Managing White Pine in a New Millennium
2003 Workshop Proceedings

October 9 and 10, 2003
Caroline A. Fox Research Forest
Hillsborough, New Hampshire

The Caroline A. Fox Research and Demonstration Forest (Fox Forest) focuses on applied practical research, demonstration forests, and education and outreach for a variety of audiences.

It has been nearly two decades since foresters and researchers gathered for the last white pine symposium held in New Hampshire. *Managing White Pine in a New Millennium* held on October 9 and 10, 2003 was designed to disseminate the latest about management, measurement, condition, and regeneration. These proceedings were prepared as a supplement to the workshop. Papers submitted were not peer-reviewed or edited. They were compiled by Karen P. Bennett, Extension Professor and Specialist in Forest Resources and Ken Desmarais, Forester with the NH Division of Forests and Lands. Readers are encouraged to contact authors directly for clarifications.

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An Overview of the White Pine Resource in New England Using Forest Inventory and Analysis Data

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Abstract: Most white pine stands are characterized by large trees. Young regenerating stands are scarce throughout New England, resulting from a maturing of the white pine resource in most states. Maine is an exception with one-third of its white pine forest type in sapling/seedling stands. Eighty-one percent of the acres in the white/red pine group are in sawtimber-size stands. White pine comprises a smaller portion of saplings than it does of sawtimber-size trees in every New England state. In New England white pine volume totals 6.4 billion cubic feet and comprises 13.0 percent of the region's growing-stock volume. Volume increased by 16.1 percent between inventories.

Introduction

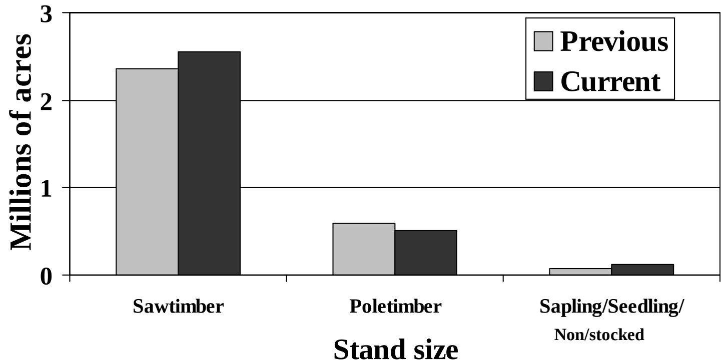
White pine plays an important role in the New England economy. It is often the largest tree in the forest and has a unique function in the forest ecosystem. This paper presents white pine data from the U.S. Department of Agriculture's Forest Inventory and Analysis (FIA) for Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont. Data described as "current" were collected during the late 1990s except for Maine data, which is derived from four panels of the FIA annual inventories, the latest panel being collected in 2002. Data described as "previous" refers to data collected during the mid-1980s except for Maine data, which were collected during the early 1990s. The period between inventories for individual states is: 13 years for New Hampshire and Vermont; 14 years for Rhode Island, Massachusetts, and Connecticut; and 8 years for Maine.

Area

About 3.1 million acres (or 10 percent) of New England timberland is in the white/red pine forest type group. This group includes the following forest types: red pine, white pine, white pine/hemlock, and hemlock. There was a small increase of 152,000 acres in this group between the current and previous inventories. Within the group, the white pine forest type represents 1.3 million acres. White pine also plays an important role in the oak/pine forest-type group, which includes 751,300 acres in the white pine/northern red oak/white ash forest type and is found scattered within other deciduous forest types.

Eighty-one percent of the acres in the white/red pine group are in sawtimber-size stands, 15.8 percent in poletimber stands and 3.4 percent in sapling/seedling stands (including some non/stocked timberland)(Fig. 1). Of the sapling/seedling stands, 60.9 percent are in Maine. Excluding Maine, 2.3 percent of the white/red pine group is in seedling/sapling stands. The portion of the group's area in the sapling/seedling stand-size class is lower than the regional average for all timberland. For all New England 19.8 percent of timberland is in this class. If Maine is excluded, 8.2 percent of timberland is in the sapling/seedling class. In Maine, 34.6 percent of the white pine forest type is in the sapling/seedling size-class.

Figure 1.-- Area of timberland in the white pine/red pine forest-type group in New England



More than half (52.6 percent) of the white pine growing-stock volume is in the white/red pine group. Other forest type groups that contain significant amounts of white pine growing stock volume are the northern hardwood group (16.6 percent), the oak pine group (14.4 percent) and the oak hickory group (7.1 percent).

Number of Trees

In the six-state New England region, there has been a 2 percent increase in the number of white pine stems 5 inches and larger diameter breast height (dbh). When plotted over diameter class, these stems show an inverse J-shaped curve (Fig. 2). A comparison of curves between the current and previous inventories shows very little change in stem distribution. Most of the increase in the numbers of trees occurred in the upper diameter classes with small decreases in the 6-, 10-, and 12-inch classes. This suggests some flattening of the curve over time. Flattening of the curve was more pronounced in New Hampshire where numbers of stems decreased in diameter classes 6 through 12 (Fig. 3). Curves for Maine contrasted with the regional trend with stems increasing in number in the 6-, 8-, and 10- inch classes and declining in classes 12 though 20 (Fig. 4).

Figure 2.-- Numbers of white pine trees on timberland in New England

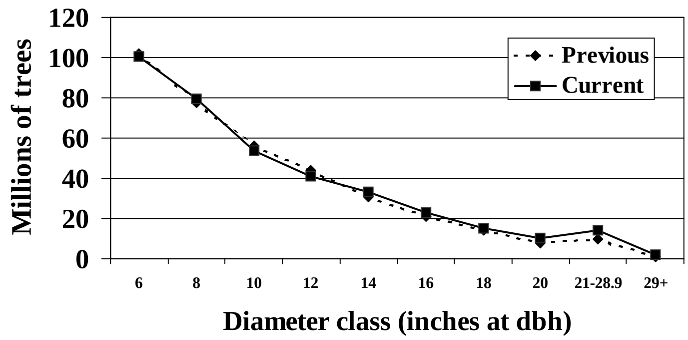


Figure 3.-- Numbers of white pine trees on timberland in New Hampshire

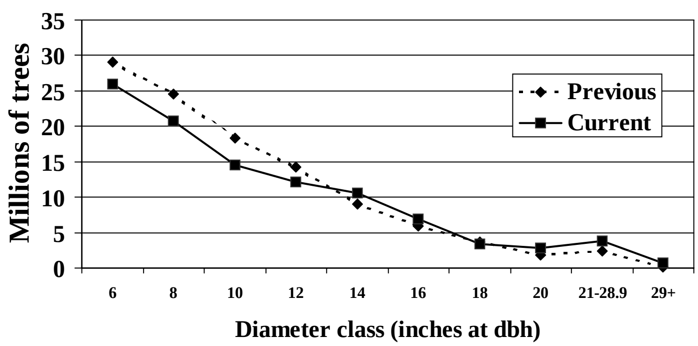
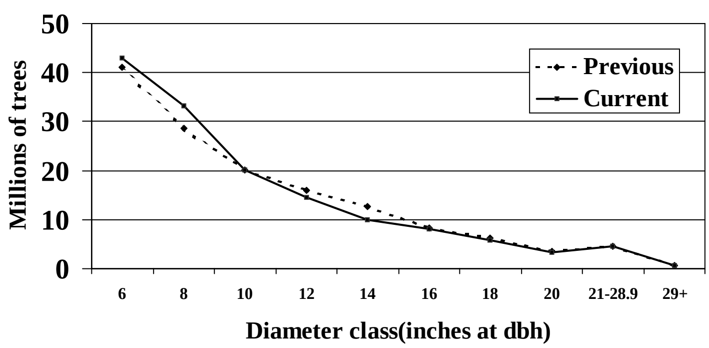


Figure 4.-- Numbers of white pine trees on timberland in Maine



Changes in sapling (trees ≥1 inch dbh and < 5 inches) composition can be understood by ranking saplings by occurrence. In New Hampshire, white pine saplings dropped from fifth to eighth place between inventory periods (Table 1). While in Maine white pine saplings experienced very little change in ranking (Table 2).

White pine comprises a smaller portion of saplings than it does of sawtimber-size trees in every New England state (Fig. 5). In New Hampshire, white pine comprises 5 percent of saplings and 21 percent of sawtimber, and in Maine 1 percent of saplings and 11 percent of sawtimber.

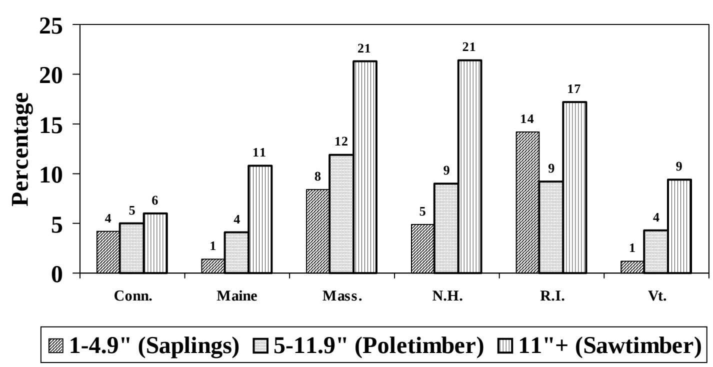
Table 1.-- Ranking of the number of white pine stems in New Hampshire

	New Hampshire	
Rank	Saplings ranked by number	
	Previous 1983	**Current 1997**
1	balsam fir	balsam fir
2	red maple	red maple
3	sugar maple	American beech
4	American beech	yellow birch
5	**white pine**	sugar maple
6	paper birch	eastern hemlock
7	red spruce	red spruce
8	eastern hemlock	**white pine**
9	yellow birch	striped maple
10	gray birch	paper birch
11	northern red oak	northern red oak
12	white ash	white ash

Table 2.-- Ranking of the number of white pine stems in Maine

	Maine	
	Saplings ranked by number	
Rank	**Previous 1995**	**Current 2003**
1	balsam fir	balsam fir
2	red maple	red maple
3	spruce	spruce
4	paper birch	paper birch
5	American beech	yellow birch
6	yellow birch	American beech
7	striped maple	striped maple
8	sugar maple	sugar maple
9	quaking aspen	northern white-cedar
10	northern white-cedar	quaking aspen
11	mountain maple	eastern hemlock
12	Ash	Ash
13	eastern hemlock	gray birch
14	**white pine**	mountain maple
15	gray birch	**white pine**

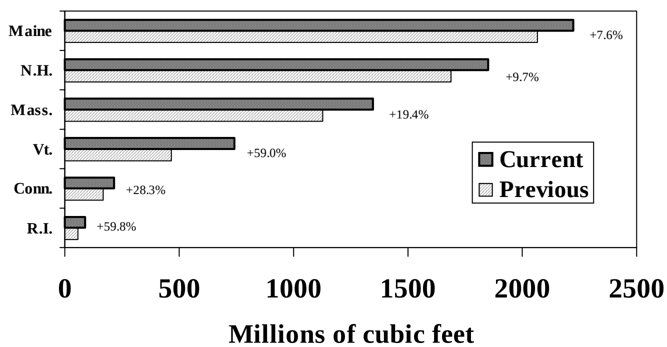
Figure 5.-- White pine stems as a percentage of all stems in size class



Volume

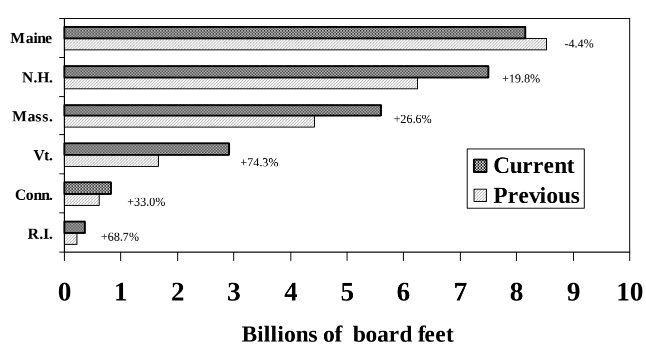
White pine volume in New England totals 6.4 billion cubic feet and comprises 13.0 percent of the regions growing-stock volume. White pine volume increased by 16.1 percent between inventories. Maine has the largest share of white pine volume and experienced the smallest volume change (Fig. 6). This increase was greater than the 12.6 percent volume increase observed for all species combined. White pine comprises the greatest portion of the growing-stock resource in Massachusetts (23.5 percent) followed by New Hampshire (20.6 percent). About a third of the region's white pine resource grows in Maine although it only represents 9.9 percent of that state's total growing-stock volume.

Figure 6.-- Change in white pine growing-stock volume on timberland in New England



Current white pine sawtimber volume (expressed in board feet, International ¼-Inch Rule) totals 25.4 billion board feet. This is a 16.7 percent increase from the previous inventory. Most states showed increases in white pine sawtimber volume with the exception of Maine, where volume decreased (Fig. 7). In Maine volume increases occurred on trees too small to be classified as sawtimber and declined in the sawtimber-size diameter classes, thus the difference between changes in board foot and cubic foot volume.

Figure 7.-- Change in white pine board-foot volume on timberland in New England



Growth and Removals

Net growth of white pine exceeds removals by a ratio of 1.4:1 in New England and by 1.6:1 if Maine is excluded. An increasing portion of removals is attributable to losses due to land-use change. Conversion occurs when timberland shifts to "reserved" forest or to urban, suburban, industrial, and other developed use. Excluding Maine, where recent data are not available, 34 percent of white pine removals are due to timberland changing to a nonforest use (Table 3). Removals to land-use change accounted for 67.6 percent of removals in Massachusetts and 34 percent in New Hampshire. Excluding removals to land use change and to reserved forest, the ratio of growth to harvesting was 2.5: 1 in the New England states excluding Maine.

Table 3.--Components of annual change (thousand cubic feet), 1980s--1990s

				Removals			
	Net Growth (G)	Total Removals (R)	G/R ratio	Harvest	Nonforest	Reserved forest	Percent due to change to nonforest
Conn	4,968	1,379	3.60	924	454	0	32.9%
Maine*	59,020	52,020	1.13	--	--	--	--
Mass.	20,686	11,061	1.87	3,158	7,479	425	67.6%
N.H.	45,101	31,791	1.42	20,715	11,076	0	34.8%
R.I.	2,563	281	9.12	0	281	0	100.0%
Vt.	20,851	13,688	1.52	13,180	508	0	3.7%
New England**	94,169	58,200	1.62	37,053	19,798	425	34.0%

*Maine date from 1982-95 period

** excludes Maine

Mortality

Mortality rates are computed as a percentage of current inventory volume. White pine mortality is lower than other species. The annual mortality rate for white pine in New England is 0.2 percent--significantly lower than the 0.8 percent average mortality rate for all species (Table 4).

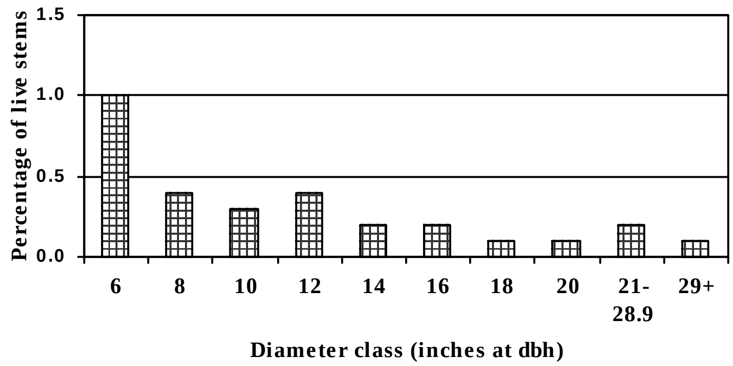
Table 4.--Average annual rates of mortality

	White pine	All species
	(Percent of inventory)	
Connecticut	0.2%	0.5%
Maine*	0.2%	1.1%
Massachusetts	0.3%	0.5%
New Hampshire	0.2%	0.6%
Rhode Island	0.3%	0.6%
Vermont	0.3%	0.6%
Regional avg.	0.2%	0.8%

*Data from 1982-1995 inventory period

White pine mortality rates are higher in the lower diameter classes (Fig. 8). On an annual basis, 1.0 percent of stems in the 6-inch class die, whereas only 0.1 percent of stems die each year in the 18- and 20-inch classes.

Figure 8.-- Annual white pine mortality on timberland in New England
(numbers of dead trees/ number live growing stock)



Discussion

Generally most stands with white pine are characterized by large trees. Young regenerating stands are scarce throughout New England, as a result of a maturing of the white pine resource in most states. Maine is the exception to this generalization. In Maine one-third of the white/red pine forest type group acreage is in sapling/seedling stands. Harvesting in Maine has made the white pine resource in that state significantly different than the other New England states.

The inverse J-shape of the curve of the numbers of trees over diameter classes shows a typical distribution of stems across diameter classes. There is a trend toward a flattening of this curve over time in states other than Maine. This trend is similar to that occurring throughout the Northeastern states for all species combined. White pine grows in association with many different species. Nearly half of white pine volume grows in stands other than the white/red pine forest-type group. Most of these mixed species stands are dominated by hardwood species with white pine often comprising a significant portion of the stand volume.

White pine is underrepresented in the sapling class compared to the sawtimber class. It is likely that as sawtimber-size white pine are harvested or die they will not be completely replaced by white pine trees growing into sawtimber. As this occurs, the current high proportion of white pine sawtimber will not be sustained.

White pine volume increases for growing stock and sawtimber volume tend to be larger than for other species. Because more of the white pine volume increases have occurred in the larger diameter classes, sawtimber-volume increases have been larger than those for all growing stock. Volumes in Maine, where there were declines in large trees are an exception to this.

White pine growth exceeds removals in all New England states, though by only a slim margin in Maine. An increasing portion of removals is due to land-use change. In New England states other than Maine, these losses comprise a third of all removals. Because white pine is found to a large extent on sites prone to urban sprawl (southern New Hampshire, eastern Massachusetts, and eastern Connecticut) losses to land-use change will likely continue. Unlike removals due to harvesting and reserved status, losses to land-use change take forest land out of production, reducing future growth and negatively impacting sustainability.

Mortality rates for white pine are low compared to other species. The mortality that does occur is higher in the smaller diameter classes. This could indicate that stress from competition from other species is the leading cause.

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White Pine Health in New Hampshire

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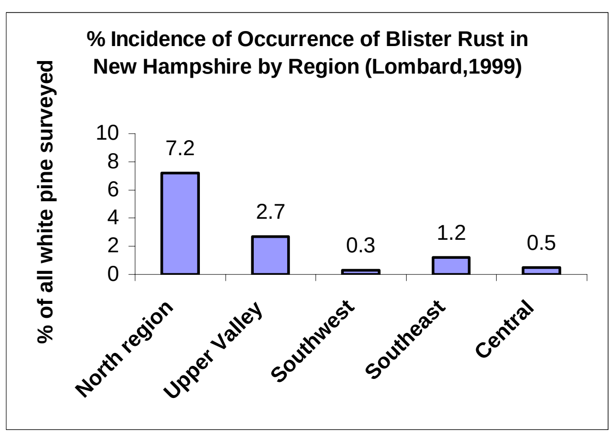
The health of New Hampshire's white pine forest, commonly described by its visual appearance and growth productivity, is affected by many factors. These forest health factors can be broken into three major groups; genetics, abiotic stressors, and biotic pests.

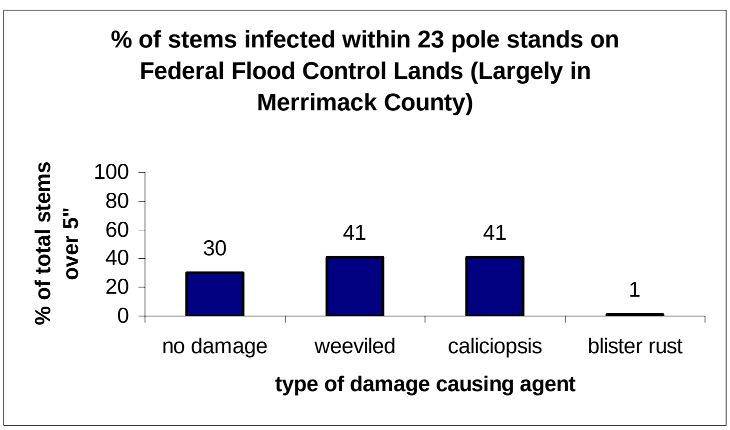
Understanding why genetics play a role in forest health requires a look at the history of white pine in the state. The white pine resource of New Hampshire has changed dramatically in the past 100 years. In the late 1800's statewide forest cover was at the historic low of 48%. By 1980 we peaked at a high of 87%. To get this reforestation process started in the early 1900's millions of white pine seedlings were planted in unused sheep pastures and unproductive agricultural lands. Through the process of importing a portion of that planting stock a wide range of genetic variability was introduced into New Hampshire. Seedlings from as far away as Europe (which at that time, had been newly infested with blister rust from Russia) were planted throughout New York and New England. Each seed source, be it from North Carolina, New Hampshire, New York, or England has a different ability to resist particular forest health stresses. For example, it's not uncommon in central New Hampshire in late summer to see a white pine turning an orange/brown hue due to sulfur dioxide pollution damage, and standing right beside it is a white pine with no visible damage. Differences in white pine genotypes allow some trees to grow longer into the fall leaving them susceptible to twig dieback from frost, others may be more accepting of poor soils, some genotypes may not be good self pruners, and yet others may break dormancy too early for this region and be annually damaged by subfreezing temperatures.

In addition to scattered genetic deficiencies in our pine resource, the abiotic and biotic stressors "weigh-in" on an annual basis to affect the way New Hampshire's white pine looks and grows. A good example of an abiotic stress to pine in New Hampshire is ozone pollution. Ozone (O_3) is created in the hot summer months when nitrogen oxides from car emissions and sulfur dioxides from coal burning power plants combine with organic compounds in the atmosphere to create an abundance of ozone. Ozone enters needle stomates during a period of wet or humid weather and causes cell collapse. It's estimated that forest productivity in New England dropped 3-16% between 1987 and 1992 from damage caused by ozone pollution (Rock, 2001). Additional examples of abiotic damage would be drought, ice storms, and surface water shifts caused by beavers, poorly constructed roads, and other development.



The health effect on white pine from biotic stressors is generally less subtle, more common, and better understood than abiotic damages. Biotic damage-causing agents common in New Hampshire include blister rust, pine canker, interior decay funguses, root rots, introduced pine sawfly, white pine weevil, needle casts, and gypsy moth. Today, with blister rust far less abundant and not a threat to pine management in most regions of the state, one of the newest and most visible biotic damage causing agents is pine canker (*Caliciopsis pinea*). This stem disease causes lesions on the thin-barked regions of the tree and pitch runs down the bole from each wound. The canker and pitch flow combination is often mistaken for blister rust. The key when visually differentiating between these diseases is to remember blister rust requires an alternate host and infects through branches while the pine canker is an annual fungus infecting directly on the bark of the upper bole. If pitching is internodal and no stem deformation exists it's most likely caliciopsis canker. If the canker has encircled a dead branch, is bleeding from the margins and causing stem deformation it's likely to be blister rust. Caliciopsis was first identified in New Hampshire in 1997 and since then has been found it in all counties. The most heavily infested counties are Merrimack, Belknap, and Carroll. One recent inventory of all white pine pole stands within a 13,000 acre management unit (Army Corp. Flood Control Properties) from Bristol to Dunbarton revealed 41% of the tallied stems infected with caliciopsis pinea. On these same plots 41% of the stems had at least one weevil injury, and only 1% had blister rust infections**.**

Figure 1. blister rust on the left, caliciopsis on the right



Today we still know relatively little about *Caliciopsis pinea*. We do know it's an annual canker that produces spores most likely spread by wind and rainfall. Healthy trees in New Hampshire are showing the ability to grow over small cankers leaving embedded pitch and bark pockets. And since 2001 many of the most heavily infested sites have stabilized or gotten slightly better. The Division of Forests and Lands has implemented a few silvicultural trials to assess the impact of thinning on the recovery rate of heavily infested pole stands. Two growing seasons after the thinnings were done the pitching symptoms have been reduced and the crown transparencies and densities have improved by 10-20%.

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The Perfect White Pine Log

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When we think about the perfect white pine log, we as foresters usually have in mind a special tree; one that inspires us to a greater forestry good; one that makes us get up each morning, we envision a tree that soars above all others, sways gently in the wind, produces cones the size of bananas and, because of its branch free form, must produce the most mouth watering pine logs anyone could want. After all, that's what King James wanted when he marked mast trees way back before the American Revolution. We all think about that clean boled, spectacular white pine tree. We've all seen that tree and strive, through our actions as loggers, foresters, or landowners, to produce more. But, despite the big white pine's majestic and spiritual presence, we have to face the reality that it may not represent the best and most desired tree from a utilization point of view.

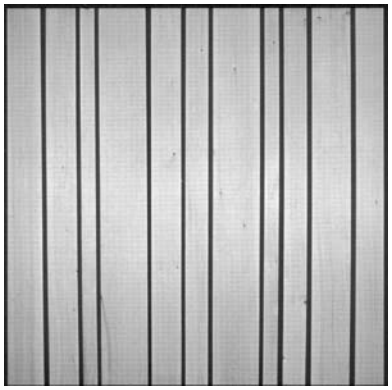
My comments this morning are meant to provoke thinking about white pine management in the context of white pine utilization.

First, let's take a look at the white pine industry in New Hampshire. As most of you know, white pine represents (volume wise) the most important timber species in our forest. In the 1950s, white pine represented 73% of lumber production. Today ('02 numbers), that figure is 66%. While the percentage of white pine produced over the years has not changed dramatically, the product produced has. What was once a box and shook (box and barrel parts) business requiring round edged, air dried lumber is now primarily a NeLMA (Northeastern Lumber Manufacturers Association), kiln-dried and planed board business. What once was a log run or "give me anything you got" business has matured into a procurement strategy that focuses on log specifications which attempt to improve the lumber grade yield from each log.

My comments will focus on the NeLMA kiln-dried and finished pine board markets. There are many other markets: cabin stock, furniture pine, wide pine flooring—to name a few. If you examine any market the definition of what constitutes a perfect log will change. I chose to concentrate on the most common, based on New Hampshire's total sawmill production.

NeLMA is the wholesale lumber grading agency sanctioned by the US Department of Commerce to apply American Softwood Lumber Standards for this region of the United States. The board grades used by most of New Hampshire's white pine sawmills are Select, Finish, Premium, Standard, and Industrial. Finish is usually mixed in with premium. The highest grade, Select, requires a virtually clear board with only an occasional, small pin knot admitted. Premium allows up to 2 ½ inch red knots or 1" black knots in a 6" wide board. Without going into detail, the object is to minimize the occurrence of black knots. Remember, black knots come from dead branches. Now, think about the typical white pine stand that you encounter in your daily work—like I said, black knots are a challenge.

The following pictures will give you a sense of what the boards look like for each grade.



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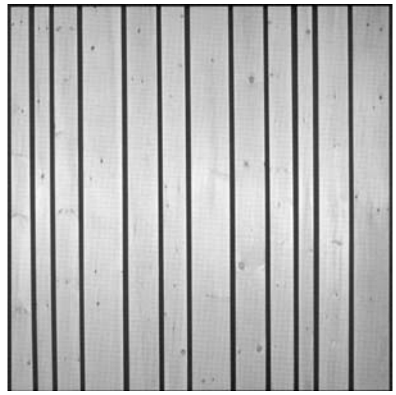

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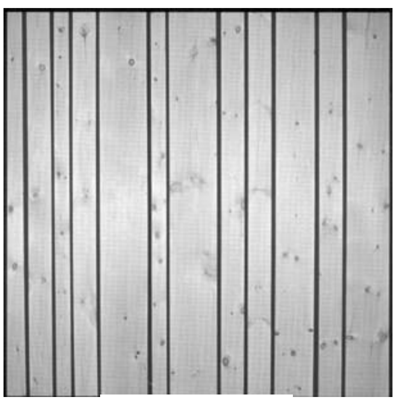

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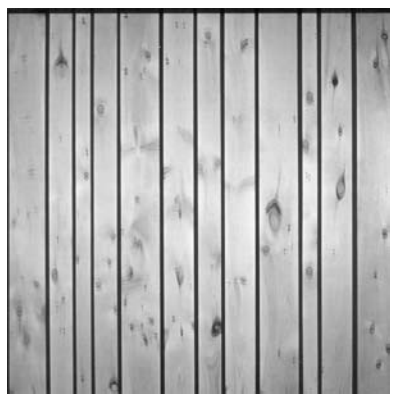

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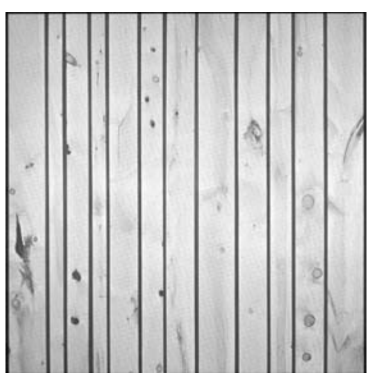

Industrial

Generally, New Hampshire white pine logs yield a small percentage of high grade lumber when using the NeLMA grading system. New Hampshire mills average below 5% select grade lumber, 30-40% premium and the balance standard and below. Some mills do better, some mills do worse. Regardless, each mill learns about their average log by monitoring statistics as to the diameter, length, and grade. And, after analyzing the numbers, comes up with expected yields. With this information the mill is also able to balance expected grade yields with market conditions, and to favor preferred logs in their pricing strategy. A clear butt log might yield a higher percentage of clear lumber but it may also produce a higher volume of black knotted standard lumber. The mill must think about the full product of the log when determining what is, indeed, the best log.

So, what does the perfect white pine log look like? I asked around and honed in on two basic descriptions. One is the 24", 16' log with four clear faces. This should come as no surprise. This large diameter and long length log produces more lumber per pass through the mill and will generate wider boards. A twelve inch board is the widest board marketed through the NeLMA grading mills. So, unless the mill has special wide board markets, anything wider than a 12" gets ripped down. I was also told that the big clear log is a risky log. This large, clean log may produce one clear board under the bark and immediately go to black knots, which usually means a standard grade (low value). These large logs are also more likely to have rot, shake, hidden weevil damage or other internal problems. The log buyer cannot tell what is inside the clear logs.

The other preferred log is—what one sawmill manager referred to as—the "steering-wheel sized log"; the log that is 12" – 14" in diameter, 16' long, little taper, no weevil and has small red knots. This may be the second log in the tree and it produces the highest percentage of premium lumber and also yields a higher percentage of high-end standard. Because our white pine sawmills have become used to a very small percentage of clear, or select boards, the marketing and sales focus of the companies tend toward the bread and butter grades of premium and standard—the bulk of the production.

But, what about pruned logs? Again, they are considered risky. Unless the provenance (history) of the stand is known, ie, when the pruning was done, what age, what growth, etc. pruned logs can be a big gamble. In their article, "Relationship Between Pruning And Thinning", Smith and Seymour caution against pruning anything greater than 10" dbh in order to develop "thick shells of clear wood." The article goes on to discuss the merits of pruning after the first thinning, thinning heavily and pruning live branches. There is no doubt that pruning under the right conditions will ultimately produce clear wood. The sawmill is concerned about how much clear wood and what is underneath it.

Should foresters concentrate on growing logs to a maximum diameter of 14" which would enable the sawmills to obtain more of the "perfect" logs? The question is very complex and I don't have the answer. What I do hope is that you to think about sawmill log preferences, commonly held white pine management beliefs and to remember red—good, black—bad.

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Cruising White Pine Stands Efficiently

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Introduction

Foresters generally cruise white pine stands for 2 reasons, (1) either they wish to appraise the volume and value of the timber, or (2) they wish to estimate stand-stocking levels to assess whether cuttings such as thinning, should be done.

Since the 1950's, horizontal point sampling (HPS) has been a very popular method to accomplish these tasks. HPS cruising attempts to answer 2 questions,

(1) What is the basal area per acre of the stand, and
(2) How much of "X" is represented by each square foot of basal area?

Basal Area

Basal area is one of the most useful measurements that a forester can take. Basal area per acre can be estimated efficiently by using a prism or angle gauge. New England forest conditions offer foresters several choices in acceptable Basal Area Factors (BAF). Generally, the average tree count should be between 4 to 8 trees per point. This count has been shown to be the most efficient range for field sampling (Iles 2003). White pine stands containing a manageable range of stocking span basal areas of 80 to 300 ft²/ac. Consequently, foresters should consider BAFs between 10 and 75. It has been shown by several researchers that even under careful use, counts exceeding 10 can often miss trees that should have been counted. Table I shows the recommended ranges for several different BAFs. It is my experience that most white pine stands carry basal areas ranging from 100 to 240 indicating BAF 20 or 30 to be the most efficient.

Table I. Recommended range for various BAFs.

BAF	Lower Range	Upper Range
10	40	80
15	60	120
20	80	160
30	120	240
40	160	320

There is a trade off for lowering the tree count. A larger BAF will generally have a greater amount of point-to-point variation. This means the forester must take more points to obtain similar confidence limits to a smaller BAF. In my discussions with practicing foresters, the mention of taking more points is often considered an undesirable feature of using a larger BAF. In reality this is not the case. Remember the larger BAF is more efficient. Although more points are required, they take less time in the field. For example, under our field trials at Fox Research Forest, a 20 BAF point takes about half the time that a BAF 10 point takes. So, for the same investment in time, twice the number of points can be taken.

Another important issue to consider is that for the same amount of time, a forester is getting more observations in to the stand. Often a cruise will yield stands with only a few points. These points often do not give a true representation of the stocking conditions within the stand. Doubling the number of points will give the forester a much more accurate view of the stocking conditions for the same investment of time.

How much of "X" is represented by each square foot of basal area?

So, if you are cruising for timber volume and you know the basal area, you will need to know how many board feet are represented by each square foot of basal area.

An example:

If the basal area = 100 ft²/ac and the average square foot of basal area represents 200 board feet (which we call the VBAR (*Volume to Basal Area Ratio*)) then,

$$\frac{100\ \cancel{ft^2}}{\text{Acre}} \ \text{X} \ \frac{200\ \text{bd. ft.}}{\cancel{ft^2}} = \frac{20{,}000\ \text{bd. ft.}}{\text{Acre}}$$

If a forester wants to calculate the number of trees per acre to compare to the white pine stocking guide, they could substitute the TBAR (Trees to Basal Area Ratio) for the VBAR. If the average TBAR = 5, then substituting 5 for 200 in the equation above would equal 500 trees per acre.

The BigBAF Method

Traditionally, foresters would measure all counted trees on the point. However, if you have sampled 30 points with 7 trees on each point, you will end up measuring 210 trees. That is usually too many for normal management conditions and is a waste of time if the basal area contains far more random error. It takes far more time to measure the trees on a point than to count them. Also, you can usually be more comfortable with the *BAR estimate than the basal area. Let's look at some pine trees to see why.

Notice in table II that even though many of the trees have greatly different volumes, their VBARs are very similar. For example tree 10 contains 573 more board feet than tree 6, yet the difference in VBAR is only 37.7 board feet per ft²/ac of basal area. VBAR is a very statistically stable measurement especially within a single species. If we are cruising a stand that is 75 or 80% white pine, you may only need to measure 30 or 40 trees (1 per point?) instead of the 210 estimated above. Instead of measuring those additional 170 trees, spend time taking more basal area counts.

Table II. Relationship between tree measures and VBAR.

Tree #	1	2	3	4	5	6	7	8	9	10
DBH	12	12	14	16	18	20	22	24	26	28
Log Ht.	1	2	2	2	3	3	3	3.5	3.5	3.5
Volume	59	98	141	190	336	427	528	708	849	1000
Basal Area	.79	.79	1.07	1.40	1.77	2.18	2.64	3.14	3.69	4.28
VBAR	74.7	124.1	131.8	135.7	189.8	195.9	200	225.5	230.1	233.6

One unbiased way to measure fewer trees is to use 2 BAFs, a smaller one such as a 20 BAF for counting the basal area and a larger one such as an 80 BAF for determining which trees to measure (see Desmarais 2001, Desmarais 2002). A simple Excel spreadsheet based cruise processor prototype for BigBAF applications is available from Fox Research Forest.

Another unbiased method to select trees to measure is Point 3P sampling. In this method the cruiser estimates the volume of each tree on the point and compares it to a randomly generated number within a set called "KZ". If the estimated volume is larger than the random number the tree is measured. More information about this method can be obtained by visiting Kim Iles' website at www.island.net/~kiles/ .

Combining Basal Area With a BAR

Above I showed how the basal area and BAR work together to produce a per acre estimate of some characteristic of interest. Here we will see how each item affects the outcome.

Table III shows a quick cruise where a forester measured only 1 tree on each of 10 cruise points (10 trees). A traditional cruise with a 10 BAF prism would have required this forester to measure 125 trees.

Table III. VBAR and Basal Area effects on the final estimate.

	VBAR	BA
1	74.7	70
2	124.1	130
3	131.8	160
4	135.7	100
5	189.8	120
6	195.9	90
7	200	140
8	225.5	180
9	230.1	120
10	233.6	140
Mean	174.1	125.0
CV%	31.08	26.20
SE%	9.83	8.28

We can multiply the average VBAR times the average basal area to produce the average volume per acre. So:

174.1 x 125.0 = 21,762 bd.ft./ac

Bruce's equation (Bruce 1961) is used to calculate confidence limits on the estimate. Bruce's equation is:

$$SE\%_{combined} = \sqrt{SE\%_{VBAR}{}^2 + SE\%_{BasalArea}{}^2}$$

In our example the combined standard error in percent works out to:

$$12.9\% = \sqrt{9.83^2 + 8.28^2}$$

If the forester had measured all 125 "In" trees, the SE% would change from 12.9% to approximately 8.7%. However it takes a lot of time to measure 125 trees. You would have been better off to only measure 25 trees and take 18 basal area counts to get approximately the same confidence limits. That works out to a BigBAF of about 90 BAF.

Let's Get Real About This

Let's face it, we seldom have the numbers to play office games with how many trees to measure and basal area counts to take. That is why experience is so important. I often use the combination of a 20 BAF for basal area counts and an 80 BAF for determining which trees to measure when I cruise. With this system I can usually put in 2 to 4 times as many points as I did when I cruised traditionally. This system works well for me especially in stands with 5 or less species.

In mixed stands with many species you may have to modify the BAFs used or cruise traditionally, measuring all "In" trees just to get a good sample of each species. However, softwood stands such as white pine, or hemlock, or spruce/fir are often heavily stocked and dominated by only a few species. This provides an opportunity to make your cruising techniques more efficient.

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Girard Form Class for Eastern White Pine in Southern New Hampshire

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Introduction

Foresters and loggers are interested in predicting the volume yields of trees prior to milling. Often, standing trees are scaled for board foot volume by measuring the diameter at breast height and the merchantable height in logs. Due to variation in taper of the first 16-foot log, volume estimation can be difficult and inaccurate unless the taper of the first log can be accounted for. Form class is a method developed by Girard to compensate for taper in the butt logs of trees. Form class is simply calculated by:

$$FC = \frac{dib}{dbh} \times 100$$

where *FC* is the form class, *dib* is the diameter inside bark at the top of the first log (17 feet) and *dbh* is the diameter outside bark at breast height. Form class is usually reported as a percent. dbh and log height of a tree can be used with the proper form class volume table to accurately predict board foot volume.

Foresters managing white pine in New England commonly use volume tables for form classes ranging from 76 to 82. There seems to be little in the literature to guide foresters on which form class should be used for white pine. The decision about which form class to use can be important because Mesavage and Girard (no date) estimate that each form class unit of error can account for an error of approximately 3%. For example, if form class 76 is used but the real form class is 80, a volume estimate error of approximately 12% can occur.

Methods and materials

In order to offer more guidance to practicing foresters about which form class should be chosen when scaling standing white pine trees, the staff at the Fox Research Forest conducted a field survey of white pine form class on 6 state forests in southern New Hampshire. For most of the stands surveyed we used the *rotated angle method* as described in Bell and Dilworth.

This method consists of

1. Using a glass wedge prism or the plot radius factor for the prism, determine the location where the tree in question is in the borderline position at breast height.
2. Next, from the above location, the 17-foot height representing the stump and top of the first log is observed with the prism.
3. The prism is then rotated parallel to the tree until the top of the first log appears to be borderline. The rotated angle is recorded in degrees. The angle can be measured with a clinometer or other device (see below).
4. The vertical angle to the top of the first log is recorded in degrees.

5. The diameter at breast height is recorded to the nearest tenth inch with a caliper or diameter tape. The caliper is the preferred method taken from the same angle as the upper stem observations.
6. The bark thickness at breast height is measured with an increment borer or increment hammer.

We manufactured an apparatus for measuring the rotated angle using a protractor, a string and a weight.

The form class *outside* bark is calculated by:

Form Class = Cosine of rotated angle/Cosine of vertical angle

The form class is adjusted to *dib* at the scaling diameter by multiplying form class by the bark thickness ratio (BTR). We calculated the BTR by sampling bark thickness with an increment hammer. An increment borer may also work well. The BTR is calculated as follows;

BTR = *(DBH-(Bark thickness X 2))* ÷ *DBH*

The rotated angle method was checked against direct measurements of pines located at Fox Forest and found to be within 1 form class unit. In the Fox #2 stand twelve white pine sawtimber trees had been felled in the fall of 2002 as part of a different experiment. For this study the felled trees were measured on the ground for form class by measuring length with a steel tape and diameter with a caliper.

Results

Fifty-three trees were sampled at 6 locations. The grand mean form class of all locations was 84.7. Table I shows that most stands exhibit form classes of 82 to 84 however, some stands can have larger form classes. For example one of the stands we sampled contained a mean white pine form class of 89.7.

Table I. Summary of samples.

Tract	Form Class	Sample size
Annett SF	82.4	18
Fox SF #1	82.7	9
Fox SF #2	89.7	12
Feuer SF	83.9	3
Bear Brk SP	85.8	8
Honey Brk SF	86.7	3
Mean	84.7	53

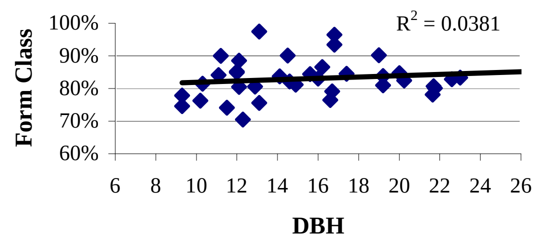
To see if there may be some relationship between form class and other predictor variables, both dbh and merchantable height were examined. These two variables were chosen because they are commonly used to calculate timber volume by foresters.

Regression analysis was used to test the relationship of dbh to form class. The relationship was not statistically significant ($p = 0.22$, $R^2 = 0.038$). This relationship is illustrated in figure 1. The relationship between sawtimber height and form class was also tested with regression analysis. Again no statistically significant relationship existed ($p = 0.38$, $R^2 = 0.031$). This relationship is illustrated in figure 2.

Discussion

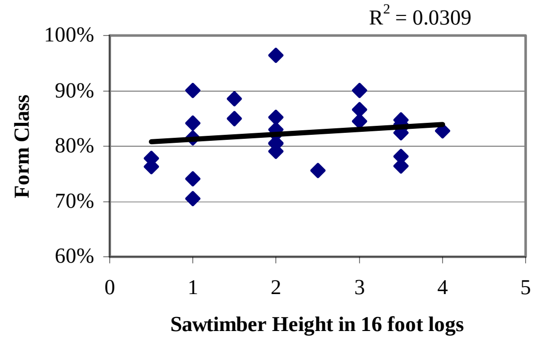
In our investigation all stands exhibited form classes of 82 or above for white pine sawtimber. One stand contained a mean form class as high as 89.7. Thus, foresters using form class-based volume tables in the high 70 range may see large overruns of timber volume. For example if the actual form class is 83 and a forester uses a form class 78 volume table, the volume should overrun by approximately 15% based simply on the error in form class estimation.

Figure 1. Relationship between DBH and Form Class for White Pine



Unfortunately, this study was unable to develop reliable predictors for form class. Diameter at breast height as well as sawtimber height does not seem to be a reliable predictor of form class.

Figure 2. Relationship Between Form Class and Sawtimber Height



However, the rotated angle method does seem to be a simple, fast and reliable method for calculating form class.

Caution should be practiced if a forester changes to a different volume table due to form class. Scaling standing timber can be an imprecise procedure developed from a combination of compensating errors. For example, if a forester constantly miscalculates sawtimber height, which is compensated by using the wrong form class table, changing to the proper table may lead to large over or under-estimates.

Foresters marking timber for sale may need to address the issue of form class if precise and accurate estimates of timber volume are required for a particular project. The proper volume table combined with good scaling techniques should lead to reliable volume estimates.

Acknowledgements

I would like to thank Dan Cyr of Bay State Forestry Inc. for suggesting the study and Jim Byers, Robert Kenning and Scott Rolfe from the NH Division of Forests and Lands' Forest Management Bureau for assisting me in the data collection for this study.

Calculating Form Class From Field Data

Table 1. Field data for a Single Tree		
		Cosine
Rotated Angle	35°	0.8192
Vertical Angle	17°	0.9563
DBH	20.4	
Bark thickness from 1 side	0.55	

1. Calculate the form class outside bark
   Cos35° / cos17° = 0.8192 / 0.9563 = 0.857 X 100 = 85.7

2. Calculate the Bark Thickness Ratio (BTR).
   0.55 X 2 = 1.10 (bark thickness X 2 for full bark thickness of both sides).
   20.4 – 1.10 = 19.3 (dib at breast height).
   19.3/20.4 = .95 (dib at breast ht / dbh outside bark).

3. Adjust the form class by the BTR
   85.7 X 0.95 = 81.4

A few tips;
Be sure when calculating the cosine of an angle that your calculator is set to *degrees*.
Irregular trees may give multiple answers. Concentrate on straight trees when possible.

Literature cited

Bell, John F. and Dilworth, J.R. 1997 **Log scaling and timber cruising.** Cascade printing company, Corvallis, Oregon. 439 pages.

Mesavage, Clement and Girard, James W. No date **Tables for estimating board-foot volume of timber.** USDA Forest Service. 94 pages.

Inventory Considerations For Quantitative Silviculture

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Introduction

Quantitative approaches to silviculture often come with the promise of improved control over stocking and productivity. They also come with a veneer of technicality that makes silviculture seem more "scientific." Making those promises come true, however, can require investment in good data.

Quantitative silvicultural guidelines can be used in a variety of ways. We're concerned here with one particular pattern, which runs roughly as follows:

1. In response to the need for a decision or a management plan, a stand-level inventory is conducted.
2. The numerical results of the inventory are compared to some sort of quantitative guidance. This guidance may come in the form of a numerical rule, a graphic chart, or a computer program.
3. Based on the outcome of Step 2, a management decision is made and put into practice.
4. The results may or may not be evaluated.
5. Some years later, you may or may not return to Step 1.

This pattern is broad enough to include a wide variety of stand-level problems. The key is the use of inventory data to drive silvicultural decisions. The challenge is that inventory data is almost always a *sample*, so it includes *sampling error*. How does sampling error impact the decisions that are made in Step 2? Is there a risk of making a wrong decision? And if so, how can we control that risk? We'll use some data from a pure white pine stand, and the Philbrook *et al.* (1973) stocking guide for eastern white pine (the same one as in Lancaster and Leak 1978), to look at this problem.

Stand Variability and Stocking Guidelines

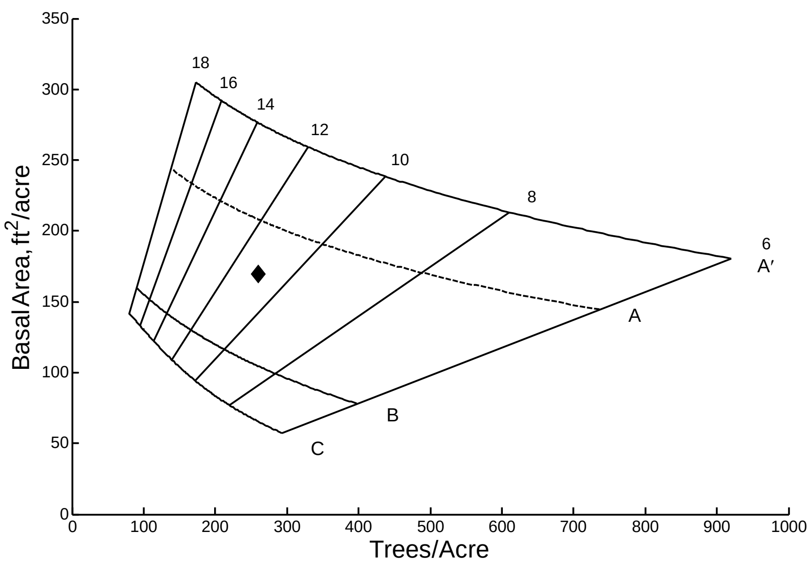
As you'll recall from your coursework in mensuration, the variability of a stand has a lot to do with how accurate your cruise numbers are. The other driving factor is how many and what kind of samples you take. The article by Ken Desmarais from this workshop will give you some insights about what kinds of sampling systems work well for eastern white pine stands.

As an example, let's look at a very homogenous stand. It is 24 acres of nearly pure white pine – a classic old-field stand, previously thinned. It was sampled with 15 prism points using a BAF 20, giving the following results:

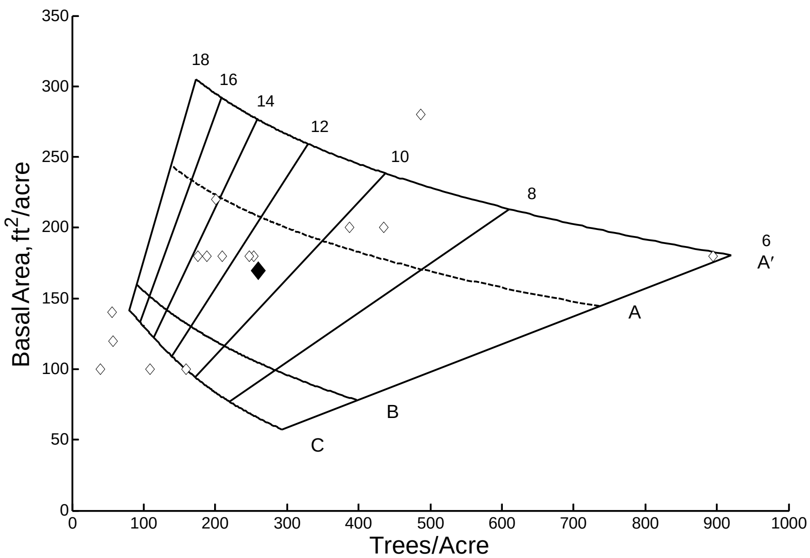
	Basal Area per Acre	Trees per Acre
Average	169	260
Coefficient of Variation (%)	30%	85%
95% Confidence Limits	169±27	260±122

These are the kind of results you should expect to pull easily from your favorite inventory package, and they are fairly typical of a pure stand. Note that trees/acre is not nailed down particularly well. That's no surprise. Prism cruising is excellent for basal area, and for variables that are closely related to it, like volume. The price for that is generally poor estimates of trees per acre. (The reverse would be true for fixed-area plots – they are great for trees per acre but it takes a lot of work to get good basal area or volume estimates.)

Now, the most straightforward thing you could imagine would be to plot this stand on the white pine stocking diagram:

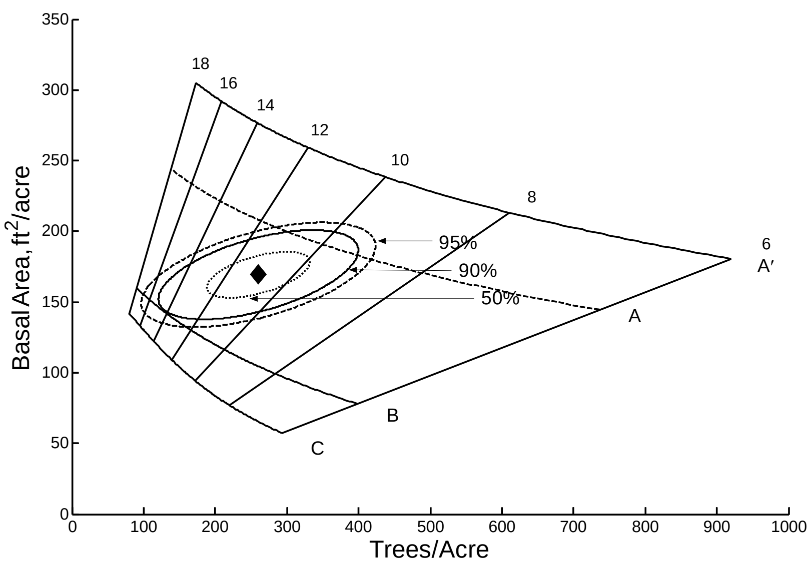


So here the stand is, on the familiar diagram. (There are two "A" lines here because there are two versions of the "A" line. The A' line here is the maximum density line; the A line is the maximum *recommended* density line.) We would probably conclude that this stand is close to ready for a thinning. But how certain should we be? Here's the same stand, but the individual plots are shown as hollow diamonds:



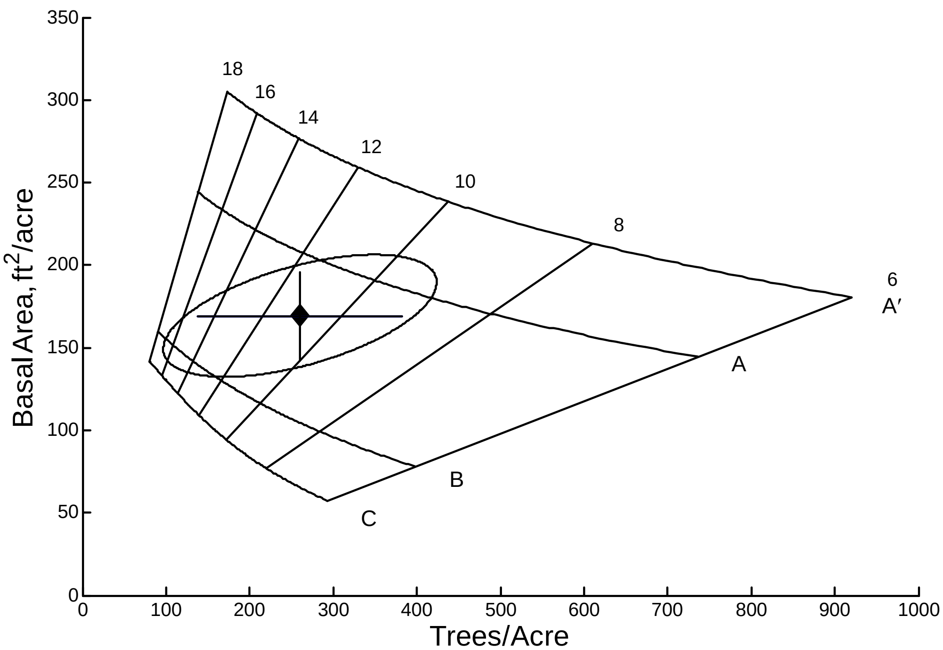
You can see there's a lot of variability – but again, this is typical for a fairly uniform stand. The points are, quite literally, all over the chart. Conceptually, that's why you need a lot of points to get a good handle on a stand. Fortunately, the situation is not as bad as the individual points make it seem.

One way of visualizing the possible error in an estimate like this is through a *confidence ellipse*. A confidence ellipse is the two-dimensional equivalent of the one-dimensional confidence interval. Just like with confidence intervals, you set a confidence level such as 90% or 95%, and that (in combination with the variability and number of your plots) sets the size and shape of the region. Here are some confidence ellipses for this stand:



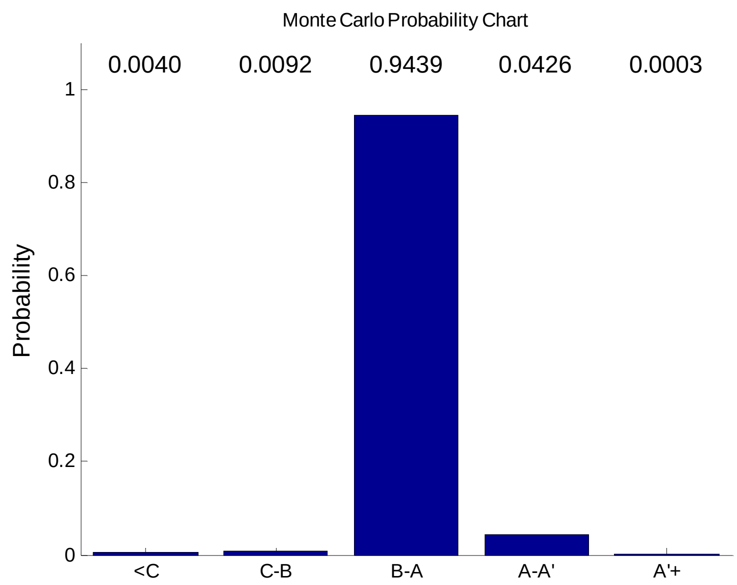
As you can see, if we are willing to be wrong about 50% of the time, we can go along with that "close to the A-line" diagnosis. But if we can only accept being wrong 10% of the time (90% confidence) or 5% of the time (95% confidence), it's not entirely obvious that's the right answer.

How do you calculate a confidence ellipse? Well, if you have a statistics package on your computer, it's probably easy. Otherwise, it can be tough. One thing that you can be certain of: the confidence ellipse is *not* formed by looking at the individual confidence limits on basal area and trees per acre! Here is the 95% confidence ellipse again, with the 95% confidence limits shown as error bars:



What the error bars don't account for is that the errors in basal area and trees per acre are *correlated* – plots with high basal area tend to have high trees per acre, and vice versa.

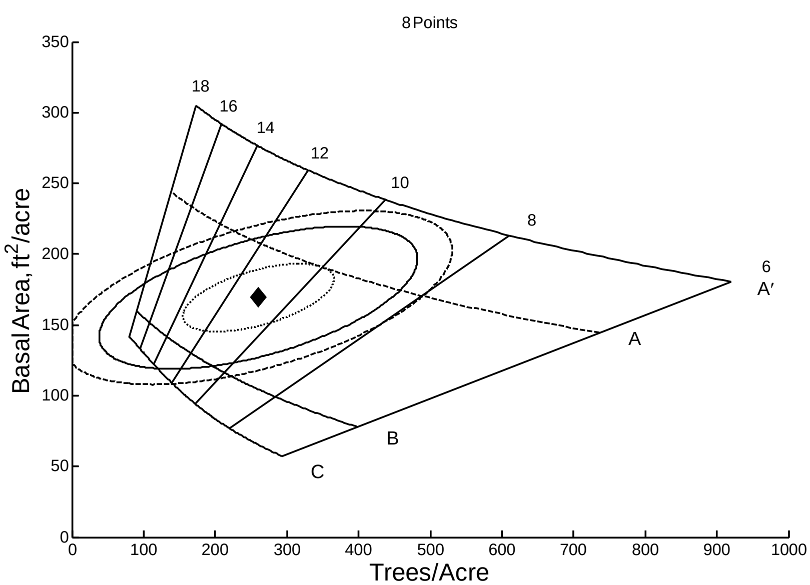
Another way of looking at this problem is to ask what the probability is that the stand is in different regions of the graph. (Just posing the question that way puts us on turf that statisticians call "Bayesian" – to some that's a dirty word! But it is fairly compatible with thinking about management as taking educated gambles.) Roughly speaking, those probabilities can be estimated by treating the confidence ellipses like contour lines on a map, and asking what portion of the volume of the "hill" is in different parts of the chart. The "easy" way to calculate that is to make the computer sample the hill at random. The result is what I call a "Monte Carlo Probability Chart", and it looks like this:



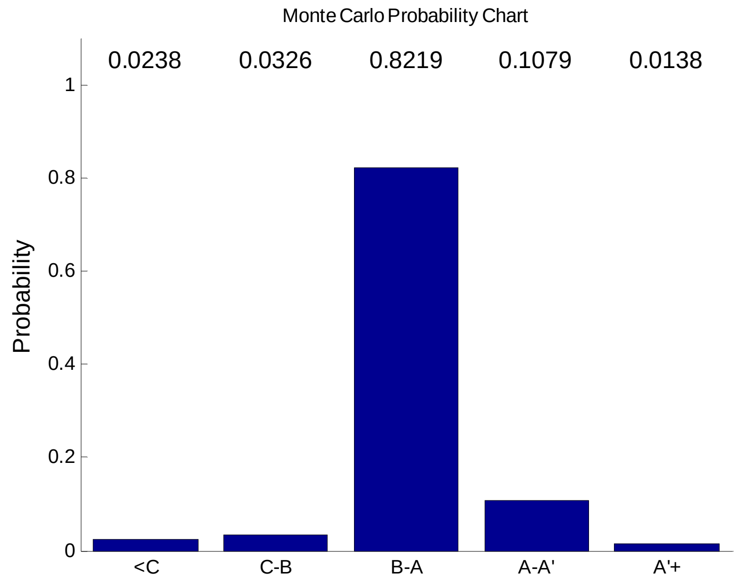
Based on the results, I suppose you can say we are confident this stand is between the A and B lines... but that's not much of a surprise! There's still an outside chance it is actually in the high-density zone above the maximum recommended density line.

Sample Size and Confidence

Suppose we hadn't used so many plots to inventory this stand. What would the confidence ellipses look like? Here's the answer:

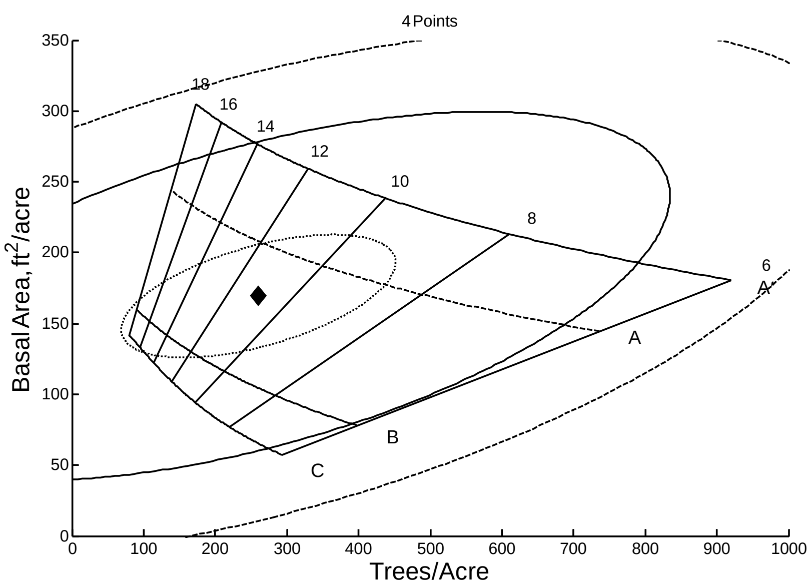


If we had only used 8 points to sample the stand, the confidence ellipses would be very wide, especially if we demanded high confidence levels. The 50% confidence ellipse (inner ellipse) is still within the A and B lines, but the 90% and 95% ellipses (middle and outer ellipses, respectively) now run from below the C line to above the A line! The Monte Carlo probability chart would look like this:

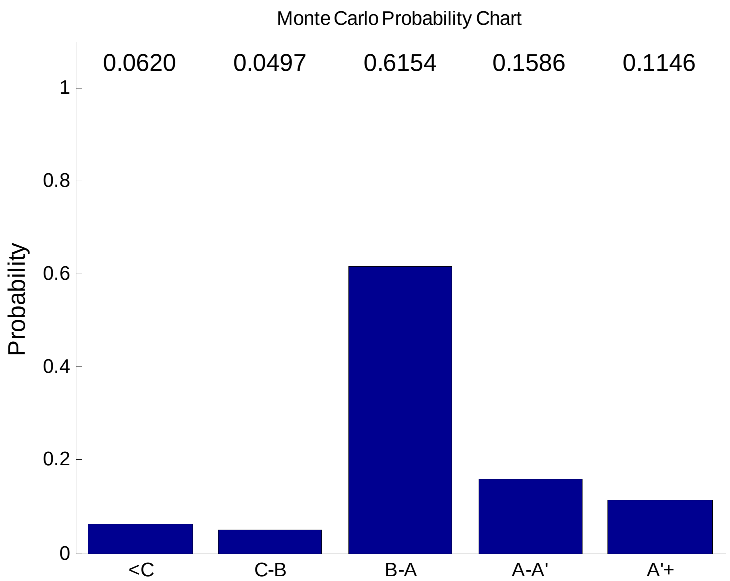


Again, the probability chart is not quite as depressing as the confidence ellipses might suggest. But, with only 8 points, we can't be very certain at all that the stand is below the A line. We are fairly sure it's above the C line, though.

Well, what if we had used only 4 points? (In this stand that's one point for every six acres – a pretty low sampling intensity for a stand-level cruise.) Here are the confidence ellipses:



With 50% confidence, we can be certain the stand is between the C and the A' lines. With 90% confidence, at least we think the mean stand diameter is bigger than 6". And with 95% confidence, we're pretty sure the stand has trees in it... Here's the probability chart:



While calculating confidence ellipses by hand is daunting, and doing the probability charts accurately by hand is impossible, the UNH Forest Biometrics Lab is developing a user-friendly program that will (among other things) allow you to calculate confidence ellipses, plot stands (including their ellipses) on the stocking diagram, and do Monte Carlo probability charts. It works (that's how the figures in this report were made) but we're still testing it to find the bugs. When it is ready, it will be made available for free on the internet.

So How Many Plots Do I Need?

It's unlikely, even with a handy computer program, that you'll want to fool with calculating a sample size every time you need to cruise a stand. So, let's look back at these results, and think about other recommendations in the literature.

If you look at the confidence ellipses, and the probability charts, it seems like things really blow up at around 8-10 points. Now, bear in mind that this is a very homogenous stand. But, we might say as a conservative lower limit that at least 10 points in a stand is needed, if you are using a BAF 20 and getting 8-10 trees per point. (Remember from your mensuration classes that the minimum number of points to get good confidence limits on a variable does not depend directly on stand size! The same is true of confidence ellipses.)

What about all those other stands – the messy ones, with gaps, pockets of hardwood and hemlock, and so on? Well, we'd expect the variability of data from such stands to be much greater, so we would need considerably more than that 10 point minimum. A lot more. Easily 2 or 3 times as many.

There aren't published estimates of what sample size is needed for good silvicultural prescription in white pine stands. But, in the northern hardwood guide, Leak *et al.* (1986) suggest a minimum of 10 points in homogenous stands, and 30 points in heterogeneous ones. That was with a BAF 10 – but remember that basal areas are lower in hardwood stands, so the number of trees per point (and the variability between points) would be similar for northern hardwoods with a BAF 10, to what they might be for white pine with a BAF 20.

As with all such rules of thumb, though, take this one for what it's worth. It's a rough guide. If you are doing stocking assessment for legal purposes – say, compliance with a heavy cut law – you may want to think very seriously about the biometrics of the problem. Remember that lawyers bill a much higher hourly rate than foresters do.

Do I Really Need To Cruise That Hard?

The answer is a definite *maybe*. Quantitative silviculture holds out a lot of promises, but to write prescriptions based on your cruise data and have real confidence in them, yes, you will have to put in a lot of points.

On the other hand, what was wrong with *qualitative* silviculture? What could the stocking diagram do for you that careful observation and thought in the woods could not do as well or better? Of course, the answer will depend on your organizational setup. If your cruising and stand exams are being done by summer interns whose silvicultural judgement you do not trust, you may have few options. Likewise, if you have to defend your silvicultural decisions based on objective, scientific guidance, you'll need cruise data to back you up, and it ought to be good enough to be up to the job. But if you can afford to have experienced, thoughtful people in the woods making your decisions based on subjective, visual examination, it may be that the long-term cost and performance will be better.

Marking Practices

Finally, think about how you *mark* stands once the prescription is made. Once you've plugged your cruise data into the stocking diagram (or the computer program, or what-have-you), and determined that a certain amount of basal area (and volume) is supposed to come out, then what?

One way of writing a prescription and marking a stand is to *prescribe to cut*. For example, suppose we think there are 150 square feet of basal area in a stand, and based on the diagram we think we want to leave 100. So we write the prescription to cut 50 square feet, and we make darn sure that many trees end the day with paint on. It works out well, because whatever volume we said we'd get, and whatever check we told the client they would get, that's about what will come out of the woods. The downside is that the uncertainty in our inventory gets translated directly into the residual stand. For example, if our original cruise result was 150±30 square feet, our residual stand (after we remove exactly 50 square feet) will have 100±30 square feet. It might be overstocked, it might be understocked. Of course, nobody will know if there isn't any follow-through after the timber is cut.

The exact opposite approach is to *prescribe to leave*. In our example stand, we'd specify that the residual basal area must be 100 square feet, and mark it that way. The final stand is likely to be very close to what we wanted. The only problem is the cut, which will come out as 50±30 square feet. Most of us would have a hard time explaining that kind discrepancy between projected harvest and actual harvest to our client or boss – especially if it comes in at the low end, about half of what we anticipated.

A hybrid approach – and one that "shares" the variability between the residual stand and the log deck – is to prescribe a *fraction*. In our example stand, if we thought we had 150 square feet and wanted to leave 100 square feet, we'd prescribe that 1/3 of the trees should be cut. Now, this is very easy for a marking crew to implement. And, the variability does get spread around. Our residual stand will be 100±20 square feet, and our cut will be 50±10 square feet. That kind of uncertainty might be acceptable in both places.

Again, none of this substitutes for good *qualitative* silviculture. The success of an operation has at least as much to do with making sure the *right* trees are left and cut, as it does with making sure the *right number* are. Cutting the right number of trees but taking out the wrong ones can be a disaster.

Conclusions

The take-home message here is simple. To do good quantitative silviculture you need good numbers. Getting good numbers in the woods costs money, because you need quite a few plots to get it right. You can put in fewer plots, but be sure that at least some of the time you'll get it wrong.

The good news is that a simple rule of thumb (at 10 plots in homogenous stands, 30 plots in heterogeneous stands) seems to work well. It could stand some testing, but it's straightforward. If that level of cruising is unappetizing, the best advice is not to rely too much on your numbers in making silvicultural decisions. Rely on your eyes and your training instead.

Finally, think about how you write thinning prescriptions. It's up to you where the sampling error winds up: in the woods, on the log truck, or a little bit of each. Putting the variability where it will do the least harm will go a long way toward improving overall decisions.

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White Pine as Wildlife Habitat

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White pine (*Pinus strobus*) provides terrestrial habitat elements across the New England landscape in ways that other large conifer species are unable to duplicate. As a food source, white pine provides seeds, needles and buds, bark, and the insects that can be gleaned from white pine substrates. White pine seed provides a food source for bird species such as red-breasted nuthatch (*Sitta canadensis*), pine warbler (*Dendroica pinus*), chipping sparrow (*Spizella passerina*), common grackle (*Quiscalus quiscala*), crossbills (*Loxia* sp.), pine siskin (*Carduelis pinus*), and evening grosbeak (*Coccothraustes vespertinus*) (DeGraaf and Yamasaki 2001; Abbott 1958). Black-capped chickadee (*Poecile atricapillus*) and pine warbler also glean insects from white pine bark, needles and twigs. White pine seed is a food source for eastern chipmunk (*Tamias striatus*), gray squirrel (*Sciurus carolinensis*), red squirrel (*Tamiasciurus hudsonicus*), northern and southern flying squirrels (*Glaucomys sabrinus* and *G. volans*), white-footed mouse (*Peromyscus leucopus*), and red-backed vole (*Clethrionomys gapperi*). White pine is an emergency winter food source for herbivores such as white-tailed deer (*Odocoileus virginianus*) and a minor food item for spruce grouse (*Falcipennis canadensis*). Finally, the porcupine (*Erethizon dorsatum*) is well-known for its tree-barking habits on white pine as well as the rectangular-shaped excavations of foraging pileated woodpeckers (*Dryocopus pileatus*) searching for carpenter ants.

White pine stands on shallow-to-bedrock, and sandy outwash sites often encompass several associated habitat features. Many seeps and vernal/autumnal pools can be found in upland areas with an overstory typed as white pine, oak-pine, or white pine/red oak/red maple or adjacent to wetlands or floodplains. Several mole salamanders particularly marbled (*Ambystoma opacum*) and Jefferson salamanders (*A. jeffersonianum*) can be found using temporary pools in these types of upland stands. Hard mast opportunities especially for red oak (*Quercus rubra*), white oak (*Q. alba*) and beech (*Fagus grandifolia*) occur routinely in white pine stands and are of benefit to a variety of hard mast seeking species such as wild turkey (*Meleagris gallopavo*), blue jay (*Cyanocitta cristata*), and white-tailed deer. Eastern hemlock stocking in white pine stands significantly increases the value of the resulting overstory canopy and horizontal cover value for wintering white-tailed deer, especially on more southerly slopes (Reay 2000).

White pine provides a variety of cavity and exfoliated bark sites, canopy cover conditions, and a variety of forest floor habitat elements, as well as a supracanopy habitat element unmatched by other conifer or hardwood species. Large white pine stems usually > 18 inches dbh having a decaying central core are very valuable habitat elements to large-bodied cavity excavators such as pileated woodpecker and other cavity dwellers such as the barred owl (*Strix varia*), red-headed woodpecker (*Melanerpes erythrocephalus*), red-bellied woodpecker (*M. carolinus*), tufted titmouse (*Baeolophus bicolor*), red-breasted nuthatch (*Sitta canadensis*), bats (*Myotis* sp.), red and gray squirrels, and flying squirrels. Exfoliated plates of white pine bark often shelter many bat species as well as the brown creeper (*Certhia americana*).

Canopy cover conditions can vary widely in stands typed predominantly white pine, pine-oak or pine-hardwood. Larger white pine stems, both live and dead, in and adjacent to old beaver ponds, impoundments, and other open wetlands are often sites in which great horned owl (*Bubo* *virginianus*) and great blue heron (*Ardea herodias*) successfully nest. Sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*A. cooperi*), northern goshawk (*A. gentilis*), great horned owl, and common raven (*Corvus corax*) all use larger white pine trees, among others in which to nest up against the tree bole. Goshawks tend to nest at the base of the canopy; sharp-shinned hawks nest in the upper canopy; while Cooper's hawks nest in the middle of the canopy. Great horned owls often use other species' nests. Red squirrels will often construct stick nests in the upper canopy of white pine stands. Hardwood inclusions in pine stands greatly improve avian diversity compared with pure pine stands.

Dense coniferous regeneration on the forest floor creates favorable foraging and cover opportunities for snowshoe hare (*Lepus americanus*), gray fox (*Urocyon cinereoargenteus*), fisher (*Martes pennanti*), and an array of small mammals such as eastern chipmunk, red-backed vole, and white-footed mouse. The presence of substantial piles of coarse woody debris, especially down hollow logs, greatly improves the cover conditions usually found under younger uniform pine stands for such ground dwellers.

Supracanopy white pines serve as nesting sites for many bald eagles (*Haliaeetus leucocephalus*) in New England, especially if the top is broken off or damaged and the nest tree/site is within 0.6 mi (1km) of a productive fishery (e.g., large lakes, rivers, and marine habitats) (Livingston et al. 1990). Osprey (*Pandion haliaetus*) also use broken-topped supracanopy white pine close to water, often out in the open; but many osprey pairs are now nesting successfully on artificial platforms. Continued increases in both bald eagle and osprey populations in New England will depend on both a plentiful and diverse fish prey base during the breeding season and continued existence of potential nesting sites not currently occupied.

Availability of open water in the winter appears to be one of several key elements to perennial winter bald eagle habitat use (McCollough et al. 1994). Open water concentrates local waterfowl activity along coastal and estuarine habitats; and inland, on the downstream reaches from dams on major rivers where bald eagles can hunt ducks, fish, and scavenge carcasses. Supracanopy white pines with branches thick enough to support an eagle's weight, and providing an unobstructed view of open water serve as day and hunting perches for foraging bald eagles in New Hampshire (Sweeney 1999). Bald eagles also use white pine trees with weight-bearing branches and open branch architecture, close to foraging areas as night roost trees. Roost sites tend to be in mixed white pine-hardwood stands with more open canopies on steeper southerly slopes close to water. Many of the current winter foraging and roost sites occur within areas of considerable human use (e.g. commercial and residential land use, recreational activities). Disturbance factors need to be minimized to ensure continued successful use of these special habitats by wintering bald eagles wherever these conditions may be found, now and into the future.

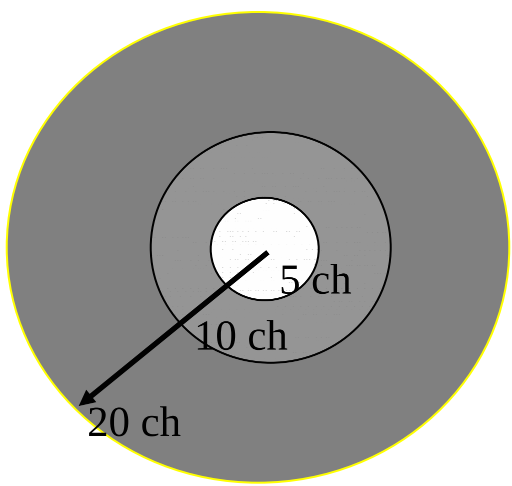
Management Recommendations

- Large supracanopy white pine in close proximity (< 0.6 mi (1 km)) to aquatic habitats (e.g., lakes $\geq$ 74 ac (30 ha); rivers; and marine habitats) that support substantial and diverse fish populations are potential nesting sites for both bald eagle and osprey. Consider these spatial-habitat values in any land-use and management planning activities, as these populations appear to be increasing.
- Pay attention to territorial raptor activity beginning in late winter/early spring (e.g. audible calls, territorial displays, nest-building and -defending behaviors) in areas with large white pine present.
- Minimize seasonal human disturbance around nest sites during the breeding season (Figure 1) and at winter roost sites.
- Maintain a sufficient number of large cavity trees per acre in a variety of upland and riparian forests and open habitats over time.

Take Home Messages

- White pine is an important habitat element to a variety of wildlife species.
- Wildlife species-stand use is dynamic over time.
- A fraction of the pine stands have some charismatic megafaunal use.
- Paying attention to these characteristics can add diversity elements to future landscapes.

Figure 1.. Generalized nest site protection guidelines for bald eagles per USFWS recovery plan.



- Establish 20 chain buffer around nest trees
- Full protection within 0 - 5 chain zone – limits human activity
- Limited activity/forestry operations outside nesting season (Feb-Aug) in the 5 – 10 chain zone
- Other operations acceptable outside of nesting season in the 10 – 20 chain zone

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Optimum Stocking of White Pine: It All Depends!!

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Stocking or stand density affects several types of stand response: growth in volume and diameter, quality development in terms of form and branch size, and understory development. In addition, stocking affects certain economic parameters as well logging/operability constraints.

Two standard stocking guides have been developed for white pine (Table 1). The first (Philbrook et al 1973, Lancaster and Leak 1978) was based primarily on crown sizes, and it showed the stocking levels that would maintain full crown closure. The recommended residual basal areas (the so-called B-line) for stands of 8 inches mean dbh and larger ranged from about 100 to 160 square feet per acre.

The second guide (Leak and Lamson 1999) was based on a reexamination of growth responses of managed stands and especially younger stands. Suggested residual basal areas (B-line) for stands 8 inches dbh and over range from about 75 to 120 square feet per acre.

Some of the data supporting these two approaches follows:

Background Information

Early growth studies in older white pine stands suggested that high stocking produced the best growth results. For example, 15-year results from the Lake States in an 80-year-old stand (Schlaegel 1971) were as follows:

Residual BA (sq.ft./acre)	Annual BA Growth (Sq.ft.)	Annual Bf Growth
80	2.56	605
100	2.95	707
120	3.07	793
140	3.15	835

Results from other studies in both white and red pine suggested even higher stocking levels (Leak 1981). An 80-year thinning study in a North Carolina plantation showed that an unthinned plot produced more board foot volume than the thinned plot, again suggesting that high stocking levels were best (Della-Bianca 1981). Thinnings in several New Hampshire stands about 25-50 years old (Gillespie 1985) showed that control plots ranging in basal area up to 245 square feet per acre produced as much or more net basal area growth than plots thinned to the Philbrook B-line or crop-tree thinned. However, thinned plots produced about 60% higher mean diameter growth.

However, foresters from the State of Vermont (e.g. Roy Burton) found that stands managed over time maintained full crown closure at stocking levels below the Philbrook C-line (the line where 10-years growth will attain the B-line). This prompted a reexamination of white pine stocking in managed stands, especially in young stands.

Data made available by Robert Breck, retired New Hampshire County Extension Forester, showed that managed plantations maintained adequate basal area growth at basal areas of 20- to 40 square feet below the Philbrook B-line (Leak 1982) (Table 2). A low-density study in an approximately 25-year-old plantation in Massachsetts (Hunt and Mader 1970) showed that the initial removal down to 30 square feet basal area per acre resulted in much less basal area growth than a thinning to 105 square feet. However, a second thinning down to 51 square feet produced (just one-year's growth) a little more basal area growth than a thinning to 84 square feet. The thinning and low-density treatments resulted in 2 to 3 times the diameter growth of the control.

The evidence is slim. But indications were that optimum residual basal areas in managed white pine could be lowered by up to 40 square feet from the Philbrook guide. This was the basis for preparing the 1999 guide. Currently, we are suggesting that the lower densities are appropriate for stands that have been thinned at least once before reaching 10 inches mean dbh . Quite possibly, the lower 1999 densities are appropriate in young previously unthinned stands that have well-developed crowns.

Discussion

There are a number of additional concerns regarding stocking of white pine. First, there seems to be great variability in stand responses to stocking levels, no doubt partly due to stand condition and tree vigor. Innes (2001) found a good correlation between cubic volume growth and estimated leaf area, but a poor correlation with stand density due to the extreme variability in growth response. Gillespie's (1985) study in young white pine showed a similar high degree of variability. Economic responses may over-ride any concerns over biological growth (Desmarais and Leak 2003, in press). High stand densities in young white pine to minimize weevil impacts (Graber 1988) and provide broader opportunities for crop-tree selection may also over-ride any concerns over stand or tree growth. An abundance of high or low quality stems may sway one's decision on residual stocking, as well as logging economics in terms of volumes per acre or total sale volume. Understory development is significantly greater under low stocking levels, but this may be good or bad depending on the regenerating species and wildlife habitat concerns. In short, growth response is just a starting point in determining optimum residual stocking.

Table 1. Basal areas by mean stand diameter for the Philbrook and 1999 white pine stocking guides. To the nearest 5 square feet.

	Philbrook			1999		
Mean Dbh	A	B	C	A	B	C
8	215	100	75	215	75	55
10	240	120	95	240	90	65
12	255	135	110	255	100	75
14	270	145	125	270	110	85
16	285	150	135	285	115	90
18	305	160	140	305	120	95

Table 2.—Growth of New Hampshire Plantations Thinned Several Times (R.W. Breck). B-line basal area of about 120 sq.ft. (Leak 1982).

Residual Basal Area (sq.ft./acre)	Annual Net Basal Area Growth (sq.ft./acre)	Annual Gross Basal Area Growth (sq.ft./acre)
139	2.4	2.8
101	2.4	2.7
82	2.2+	2.6

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Low-density management of white pine crop trees: A primer and short-term research results

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Abstract: Growing white pines at low density after pruning appears to offer many advantages over more conventional silvicultural systems. This paper describes how to design and implement a low-density thinning schedule using published relationships between crown architecture and stemwood growth. Short-term results from a replicated thinning study in east-central Maine show that diameter growth of heavily released crop trees was 2.7 times that of similar trees in the unthinned controls, and 1.5 that of similar trees in plots thinned to the B line on the pine stocking guide. Despite the important differences in tree development between thinning methods, total stemwood volume yields of the low-density treatment were 91% that of the B-line treatment, suggesting that extra trees left simply to achieve B-line stocking do more harm in retarding crop-tree development than they contribute to stand growth.

Introduction and Background

Low-density white pine management can be described as a method of growing carefully selected crop trees at unconventionally low stand densities, well below the "managed B line" on the new pine stocking guide (Leak and Lamson 1999). As far as I can determine from the literature and personal knowledge, low-density white pine culture originated in the 1960s with Dave Smith on the Yale Forest in Keene, and Fred Hunt when he was the forester for MDC on the Quabbin Reservoir (Hunt and Mader 1970). New England forestry being a close-knit bunch, I suspect there was ample cross-fertilization here. Alan Page of Green Diamond Forestry in Belchertown, Massachusetts, has arguably been the best-known and most serious proponent of this silvicultural system. Brooks Mills, forester and tree farmer in eastern Maine is also a strong advocate and practitioner.

I learned about this concept as a student at the Yale Forestry School in 1975, on a field trip to the Toumey Forest in Keene. We were in a stand where in the 1960s, Dave Smith discovered the remnants of old pine thinning study reported by Hawley and Clapp (1942). Most trees blew down in the 1938 hurricane and the study was abandoned, though a few trees survived and grew very rapidly without competition for several decades. Ultimately my interest led to the formulation of a new height-dependent stocking guide for white pine, in which we outline a quantitative approach for implement this unconventional form of silviculture (Seymour and Smith 1986). This paper will draw heavily from this publication, as well as some of my own research on the University of Maine forest near Orono begun in 1991.

Rationale

Like most hardwood species, white pine trees are valuable only if knot-free and straight. Unlike hardwoods, however, pines must either be pruned or grown on very long (150+ years) rotations that do not withstand financial scrutiny. Attention is focused on growing a high-quality butt log rapidly, which can only be done by an unconventionally heavy release of relatively few crop trees per acre (100 or less). The goal is to prune trees as early as crop trees can be selected, ideally in several lifts, to create a small, cylindrical knotty core to a height of no more than 1.5 logs. Above the pruned zone, branches remain alive, with the aim of producing very large live crowns by the end of the rotation. Another benefit of this system is the avoidance of low-value, black-knotted upper logs.

On good sites, such trees can grow as fast as 0.5 inches per year (i.e., four rings per inch). At this rate, and if lumber is marketed judiciously, compound interest returns can exceed 10% until the tree reaches 22 inches dbh, and may remain above 6% until 27 inches dbh 62 years after pruning (Page and Smith 1994). In contrast, unpruned trees in conventionally thinned stands never exceed 6%, and are usually below this.

How to Do It

One must begin with a population of straight-stemmed pines that are worth pruning. Historically in central New England, such trees have occurred sporadically throughout 25-40-year-old stands of old-field origin (though these are getting scarcer) that have, for whatever reason, largely escaped serious weevil deformation in the butt log. In the future, pines of the proper size (height) may become more common as scattered residual saplings or poles left after an improvement or release cutting of hardwood species. In the spruce-fir region, clearcuts from the budworm salvage era (ca 1970-85) sometimes have an excellent stocking of such trees mixed with more tolerant conifers. Such harvest-origin stands usually have less weeviling than their old-field counterparts, with a much higher proportion of well-formed potential crop trees.

Assuming all crop trees survive, there is no point in pruning more than 65 trees per acre (equivalent to a 26 foot spacing) which can be grown to about 16 inches dbh by the time they reach a height of 65 feet (Seymour and Smith 1986, Table 2). There is no lower limit; every quality tree could be pruned and cultured in stands with fewer crop trees. Trees should be pruned by the time the live crown recedes to about one log (17 feet), or perhaps a bit higher if efficient technology is available.

As in crop-tree systems designed for hardwoods (Perkey et al. 1994), one simply ignores the stand basal area and does not worry that this parameter of stocking will fall well below the putative lower limit of site occupancy defined by the B line. Relative density after crop-tree release may drop as low as .15 with a leaf area index of under 2. Trees per acre, or its corresponding spacing, is the operative stand density measure, as we strive to prevent crown recession. Relative to maximum volume production, such stands obviously waste much growing space, which can be filled with pine regeneration (in pure old-field stands) or slower-growing tolerant species of the same cohort (in spruce-fir dominated communities).

Once crop trees are chosen, implementing a low-density schedule involves making timely heavy crown thinnings to prevent lower branches from dying. On the backyard woodlot that is visited every year, one can simply implement the crop tree release and re-enter as needed to keep trees free-growing. Studies of pine crown geometry and its relationship to stemwood volume (Seymour and Smith 1986) permit a more rigorous, quantitative approach allowing foresters to define specific schedules that meet particular product objectives. The following steps (adapted from Seymour and Smith 1986) illustrate the procedure:

Step 1: Measure total heights (H) and live crown ratios (heights to the crown base) on a representative sample of crop trees.

Example: Total height = 35 feet, live crown base at 23.4 feet. Avg dbh = 6.1 inches.

Step 2: Define the stand heights when future thinnings will be made, or the height-growth interval between them.

Example: Every 15 feet, or at 35, 50, 65 and 80 feet; rotation ends at 95 feet.

Note: a site index curve can be used to convert height growth to time.

Step 3: Determine the height at the next entry, and calculate how long and wide the crown will be then assuming no crown recession, using equation 10 from Seymour and Smith.

Example: Future height = 50, crown base stays at 23.4, thus crown length (CL) = 26.6 feet.

Crown Radius (CR) = $0.6027 * CL – 0.009988 * CL^2 + 0.00006024 * CL^2 * H$ = 11.10 feet.

Step 4: Compute the crown projection area and equivalent density, assuming circular crowns that fully occupy one acre (43,560 ft^2).

Crown Projection Area = pi CR^2 = 386.8 ft^2

Equivalent density = 43,560/386.8 = 113 trees per acre.

Step 5: Convert density to an average spacing to guide thinning operations (assuming circular CPA).

Spacing = 2 * CR = 22.2 feet.

Note: one could also use square spacing by dividing the density into 43,560 and taking the square root, but this is logically inconsistent with the assumptions of circular crowns. Square spacing in this example is 19.7 feet.

Step 6 (if desired): Compute the dbh of the crop trees at this future entry using equation 8 in Seymour and Smith.

Dbh = $.1367 * CPA^{0.2786} * H^{0.7003}$ = 11.1 inches

Step 7 (if a rotation-long forecast is needed):

Increment H to the next scheduled thinning and repeat steps 3-6.

Results of these calculations are shown in Table 1.

Table 1. Changes in crown dimensions and dbh from a typical low-density thinning schedule defined by 15-foot height increments (from Seymour & Smith, extended to 95 ft).

Height (feet)	35	50	65	80	95
Crown Base (feet)	23.4	23.4	23.4	23.4	23.4
Crown Length (feet)	11.6	26.6	41.6	56.6	71.6
Crown Radius (feet)	5.93	11.10	14.56	17.55	21.29
Crown Projection Area (ft2)	111	387	666	968	1,424
Prethinning Density (Trees per acre)	394	113	65	45	31
Square spacing (feet)	10.5	19.7	25.8	31.1	37.7
Circular spacing (feet)	11.9	22.2	29.1	35.1	42.6
Dbh (inches)	6.1	11.1	15.6	20.0	25.1
Spacing:Height ratio (before thinning)	.30	.39	.40	.39	.40
Spacing:Height ratio (residual stand)	.56	.52	.48	.47	n/a

The first thinning at about 6 inches dbh leaves more crop trees than will ever be utilized for decent-size high-quality sawlogs. But thinning more heavily when starting with a dense stand near the A-line can result in blowdown and sunscald. Plus, having a population of at least 100 crop trees from which to select the eventual winners is always a good idea, because no one can be perfectly prescient in this decision. Here, I endorse the principle, if not the details, of Leak and Lamson's (1999) concept of using multiple B- and C-lines depending on the timing of the first entry and management history. However, when plotted on the new stocking guide (Fig. 1), we see that this low-density schedule only barely reaches the "managed C-line" before thinning; residual densities are much lower.

The last two rows in Table 1 suggest a much simpler approach than the steps above, viz., using Wilson's (1955) spacing fraction (the ratio of spacing to tree height) to guide thinnings. Empirically, it appears that thinning to a spacing fraction of about 0.5 or slightly higher in young stands, then re-entering for the next thinning when it drops to about .4, would effectively accomplish the same purpose.

Research Results

The study I report on here was established in 1991, in what was then a 42-year-old plantation established on an old field with a site index of about 65 (average for pine in this area). Originally it was a spacing experiment, with spacings ranging from 8x8 feet (680 trees per acre) down to an incredible 2x2 feet (10,890 trees per acre), which must have been an attempt to use up leftover planting stock. The stand had no prior treatment, other than perhaps early cleanings. Initial stand conditions are summarized in Table 2.

Table 2. Tree and stand conditions immediately after initial thinnings in fall, 1991, at age 42 from planting.

	Stand Data			Tree Data (Dominants and Codominants only)					
Treatment	Density (trees per acre)	Basal area (ft^2/acre)	Stemwood Volume (ft^3 per acre)	Total Height-Average (feet)	Total Height-Maximum (feet)	Dbh (inches)	Height to lowest live branch (feet)	Crown Length (feet)	Live-crown ratio
B Line	250	90.5	2,052	48.9	57.2	8.3	26.1	22.4	.46
Low-Density	128	53.3	1,224	49.6	58.6	8.8	26.6	23.1	.47
Unthinned Control	553	181.8	4,226	49.9	60.9	8.2	28.3	22.9	.45
Unthinned High-density	1,942	247.1	5,525	48.2	57.4	5.3	37.2	11.8	.24

I installed 8 replicate blocks, each having three treatments:

1. A conventional B-line thinning, using the “old” stocking guide (Philbrook et al. 1973);
2. A low-density thinning to 110-140 crop trees per acre; and
3. A “paired” control plot of similar initial spacings to the thinned plots.

Three plots were also installed in a high-density stand (planted originally at a 2x2-foot spacing; these data will be reported for reference, but are not used in the comparisons below.

Thinnings were implemented on the low-density plots by selecting well-formed crop trees on the requisite spacing, then cutting all other trees. On the B-line plots, crop trees were selected identically, and then released via crown thinnings by removing trees from the upper crown classes until the target B-line residual stand was achieved for that quadratic mean dbh. Generally this treatment released trees on 3-4 sides, but left many intermediates. Plots were rethinned after 10 years to restore B-line stocking on those treatments and to further release crop trees on the low-density plots. The latter brought densities down to between 60-80 crop trees per acre, favoring those with the best crowns and bole quality.

It is premature to render any firm conclusions from 10-year results; the main focus is on whether the crown development and diameter growth of crop trees responded as planned.

Crown Development. Results are much as expected. On the paired control plots, crowns on the upper crown classes receded 7 feet; crown length increased slightly, and live crown ratio lost 5% (Table 3). Relative to the controls, B-line treatments slowed crown recession, increasing crown length about 4 feet and not changing the live-crown ratio. The low-density treatment experienced slight crown recession, much of which occurred on trees that were left too crowded initially and were removed in the second (2001) thinning. Crown length increased nearly 7 feet, improving the live crown ratio over 5%.

Table 3. Ten-year changes in tree characteristics and stand volume (upper crown classes only).

	10-year changes in (dominants and codominants only):					Stand volume growth (ft^3 per acre per year)		
Treatment	Change in Crown Length (feet)	Change in Live Crown Ratio	Height to crown base (lowest living branch, feet)	Dbh (inches)	Volume per Tree (cubic feet)	Gross	Mortality	Net
B Line	4.28	.009	3.46	1.4	5.0	113.6	8.4	105.2
Low-Density	6.88	.051	1.14	2.1	8.1	99.5	4.0	95.5
Unthinned Control	1.13	-.046	7.40	0.8	3.7	165.6	24.6	141.0
Unthinned High-density	2.77	.013	4.99	0.4	1.2	168.2	96.8	71.4

Diameter Growth. In only 10 years, the low-density treatment produced average dbh increments that were 2.6 times that of initially similar trees in the unthinned controls (Table 3). B-line treatments also produced a strong response, at 1.7 times the controls. Radial increment measurements (not shown) made in 2001 on both stem-analyzed trees and increment cores suggest that much of the response occurred during the most recent 5-year period, as the trees began to build larger crowns. Thus, we are only beginning to see the important differences that lie ahead.

Stemwood Volume Growth. Volume increases for individual crop trees are essentially similar to those for dbh, as expected. At the stand level, it is very interesting to observe that the important differences in *tree* development between the low-density and B-line treatments did not translate into similar, offsetting differences in *stand* yield, as one might expect. Immediately after thinning, the low-density plots had only 58% as much basal area as the B-line plots (Table 1), yet they grew 91% as much cubic volume (Table 3, net growth). This illustrates vividly that the extra trees left just to achieve B-line stocking do more harm in retarding crop tree development than they contribute to stand increment. It is also clear, however, that both methods of thinning grew significantly less wood than the unthinned controls. This is true even after deducting 25 cubic feet per year for mortality, which was negligible in both thinning treatments.

Conclusions

I note in conclusion that low-density management runs counter to Ken Lancaster's (1984) excellent review, but that was 20 years ago. I'd like to think that we've learned a thing or two since then about how to make forestry financially viable. The sad truth is that when subjected to economic scrutiny, growing high volumes of black-knotted pine is simply not attractive to landowners. As Arlyn Perky and Neil Lamson have discovered, low-density crop-tree management is fundamentally simple, and thus attractive to landowners, because they can relate to real trees rather than some obscure concept of stand basal area or relative density. B-line management is arguably more complex (requiring the use of stocking guides and stand-level assessments), is not financially attractive, and delays regeneration, without producing significantly higher yields, especially if one counts only valuable, large-diameter, knot-free sawtimber.

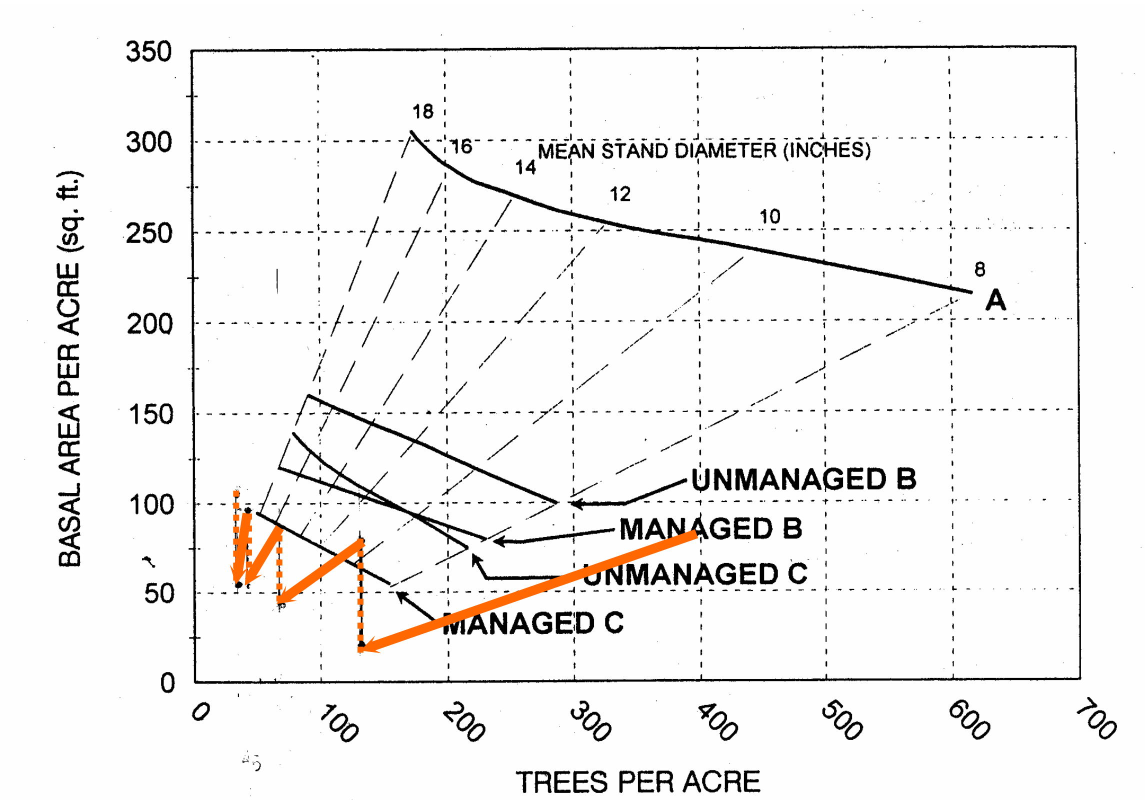

Figure 1. Low-density thinning schedule from Table 1 plotted on the revised stocking guide of Leak and Lamson (1999). Note that the schedule barely reaches the managed C-line *before* thinning.

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White Pine and Prescribed Fire

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Introduction

Eastern white pine (*Pinus strobus*) is an important forest tree species in northeastern U.S. and southeastern Canada. In New Hampshire the white pine forest type group occupies 25 - 30 percent of forest land (USFS, 1985). In addition eastern white pine is well represented in most other type groups that occur in New Hampshire. The growth and form potential, as well as the wood characteristics of the species makes eastern white pine the most valuable softwood species throughout most of its range; certainly this is the case in New Hampshire.

The proportion of eastern white pine in New Hampshire forests increased dramatically in the wake of farm abandonment, due to the ability of the species to reproduce and become established in such sites. In recent decades, however, the proportion of white pine in New Hampshire forests has declined, as revealed in USFS resource evaluations from the 60's, 70's and 80's. Of particular concern is the decline of seedling and sapling white pine, indicating that reproduction is giving way to other, presumably more shade tolerant trees species, notably red maple (*Acer rubrum*) and eastern hemlock *(Tsuga canadensis*).

To some extent, these changes are consistent with the silvical characteristics of the species and unique origin of many 20th century stands of white pine, particularly on soils and sites where white pine reproduction does not compete effectively with other species in forest stands. Silvicultural guidelines for eastern white pine (Lancaster, 1984; Lancaster and Leak, 1978) specifically recognize that white pine silviculture is greatly facilitated if establishing and growing white pine is limited to favorable soils and sites. In addition, work by Barrett and his students (Cook, Byron, etc.) verifies that eastern white pine tends to reproduce and become established very readily in soils that have a high sand component in one or more horizons.

There remains, however, interest in identifying treatments and methods that facilitate the establishment and maintenance of eastern white pine as a dominant tree species throughout the management of a stand and into subsequent rotations. This paper seeks to examine the role that fire plays as an ecological influence and the potential of prescribed fire as a silvicultural means for promoting eastern white pine as a component of forests in New Hampshire.

Reproduction Ecology Re Fire

Eastern white pine is generally considered to be intermediate in shade tolerance (Baker, 1950, p.66; Johnson, 1995, p.102), which suggests that seedlings can become established beneath a forested canopy and that young trees can compete successfully with some same-cohort competition or beneath light-foliaged species like birches and aspens. There is little doubt that the establishment and survival of young seedlings can be enhanced by the reduction of both deep litter and duff and intense woody competition at the forest floor. Favorable conditions can be produced through mechanical scarification of the forest floor and by cutting or chemically treating herbaceous and/or woody competition. Olson and Weyrick (1987, Trotta, 1980) have found that low intensity prescribed fires in the understory of white pine stands and mixed white pine - hardwood stands are able to reduce woody competition as well as reduce the depth of litter and duff layers.

Dormant Season Spring Burns

This is most easily accomplished by means of a spring dormant season burn, utilizing low intensity backing fires or strip head fires, depending on the burning conditions at the time of the burn. The primary fuels consumed in these burns are leaf litter from the previous growing season. Flame lengths vary from 0.5 to 1 foot in the case of backing fires to 1 to 2.5 feet in the case of strip head fires. The consumption of litter and the capability for girdling woody stems is similar for these two fire types. The longer residence time for backing fires is offset by the higher intensities in a shorter residence time for strip head fires.

In maturing eastern white pine stands, Olson and Weyrick (1987) found that abundant seedlings can result from a spring burn following an abundant seed fall the previous autumn. This is apparently facilitated by the tendency for dispersed seeds to filter downward through the leaf litter during autumn and winter, so that a large portion of the seeds escape heat injury. The same workers found that there was high mortality of first year seedlings following a single burn; a higher survival of first year seedlings resulted following two spring burns in quick succession. Although this explanation was not specifically tested, it was suggested that a single burn was not sufficient to reduce surface litter enough to permit seedling root establishment in mineral soil. Seedlings established in organic duff would be apt to suffer drought mortality during dry spells in the growing season.

If managers are not comfortable with the idea of burning the spring after an abundant seed crop, It is suggested that seed crops can be predicted by observing conelet development in the upper canopy. This would facilitate timing a spring burn to follow observation of abundant conelets in the winter.

After satisfactory reproduction is secured, it is obvious that fire must be excluded until the reproduction grows to a size that would be resistant to fire injury. Trials at the University of New Hampshire have indicated that young white pine trees are relatively resistant to injury from low intensity surface fires when they have attained a dbh of 5 inches. Informal observations suggest that a roughened bark surface represents a resistant condition. In some instances, low intensity understory burns in young, smooth-barked white pines has resulted in a roughened bark appearance.

The Place of Mid-Rotational Fires

There is good evidence that larger white pine trees are resistant to low intensity understory fires (Olson and Weyrick, 1987). Eastern white pine has been likened to red pine in this respect (Wright and Bailey, 1982, p.336; Little, 1974, p. 233). The fact that white pine trees larger than saplings tend to be resistant to low intensity understory fires suggests that prescribed burns may be useful in controlling understory vegetation, woody or otherwise. Trials at UNH indicate that this is indeed the case (Trotta,1980). It must be recognized, however, that there are some realities associated with such a regime.

On sites where tolerant hardwoods can be expected to provide substantial understory competition, periodic understory burns can maintain temporary control of these species. It must be recognized that control is likely to be temporary. Low intensity understory burns can effectively girdle stems up to 0.5 inch at the ground, but many will resprout. Red maple has been observed to be a net reducer in an environment of frequent burns; other species are increasers. No species will be eliminated. In fact, Ross (1978) found that total species diversity can be expected to increase in a frequent understory fire regime in white pine and mixed pine-hardwood stands. This means that once a prescribed fire sequence is initiated, there is a limit on how long the understory hardwoods can be controlled. There has been no estimate made on this time limit, but a rough estimate of 10 to 20 years may be realistic, depending on site and seed source of hardwoods.

If white pine reproduction is to be represented in the following rotation, it should be established by the end of this control period. So some short interval fires should be conducted, matched with good pine seed years.

It should also be recognized that white pine stands on hardwood soils are likely to be a result of the special conditions favoring white pine reproduction in old field circumstances. The above fire regime should be helpful in developing a substantial pine component in the next forest, but that forest will be a mixed forest, unless special control measures (chemical/mechanical) are implemented.

Growing Season Burns

If competition from hardwood sprouts is a problem, the literature suggests (Smith et al, 1997, pages 132, 216) that understory burns conducted during the growing season may effectively reduce resprouting vigor. Limited summer prescribed burns at the University of New Hampshire suggests that this may be the case, but the situation becomes more complicated. Appropriate burning conditions for understory burning are less frequent after spring green-up. The dead litter fuels are still there, but they are less available for combustion due to the humidity provided by the understory vegetation, notably canada mayflower (*Maianthemum canadense*) in white pine and mixed pine-hardwood stands.

This means that a longer drying period following rain is necessary in order to allow a larger portion of the total fuel load (notably 10 hour time-lag fuels) to be available for combustion. The more green vegetation, the longer the period after rain is necessary.

Other complicating features of growing season burns are their tendency to be more spotty (incomplete burn coverage of the area) and to retain long-term smouldering, which increases mop-up and patrol requirements. So there are trade-offs to be evaluated.

Autumn Burns

Although fall burns can accomplish results similar to early spring dormant season fires, it is difficult to obtain appropriate burning conditions, given autumn weather patterns in New England. In addition, it is surprising to find that newly fallen dead leaves require curing time before they are readily available for combustion. Therefore, uniform burns are uncommon. There is also a high likelihood that soil moisture deficiencies holding over from the growing season will result in long-term smoulders.

In general, early spring dormant season understory burns tend to be easiest to conduct and have the most uniform results.

Site Preparation Following Harvest

Following harvest activities, site preparation is often considered to be conducive to establishing the new forest. In the instance of partial harvest (shelterwood or single tree selection), the usefulness of prescribed fire for site preparation is limited. Slash accumulations supply high levels of fuel loading which would burn with sufficiently high intensity to injure the residual trees. About the only way in which fire could be useful in this context would be to pile the logging slash away from the trees so that burning may be carried out in favorable conditions to reduce the likelihood of injury.

Such a practice would be a combination of mechanical and fire; the mineral bed produced by fire would then be a relatively small portion of the whole area, but either planting or natural reproduction could then occur.

<u>Windrows and Burning</u>
Following clearcuts or patch cuts, there are more options for site preparation. One would be to use a bulldozer or other clearing tractor (preferably fitted with a raking blade) to pile the slash into windrows and to burn the slash when conditions are favorable.

The advantages of this approach include:
1) The windows for favorable burning conditions become longer because even partially moist fuels can sustain combustion after ignition is accomplished.
2) There is less chance for unwanted fire spread because the clearing activity produces useful fire breaks.

The disdadvantages include:
1) The clearing activity is expensive because of the cost of equipment time, and there is a fair amount of skill required of the operator to avoid moving topsoil and duff into the windrows. This reduces fertility on the cleared portions, which could have substantial repercussions on land that is relatively infertile, as many pine sites are. In addition, topsoil and duff can contribute significantly to long-term smouldering.
2) The high intensity fires that typically result from this practice commonly increase consumption of larger debris. This has two effects: less large woody debris to contribute to

habitat and longer time to complete the burn. In New Hampshire, There are limitations on burning permits when materials to be burned include logs over 5 inches in diameter.

Broadcast Burning

The alternative to piling and burning is to carry out the burn where slash lies after logging, broadcast burning. The result of broadcast burns tends to be more of a mosaic, because there will be locations where fuels are not sufficient to carry the fire. The burn coverage, however will be much greater than with a pile and burn method.

The advantages of broadcast burning include:

1) The cost is usually lower than pile and burn because there is much less equipment time needed. It may still be desirable to use equipment to clear control lines around burn units.
2) The burn area coverage will be greater than with pile and burn, so there will be more site prepared by fire.
3) There will be less tendency for larger debris to become ignited, thereby reducing burn time and increasing debris left for habitat enhancement. Adequate site preparation for either planting or natural reproduction rarely requires reduction of logging slash materials larger than two or three inches in diameter.

Disadvantages of broadcast burning include:

1) Greater potential for fire spread into unplanned areas, especially if there are slash concentrations close to the control lines.
2) Shorter burn windows due to more limited range of appropriate burning conditions and fuel availability.
3) Higher level of competence required in order to carry out ignition and containment successfully.

Season of Burn

Pile and burn activities can include burning in any season, which can greatly reduce chance for escape in snow or wet weather. Winter or wet weather burning generally requires that at least a portion of the pile be covered before burning to facilitate successful ignition. Broadcast burning requires relatively dry periods for successful ignition and fuel reduction.

In either instance, growing season fires have the better chance for controlling hardwood sprouting, as well as reducing opportunity for escape due to the inhibiting effect that green vegetation has on fire intensity.

Prescribed Fire and White Pine Rotations

During the course of a rotation where eastern white pine is the dominant or preferred species, there are several opportunities for using prescribed fire to facilitate the progress of a stand.

Initial establishment following harvest or in conjunction with type conversion treatments can be facilitated by pile-and-burn or broadcast burn treatments. These would be relatively high intensity burns which should help in clearing debris, exposing mineral soil, and in reducing vegetative competition.

Early in the rotation, it has been suggested that low intensity understory burns may be useful in thinning dense sapling/small pole stands (Olson & Weyrick, 1987). Initial trials at the University of New Hampshire have shown some promise, but highly restrictive burning conditions and ignition techniques are necessary. This approach should be considered exploratory and is not recommended.

After the stand reaches pole size, understory prescribed fires may be conducted at 3 to 8 year intervals to maintain control of the understory and surface fuels. This sequence can be maintained up until the time when reproduction for the next forest is needed. As indicated above, multiple burns in quick succession can be helpful in securing successful white pine reproduction.

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The Nuts & Bolts of Prescribed Burning

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Once you have determined that a prescribed burn should be part of your silvicultural strategy for a stand you are still only part way to being able to execute a burn. After close to a century of "Smokey Bear" and virtual elimination of fire from the landscapes of the northeast, reapplication of this management tool to the ground cannot be lightly undertaken.

Regulations

"All northeastern states have forest practice legislation that requires of burning permits for most intentional outdoor fire situations. Each state has its own procedures and regulations, representing a different degree of difficulty with respect to steps to be taken in order to secure a permit to burn. In some instances, there is more than one agency involved in the permit process: a forest protection agency plus some environmental or air quality agency" (Weyrick and Olson 1991). Knowing what agencies and regulations pertain to prescribed burning in your area is key to being able to execute a burn. A little research will undoubtedly save you time and aggravation in the long run.

Statutory responsibility for environmental protection in New Hampshire is divided between several agencies, including the Department of Environmental Services (DES) and the Department of Resources and Economic Development (DRED), Division of Forests and Lands: Forest Protection Bureau. However, in New Hampshire "on-premises burning for the purpose of frost prevention, or agricultural, forestry or wildlife habitat improvement" is "permissible" under Env-A 1001.03 without special permitting from the DES, Air Quality Board as long as certain criteria are met. Chief among these is a limitation on fuels in excess of five (5) inches in diameter, which can result in prolonged smoldering (the type of combustion which results in the most air pollution).

However, burn permits are required for any outdoor fires kindled when the ground is not snow covered. These permits are issued by the local Forest Fire Warden (often the town Fire Chief), and are issued for the period of 5:00 p.m. to 9:00 a.m., unless it is raining. Obviously, these constraints will not mesh with most prescribed fire plans. Burning outside these constraints requires a Commercial Fire Permit (RSA 227-L:17). Once again the local Warden must sign off on this permit, however, in addition the state Forest Ranger for the district you are burning in will have to authorize the permit. (To find out what district you are working in, and who the Forest Ranger is contact the NH. Division of Forests and Lands in Concord.) Authorization by the Forest Ranger is dependant upon acceptance of a prescribed burn plan by not only the local Forest Ranger, but by the Administrator of the Forest Protection Bureau.

Prescribe Burn Planning

An effort is currently underway among New Hampshire's resource management agencies to help standardize and streamline the process by which private individuals, and consulting foresters can obtain the necessary permits for prescribed burns. This may include a process for obtaining assistance with burn planning. However, until that effort is finalized, it is important to recognize that there is a level of minimum why, where, when and how information which must be supplied. Generally the more information made available the better. A thoroughly thought out and executed plan bodes well for a similarly well conducted burn. And keep in mind it is never too early to make contact with anyone who will possibly be affected by your burn, from the local fire department, to abutters.

Location. Where will the burn take place? A description of the project area, and its acreage should be provided along with a map. A good idea is to provide a topographic map showing the location of the proposed project and nearby water supplies suitable for use in fire protection. Including a copy of the town tax map showing abutting landowners (map and lot #'s), buildings and roads is advisable. What is the distance to the nearest occupied building? (If it is under 1000 feet have you notified the owner of your plans?) What is the distance to the nearest town road? What is its status/class? What is the distance to the nearest water supply for fire protection? What is it (pond, stream, hydrant etc.)? Are there any adjacent smoke sensitive areas? (These could include schools, elderly housing, health care facilities, and well traveled roads.) Additional information you may include could be whether the property is under current use assessment, or what the local zoning is for the property.

Prescription. What is the current status of the stand to be treated? (Forest type? Recent treatments? Fuel type and loading? Acreage?) What are the silvicultural objectives to be met by the burn? What are the necessary fire behavior and seasonal/weather constraints to achieve your objectives? (see Burning Parameters.) Include supporting documentation, or references. When do you plan to conduct the burn?

Burning Parameters. Part and parcel of the prescription are your "predicted optimum burning parameters". Ideally the following should be addressed:

- Type of fire to be used: Strip, Head, Backing, etc.
- Desired rate of spread (and calculation method).
- Type of control line to be used: hand line, foam line, blackline, existing fire breaks (woods roads, water bodies), etc.
- Maximum and minimum desired flame length.
- Maximum and minimum wind speed and direction. (This can be a major consideration for smoke management.)
- Optimum relative humidity.
- Optimum air temperature.
- Dates of the optimum burn window to achieve your management objective.
- Optimum number of days since last rain.
- Optimum fuel moisture content.

Include who calculated the burning parameters, and their previous prescribed burn experience.

Personnel and Equipment. Identify the number (and the level of training) of people who will be working on the burn. What tools will be available? (Hand tools, Indian tanks, pumps, hose, weather kit, etc.) What is the water source and how will water handling be accomplished?

What safety equipment (leather boots, gloves, eye protection, etc.) is available (or will be required) for the personnel on the burn? (Check with the local fire department, members of the department may be willing to help for training purposes.) How will communications be handled?

Fire Permit Requirements. The following can be looked at as standard requirements:

- Prior to ignition, determine if local conditions fall within predicted burning parameters (Have an approved weather kit on site, to check conditions prior to and during burn execution).
- If local conditions are met, contact the Division of Forests & Lands for the daily fire weather forecast to determine if the parameters will maintain throughout the time of the burn.
- Notify local fire departments, emergency dispatch and fire towers in advance and immediately prior to ignition.
- Have required equipment in place and in good working order prior to ignition.
- Have control lines established and checked prior to ignition.
- Make sure all personnel within the project area are equipped with appropriate safety gear.
- In the event of an escaped fire, notify the appropriate emergency dispatch immediately.

Execution

The following is from "Checklist for Prescribed Burning in Central New England Forests" (Weyrick and Olson 1991)

Pre-Burn

1. Permits and Notification. All prescribed burning requires a permit from the appropriate forest fire protection authority. In New Hampshire the permit should be secured from the town Forest Fire Warden. Local protection authorities, as well as fire towers and detection personnel, should be notified when burning begins and ends each day. Adjacent land owners and residents should also be notified in advance.

2. Burning Conditions. The best conditions occur 5 to 10 days after a soaking rain. The wind should be 5 to 15 mph in a dependable direction. Air temperatures of 60° to 80° F with relative humidities of 40% to 60% should be present.

3. Weather Forecasts. Forecasts should be available for local conditions. National Weather Service forecasts are generally updated during the day for portions of the state. Constant conditions should be forecast for the duration of the burn, with no frontal or storm activity expected. It should be remembered that afternoon winds should be expected to increase on any day, and coastal and mountainous areas should have associated diurnal wind shifts.

4. Time of Burning. Burning generally should commence from noon to mid-afternoon. Fine fuel moisture content is relatively higher in the morning, leading to incomplete ignition and poor coverage of the area burned. By the same token, higher humidities occurring in late afternoon and evening bring about similar difficulties. These problems are not a pronounced in slash burning, where higher fire intensities tend to pre-heat and dry fine fuels as the fire progresses.

5. Equipment.
Understory burning requires primarily hand tools and back pumps for line clearing, for fire containment while burning is in progress, and for mop up and extinguishment. For these purposes, leaf rakes, fire rakes, and shovels are the most useful hand tools. In some instances cutting tools may be necessary for removing larger fuels and interfering vegetation from control lines. Back pumps should be accompanied by a water source, either in truck or trailer mounted tanks or in nearby surface water.

   Power pumps and hose lines may be brought on-site for standby purposes, but understory burns should be controlled primarily by initial cleared lines and proper ignition techniques. Drip torches are the primarily ignition tools.

   Slashburning generally requires the use of heavy equipment and powered water delivery. Heavy equipment is primarily for preparation, either in windrowing slash or in clearing control lines for broadcast burning. Since fire intensity is expected to be high, there should be powered water delivery in the form of vehicle mounted tanker units and/or by means of pump and hose lay systems from surface water sources. Even in this mode back pumps can be very useful in controlling spots or escapes beyond control lines.

   Drip torches are effective in igniting slash fires, but flame throwing torches or helicopter-mounted ignition devices are becoming more common, especially on larger windrow and slash burns conducted by forestry industry.

6. Personnel and Gear. The number of people involved depend largely on the area to be burned and the kind of burning involved. For understory burning 3 or 4 people could maintain effective control of burns up to 20 acres. More people would be necessary if large areas are to be ignited at one time.

   For slash burning additional people are required for standing by with equipment and water delivery systems. Very often, larger numbers of people are necessary for a relatively short period while fire intensities are highest. Once the fire has spread through the area and intensities are past their peak, crew size could be reduced to those necessary for mop up and patrol.

   Workers should be fully clothed (long sleeves) with sturdy cotton work clothes and rubber or heavy leather boots. Hard hats (brimmed cloth hats at the least), gloves and safety glasses are strongly advised.

7. Supervision and Communication. Each burn should be under the direction of one supervisor who is experienced in prescribed burning. Directions must be clearly understood and carried out correctly. If burns cover larger areas or if multiple burns are being carried out, radio communications would be very helpful.

Burning Procedures

1. Test Fires. Before full-scale ignition patterns are begun one or more test fires in safe portions of the burn area should be ignited to determine if actual fire behavior meets target behavior. If not, there are two options – wait until conditions improve later in the day if such is expected, or postpone burn until more favorable conditions occur.

   It must be remembered that it is as important to postpone if conditions are not severe enough as it is if conditions are too severe. It is true that burning in conditions that are too severe leads to a certain probability of escape, but careful ignition practice should minimize that chance. The more important consideration is the undesired silvicultural effect of the wrong kind of fire. It is relatively easy to contain a prescribe burn within its intended perimeter with proper ignition techniques. It is much more difficult to put a fire out if it is found to be burning at an intensity greater than desired; worst of all is to use fuel and time to produce a burn without favorable effects.

2. Control lines. Control lines should be clear of flammable materials. The width of control lines necessary depends up on the expected fire behavior as well as slope and wind direction. Downwind and uphill lines should be wider than those on other sides of the intended burn. A rule of thumb is that control lines should be cleared to a width equal to 1.5 times the height of available fuels adjacent to the perimeter. (In understory burning, the crowns of overstory trees are not considered to be available fuels.)

3. Ignition. The general rule is to begin burning on the downwind (or uphill) side of the perimeter. If a backing fire maintains itself and accomplishes the objective, it is the best means. The exception to this rule occurs in broadcast slash burning, when first ignition may be toward the center of the unit in order to establish a strong convection column, so flames in subsequent ignition along the perimeter will be drafted toward the center.

   If a backing fire does not maintain itself or does not make satisfactory progress in covering the area, narrow strip headfires may suffice. Strip headfires and backing fires both have a control advantage, because if it is decided to cease burning for any reason, the point of greatest progress of the fire would be a backing fire. Backing fires are relatively easy to extinguish with hand tools and back pumps.

4. Hills and Uneven Terrain. Topographic features tend to cause changes in fire behavior as flames progress through an area. Since fire spreads quickly up slopes, ignition patterns should be planned so that the tops of hills are burned with backing fires before sides are ignited. Fires should be backed down slopes of narrow strip head fires should progress down a slope

5. Smoke. Even under the best of burning conditions smoke may travel considerable distance along the ground, with a potential for obscuring travel ways or causing alarm. It is important that protection organizations and nearby residents are fully informed or prescribed burning activities. Signs or workers should be posted where smoke crosses roads. In general, drier fuels produce less smoke than damp fuels. Also neutral or unstable atmospheric conditions (no temperature inversion) promotes upward dispersion of smoke.

After the Burn

1. Mop-up. After the fire has completed its spread and the flames have died, temperatures throughout the burned area lower rapidly, unless concentrations of larger fuels continue to burn. Long-term smouldering can be prevented if the burning crew conducts a mop-up by scattering fuels and soaking smouldering spots before leaving the area. A combination of raking and soaking is most effective in extinguishing smouldering in deep duff and rotten fuels.

2. Notification. Local forest protection officials should be notified when burn is completed.

3. Patrol. The burn should be patrolled or checked frequently until there is no doubt that all portions of the burned area are completely extinguished. Checks are especially important during the hottest part of the day or when fire weather has become more severe. A burn may safely be considered out if 24 hours have elapsed since the last smoke was extinguished. Responsibility for patrol must be definitely understood among crew members, so there is no doubt that checking will be made on schedule.

4. Final notification. When fire is out, local fire protection officials should be notified that the site will no longer be checked.

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Site Scarification for Natural White Pine Regeneration

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Establishing white pine on an abandoned field site is readily accomplished through the efforts of mother nature. Virtually most of our white pine stands throughout New Hampshire and New England resulted in this way. The abandoned field with its grass layer provides an ideal medium for the white pine seed supplied by neighboring seed trees to germinate in to a dense thicket of seedlings. The hardwood seed is much less successful although gray birch, poplar, cherry and other hardwood species are often present. These hardwood trees serve the role of a nurse tree providing some shade to help discourage significant damage by the white pine weevil. If the white pine seeds in prolifically, the evidence of weevil damage is much less than if the seedlings were widely spaced in full sun. The thicket of pine develops quite uniformly with certain trees expressing dominance and the suppressed, intermediate and co-dominants helping to shape the potential crop trees into straight stems with minimal side limb development. These pure stands of primarily white pine have resulted in some of our most productive and valuable forest type supporting a very important forest products industry throughout the state.

During the initial stages of these white pine forests, the grasses died out quickly due to the intense shade. Over time, an organic layer made up of needles and leaf material replaced the grass layer. Once the stand reached merchantable size and the area was harvested using either a selection thinning method or the clear cut approach, these sites often reverted to a future hardwood forest. This was particularly true if the soil type was a loamy till with good moisture retention. Hardwood competition would often become so intense that any pine seedlings which happened to seed naturally would be quickly suppressed by shade and stagnation. Today, some very valuable hardwood forests have replaced those former productive white pine stands. The concern arises when a productive pine type is replaced with low quality red maple and beech. Forest Service inventory results of the past two decades reveals that these two species are increasing in number faster than any other species in New Hampshire. During our own state wide inventory during the early 1990's, we discovered that we were growing more white pine than we were harvesting but that we are not regenerating white pine in sufficient amounts to ensure that this species will remain a very productive forest type well into the next century.

Although, it is certainly an option, planting pine is generally not done on a large scale. The major factors that serve as a deterrent to this method of reforestation include available labor, cost, adequate stocking level to minimize weevil damage, and follow up hardwood control essential for success. When growing in open lightly stocked conditions, the likelihood of developing what is referred to as a pasture pine quality tree is highly probable. The future of such a crooked, multi-topped, tree with large limbs is limited to a low valued box quality log at best and pulpwood at the very least.

Case Studies

The challenge of regenerating white pine by scarifying the site in conjunction with a cone crop has been a major focus of our white pine management program in Carroll County. The following examples illustrate the variety of site conditions where this reforestation technique has been applied and succeeded.

One site involved a small parcel of land about 12 acres in size located off Mill Street in Center Conway, New Hampshire. This parcel is near the town beach on Conway Lake. I first became acquainted with the property in 1975. This pure stand of 90 year old pine showed no evidence of any previous harvest activity. The trees were about 90-100 feet tall. The basal area was between 250-300 square feet. There was no significant regeneration established due to the closed canopy. The soil type is Croghan loamy fine sand with 0-3% slope. Permeability is rapid and available water capacity is low.

Due to its visibility and susceptibility to potential blow down, a very conservative harvest schedule was planned. It was "guesstimated" that the original volume ranged between 500-600 MBF. The first harvest conducted in 1975 removed about 25% of the volume focusing on removal of predominantly suppressed, intermediate and a few co-dominant trees. Considerable red rot was present in those trees removed in the initial thinning. An excellent white pine cone crop was present the year of the harvest. Ground scarification was accomplished by the logging equipment. The following year, excellent pine regeneration was established on the site. Hardwood competition also became established after the first harvest. This undesirable regeneration was mist blown with an herbicide in 1978. Excellent control was accomplished. It was evident the pine seedlings needed additional light so a second harvest scheduled for winter was planned. Approximately 83 MBF of sawlog material was cut during the winter of 1979. The snow cover protected the seedlings from logging damage. Since 1979, there have been four additional commercial harvests removing approximately 280 MBF of sawlogs. The present residual basal area is about 60-70 square feet of large dominant 16-24 inch dbh trees. The regeneration following each of the timber harvests has responded nicely. The current understory is so thick it is hard to crawl through it. I estimate there is between 250-300 MBF of standing timber left. The logging has been carefully executed to minimize damage by laying out skid trails and restricting skidding to 1-2 log lengths.

The success of this project has been due to a combination of factors. Timing of the first timber sale with a cone crop resulted in a blanket of regeneration. Controlling hardwood competition and removing the hemlock that had established itself in thick clumps was essential in order to give the pine a chance. Frequent light thinnings allowed for good stocking levels to maximize saw timber production while still permitting adequate growth of the seedlings. Careful logging ensured that the next pine forest to occupy this site would reach its full potential

The second site is a 191 acre wood lot in Tamworth, New Hampshire. This property consisted of a mixed forest with pockets of white pine mixed with hemlock and a wide range of hardwoods including birch, maple, red oak, ash and beech.

A commercial thinning using both the group selection and the single tree selection system was chosen by the consultant managing the property. Biomass harvesting technology was selected because of the large percentage of small diameter understory trees that needed to be removed. Also, in the group selection areas the forester desired to create a total clear cut except for some strategic white pine seed trees.

Many foresters would have concluded after viewing the site that it made little sense to attempt to regenerate the area to white pine. The predominance of mixed forest, the rocky terrain and the Lyman-Berkshire very rocky fine sandy loam which occupied the site all pointed to the difficulty of growing white pine. This type belongs in Group IB (Important Forest Soils) and has a successional trend toward a climax of tolerant hardwoods, predominantly beech. Without some effort, the regeneration of white pine is difficult at best. Successful softwood regeneration is dependent upon hardwood control.

The consultant was not discouraged and viewed it as a challenge. The forestry profession has an obligation to not only manage the overstory to its fullest potential but also to try and ensure a stocking of desirable regeneration for the next generation to manage.

The first step was to discuss the landowner objectives for the sale and to outline the timing and procedure to follow in order to increase the chances of regenerating pine on this site. The first requirement was to identify the next cone crop to ensure a seed supply. Since it takes two years for a cone to mature and drop seed, there is adequate time to plan the operation.

Although, winter is not the ideal time because of limited scarification opportunities, the rockiness dictated that the job be done in winter. The white pine seed crop had fallen in mid-September. The logging operation was conducted during the winter months. Immediately after snow melt, the site scarification work was completed throughout the harvest area. It was critical to complete this work before the germination of the pine seed which occurs about mid-May.

A rock rake from a John Deere 450 bulldozer that was modified with a hitch and attached to the rear of a skidder was used. This heavy duty rake and skidder can traverse very rocky terrain. When the rake gets clogged with logging slash, the cable lifts the rake and the debris falls to the ground. Our experience showed that on average site conditions you can scarify an acre an hour. Rocky terrain requires about 1.5 to 2 hours per acre.

The results of this treatment are very impressive. The ground is carpeted with seedlings in both the single tree selection areas as well as the group selection cuts. Adequate light conditions the past seven years has resulted in excellent leader growth. Within the next few years, a mechanical brush treatment will be done to reduce the understory competition. As many as two treatments 3-5 years apart will be necessary in order to ensure the white pine gains dominance. Both the site scarification and the brush control treatment qualify for cost share assistance under the Federal FLEP (Forest Land Enhancement Program) and the EQIP, (Environmental Quality Incentive Program) thus greatly reducing the landowner's personal investment.

Virtually no weevil damage has been detected. The thick density of regeneration will help ensure the development of properly spaced crop trees that will express dominance. Limb development will be kept to a small diameter because of the side competition.

Future harvest activity in the selection cut will involve the gradual removal of the over story in two or three operations. This will maximize the timber production and income generation. A permanent skid road system will be developed to minimize damage to the regeneration in future operations.

Planning, a great deal of effort, and cooperation from Mother Nature has ensured that this site will support a forest of white pine for the next century.

Recommendations for Success

Our experience over the past eight years and 1500± acres treated under a myriad of site and soil conditions points out certain "musts that must be followed" if there is to be success. These are as follows:

1. The first requirement is that there must be a good seed year. Foresters have to monitor the site to determine the best timing. Since it takes two years for a cone to mature, there is plenty of time to plan.

2. The next is a timber sale using a variety of silvicultural systems to create the required openings in the forest canopy. White pine can germinate under shade but needs light to grow. The harvest technology can be either conventional or whole tree harvesting. It is easier to scarify the site if it has been biomassed. The presence of slash is minimized. The ideal timing of the sale is in the summer preceding the seed drop or throughout the fall until snow fall and frozen ground. This time period ensures an exposed mineral bed for the seed to germinate and take root. Logging can occur a year or two prior to seed fall, but then scarification of the site has to occur in the summer or fall the year the seed drops or right after snow melt and prior to seed germination in mid-May.

3. Scarification can be accomplished using a variety of methods. The rock rake dragged behind a skidder is fairly sophisticated. Other effective ways include chaining engine blocks together and dragging them behind the skidder. Several large beech or hemlock logs with 8-12 inch branch stubs protruding from the log has been effective. The twitch should be dragged from the small end so that the limbs dig into the soil as much as possible. Dragging bulldozer tracks with reinforced short spikes welded to the track is another option.

4. Once seedlings are established, the site needs to be monitored to determine when the next harvest should be done . Adequate light is essential for increased growth of the seedlings. Light conditions are adequate when the terminal seedling growth shows continued increase in height from a few inches to 6-8 + inches annually. If it stagnates or shows signs of decline the shade is excessive. Re-entry into the stand needs to occur in order to provide adequate light for seedling development. More frequent entry can result in trees being harvested before their growth is maximized. Loss of some volume and thus income may be the consequence for guaranteeing the presence of a future white pine stand.

5. Hardwood brush control is essential. At least one and perhaps two treatments are needed about 3-5 years apart to control this competition and get the pine to a height where it will out-compete the hardwood.

6. Pine crop tree release should occur when the trees are 20-25 feet tall. At this point dominance is easily recognized and proper spacing can be achieved by mechanical thinning. This is also the ideal time to prune those select crop trees that represent the final harvest.

In conclusion, this technique has proven to be a very successful and a cost efficient method of regenerating white pine. If the above guidelines are followed, the forestry community will ensure a sustainable supply of this most important resource.

Direct Seeding White Pine

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One method of establishing white pine seedlings on a site involves the use of a direct seeding technique. During the early 1960's, Ray E. Graber, a plant ecologist, and Donald F. Thompson, a forestry research technician authored a research publication in which they discussed the testing and research involved in the development of a direct seeder for northern conifers. Both were stationed at the USDA. Forest Service Research Station located in Durham, NH. Much of the research and experimentation was conducted at the Massabesic Experimental Forest located in Alfred, Maine.

The goal of this project was to develop a practical technique for establishing forest trees directly from seed. No commercial equipment suitable to plant tree seed on the stony northeastern brush land existed at the time. Researchers used Yankee ingenuity and adapted existing equipment to accomplish their goal. From a traditional heavy duty fire plow and a beet planter, they devised a furrow seeder. They then tested this equipment pulled by a bulldozer to determine its effectiveness in establishing both red and white pine seedlings by planting seed. The dozer was capable of traversing rough and rocky ground drawing a fire plow to create the disturbed furrow in which to plant the seed. The beet seeder attached directly to the rear of the fire plow was modified to plant either white or red pine seed on approximately a 3 - 4 inch spacing in the furrow. Different size seed plates were created in order to accommodate either the red or white pine seed depending upon the species to be planted.

The final essential step in order to achieve success was to cover the seed with 1/4 to 1/2 inch of soil. This was accomplished by attaching a short length of chain to the end of the beet seeder in the form of a loop. The dragging action of the chain covered the seed with soil.

The only other essential step in this process was to treat the seed with a rodenticide in order to minimize consumption of the seed by small mammals and birds. Endrin was a common material used to treat the seed. Many of the materials previously used are now no longer environmentally safe to use and have been removed from the market.

A symposium titled “Direct Seeding In The Northeast” and held at the Department of Forestry and Wildlife Management at the University of Massachusetts in August of 1964 was well attended by 70 people. Over 36 papers were presented by an impressive list of speakers on this subject. Arthur G. Dodge, UNH County Extension Forester for Carroll County from 1961-1970 was one of those who attended. Dodge saw the opportunity to apply this cost effective technique on acres of marginal land consisting of primarily scrub oak and pitch pine located in the Ossipee Plains area of Carroll County. White pine had once been present in greater abundance throughout this region. The fire history of the area had eliminated most of the red and white pine and had left virtually a pure stand of fire resistant pitch pine. The thick understory of scrub oak made it physically impenetrable to hand plant seedlings. Dodge saw the opportunity to use this technique to reforest select areas with both red and white pine.

Camp Huckins, a YMCA camp located in Freedom, NH, owned a significant parcel of land and was willing to experiment using this new technique. Between 1967 and 1969 over 100 acres were treated with excellent results. The equipment created fire lanes throughout the pitch pine forest ripping out the scrub oak brush and meandering around and through the densely stocked pitch pine stand. It took approximately one hour to deposit one half pound of seed per acre. At the time, the seed cost was about $6.00 per pound and the machine expense per hour was $12-$14. Thus for a cost of about $16-$18 per acre, this acreage was being reforested with a potentially much more valuable product. The work was accomplished both in the fall with mother nature accomplishing the necessary stratification or in the early spring prior to mid May before the natural germination of the seed. In the spring scenario the seed had to be artificially stratified in the refrigerator prior to planting.

Once the seedlings had germinated in the rows that were about 8-10 feet apart, it was apparent that some understory release from the competing scrub oak was essential in order to allow for sufficient light penetration to reach the seedlings. Scrub oak is virtually impossible to eradicate, however it's growth can be retarded through the use of a variety of herbicides. In the late 1960's, the common material used was a mixture of 2-4D and 2-4-5T mixed with water. A foliar application was generally applied during the height of the summer growing season. This miserable job was done under the most difficult conditions. The weather was generally hot and the scrub oak made it difficult for the spray crews. This treatment was successful in knocking back the growth thus allowing more sunlight to reach the seedlings. After a two to three year period, the scrub oak would have begun to re-sprout. A second treatment was sometimes warranted if seedling growth was not responding. This herbicide is no longer permissible to use. Other substitutes are currently available.

The other shade factor was the thick overstory of pitch pine occupying the site. This work was done prior to the availability of whole tree biomass harvesting equipment. During the winter of 1975, a large demand for softwood pulp allowed us to schedule a conventional timber harvest. The snow cover at this time of year provided protection to most of the seedlings from both felling and skidder damage. The majority of the pulpwood size pitch pine was removed leaving occasional sawtimber quality pitch pine to provide light shade to discourage white pine weevil damage and to produce an interim crop of sawtimber at a later harvest. The residual basal area left after this pulpwood harvest was between 40-70 square feet The seedling response to both the herbicide treatment of the scrub oak and the heavy thinning of the overstory pitch pine pulpwood and sawtimber trees was dramatic. The seedlings are densely stocked along the rows. The height ranges from a few feet to 30 plus feet on the trees that have expressed dominance.

A biomass thinning of this site was conducted in the summer of 2003. Skid rows created throughout the 50 plus acres harvested removed about every third row. In addition, much of the residual overstory pitch pine was removed virtually releasing the planted seedlings to full sun. Some occasional thinning was done in the remaining rows accomplishing some necessary thinning between future crop trees. One section of the area treated which borders the Ossipee Lake Road appeared to be thinned more heavily than the remainder of the area harvested. This author was concerned about sun scald and possible ice and snow damage to this area. The people involved with this initial experiment were not consulted by the licensed forester that oversaw this latest harvest. I for one would have been more conservative especially where apparent overthinning occurred. I also would have retained some pitch pine overstory if for nothing else to maintain diversity as well as continued protection from white pine weevil damage.

When I became Carroll County Forester in 1970, I pursued this technique on a number of sites in the pitch pine barrens area. I was met with mixed results. The only thing I did differently was to avoid the use of a rodenticide to treat the seed. After several discouraging experiences, I elected not to try it again. The reasons for my minimal success were never determined. Since the seeding I conducted was never treated with a rodenticide, consumption of seed by rodents and birds were always suspect.

The speakers at the direct seeding symposium mentioned earlier stressed a number of conditions were necessary in order for direct seeding to be successful. They include the following:

1. The most important factor was the availability of enough soil moisture to ensure the seed germinates and the seedling gets established. Obviously, only nature can control this factor.

2. Scarification of the seeding site is necessary to allow for good germination of the seed. The mineral soil must be exposed and a thin layer of soil 1/4-1/2 inch thick should be spread over the seed to achieve good germination results.

3. Seed stratification is needed on certain species of seed. This can be determined by referring to the “Woody Plant Seed Manual”.

4. The tree seed must be coated with a bird repellant and a fungicide in order to produce satisfactory density of seedlings with a minimum amount of seed per acre.

5. After seedlings are established, competition is the main factor which determines if a thrifty stand develops. This is also true if you plant seedlings. Release from competition is essential in developing the stand.

This method to reforest a site is cost effective. The costs associated with direct seeding include the price of the seed, the hourly cost of a bull dozer the size of a John Deere 350 or 450, the rental of a fireline plow and the beet seeder. The current price of white pine is $34/lb. The price of red pine is $95.60/lb. You use approximately one half pound to direct seed an acre. The cost per hour for a medium size bulldozer ranges between $75-$100. The Division of Forest and Lands in Concord did at one time have both the fireline plow and beet seeder. It’s availability and cost to rent are unknown. Our experience proved that you could seed an acre an hour under the average conditions. Thus it is estimated that the costs to direct seed an acre should range between $150-$200. This method of reforestation mechanizes the entire planting operation and more closely mimics the density with which mother nature reforests an area. This ensures an over abundance of seedlings and a minimal impact by the white pine weevil. The dense stocking of seedlings encourages height growth on those trees that express dominance and minimizes the development of understory branching, thus creating earlier self-pruning of lower limbs and a higher quality butt log.

As I reflect back 30 years on the use of this technique and our effort to eradicate on a small area a very distinct local ecosystem, I am glad that we did not continue this effort on a large scale in this forest type. We as a profession have come to realize the importance of unique ecosystems and the important role they play in the ecology of the area. The 2000+ acre pitch pine barrens located in the towns of Ossipee, Madison, Freedom and Effingham are unique to both the state and the county. An effort to eradicate this unique plant community would have been an ecological mistake of major proportion.

There are needless to say other less sensitive ecological sites where this method of reforestation would be appropriate. I would encourage foresters to explore this technique if they think the site warrants this treatment.

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Conifer Release Using Herbicides

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Herbicides are an economical and effective tool to release conifers such as white pine and spruce here in the Northeast. The following outline looks at various situations where herbicides can be used and where it is most effective to apply the herbicides. Though I mention a few herbicides, I am not specifically endorsing any one in particular. This is intended for use as a guideline only. Directions on labels and all pertinent laws should always be followed.

1) When is it practical to apply herbicides?

A) Herbicides may be effectively used to kill competing hardwood vegetation where a site conversion to softwoods is desirable. Spraying with mist blower one year after a commercial harvest to kill the hardwood competition is desirable.

B) Under planting softwoods in a clearcut then spraying late summer after hardening off of the conifers has taken place.

C) Natural softwood regeneration over-topped by hardwood saplings can be released after hardening off with no damage to the conifers. The desirable height of the hardwoods to spray is in the 6-10" height range. Taller hardwoods can be killed but more herbicide would be required. Sometimes, cutting the scattered larger hardwoods and stump treating with a 50% mix of water and Roundup is more effective.

2. Equipment and mode of application

A) Mistblower – powerized
Very desirable in thick brush and taller saplings to "penetrate" the foliage for better coverage of the herbicide. Holds about 3 gallons of mix.

B) Backpack sprayer – non-motorized – foliage spraying
Very good for lighter density brush and can be used to be more selective on target trees without damaging conifers if spraying is being done before hardening off. Holds about 3 gallons.

C) Backpack sprayer - nonmotorized – Basal bark application
Very good for releasing conifers which might be susceptible to foliage spraying. Can be done when leaves are off hardwoods. Limited to lower density hardwood brush where high stem counts may not be economically feasible.

D) Hydraulic spray rigs
Not very feasible for off road applications. Difficult to target just the trees to be sprayed. Puts out too much material off-target.

3) Some desirable herbicides for conifer release and mode of action

Herbicide	**Rate**	**Mode of action**
Roundup	1.5-2 Qts/Ac	Amino acid inhibitor
Accord	2-5 Qts/Ac	Amino acid inhibitor
Garlon 3A	2-4 Qts/Ac	Growth regulator
Garlon 4	1.5-3 Qts/Ac	Growth regulator
Arsenal	¾-2 parts/Ac	Inhibits enzyme pathway

4) Surfactants for conifer release

Surfactants help the herbicide penetrate the leaves and stems of the plant better by spreading the mix more thoroughly over the foliage.

- The best surfactant to add for conifer release would be ENTRY II. Add 5-10 oz of Entry for every quart of Accord or Roundup.
- KINETIC – (organo-silicas) too hot for conifer release
- INDUCE – could be used at 1/8 – ¼%

5) Low-Drift adjuvants

- 38F – liquid
- 41A – powder

6) Permitting and Licenses

- Pesticide applicator license required to apply herbicide
- Special permit required on applications of 50 acres or more or on “sensitive site” from the NH Pesticide Board

7) Approximate costs of conifer release/site preparation

- Foliage spraying using mist-blower on medium density brush, 1-4’ tall would range between $120.00 to $150.00/acre with good equipment access.
- Foliage spraying using mist blower or heavy brush following a clearcut or field mowing for reclamation could go as high as $200-$250/acre.
- Mowing of abandoned fields with own equipment where brush is no larger than 2” dbh will range from $300.00 to $500.00/acre.

8) Cost sharing for conifer release

Two programs are available to help defray the costs of conifer release.

- Forest Land Enhancement Program (FLEP): field approvals by the County Extension Foresters and sign ups at county Farm Service Agency.
- Environmental Quality Incentive Program (EQIP): Administered by NRCS.

Practices and cost share rates:

- tree planting: 50 % of the cost not to exceed $250 per acre
- back pack mist blowing: 50% of the cost not to exceed $100 per acre
- forest site prep: 50% of the costs, not to exceed $80.00 per acre

New Hampshire White Pine Harvest for 2000 and 2001

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Introduction

White pine (*Pinus strobus*) is New Hampshire's most important commercial tree species. In recent years the New Hampshire Division of Forests and Lands has estimated white pine harvesting using USDA Forest Service FIA data and state sawmill surveys. Presently, the Division of Forests and Lands has started to tally the state harvest using the Report of Cut (ROC) forms that are filed for each harvest operation. All the forms are entered into an Access database that the New Hampshire Department of Revenue Administration created. When queried this database will yield volume, species, town and other data related to current harvesting. The form has a category for white pine as sawtimber (mbf) and pulp (cords or tons). White pine can also make up a portion of the volume in other categories such as whole tree chips or pallet and tie logs.

Results

The results of 2000 tax year (April 1, 2000 to March 31, 2001) are based on 3,847 ROC forms that were submitted to the state. In that time period 150,594 mbf of white pine were harvested in New Hampshire. The tax year 2001 saw the number of ROC forms drop to 3,421 and experienced a drop in the white pine sawlog harvest to 127,385 mbf. White pine pulpwood can be recorded as cords or tons. All volumes in tons were converted to cords. In the 2000 tax year 54,971 cords of pine pulp were harvested. In 2001 that volume grew to 71,589. After converting the sawtimber volume to cords the total harvest for white pine in 2000 was 356,159 cords (Figure 1). The total white pine harvest in 2001 dropped to 326,358 cords (Figure 2). It is interesting to note that during this span the sawlog harvest dropped 15% while the pulpwood harvest increased 30%.

Across New Hampshire, Hillsborough and Merrimack Counties dominate sawlog production (Table 1) while Grafton and Carroll Counties dominate pulp harvesting. Coos and Strafford Counties are last in both sawlog and pulp harvesting. The spatial patterns indicate that most harvesting takes place in the south/central region of the state, more specifically Merrimack County and its periphery. White pine harvesting is sparse in areas that are developed, northern New Hampshire, and high elevation areas in the west and White Mountain region.

The ROC form has volumes for "pallet & tie logs," "other" and "exempt." Usually the "exempt" category includes trees that were in proximity to a structure or a particular harvest was under 10 mbf in total. The "pallet & tie log" category is self explanatory while the "other" category is used for species like basswood or cherry or can be used for other low grade sawtimber. White pine made up 49% of the sawtimber harvest in both 2000 and 2001. It is reasonable to assume that 49% of these three categories could also be white pine. Applying this 49% to the total volume of these three categories will add an estimated 14,287 mbf of white pine to the 2000 year and 12,383 mbf in 2001.

Similarly, in the pulp section of the ROC form there are categories for "cordwood and fuelwood" and "exempt cords." It is difficult to tell which species of wood this is but safe to assume that most of this volume is hardwood for home heating. However, "whole tree chips" can potentially be any species of tree. Again, it could be assumed that since white pine makes up approximately 8% of the pulp harvest that 8% of whole tree chips are white pine also. This conservative estimate adds 24,284 cords to the white pine harvest in 2000 and 28,452 cords in 2001.

Adding all the white pine from the sawn category, pulp category and estimating volumes from other categories there were approximately 394,694 cords of white pine harvested in 2000. Using the same methodology that volume dropped to 367,193 in 2001.

Conclusion

These data represent two years of harvesting in New Hampshire. It is clear that the sawn volume of white pine decreased and the pulp volume of white pine has increased in this time period. These changes in volume seem substantial but more years of data are required to gauge the size of these fluctuations. The 2002 and 1999 tax year forms will be entered into the database and added to this trend. Once there are four years of harvesting information in the database the trends should be better defined. When the baseline is established the harvesting trends can be analyzed with other data such as population growth, land use change, weather anomalies and wood markets.

Table 1. White pine harvest by county in cords.

County	***Sawtimber***		***Pulpwood***	
	2000	**2001**	**2000**	**2001**
Belknap	26,150	17,539	5,129	4,406
Carroll	31,305	35,668	10,642	7,727
Chesire	25,614	22,171	2,847	2,404
Coos	4,647	5,614	2,003	1,830
Grafton	37,682	31,364	10,833	31,128
Hillsborough	64,470	42,369	4,091	2,751
Merrimack	55,974	48,539	7,085	7,916
Rockingham	20,956	20,315	4,159	4,443
Strafford	14,336	14,392	3,927	4,659
Sullivan	20,054	16,798	4,255	4,324
Totals	**301,188**	**254,769**	**54,971**	**71,589**

Figure 1

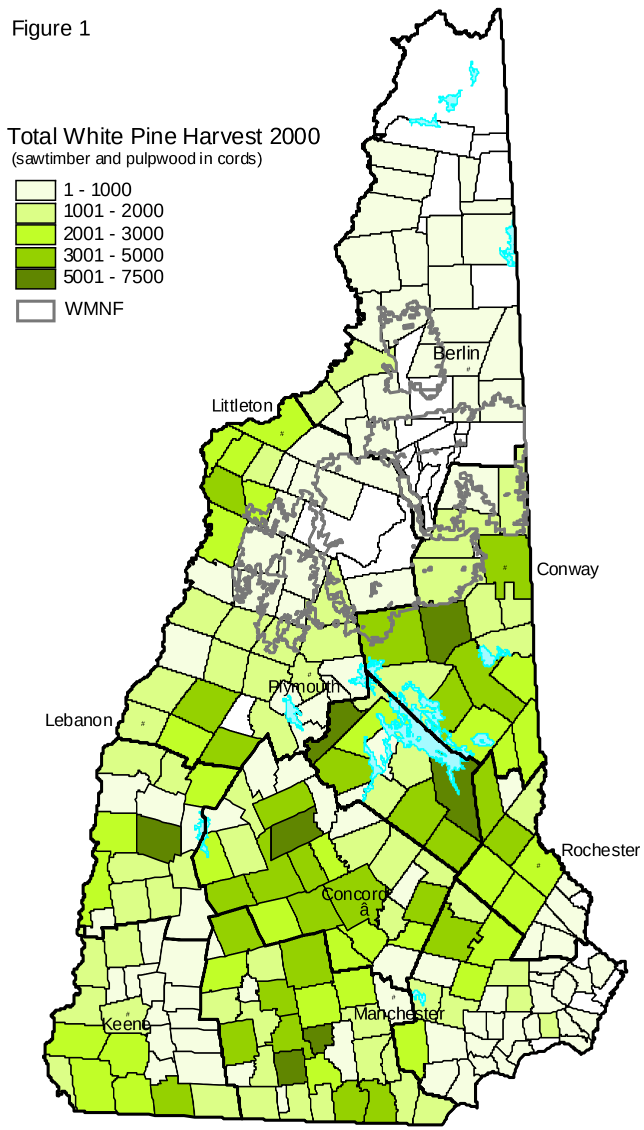
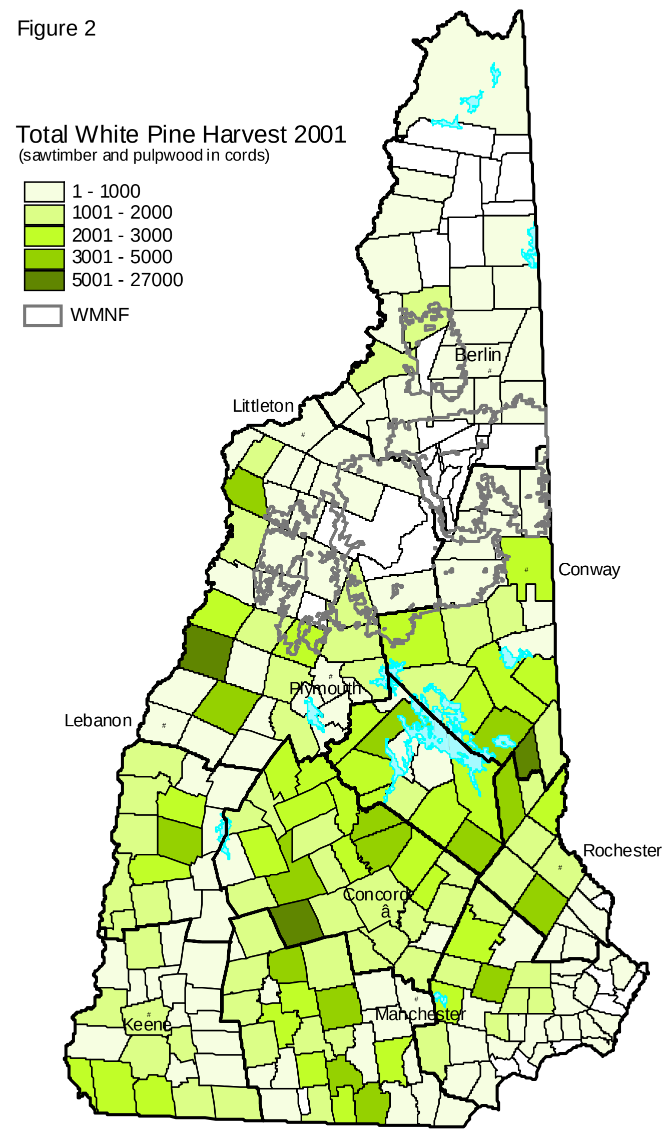


Figure 2



Silvicultural Approaches for Growing Quality White Pine

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The white pine workshop at Fox Research Forest (Oct., 2003) produced a wealth of information on the problems and opportunities for growing white pine in New Hampshire. Perhaps it would be worthwhile to summarize some of this information into a very general approach for growing quality white pine in an effective but economical fashion.

Some dedicated forestland owners may wish to follow a low-density, crop-tree management regime, which several of the speakers aptly described. This approach involves early recognition of crop trees, wide spacing, and repeated pruning operations to grow the maximum amount of knot-free and red-knotted pine as rapidly as possible. The results of this approach were evident in the examples of clear, fast-grown boards displayed at the workshop.

However, Forest Inventory and Analysis data from the USDA Forest Service shows that most of New Hampshire's white pine stands are at mid- to late rotation age and few young stands are available for management.

Also, other owners may wish to follow a regime that requires less time, effort and investment. This might be especially true of owners whose tenure or projected time frame is limited. This is the group addressed in this summary.

Principles

There are several guidelines or principles that are important in producing white pine:

1. Regeneration.--Since there is some evidence that regeneration may be inadequate for maintaining the white pine resource in New Hampshire, the regeneration phase seems especially important for both the individual landowner and the overall health of the forest industry. Tools available for this phase include appropriate silvicultural methods (shelterwoods, small groups/patches) coupled with mechanical site/seedbed preparation and reinforcement planting. On good soils (Group IA and IB Important Forest Soils), it is necessary to initiate white pine regeneration during the first commercial entry; otherwise, hardwood competition becomes overwhelming.

2. Equally important during the regeneration phase and early stand development is controlling unwanted species through maintenance of some overstory cover, chemical control, and the appropriate use of fire. The overstory cover also provides a measure of control over weevil and heavy snow/ice damage. Under the small-patch approach, the adjacent stand provides some level of overstory protection.

3. Quality development.--Some level of pruning seems necessary to develop the highest quality white pine coupled with thinning (stocking control) to rapidly develop clear wood after pruning. Appropriate thinning schedules also help maintain or develop adequate live crown ratios as well as red, tight knots as opposed to black, loose knots.

4. Income/cash flow.--One concern in managing white pine is the maintenance of some level of income at each step in the process. Probably our best approach is to maintain (and harvest) some overstory (see #2 above) throughout the early life of a stand; this should help offset some of the investments required to produce quality pine.

Approach

With these guidelines in mind, a suggested schedule for growing quality pine is outlined in Table 1 and described below. The intention is to provide a system that can be entered at almost any stage regardless of whether there has been prior management or not.

Time 0 (Stand age 60-80)

We'll begin the sequence with a 60-80-year old stand, probably averaging 12-14 inches in mean dbh, with some trees ranging up to 18 inches or so – usually of fairly poor quality. Basal area might be around 200 square feet/acre.

Begin the regeneration sequence.

- It is important to wait for a good pine seed year if possible; harvest the lower quality stems, stems with small crowns (like intermediates) and stems in the understory that cast heavy shade upon the forest floor, during the fall season using a uniform shelterwood or small patches.
- Provide ground disturbance through the logging activity or mechanical means. If the stand has already developed a layer of young pine seedlings, this step should be skipped.
- Leave the equivalent of about 120 square feet of basal area per acre (with patch cuts, this would be the average over a larger stand).

The harvest should remove about 80 square feet of basal area per acre, which should gross at least 10 Mbf per acre. If the catch of pine seedlings seems spotty or poor after 2-3 years, consider reinforcement planting.

Time 10-15 years (Stand age 70-90)

When the pine regeneration is 10-15 years old, an overstory release is the next step. A decline in height growth of the young seedlings will dictate the timing of this release. Following a uniform shelterwood, the release harvest should leave an open stand of about 50-60 square feet of basal area per acre made up of mostly good quality codominant stems from the original stand. Several light releases, 5 years or more apart, is another alternative. Logging under winter snow conditions, using log-length harvesting and/or special equipment will reduce damage to young seedlings. At the same time, a chemical/mechanical treatment of hardwood competition may be needed.

Under a small patch regime, a chemical/mechanical release from hardwood competition probably will be needed, coupled with a B-line thinning in the adjacent stand and/or the initiation of some new regeneration patches.

This harvest should provide somewhere around 10 Mbf per acre.

Time 40 years (Stand age 40 plus older standards)

At about this age, the trees in the new stand should be 6-8 inches dbh and 40 feet tall, somewhat larger and taller under a small patch system.

At this point we suggest pruning around 25-50 crop trees per acre, perhaps more if available, and thinning this younger age class to about the Managed B-line (about 60-80 square feet of basal area) making sure that the pruned trees are well released. Also reduce the overstory to a few trees per acre – maybe 30 square feet basal area or less.

Under a patch system, the crop tree work would be done in the patches, while the remaining stand would be thinned to the B-line and/or patch-cut.

We estimate a harvest of 7-8 Mbf plus significant amounts of pulp or chips.

Time 60 years (Stand age 60 plus older standards)

At this age, the entire overstory or older age class could be removed coupled with a thinning to the Managed B-line in the young stand with particular emphasis on releasing the best crop trees – these would be the crops that were thinned and pruned at the previous stage OR , if prior management had not taken place, the best crop trees available at the time. It is probably too late for additional pruning.

This thinning would be crop-tree level thinning (not a thinning from below) so much of the harvest would be sawtimber -- perhaps 10 Mbf including the overstory volume.

Under the patch regime, the 60-year-old patches would be thinned to the B-line and new patches cut in the remaining stand.

Time 80 years (Stand age 80 with no remaining older standards)

The regeneration sequence could begin again as described above under Time 0.

Conclusion

This sequence must be regarded as very general, subject to a great deal of fine tuning depending on current stand conditions and previous levels of management. However, the basic principles seem sound: adequate regeneration, maintenance of some overstory for protection and steady income, and adequate pruning-and-release of the best crop trees.

Table 1.—General schedule for quality white pine management. Basal areas and volumes very approximate.

App.Time	Stand Age	Initial BA	Residual BA	Description	Yields
	(years)	(sq.ft./A)	(sq.ft./A)		(Mbf)
0	60-80	200	120 (Unmanaged C-line)	Initial regeneration cut	10 Mbf
10	70-90	140	50-60 (Managed C-line)	Overstory Release. Hdwd control.	10 Mbf
40	40 plus older standards	100 (overstory) 100 (understory)	30 (overstory) 60-80 (understory)	Release, thinning, pruning of 25-50 trees/A	7-8 Mbf plus pulp
60	60 plus older standards	70 (overstory) 120 (understory)	100	Remove overstory, thin younger age class	10 Mbf
80	80	160	120	Begin regeneration sequence again	5-6 Mbf (quality pine)