidity averaged 35 to 38% during the burn and fuel moisture sticks registered 8%.

There was no apparent mortality in either the overstory or the midstory size classes following the fire which may indicate that fire intensity was relatively low. Bark char averaged 1.25 m. A midstory cutting treatment applied in 1995 to improve red-cockaded woodpecker habitat reduced total canopy basal area from 38.9 to 35.9 m^2/ha and total canopy density from 1515.0 to 1140.0 stems/ha. Neither of these reductions was significant and shortleaf pine, chestnut oak and red maple, respectively, remained the most important overstory species following the cutting and the fire (Table 19). The midstory reduction treatment removed approximately one-third of red maple and chestnut oak stems < 15 cm dbh (Figure 7). Red maple and blackgum predominated the post-cut/burn midstory (Table 20).

Red maple, blueberry and black oak were the most important understory species following the burn (Table 21). Stems of sourwood, blueberry, catbriar and maple leaf viburnum (*Viburnum acerifolium*) produced many sprouts after the burn that grew into the understory size class. Understory density did not change significantly following the burn. Species richness of the understory size class increased significantly from 5.1 ± 0.5 to 8.0 ± 0.5 species/0.01 ha ($P<0.05$) after the burn.

Blueberry and red maple were the most important ground layer species following the burn (Table 22). Sprouts or seedlings of red maple occurred in 75% of the ground

layer subplots following the burn. Cover of ground layer vegetation did not change significantly after the burn. Ground layer species richness increased significantly from 1.8±0.2 to 3.8±0.3 species/m^2 ($P<0.05$). I did not observe any shortleaf pine seedlings or saplings after the fire. Burning reduced litter depth significantly from 6.2±0.5 to 1.5±0.3 cm ($P<0.05$). Burning did not reduce duff depth.

This stand had a moderately large basal area and a small number of stems prior to the midstory reduction treatment and the prescribed burn. The fire prescription resulted in a very low intensity fire that did not reduce the basal area and density of either the overstory or the midstory size classes. Burning did not significantly change the order of species importance for any of the vegetation size classes. I did not expect to find shortleaf pine seedlings since post-burn vegetation sampling occurred prior to shortleaf pine seedfall. However, shortleaf pine regeneration most likely will not occur because of shading from taller vegetation and the remaining litter and duff.

Spring and Fall Burns on the Cherokee National Forest, Hiwassee Ranger District

CKHW Pre-Burn Vegetation

Shortleaf pine was the most important overstory species followed by red maple and sourwood (Table 23). Total density of the overstory size class was 663 stems/ha. Blackgum, red maple and sourwood predominated the midstory of this stand (Table 24). Total density of the midstory size class was 700 stems/ha. Most shortleaf pine stems exceeded 20 cm dbh (Figure 8). Only two shortleaf pine stems were less than 10 cm dbh. The majority of red maple and sourwood stems was less than 15 cm dbh. Basal area averaged 29.0±1.7 m^2/ha and density averaged 1359.5±92.5 stems/ha for the overstory

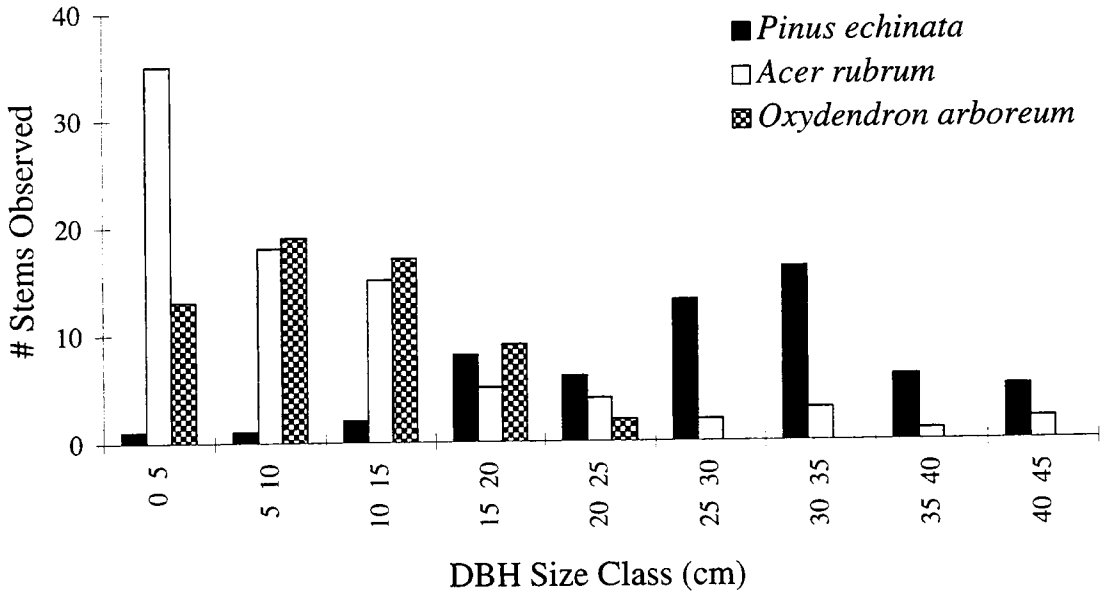
Table 23. Overstory (trees ≥ 10 cm dbh) species of the Cherokee National Forest, Hiwassee Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pinus echinata	12.4	(45.5)	175.0	(26.4)	71.9
Acer rubrum	3.6	(13.4)	100.0	(15.1)	28.5
Oxydendron arboreum	1.5	(5.7)	87.5	(13.2)	18.9
Quercus prinus	2.4	(8.8)	56.3	(8.5)	17.3
Nyssa sylvatica	1.1	(4.1)	53.1	(8.0)	12.1
P. virginiana	1.3	(4.8)	40.6	(6.1)	11.0
Acer saccharum	1.3	(4.7)	37.5	(5.7)	10.3
Q. falcata	1.3	(5.3)	25.0	(3.8)	9.1
Cornus florida	0.4	(1.4)	34.4	(5.2)	6.6
Q. coccinea	0.5	(1.8)	18.8	(2.8)	4.6
Q. alba	0.5	(1.8)	9.4	(1.4)	3.2
Carya sp.	0.3	(1.1)	3.1	(0.5)	1.6
Q. velutina	0.1	(0.4)	6.3	(0.9)	1.3
Q. rubra var. *borealis*	0.1	(0.4)	6.3	(0.9)	1.3
Q. stellata	0.1	(0.4)	3.1	(0.5)	0.9
Liriodendron tulipifera	0.1	(0.3	3.1	(0.5)	0.7
P. strobus	0.0	(0.2)	3.1	(0.5)	0.6
Total	27.0		662.6		

Table 24. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Cherokee National Forest, Hiwassee Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Nyssa sylvatica	0.4	(22.1)	150.0	(21.4)	43.6
Acer rubrum	0.3	(18.3)	165.6	(23.7)	42.0
Oxydendron arboreum	0.3	(19.2)	100.0	(14.3)	33.5
Acer saccharum	0.2	(11.5)	75.0	(10.7)	22.2
Cornus florida	0.1	(8.2)	71.9	(10.3)	18.4
Pinus virginiana	0.1	(5.9)	18.8	(2.7)	8.6
Liriodendron tulipifera	0.1	(3.7)	28.1	(4.0)	7.8
Quercus alba	0.0	(2.4)	15.6	(2.2)	4.6
Carya sp.	0.0	(1.5)	18.8	(2.7)	4.2
Q. prinus	0.0	(1.8)	9.4	(1.3)	3.1
Q. velutina	0.0	(1.6)	6.3	(0.9)	2.5
Juniperus virginiana	0.0	(0.9)	9.4	(1.3)	2.2
Q. rubra var. *borealis*	0.0	(1.3)	6.3	(0.9)	2.2
P. echinata	0.0	(0.8)	6.3	(0.9)	1.7
P. strobus	0.0	(0.3)	6.3	(0.9)	1.2
Ilex sp.	0.0	(0.2)	3.1	(0.4)	0.6
Sassafras albidum	0.0	(0.1)	3.1	(0.4)	0.6
Q. falcata	0.0	(0.1)	3.1	(0.4)	0.5
Amelanchier arborea	0.0	(0.1)	3.1	(0.4)	0.5
Total	1.5		700.2		

Figure 8. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Cherokee National Forest, Hiwassee Ranger District. The number of stems observed represents the number of trees tallied in 0.32 ha.


40
30
20
10
0
Stems Observed
Pinus echinata
Acer rubrum
Oxydendron arboreum
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

and midstory size classes combined. Mean species richness was 8.6±0.3 species/0.02 ha for these combined size classes.

Red maple predominated in the understory size class (Table 25). Tree species accounted for 73% of the species observed in the understory size class. Mean understory density and mean understory species richness were 186.9±13.1 stems/0.01 ha and 7.7±0.5 species/0.01 ha, respectively. Blueberry and red maple were the most important ground layer species (Table 26). Ground layer cover averaged 24.6±3.0 %/m^2 and herb layer species richness averaged 2.8±0.3 species/m^2. Virginia pine seedlings occurred in 7.8% of the ground layer subplots. I did not observe any shortleaf pine seedlings. Mean litter depth was 3.2±0.3 cm and mean duff depth was 0.8±0.1 cm.

CKHW Spring Burn

The USDA Forest Service, Hiwassee District did not conduct the proposed spring burn because the prescribed weather conditions did not occur throughout the study period.

CKHW Fall Burn

The USDA Forest Service, Hiwassee District did not conduct the proposed fall burn because the prescribed weather conditions did not occur throughout the study period.

Table 25. Understory (stems <2.5 cm dbh and >1 m in height) species of the Cherokee National Forest, Hiwassee Ranger District. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Height (m)		IV
Tree Species					
Acer rubrum	837.5	(28.1)	1.9	(29.8)	57.9
Oxydendron arboreum	362.5	(12.2)	1.9	(13.4)	25.6
Liquidambar styraciflua	221.9	(7.5)	2.1	(9.1)	16.6
Liriodendron tulipifera	193.8	(6.5)	2.0	(7.4)	13.9
Nyssa sylvatica	162.5	(5.5)	2.1	(6.5)	12.0
Cornus florida	140.5	(4.7)	2.4	(6.4)	11.2
Carya sp.	84.4	(2.8)	1.6	(2.6)	5.5
Quercus alba	75.0	(2.5)	1.9	(2.7)	5.2
Q. falcata	75.0	(2.5)	1.3	(1.9)	4.4
Q. velutina	62.5	(2.1)	1.8	(2.2)	4.3
Q. coccinea	59.4	(2.0)	1.3	(1.4)	3.4
Ilex sp.	56.3	(1.9)	1.2	(1.3)	3.2
Q. prinus	40.6	(1.4)	1.8	(1.4)	2.8
Sassafras albidum	40.6	(1.4)	1.5	(1.1)	2.5
P. virginiana	40.6	(1.4)	0.8	(0.6)	2.0
Q. rubra var. *borealis*	28.1	(0.9)	1.1	(0.6)	1.6
Prunus sp.	9.4	(0.3)	2.4	(0.4)	0.8
Pinus echinata	12.5	(0.4)	0.7	(0.2)	0.6
Fraxinus sp.	3.1	(0.1)	3.6	(0.2)	0.3
P. strobus	3.1	(0.1)	2.2	(0.1)	0.2
Ilex sp.	3.1	(0.1)	0.7	(0.0)	0.2
Fagus grandifolia	3.1	(0.1)	0.7	(0.0)	0.2
Juniperus virginiana	3.1	(0.1)	0.7	(0.0)	0.2
Amelanchier arborea	3.1	(0.1)	0.7	(0.0)	0.2
Total	2521.7		38.4		
Shrub Species					
Vaccinium sp.	368.8	(12.4)	1.0	(7.1)	19.5
Kalmia latifolia	31.3	(1.1)	1.6	(1.0)	2.0
Diospyros virginiana	21.9	(0.7)	2.7	(1.1)	1.9
Gaylussacia sp.	12.5	(0.4)	1.1	(0.3)	0.7
Elaeagnus umbellata	6.3	(0.2)	2.2	(0.3)	0.5
Euonymus sp.	6.3	(0.2)	1.1	(0.1)	0.3
Ulmus sp.	3.1	(0.1)	3.6	(0.2)	0.3
Rhus copallina	3.1	(0.1)	2.2	(0.1)	0.2
Viburnum acerifolium	3.1	(0.1)	0.7	(0.0)	0.2
Total	456.4		16.2		

Table 26. Ground layer (vegetation ≤1 m in height) species of the Cherokee National Forest, Hiwassee Ranger District. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Tree Species					
Acer rubrum	2.8	(11.3)	54.7	(19.4)	30.1
Oxydendron arboreum	0.6	(2.6)	10.9	(3.9)	6.5
Prunus sp.	0.6	(2.3)	9.4	(3.3)	5.7
Cornus florida	1.0	(3.9)	4.7	(1.7)	5.5
Liriodendron tulipifera	0.2	(0.9)	9.4	(3.3)	4.2
Nyssa sylvatica	0.4	(1.5)	6.3	(2.2)	3.7
Quercus prinus	0.3	(1.3)	6.3	(2.2)	3.5
Q. alba	0.3	(1.1)	6.3	(2.2)	3.4
Pinus virginiana	0.1	(0.6)	7.8	(2.8)	3.4
Sassafras albidum	0.3	(1.0)	6.3	(2.2)	3.2
Liquidambar styraciflua	0.6	(2.5)	1.6	(0.6)	3.1
Q. coccinea	0.1	(0.4)	3.1	(1.1)	1.5
Q. rubra var. *borealis*	0.2	(0.6)	1.6	(0.6)	1.2
Q. falcata	0.1	(0.3)	1.6	(0.6)	0.9
Q. velutina	0.0	(0.1)	1.6	(0.6)	0.7
Magnolia sp.	0.0	(0.1)	1.6	(0.6)	0.7
Total	7.6				
Shrub Species					
Euonymus sp.	0.6	2.5	15.6	5.6	8.1
Herbaceous Species					
Vaccinium sp.	12.3	53.4	75.0	26.7	80.1
Smilax rotundifolia	0.3	1.4	18.8	6.7	8.1
Chimaphila maculata	0.3	1.2	14.1	5.0	6.2
Andropogon sp.	0.3	1.4	7.8	2.8	4.2
Dryopteris spinulosa	0.8	3.2	1.6	0.6	3.7
Cassia fasciculata	0.6	2.5	1.6	0.6	3.1
Panicum sp.	0.4	1.6	1.6	0.6	2.1
Galax sp.	0.3	1.3	1.6	0.6	1.8
Rubus sp.	0.1	0.2	3.1	1.1	1.3
Rhus radicans	0.1	0.5	1.6	0.6	1.1
Solidago sp.	0.1	0.2	1.6	0.6	0.8
Elaeagnus umbellata	0.0	0.1	1.6	0.6	0.7
Cypripedium acaule	0.0	0.1	1.6	0.6	0.7
Smilax erectum	0.0	0.1	1.6	0.6	0.7
Total	15.6				

Spring and Fall Burns on the Pisgah National Forest, Grandfather Ranger District

PSGF Pre-Burn Vegetation

Table mountain pine was the most important overstory species followed by pitch pine (Table 27). Total density of the overstory size class was 900 stems/ha. Blackgum predominated the midstory size class (Table 28). Total density of the midstory size class was 1000 stems/ha. Although some table mountain pine and pitch pine stems were less than 15 cm dbh, the majority of pine stems exceeded 20 cm dbh (Figure 9). All blackgum stems were less than 20 cm dbh. Mean basal area was 28.9±2.4 m^2/ha and mean canopy density was 1806.5±99.5 stems/ha for the combined overstory and midstory size classes. Canopy species richness averaged 7.6±0.2 species/0.02 ha for these combined size classes.

Mountain laurel was the most important understory species (Table 29). Mean understory density was 127.4±9.6 stems/ha and mean understory species richness was 2.3±0.3 species/0.01 ha. Blueberry was the most important ground layer species followed by mountain laurel and catbriar (Table 30). I did not observe any table mountain pine or pitch pine regeneration. Ground layer cover and ground layer species richness averaged 31.7±4.1%/m^2 and 2.2±0.2 species/m^2, respectively. Mean litter depth was 5.2±0.4 cm and mean duff depth was 6.9±1.3 cm.

PSGF Spring Burn

USDA Forest Service crews used a combined ring and head fire technique to burn approximately 3 ha of a table mountain pine stand in early May 1996. The stated purpose

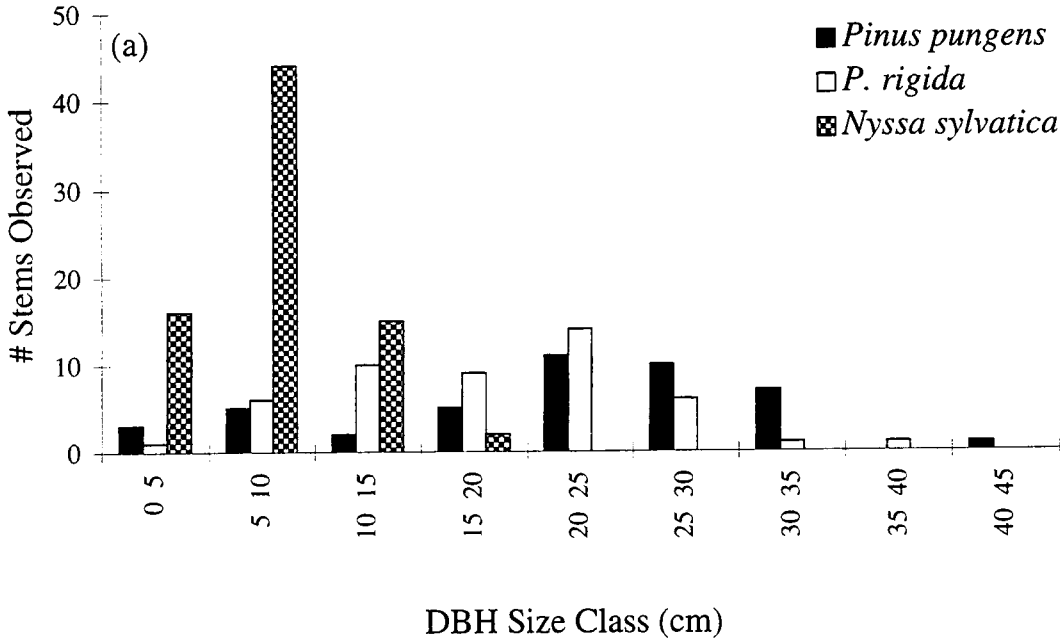
Table 27. Overstory (all stems ≥ 10 cm dbh) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Pinus pungens	12.0	(41.3)	225.0	(25.0)	66.3
P. rigida	9.0	(30.9)	256.3	(28.5)	59.4
Nyssa sylvatica	1.4	(4.8)	106.3	(11.8)	16.6
P. virginiana	2.2	(7.5)	62.5	(6.9)	14.4
Quercus coccinea	1.8	(6.1)	68.8	(7.6)	13.7
Acer rubrum	1.1	(3.9)	68.8	(7.6)	11.5
Q. prinus	0.9	(3.0)	56.3	(6.3)	9.3
Oxydendron arboreum	0.7	(2.5)	56.3	(6.3)	8.7
Total	29.1		900.3		
Post-Burn					
Pinus pungens	13.8	(55.4)	287.5	(42.6)	98.0
P. rigida	5.3	(21.4)	137.5	(20.4)	41.7
P. virginiana	2.4	(9.5)	56.3	(8.3)	17.9
Nyssa sylvatica	1.3	(5.3)	81.3	(12.0)	17.4
Acer rubrum	0.9	(3.6)	50.0	(7.4)	11.0
Quercus coccinea	0.6	(2.3)	25.0	(3.7)	6.0
Q. prinus	0.4	(1.4)	18.8	(2.8)	4.2
Oxydendron arboreum	0.3	(1.0)	18.8	(2.8)	3.8
Total	25.0		675.2		

Table 28. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pre-Burn					
Nyssa sylvatica	1.3	(39.0)	375.0	(37.5)	76.5
Oxydendron arboreum	0.6	(19.1)	168.8	(16.9)	35.9
Acer rubrum	0.5	(15.4)	150.0	(15.0)	30.4
Hamamelis virginiana	0.1	(3.0)	93.8	(9.4)	12.4
P. rigida	0.2	(6.4)	43.8	(4.4)	10.8
Pinus pungens	0.1	(4.4)	50.0	(5.0)	9.4
Q. prinus	0.2	(5.3)	37.5	(3.8)	9.1
Quercus coccinea	0.1	(4.3)	43.8	(4.4)	8.7
P. virginiana	0.1	(1.7)	12.5	(1.3)	2.9
Amelanchier arborea	0.0	(1.0)	12.5	(1.3)	2.3
Sassafras albidum	0.0	(0.4)	6.3	(0.6)	1.0
P. strobus	0.0	(0.1)	6.3	(0.6)	0.7
Total	3.2		1000.3		
Post-Burn					
Nyssa sylvatica	0.5	(51.6)	93.8	(44.1)	95.7
Acer rubrum	0.2	(26.7)	68.8	(32.4)	59.0
Oxydendron arboreum	0.1	(12.4)	37.5	(17.6)	30.0
Pinus rigida	0.1	(9.4)	12.5	(5.9)	15.3
Total	0.9		212.6		

Figure 9. Pre- and post-burn distribution of the three most important canopy species (combined overstory and midstory size classes) of the Pisgah National Forest, Grandfather Ranger District. The number of stems observed represents the number of trees tallied in 0.16 ha. The prescribed burn occurred in June 1996. Post-burn vegetation sampling took place in August 1996.


(a)
Pinus pungens
P. rigida
Nyssa sylvatica
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

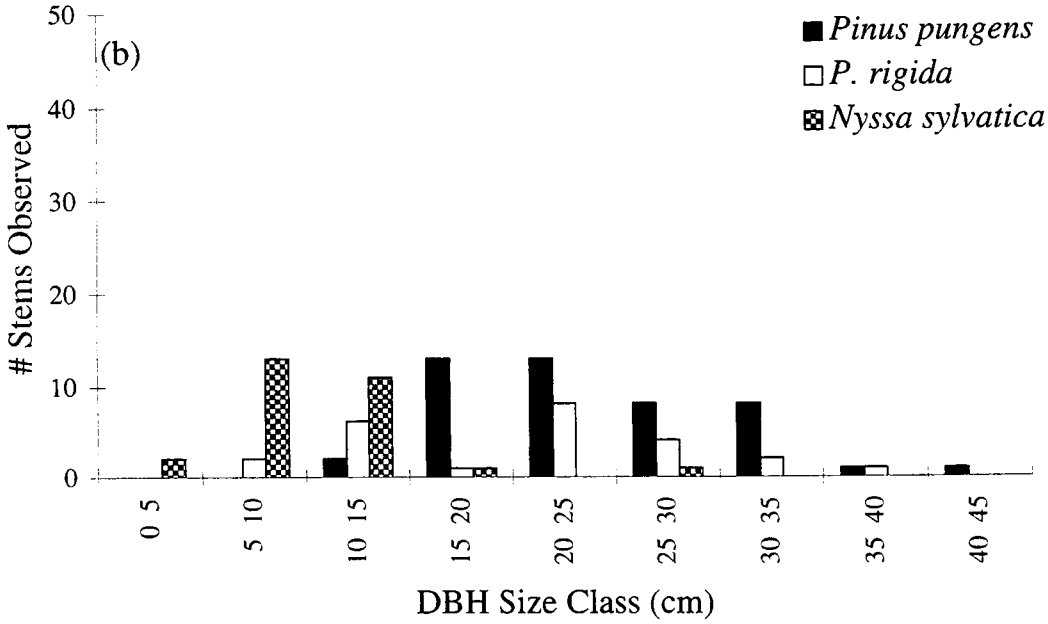

(b)
Pinus pungens
P. rigida
Nyssa sylvatica
Stems Observed
50
40
30
20
10
0
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
DBH Size Class (cm)

Table 29. Understory (stems <2.5 cm dbh and >1 m in height) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative density (% of total) and relative height (% of total). Importance value (IV) calculated as relative density plus relative height.

Species	Density (# stems/ha)		Height (m)		IV
Pre-Burn					
Tree Species					
Oxydendron arboreum	31.3	(1.8)	2.8	(1.8)	3.6
Pinus strobus	12.5	(0.7)	3.3	(0.9)	1.6
Quercus coccinea	12.5	(0.7)	2.9	(0.8)	1.5
Acer rubrum	12.5	(0.7)	1.8	(0.5)	1.2
Q. prinus	6.3	(0.4)	2.9	(0.4)	0.7
Total	75.1				
Shrub Species					
Kalmia latifolia	1581.3	(92.3)	2.8	(92.4)	184.8
Hamamelis virginiana	31.3	(1.8)	2.8	(1.8)	3.6
Symplocos tinctoria	12.5	(0.7)	4.0	(1.1)	1.8
Vaccinium sp.	12.5	(0.7)	1.5	(0.4)	1.1
Total	1637.6				
Post-Burn					
Tree Species					
Nyssa sylvatica	552.5	(6.8)	0.1	(6.1)	12.9
Acer rubrum	344.5	(3.8)	0.1	(7.0)	10.7
Oxydendron arboreum	156.0	(3.0)	0.0	(3.0)	6.0
Quercus coccinea	19.5	(2.1)	0.4	(3.0)	5.1
Q. prinus	26.0	(2.1)	0.1	(2.5)	4.7
Total	1098.5				
Shrub Species					
Kalmia latifolia	975.0	(75.9)	0.1	(71.6)	147.5
Symplocos tinctoria	195.0	(3.8)	0.0	(4.5)	8.2
Hamamelis virginiana	19.5	(2.3)	0.1	(2.1)	4.5
Rhododendron sp.	6.5	(0.2)	0.4	(0.2)	0.5
Total	1196.0				

Table 30. Ground layer (vegetation ≤1 m in height) species of the Pisgah National Forest, Grandfather Ranger District, both prior to and following a spring prescribed burn. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover (%/m^2)		Frequency (% occurrence)		IV
Pre-Burn					
Tree Species					
Quercus coccinea	0.4	(0.7)	7.8	(3.7)	4.3
Acer rubrum	0.3	(0.5)	7.8	(3.7)	4.1
Oxydendron arboreum	0.3	(0.5)	1.6	(0.7)	1.2
Pinus strobus	0.2	(0.3)	1.6	(0.7)	1.0
Nyssa sylvatica	0.1	(0.2)	1.6	(0.7)	0.9
Total	1.3				
Shrub Species					
Kalmia latifolia	18.2	(28.8)	68.8	(32.1)	60.9
Herbaceous Species					
Vaccinium sp.	36.5	(57.8)	67.2	(31.4)	89.2
Smilax rotundifolia	2.3	(3.6)	45.3	(21.2)	24.7
Galax sp.	3.9	(6.2)	4.7	(2.2)	8.4
Pteridium aquilinum	0.4	(0.7)	4.7	(2.2)	2.9
Panicum sp.	0.5	(0.7)	3.1	(1.5)	2.2
Total	43.6				
Post-Burn					
Tree Species					
Quercus coccinea	0.9	(8.5)	9.4	(5.5)	13.9
Acer rubrum	0.8	(6.8)	6.3	(3.6)	10.4
Pinus pungens	0.1	(1.1)	3.1	(1.8)	2.9
Nyssa sylvatica	0.0	(0.3)	3.1	(1.8)	2.1
Total	1.8				
Shrub Species					
Kalmia latifolia	4.7	(42.3)	62.5	(36.4)	78.6
Gaylussacia sp.	2.7	(23.9)	40.7	(23.6)	47.6
Rhododendron sp.	0.0	(0.3)	3.1	(1.8)	2.1
Symplocos tinctoria	0.0	(0.3)	3.1	(1.8)	2.1
Total	7.4				
Herbaceous Species					
Vaccinium sp.	1.7	(14.9)	28.1	(16.4)	31.3
Smilax rotundifolia	0.1	(0.9)	9.4	(5.5)	6.3
Gaylax sp.	0.1	(0.9)	3.1	(1.8)	2.7
Total	1.9				

of this burn was to promote table mountain pine regeneration. Air temperature during the burn was 27°C and relative humidity ranged from 36 to 46%. Fuel sticks indicated low fuel moisture (7.6 to 10.2%) but litter moisture averaged 44.2% two hours before the burn. Reported flame heights at greatest intensity ranged from 12 to 46 m. However, the mean flame height was probably much lower as indicated by the mean bark char height of 4 m and canopy scorch of only 21.3%. Average temperature 1 m above the ground was 180°C. Sampling of post-burn vegetation occurred in August 1996.

The burn reduced the density of the combined overstory and midstory size classes by 47% [1900.0±166.5 to 887.5±193.5 stems/ha ($P<0.05$)]. Accompanying this was a 20% loss of basal area for these combined size classes [32.0±2.0 to 25.9±50.0 m^2/ha ($P<0.05$)]. Burning reduced canopy species richness from 7.9±0.3 to 4.6+0.7 species/0.02 ha ($P<0.05$). Table mountain pine and pitch pine remained the most important overstory species following the burn (Table 27). Blackgum and red maple were the most important midstory species following the burn (Table 28). The fire eliminated some stems less than 10 cm dbh (Figure 9). The majority of overstory and midstory stems survived the fire.

Mean understory density increased from 116.3±9.4 to 167.5±11.9 stems/ha ($P<0.05$) following the burn. Shrub layer species richness also increased from 2.1±0.3 to 4.5±0.3 species/0.01 ha ($P<0.05$). Mountain laurel was the most important understory species following the burn (Table 29). Top-killed stems of blackgum, red maple and sourwood sprouted after the burn and grew into the understory size class. The density of mountain laurel stems decreased following the fire.

Burning reduced mean ground layer cover values [28.4±6.4 to 11.4±2.9 %/m^2 ($P<0.05$)] but there was no change in ground layer species richness. Mountain laurel, huckleberry, and blueberry were the most important ground layer species following the

burn (Table 30). Burning reduced litter depth significantly [5.7±0.3 to 2.5±0.5 cm ($P<0.05$)] but duff depth remained unchanged. Mineral soil was not exposed in any of the ground layer subplots. I recorded sparse table mountain pine regeneration following the fire (0.77±0.63 seedlings/m^2). Table mountain pine seedlings occurred in only 3.1% of the ground layer subplots.

Prior to burning this stand was characterized by a large number of stems and a relatively low basal area. The understory contained many large mountain laurel shrubs. The prescription used resulted in a relatively high intensity fire. Burning eliminated many midstory stems but did little damage to the overstory of this stand. Hardwood and shrub species of the understory sprouted following the fire and increased the density of stems in this size class. Some changes in species importance occurred following the fire. Although the fire reduced the combined overstory and midstory basal area and density of this stand, it generally was ineffective at opening the forest canopy. Nearly complete removal of the canopy only occurred in the center of the stand where the fire reached its greatest intensity. The number of table mountain pine seedlings observed after the fire is insufficient to regenerate this stand. Furthermore, these seedlings are not likely to survive because they germinated on duff and because of shading from overhead vegetation.

PSGF Fall Burn

The USDA Forest Service, Grandfather District did not conduct this burn because of the lack of available weather conditions for burning throughout the study period.

Spring Burn on the Chattahoochee National Forest, Tallulah Ranger District

CHTL Pre-Burn Vegetation

Table mountain pine was the most important overstory species followed by chestnut oak and scarlet oak (Table 31). The total density of the overstory size class was 880 stems/ha. Pitch pine predominated the midstory size class (Table 32). The total density of the midstory size class was 508 stems/ha. Distributions of table mountain pine, chestnut oak, and scarlet oak were similar with the majority of all stems exceeding 10 cm dbh (Figure 10). The stand contained three stems of table mountain pine that exceeded 45 cm dbh. Mean basal area was 31.1±2.4 m^2/ha and mean density was 1189.5±64.5 stems/ha for the overstory and midstory size classes combined. Canopy species richness averaged 7.2±0.4 species/0.02 ha for these combined size classes.

Mountain laurel was the only species present in the understory and averaged 138.1±23.3 stems/ha. Blueberry, galax and mountain laurel, in order of dominance, were the only identified species of the ground layer (Table 33). Ground layer cover averaged 43.2±5.1 %/m^2 and ground layer species richness averaged 1.7±0.1 species/m^2. There were no table mountain pine or pitch pine seedlings present in the ground layer. Mean litter depth and mean duff depth were 4.2±0.4 cm and 11.1±0.9 cm, respectively.

CHTL Spring Burn

USDA Forest Service personnel attempted a prescribed burn April 10, 1996. The fire covered much of the lower slopes below the table mountain pine stand but did not enter

Table 31. Overstory (trees ≥ 10 cm dbh) species of the Chattahoochee National Forest, Tallulah Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pinus pungens	11.9	(37.2)	262.5	(30.1)	67.4
Quercus prinus	9.3	(29.1)	250.0	(28.7)	57.8
Q. coccinea	4.1	(12.8)	108.3	(12.4)	25.2
Q. alba	2.2	(6.8)	75.0	(8.6)	15.4
Nyssa sylvatica	1.4	(4.3)	58.3	(6.7)	11.0
Oxydendron arboreum	1.3	(4.2)	20.8	(2.4)	6.6
Acer rubrum	0.6	(2.0)	25.0	(2.9)	4.9
Amelanchier arborea	0.3	(1.0)	20.8	(2.4)	3.4
Acer sp.	0.3	(1.0)	16.7	(1.9)	2.9
Carya sp.	0.2	(0.8)	16.7	(1.9)	2.7
Sassafras albidum	0.1	(0.4)	12.5	(1.0)	1.3
Ilex opaca	0.1	(0.3)	6.3	(0.5)	0.8
Betula lenta	0.1	(0.2)	6.3	(0.5)	0.6
Total	31.9		879.2		

Table 32. Midstory (trees ≥2.5 cm to <10 cm dbh) species of the Chattahoochee National Forest, Tallulah Ranger District. Values in parentheses are relative basal area (% of total) and relative density (% of total). Importance value (IV) calculated as relative basal area plus relative density.

Species	Basal Area (m^2/ha)		Density (# stems/ha)		IV
Pinus rigida	2.4	(55.6)	25.0	(4.9)	60.5
Nyssa sylvatica	0.4	(9.3)	104.2	(20.5)	29.8
Quercus prinus	0.5	(10.5)	87.5	(17.2)	27.7
Q. coccinea	0.2	(3.5)	54.2	(10.7)	14.2
Acer rubrum	0.2	(4.1)	50.0	(9.8)	14.0
Amelanchier arborea	0.2	(3.9)	41.7	(8.2)	12.1
Q. alba	0.2	(3.8)	37.5	(7.4)	11.1
P. pungens	0.2	(4.0)	33.3	(6.6)	10.5
Castanea dentata	0.1	(2.1)	33.3	(6.6)	8.6
Oxydendron arboreum	0.1	(1.5)	16.7	(3.3)	4.8
Acer sp.	0.0	(0.7)	4.2	(0.8)	1.5
Carya sp.	0.0	(0.5)	4.2	(0.8)	1.3
Sassafras albidum	0.0	(0.4)	4.2	(0.8)	1.2
Betula lenta	0.0	(0.2)	4.2	(0.8)	1.0
Fraxinus sp.	0.0	(0.1)	4.2	(0.8)	0.9
P. strobus	0.0	(0.0)	4.2	(0.8)	0.8
Total	4.5		508.6		

Figure 10. Distribution of the three most important canopy species (combined overstory and midstory size classes) of the Chattahoochee National Forest, Tallulah Ranger District. The number of stems observed represents the number of trees tallied in 0.28 ha.

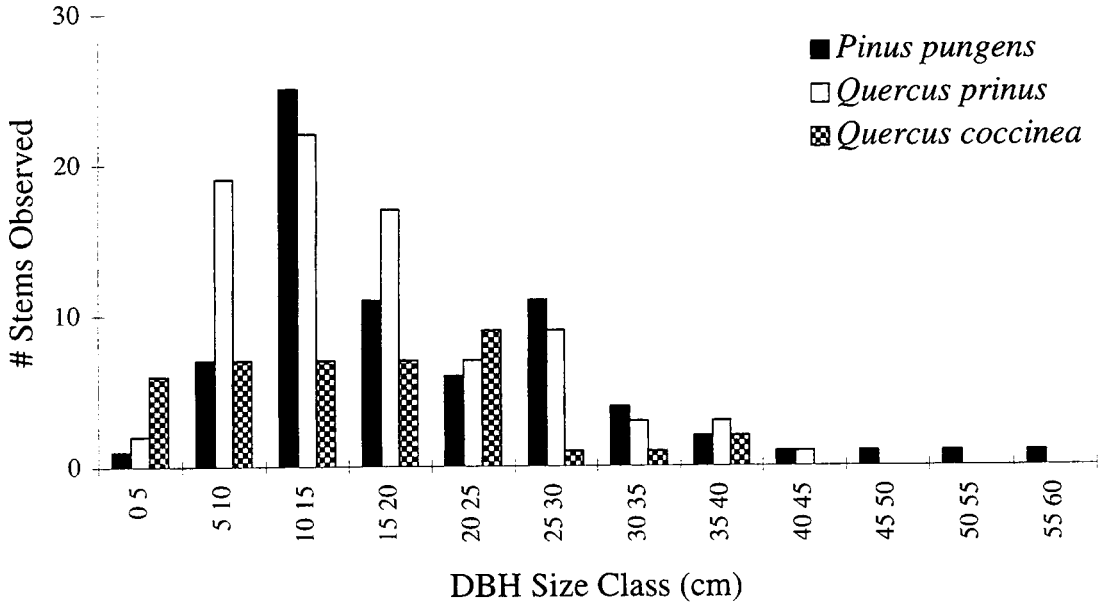

30
20
10
0
Stems Observed
Pinus pungens
Quercus prinus
Quercus coccinea
0 5
5 10
10 15
15 20
20 25
25 30
30 35
35 40
40 45
45 50
50 55
55 60
DBH Size Class (cm)

Table 33. Ground layer (vegetation ≤1 m in height) species[1] of the Chattahoochee National Forest, Tallulah Ranger District. Values in parentheses are relative cover (% of total) and relative frequency (% of total). Importance value (IV) calculated as relative cover plus relative frequency.

Species	Cover ($\%/m^2$)		Frequency (% occurrence)		IV
Shrub Species					
Kalmia latifolia	8.3	(16.7)	39.3	(22.7)	39.4
Herbaceous Species					
Vaccinium sp.	30.2	(60.5)	75.0	(43.3)	103.8
Galax sp.	10.4	(20.8)	48.2	(27.8)	48.6
Total	40.6				

[1]Unidentified tree and other species covered 1.0 $\%/m^2$ and occurred in 10.7% of the ground layer subplots.

the stand itself, likely due to high fuel moistures. The duff layer was observed to be frozen just prior to ignition. I did not collect post-burn data for this site.

Discussion

I describe my study sites as pine-oak forests with mixed xeric hardwood midstory and understory trees and ericaceous ground layer vegetation. Canopy species richness averages 6 species/0.02 ha for combined overstory and understory strata. Understory species richness is higher than expected with approximately 5 species/0.01 ha. Ground layer species richness (approximately 3 species/m^2) is comparable to ground layer species richness of central Appalachian hardwood forests (Gilliam and Turrill 1993).

Southern Appalachian pine forests likely have endured changes in structure and composition in the absence of fire. Other factors such as wind damage, chestnut blight, and southern pine bark beetle epidemics also have induced changes in these forests. When Whittaker (1956) described the pitch pine stands of the Great Smoky Mountains, pitch pine stems 30 to 40 cm dbh occasionally shared overstory dominance with scarlet oak and chestnut oak. Blackgum "occurred in small numbers" in the understory and red maple and sourwood were "important small trees." For the table mountain pine stands, Whittaker (1956) stated that table mountain pine stems 25 to 40 cm dbh dominated the areas followed decreasingly by pitch pine, scarlet oak, chestnut oak, and American chestnut. Understories contained "small numbers" of blackgum and small stems of red maple, sourwood, locust, and sassafras. He observed both pitch pine and table mountain pine regeneration. Whittaker (1956) also noted that the oaks in these pine forests were "reproducing well," but was "by no means certain that the oaks and their associates are capable of taking dominance from the pines on these sites."

The overstory structure of the nine stands sampled for this study was similar to that described by Whittaker (1956). Yellow pines were the canopy dominants and were of similar diameter to those recorded by Whittaker (1956). Table mountain pine trees on the CHTL closely match his descriptions but the midstory and understory vegetation is larger in dbh and density. The numbers and diameters of scarlet oak, chestnut oak, blackgum, and red maple stems cannot be described as "small." Instead, the understories appear much more dense and dominated by potential canopy species (i.e., scarlet oak and chestnut oak) than those depicted by Whittaker (1956). The differences between my study plots and those of Whittaker (1956) likely are caused by many factors such as location, soils, and time since disturbance. However, these differences may provide a rough approximation of the successional changes that have occurred in the absence of fire for the last forty years.

Composition of the midstory and understory size classes of my study sites resembled those reported in studies of shortleaf, pitch, and table mountain pine stands throughout their geographic range. Cain and Shelton (1995) recorded the presence of midstory and understory shade-tolerant species, poised to move into the overstory of a shortleaf pine stand in southern Arkansas. Likewise, Abrams and Nowacki (1992) described the decline of shortleaf pine forests in central Pennsylvania as succession toward oak-dominance and, later, maple-dominance continues. Other authors predicted eventual overstory invasion by oaks and maples in pitch pine forests of North Carolina (Waterman et al. 1995), central Pennsylvania (Nowacki and Abrams 1992) and central and western New York (Seischab and Bernard 1991). Sutherland et al. (1995) and Williams and Johnson (1990; 1992) predicted chestnut oak and scarlet oak dominance of table mountain pine stands in Virginia.

The understory size classes and ground layers I sampled all contained hardwood species as well as shrub species. In Whittaker's (1956) study, shrub species (mountain

laurel, blueberry and huckleberry) dominated understory layers and averaged 50 to 80% cover. The number of hardwood species in the understory size class of my study sites outnumbered shrub species. Galax, bracken fern and various grasses dominated the ground layer of Whittaker's plots and averaged 5 to 20% cover (Whittaker 1956). The amount of ground layer cover I observed on my study sites was much greater (35 to 40%/m^2) than that reported by Whittaker (1956). The most important species I observed in the understory and ground layer size classes were similar to those reported by Whittaker (1956). However, saplings and seedlings of hardwoods frequently appeared and attested to the success of hardwood regeneration in the observed yellow pine stands.

Unlike Whittaker (1956), I did not observe pine seedlings on any of my study sites during pre-burn sampling. The closed canopies and deep litter and duff layers of the study sites may have inhibited pine regeneration. Overstory and understory oaks and other hardwoods shade and contribute much litter to the forest floor. Williams et al. (1992) showed that oak litter inhibits table mountain pine regeneration. Oak litter physically depressed seedling emergence compared to pine litter or litter-free conditions. The authors suggested that oak litter prevented emerging pine radicals from reaching moist soil and seedlings died of desiccation. Williams et al. (1992) suggested that seedbeds of pine litter encouraged regeneration because pine seeds contacted soil by falling through the interstices of pine litter and the pine litter aided in soil moisture retention.

On one of the sample sites, GWWY, other disturbances such as ice storms and windthrow opened gaps in the forest canopy. Subsequently, I observed some pitch pine and table mountain pine saplings in these gaps. Barden (1977) described another occurrence of yellow pine regeneration following an unnamed disturbance other than fire. His study of pure table mountain pine populations on steep, xeric southwest slopes in North Carolina suggested that extreme drought conditions can induce cones to release

seeds. Very little vegetation can survive these conditions and released seeds often encounter favorable seedbeds of pine litter over mineral soil (Williams et al. 1990) and little competition for available light. Thus, an edaphic climax community of table mountain pine is maintained in such areas.

USDA Forest Service crews planned a total of ten prescribed burns at the beginning of this project. However, of the ten burns proposed, only five occurred (Table 2). Three burns, GWWS (fall and spring) and PSGF, were of greater intensity and produced greater higher flame heights and fire temperatures compared to those on the DBSM and DBST. Burns on the GWWS and PSGF reduced both canopy basal area and canopy density whereas burns on DBSM and DBST did not. Regelbrugge and Smith (1994) reported similar mortality following The Big Run Fire of May 1986 in the Shenandoah National Park, Virginia. This fire top-killed 81% of trees in the high-intensity burn areas compared to only 15% of trees in the low-intensity burn areas. Accompanying this was a 67% and an 8% reduction in stand basal area in the high- and the low-intensity burn areas, respectively. The burns on the GWWS and PSGF, however, reduced both basal area and density by only 20%. Such low reductions likely will prevent sufficient light from reaching the forest floor for successful pine regeneration.

The two burns that significantly reduced canopy basal area and density (GWWS and PSGF) were small in area and ignited with drip torches. Burning crews ignited the perimeters of these stands and allowed the fire to burn toward the center. Such prescriptions produced higher intensity fires than those ignited with delayed aerial ignition devices (DBSM and DBST). Perhaps burning crews released too many ping-pong balls on those areas to allow for sufficient convection conditions that would be produced in a higher intensity fire.

Burning on GWWS and PSGF changed the relative importance of some midstory species. Chestnut oak and blackgum increased in importance following both the fall and the spring burns on GWWS. Importance of red maple increased following burning on PSGF. Such changes in species importance may be short-term, however, according to the results of McGee et al. (1995). They showed that the order of important post-burn species returned to that of the pre-burn within twelve years after burning in New York mid-seral oak forests.

None of the burns reduced understory vegetation. The density of understory stems nearly doubled following all five burns due to tenacious sprouting from basal buds of top-killed overstory, midstory and understory stems. These results are similar to those of Kauffman and Martin (1990) for vegetation response to fire in Sierra Nevada mixed conifer ecosystems. The authors reported significant increases in the number of individual stems per individual following burning. Working in mid-seral oak forests of New York, McGee et al. (1995) demonstrated that such post-burn increases in understory and shrub densities may persist for more than twelve years. Waldrop et al. (1992) showed increases in red maple and sweetgum (*Liquidambar styraciflua*) stem numbers on the Atlantic Coastal Plain even after forty-three years of annual winter burning.

Post-fire sprouting occurred more frequently in hardwood tree species (red maple, chestnut oak, and scarlet oak) than it did in shrub species confined to the understory layer (mountain laurel and huckleberry). Blackgum and dogwood decreased in importance on DBSM and DBST whereas red maple generally increased. Following both burns on GWWS, sassafras, chestnut oak and scarlet oak importance increased whereas that of huckleberry and mountain laurel decreased.

Only one of the burns significantly reduced both litter and duff depths. Fires that reduce these layers may be necessary to kill regenerative basal buds and, in turn, reduce

post-burn sprouting of hardwood and shrub species (Kauffman and Martin 1990; Armour et al. 1984). Eliminating deep litter and duff layers, such as those observed on my field sites, probably will be difficult with a single prescribed burn. Several decades of fire suppression likely have allowed litter and duff to accumulate. Fast moving, high intensity head fires, flanking fires and ring fires may not be effective in removing these layers. However, fires of this intensity were not tested in this study.

Although yellow pine regeneration was the goal of this study, I observed pine regeneration only on the GWWS fall burn site and PSGF. Prescribed burning reduced ground layer cover and litter depth on PSGF but not duff depth. Table mountain pine seedlings on PSGF germinated on a seedbed of duff and, although not measured, they may desiccate before their radicals reach mineral soil. In contrast, emerging radicals of germinating pitch pine seeds had a greater chance of encountering mineral soil on the GWWS fall burn site due to significant reductions in ground layer cover, litter depth and duff depth. Such results are similar to those obtained by Sanders (1992) following the 1986 Bote Mountain Fire in the Great Smoky Mountains National Park, Tennessee. He observed the greatest proportion of table mountain pine seedlings (96%) in high and moderate burn areas where the forest canopy was open and mineral soil was exposed.

In summary, extensive midstory and understory vegetation and deep litter and duff layers exist in southern Appalachian yellow pine forests most likely due to years of fire suppression practices. Prescribed burns of higher intensity and severity than those observed in this study are probably necessary to reduce this competing vegetation as well as to expose mineral soil. Prescribed burns that do not accomplish these goals probably will not restore yellow pine forests and may actually encourage succession towards hardwood-dominated stands by increasing the number of hardwood stems present in the stand through sprouting.

Recommendations for Future Measurements

Ecosystem management programs targeted at regenerating southern Appalachian yellow pines should include monitoring of several pre- and post-burn variables. The sample plots used for monitoring should be more numerous than those used in this study. The appropriate number of sample plots will vary with the area of the stand being burned. However, plot location must capture the range of topography of the given stand. Fire behavior is not predictable. Therefore, the more plots located throughout the burn area the greater the probability of sampling the complete range of post-burn conditions. For example, the spring fire on the PSGF reached its greatest intensity outside of the area where we had established sample plots. Since plots were not located within these high-intensity areas, the post-burn data set did not represent the complete range of post-burn conditions and most likely underestimated the effectiveness of the burn on opening the forest canopy. Furthermore, we selected the plot size used in this study to emphasize changes in the overstory because high-intensity fires were expected. With the resulting fires, the majority of changes occurred in the understory and ground layers where the fewest data were collected.

The day of the burn, many ceramic tiles with Templaq© paints should be placed within each plot. Estimations from one tile are not sufficient at capturing variations in temperature. Furthermore, I suggest acquiring direct measurements of fuel moisture with a moisture probe in addition to using fuel moisture sticks. Fuel moisture sticks measure small woody fuels but miss an important variable, the moisture content of the litter. In addition, crown scorch should be estimated soon after burning and post-burn data collection should be conducted after pine seedfall.

Pre- and post-burn monitoring data will allow federal land managers to assess the effectiveness of each prescribed burn. Analysis of pre-burn data will suggest the degree of hardwood encroachment in the midstory and understory size classes. If it is significant, prescriptions may require repeated burning to open the forest canopy. Following the fire, the success of canopy reduction and exposure of mineral soil must be assessed from the post-burn data. Finally, survival of yellow pine seedlings must be monitored over several growing seasons. Particularly, survival of seedlings that germinated on mineral soil should be compared to those that germinated on duff.

CHAPTER VI

EFFECTS OF PRESCRIBED BURNING ON SOIL NUTRIENT CONTENT

Introduction

Burning can have both positive and negative effects on the physical and chemical properties of forest soils depending upon the intensity and severity of the fire. Physical properties such as soil temperature and water holding capacity generally increase following burning. Soil temperature increases after low, moderate and high intensity burning by direct heating of the fire. Increased radiant energy reaching the soil, due to reduced litter and duff depths and opened canopy conditions, also increase soil temperature. Soil warming improves conditions for microbial activity and nutrient uptake (Swift et al. 1993; Barbour et al. 1987; Viro 1974). In pine forests, water holding capacity and wetability of mineral soils generally is enhanced by volatilization of hydrophobic monoterpenes (Swift et al. 1993; Groeschl et al. 1991; Barbour et al. 1987).

Chemical properties of the soil, such as pH and nutrient concentrations, also benefit from low- to moderate-intensity and severity burns. Soil pH is higher following a fire by virtue of the release of mineral bases in soluble ash (Groeschl et al. 1991; Barbour et al. 1987). Soil nutrient concentrations increase after burning as a result of ash deposition, increased decomposition rates, increased mineralization rates, and alteration of soil ion exchange properties (Knoepp and Swank 1993; Vose and Swank 1993; Groeschl et al. 1991; Christensen 1987).

High-intensity and high-severity burns may negatively influence soil physical and chemical properties. In especially intense fires on sloping terrain, increased erosion and

reduced infiltration occur if both litter and duff layers are removed (Robichaud and Waldrop 1994; Stone et al. 1994). Conversely, erosion is not prevalent when litter and duff layers remain intact (Swift et al. 1993). Soil nutrients sometimes are lost through leaching and volatilization following high-intensity and high-severity burns (Knoepp and Swank 1993; Christensen 1987).

Successful regeneration of southern Appalachian yellow pines requires moderate intensity fires to open the forest canopy and moderate severity fires to remove the litter layer and reduce the duff layer (Chapter V this dissertation). As interest in restoring these pine communities with prescribed burning increases, there is concern as to the effects of such fires on the soils of these forests. The purpose of this study is to ascertain the effects of prescribed burning on soil pH, organic matter, and macronutrient concentrations. I hypothesize that soil pH and nutrient concentrations both will increase following prescribed burning and that soil organic matter concentrations will decrease.

Methods

Field Sampling and Chemical Analysis

In the growing season both prior to and following burning, I collected the top 10-cm of soil from the center of each sample plot. I sieved each sample to pass a 2-mm screen and allowed it to air dry. The University of Maine Soil Testing Service and Analytical Lab, Orono, Maine, analyzed the samples for pH and macronutrient content. They measured pH with a glass electrode and soil organic matter as percent loss upon ignition at 500°C. The lab determined extractable (available) Ca, K, Mg, and P with plasma emission following extraction with pH 4.8 ammonium acetate [Modified Morgan extraction method

(Anonymous 1996)]. Lastly, technicians estimated cation exchange capacity by summation of exchangeable acidity and extractable Ca, K, Mg and acidity.

Data Analysis

I averaged both pre-burn and post-burn plot values for each variable to obtain mean values for each study area. Next, I compared pre-burn and post-burn means with paired t-tests. I also assessed the relationships within both pre-burn and post-burn soil variables using Pearson product-moment correlation coefficients for each burn site (SAS 1994; Zar 1973).

Results

Pre-burn soils from all sites were acidic (Table 34). Pre-burn CEC (cation exchange capacity) averaged 3.7 meq/100g. CEC correlated positively with soil organic matter on all sites and significantly so on GWWS, DBST and CHTL (Table 35). Base cations correlated positively with soil organic matter on PSGF and DBST and significantly so on GWWS and CHTL. Base cations correlated positively with pH on DBSM. Pre-burn macronutrient concentrations were similar for all study sites and concentrations of nutrients in the extractable soil pool were in the order of K>Ca>Mg>P for GWWS, CKHW, PSGF and CHTL and Ca>K>Mg>P for GWWY, DBSM and DBST.

Following burning, percent soil organic matter and concentrations of K decreased on the DBSM. Ca correlated positively with both organic matter and pH and Mg correlated positively with organic matter. On the DBST, concentrations of K increased following the fire and both the base cations and CEC correlated positively with organic matter. Both the

Table 34. Chemical properties of pre-burn and post-burn soils. Values given are means ± 1 standard error. CEC=cation exchange capacity.

Variable	Pre-Burn	Post-Burn
GWWS Fall Burn		
pH	3.8±0.1	4.0±0.1
Organic Matter (%)	4.9±0.7	3.2±0.5
Ca (mg/kg)	26.5±8.3	19.1±2.3
K (mg/kg)	41.3±3.6	43.5±3.0
Mg (mg/kg)	14.4±2.7	10.0±1.3
P (mg/kg)	3.4±0.3	*2.3±0.2
CEC (meq/100g)	3.8±0.3	3.3±0.3
GWWS Spring Burn		
pH	3.6±0.1	*3.9±0.1
Organic Matter (%)	5.8±0.4	*4.1±0.6
Ca (mg/kg)	16.5±2.6	21.6±5.1
K (mg/kg)	47.4±5.7	53.3±7.8
Mg (mg/kg)	12.7±1.4	14.0±2.7
P (mg/kg)	3.2±0.1	*2.3±0.1
CEC (meq/100g)	4.2±0.2	2.1±0.3
GWWY Spring Burn		
pH	4.0±0.0	-----
Organic Matter (%)	7.2±0.6	-----
Ca (mg/kg)	92.6±9.0	-----
K (mg/kg)	72.4±6.5	-----
Mg (mg/kg)	31.7±3.9	-----
P (mg/kg)	7.2±0.4	-----
CEC (meq/100g)	4.3±0.1	-----
DBSM Spring Burn		
pH	4.2±0.1	4.4±0.1
Organic Matter (%)	6.2±0.7	*3.6±0.2
Ca (mg/kg)	119.9±33.2	129.6±31.6
K (mg/kg)	53.9±4.4	*38.4±2.2
Mg (mg/kg)	15.0±2.0	16.5±2.1
P (mg/kg)	4.7±0.4	4.8±0.3
CEC (meq/100g)	3.6±0.2	3.2±0.2

Table 34 (continued).

Variable	Pre-Burn	Post-Burn
DBST Spring Burn		
pH	4.0±0.1	4.0±0.1
Organic Matter (%)	5.1±0.7	5.2±0.7
Ca (mg/kg)	52.1±9.8	77.3±18.7
K (mg/kg)	37.1±5.0	*59.0±7.1
Mg (mg/kg)	18.2±2.6	21.5±2.8
P (mg/kg)	6.2±0.7	5.3±0.6
CEC (meq/100g)	3.7±0.2	4.0±0.2
CKHW Spring and Fall Burn		
pH	4.2±0.2	-----
Organic Matter (%)	6.0±0.7	-----
Ca (mg/kg)	144.1±71.2	-----
K (mg/kg)	588.9±4.4	-----
Mg (mg/kg)	24.6±5.9	-----
P (mg/kg)	4.6±0.3	-----
CEC (meq/100g)	4.0±0.3	-----
PSGF Spring Burn		
pH	4.1±0.0	4.0±0.1
Organic Matter (%)	4.5±0.7	3.7±0.3
Ca (mg/kg)	11.8±3.3	16.5±3.9
K (mg/kg)	41.3±9.0	50.5±3.2
Mg (mg/kg)	7.0±1.4	11.3±2.0
P (mg/kg)	3.1±0.4	3.1±0.4
CEC (meq/100g)	3.2±0.1	3.7±0.2
PSGF Fall Burn		
pH	4.0±0.1	-----
Organic Matter (%)	5.4±0.5	-----
Ca (mg/kg)	10.8±1.7	-----
K (mg/kg)	35.8±4.9	-----
Mg (mg/kg)	7.7±0.8	-----
P (mg/kg)	3.0±0.2	-----
CEC (meq/100g)	3.5±0.1	-----

Table 34 (continued).

Variable	Pre-Burn	Post-Burn
CHTL Spring Burn		
pH	4.2±0.1	-----
Organic Matter (%)	7.5±0.7	-----
Ca (mg/kg)	16.4±4.2	-----
K (mg/kg)	51.3±4.5	-----
Mg (mg/kg)	14.3±2.8	-----
P (mg/kg)	4.2±0.3	-----
CEC (meq/100g)	3.2±0.2	-----

*Pre- and post-burn values are significantly different at $P<0.05$.

Table 35. Correlations of pre-burn and post-burn soil variables. Values given are Pearson product-moment correlation coefficients. Abbreviations are as follows: OM=organic matter, CEC=cation exchange capacity.

	Pre-Burn						Post-Burn					
GWWS Fall Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	*-0.70						*-0.71					
Ca	*-0.51	0.46					*-0.81	0.20				
K	-0.04	*0.53	0.04				-0.51	0.11	0.55			
Mg	*-0.64	*0.50	*0.87	0.24			*-0.95	0.68	*0.80	0.33		
P	-0.36	*0.56	0.35	0.39	*0.53		-0.39	0.18	0.48	0.29	0.43	
CEC	-0.97	*0.80	*0.64	0.21	*0.77	0.45	*-0.99	*0.77	*0.76	0.47	*0.96	0.42
GWWS Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	*-0.70						*-0.84					
Ca	*-0.51	0.46					*-0.71	0.52				
K	-0.04	*0.53	0.04				*-0.71	*0.66	0.45			
Mg	*-0.64	*0.50	*0.87	0.24			*-0.94	*0.81	*0.88	*0.73		
P	-0.36	*0.56	0.35	0.39	*0.53		-0.33	0.23	*0.78	0.27	0.55	
CEC	-0.97	*0.80	*0.64	0.21	*0.77	0.45	-0.99	*0.90	*0.72	*0.75	*0.96	0.36
GWWY Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	*-0.67						-----					
Ca	-0.04	0.11					-----	-----				
K	-0.14	-0.17	-0.28				-----	-----	-----			
Mg	-0.18	0.01	0.38	*0.66			-----	-----	-----	-----		
P	*-0.63	0.42	0.13	0.29	0.35		-----	-----	-----	-----	-----	
CEC	*-0.81	0.58	0.42	0.28	*0.63	*0.67	-----	-----	-----	-----	-----	-----

Table 35 (continued).

	Pre-Burn						Post-Burn					
DBSM Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	-0.51						0.64					
Ca	0.64	-0.16					0.63	*0.79				
K	0.38	0.25	0.46				0.36	0.61	0.35			
Mg	0.68	-0.22	*0.94	0.43			0.41	*0.73	*0.94	0.30		
P	-0.30	0.60	-0.14	0.59	-0.33		0.12	0.69	0.29	0.46	0.25	
CEC	-0.63	0.61	0.18	0.13	0.08	0.33	0.05	0.59	*0.80	0.24	*0.89	0.38
DBST Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	-0.51						-0.40					
Ca	0.13	0.46					0.07	0.55				
K	-0.01	0.34	*0.70				-0.21	*0.96	0.60			
Mg	-0.14	0.41	*0.87	*0.70			-0.11	*0.87	*0.74	*0.90		
P	-0.40	0.53	0.56	*0.64	*0.79		0.18	*0.70	0.58	*0.79	*0.82	
CEC	*-0.77	*0.67	0.50	0.54	*0.72	*0.78	*-0.70	*0.82	0.59	*0.75	*0.72	0.40
CKHW Fall and Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	*-0.59						-----					
Ca	*0.75	-0.21					-----	-----				
K	*0.55	0.12	*0.58				-----	-----	-----			
Mg	*0.74	-0.19	*0.88	*0.81			-----	-----	-----	-----		
P	0.05	0.18	-0.20	0.42	0.13		-----	-----	-----	-----	-----	
CEC	-0.01	0.45	*0.64	0.39	*0.53	-0.22	-----	-----	-----	-----	-----	-----

Table 35 (continued).

	Pre-Burn						Post-Burn					
PSGF Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	-0.30						0.08					
Ca	0.17	0.07					-0.02	*0.73				
K	0.30	0.20	*0.74				-0.28	0.26	0.59			
Mg	-0.39	0.45	*0.74	0.60			-0.62	0.49	0.62	*0.71		
P	-0.01	0.36	*0.66	*0.65	*0.76		-0.22	*0.85	*0.71	0.44	0.30	
CEC	*-0.91	0.43	0.15	0.02	*0.69	0.39	*-0.93	0.21	0.35	0.42	*0.83	0.49
PSGF Fall Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	-0.30						-----					
Ca	0.17	0.07					-----	-----				
K	0.30	0.20	*0.74				-----	-----	-----			
Mg	-0.39	0.45	*0.74	0.60			-----	-----	-----	-----		
P	-0.01	0.36	*0.66	*0.65	*0.76		-----	-----	-----	-----	-----	
CEC	*-0.91	0.43	0.15	0.02	*0.69	0.39	-----	-----	-----	-----	-----	-----
CHTL Spring Burn												
	pH	OM	Ca	K	Mg	P	pH	OM	Ca	K	Mg	P
OM	*-0.79						-----					
Ca	*-0.59	*0.77					-----	-----				
K	-0.45	*0.74	*0.56				-----	-----	-----			
Mg	*-0.74	*0.88	*0.95	*0.70			-----	-----	-----	-----		
P	*-0.53	*0.80	*0.62	*0.93	*0.78		-----	-----	-----	-----	-----	
CEC	*-0.96	*0.87	*0.75	*0.57	*0.89	*0.68	-----	-----	-----	-----	-----	-----

*Significant correlation at $P<0.05$.

fall and spring burns on the GWWS lowered P concentrations. Spring burning appeared to decrease organic matter as well on this site. Mg correlated positively with organic matter following both burns as did K following the spring burn. There were no significant changes in nutrient concentrations following burning on the PSGF and Ca correlated positively with organic matter. There were no changes in the order of nutrient concentrations in the post-burn extractable soil pool for any of the study sites.

Discussion

Soils of the study sites are acidic with pH values comparable to soils supporting pitch pine and table mountain pine forests of the Shenandoah National Park, Virginia (Groeschl et al. 1991) and early and mid-successional hardwood stands from the central Appalachian region (Gilliam et al. 1994). Several factors contribute to the acidity of the soils supporting yellow pine forests. First, decomposition of pine litter, weathering of parent material (acidic shale and sandstone), and leaching contribute to the acidic nature of these soils (Knoepp and Swank 1994). Furthermore, the southern Appalachian region receives very acidic precipitation (Binkley et al. 1989). The National Atmospheric Deposition Program (1994) reports average pH for wet deposition in 1993 to be between 4.5 and 4.3 for the region. Such values are second only to industrial areas of the northeastern and north central United States (SAMAB 1996c).

Similar to the results of Knoepp and Swank (1994) and White et al. (1988), soils of these pine forests are oligotrophic. Soils from shortleaf pine stands (DBSM and DBST) are higher in Ca content compared to those from pitch pine (GWWS) and table mountain pine (PSGF and CHTL) stands. Cation exchange capacity (CEC) was on the low end of the 0.10 to 40.00 meq/100g scale reported by Black (1968).

Acidic, nutrient poor Ultisols and Inceptisols of southern Appalachian yellow pine forests are highly weathered (Buol et al. 1989). The negative correlations of base cations and P with pH suggest that further weathering of parent material contributes little to the soil nutrient pool. Instead, positive correlations between soil organic matter and all macronutrients suggest that nutrients leached from organic matter provide the primary control over soil fertility in these forests (Gilliam and Roberts 1992). Working in an oak-hickory watershed of the Coweeta Hydrologic Laboratory, Otto, North Carolina, Qualls and Haines (1992) also demonstrated the importance of organic matter to the nutrient status of southern Appalachian soils. Field and laboratory manipulations showed that the A horizon of these soils absorbs large quantities of dissolved organic matter leached from the forest floor and the forest canopy (Qualls and Haines 1992). Subsequently, this dissolved organic matter undergoes slow biological mineralization. Thus, dissolved organic matter is important to cation exchange capacity and N concentrations in these soils.

These results suggest that prescribed burning to restore yellow pine habitat will not negatively affect forest soils. Prescribed burning did not affect the pH, soil nutrient content, or control of soil fertility. My hypothesis was incorrect. Soils remained acidic and there were no changes in the order of nutrient concentrations in the extractable soil pool. CEC and base cations remained positively correlated with soil organic matter suggesting that burning did not alter the influence of soil organic matter on soil fertility.

The fact that prescribed burning did not consistently increase either the pH or nutrient concentrations of these soils is surprising, especially for the two field sites where pine regeneration was successful following moderate intensity and moderate severity fires [GWWS (spring) and PSGF]. Another study of an intense, low to moderate severity prescribed burn in a southern Appalachian pitch pine forest reports increased nutrient availability following burning (Swift et al. 1993). My results suggest that the seedlings

growing on the post-burn GWWS (spring) and PSGF soils are not receiving the benefits of a post-burn nutrient flush afforded to most yellow pine seedlings that germinate following a fire.

CHAPTER VII

AVAILABILITY OF PRESCRIBED BURNING CONDITIONS IN THE SOUTHERN APPALACHIAN MOUNTAINS

Introduction

Preparing for and executing a successful prescribed burn on National Forest land is a time and labor intensive process. At minimum, an environmental assessment is completed for the burn area and a written burn plan explaining management goals and conditions under which a burn will be allowed is submitted and approved (USDA Forest Service 1991). Land managers then wait for a day meeting those required weather conditions.

Prescribed burning is conducted only on days that satisfy specific environmental conditions. On most southeastern National Forests, prescribed burning is permitted on days when relative humidity is between 30 and 55%, soils are damp, fine fuel moisture is between 10 and 20% and in-stand winds are between 1.6 and 4.8 km per hour (USDA Forest Service 1989). When canopy damage is undesirable, air temperatures during the burn should be below 16°C. If reducing canopy cover is a management goal, air temperatures should exceed 27°C to increase the likelihood of reaching internal plant tissue temperatures above 63°C, the average instantaneous lethal temperature for living tissue (USDA Forest Service 1989). Smoke management guidelines dictate that prescribed burns occur only when the air is slightly unstable or neutral, mixing heights are 520 to 1980 m, and transport wind speeds are 14.5 to 32.2 km per hour and blowing away from towns, cities and thoroughfares (USDA Forest Service 1989).

These parameters are designed to aid in containing prescribed fires and in meeting air quality standards. Yet, days with weather conditions meeting all of these parameters are rare. In addition to these regional parameters, each USDA Forest Service Ranger District has individual requirements for burning conditions. These include ecological, social, and economical parameters and further decrease the number of days available for prescribed burning. In spite of these restrictions, ecologists and USDA Forest Service policy call for increased use of prescribed burning. Will this be possible under current guidelines? This study estimates the number of days that were suitable for prescribed burning during the 1995 and 1996 burning seasons for each field site involved in this study.

Methods

I reviewed the National Interagency Fire Management Integrated Data Base, Fire Weather Observation files for this project. I obtained these data from the USDA Forest Service, Intermountain Research Station, Fire Behavior Unit, Missoula, Montana. From these data, I retrieved daily fine fuel moisture, maximum daily temperature, minimum daily temperature, and minimum daily relative humidity data gathered by the Weather Information Management System (WIMS) station located near and utilized by each study site to assess burning conditions. Those WIMS stations (identification number), followed by the appropriate study site, were Headquarters (440901) GWWS, Wythe (447501) GWWY, Somerset1 and Somerset2 (157001 and 157002) DBSM and DBST, Coker Creek (407502) CKHW, Grandfather (314201) PSGF, and Brasstown (90602) CHTL. I reviewed the data collected between March 1 and October 31,1995 and March 1 to October 31, 1996. The days I considered suitable for burning met the following subset of Forest Service specifications (USDA Forest Service 1989): fine fuel moisture $\geq$10 and $\leq$20%,

maximum daily temperature ≥15.6°C, minimum daily temperature >0°C, and minimum daily relative humidity ≥30 and ≤55%.

Results

The number of days per month for which all data were available varied between the sites (Table 36). Fine fuel moisture data were not available for PSGF. The GWWY WIMS station did not collect data between June 1 and September 30, 1995 and June 1 and October 31, 1996. Likewise, the PSGF WIMS station was inoperable between June 1 and September 30, 1995 and June 1 and August 31, 1996.

The average number of days per month meeting burning conditions on each site ranged from 2 to 9. In both 1995 and 1996, the average number of burning days per month was highest on DBSM followed decreasingly by PSGF, GWWS, CHTL, GWWY and CKHW. In 1995, burning days were most numerous during the months of May, June and October. In 1996, May, September and October provided the most burning opportunities.

Discussion

The four parameters I used to summarize these data are but a subset of the numerous parameters examined in burning decisions. I omitted parameters such as wind speed and wind direction because of inconsistencies in the reporting of these data between sites. In addition, many of the parameters I omitted were site specific. For example, each Ranger District must make sure that winds are of sufficient speed and direction to carry

Table 36. Number of days meeting prescribed burning parameters for the 1995 and 1996 burning seasons. Values in parentheses are the number of days with complete data for that month. Abbreviations are as follows: GWWS=George Washington and Jefferson National Forest, Warm Springs Ranger District, DBSM=Daniel Boone National Forest, Somerset Ranger District, DBST=Daniel Boone National Forest, Stearns Ranger District, CKHW=Cherokee National Forest, Hiwassee Ranger District, PSGF=Pisgah National Forest, Grandfather Rager District, CHTL=Chattahoochee National Forest, Tallulah Ranger District,

National Forest	Month							
	March	April	May	June	July	August	September	October
1995								
GWWS	5(29)	3(30)	9(30)	10(26)	6(23)	0(25)	3(29)	13(26)
GWWY	2(31)	6(30)	5(15)	-----	-----	-----	-----	3(29)
DBSM	3(31)	8(30)	12(31)	6(30)	12(31)	6(31)	10(30)	15(31)
CKHW	4(31)	6(30)	5(26)	2(10)	0(12)	0(18)	0(27)	6(31)
PSGF	2(31)	7(30)	10(14)	-----	-----	-----	-----	8(17)
CHTL	0(31)	1(30)	7(31)	14(29)	5(29)	4(31)	5(30)	2(31)
1996								
GWWS	0(31)	1(30)	3(31)	7(30)	7(31)	13(31)	8(30)	7(17)
GWWY	1(31)	3(30)	3(15)	-----	-----	-----	-----	-----
DBSM	2(31)	6(30)	5(31)	3(30)	3(31)	26(31)	20(30)	9(31)
CKHW	2(31)	4(30)	5(31)	1(28)	1(23)	0(22)	0(18)	5(21)
PSGF	2(25)	6(30)	14(29)	-----	-----	-----	11(16)	7(17)
CHTL	1(31)	3(30)	8(30)	5(27)	1(31)	10(31)	8(25)	10(30)

smoke away from town, cities, and thoroughfares. This wind direction is different for each study site and makes comparisons between sites difficult.

The limits I used for fine fuel moisture and relative humidity were the same as those suggested by *A Guide for Prescribed Fire in Southern Forests* (USDA Forest Service 1989). The limits for maximum daily temperature and minimum daily temperature were more specific to this study. Fires with the intent of regenerating southern Appalachian yellow pines must reduce overstory and understory canopy cover. To achieve this, active plant tissues must reach temperatures greater than 63°C in order to kill the vegetation (USDA Forest Service 1989). Therefore, I selected a minimum daily temperature limit of 0°C to insure that plant tissues were not dormant and a maximum daily temperature limit of 15°C to increase the likelihood that lethal internal temperatures could be reached during a fire.

There was a great deal of spatial and temporal variation in the availability of burning days. Overall, prescribed burning parameters were met most often on DBSM and least often on CKHW. Late spring and early fall months appeared as the best times for prescribed burning in the southern Appalachian region. Because understory hardwoods are susceptible to lethal damage during late spring months, burning at this time could benefit yellow pine regeneration.

Of the ten prescribed burns proposed at the beginning of this research, only five successfully occurred (Chapter V; this dissertation). The number of days meeting my subset of burning conditions did not differ greatly between those sites where burning did occur versus those sites where burning did not occur. For example, spring burning was successful on both the DBSM and GWWS even though the availability of burning days was much greater on the DBSM (twenty-three days from March to May 1995) compared to the GWWS (four days from March to May 1996). The number of days suitable for

burning on those sites where burning did not take place ranged from five to twenty-three per burn season. These results suggest that availability and readiness of personnel, equipment and funding, and social concerns over the use of prescribed burning may have greater influences on burning decisions than do weather conditions.

Regardless of the study site, days meeting my subset of prescribed burning parameters were limited. However, fine fuel moisture, maximum daily temperature, minimum daily temperature and minimum relative humidity are by no means all of the factors considered when executing prescribed burning operation. If all required variables were considered, the number of days suitable for prescribed burning in 1995 and 1996 would be fewer than those reported here. More importantly, this study summarizes these data after the fact. Predicting good days for burning is extremely difficult.

Finally, current guidelines for prescribed burning were developed in the Atlantic Coastal Plain region of the United States. Differences in topography, vegetation and weather between the Atlantic Coastal Plain and the southern Appalachian Mountains are dramatic and make application of current prescribed burning parameters difficult in montane yellow pine forests. With no physical boundaries to stop an advancing fire, prescribed burning on the Atlantic Coastal Plain depends largely upon atmospheric variables, such as wind speed, fuel moisture and relative humidity, to control the rate of spread of a fire. In mountainous terrain, topographic barriers such as ridge lines, streams, and changes in aspect are often more important than atmospheric conditions in containing a prescribed fire.

CHAPTER VIII

CONCLUSIONS

We must first understand the ambiguous concept of ecosystem management before we can prescribe fires of sufficient intensity and severity for regenerating yellow pines. The USDA Forest Service defines ecosystem management as "a concept of natural resources management wherein National Forest activities are considered within the context of economic, ecological, and social interactions within a defined area or region over both short and long term" (Thomas and Huke 1996). To most, this definition is open-ended and confusing (Fedkiw 1997; More 1997; Czech 1995; Gerlach and Bengston 1994). Perhaps the uncertainty of ecosystem management arises because it is not a set process (Tarver 1995). Ecosystem management requires land managers to take a generalist approach (Marcin 1995) to broad-scale spatial (Toman and Ashton 1996; Lucier 1994) and temporal (Ward and Huke 1996; Lucier 1994) plans. In addition, ecosystem management challenges land managers to meet the needs of current as well as future generations (Lucier 1994) while maintaining forest health, diversity and productivity (Thomas and Huke 1996).

Another factor confounding the use of prescribed fire in forest management is the notion of "desired future conditions." Who will decide what forest types should cover the southern Appalachian landscape? To what extent should yellow pine forests occupy this landscape? Human emotions and social concerns ultimately will drive these decisions (Sedjo 1996; Salwasser 1994; Huck 1985). Proper decisions, however, should weigh the past and present ecology of yellow pine forests. Prehistoric and historic burning for hunting, grazing, and agriculture maintained yellow pine habitat (Chapter II; this

dissertation). Indeed, macroscopic charcoal from past fire occurrences is buried in the soils of these forests (Chapter IV; this dissertation).

This report provides many details of the ecology of southern Appalachian yellow pine forests necessary for developing ecosystem management plans for these forests. Most importantly, land managers must realize that the ecology of these systems has changed through many decades of fire suppression. At the time of their inception, suppression and exclusion initiatives benefited the landscape. Federal land acquisition occurred during a period when uncontrolled wildfires raged throughout the eastern United States, especially in the Great Lakes region. When the USDA Forest Service acquired public lands, commercial logging and grazing as well as frequent wildfires had degraded the southern Appalachian landscape. Also, destructive logging, slash fires and fuels buildup from dying American chestnuts made it evident that protection from wildfire was an essential step in responsible forest management.

But suppression efforts probably have changed the structure of southern Appalachian yellow pine forests. While species composition remains generally unchanged, some shifts in dominance are inevitable through forest succession. Yellow pines prevail in the overstories of my study areas but they share canopy dominance with chestnut and scarlet oak (Chapter V; this dissertation). Midstories are dense and contain hardwood species, such as chestnut oak, scarlet oak and red maple. Hardwood components also predominate understory layers of increased cover and density. Dense midstory and understory vegetation shade a forest floor covered in thick layers of litter and duff. As a result, hardwood regeneration is successful whereas pine regeneration is not.

Increased hardwood dominance in the understory has changed the way yellow pine forests respond to fire. Historic fires may have maintained open understories in these forests but prescribed burns today could increase midstory and understory density and

ultimately close the forest canopy if they are too low in intensity, severity and frequency. Prescribed burns of moderate intensity opened the forest overstory but encouraged sprouting of understory hardwood species (Chapter V; this dissertation). In addition, only sparse pine regeneration occurred following such burns. Restoration of yellow pine forests probably will require repeated fires of moderate to high intensity and moderate severity to open the forest canopy, lessen hardwood competition, and expose mineral soil. These fires must remove the thick litter and duff layers that cover the forest floor and protect the regenerative basal buds of hardwoods. Burning that removes these layers will expose regenerative basal buds to lethal temperatures and prevent sprouting of understory and shrub layer species. Likewise, pines that regenerate on mineral soil will be more likely to avoid desiccation and survive than those that regenerate on duff. Prescribed burns that do not promote understory reduction and pine regeneration may further increase hardwood dominance of the understory and, in turn, speed succession toward hardwood-dominated stands.

Prescribed burning did not degrade the nutrient content of the acidic, oligotrophic soils of my study areas. Burning did not change soil pH, soil nutrient content, or the influence of soil organic matter on soil fertility (Chapter VI; this dissertation). These results are from four low-severity burns and one moderate-severity burn. Since yellow pine regeneration likely requires moderate- to high-severity fires, more research is needed to determine the effects of such fires on soil nutrients as well as on soil erosion.

Prescribed burning must become more accessible to southern Appalachian land managers before restoration of yellow pine habitat can be successful. The number of days meeting current prescribed burning weather parameters are very rare and occur during late spring and early fall months of the year (Chapter VII; this dissertation). This is not surprising because current burning parameters were not designed for montane regions of

the southeastern United States. There is a great need for a set of prescribed burning parameters specific to the southern Appalachian Mountains.

Other political and economic factors such as availability of funding and personnel for burns limit proactive fire initiatives. Successful ecosystem management requires long-term stability in policy and funding (Gerlach and Bengston 1994; Irland 1994). These two elements are especially important to fire management. Moderate intensity and severity prescribed burning is expensive. Inconsistencies in funding can greatly limit the success of burning programs. Prescribed burning also involves risks to life, property and natural resources (Babbit 1995; Johnson 1984). Land managers not willing to accept those risks will further prohibit the use of fire in southern Appalachian forests.

Most importantly, successful restoration of yellow pine habitat using prescribed fire will require public involvement and education. Since wildfire is not common in the southern Appalachian region, land managers find it difficult to convince the public that fire is beneficial to fuel reduction (McLean 1995; Manfredo et al. 1990; Huck 1985). The general public does not understand that fire restores balance to these fire-dependent ecosystems (Mutch 1994; Huck 1985). Instead, there seems to be a fear of fire and general a lack of trust in federal land managers (Sampson 1995; Reeves 1989). To change these perceptions, local media should cover prescribed burning operations, and, more importantly, explain why they are taking place (Beebe and Omi 1993). Resolving these differences in ideals will require not only education programs for future generations, but also conflict management programs for current residents. Prescribed burning operations cannot wait for total public acceptance of fire in the forests. Land managers must proceed with ecosystem management programs targeted at restoring yellow pine habitat.

LITERATURE CITED

Abrams, M.D. and G.J. Nowacki. 1992. Historical variation in fire, oak recruitment, and post-logging accelerated succession in central Pennsylvania. Bulletin of the Torrey Botanical Club **119**:19-28.

Anonymous. 1996. Recommended Soil Testing Procedures for the Northeastern US. 2nd ed. University of Delaware Experiment Station Bulletin 493.

Armour, C.D., S.C. Bunting, and L.F. Neuenschwander. 1984. Fire intensity effects on the understory in ponderosa pine forests. Journal of Range Management **37**:44-48.

Arno, S.F. 1996. The concept: restoring ecological structure and process in ponderosa pine forests. pp. 37-38. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Res. Station General Technical Report INT-GTR-341.

Babbitt, B. 1995. To take up the torch. American Forests **101**:17-18.

Barbour, M. 1988. Californian upland forests and woodlands. pp. 131-164. In: M. Barbour and W.D. Billings [Eds.], The terrestrial vegetation of North America. Cambridge University Press, London.

Barbour, M.G., J.H. Burk, and W.D. Pitts. 1987. Terrestrial plant ecology. 2nd ed. The Benjamin/Cummings Publ. Co., Inc., Menlo Park, California.

Barden, L.S. 1978. Serotiny and seed viability of *Pinus pungens* Lam. in the southern Appalachian Mountains. Castanea **44**:44-47.

Barden, L.S. 1977. Self-maintaining populations of *Pinus pungens* Lam. in the southern Appalachian Mountains. Castanea **42**:316-323.

Beebe, G.S. and P.N. Omi. 1993. Wildland burning: the perception of risk. Journal of Forestry **91**:19-24.

Binkley, D., C.T. Driscoll, H.L. Allen, P. Schoeneberger, and D. McAvoy. 1989. Acidic deposition and forest soils. Springer-Verlag, New York.

Black, C.A. 1968. Soil-plant relationships. John Wiley and Sons, Inc., New York.

Boggs, J.A. and R.F. Wittwer. 1993. Emergence and establishment of shortleaf pine seeds under various seedbed conditions. Southern Journal of Applied Forestry **17**:44-48.

Brennan, L.A. and S.M. Hermann. 1994. Prescribed fire and forest pests: solutions for today and tomorrow. Journal of Forestry **92**:34-37.

Brown, J.K., E.D. Reinhardt, and W.C. Fischer. 1991. Predicting duff and woody fuel consumption in northern Idaho prescribed fires. Forest Science **37**:1550-1566.

Buckner, E.R. 1989. The changing landscape of eastern North America. pp. 55-59. In: 100 years of professional forestry, Proceedings of the Appalachian Society of American Foresters, 71st Annual Meeting, Asheville, North Carolina.

Buol, SW., F.D. Hole, and R.J. McCracken. 1989. Soil genesis and classification. 3rd ed. Iowa State University Press, Ames Iowa.

Cain, M.D. and M.G. Shelton. 1995. Thirty-eight years of autogenic, woody understory dynamics in a mature, temperate pine-oak forest. Canadian Journal of Forest Research **25**:1997-2009.

Chapman, J. 1985. Tellico Archaeology: 12,000 years of native American history. Report No. 43. Dept. of Anthropology. The University of Tennessee, Knoxville, Tennessee.

Christensen, N.L. 1988. Vegetation of the southeastern Coastal Plain. pp. 317-363. In: M. Barbour and W.D. Billings [Eds.], The terrestrial vegetation of North America. Cambridge University Press, London.

Christensen, N.L. 1987. The biogeochemical consequences of fire and their effects on the vegetation of the Coastal Plain of the southeastern United States. pp. 1-23. In: L. Trabaud [Ed.], The role of fire in ecological systems. Academic Publishing, The Hague, The Netherlands.

Clark, J.S. and P.D. Royall. 1995. Particle-size evidence for source areas of charcoal accumulations in Late Holocene sediments of eastern North American lakes. Quaternary Research **43**:80-89.

Collins, S.L. and R.E. Good. 1987. The seedling regeneration niche: habitat structure of tree seedlings in an oak-pine forest. Oikos **48**:89-98.

Czech, B. 1995. Ecosystem management is no paradigm shift. Journal of Forestry **93**:17-23.

Davidson, J.L. 1983. Paleoecological analysis of Holocene vegetation, Lake in the Woods, Cades Cove, Great Smoky Mountains National Park. Master's Thesis. The University of Tennessee, Knoxville, Tennessee.

Delcourt, P.A. and H.R. Delcourt. 1987. Long-term forest dynamics of the temperate zone. Springer Verlag, New York.

Delcourt, P.A. and H.R. Delcourt. 1997. Pre-Columbian Native American use of fire on southern Appalachian landscapes. Conservation Biology **11**:1010-1014.

Delcourt, H.R. and P.A. Delcourt. 1991. Quaternary ecology, a paleoecological perspective. Chapman Hall, New York.

Della-Bianca, L. 1990. *Pinus pungens* Lamb., Table Mountain Pine. In: R.M. Burns and B.H. Honkala [Eds.], Silvics of North America. Vol. 1, Conifers. USDA Forest Service Agriculture Handbook 654.

DeVivo, M.S. 1991. Indian use of fire and land clearance in the Southern Appalachians. pp. 306-312. In: S.C. Nodvin and T.A. Waldrop [Eds.], Fire and the environment: ecological and cultural perspectives. USDA Forest Service Southeastern Forest Experiment Station General Technical Report SE-69.

Dobyns, H.F. 1983. Their numbers become thinned. The University of Tennessee Press, Knoxville, Tennessee.

Ehle, J. 1988. Trail of Tears: the rise and fall of the Cherokee Nation. Anchor Books/Doubleday, Inc., New York.

Fedkiw, J. 1997. The Forest Service's Pathway toward ecosystem management. Journal of Forestry **95**:30-34.

Fenneman, N.M. 1938. Physiography of eastern United States. McGraw Hill Pub. Co., Inc., New York.

Forman, R.T.T. and E.B. Russell. 1983. Evaluation of historical data in ecology. Bulletin of the Ecological Society of America **64**:5-7.

Gerlach, L.P. and D.N. Bengston. 1994. If ecosystem management is the solution, what's the problem? Journal of Forestry **92**:18-21.

Gilliam, F.S. and M.R. Roberts. 1990. Nutrient changes in soils of successional forests of northern lower Michigan. Bulletin of the Ecological Society of America **71**:165-166.

Gilliam, F.S. and N.L. Turrill. 1993. Herbaceous layer cover and biomass in a young versus a mature stand of a central Appalachian hardwood forest. Bulletin of the Torrey Botanical Club **120**:445-450.

Gilliam, F.S., N.L. Turrill, S.D. Aulick, D.K. Evans, and M.B. Adams. 1994. Herbaceous layer and soil response to experimental acidification in a central Appalachian hardwood forest. Journal of Environmental Quality **23**:835-844.

Good, R.E. and N.F. Good. 1984. The Pinelands National Reserve: an ecosystem approach to management. BioScience **34**:169-173.

Goudsblom, J. 1992. Fire and civilization. Penguin Books, New York.

Groeschl, D.A., J.E. Johnson, and D.W. Smith. 1991. Forest soil characteristics following wildfire in the Shenandoah National Park, Virginia. pp. 129-137. In: S.C. Nodvin and T.A. Waldrop [Eds.], Fire and the environment: ecological and cultural perspectives. USDA Forest Service Southeastern Forest Experiment Station General Technical Report SE-69.

Guffey, S.Z. 1977. A review and analysis of the effects of pre-Columbian man on the eastern North American forests. Tennessee Anthropologist **2**:121-137.

Harmon, M. 1982. Fire history of the westernmost portion of the Great Smoky Mountains National Park. Bulletin of the Torrey Botanical Club **109**:74-79.

Harrington, M.G. 1996. Prescribed fire applications: restoring ecological structure and process in ponderosa pine forests. p. 41. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-341.

Harrod, J., P.S. White, and M.E. Harmon. 1997. Changes in xeric forests in western Great Smoky Mountains National Park, 1936-1995. Bulletin of the Association of Southeastern Biologists **44**: 104.

Hessl, A. and S. Spakman. 1995. Effects of fire on threatened and endangered plants: an annotated bibliography. USDI NBS Information and Technology Report 2.

Hidore, J.J. and J.E. Oliver. 1993. Climatology: an atmospheric science. MacMillian Pub. Co., Inc., New York.

Horn, S.P. and R.L. Sanford. 1992. Holocene fires in Costa Rica. Biotropica **24**:354-361.

Horn, S.P., T.R. Wallin, and L.A. Northrop. 1994. Nested sampling of soil pollen, charcoal, and other soil components using a root corer. Palynology **18**:87-89.

Huck, C. 1985. Burning the wilderness. American Forests **91**:13-16.

Irland, L.C. 1994. Getting from here to there: implementing ecosystem management on the ground. Journal of Forestry **92**:12-17.

Johnson, V.J. 1984. Prescribed burning: requiem or renaissance? Journal of Forestry **82**:82-90.

Kauffman, J.B. and R.E. Martin. 1990. Sprouting shrub response to different seasons and fuel consumption levels of prescribed fire in Sierra Nevada mixed conifer ecosystems. Forest Science **36**:748-764.

Keane, R.E. and S.F. Arno. 1996. Whitebark pine ecosystem restoration in western Montana. pp. 51-53. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-341.

Knoepp, J.D. and W.T. Swank. 1994. Site preparation burning to improve southern Appalachian pine-hardwood stands: nitrogen responses in soil, soil water, and streams. Canadian Journal of Forest Resources **23**:2263-2270.

Kolb, T.E., M.R. Wagner, and W.W. Covington. 1994. Concepts of forest health. Journal of Forestry **92**:10-15.

Komarek, E.V. 1974. Effects of fire on temperate forests and related ecosystems: southeastern United States. pp. 251-278. In: T.T. Kozlowski and C.E. Ahlgren [Eds.], Fire and ecosystems. Academic Press, New York.

Kurth, L.L. 1996. Examples of fire restoration in Glacier National Park. pp. 54-55. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-341.

Langdon, K. 1997. Great Smoky Mountains National Park, *personal communication.*

Ledig, F.T. and S. Little. 1979. Pitch pine (Pinus rigida Mill.): ecology, physiology, and genetics. pp, 347-372. In: R.T.T. Forman [Ed.], Pine Barrens: ecosystem and landscape. Academic Press, New York.

Leuschen, .TJ. 1996. Restoring fire to mixed conifer forests in the northern Cascades. p. 77. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-341.

Little, S. and P.W. Garrett. 1990. *Pinus rigida* Mill., Pitch Pine. In: R.M. Burns and B.H. Honkala [Eds.], Silvics of North America. Vol. 1, Conifers. USDA Forest Service Agriculture Handbook 654.

Lowe, J.J. 1984. Reconstructing quaternary environments. Longman Group Limited, New York.

Lucier, A.A. 1994. Criteria for success in managing forested landscapes. Journal of Forestry **92**:20-24.

Manfredo, M.J., M. Fishbein, G.W. Haas, and A.E. Watson. 1990. Attitudes toward prescribed fire policies. Journal of Forestry **28**:19-23.

Marcin, T.C. 1995. Integrating social sciences into forest ecosystem management research. Journal of Forestry **93**:29-33.

Maxwell, H. 1910. The use and abuse of forests by the Virginia Indians. William and Mary College Quarterly Historical Magazine **19**:73-103.

McGee, G.G., D.J. Leopold, and R.D. Nyland. 1995. Understory response to springtime prescribed fire in two New York transition oak forests. Forest Ecology and Management **76**:149-168.

McLean, H.E. 1995. Fighting fire with fire. American Forests **101**:13-16.

Meier, A.J. and S.P. Bratton. 1995. Disturbance dynamics in the Chattooga Watershed. USDA Forest Service, Chattooga River Demonstration Project, Clemson, South Carolina.

Mirov, N.T. 1967. The genus *Pinus*. The Roland Press Co., New York.

Moore, T.A. 1996. Forestry's fuzzy concepts: an examination of ecosystem management. Journal of Forestry **94**:19-23.

Mutch, R.W. 1994. Fighting fire with prescribed fire: a return to ecosystem health. Journal of Forestry **92**:31-33.

National Atmospheric Deposition Program. 1994. NADP/NTN annual data summary: precipitation chemistry in the United States, 1993. Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado.

Nowacki, G.J. and M.D. Abrams. 1992. Community, edaphic, and historical analysis of mixed oak forests of the Ridge and Valley Province in Central Pennsylvania. Canadian Journal of Forest Resources **22**:790-800.

Patterson, W.A., K.J. Edwards, and D.J. Maguire. 1987. Microscopic charcoal as a fossil indicator of fire. Quaternary Science Reviews **6**:3-23.

Pyne, S.J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, New Jersey.

Qualls, R.G. and B.L. Haines. 1992. Biodegradability of dissolved organic matter in forest throughfall, soil solution, and stream water. Soil Science Society of America Journal **56**:578-586.

Radford, A.E., H.E. Ahles, and C.R. Bell. 1968. Manual of the vascular flora of the Carolinas. The University of North Carolina Press, Chapel Hill, North Carolina.

Reeves, H.C. 1989. A better understanding of fire management. Journal of Forestry **87**:back cover.

Regelbrugge, J.C. and D.W. Smith. 1994. Postfire tree mortality in relation to wildfire severity in mixed oak forests in the Blue Ridge of Virginia. NJAF **11**:90-97.

Roberts, N. 1991. The Holocene: an environmental history. Basil Blackwell, Inc., Cambridge, Massachusetts.

Robichaud, P.R. and T.A. Waldrop. 1994. A comparison of surface runoff and sediment yields from low- and high-severity site preparation burns. Water Resources Bulletin **30**:27-34.

Russell, E.W.B. 1983. Indian-set fires in the forests of the northeastern United States. Ecology **64**:78-88.

Salwasser, H. 1994. Ecosystem management: can it sustain diversity and productivity? Journal of Forestry **92**:6-10.

Sampson, N. 1995. Prescribed burning: the smoking gun. American Forests **101**:19.

Sanders, G.L. 1992. The role of fire in the regeneration of Table Mountain Pine in the southern Appalachian Mountains. Master's Thesis, The University of Tennessee, Knoxville, Tennessee.

SAS. 1994. JMP® Statistics and Graphics Guide. SAS Institute Inc., Cary, North Carolina.

Sedjo, R.A. 1996. Toward an operational approach to public forest management. Journal of Forestry **94**:24-27.

Sieischab, F.K. and J.M. Bernard. 1991. Pitch pine (*Pinus rigida* Mill.) communities in central and western New York. Bulletin of the Torrey Botanical Club **118**:412-423.

Shaefer, V.J. 1974. Some physical relationships of fire particulate smoke. Proceedings of the 13th Annual Tall Timbers Fire Ecology Conference, pp. 303-307.

Shafer, D.S. 1984. Late-Quaternary paleoecologic, geomorphic, and paleoclimatic history of Flat Laurel Gap, Blue Ridge Mountains, North Carolina. Master's Thesis. The University of Tennessee, Knoxville, Tennessee.

Southern Appalachian Man and the Biosphere (SAMAB). 1996a. The Southern Appalachian Assessment Social/Cultural/Economic Technical Report. Report 4 of 5. Atlanta: USDA Forest Service, Southern Region.

Southern Appalachian Man and the Biosphere (SAMAB). 1996b. The Southern Appalachian Assessment Terrestrial Technical Report. Report 5 of 5. Atlanta: USDA Forest Service, Southern Region.

Southern Appalachian Man and the Biosphere (SAMAB). 1996c. The Southern Appalachian Assessment Atmospheric Technical Report. Report 3 of 5. Atlanta: USDA Forest Service, Southern Region.

Stone, S.L., A.B. Carraway, T.A. Waldrop, and P.R. Robichaud. 1995. Impacts of burning serverity on a southern Appalachian site. pp. 613-619. In: M.B. Edwards [Compl.], Proceedings of the Eighth Biennial Southern Silvicultural Research Conference. USDA Forest Service Southern Research Station General Technical Report SRS-1.

Sutherland, E.K., H. Grissino-Mayer, G.A. Woodhouse, W.W. Covington, S. Horn, L. Huckaby, R. Kerr, J. Kush, M. Moore, and T. Plumb. 1995. Two centuries of fire in a southwestern Virginia *Pinus pungens* community. In: Inventory and management techniques in the context of catastrophic events: Altered states of the forest (hypertext proceedings); 1993 University Park, Pennsylvania. Pennsylvania State University, Center for Statistical Ecology and Environmental Statistics.

Sutton, A. and M. Sutton. 1985. Eastern forests. Aldred A. Knopf, New York.

Swift, L.W., K.J. Elliot, R.D. Ottmar, and R.E. Vihnanek. 1993. Site preparation burning to improve Southern Appalachian pine-hardwood stands: fire characteristics and soil erosion, moisture, and temperature. Canadian Journal of Forest Resources **23**:2242-2254.

Tarver, C.M. 1995. Ecosystem management: giving it meaning. Journal of Forestry **93**:60.

Taylor, J.G. and T.C. Daniel. 1984. Prescribed fire: public education and perception. Journal of Forestry **82**:361-365.

Thomas, J.W. and S. Huke. 1996. The Forest Service approach to healthy ecosystems. Journal of Forestry **94**:14-18.

Toman, M.A. and M.S. Ashton. 1996. Sustainable forest ecosystems and management: a review article. Journal of Forestry **42**:366-377.

Turrill, N.L., E.R. Buckner, and T.A. Waldrop. (in press). *Pinus pungens* Lam. (table mountain pine): a threatened species without fire? Proceedings--Fire effects on rare and endangered species and habitats conference. International Association of Wildland Fire.

US Department of Commerce. 1968. Climatic atlas of the United States. Environmental Services Administration, Washington, DC.

USDA Forest Service 1996. Increasing programmatic accomplishments and reducing agency differences in prescribed fire management. Federal Fire and Aviation Leadership Council.

USDA Forest Service. 1991. Fire management. FSM 5100.

USDA Forest Service. 1989. A guide for prescribed fire in southern forests. Southern Region Technical Publication R8-TP-11.

USDA Forest Service. 1965. Silvics of forest trees of the United States. Agriculture handbook No. 271.

USDA and USDI. 1995. Federal wildland fire management: policy and program review.

USDA Soil Conservation Service. 1975. Soil taxonomy. Agriculture Handbook No. 436.

Vanderlinden, L.A. 1996. Applying stand replacement prescribed fire in Alaska. pp. 78-80. In: C.C. Hardy, S.F. Arno [Eds.], The use of fire in forest restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR-341.

VanLear, D.H. and T.A. Waldrop. 1989. History, use, and effects of fire in the Appalachians. USDA Forest Service Southeastern Forest Experiment Station General Technical Report SE-54.

Viro, P.J. 1974. Effects of forest fire on soil. pp. 7-46. In: T.T. Kowlowski and C.E. Ahlgren [Eds.], Fire and ecosystems. Academic Press, New York.

Vose, J.M. and W.T. Swank. 1993. Site preparation burning to improve southern Appalachian pine-hardwood stands: aboveground biomass, forest floor mass, and nitrogen and carbon pools. Canadian Journal of Forest Resources **23**:2255-2262.

Waldrop, T.A., D.L. White, and S.M. Jones. 1992. Fire regimes for pine-grassland communities in the southeastern United States. Forest Ecology and Management **47**:195-210.

Waterman, J.R., A.R. Gillespie, J.M. Vose, and W.T. Swank. 1995. The influence of mountain laurel in regeneration of pitch pine canopy gaps of the Coweeta Basin, North Carolina, USA. Canadian Journal of Forest Resources **25**:1756-1762.

Watts, W.A. 1979. Late Quaternary vegetation of central Appalachia and the New Jersey Coastal Plain. Ecological Monographs **49**:427-469.

White, D.L., B.L. Haines, and L.R. Boring. 1988. Litter decomposition in southern Appalachian black locust and pine-hardwood stands: litter quality and nitrogen dynamics. Canadian Journal of Forest Resources **18**:54-63.

Whittaker, R.H. 1979. Vegetational relationships of the pine barrens. pp. 315-332. In: R.T.T. Forman [Ed.], Pine Barrens: ecosystem and landscape. Academic Press, New York.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs **26**:1-80.

Williams, C.E. (in press). History and status of table mountain pine-pitch pine forests of the southern Appalachian Mountains. Proceedings Appalachian Biogeography Symposium. Virginia Museum Natural History.

Williams, C.E. and W.C. Johnson. 1992. Factors affecting recruitment of *Pinus pungens* in the southern Appalachian Mountains. Canadian Journal of Forest Resources **22**:878-887.

Williams, C.E. and W.C. Johnson. 1990. Age structure and the maintenance of *Pinus pungens* in pine-oak forests of southwestern Virginia. American Midland Naturalist **124**:130-141.

Williams, C.E., M.V. Lipscomb, W.C. Johnson, and E.T. Nilson. 1992. Influence of leaf litter and soil moisture regime on early establishment of *Pinus pungens*. American Midland Naturalist **124**:142-151.

Wright, H.A. and A.W. Bailey. 1982. Fire ecology: United States and southern Canada. John Wiley & Sons, New York.

Zar, J.H. 1973. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

Zobel, D.B. 1969. Factors affecting the distribution of *Pinus pungens*, an Appalachian endemic. Ecological Monographs **39**:303-333.

VITA

Nicole Leigh Turrill was born in Huntington, West Virginia, on December 22, 1968. She attended schools in the public system of Cabell County, West Virginia, including Meadows and Gallaher Elementaries and Beverly Hills Junior High School. She graduated from Huntington East High School in June 1987. Nicole entered Marshall University, Huntington, West Virginia, in August 1987 and received a Bachelor of Science Degree in Biological Sciences in May 1991. She returned to Marshall Univesity in August 1991 and received a Master of Science Degree in Biological Sciences in May 1993. Her Master's Thesis is entitled "Factors Influencing Herbaceous Layer Vegetation of a Central Appalachian Hardwood Forest Ecosystem." In August 1993, Nicole entered the Ph.D. program in the Graduate Program in Ecology at The University of Tennessee, Knoxville, Tennessee. She completed this dissertation in December 1997 and received her doctoral degree in May 1998.

In July 1997, Nicole married Mark Welch of Knoxville, Tennessee. They now live in Bloomington, Indiana where she is a part-time instructor in the Department of Biology, Indiana University. Nicole now publishes under the name Nicole Turrill Welch.