

Post-fire Stand Development and Potential Fire Behavior for the
Ossipee Pine Barrens Preserve, New Hampshire

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by

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TABLE OF CONTENTS

Title page.....	1
TABLE OF CONTENTS.....	2
List of Figures.....	3
List of Tables.....	3
List of Appendices.....	4
INTRODUCTION.....	5
OBJECTIVE.....	5
STUDY AREA.....	6
MANAGEMENT CONCERNS.....	7
METHODS.....	8
Field Sampling.....	8
Data Analysis.....	8
<u>Stand Dynamics</u>	8
<u>Fuel Model Development</u>	8
RESULTS.....	10
Recent Fire History.....	10
<u>Hobbs Tract</u>	10
<u>West Branch Tract</u>	10
Stand Composition.....	11
Species Size/Age Structure.....	13
Custom Fuel Model Definition.....	14
Fuel Bed Characteristics.....	14
Fuel Model Performance.....	17
DISCUSSION AND MANAGEMENT RECOMMENDATIONS.....	19
LITERATURE CITED.....	22
APPENDICES.....	23

List of Figures

Figure 1. Locator map - West Branch and Hobbs Tracts of the West Branch Pine Barrens Preserve, Madison and Freedom, New Hampshire. see Results, p. 12, for an explanation of stand designations.

Figure 2. Sample plot locations: a.) West Branch Tract, b.) Hobbs Tract.

Figure 3. Pitch pine stem density by size (diameter) class for the West Branch Tract (a.) Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

Figure 4. Age versus diameter for West Branch pitch pine stems cored in August, 1998: a.) all stems, b.) stems less than 10 inches at core height.

Figure 5. White pine stem density by size (diameter) class for the West Branch Tract (a.) and Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

Figure 6. Results of detrended correspondence analysis: distribution of West Branch and Hobbs Tract plots (Fig. 6a) in space defined by fuel bed characteristics (see Fig. 6b). Plots are coded by cover type: 1 = PP/WP/SO Forest, 2 = PP/SO Forest, 3 = PP/SO Thicket.

List of Tables

Table 1. Average basal area by species for 73 variable radius plots sampled in 1998 on the West Branch Tract, Ossipee Barrens, New Hampshire.

Table 2. Average basal area by species for 20 variable radius plots sampled in 1998 on the Hobbs Tract, Ossipee Barrens, New Hampshire.

Table 3. Summary of stand characteristics by cover types for the West Branch Tract - Ossipee Barrens, New Hampshire.

Table 4. Summary of stand characteristics for the Pitch Pine-Scrub Oak Forest cover type on the Hobbs Tract - Ossipee Barrens, New Hampshire.

Table 5. Average stand characteristics based on 10-m² "stand surveys" at the Waterboro (ME) and Ossipee (NH) Barrens.

Table 6. Summary of fuel bed characteristics derived from sampling downed woody fuel lines and 40 by 40 cm "harvest" plots at the Waterboro (ME) and Ossipee (NH) Barrens.

Table 7. Mass of live scrub oak leaves and stems/branches by time-lag (size) class estimated from stem density by size class sampled on 1 m by 1 m plots.

Table 8. Custom fuel model input values for Waterboro, Maine and Ossipee, NH sites. Values are taken from Tables 5 - 7, with explanations on how they were derived presented in the text.

Table 9. Comparison of flame lengths and rates of spread predicted by Ossipee and Waterdoro custom fuel models versus standard fuel model #7 (southern

rough). Environmental parameters as well as complete BEHAVE run outputs are found in Appendix D.

Appendices

Appendix A. Methods used to sample vegetation and fuels at West Branch Pine Barrens Preserve, Madison, NH.

Appendix B. Field notes on trees cored at the Hobbs Tract, West Branch Pine Barrens Preserve, Freedom, NH on August 21-22, 1998.

Appendix C. Field notes on trees cored at the West Branch Tract, West Branch Pine Barrens Preserve, Madison, NH on August 5-6 and 21, 1998.

Appendix D. Input/output tables for TESTMODEL runs of Ossipee and Waterboro Custom Fuel Models with standard fuel model 7 included for comparison

INTRODUCTION

The Ossipee Barrens in Madison, New Hampshire represent the largest remaining tract of Pitch Pine-Scrub Oak barrens vegetation in New Hampshire. A portion of this area, which is an example of the boreal variant of pitch pine-scrub oak barrens (Schweitzer, 1986), is currently protected by conservation interests. Two tracts - the West Branch and the Hobbs - comprise the West Branch Pine Barrens Preserve (WBPBP), which is owned and managed by the New Hampshire Chapter of The Nature Conservancy (Figure 1). Historic evidence (Finton, 1998) and experience with pine barrens elsewhere in the Northeast suggest that barrens like that at Ossipee are fire-dependent ecosystems. The dominant species - pitch pine, scrub oak and blueberries - are all intolerant of shade and are capable of reproducing vegetatively after fire. They provide food and cover for a variety of species that are increasingly rare on the landscape including several species of rare *Lepidoptera*. Following major wildfires in 1947 and 1957, enhanced prevention, detection and suppression have excluded fire from the Ossipee Barrens. Managers are concerned that accumulating fuels and succession to more tolerant hardwoods and conifers pose a threat of future catastrophic wildfires on the one hand and the loss of rare species habitat on the other.

Options for managing the Ossipee Barrens include prescribed fire. But the success of a prescribed fire program would depend heavily on the ability of fire leaders to accurately predict the behavior of the fires they ignite. Experience elsewhere in eastern barrens shows that existing fuel models fail to accurately predict rates of spread and fire line intensities and are likely to underestimate (Fuel Models 6 and 7) or grossly overestimate (Fuel Model 4) fire behavior in pitch pine-scrub oak (PP-SO) fuels. The goals of this study are to: 1.) characterize the vegetation, especially as it is fuel for wildland fires; 2.) to develop (using BEHAVE, a fire behavior prediction system) site-specific, custom fuel models to aid managers in fire behavior prediction - both for prescribed fire management and for wildfire control; and 3.) to identify management units within the West Branch and Hobbs tracts of the West Branch Pine Barrens Preserve. Custom fuel models presented here can only be verified with research burns conducted on the site. Once verified, they should increase the likelihood that management burns could be conducted safely to produce the desired results. The work described here should be viewed as part of an ongoing effort to characterize potential fire behavior for the area, because fuels change with time and especially following management activities. New custom models should be developed to predict the behavior of fires once conditions described in this report (based on sampling in 1998) change. For this reason, protocols to guide sampling for the development additional models are included.

OBJECTIVE

The objective of this study is to document variation in vegetation cover and composition with the goal of identifying and defining unique management units on the West Branch and Hobbs tracts of the West Branch Pine Barrens Preserve. Parameters sampled include: overstory species composition, density and cover; understory (shrub) composition and cover; fuel bed characteristics; and fire and land-use history, which is useful in determining stand dynamics.

STUDY AREA

The 573-acre (232 ha) West Branch Tract of the West Branch Pine Barrens Preserve occupies flat terrain bounded on the west by Route 41, on the north by East Shore Drive and on the east and south by the West Branch of the Ossipee River northwest of Ossipee Lake (Figure 1). The Tract is bisected from west to east by a foot path and from the west-central boundary to the northeast corner by a Class VI town road. Soils include Colton series gravelly loamy fine sands and Adams series loamy sands derived from glacial outwash with 0-to-3 percent slopes. Located in east-central New Hampshire, the Tract is part of what was once a 7000 acre (2833 ha) barrens (Finton 1998). The Hobbs Tract lies south and southeast of the West Branch Tract and occupies approximately 150 acres (62.5 ha) of upland and floodplain north and east of the West Branch of the Ossipee River. A small portion of the tract lies on the shore of Ossipee Lake.

The Ossipee Barrens is a dynamic ecosystem that is dependent on disturbance for its maintenance and supports a variety of rare insects, plants and declining bird species (Sperduto, 2000). The barrens have a long history of logging for red, white and pitch pine timber, a history that has been reviewed by Cook (1989), Finton (1998) and Sperduto (2000). Nineteenth century selective logging of the more valuable red and white pine, plus slash and railroad fires that followed logging, probably favored the development of the extensive, modern pitch pine stands. Recent fire suppression, logging of pitch pine for timbers and guard rail posts, and silvicultural practices favoring white pine have reduced the proportion of pitch pine in modern stands, but it is still the dominant pine throughout the WBPBP and the larger Ossipee Barrens as a whole. Dense scrub oak over a ground cover of blueberries occupy the understory.

The last major fires at Ossipee were a large wildfire in April, 1957 and, before that, the great fires of October, 1947, which also burned a large portion of adjacent southwestern Maine. Field surveys conducted in August, 1998 failed to provide conclusive evidence that either of these fires burned extensively in the West Branch or Hobbs Tracts, but I found some evidence that the 1947 fire burned a portion of the West Branch. The 1957 fire burned intensely just north of the Hobbs Tract and may have burned as a flanking or backing fire in the Hobbs Tract itself. A smaller fire apparently burned in the eastern portion of the West Branch about in the late 1960's or early 1970's.

Logging has been the principal disturbance in both tracts during the past 30 years. The West Branch was heavily thinned of mature pitch pine in the early 1970's, and a small portion in the northern section of the Hobbs Tract was clearcut about the same time. This later area is the only portion of either tract currently typed (by J. Stone, University of Massachusetts Resource Mapping Unit; see Finton, 1998) as pitch pine-scrub oak thicket (PP-SOT) (rather than PP-SO Forest). In 1947, approximately 20% of the West Branch was typed as PP-SOT, but none of the Hobbs Tract (Finton, 1998). The results of the 1998 field sampling suggest that, based on the canopy cover criteria used by Stone, some PP-SOT remains on the West Branch Tract.

In the early 1990's, several very large pitch pines were harvested from an old growth stand near the shores of Ossipee Lake on the Hobbs Tract. Some of the remaining trees are 80-100 cm diameter at breast height and 175-200 years old. At least one stump was 115-120 cm across at the cut and another

had an estimated 230-250 growth rings. Most of the virgin pines on both tracts were harvested in the late 18th through 19th centuries, however.

The principal cover type is pitch pine-scrub oak forest (PP-SOF) and is typical of the boreal variant of pine barrens, which occurs in areas of eastern New Hampshire and southwestern Maine (Widoff 1987). The PP-SOF type has a more-or-less open canopy of pitch pine (with a tree canopy cover of generally >60%) combined with a dense understory of varying amounts of scrub oak, black huckleberry (*Gaylussacia baccata*) and low-bush blueberry (*Vaccinium* spp.). Ground cover is sparse and includes bracken fern (*Pteridium aquilinum*) and Pennsylvania sedge (*Carex pennsylvanica*). A thick litter layer on the forest floor and draped from low shrubs provides abundant fuel for fires that might start as surface fires but quickly move into the canopy of dense scrub oak and, where present, pitch pine overstories.

MANAGEMENT CONCERNS

The threat of wildfire igniting in and escaping the barrens to threaten adjacent properties is real. Residential development along the north boundary of the West Branch Tract (on East Shore Drive) and summer cottages east of the Hobbs Tract (on the shores of Ossipee Lake) have little protection from fires that can easily cross breaks of 100-200 feet under high wind conditions. Roads along the west and north boundaries of the West Branch Tract and near the north boundary of the Hobbs Tract represent areas prone to human ignitions. Areas to the south and east of the West Branch Tract and south of the Hobbs Tract are less developed and prevailing winds during the fire season are from the southwest, west and northwest, so these areas are less likely to be threatened by wildfire. The West Branch of the Little Ossipee River bounds the east and south portions of the West Branch Tract and the southwest portion of the Hobbs Tract and will help to prevent at least surface fires from burning on to or off of the two tracts. Crown fires would, however, easily cross any of the roads or river beds bounding the two tracts.

Frequent fires and poor soil conditions allow pitch pine to remain the dominant species in upland barrens communities. In the absence of fire, PP-SOF communities will be replaced by mixed conifer/hardwood types composed of hardwoods more suited to mesic soils (e.g. tree oaks and red maples) and conifers less tolerant of fire (e.g. white pine, hemlock, spruce and fir). Fire suppression efforts, while successful at protecting human resources, are currently degrading the habitat for species unique to barrens vegetation (The Nature Conservancy 1994). When burned frequently (e.g. at 10-20 year intervals) or selectively cut for timber, the PP-SOF type is replaced by pitch pine-scrub oak thickets (as was recently the case in the northern portion of the Hobbs Tract). Removal of pines by cutting can lead to shrub communities dominated by scrub oak, although Finton (1998) found these communities to be more common in Albany, NY and Waterboro, ME than in Ossipee. Frequent burning (i.e. at <10-year intervals) of the PP-SOT type will increase the importance of grasses, sedges, forbs and ericaceous shrubs and lead to the development of Pitch Pine-Scrub Oak Barrens vegetation, an ecologically important type that has been all but lost from most northeastern barrens during the past 50 years (Finton 1998).

METHODS

Field Sampling

Field sampling focused on characterizing stand structure and development on the one hand and fuel bed conditions on the other. This was consistent with the goal of determining what factors influenced the development of the existing vegetation, especially as it represents fuel, and how vegetation and fuels might be managed in the future. A detailed outline of procedures is included as Appendix A. Stands were sampled on both the West Branch (WBT) and Hobbs Tracts (HT), with 45 plots on the WBT and 20 on the HT located along transects systematically placed throughout the areas (Figure 2). These "stand surveys" sampled the height and cover of vegetation/fuels by strata [forest floor (litter), low (blueberry) and high (scrub oak) shrubs, and canopy]. The overstory was characterized using the variable radius plot (Bitterlick) sampling procedure (Mueller-Dombois and Ellenberg 1974) at the 65 plots mentioned above, plus an additional 28 plots on the WBT (see Figure 2a).

Fuel bed conditions were characterized by inventories of live and dead plant materials. A modified version of the planar intercept method (Brown 1974) was used to inventory downed wood at each of the 65 "stand survey" plots. Brown's method does not adequately estimate overall fuel depth in this cover type (Patterson 1998), so measurements of shrub height were added to improve the accuracy of overall fuel characterizations. Forest litter, live and dead standing herbs, and low shrubs were harvested from 30, 1600-cm² plots (10 each in PP-WP-SO and PP-SO Forest on the WBT, and 10 in PP-SO Forest on the HT). Samples were placed in an oven at 70° C. until dry and then weighed. Scrub oak stems were sampled on 40, 1-m² plots (10 each in PP-WP-SO and PP-SO Forest at the WBT, and 20 in PP-SO Forest at the HT), with dry mass estimated from allometric equations developed by Patterson (1998).

Forty stems (or stumps of previously logged trees) were aged on the WBT, and 21 on the HT. The diameters of stems cored were recorded to determine the relationship between diameter and age.

Data Analysis

Stand Dynamics. Variable radius plot data were converted to basal area by species to determine the relative importance of pitch and white pine on plots sampled, and to stem density by size class to estimate age class distributions within sample stands. Total stem age, fire scars on stumps, and variations in ring width observed on increment cores were used to interpret fire history, especially as it relates to the establishment and development of modern stands.

Fuel Model Development. The BEHAVE fire behavior prediction and fuel modeling system is a set of interactive programs that permits the construction of site-specific fuel models to predict wildland fire behavior (Burgan and Rothermel 1984). The FUEL subsystem allows the user to develop site-specific, "custom" fuel models, whereas the BURN subsystem uses custom fuel models and environmental parameters to predict fire behavior (Andrews 1986). Together these components provide a way to predict fire behavior in areas that are not well represented by the 13 "standard" fuel models. Custom fuel model

development requires site specific information on fuel load, depth and cover; and acquiring this information was an important part of this study.

A goal of the study was to determine if a single custom fuel model would adequately describe conditions at Ossipee, or if more than one fuel model would be required. This was done by applying detrended correspondence analysis (DCA) to estimates of fuel bed parameters from the stand surveys and DWF lines. DCA produces a graph with plots distributed (or "ordered") according to their fuel bed characteristics. Groups of plots with similar fuel bed characteristics were identified, and custom fuel models were developed from input values derived from group averages.

The NEWMDL program of BEHAVE requires several inputs for custom fuel model development. Weights of materials harvested from 1600-cm² plots were converted to tons per acre for 1-hour (0-1/4") and 10-hour (1/4-1") time lag classes. Weights of larger fuels were estimated from the downed woody fuel lines. Cover estimates for litter and grass were taken from the stand surveys. Litter fuel loads came solely from 1600-cm² plots. The shrub category required an estimate of scrub oak mass. Scrub oak fuel components were estimated from equations developed from samples obtained at Waterboro, ME (Patterson 1998), using density by size class data for the 20, 1-m² plots sampled on each of the two tracts. Depth and cover of the shrub layer from stand surveys were entered for the shrub category. The optional slash category was not used as no significant timber harvesting has occurred on either site in recent years.

NEWMDL also requires estimates of surface-area-to-volume (s/v) ratio and heat content for each fuel component. The higher the s/v ratio of the fuel, the more rapidly it burns and higher the rate of spread and flame length. The heat content is the potential heat of a fuel when burned and also affects rate of spread and flame length. We did not measure these fuel characteristics directly, but used values similar to those used for other New England barrens custom fuel models (Del'Orfano 1996, Woodall 1998).

BEHAVE models fire behavior using one of two distinct fuel drying modes. Static mode assumes constant fuel moistures for live fuels (i.e., dormant season conditions). The dynamic mode estimates the contribution of live herbaceous material (entered as "grass") to the 1-hour fuels complex based on changes in the live moisture content on the site during the growing season. Static mode assumes the vegetation is dormant, so all of the grass load will be counted as litter. Both modes require the entry of fuel load in tons per acre, an average depth of the grass fuel, percent cover of the various fuel types, and the proportion of the grass load that is alive. Because the grass component comprises such a small percentage of the total fuel load at the Ossipee sites I sampled, the static mode was used in custom fuel model development.

Fuel model outputs were generated by the TESTMODEL program of BEHAVE using a standard set of environmental variables (see Table x) and compared, one with another and with output for the "southern rough" standard fuel model (SFM 7) and a previously developed custom fuel model for the Waterboro Barrens. Estimates for rate of spread and flame length were compared.

RESULTS

Recent Fire History

Hobbs Tract. Fire scars on trees examined on the Hobbs Tract suggest that fires burned this area in ca. 1898, 1905, and 1912 (see Appendix B). Because of the difficulties associated with aging sections in the field, these dates are probably accurate to no more than ± 2 to 3 years. Estimated ages of establishment for cored trees may identify additional fires, especially for Pitch Pine, but even pitch pine may take several years to establish following a fire, and conjecture about fire dates based on age of establishment is far more speculative than dating based on fire scars. Never-the-less, three of the older trees that I aged established ca. 1818, 1822 and 1878, and one of the very large cut stumps near Ossipee Lake originated between 1750 and 1800. This suggests that fires have burned on the Hobbs Tract since before the time of local logging and settlement (and before the establishment of the railroad in 1870 - Finton 1998). Additional stem origin dates include the period 1909-1916 for pitch pine, and 1946-1958 for white pine, scrub oak and red spruce. The earlier dates for pitch pine suggest establishment (actually stump sprouting) following the ca. 1905 and/or 1912 fires. The later dates for other species - all of which are easily girdled or top-killed by surface fires when young, indicate that the area may well have burned lightly in 1947. The area may also have burned in the 1957 fire that burned as a crown fire north of the road, but the presence of two white pine and a red spruce that clearly established before 1957 suggest that if this fire did burn the area, it was of low intensity and patchy in nature, perhaps burning at night or as a backing fire.

West Branch Tract. Fire scars and periods of slow growth on the few remaining older pitch pine and one well-preserved pitch pine stump provide clues to the fire history of the Tract. A cut stump (Tree #30, Appendix C) contained four clearly identifiable fire scars which probably date to the period 1880-1920. A fifth possible scar may date to the mid 1920's, although all of these dates assume that the tree was between 90 and 110 years old when it was harvested and that it was harvested some time in the 1970's. A large pitch pine east of the Memorial Rock dates to the 1840's, has several visible fire scars, and has narrow ring widths dating to ca. 1860, 1890, 1910, 1919, 1933, 1952 and 1968. Some of these narrow rings probably date historic fires, especially those for the period 1890 to 1920 (see discussion for the Hobbs Tract below), but other factors including insect defoliation and drought may have contributed to decreased radial increment in some years.

Of the younger stems, four date to the late 1800s. The remainder date to the period 1920 through 1978. Unlike trees on the Hobbs Tract, none of the trees cored on the West Branch date from 1895-1919. It was this cohort of trees, which on the Hobbs Tract established following fires during that period, that was apparently harvested most heavily by the Kennett Co. during the 1970s. Most of the white pine cored established during ca. 1935 to 1943 (four stems) or during 1952-1959 (nine stems). Only one stem younger than that was aged. I found no evidence in the form of standing stems or large stumps of white pine dating to before 1930, and it seems at least possible that many of the white pine currently present were planted on the area, perhaps during the Great Depression and/or after the October, 1947 fire. There is no clear evidence that the 1947 fire burned extensively on either the West Branch or Hobbs Tracts, but it may have burned portions of one or both of the areas, and many areas burned in 1947 were later planted to pine.

Stand Composition

For the West Branch Tract, 45 plots sampled along two long transects in the east and west portions plus one in the north-central portion of Tract provide complete stand characterizations (downed woody fuel, stand surveys, canopy cover and variable radius plots). Variable radius plots alone were sampled at an additional 28 points along three shorter transects in the central portion of the WBT (Figure 2). Twenty points were sampled completely along two transects at the Hobbs Tract (see Figure 2b). Basal area summaries by species (Tables 1 and 2) characterize the overstories of the two tracts. The West Branch Tract, with its recent (mid-1970's) history of logging of the early 20th century cohort of pitch pine has only 40% of the total basal area of the Hobbs Tract (60.9 vs. 145 ft²/acre). Although white pine has a higher average basal area on the Hobbs Tract compared to the West Branch, it is, as a fraction of the total basal area, less important on the HT.

Table 1. Average basal area by species for 73 variable radius plots sampled in 1998 on the West Branch Tract, Ossipee Barrens, New Hampshire.

Species	Basal Area (ft ² /acre)			SEM/Mean (%) ²
	Mean	StDev	SEM ¹	
<i>Pinus rigida</i>	48.8	28.5	3.5	7.1
<i>Betula populifolia</i>	0.4	2.0	0.2	59.4
<i>Pinus strobus</i>	11.2	10.1	1.2	10.9
<i>Prunus</i>				
<i>pensylvanica</i>	0.1	0.6	0.1	0.0
<i>Acer rubrum</i>	0.2	1.3	0.2	77.4
<i>Picea rubens</i>	0.2	1.0	0.1	59.4
Sum	60.9			

¹ SEM = standard error of the mean.

² SEM expressed as a percent of the mean (SEM/Mean) gives a measure of variability and thus adequacy of the sample. Values less than approximately 10% indicate a reasonably stable estimate of the population mean.

Table 2. Average basal area by species for 20 variable radius plots sampled in 1998 on the Hobbs Tract, Ossipee Barrens, New Hampshire.

Species	Basal Area (ft ² /acre)			SEM/Mean (%)
	Mean	StDev	SEM	
<i>Pinus rigida</i>	121.3	39.7	8.9	7.3
<i>Pinus strobus</i>	16.8	12.2	2.7	16.2
<i>Acer rubrum</i>	4.0	11.0	2.4	61.2
<i>Picea rubens</i>	0.5	2.2	0.5	100.0
<i>Quercus rubra</i>	1.5	3.7	0.8	54.6
<i>Fraxinus americana</i>	1.0	4.5	1.0	100.0
Sum	145.0			

An evaluation of these data for the two tracts suggests three cover types, two of which correspond with types defined by Finton (1998) for the larger Ossipee Barrens area. These are:

Pitch Pine/Scrub Oak Forest (PP-SOF) defined by Finton as areas of predominantly pitch pine with a canopy closure of approximately 60% or more.

Pitch Pine/Scrub Oak Thicket (PP-SOT) - areas with a sparse canopy of pitch pine and a dense understory of scrub oak. Most of this type has tree canopy cover of less than 50%, although cover can be up to approximately 60%.

I also recognize a **Pitch Pine-White Pine/Scrub Oak Forest (PP-WP-SOF)** type which is similar to the PP-SOF type of Finton, but with generally 40% or more of the plot basal area in white pine.

Basal area and crown cover data for the tracts are summarized by cover type in Tables 3 and 4, with type boundaries delineated on Figure 1. PP-WP-SOF occupies the western and southwestern portions of the West Branch Tract, with PP-SOT in the north central portion. Much of the rest of the West Branch Tract is PP-SOF, although occasional plots within one or the other of these three types had basal areas and/or crown covers typical of one of the other two types.

Table 3. Summary of stand characteristics by cover types for the West Branch Tract - Ossipee Barrens, New Hampshire.

Cover Type ¹	Plots (#)	Cover (%)	Plots (#)	----- Basal Area -----	
				Pitch Pine	White Pine
				----- ft ² /acre -----	
PP-WP-SOF	12	58.5	13	29.2	25.4
PP-SOF	18	61.2	42	66.1	8.1
PP-SOT	15	31.9	18	25.0	7.8

¹ Cover Type Designations:

PP-WP-SOF = Pitch Pine-White Pine-Scrub Oak Forest
 PP-SOF = Pitch Pine-Scrub Oak Forest
 PP-SOT = Pitch Pine-Scrub Oak Thicket

At the Hobbs Tract, all 20 plots were characterized as Pitch Pine/Scrub Oak Forest (Table 4). The small, recently clear-cut area in the north-central portion of the Hobbs Tract that is identified as PP-SOT on Finton's (1998) map was not sampled.

Table 4. Summary of stand characteristics for the Pitch Pine-Scrub Oak Forest cover type on the Hobbs Tract - Ossipee Barrens, New Hampshire.

Cover Type	Plots (#)	Cover (%)	Plots (#)	-----Basal Area -----	
				Pitch Pine	White Pine
				----- ft ² /acre -----	
PP-SOF	20	70.1	20	121.5	17.5

Species Size/Age Structure

Stem frequency by size (diameter) class (Figure 3) data indicate that pitch pine in both the West Branch and Hobbs Tracts do not exhibit the typical inverse J-shaped curve that would characterize an all-aged stand. Most stems are concentrated in larger size classes, with pitch pine in the Hobbs Tract nearly twice as large, on average, as those in the West Branch Tract. This is consistent with what I know of the silvicultural practices on the two tracts - specifically, the removal of larger stems from the West Branch in the 1970s and the lack of evidence for any recent cutting on much of the Hobbs Tract. Stands in both tracts contain smaller diameter pitch pine, but age/size correlations show that although diameter is a reasonably good predictor of age for the pitch pine population as a whole (Figure 4a), the relationship between age and diameter is not nearly so good for smaller stems (Figure 4b). In fact, many of the small stems on the West Branch Tract are quite old, and exist as slow growing, suppressed or intermediate stems beneath the larger, more vigorous canopy trees. Radial growth for many of these small stems is very low - generally less than 0.2 cm/year for stems less than 20 cm dbh (see Appendix C). The y intercept of the trend line for all stems (11.2 years) suggests the presence of a younger cohort in the populations, but when only small stems are included in the regression, the y intercept increases to 27.2 years indicating few young pitch pine. This second interpretation is supported by subjective observations of a lack extensive regeneration of pitch pine in response to past harvesting operations on the West Branch, and of any young pitch pine in the last 80-100 years on the Hobbs Tract.

White pine, in contrast, shows low but steady recruitment on both Tracts (Figure 5). This is probably a response to lack of fire on the one hand, and an available seed source on the other. White pine that regenerated in the mid 20th century are maturing, and the more tolerant white pine, which are better able to establish in the heavy litter and duff beneath mature stands, are more likely to fill available gaps than are pitch pine.

Red pine is virtually absent from both Tracts. I found only a few mature red pine along the West Branch, west of the Hobbs Tract, and a single mature red pine in the central portion of the West Branch Tract. Although there are undoubtedly a few additional red pine on both tracts, the species is not currently a significant component of stands on either tract. Interestingly, red spruce, although present, is uncommon on both tracts (Tables 1 and 2), and there is little evidence that it is regenerating in the recent absence of fire (which undoubtedly either removed it or kept it from invading both tracts during the 1800-1920 period of high fire activity in the area). Both red pine and red spruce are more common at the White Lake State Park west of the Preserve.

Similarly, there are very few hardwoods establishing on either tract. We tallied fewer than a dozen gray birch, red maple and cherry on 73 variable radius plots on the West Branch Tract, and only 13 hardwood stems (red oak, ash and red maple) on 20 plots on the Hobbs Tract. There is little evidence at this point of succession to hardwoods in the absence of fire, although sampling of stems less than 2.5 cm dbh might better indicate the status of advance regeneration.

Custom Fuel Model Definition

Plots are displayed in two-dimensional space defined by fuel bed characteristics using detrended correspondence analysis (PCORD,) The results of the ordination (Figure 6) indicate that "Forest" and "Thicket" plots are distinct with respect to fuel characteristics. Plots on the West Branch Tract characterized as being PP-SO Thicket (Covertyp 3 on Figure 6b) have high axis 1 scores with higher values for high shrub cover and lower 100-hour fuel load, percent canopy cover, and grass cover compared with PP-WP-SO and PP-SO Forest plots (Covertyp 1 and 2, respectively). Among the "Forest" plots, those on the Hobbs Tract had higher canopy cover and 100-hr fuel loads and lower high shrub heights than did Forest plots on the West Branch Tract. Forest plots with more white pine (the PP-WP-SO Forest type) were not substantially different from the PP-SO Forest plots with respect to fuelbed characteristics. This analysis suggested that there might be three distinct areas of differing fire behavior, so I constructed three separate fuel models - one for the Hobbs Tract "Forest" and one each for the West Branch Tract "Forest" and "Thicket".

Fuel Bed Characteristics

Average values for parameters sampled are presented in Tables 5-7 and summarized by fuel model in Table 8. Most of the fuels are in the one-hour size class - especially as non-woody fuels (i.e. litter). Fuel depths for both litter (0.7-0.9 ft) and shrubs (2.5-3.1 ft) are large indicating a well-aerated fuel bed. This is evident in the packing ratios (i.e. fuel mass per volume of fuel bed) calculated for the custom fuels models (see Appendix D). Ratios proportional to optimum ration (PR/OPR in Appendix D) are near one suggesting optimal fuel aeration. It is this abundance of well aerated, fine fuels that contributes to the extreme volatility of the pine barrens fuel type. Grass fuel loading is low throughout the Ossipee barrens, resulting in no difference in fire behavior for dynamic and static custom fuel models.

Table 5. Average stand characteristics based on 10-m² "stand surveys" at the Waterboro (ME) and Ossipee (NH) Barrens.

	Waterboro	Hobbs Tract	West Branch (forest)	West Branch (thicket)
Number of survey plots	20	20	35	10
Slope (%)	5.1	2.1	2.1	2.8
Aspect	NW	generally W	variable	E
Canopy				
Cover (%)	59.1	70.1	56.1	31.9
Tree Height (ft)	36	63	40.1	35.0
Height - base of live crown (ft)	20	42	20.1	13.9
High Shrubs				
Cover (%)	55.4	68.9	52.4	75
Height (ft)	6.5	7.5	6.7	7.9
Low Shrubs				
Cover (%)	73.5	66.4	78.2	87.5
Height (ft)	0.7	0.9	0.8	0.9
Grass/forbs				
Cover (%)	1.5	1.0	1.4	1.2
Height (ft)	0.5	0.5	0.5	0.5
Litter				
Cover	87.5	87.5	86.8	85

Table 6. Summary of fuel bed characteristics derived from sampling downed woody fuel lines and 40 by 40 cm "harvest" plots at the Waterboro (ME) and Ossipee (NH) Barrens.

	Waterboro	Hobbs Tract	West Branch (forest)	West Branch (thicket)
Downed Woody Fuel				
No. of 50-foot lines	20	20	35	10
Fuel Depths (in ft)				
Duff	0.2	0.2	0.2	0.2
Litter	0.2	0.2	0.2	0.2
Fuel (litter+downed wood combined)	1.3	0.6	0.6	0.6
Low Shrubs	0.8	0.8	0.9	1.0
High Shrubs	3.3	3.7	3.8	4.8
Woody Fuel Load (tons/acre)				
1-hour	0.5	0.4	0.5	0.4
10-hour	1.7	0.7	1.0	1.0
100-hour	1.7	0.9	0.3	0.2
1000-hour sound	0.7	1.4	0.2	0
1000-hour rotten	0	0.2	0.1	0.3
Total	4.6	4.0	2.2	2.0
40 X 40 cm "harvest" plots				
No. of Plots	10	10	20	-
Litter (dead/downed - tons/acre)				
Non-woody	6.0	3.7	3.4	-
1-hour woody	1.1	0.7	0.7	-
10-hour woody	1.0	0.6	0.7	-
100-hour woody	0.2	0.1	0.1	-
Total	8.2	5.1	4.9	-
Live Rooted (tons/acre)				
Leaves, grasses/forbs	0.4	0.2	0.5	-
1-hour woody	0.4	0.3	0.6	-
10-hour woody	0.003	0	0	-
100-hour	0	0	0	-
Total	0.8	0.5	1.1	-
Dead Rooted (tons/acre)				
Leaves, grasses/forbs	0	0	0	-
1-hour woody	0.1	0.1	0.1	-
10-hour woody	0	0	0	-
100-hour woody	0	0	0	-
Total	0.1	0.1	0.1	-

Table 7. Mass of live scrub oak leaves and stems/branches by time-lag (size) class estimated from stem density by size class sample on 1 by 1 m plots and regression equations (see below).

Plant Component	Scrub Oak Mass (tons/acre)		
	Waterboro	Hobbs	West Branch (forest)
No. of Plots	20	20	20
Plant Component			
Leaves	0.5	0.6	0.8
1-hour wood	0.9	0.9	1.2
10-hour wood	1.5	1.9	2.6
100-hour wood	0.1	1.0	0.7
Total	3.0	4.1	4.9

Regression equations for estimating scrub oak weight based on basal diameter (weight, y , in grams; diameter, x , in cm):

Leaves:	$y = 14.467x^{2.1303}, r^2 = 0.98$
1-hour wood:	$y = 23.931x^{2.0716}, r^2 = 0.97$
10-hour wood:	$y = 286.97x - 271.04, r^2 = 0.96$
Total above-ground:	$y = 58.247x^{2.8467}, r^2 = 0.97$

Note: 100-hour wood is estimated as the difference between total weight and weight of leaves, 1- and 10-hour components.

Fuel Model Performance

To compare fuel models, I ran each with similar environmental inputs -values for live and dead fuel moisture, 20-foot wind speed and an assumed slope of 5%, all with fire assumed to be burning up slope with a wind blowing upslope as well. (See the table at the head of Appendix D for environmental variables used in test runs.) Because there are few live, non-woody fuels (i.e. grasses, sedges or forbs) in the fuel bed of any of the types, I report only the results for static models (Table 9). Values for the Waterboro custom fuel model (#62) and for the standard fuel model #7 (southern rough) are included for comparison.

The "Forest" models yield estimates of rate of spread that are 60-70% lower than for FM #7, whereas the West Branch "Thicket" model (#63) predicts a somewhat higher estimate for rate of spread. Although the Waterboro model was generated from an area typed as PP-SOT (Patterson 1998) and thus is referred to as a "Thicket" model in Table X), the average crown cover of 59% (Table 5) suggests that the sample site was actually Pitch Pine/Scrub Oak "Forest", and it is thus not surprising that the predicted rate of spread for this model is comparable to the "Forest" plots at Ossipee. Higher rates of spread for FM #7 and 63 are a function of the lower wind reduction factor for these fuel models. Wind reduction is proportional to the amount of canopy cover, and canopy cover is less in PP-SOT and southern rough fuels than in PP-SOF vegetation. Predicted flame lengths for the Ossipee models are all greater than that for FM #7, and that is consistent with our observations that northern barrens burn with higher intensity than predicted by FM #7 (Woodall 1998).

Table 8. Custom fuel model input values for Waterboro, Maine and Ossipee, NH sites. Values are taken from Tables 5 - 7, with explanations on how they were derived presented in the text.

	Waterboro	Hobbs Tract	West Branch (Forest)	West Branch (Thicket)
Shrubs				
Cover (%)	96.7	100	98.0	100
Depth (ft)	2.5	2.9	2.6	3.1
1-hr fuels (t/acre)	0.1	0.1	0.1	0.1
Live Leaves and twigs (t/acre)	2.1	1.9	3.0	3.0
Oils present?	Y	Y	Y	Y
Litter				
Cover (%)	100	100	100	100
Depth (ft, from low shrub depth)	0.7	0.9	0.8	0.9
1-hr fuels (t/acre)	7.1	4.4	4.1	4.1
10-hr fuels (t/acre)	1.7	0.6	0.7	0.7
100-hr fuels (t/acre)	1.7	0.9	0.2	0.2
Grass				
Cover (%)	1.5	1.0	2.0	1.2
Depth (ft)	0.5	0.5	0.5	0.5
Load (t/acre)	0.1	0.1	0.1	0.1
% Green	35	35	35	35
Surface area:Volume				
1-hr	1750	1750	1750	1750
dead grass	2500	2500	2500	2500
live herb	2250	2250	2250	2250
live woody	1550	1550	1550	1550
Heat				
Dead (btu/lb)	8000	8000	8000	8000
Live (btu/lb)	9000	9000	9000	9000
Twigs and leaves (btu/lb)	9000	9000	9000	9000

Table 9. Comparison of flame lengths and rates of spread predicted by Ossipee and Waterdoro custom fuel models versus standard fuel model #7 (southern rough). Environmental parameters as well as complete BEHAVE run outputs are found in Appendix D.

Fuel Type	Model No.	Flame Length (feet)	Rate of Spread (feet/minute)	Effective Wind Speed ¹ (mph)
Hobbs Tract PP/SO Forest	60	7.3	10	2
West Branch PP/SO Forest	61	7.5	10	2
West Branch PP/SO Thicket	63	11.8	29	4
Waterboro PP/SO Thicket	62	6.8	8	2
Southern Rough	7	5.5	24	4

¹ Assumes 20-foot wind speed of 10 mph.

Custom fuel models have shortcomings. Woodall (1998) found that initial fuel models built for other pine barrens in New England underestimate fire behavior when compared to observations of actual fires. Patterson (1998) observed that fuel bed depth and cover of shrubs are difficult to measure in barrens, and one or both may be underestimated in our sampling. Manipulation of fuel beds by mechanical means and/or prescribed fire usually result in changes to fuel depth and cover. Management activities designed to reduce the intensity of fires burning in these fuels require accurate measurement of these variables when developing revised custom fuel models.

BEHAVE fuel models also do not predict crown fire behavior. This is an important point for PP/SOT and PP/SOF cover types, because the presence of mature pitch pine in these types virtually insures the torching of pines with flame lengths like those predicted for the example above (especially given that they ~~are~~ probably underpredict actual flame lengths). Where canopy cover exceeds 50-60%, crown fires can develop when winds exceed 15-20 miles per hour. even in the absence of crown fire development, torching of individual trees greatly increases the likelihood that spotting will occur beyond the main fire front as cones and small branches from pine canopies are lifted in the convection column and carried downwind. FARSIGHT modeling of fire behavior at the landscape level is a way to integrate area-wide fuel complexes with topography and existing fire breaks to estimate spread of crown fires, but such an analysis is beyond the scope of this study.

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

The Ossipee area was first settled by Europeans after about 1770, but the barrens themselves were not settled until the early 1800's, and then only sparsely (Cook 1989). Early accounts of the area note pine stands on course soils deemed poor for cultivation. Red, pitch and white pine were all present, with the better stands being subjected to logging before homesteads were established. The presence of all three pines suggest at least some degree of fire on the landscape prior to settlement by Europeans. Of the three species, pitch and red pine would be favored by somewhat more frequent fires - perhaps at 20 to 50 year intervals for pitch pine and 50 to 100 or

more year intervals for red pine. The longer lived, more shade tolerant white pine could have persisted with stand level fire return intervals of 100 to 200 years or more. Dominance of one species over another was undoubtedly due to soils and landscape position as much as fire return interval, with red pine more prevalent along lake shores and pitch pine on the coarsest, driest soils. The largest pitch pines I sampled were, however, on mesic sites adjacent to the northwest shore of Ossipee Lake. These may have established during a period of lower Ossipee Lake levels or on sand ridges pushed up by ice. The trees show less evidence of scarring by fire than trees on the upland, and the lack of fire damage and abundant moisture near the Lake probably contributed to the trees' great size and longevity.

Further knowledge of pre-settlement fire regimes will have to await paleoecological investigations of the fossil pollen and charcoal content of sediments from ponds or bogs in the area. Although sites suitable for such work are generally lacking in pine barrens, there are small wetlands near White Lake and elsewhere on the Ossipee barrens that could be utilized for this purpose.

Modern stands show evidence of extensive burning during the 19th and early 20th centuries. Most virgin stands were cut in the first half of the 19th century, and a railroad connecting southeastern New Hampshire with the Conway gateway to the White Mountains was extended through Freedom and Madison in 1870 (Cook 1989). Apparently most of both the Hobbs and West Branch tracts burned at least three times between about 1885 and 1920. Most mature pitch pine on the Hobbs Tract date to the these fires, with the multi-stemmed nature of several pines suggesting that saplings established after one or both of the first two fires were top killed by the last causing them to resprout. The large number of pines with two to as many as five well-formed stems reaching the canopy is an unusual feature of this stand. At the West Branch, thinning operations which continued into the 1970s appear to have selected against stems which originated after these early fires. Most mature pitch pine on the West Branch date from after 1920, whereas white pine on the West Branch mostly date from the 1950's. The origin of these white pine is puzzling. Old pitch pine dating to the mid 19th century undoubtedly served as a seed source for the pitch pine establishing in the late 19th century, but I found no white pine dating to before about 1935. Frequent fires following the establishment of the railroad probably selected against both red and white pine, but it is unusual that there are no remnants - even of cut stumps - of stems that could have given rise to the white pine that are beginning to dominate the western portions of the West Branch Tract. It is conceivable that CCC or Kennett Company crews planted white pine (as a more desirable timber species) on the West Branch Tract during the 1930s, and that the 1947 fire, which may have burned a portion of the tract, destroyed some young white pines. Additional planting during the 1950s may account for the large number of white pine that date from 1952-1959. I have no real concrete evidence for planting on the Tract, but can see no other explanation for the abundance of white pine on portions of the area.

Although Finton's (1998) maps indicate that the Pitch Pine-Scrub Oak Thicket type disappeared from all but the extreme northeast corner of the West Branch Tract between 1947 and 1992, our field sampling indicates that some of area still has less than the 60% canopy cover required for Pitch Pine-Scrub Oak Forest designation. The eastern portions of the West Branch generally have lower cover and fewer white pine, again suggesting that the 1947 (or 1957?) fire burned through this area. There is little evidence that the Hobbs Tract burned in 1947, but it is possible that the April, 1957 fire

that burned northeast of Ossipee Lake Road also burned a portion of the Tract, perhaps creeping to the south and southwest as a backing or flanking fire at night. The understories of stands on both tracts contain dense stands of old, declining scrub oak which support our conclusion that few fires have burned no more than small portions of either tract during the last 45 years.

An analysis of fuel loading and distribution suggests that areas of Pitch Pine-Scrub Oak Thicket will support more active fire with higher rates of spread and greater flame lengths than areas of Pitch Pine-Scrub Oak and Pitch Pine-White Pine-Scrub Oak Forest. BEHAVE does not model crown fire potential, and under extreme fire weather conditions areas of PP-SO or PP-WP-SO Forest have the potential to support catastrophic crown fires. But the increased canopy cover, which is causing the decline of scrub oak/ericaceous shrub understories and would reduce surface windspeeds, reduces the potential for fast-moving surface fires. Areas of the West Branch Tract that may have burned in 1947 and have been logged for pitch pine in more recent years pose the greatest risk for wildfire at the present time. The pursuit of ecological goals for the barrens could lead to opening of additional closed stands, and without an active fuels management program, thinning on either tract could increase the hazard of wildfires. It is of particular concern that the area just north of the present PP-SOT stand on the West Branch Tract (along East Shore Drive) has seen the construction of several residences in the past 10-20 years. These residences would clearly be threatened by a wildfire that might originate within the Preserve, or along Route 41, and spread in their direction on strong southwest winds. Summer camps along the shore of Ossipee Lake, although potentially down wind of the Hobbs Tract are somewhat less threatened both because of the closed canopy nature of much of the PP-SOF stand to the west of the camps and because the likely upwind portions of the Hobbs Tract are less accessible to possible ignition sources (except along Ossipee Lake Road where timber management activities during the past 30 years have resulted in younger stands of dense pine and scrub oak.)

If management of the Tracts involves opening up the canopies of Pitch Pine/Scrub Oak Forest stands (to create more PP/SO Thicket vegetation), efforts should be made to reduce fuel depths, and slash and fine fuel loads. The former can be accomplished by specifying in logging contracts that slash be lopped, but unless chippers are employed, reducing fuel loads is difficult without the use of prescribed fire. Because fuel loads and fuel depths are large in existing stands, mechanical pretreatment of fuels, whether associated with logging operations or contracted separately, will almost certainly be required. Timing of burns during periods of reduced risk of wildfires is essential in volatile pine barrens fuels. Burning during the growing season can reduce rates of spread and the risk of escapes, although growing season burns should not be attempted under dry conditions, as residual duff burning can cause prolonged periods of reduced air quality due to smoke. Any burning that is undertaken should be done as part of a larger ecological management plan and should be directed at specific, measurable, habitat improvement and fire hazard reduction objectives.

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Figure 1. Locator map - West Branch and Hobbs Tracts of the West Branch Pine Barrens Preserve, Madison and Freedom, New Hampshire. see Results, p. 12, for an explanation of stand designations.

Figure 2. Sample plot locations: a.) West Branch Tract, b.) Hobbs Tract.

Figure 3. Pitch pine stem density by size (diameter) class for the West Branch Tract (a.) Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

Figure 4. Age versus diameter for West Branch pitch pine stems cored in August, 1998: a.) all stems, b.) stems less than 10 inches at core height.

Figure 5. White pine stem density by size (diameter) class for the West Branch Tract (a.) and Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

Figure 6. Results of detrended correspondence analysis: distribution of West Branch and Hobbs Tract plots (Fig. 6a) in space defined by fuel bed characteristics (see Fig. 6b). Plots are coded by cover type: 1 = PP/WP/SO Forest, 2 = PP/SO Forest, 3 = PP/SO Thicket.



Legend

— Preserve Boundaries

— Type Boundaries

PP-SOT Pitch Pine-Scrub Oak Thicket
 PP-SOF Pitch Pine-Scrub Oak Forest
 PP-WP-SOF Pitch Pine-White Pine-Scrub Oak Forest

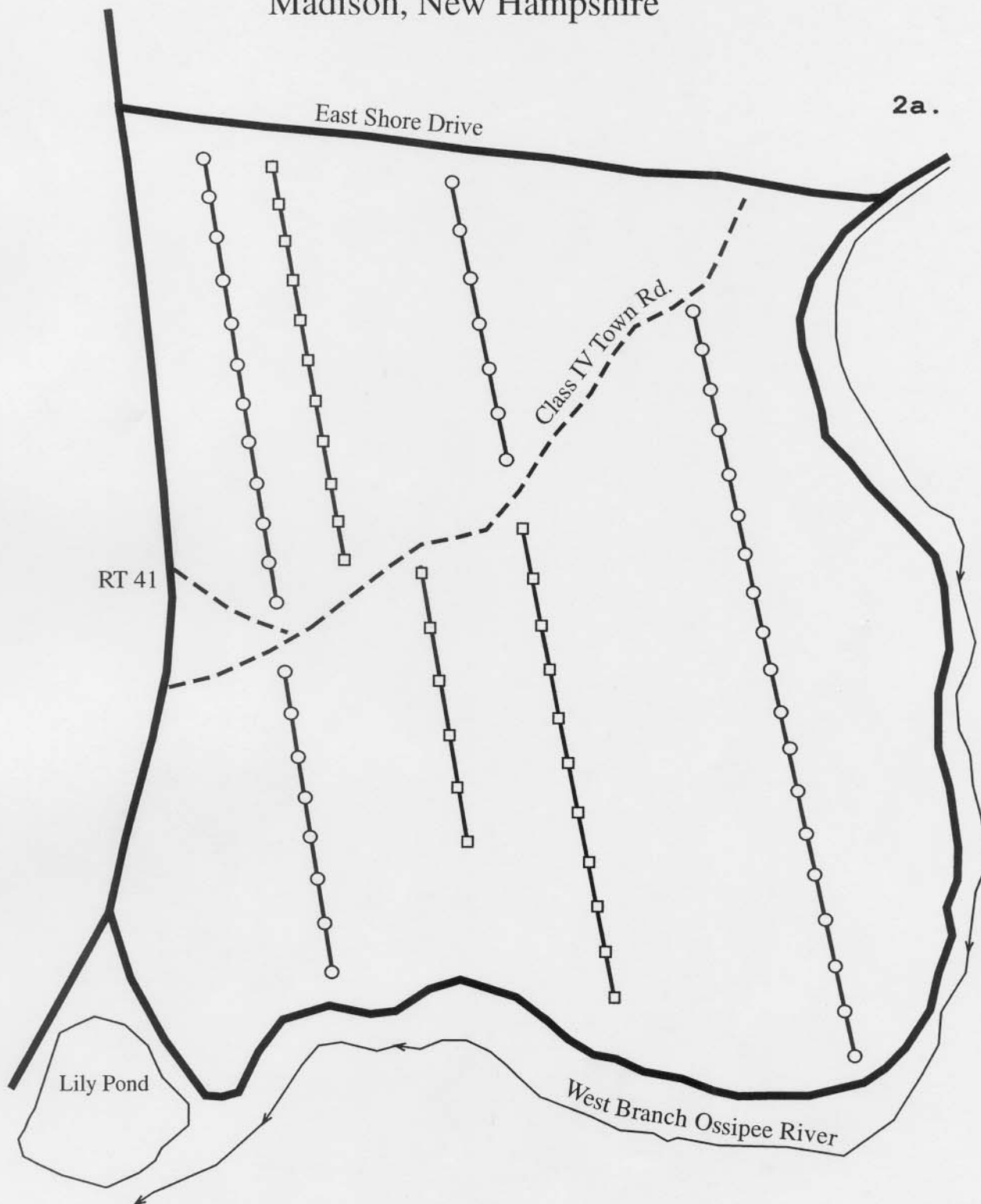


0 1.2 2.4 3.6



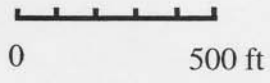
Kilometers

West Branch Pine Barrens Preserve
Madison, New Hampshire



2a.

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- canopy only sampled

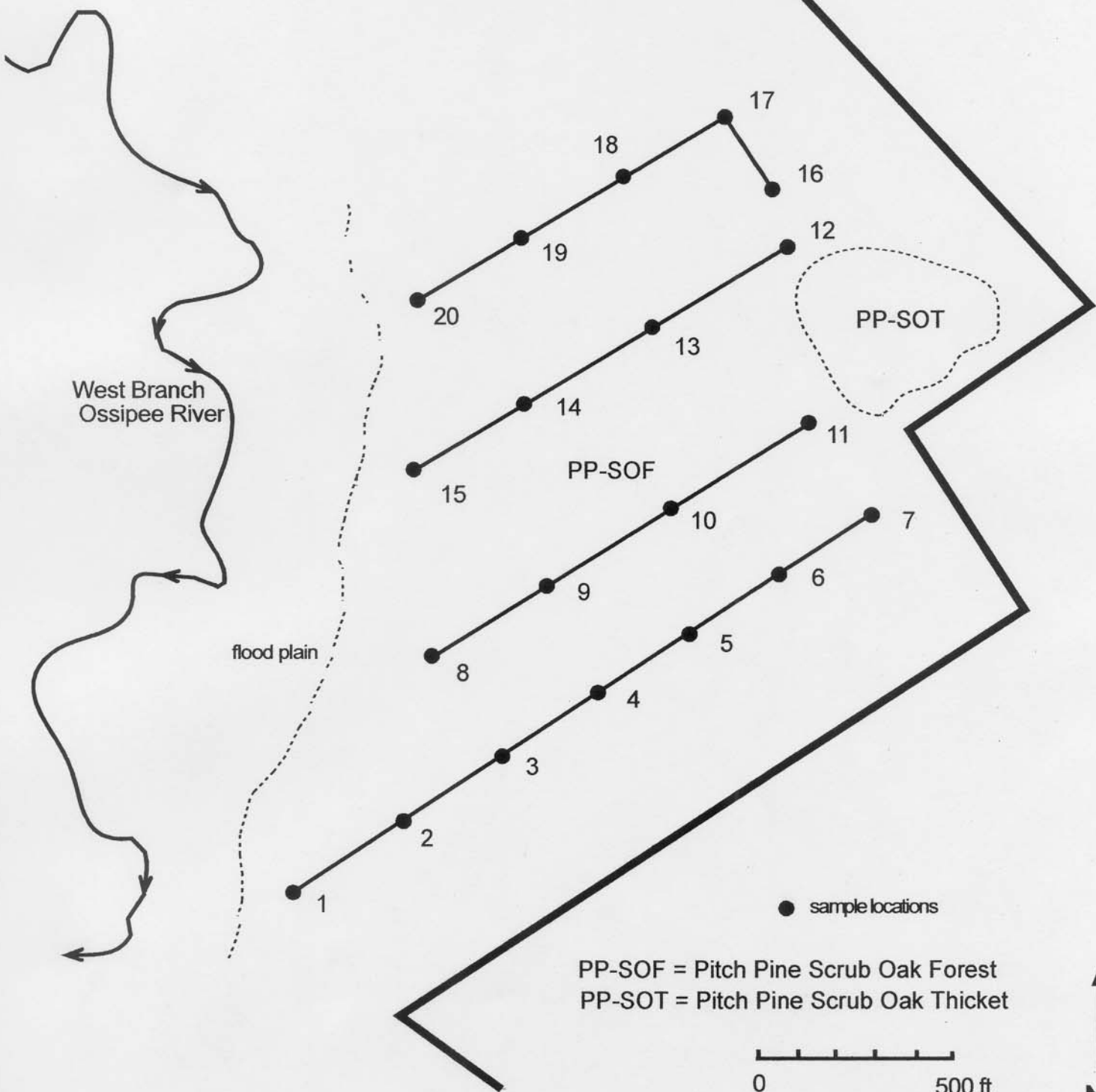


KEN, July 1999



Hobbs Tract
Freedom, New Hampshire

2b.



KEN, July 1999

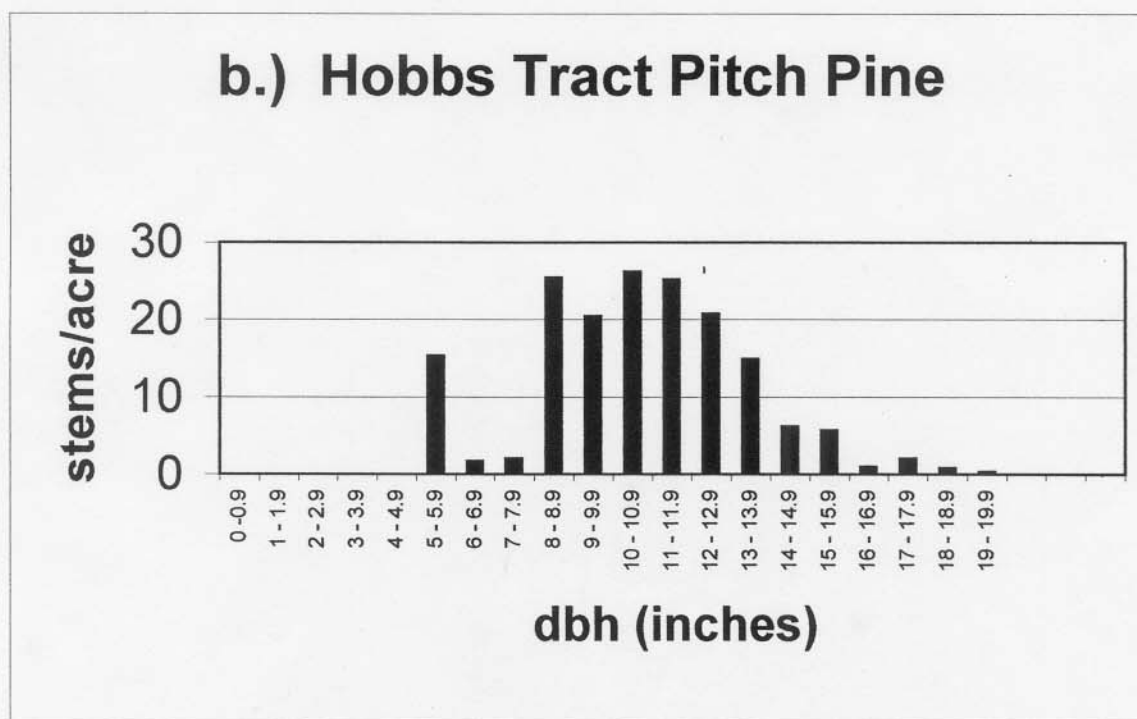
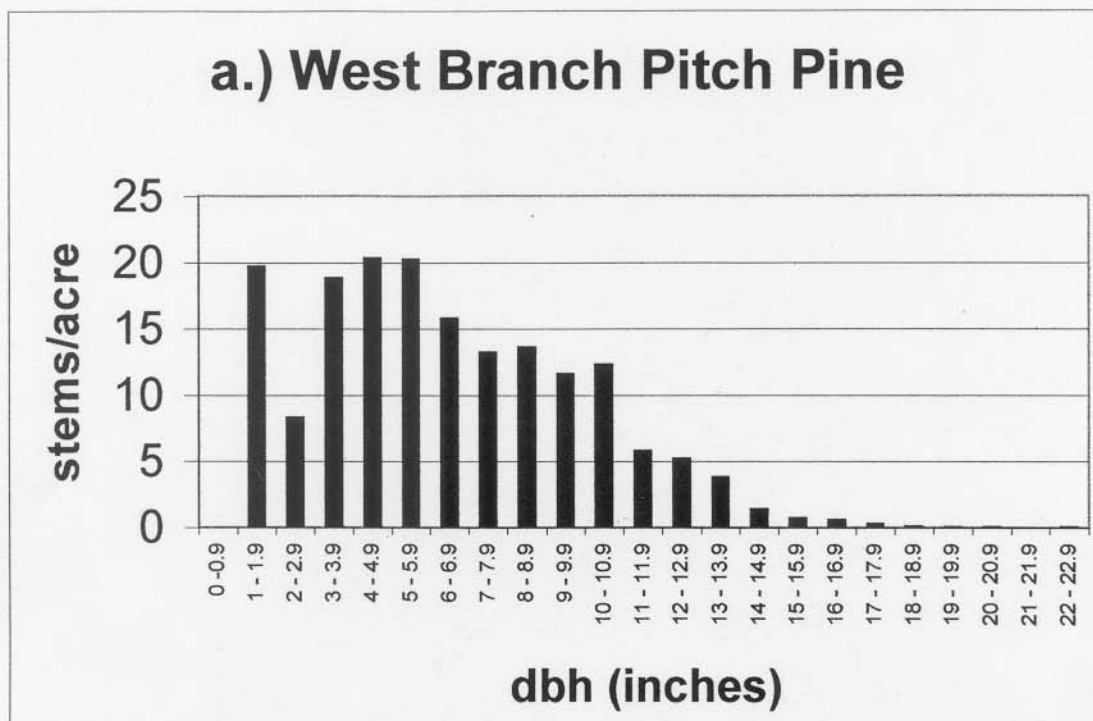


Figure 3. Pitch pine stem density by size (diameter) class for the West Branch Tract (a.) Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

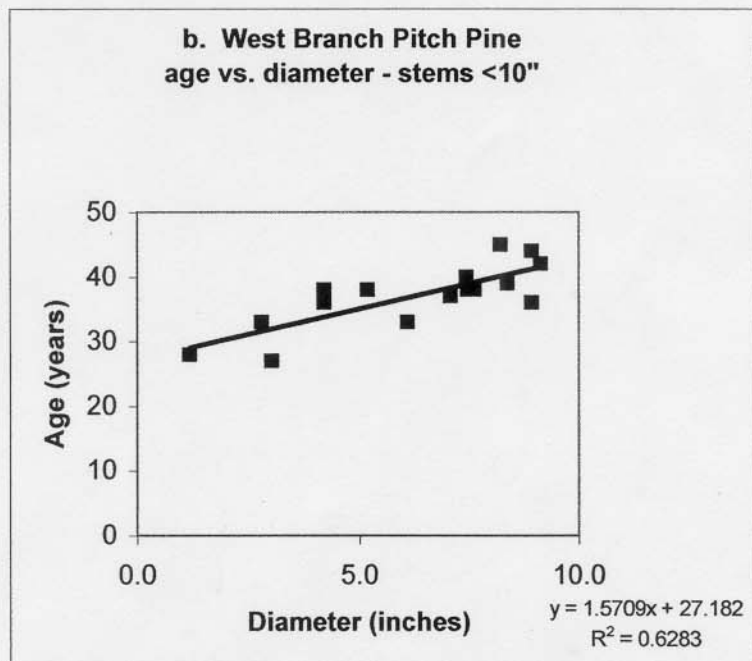
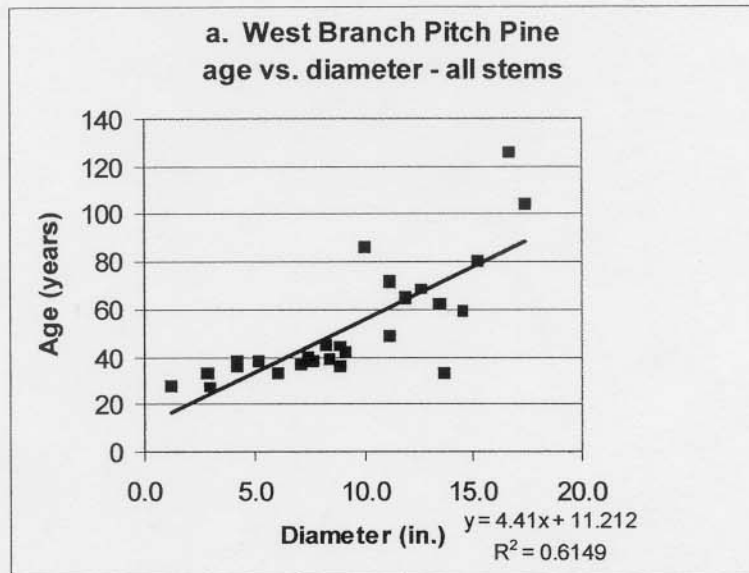
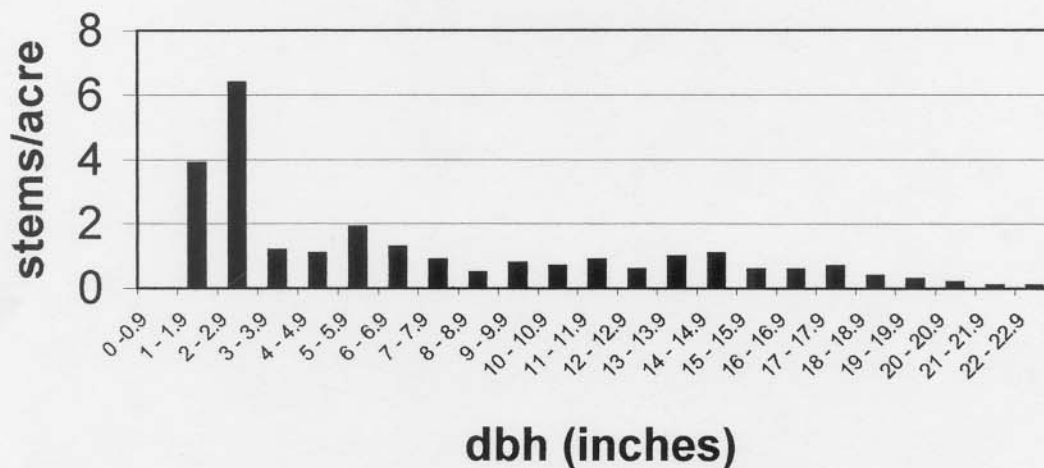


Figure 4. Age versus diameter for West Branch pitch pine stems cored in August, 1998: a.) all stems, b.) stems less than 10 inches at core height.

a.) West Branch White Pine



b.) HobbsTract White Pine

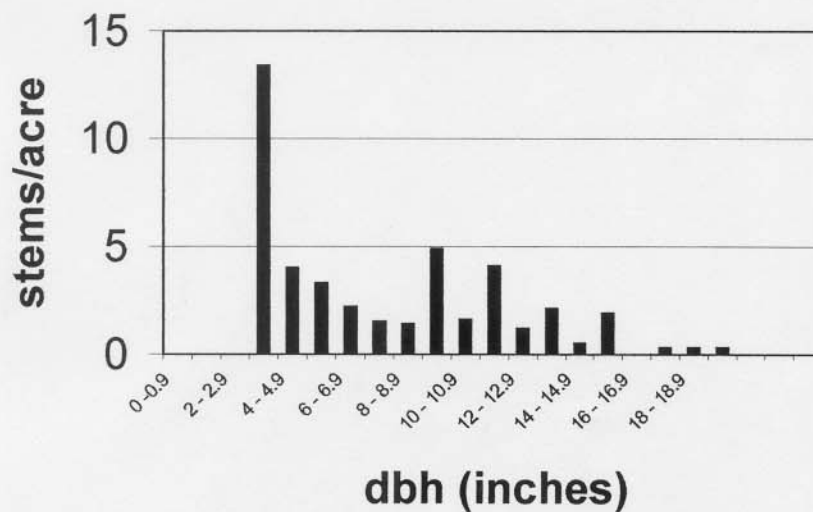


Figure 5. White pine stem density by size (diameter) class for the West Branch Tract (a.) and Hobbs Tract (b.), West Branch Pine Barrens Preserve, Ossipee, New Hampshire.

Scatter plot showing the distribution of 42 samples (WB1-WB44, HT1-HT20) categorized by Covertyp (1: triangle, 2: square, 3: circle). The plot shows a clear separation of samples along Axis 1, with most samples falling into one of the two main clusters.

6b.)

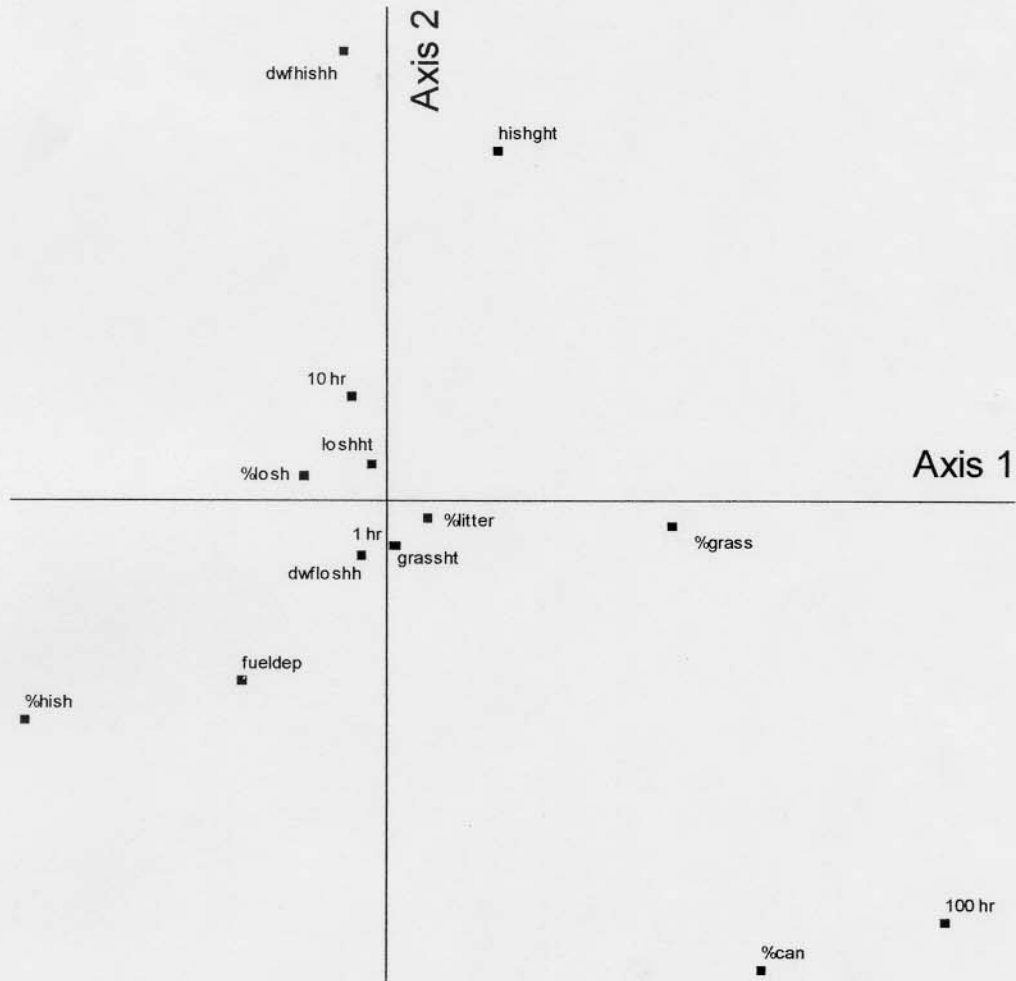
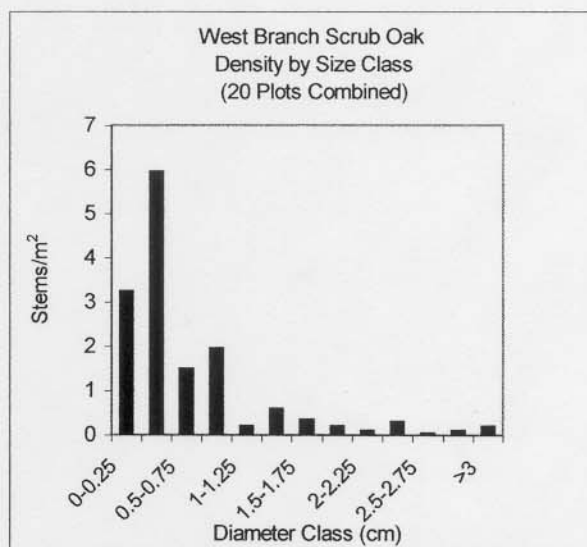
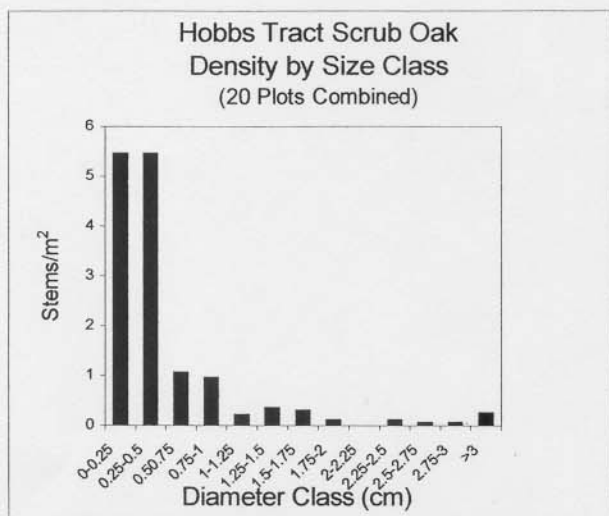


Figure 6. Results of detrended correspondence analysis: distribution of West Branch and Hobbs Tract plots (Fig. 6a) in space defined by fuel bed characteristics (see Fig. 6b). Plots are coded by cover type: 1 = PP/WP/SO Forest, 2 = PP/SO Forest, 3 = PP/SO Thicket.



Appendix A

Methods used to sample vegetation and fuels at
West Branch Pine Barrens Preserve, Madison, NH

Supervisor - William Patterson
Field Workers - Kent Nelson, Erin Kenney and Nate Gourd.

I. Equipment

A. measuring devices

1. tree calipers
2. 100' measuring tapes, marked in feet and tenths (2)
3. sturdy, readable yard stick, marked in feet and inches
4. go-no-go gauges, with increments that correspond to time lag classes (2)
5. spherical densiometer, concave
6. clinometer
7. cruise-all

B. other equipment

1. rear sighting compass
2. map of study area
3. blank data sheets and clipboard
4. pencils, permanent markers, calculator
5. chaining pins (2)
6. small trowel or old knife for digging through duff
7. paper bags for litter samples
8. 40cm x 40cm (1600 m²) frame made from 1/2" PVC pipes
9. 1m x 1m frame made from 1/2" PVC pipes
10. pruning shears

II. Gathering data for sample plots

A. Downed woody fuel inventory (per Brown 1974 and Patterson 1998)

1. Select directions (N-S or E-W) for transects based on presence of roads, trails and changing forest types.
 - a. four transect lines, 100' apart
 - b. five points on each transect, each 100' apart
2. Measure 150' from plot center in a direction perpendicular to transects (to avoid sampling through the plot center, which is fairly well trampled by now). This is point #1.
3. At each point:
 - a. use the densiometer to measure % cover of all vegetation above waist height.
 - b. use cruise-all to tally all live stems (variable radius plots).

(1) BAF of 5 or 10 can be used based on density.

(a) record diameters at breast height to the nearest 10th of an inch.

c. look at the second hand of a watch. The sampling plane will extend 50' in the direction which corresponds to 30 times the number at which the second hand points *plus* the bearing of the transect line.

(1) example: transect runs west at 270°. Your second hand is on the 3. $3 \times 30^\circ = 90^\circ$. $90^\circ + 270^\circ = 360^\circ$, or true north.

(2) example: transect line runs south at 180°. Your second hand is on the 10. $10 \times 30^\circ = 300^\circ$. $300^\circ + 180^\circ = 480^\circ$. $480^\circ - 360^\circ = 120^\circ$. Your sampling plane should run at a bearing of 120°.

d. Attach a measuring tape to a pin at the point

e. Extend the measuring tape for 50 ft in a straight line following the bearing calculated above. The tape should lie as close to the ground as possible and vegetation surrounding the plane should be disturbed as little as possible.

f. With one person standing at the end of the sampling plane and another at the point, the clinometer should be used to measure the slope along the line.

g. Along the sampling plane:

(1) in the first 6':

(a) count all intersections between the sampling plane and any dead, unrooted woody material below 9'. Intersections should be divided into size classes:

- (i) 0 - 1/4" diameter
- (ii) 1/4 to 1" diameter
- (iii) 1 - 3" diameter
- (iv) >3" diameter

Note 1: for all intersections with pieces >3", measure actual diameter where intersected, perpendicular to the center axis of the piece and record as either sound or rotten.

Note 2: dig into litter along the ground and record intersections of wood within the litter as well as those above it.

(2) Between 6' and 12':

(a) count all intersections between the sampling plane and any dead, unrooted woody material > 1/4" in diameter and below 9'.

Intersections should be divided into size classes:

- (i) 1/4 to 1" diameter
- (ii) 1 - 3" diameter
- (iii) >3" diameter

Note: For all intersections with pieces >3", measure actual diameter where intersected, perpendicular to the center axis of the piece and record as either sound or rotten.

(3) Between 12' and 20':

(a) count all intersections between the sampling plane and any dead, unrooted woody material >1" in diameter and below 9'. Intersections should be divided into size classes:

- (i) 1 - 3" diameter
- (ii) >3" diameter

Note: For all intersections with pieces > 3", measure actual diameter where intersected, perpendicular to the center axis of the piece and record as either sound or rotten.

(4) At 15':

(a) measure the height of the tallest scrub oak or tree shorter than 9' that intersects the sampling plane between 15 and 16'.

(b) measure the height of the tallest other shrub that intersects the sampling plane between 15 and 16'.

(c) measure the depth of the litter layer or the highest dead woody fuel (whichever is greater) that intersects the sampling plane between 15 and 16'.

(5) At 20':

(a) Measure the depth of the duff layer -(the base of the litter down to the top of the mineral soil)

(6) Between 20 and 50':

(a) Count all intersections between the sampling plane and any dead, unrooted woody material > 3" in diameter and below 9'. Note: for all intersections with pieces > 3", measure actual diameter where intersected, perpendicular to the center axis of the piece and record as either sound or rotten.

(7) At 30':

(a) measure the height of the tallest scrub oak or tree shorter than 9' that intersects the sampling plane between 30 and 31'.

(b) measure the height of the tallest other shrub that intersects the sampling plane between 30 and 31'.

(c) measure the depth of the litter layer or the highest dead woody fuel (whichever is greater) that intersects the sampling plane between 30 and 31'.

(8) At 40':

(a) measure the depth of the duff layer -(the base of the litter down to the top of the mineral soil)

(9) At 45':

(a) measure the height of the tallest scrub oak or tree shorter than 9' that intersects the sampling plane between 45 and 46'.

(b) measure the height of the tallest other shrub that intersects the sampling plane between 45 and 46'.

(c) measure the depth of the litter layer or the highest dead woody fuel (whichever is greater) that intersects the sampling plane between 45 and 46'.

4. Move along the transect to the next point, 100' away from the first, and repeat procedure.

B. Relieve/stand survey to record vegetation types

1. Relieve plots - estimate % cover of all woody and herbaceous plant species by

- a. canopy
- b. high shrub
- c. low shrub
- d. grasses/forbs
- e. leaf litter

Note: Percent cover is a subjective measure that uses a reference area of a 10m^2 circle. The vertical projection of the crown or shoot area of each plant species is projected on the ground surface and estimated by using the following cover classes:

- 1 = < 1% (1 sq. meter)
- 2 = 1 - 5%
- 3 = 5 - 25%

- 4 = 25 - 50%
- 5 = 50 - 75%
- 6 = 75 - 100%

After the percent cover of individual plant species is recorded, a subjective estimate of total % cover *by strata* is also recorded.

2. Stand survey

- a. Originate from the same plot center as the releve plots.
- b. 10 subplots are completed at apprx. 1 chain intervals away from the original releve plot center.

(1) Based on a 6' radius circle, the following observations are recorded:

- (a) slope/aspect
- (b) Percent canopy listed by dominant species
 - (i) average height (ft)
 - (ii) distance to live crown (ft)
- (c) % cover of strata by classes listed above
 - (i) % high shrub and average height (to nearest .5 meter)
 - (ii) % low shrub and average height (to nearest 2" class)
 - (iii) % grass/forbs and average height (to nearest inch)
 - (iv) % leaf litter

(2) Other observations such as fire scars, unique plants and a sketch map of the sampling scheme are also recorded.

C. Clip Plots - used to measure litter accumulation

1. Using approx. 1 chain spacing, harvest samples of fine fuels from untrampled locations within known cover types. Each 40cm x 40cm (1600cm²) frame encompasses 1 subplot; 10 subplots per plot.

- a. Randomly throw 40cm x 40cm (1600cm²) frame until it lies flat on forest floor.
- b. Clip all stems < 1" at base, sorting material as you cut
- c. Place stems into properly labeled bags
 - (1) live stems
 - (2) dead standing material
 - (3) litter
- d. Store bags of litter in a dry area until they can be oven dried.

D. Scrub oak plots to measure scrub oak density

1. Using approx. chain spacing, sample scrub oak stems from locations within known cover types. Each 1m x 1m frame encompasses 1 subplot; 10 subplots per plot.

- a. Randomly throw yard stick (made visible w/ flagging) in area to be sampled
- b. Line 1m x 1m frame up with yard stick so it lies flat on forest floor
- c. Measure and record the number of stems (by size class using go-no-go gauge). To avoid double counting, destructive sampling may be used.

III. Laboratory procedures

A. Clip plots

1. Dry bags and contents at 70° Celsius
2. Separate herbaceous material from woody material
3. Weigh components and record according to the categories collected:
 - a. live vegetation
 - b. dead standing vegetation
 - c. litter
4. Record weight of woody components by timelag class
 - a. 0 - 1/4" diameter = 1 hour fuels
 - b. 1/4" - 1" diameter = 10 hour fuels
 - c. 1" - 3" diameter = 100 hour fuels

Note: No 1000-hour fuels were collected.

IV. Preparing data for input to BEHAVE

- A. Input data into spreadsheet, sorted by cover type.
- B. Use ordination analysis to determine distinct custom fuel models.
- C. Organize data according to distinctions made using ordination analysis.
 1. Get fuel loads from dry weights from clip plot samples
 - a. Shrub loads must include weights estimated using allometric equations.
 2. Depth calculations
 - a. litter and shrub depth are the average of actual sample points along DWF lines.
 - b. grass cover is taken from Stand Survey data
 3. Cover percent
 - a. Litter and grass are taken directly from Stand Surveys
 - b. Shrub cover is the average of the low and high shrub covers from the stand survey

D. Follow prompts to enter data into the NEWMODEL program of BEHAVE.

1. Litter load and depth
2. Grass load and depth
3. Shrub load and depth
4. Heat content
5. Surface area-to-volume ratio

Appendix B

Field notes on trees cored at the Hobbs Tract, West Branch Pine Barrens Preserve, Freedom, NH on August 21-22, 1998.

Note: Cores aged in the field with aid of a 10X hand lense. Precision \pm 1-3 years.

Tree No.	Species	DBH (cm)	Core Age (yrs.)	Estimated Date of Establishment ¹ (yr. AD)	Radial Growth (cm/yr)	Notes
1	PINSTR	21.3	37	1957	0.58	fire scared stump with scars about and 1906 and 1914 south of trees nos. 3 and 4
2	PINSTR	39.8	48	1946	0.83	
3	PINRIG	34.0	~78	~1916	0.44	
4	PINRIG	34.5	83	1911	0.42	
5	PINSTR	42.5	43	1951	0.99	near PINRIG snag with several old fire scars - some close together but at least one much earlier
6	PINRIG	42.5	116	1878	0.37	fire about 86 years ago (ca. 1912)
7	PINRIG	66.5	no age			nearby stump is 79 cm basal diameter and 200-250 years old slow growth ca. 1948 and 1963
8	PINRIG	60.1	~172	~1822	0.35	
9	PINRIG	31.2	82	1912	0.38	
10	PINSTR	39.0	36	1958	1.08	
11	PINSTR	50.4	39	1955	1.29	in clear cut area. Based on the age of PINRIG and PINSTR regeneration and the pattern of release of canopy PINSTR, the stand seems to have had all PINRIG cut out about 1978.
12	PINRIG	22.5	80	1914	0.28	slow growth about 1967. fire scared snag nearby has scars that might date to about 1898, 1905, and 1915. Abundance of 2 and 3-stemmed PINRIG in this stand may reflect sprouting of young stems established after the first and top-killed by the last 1 or 2 of these fires.
13	PINRIG	45.7	85	1909	0.53	very slow growth 1967-1973. Slow growth about 1923 and major shift to slower growth ca. 1946.
14	PINSTR	41.3	38+	>1956	1.09	basal section 71.5 cm at stump
15	QUEILI	4.4	~40	~1958	0.11	
16	PINRIG	68.1	~176	~1818	0.39	
17	PINRIG	72.0	no age			
18	PINRIG	73.2	no age			
19	PINRIG	80.5	no age			
20	QUERUB	63.1	no age			
21	PICRUB	16.3	44	1950	0.37	

Appendix C

Field notes on trees cored at the West Branch Tract, West Branch Pine Barrens Preserve, Madison, NH on August 5-6 and 21, 1998.

Note: Cores aged in the field with aid of a 10X hand lense. Precision \pm 1-3 years.

Tree #	Species	DBH (cm)	Core Age (yrs.)	Estimated Date of Establishment ¹ (yr. AD)	Radial Growth (cm/yr)	Notes
[tree nos. 1-10 are just north of Memorial Rock. Several old, cut PINRIG stumps in this area. Mid-20th century logging road thru area.]						
1	PINRIG	46.6	ca. 110	1884	0.21	fire scared lower branches, period of slow growth in 1930's slow growth about 50 years ago (ca. 1948)
2	PINRIG	19.8	74	1920	0.13	
3	PINRIG	20.8	65	1929	0.16	
4	PINRIG	8.8	44	1950	0.10	
5	PINSTR	20.3	35	1959	0.29	
6	PINSTR	45.3	54	1940	0.42	
7	PINSTR	38.0	37	1957	0.51	
8	PINRIG	58.2	ca. 103	<1891	<0.28	too large to reach pith, core at breast height, slow growth ca. 50 & 78 y.a.
9	PINRIG	36.8	100+	<1894	<0.18	center rotten; slow growth ca. 50 y.a.
10	PINRIG	15.0	49	1945	0.15	very slow early growth
[tree nos. 11-19 about 3 chains north of Memorial Rock. Cut stump in area was 60+ years old when tree cut, logging road near by]						
11	PINRIG	20.7	39	1955	0.27	rapid early growth too large to core
12	PINSTR	48.3	41+	<1953	<0.59	
13	PINRIG	29.9	67	1927	0.22	very slow growth ca. 1960-65
14	PINRIG	18.3	59	1935	0.16	
15	PINSTR	30.5	42	1952	0.36	
16	PINSTR	13.5	39	1955	0.17	
17	PINRIG	9.5	37	1957	0.13	
18	PINRIG	11.5	43	1951	0.13	
19	PINRIG	29.5	68	1926	0.22	

[tree nos. 20-22 about 5 chains north of Memorial Rock. Seems like this area may have burned in 1957 and was cut shortly after. Old PINRIG to the NW with several fire scars on a good "catface". May have been burned ca. 1928. and before that back to ca. 1888. Few PINSTR date to before 1938-1948, although oldest PINSTR are too large to core. Many cut stumps of very large, old PINRIG in this area.]

20	PINSTR	38.1	36	1958	0.53
21	PINRIG	16.0	38	1956	0.21
22	PINSTR	24.4	38	1956	0.32

[tree nos. 23-25 were cored in the south portion of the tract. This area is like the NW portion of the tract - several large 40-60 year old PINSTR and PINRIG of varying sizes and ages. Cut PINRIG stumps throughout, but rather scattered in places. Farther to the east, few PINSTR but extensive patches of 20-30 year old PINRIG. Charcoal on boles of some larger PINRIG suggests a fire ca. 1968. PINRIG stumps still common. Regeneration due to fire and/or logging? Could PINSTR have been planted? No evidence of seed trees for PINSTR. Large PINSTR occur on last 18-20 chains of NE section of Class VI Road and along the north boundary of tract. Many cut PINRIG stumps in these areas.]

23	PINSTR	44.8	39	1955	0.57
24	PINSTR	8.9	21	1973	0.21
25	PINRIG	10.3	23	1971	0.22

near river in SW portion of tract
26 whorls

[tree nos. 26-31 were scattered in the east, northeast, and northern portions of the tract.]

26	PINRIG	20.2	60	1934	0.17
27	PINRIG	4.4	52	ca. 1942	0.04
28	PINRIG	27.2	>55	<1939	<0.25
29	PINSTR	61.1	>44	1930-1940	-
30	PINRIG	(stump - about 13 inches basal diameter)			too large to reach pith
					total age about 90-100 to 100-110 when cut)
31	PINRIG	7.3	16	1978	0.23

slow growth 1948 and 1978.
slow growth from 1968-1971

[tree nos. 32-36 are east of the 3-corners in an area dominated by dense PINRIG, most of which area ~70 years old.]

32	PINRIG	18.2	21	1973	0.43
33	PINRIG	44.5	71	1923	0.31
34	PINRIG	28.0	68	1926	0.21
35	PINRIG	44.8	146+	1848	<0.15
36	PINSTR	22.1	41	1953	0.27

slow growth ~30 & 46 y.a.
slow growth ~30 & 46 y.a.
big, open-grown "wolf tree", slow growth began ca. 1868-1872, 1890, 1910, 1919, 1933, 1952 and 1968

[these four trees are within 50-75 m (N,W,S) of the Memorial Rock.]

37	PINSTR	67.3	55+	<1939	<0.61
38	PINSTR	57.3	51	1943	0.56
39	PINRIG	48.5	108	1890	0.22
40	PINSTR	48.8	55	1939	0.44

not quite to center?
slow growth ca. 1915, 1928, 1948.

1 Age at core height plus 4 years.

Appendix D

INPUT/OUTPUT TABLES FOR TESTMODEL RUNS OF OSS�PEE AND WATERBORO CUSTOM FUEL
MODELS WITH STANDARD FUEL MODEL 7 INCLUDED FOR COMPARISON

ENVIRONMENTAL (INPUT) PARAMETERS FOR FUEL MODEL TEST RUNS

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2--1-HR FUEL MOISTURE, % --      6.0
3--10-HR FUEL MOISTURE, % -     10.0
4--100-HR FUEL MOISTURE, %      15.0
6--LIVE WOODY MOISTURE, % -     80.0
7--20-FOOT WINDSPEED, MI/H -    5.0   10.0   15.0
8--TERRAIN SLOPE, % -----     5.0
9--DIRECTION OF WIND VECTOR      .0
    DEGREES CLOCKWISE
    FROM UPHILL
10--DIRECTION OF SPREAD ----     .0   (DIRECTION OF MAX SPREAD)
    CALCULATIONS
    DEGREES CLOCKWISE
    FROM UPHILL
  
```


FUEL MODEL TEST RUN OUTPUTS

MODEL: STATIC 60 (HOBBS)

BY: PATTERSON

LOADS, T/AC	S/V RATIOS, 1/FT	OTHER
1 HR 4.50	1 HR 1746.	DEPTH, FT 1.46
10 HR .60	LIVE HERB 2250.	HEAT CONTENT, BTU/LB 8273.
100 HR .90	LIVE WOODY 1550.	EXT MOISTURE, % 21.
LIVE HERB .00	SIGMA 1679.	PACKING RATIO .00776
LIVE WOODY 1.90		PR/OPR 1.01
		WIND REDUCTION FACTOR 0.2

ENVIRONMENTAL DATA

FIRE BEHAVIOR RESULTS

ENVIRONMENTAL DATA	FIRE VARIABLE	20-FOOT WIND, MI/H		
1 HR FM 6.		5.	10.	15.
10 HR FM 10.		---	---	---
100 HR FM 15.	ROS (FT/M)	6.	11.	18.
LIVE HERB FM 150.	FL (FEET)	5.4	7.3	9.1
LIVE WOODY FM 80.	IR (BTU/SQFT/M)	9124.	9124.	9124.
	H/A (BTU/SQFT)	2087.	2087.	2087.
SLOPE, % 5.	FLI (BTU/FT/S)	223.	431.	686.
	EFFECT. WIND (MI/H)	1.0	2.0	3.0

MODEL: STATIC 61 (WEST BRANCH - FOREST)

BY: PATTERSON

LOADS, T/AC

S/V RATIOS, 1/FT

OTHER

1 HR 4.20
10 HR .70
100 HR .20
LIVE HERB .00
LIVE WOODY 2.94

1 HR 1746.
LIVE HERB 2250.
LIVE WOODY 1550.
SIGMA 1660.

DEPTH, FT 1.46
HEAT CONTENT, BTU/LB 8383.
EXT MOISTURE, % 23.
PACKING RATIO .00790
PR/OPR 1.02
WIND REDUCTION FACTOR 0.2

ENVIRONMENTAL
DATA

FIRE BEHAVIOR RESULTS

1 HR FM 6.
10 HR FM 10.
100 HR FM 15.
LIVE HERB FM 150.
LIVE WOODY FM 80.

SLOPE, % 5.

FIRE VARIABLE	20-FOOT WIND, MI/H		
	5.	10.	15.
ROS (FT/M)	5.	10.	17.
FL (FEET)	5.5	7.5	9.2
IR (BTU/SQFT/M)	10101.	10101.	10101.
H/A (BTU/SQFT)	2337.	2337.	2337.
FLI (BTU/FT/S)	233.	448.	710.
EFFECT. WIND (MI/H)	1.0	2.0	3.0

MODEL: STATIC 63 (WEST BRANCH - THICKET)

BY: PATTERSON

LOADS, T/AC		S/V RATIOS, 1/FT		OTHER	
1 HR	4.20	1 HR	1750.	DEPTH, FT	1.74
10 HR	.70	LIVE HERB	2250.	HEAT CONTENT, BTU/LB	8387.
100 HR	.20	LIVE WOODY	1550.	EXT MOISTURE, %	23.
LIVE HERB	.00	SIGMA	1662.	PACKING RATIO	.00668
LIVE WOODY	3.00			PR/OPR	.87
				WIND REDUCTION FACTOR	0.4

ENVIRONMENTAL
DATA

FIRE BEHAVIOR RESULTS

		FIRE VARIABLE	20-FOOT WIND, MI/H		
1 HR FM	6.		5.	10.	15.
10 HR FM	10.				
100 HR FM	15.	ROS (FT/M)	13.	29.	48.
LIVE HERB FM	150.	FL (FEET)	8.1	11.8	15.1
LIVE WOODY FM	80.	IR (BTU/SQFT/M)	10132.	10132.	10132.
		H/A (BTU/SQFT)	2341.	2341.	2341.
SLOPE, %	5.	FLI (BTU/FT/S)	539.	1224.	2060.
		EFFECT. WIND (MI/H)	2.0	4.0	6.0

MODEL: DYNAMIC 62 (WATERBORO PP/SO THICKET)

BY: PATTERSON

LOADS, T/AC		S/V RATIOS, 1/FT		OTHER	
1 HR	7.20	1 HR	1748.	DEPTH, FT	1.01
10 HR	1.00	LIVE HERB	2250.	HEAT CONTENT, BTU/LB	8201.
100 HR	1.70	LIVE WOODY	1550.	EXT MOISTURE, %	24.
LIVE HERB	.00	SIGMA	1692.	PACKING RATIO	.01696
LIVE WOODY	2.04			PR/OPR	2.23
				WIND REDUCTION FACTOR	0.2

ENVIRONMENTAL
DATA

FIRE BEHAVIOR RESULTS

		FIRE VARIABLE	20-FOOT WIND, MI/H		
1 HR FM	6.		5.	10.	15.
10 HR FM	10.				
100 HR FM	15.	ROS (FT/M)	4.	8.	12.
LIVE HERB FM	150.	FL (FEET)	5.2	6.8	8.3
LIVE WOODY FM	80.	IR (BTU/SQFT/M)	11535.	11535.	11535.
		H/A (BTU/SQFT)	2618.	2618.	2618.
SLOPE, %	5.	FLI (BTU/FT/S)	201.	364.	565.
		EFFECT. WIND (MI/H)	1.0	2.0	3.0

STANDARD FUEL MODEL # 7 (SOUTHERN ROUGH)

WIND REDUCTION FACTOR: 0.4

20-FOOT WIND	I	RATE OF SPREAD	HEAT PER UNIT AREA	FIRELINE INTENSITY	FLAME LENGTH	REACTION INTENSITY	EFFECT. WIND
(MI/H)	I	(CH/H)	(BTU/SQFT)	(BTU/FT/S)	(FT)	(BTU/SQFT/M)	(MI/H)
5.0	I	10.	524.	99.	3.7	2119.	2.0
10.0	I	24.	524.	226.	5.5	2119.	4.0
15.0	I	39.	524.	378.	6.9	2119.	6.0