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White Pine Silviculture for Timber and Wildlife Habitat in New England

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131 Main Street, 225 Nesmith Hall, Durham, NH 03824

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AUTHORS

William B. Leak, research forester, U.S. Forest Service, Northern Research Station, Durham, NH. bleak@usda.gov

Mariko Yamasaki, research wildlife biologist, U.S. Forest Service, Northern Research Station, Durham, NH. mariko.yamasaki@usda.gov

Karen P. Bennett, extension forestry professor and New Hampshire state extension forester, emeritus, UNH Cooperative Extension. karen.bennett@unh.edu

Ken Desmarais, assistant ranger, U.S. Forest Service, White Mountain National Forest, Campton, NH, formerly N.H. Division of Forests and Lands, Dept. of Resources and Economic Development. kenneth.desmarais@usda.gov

Peter Pohl, Carroll County extension forester, retired, UNH Cooperative Extension

Christine Costello, wildlife biologist, U.S. Forest Service, Northern Research Station, Bartlett, NH. chris.costello@usda.gov

Isabel Munck, forest pathologist, U.S. Forest Service, Eastern Region State and Private Forestry, Durham, NH. isabel.munck@usda.gov

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ABSTRACT: This update of the 1978 guide (Lancaster and Leak 1978) includes new information on practical silvicultural alternatives such as low-density management, pine-oak mixtures, and wildlife management options. We include the latest on regeneration techniques—a current urgent problem—including the influence of prior agricultural disturbance. Site relationships, successional trends, growth and yield, and economics are discussed as well as suggested stand prescriptions. There are several widely different approaches for managing white pine; we have tried to cover the options. For additional information on white pine silviculture and management see the workshop proceedings from *Managing White Pine in a New Millennium* (Bennett and Desmarais 2003) and *Good Forestry in the Granite State* (Bennett 2010), both publications available from UNH Cooperative Extension.

KEY WORDS: white pine silviculture, New England white pine stands, white pine regeneration, white pine wildlife habitat.

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White Pine Silviculture for Timber and Wildlife Habitat in New England

INTRODUCTION TO THIS GUIDE

This update of the 1978 guide (Lancaster and Leak 1978) includes new information on practical silvicultural alternatives such as low-density management, pine-oak mixtures, and wildlife management options. We include the latest on regeneration techniques—a current urgent problem—including the influence of prior agricultural disturbance. Site relationships, successional trends, growth and yield, and economics are discussed as well as suggested stand prescriptions. There are several widely different approaches for managing white pine; we have tried to cover the options.

DISTRIBUTION OF WHITE PINE IN NEW ENGLAND

White pine (*Pinus strobus*) is one of the most commercially valuable and sought-after species in New England. It has a rich history with trees marked in colonial times for the Royal navy (Great Britain 1711). The historical use of white pine for shipbuilding is evidenced by the presence of Mast Roads in so many southern and eastern towns in the New England region.

White pine occurs throughout the middle and northern latitudes of New England at elevations up to at least 2,000 feet. It naturally occurs on dry sites—sandy, gravelly outwash and shallow bedrock. However, it is found on a complete variety of soil conditions primarily due to prior agricultural land use.

White pine accounts for about 10 (Vermont) to 27 (Massachusetts) percent of the cubic volume on timberland (Table 1). However, white pine regeneration is not found in the same abundance as the current growing stock. The percentage of 1- to 2.9-inch stems ranges from only about 0.5 to 3.5 percent in northern New England to only 18.6 percent in Massachusetts. This is primarily due to the decline in agricultural abandonment and the dependence of white pine on a narrow range of suitable soil and site conditions as discussed below.

Table 1.—Percent of cubic volume on timberland and percent of 1- to 2.9-inch stems on forestland by states in white pine (FIA Core Tables 2017) (Accessed at https://www.nrs.fs.fed.us/fia/data-tools/state-reports/default.asp).

	Cubic volume on timberland acres	1 to 2.9" dbh stems on forestland acres
State	--------------- Percent ---------------	
Maine	11.49	1.49
New Hampshire	21.47	3.51
Vermont	10.05	0.52
Massachusetts	27.45	18.63

Site, Succession and Land Use

White pine occurs throughout the middle and northern latitudes of New England at elevations up to at least 2,000 feet (Wendel and Smith 1990). It naturally occurs on dry sites—sandy, gravelly outwash and shallow bedrock. However, it is found on a complete variety of soil conditions primarily due to prior agricultural land use. At least half of New Hampshire was cleared for agriculture or grazing by the middle of the 19th century (Kingsley 1976)—quite possibly a higher percentage in states such as Massachusetts and Vermont.

As farmland was abandoned, white pine thrived where it was barely present prior to agricultural land-clearing because it could endure conditions found in abandoned agricultural lands—grass and sod competition and erosion. Mammal herbivory pressure on regenerating hardwood species also favored white pine regeneration over species that would normally be found. These sites will tend to revert to their prior species composition, and therein lies the concern over maintaining the white pine resource—and the need for special attention to regenerating this species.

On sandy, dry white pine sites the natural succession appears to be toward hemlock. However, thinning or heavier cutting will generally move the species mix back toward pine-oak with mixed hardwoods.

On sandy, dry white pine sites the natural succession appears to be toward hemlock. However, thinning or heavier cutting will generally move the species mix back toward pine-oak with mixed hardwoods. On these dry sites the oak component may include white and black oaks. On better, high-site soils, early broad-scale studies of 225 stands throughout southern New Hampshire and Massachusetts (McKinnon et al. 1935) showed that clearcutting of the old-field pine resulted in a mix of hardwoods, including an abundance of northern red oak, with a minimal proportion of white pine. Results on less-productive sites also produced mixed oak with few pine. However, regenerating the mature oak stands that develop is well-recognized as difficult, requiring special silvicultural approaches such as well-buried acorns and removal of competing understory species (Leak et al. 2017).

Similarly at the Massabesic Experimental Forest in Lyman, Maine, fire-origin stands of white pine-red maple-hemlock on sandy soils that resulted from the widespread 1947 fires in southern Maine, produced stands of mixed hardwood-oak with a component of white pine when clearcut 60 years later (Figure 1). On slightly better till sites, mixed hardwood-oak poles have outcompeted the minimal white pine component found in younger stands (Figure 2).

Figure 1.–A 12-year-old regenerating stand of mixed hardwood-oak with a component of white pine following a clearcut of a fire-origin stand of pine-red maple-hemlock, Massabesic Experimental Forest, Lyman, ME. Photo by M. Yamasaki, U.S. Forest Service.

Figure 2.–A small pole mixed hardwood-oak stand following a clearcut, Massabesic Experimental Forest, Lyman, ME. Photo by M. Yamasaki, U.S. Forest Service.

REGENERATION

Seed Production

White pine begins to bear cones before age 20 and produces full crops between ages 50 to 100 (Figure 3). Abundant crops may occur only every three to five years, sometimes up to seven years. The cones require two years to mature. By the fall of the first year, the cones are 1- to 2-inches long. They reach full size, 5- to 7-plus inches long, and maturity by fall of the second year (Lancaster and Leak 1978). By checking the one-year cone-crop, a forest manager can predict the likelihood of a seed-crop and make plans for a regeneration harvest. However, infestation by the white pine cone beetle can cause extensive damage to the second-year crop (Figure 4).

Figure 3.–Developing second-year white pine cones, Massabesic Experimental Forest, Lyman, ME. Photo by M. Yamasaki, U.S. Forest Service.

Figure 4.–Dead white pine cones, infested by white pine cone beetle larvae, may hang on trees for a period of time before dropping to the ground. Photo by S. Katovich, U.S. Forest Service, Bugwood.org.

Seed production varies with stand density (Graber 1970). A test of high, medium, and low densities (187, 120, and 80 square feet of basal area per acre) in an 80-year-old stand in southern Maine showed that the intermediate density produced about 40 percent more seed than the other levels: 1,793 thousand per acre in a good seed year and 409 thousand in a poor year (Table 2). Seedfall began in early September and diminished rapidly after early October. Heavy consumption by birds, squirrels, and small mammals was observed. These losses can be moderated by scarification and burying (generally through the harvest operation) following seedfall.

Table 2.—White pine seed production (thousands of seed per acre) in relation to stand density and seed year (Graber 1970) in an 80-year-old stand on the Massabesic Experimental Forest, Lyman, ME.

Basal area/acre (square feet)	Average dominant height (feet)	Average dbh (inches)	Percent live crown	Good seed year (thousand seed)	Poor seed year (thousand seed)
187	96	17.1	28	1,140	298
120	95	18.0	36	1,793	409
80	101	18.4	40	1,254	298

Regeneration, Harvest Methods and Seedling Development

It is common to see stands of white pine, especially managed stands in central and southern New England, with a mixed understory of oak. Conversely, oak stands sometimes have an understory of pine, especially on sandy and dry sites. This alternation of species is facilitated by wildlife interactions—planting of acorns by squirrels and blue jays and preparation of pine seedbeds by small mammal activity (Alexander 1980). Alternation of species, or mixed-species management, in these situations is a logical approach, although beech and other northern hardwoods will invade on better soils. Mixes of white pine and red oak appear to be productive (Waskiewicz et al. 2013). Since both species are subject to insect and disease problems, species mixtures can maintain some level of diversity, stability, and market flexibility.

Thinned stands, not ready for final harvest, will often perform like a shelterwood by producing a vigorous understory of pine, oak, and miscellaneous other species (Figure 5a and b) (Leak and Yamasaki 2013) especially on sandy or gravelly outwash or sandy tills. This is especially common under lower residual-densities. This desirable understory can be maintained (left untouched) over time. However, on finer-textured soils, the entire understory may develop into a mix of less desirable hardwood species with little or no pine or oak. To deal with this tendency, it may be useful to remove an undesirable understory and midstory during a follow-up low-density thinning—to scarify the seedbed and make room for better understory species. Keep in mind the importance of a pine or oak seed year.

Figure 5a and b.–(a) Low-density (32 square feet per acre) and (b) medium low-density (60 square feet per acre) thinning with a vigorous mix of understory pine, red and white oak, and other hardwoods, 4 years post-treatment, Massabesic Experimental Forest, Lyman, ME. Photo by M. Yamasaki, U.S. Forest Service.

Figure 5a.–Low-density (32 square feet per acre)

Figure 5b.–Medium low-density (60 square feet per acre)

Non-Native Invasive and Native Nuisance Plants

One of the chief concerns when growing and regenerating white pine is the invasion of weed species—non-native invasive and native nuisance plants—especially on the better soils or wet soils (Leak 2014; Campbell et al. 2015; Kozikowski 2016). These plants regenerate quickly and profusely, occupying the site and preventing the establishment of white pine seedlings.

The most damaging are ferns, buckthorn, and mountain laurel. Where present, glossy buckthorn is especially vigorous under pine stands as compared with hardwood stands and difficult to eliminate (Bibaud in preparation). Chemical treatments along access roads, trails and stand borders prior to invasion seem worthwhile and at least partially effective.

One of the chief concerns when growing and regenerating white pine is the invasion of weed species—non-native invasive and native nuisance plants—especially on the better soils or wet soils.

Where white pine advance regeneration is in a dominant position relative to these plants, release it. When advance regeneration is absent, apply heavy site preparation through the harvest operation to eliminate some of the nuisance understory.

Another approach is to regenerate hardwood by using groups or patches to release a desirable hardwood understory (e.g., oak), or use scarification to regenerate hardwoods, which have a lower tendency toward buckthorn invasion. Many pine stands (old-field pine) are natural hardwood sites and conversion is straightforward using even-aged methods.

Where undesirable understory vegetation is abundant, the use of narrow harvest-strips has proven useful (R. Hardy, N.H. Division of Forests and Lands, pers. comm.). The disturbance during logging can do a thorough job of removing the undesirables and preparing the seedbed. However, strips are best applied to stands that contain a predominance of timber ready to be harvested.

Field Observations on Regenerating White Pine on Good Quality Sites

Much of the information on effective and practical ways to regenerate white pine was developed through observations and experience and we share one forester's thoughts.

FIELD OBSERVATIONS ON REGENERATING WHITE PINE ON GOOD QUALITY SITES by Peter Pohl

Regenerating white pine on good hardwood soils (group IA and group IB soils described in Appendix A) poses a silvicultural challenge. I will address two scenarios as they relate to the challenge of perpetuating white pine on these soil types. The following comments are from my observations as a field forester.

The first scenario deals with abandoned agricultural land that reverted to essentially pure white pine. The second deals with mixed hardwood and white pine stands. Can we maintain white pine on these sites, or is it inevitable that hardwood will eventually dominate? Field observations convinced me that with planning, proper timing, appropriate silviculture and some luck, white pine can be perpetuated.

Timing harvests with a productive cone crop is essential to achieve successful regeneration. In the case of pure pine stands as well as mixed stands, it is important to establish regeneration upon the first commercial entry in the stands. Failure to do so allows the establishment of hardwood reproduction, which poses serious competition for white pine regeneration. In the case of pure pine stands, thinning to 110 to 130 square feet per acre creates ideal spacing for crown expansion and space enough for adequate sunlight to reach the ground for seedling germination.

For mixed stands, leave a residual basal area between 80 to 100 square feet per acre. Retain the majority of the good quality white pine to ensure an adequate well-dispersed seed-source. Hardwood competition poses a greater threat on these sites due to the presence of the residual hardwood as well as the prolific sprouting that occurs from harvested hardwoods. The hardwood seed-source will result in the establishment of abundant hardwood regeneration as well.

Since white pine seed is released from the cone about mid-September, schedule logging just prior to, during or after seed-release. Site scarification by harvest equipment will ensure the seed mixes with mineral soil, which is important for germination. Avoid harvesting during snow-cover since snow-cover does not allow for adequate scarification. If the harvest cannot be timed in late summer or fall of seed-drop, then the next best time is just after snowmelt and prior to about mid-May when the seed germinates.

Scarification is the key to success. Strive to scarify at least 50 percent of the harvest area. If this cannot be achieved during the harvest, a follow-up treatment using a device such as a rock-rake towed behind a skidder, combing and mixing the soil and duff, works well. One could cover about an acre an hour over recently logged, rough terrain with slash on the ground.

In both scenarios, observing the annual height growth of the white pine regeneration is key to deciding when a release treatment is needed. White pine seedling growth begins slowly and within a five-year period shows a steady increase in the annual height growth. When the rate of growth begins to stagnate (a reduction of 50 percent, or so), additional sunlight is needed.

For pure white pine stands, this triggers a thinning of the overstory. Time this harvest with adequate snow-cover to minimize damage to the reproduction.

With mixed stands, the invasion of hardwood reproduction as well as the sprout-growth from harvested hardwoods pose a threat to the regeneration. A pre-commercial treatment—cutting or herbiciding the hardwood sprouts and seedlings—will likely be needed within 10 to 15 years after white pine regeneration is established.

Allowing the successfully regenerated white pine to grow as thick as possible for 15 to 20 years reduces damage from the white pine weevil and white pine blister rust, minimizes side limb development and achieves dominance of identifiable crop trees that can be released in a precommercial thinning. (Where *Caliciopsis* canker is present, high densities may increase susceptibility towards this canker.)

Time future harvests of the overstory with care to protect the regenerated trees. The operator needs to exercise additional care in order to minimize damage during these essential successive harvests.

GROWTH, YIELD AND STOCKING

White pine is one of the most productive species in New England in volume production. Early studies in New England (Frothingham 1914) showed yields of fully stocked, high-site (Figure 6) 100-year-old stands reaching 10,000 cubic feet and 65,000 board feet per acre (Tables 3 and 4, Leak et al. 1970). There are reports of higher volumes on good sites with tall (120-foot plus) trees. However, much of the Northeastern acreage is on moderate site indexes of 50 to 70.

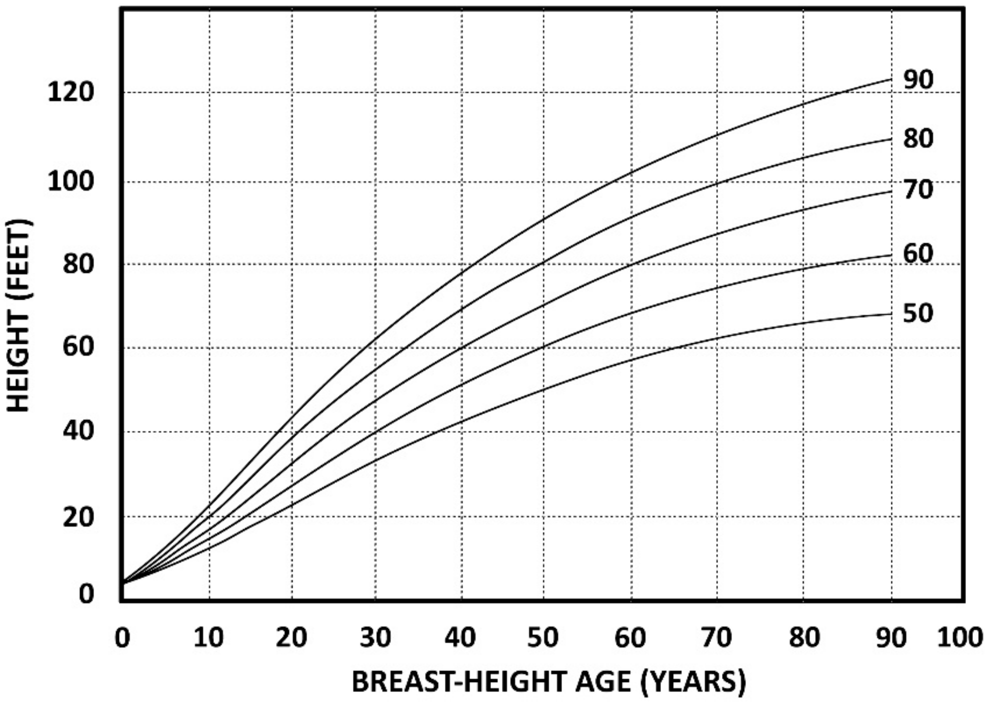

Figure 6.–Site-index curves for eastern white pine in New England (curves corrected to breast height age of 50) (Frothingham 1914).

Table 3.–Cubic-foot yields per acre to a 3.0-inch inside bark top in Maine, Massachusetts, and New Hampshire, by age, site index (breast height at age 50), and stocking present [Applies to overstory pine trees 3.0-inches dbh and over] (Leak et al. 1970).

		-------------- Stocking percent --------------									
Age (years)	Site index	40	50	60	70	80	90	100	110	120	130
20	50	761	931	1,098	1,262	1,423	1,583	1,741	1,897	2,052	2,206
	60	892	1,090	1,286	1,477	1,667	1,854	2,039	2,222	2,403	2,583
	70	1,044	1,277	1,506	1,730	1,952	2,171	2,387	2,602	2,814	3,025
	80	1,223	1,496	1,763	2,026	2,286	2,542	2,796	3,047	3,296	3,543
	90	1,432	1,752	2,065	2,373	2,677	2,977	3,274	3,569	3,860	4,149
40	50	1,886	2,307	2,719	3,125	3,526	3,921	4,313	4,700	5,084	5,465
	60	2,209	2,702	3,185	3,660	4,129	4,592	5,051	5,504	5,954	6,400
	70	2,587	3,164	3,730	4,287	4,836	5,378	5,915	6,446	6,973	7,495
	80	3,029	3,075	4,368	5,020	5,663	6,298	6,927	7,549	8,166	8,778
	90	3,548	4,339	5,115	5,879	6,632	7,376	5,112	8,841	9,563	10,280
60	50	2,552	3,121	3,680	4,229	4,771	5,306	5,836	6,360	6,879	7,395
	60	2,989	3,656	4,309	4,953	5,587	6,214	6,834	7,448	8,057	8,660
	70	3,500	4,281	5,047	5,800	6,543	7,277	8,003	8,722	9,435	10,142
	80	4,099	5,014	5,910	6,793	7,663	8,523	9,373	10,215	11,050	11,878
	90	4,800	5,871	6,922	7,955	8,974	9,981	10,977	11,963	12,940	--
80	50	2,968	3,631	4,280	4,919	5,550	6,172	6,788	7,398	8,002	8,602
	60	3,476	4,252	5,013	5,761	6,499	7,228	7,950	8,664	9,372	10,074
	70	4,071	4,980	5,871	6,747	7,611	8,465	9,310	10,146	10,975	11,798
	80	4,768	5,832	6,875	7,902	8,914	9,914	10,903	11,882	12,853	--
	90	5,584	6,830	8,052	9,254	10,439	11,610	12,769	--	--	--
100	50	3,250	3,976	4,687	5,387	6,077	6,758	7,433	8,100	8,762	9,419
	60	3,806	4,656	5,489	6,308	7,116	7,915	8,704	9,486	10,262	11031
	70	4,458	5,453	6,428	7,388	8,334	9,269	10,194	11,110	12,018	12918
	80	5,221	6,386	7,528	8,652	9,760	10,855	11,938	--	--	--
	90	6,114	7,478	8,816	10,133	11,431	12,713	--	--	--	--

Table 4.–Board-foot yields per acre (International ¼-inch) to a 6.0-inch inside bark top for eastern white pine in New Hampshire by age, site index (breast height at age 50) and stocking percent (Leak et al. 1970).

		-------------- Stocking percent --------------							
Age (years)	Site index	50	60	70	80	90	100	110	120
40	60	7,660	7,876	8,064	8,230	8,379	8,514	8,639	8,755
	70	10,405	10,699	10,953	11,179	11,381	11,566	11,735	11,892
	80	14,134	14,533	14,878	15,184	15,460	15,710	15,940	16,153
60	60	19,864	20,425	20,911	21,341	21,728	22,080	22,403	22,702
	70	26,983	27,744	28,404	28,988	29,514	29,992	30,431	30,838
	80	36,652	37,686	38,582	39,376	40,090	40,739	41,336	41,888
80	60	31,988	32,891	33,673	34,366	34,989	35,556	36,076	36,558
	70	43,451	44,677	45,740	46,681	47,527	48,297	49,004	49,659
100	60	42,574	43,774	44,816	45,738	46,567	47,322	48,014	48,656
	70	57,830	59,461	60,875	62,128	63,254	64,279	65,220	66,092

Current annual growth rates of 140 cubic feet and nearly 1,000 board feet per acre have been reported (Barrett et al. 1976; Cooke 1989) with mean annual rates (up to about 100 years) of about 120 cubic feet and 600 board feet. These are in fully stocked stands. The New Hampshire case study shows B-line, crop-tree and lower-density crop-tree thinning will produce similar volumes especially when including the intermediate harvest volumes. Innes et al. (2005) report current annual increments of 259 cubic feet per acre per year in their most productive stand, with two others within 20 per cent of that value, demonstrating white pine produces high yields on quality sites.

An early examination of stocking guides showed that lightly managed stands of white pine grew best and produced more volume at basal areas well above current stocking recommendations (Leak 1981). Further study showed, however, that thinned and managed white pine with well-developed crowns would maintain growth per acre at fairly low stocking (Leak 1982). This led to the development of stocking guidelines (Leak and Lamson 1999) that recognized the difference between managed and unmanaged pine (Figure 7). The managed C-line on this chart approximates the range in residual basal area appropriate for low-density management.

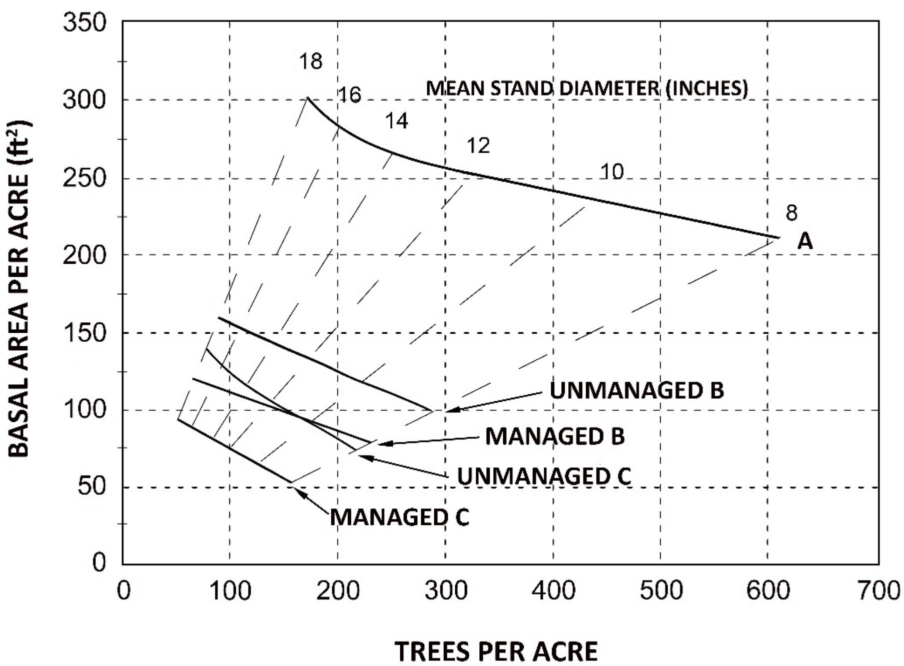

Figure 7.–Revised white pine stocking guide for managed stands. From Leak and Lamson (1999).

Low-density white pine management grows carefully selected crop trees at unconventionally low stand densities, well below the managed B-line and even below the managed C-line on the Leak and Lamson (1999) pine stocking guide. Heavy thinning begins once crowns recede above one log (Seymour et al. 2009).

Low-Density Management

Low-density thinning produces a flush of regeneration as well as unique growth and yield responses. This system was pioneered by Hunt and Mader (1970), Seymour and Smith (1987), Page and Smith (1994), Desmarais (1995) and Seymour (2007). With this approach, the stand is thinned to a level at or below the managed C-line on the standard white pine stocking chart (Figure 7; Leak and Lamson 1999). Ideally, thinning begins when the stand is ready for pruning of 50-plus crop trees per acre (approximately 6-inches dbh). The system can also be applied—perhaps without pruning—when the stand is older. Under low-density management, diameter growth is rapid, growth per acre is only slightly or moderately diminished, and the rotation is shortened.

After a low-density thinning in small sawtimber on the Massabesic Experimental Forest (Leak and Yamasaki 2013)—thinned to 32 or 60 square feet with a control at 148 square feet per acre—the annual gross basal area growth was 1.08 and 2.74 square feet per acre, respectively and the annual dbh growth was 0.21 and 0.25 inches. In other words, the 60 square foot treatment produced more than twice the basal area growth and a little greater diameter growth than the 32 square foot treatment. Work by Seymour et al. (2009) in Maine showed that low-density thinning (with pruning) produced nominal sacrifices in total growth and yield but important gains in clear timber production.

Mast Yard State Forest (Hopkinton, NH) Growth & Yield Case Study

Two different field studies explored stand and individual tree growth for B-line, crop-tree, and lower-density crop-tree thinning regimes.

Comparing B-line thinning with crop-tree release

A side-by-side paired plot study began in 2003 with a remeasurement in 2016 (Table 5). Each plot had a 33-foot treated buffer to avoid edge effects. One plot was thinned to B-line stocking of 137 square feet per acre and the other plot received a crop-tree release with a residual basal area of 85 square feet per acre. Thirteen years after treatment the B-line thinning had an average annual diameter growth of 0.09 inches while the crop-tree plot was higher at 0.13 inches. However, the annual basal area growth for the B-line plot was 2.0 square feet per acre and only 1.7 square feet per acre for the crop-tree plot.

In the discussion of the New Hampshire case study, we use the term "lower-density crop-tree release," to distinguish the two crop-tree variants in the case study and to emphasize the densities in this study are higher than densities indicated by low-density management guidelines.

Volume growth differences were substantial between the plots. The B-line plot volume per acre changed by 8,228 board feet from 21,275 board feet per acre in 2003 to 29,504 board feet in 2016, an annual growth of 633 board feet per acre. This is roughly 4 board feet of volume growth per tree annually. This plot is compounding volume growth at about 2.5 percent annually.

On the crop-tree plot, the volume per acre changed by 6,218 board feet from 15,268 board feet in 2003 to 21,486 board feet in 2016, an annual volume growth of 478 board feet or roughly 6 board feet of volume growth per tree annually. This stand is compounding volume growth at a slightly better 2.66 percent annually. The quadratic mean diameter of the B-line plot changed from 12.9 to 14.1 inches (1.2 inches) over the 13-year period, while the crop-tree plot grew from 14.0 to 15.6 inches (1.7 inches) over that same period.

Table 5.—Mast Yard State Forest (New Hampshire) 13 year paired plot study.

Treatment	Trees per acre	Basal area (square feet per acre)	Board feet per acre	Quadratic mean diameter
B-line in 2016	150	162.6	29,504	14.1
B-line in 2003	150	137.0	21,275	12.9
	13-year change >>	25.6	8,228	1.2
	Mean annual >>	2.0	633	0.09
Crop-tree release in 2016	80	106.8	21,486	15.6
Crop-tree release in 2003	80	85.0	15,268	14.0
	13-year change >>	21.8	6,218	1.7
	Mean annual >>	1.7	478	0.13

Lower-density crop-tree release

In the second field study, data was collected from fall 1991 to fall 2011 from three plots treated with lower-density crop-tree release (Table 6). The stand is located on a deep, sandy outwash site and was treated at age 28. The post treatment stand contained about 100 stems per acre. After 20 growing seasons, the average basal area increased from 69.3 to 109.0 square feet per acre. The mean annual basal area growth was 1.98 square feet per acre and ranged from 1.72 to 2.37 depending on the plot. The plot with the greatest basal area growth happened to be the plot with the fewest number of stems per acre (80 trees per acre). Quadratic mean stand diameter changed from 11.3 inches in 1991 to 14.9 inches in 2011, an increase of 3.6 inches or 1.8 inches per decade. Mean annual diameter growth was 0.18 inches per stem. In 20 more years with sustained growth, these stems could average 18.5-inches dbh and could be ready for a final harvest at age 68 years.

Table 6.—Lower-density crop-tree release. Basal area in square feet per acre and trees per acre.

Plot	BA 1991	BA 2011	Mean annual	Trees per acre
1	79.6	113.9	1.72	100
2	52.0	99.4	2.37	80
3	76.3	113.6	1.86	120
Mean per acre	69.3	109.0	1.98	

This study shows the importance of choosing the highest quality and most vigorous stems to release in intermediate treatments regardless of diameter.

Though individual trees performed differently, we found no clear distinction between larger and smaller dbh stems with respect to diameter or basal area growth. Some trees were able to add 6 inches of diameter over 20 years while other stems of approximately the same diameter added less than 3 inches. This study shows the importance of choosing the highest quality and most vigorous stems to release in intermediate treatments regardless of diameter. Some of the best performers were released on three to four sides of their crown showing the importance of paying attention to spacing of good quality stems in thinning operations. Larger stems may not be the best competitors within a stand and may not show the greatest promise for financial returns. Harvesting larger stems can often bring early income to a landowner and help cover the carrying costs of the stand while it matures.

Economic implications

Economics are one of several reasons for owning land and growing trees. Rate of return is one means of assessing the financial return. Where V_2 is the later value or volume and V_1 is the previous value or volume and n is the number of years between, the following equation calculates a basic rate of return:

$$\sqrt[n]{\frac{V_2}{V_1}} - 1$$

By using volume in our example, we ignore value-increase from improvements in grade. For pruned trees it may be prudent to carry growing stock longer than suggested by our example.

In the crop-tree release example, the plots represented 21,486 board feet at the conclusion of the 13-year growth period and 15,268 at the beginning. Substituting these numbers into the equation gives a rate of return of:

$$\sqrt[13]{\frac{21{,}486}{15{,}268}} - 1 = 0.0266 \text{ } or \text{ } 2.66\%$$

More complex calculations can reflect the compounding costs and revenues from a forest; however, the equation shown here is a nice start to evaluating how well a pine stand is growing.

Although the value-increase from increased grade can be modest in the case of white pine stumpage, it can be appreciable for trees with clear boles. By using volume in our example, we ignore value increase from improvements in grade.

For pruned trees it may be prudent to carry growing stock longer than suggested by our example.

A pine stand earning a rate of return less than other available investments can be a good candidate for additional thinning or regeneration cutting. The crop-tree-release stand above was earning only 2.66 percent although it has been well managed. The B-line stand had an even lower rate of return. As trees get larger they must grow even faster in order to maintain a reasonable rate of return. A pine stand growing 1,000 board feet per acre each year sounds like a good investment, but how many board feet of timber is locked up in the stand to produce this volume? Consider an investment that returns $10,000 per year. If the initial amount invested is only $50,000, this may be a very good return from that investment. If the initial amount is $5,000,000 it may be a poor investment. The same is often true for timber. Economics is one consideration, when determining how long to maintain a stand before applying regeneration cutting.

The quality, vigor, and rate-of-return potential of the reserved and removed trees, as well as effects on regeneration, guide the technique chosen as well as individual tree choice.

Additional thoughts about B-line, crop tree and lower-density crop-tree thinning

Growth per acre is good under all three treatments showing there is a range of options. Table 7 summarizes key metrics of each thinning technique for a quick comparison. The quality, vigor, and rate-of-return potential of the reserved and removed trees, as well as effects on regeneration, guide the technique chosen as well as individual tree choice. Removing young high-quality-potential trees to achieve low-density conditions is questionable, while a low-density treatment in stands with limited, but vigorous, high-quality-potential pine can produce favorable tree and stand development, as well as a desirable understory. Consider pruning with low-density pine, especially. Certain health risks such as *Caliciopsis* canker, white pine bast scale, red rot and needle damage lessen with the low-density option (Livingston et al. 2019).

Table 7.—Comparing results from Mast Yard State Forest B-line, crop-tree, and lower-density crop-tree thinning studies.

Treatment (number of plots)	Post-cut basal area (square feet/acre)	Quadratic mean diameter (inches)	Annual basal area growth (square feet/acre)	Annual dbh growth (inches)	Annual board foot growth (board feet)
B-line (1)	137	12.9	2.0	0.09	633
Crop-tree (1)	85	14.0	1.7	0.13	478
Lower-density (3)	69	11.3	1.98	0.18 – 0.20	Approx. 600

Grades and Values

Eastern white pine log grades and prices vary considerably across New England—grades and prices are set by mills based on expected lumber volume and value yields. Each mill develops their own log grade specifications using expected yields of lumber in NELMA (Northeastern Lumber Manufacturers Association) white pine lumber grades. There is not a uniformly used log-grading system and knowing the log market is necessary when timber is sold to maximize income.

Silvicultural actions that minimize black knots, eliminate weevil damage, and minimize pitch pockets and rot from mechanical injury increase tree- and log-value. Actions that maintain vigor and fast growth allow trees to build clear wood.

Predicting the value of a tree at harvest 20, 30 or 40 years in the future is difficult. However, there are certain attributes of log diameter, length, and defect that historically correlate with value. Promoting these attributes is often a goal underlying silvicultural actions and tree selection. Larger log diameter (measured at the small end and inside the bark) is preferred up to a certain point. Longer logs are preferred and mills often pay premium prices for longer logs (i.e., 12, 14, 16 feet). Fewer and smaller knots increase grade and price. All else being equal, black knots, reduce grade and price more than red knots.

The outer shell of pine logs will either yield the highest or the lowest grades depending on the presence or absence of dead branches (i.e., black knots). With white pine, generally, grades slowly improve towards the center of the tree as the knots turn from black to red and reduce in size (Quigley 1999).

Silvicultural actions that minimize black knots, eliminate weevil damage, and minimize pitch pockets and rot from mechanical injury increase tree- and log-value. Actions that maintain vigor and fast growth allow trees to build clear wood—a tree needs to grow 5 inches in diameter to overgrow any current defect and produce clear wood (Quigley 1999). For certain markets, tight red knots—those produced from live branches—are preferred. Coupled with the pruning of lower branches, low-density management improves grade by helping to maintain red knots through high live-crown ratios (Germain et al. 2016).

Though pruning produces clear wood when trees are given adequate space and time to grow, sawmills may be skeptical that enough clear wood developed on the trees to warrant paying a premium for the logs (Smith 2003). To see a return on those silviculture investments, evaluating the costs associated with precommercial treatments and documenting when pruning and thinning occurred is prudent.

Damaging Agents

Thorough reviews of white pine insects and diseases are found in Ostrander (1971) and Livingston et al. (2019). Here we focus on the silvicultural challenges these damaging agents pose.

White pine weevil damage produces stem crooks or forks—both serious defects. Maintaining light shade through partial harvests or small group and patch openings can limit weevil damage. When the stems reach two logs (i.e., 32 feet plus) or more in height the shade can be removed.

Figure 8.–Seeping resin from red rot associated with a branch stub. Photo by I. Munck, U.S. Forest Service (Livingston et al. 2019).

Red rot (Figure 8), although it does not kill the tree, causes serious degrade and is usually more common in older trees. Also known as red-ring rot because of the pattern of rot it causes in the tree bole, decay progresses slowly from reddish staining in the bole, eventually developing into rot. It originates from bole damage or weevil attacks in younger trees.

The cause of white pine decline (Livingston et al. 2005) is uncertain, but has been attributed to the effects of drought on shallow-rooted pine growing on agricultural soils with a "plow-pan"—the shallow, firm soil-layer caused by repeated plowing and cultivation (Livingston and Kenefic 2018).

Needle blights and dieback, including White Pine Needle Damage (WPND) from several pathogens, have become common in recent years with some impact on growth and mortality. Removal of severely affected trees is a partial solution as well as maintaining rapid growth. Low-density thinning is an approach to reduce white pine health risks (Livingston et al. 2019). McIntire et al. (2018) demonstrated an early response of foliar pathogens to thinning in white pine. Although effects were strongest with low-density thinning, even conventional B-line thinning had an impact.

Caliciopsis canker caused by a native fungus is common and widespread. This disease is not lethal to mature or older trees, but can degrade the quality of the wood products and kill regeneration. *Caliciopsis* is most frequent in poletimber, on outwash sands and gravel (see group IC in Appendix A), and in dense stands. (Munck et al. 2016). Maintaining moderate to low stand densities helps prevent damage by the *Caliciopsis* canker.

Maintaining moderate to low stand densities helps prevent white pine decline or damage by the *Caliciopsis* canker.

White pine blister rust was once the focus of much control. Although still present, the incidence is low enough not to be a significant factor in most white pine stands today.

Maintain fast-growing trees with well-developed live crowns to foster health and quality in white pine. Discourage excessive dead branching by early pruning or, where possible, by encouraging natural pruning by maintaining a dense lower crown-class layer—hemlock especially—until it is time for regeneration.

PRESCRIPTIONS

The first step is to classify groups, patches, or entire stands as ready for regeneration, intermediate, or precommercial.

- Ready for regeneration: Regard stands, groups, or patches as mature when over 50 percent of the stems are at least 18- to 22-inches dbh especially if there is a component of clear, high-quality trees. Otherwise, 16 to 20 inches (or less if defect is high) is a reasonable goal.
- Intermediate: These are stands and groups averaging about 10 to 16 inches where there is opportunity to harvest small sawlogs and low-grade when thinning. Pruning is not a good option in the larger trees within this class.
- Precommercial: Most stems are 6- to 8-inches dbh or less.

Ready for Regeneration

Areas are ready for a regeneration harvest where there is a desirable understory of pine, oak and other species at least 1- to 2-feet tall. The stands, groups, or patches are ready for a release by removing about half the basal area (a rough, approximate estimate) with minimal damage to the understory. Lower residual basal areas allow for less damage on the next entry. If past practice indicates no threat from the weevil, and the pine-oak regeneration is well-established (perhaps 2- to 4-feet tall), all the basal area may be removed.

We use the terms "groups" and "patches" to suggest small and larger openings are intermingled in the same stand to reflect actual stand conditions. Implementing group-selection should not result in equally spaced, one-size-openings.

Where the understory is undesirable or lacking in pine or oak, a shelterwood harvest should remove about a third of the basal area including the understory and midstory on snow-free ground to encourage a more valuable regeneration mix and provide for ground disturbance. Time this operation after a pine or oak seedfall. Initially, higher basal areas of 100 to 130 square feet in pure pine, or 80 to 100 square feet per acre in mixed stands will limit invasion by less desirable species. Lower residual basal areas of 30 to 60 square feet should work after the regeneration is well-established—it is important to maintain height growth of the seedlings. (Check the stocking options in Figure 7). The response will probably vary by site—pine-oak will be more competitive on the drier, sandier soils while northern hardwoods (beech especially) will be competitive on better soils. Invasives may be a problem; see the section on non-native invasive and native nuisance plants.

Snow damage to young white pine is one concern in these regenerating stands. The damage seems less in heavily stocked stands of regeneration and in mixed understories with a component of oak and other hardwoods. A light overstory basal area will tend to limit both snow and weevil damage (if present in the area). Complete removal is feasible when the white pine is beyond the weevil-damage-stage (two logs or 32 feet plus in total height).

Intermediate

Stands, groups and patches averaging about 10- to 16-inches dbh will support a commercial thinning if stocked heavily enough. Thinning to basal areas of 100 to 130 square feet per acre in pure stands or 80 to 100 square feet in mixed stands, with ground disturbance, will begin the regeneration process and allow for adequate growth per tree and per acre on the better stems. At this stage, the larger-diameter stems are beyond the point where pruning is advisable. However, consider pruning coupled with low-density thinning in the smaller-diameter stands. Maintaining moderate to low stand densities helps prevent white pine decline or damage by the *Caliciopsis* canker.

Though the larger-diameter stands are moving beyond the optimum stage for the initiation of low-density management, continuation of a previously initiated low-density regime suggests a thinning to roughly the managed C-line or below on the stocking chart (Figure 7). Where needed to remove poor-quality or diseased stems, residual basal areas of 50 to 60 square feet per acre will produce good growth in basal area and tree diameter (Leak and Yamasaki 2013). The stands will begin to regenerate profusely, so it is advisable to remove or destroy unwanted understory stems, although understory hemlock can foster natural pruning and provide valuable winter habitat for snowshoe hare and other mammals. Repeat thinnings at about 10- to 15-year intervals using careful layout and access to minimize damage to the advance regeneration.

For precommercial stands, where there are 50 to 75 stems per acre with quality potential, crop-tree thin and prune to one log, (i.e., 16 feet). The crop-tree approach, freeing the crowns on all sides, probably is most cost-effective as compared with area-wide thinning.

Precommercial

Unless extremely poor quality throughout, stands and groups, up to about 6- to 8-inches dbh, are not generally ready for harvest. If harvested, maintain a nearby seed-source to regenerate the heavily disturbed site. Where there are 50 to 75 stems per acre with quality potential, crop-tree thin and prune to one log, (i.e., 16 feet). The crop-tree approach, freeing the crowns on all sides, probably is most cost-effective as compared with area-wide thinning. The thinning approaches a low-density regime as the residual basal area nears the managed C-line or even below and the stand will begin to regenerate. Low-density management should limit *Caliciopsis* canker—especially important on dry or shallow sites where this canker is most damaging.

WILDLIFE HABITAT CONSIDERATIONS

Around 170 vertebrate species use white pine stands, about ½ of the total number of terrestrial vertebrate species in New England (DeGraaf et al. 2006). Roughly 20 commonly occurring species such as northern redbelly snake, turkey vulture, bald eagle, northern saw-whet owl, pileated woodpecker, blue-headed vireo, pine warbler, chipping sparrow, snowshoe hare, red squirrel, and southern red-backed vole use stands with significant white pine components which provide preferred breeding, feeding or winter-use habitats (Appendix B). Pine, oak-pine, and hemlock-pine stands offer a considerable array of foraging and cover habitat features that both vertebrate and invertebrate communities use. White pine also occurs as an important component of northern hardwoods (Leak et al. 2014).

Pine Seed

Good white pine seed years can be infrequent, every three to five years (Wendel and Smith 1990), and at the Massabesic Experimental Forest, York County, ME, the time between good seed crops can be 10 years, often due to considerable cone damage by the white-pine cone beetle (Graber 1964). Local collection of white pine seed in southwestern Maine yielded 17,700 to 24,000 seeds per pound with seed viabilities ranging from 87.5 to 99.5 percent (Graber 1968).

Small mammals well-known for seeking out and consuming white pine seeds in New England include the white-footed mouse and southern red-backed vole (Abbott 1961; Graber 1969; and McCracken et al. 1999), as well as others such as the red squirrel, northern flying squirrel, and deer mouse (Martell 1979; Wells-Gosling and Heaney 1984; and DeGraaf and Yamasaki 2001).

Around 170 vertebrate species use white pine stands, about ½ of the total number of terrestrial vertebrate species in New England (DeGraaf et al. 2006).

Well-known avian consumers of white pine seed include black-capped chickadee, red-breasted nuthatch, pine warbler, pine siskin, evening grosbeak; and especially where white pine occurs in northern conifer stands, pine grosbeak and red- and white-winged crossbills (DeGraaf and Yamasaki 2001).

Browse

Porcupines are well-known for consuming the inner cambium and bark of white pine and hemlock while sitting high up in the live canopy during winter (Griesemer et al. 1998). Numerous white pine and hemlock clipped branch tips, lying on the snow often indicate recent porcupine foraging activity in an area.

White-tailed deer can consume small amounts of white pine shoots and needle bundles in winter (Crawford 1982; Ludewig and Bowyer 1985) but white pine is not considered much of a deer food. Kittredge and Ashton (1995) studied browsing impacts to mixed forest regeneration in Connecticut with deer densities around 23 deer per square mile and found mean percentages of deer-browsed small white pine seedlings ranged from 12 to 36 percent; less browsing than was found on comparable hemlock and black birch seedlings, 52 to 58 percent and 36 to 53 percent respectively. On landscapes with moderate- to high-browse impacts (see McWilliams et al. 2018) browsing on white pine can be considerably greater; require using a variety of strategies to protect seedlings (Ward and Mervosh 2008; Ward et al. 2000); and be an indicator of poor range conditions.

White pine buds and young needle bundles are sought after as forage by spruce grouse and pine grosbeak (DeGraaf and Yamasaki 2001).

Early Successional Habitat

Silvicultural treatments to develop or tend natural white pine-oak-red maple stands often involve shelterwood applications and crown thinnings as well as group selection and smaller clearcuts (Lancaster and Leak 1978; Seymour and Smith 1987; Seymour 2007; Leak et al. 2017). These types of treatments can also create ephemeral early successional habitat needed by birds using young forests of different types as well (Costello et al. 2000; Trani et al. 2001; Thompson and DeGraaf 2001; DeGraaf and Yamasaki 2003; Yamasaki et al. 2014).

In southern New England at the Yale-Myers Forest (CT), changes in breeding bird abundance and species composition following shelterwood harvests and crown thinnings in oak-hardwoods have been followed by Goodale et al. (2009) and more recently by Duguid et al. (2016). Shelterwood stand conditions following treatment produced higher average species richness and total birds than unmanaged forest (Goodale et al. 2009). Songbird use of thinned stands was intermediate between shelterwood and unmanaged conditions.

Silvicultural treatments to develop or tend natural white pine-oak-red maple stands often involve shelterwood applications, crown thinnings, group selection or smaller clearcuts which also create ephemeral early successional habitat needed by birds using young forests.

Ongoing observations of breeding bird abundance and species composition in white pine-red oak-red maple patch cuts, group selection, shelterwood, and low-density thinning (Figure 9) at the Massabesic Experimental Forest (Yamasaki and Costello, unpublished data) show similar avian patterns of occurrence to the Yale-Myers Forest studies.

Duguid et al. (2016) found that younger early successional regenerating stands (less than 12 years since shelterwood treatment) had higher avian abundance than older regenerating stands (13 to 22 years since shelterwood treatment) and mature stands (80 to 100 years old). Species richness was greater in regenerating shelterwoods than mature stands as well because of the remaining overstory canopy, residual basal area, and the growth and density of the resulting regeneration. Early successional birds (e.g., gray catbird, chestnut-sided warbler, indigo bunting, prairie warbler, common yellowthroat, and song sparrow) were confined to the younger early successional regenerating stands (less than 12 years old).

Late-successional birds (e.g., hermit thrush and ovenbird) were present in regenerating stands (13 to 22 years old) in similar numbers seen in mature stands, most likely because of the dense regeneration created by the shelterwood treatments.

Additionally, as the dense, mixed pine-oak-red maple-hemlock regeneration develops with time, these stand conditions become more interesting habitat for snowshoe hare and bobcat as well. Encouraging patches of young hemlock and other conifers with live branches near the ground to this mix of young regeneration increases the seasonal value to both hare and the medium-sized carnivores that forage upon them.

Figure 9.–Low-density thinning at the Massabesic Experimental Forest

Insects as Forage

Prey size and abundance, and the detectability of prey on various foliar substrates shape the availability of food items for insectivorous birds (Holmes and Schultz 1988). Defoliating lepidopteran irruptions occur with relatively few species, and demonstrate a geographic and temporal patchiness across forest landscapes when they occur (Holmes 1990). Bird community foraging has a minimal effect on irruptive prey populations when prey densities are high (Holmes 1990; Crawford and Jennings 1989). The impact of avian predation is relatively much greater when insect populations are present at low densities (Holmes 1990; Crawford and Jennings 1989). Additionally, the hairiness of some lepidopteran larvae can deter some avian predation activity.

Gypsy moth defoliation can occur on white pine and hemlock during severe outbreaks, especially where growing in mixed stands with oak. Older larval caterpillars will consume pine and hemlock needles after defoliating nearby oaks and other hardwoods. Both black-billed and yellow-billed cuckoos are considered "hairy" caterpillar specialists on gypsy moth larvae (Smith 1985); and local irruptions of cuckoo populations track with gypsy moth outbreaks (Barber et al. 2008). Cooper and Smith (1995) observed black-capped chickadees, white-breasted nuthatches, and blue jays among others foraging on gypsy moth egg masses in experimental feeding trials. Other species (e.g., gray catbird, eastern towhee, American robin) will opportunistically forage on gypsy moth larvae (Smith and Lautenschlager 1981; Smith 1985). Species such as black-throated green warbler, American redstart, ovenbird, and red-eyed vireo took younger gypsy moth larvae in experimental foraging tests but usually consumed any "hairless" larvae when offered (Whelan et al. 1989).

Small mammals, especially white-footed mice, northern short-tailed shrew, masked and smoky shrews are the principal mammalian predators of gypsy moth pupae (Smith and Lautenschlager 1981).

Carpenter ants, often found in decaying portions of larger-diameter deciduous and coniferous species (Holloway et al. 2007; Nappi et al. 2015) including white pine, are routinely excavated by pileated woodpeckers.

Ground-foraging birds such as veery and ovenbird, consume a broad range of insect taxa as well (e.g., lepidoptopterans, hymenopteran, coleopterans, and dipterans) in northern hardwoods (Holmes and Robinson 1988) and probably in oak-pine as well. White pine weevil larvae and pupae are preyed upon by chipping sparrows (Dixon and Houseweart 1982).

Heron Colonies

Great blue herons can nest singly or in colonies (rookeries), in or near wetlands, estuaries, lake and river riparian areas, and beaver ponds (Gibbs 1991; Elkins and Swift 1994), often adjacent to white pine stands and hardwood stands mixed with white pine. Rookery site-use can be short term or for longer intervals. Where white pine occur on the edge of beaver ponds, wetlands and flowages, great blue herons often build nests in the taller white pine trees. Nesting great blue herons can be very sensitive to human activity during the breeding season. *Good Forestry in the Granite State* (Bennett 2010) offers guidance on recommended practices to minimize the disturbance of active heron nesting colonies.

Nesting great blue herons can be very sensitive to human activity during the breeding season. *Good Forestry in the Granite State* (Bennett 2010) offers guidance on recommended practices to minimize the disturbance of active heron nesting colonies.

Woodland Raptor Nesting Sites

Woodland hawk use of nest trees depends on finding secure places to place a nest and safely rear young (Newton 1979). In hardwoods, a main crotch with multiple limbs in the live crown presents a secure nesting opportunity. In softwoods, a fan of branches next to the tree bole or a broken top can present secure nesting sites for woodland raptors. Osprey will build nests on top of high snags that have lost their tops as well. White pine trees are often favored woodland raptor nesting sites within pine stands intermixed with oak, hemlock, and red maple, as well as in pine plantations. The accipiters—northern goshawk, Cooper's hawk, and sharp-shinned hawk—use different parts of the tree crown. Goshawks build stick nests lined with fresh conifer sprigs at the base of the live crown on branch fans against the tree bole. Sharp-shinned and Cooper's hawks tend to build their nests higher in the canopy (Trexel et al. 1999). Sharp-shinned hawks tend to nest in younger, dense forest stands; Cooper's hawks nest in more open forests. Buteos such as broad-winged hawk, and red-tailed and red-shouldered hawks use white pine as nest trees, as well as deciduous species. Merlins and great horned owls will often occupy nests constructed by other raptors.

Nesting tree dbh can be highly variable at times. We often think of raptor nest trees as sawtimber-sized stems but these trees can often be smaller.

Where these within-stand features are found can be important as well. Often, goshawk nest sites are adjacent to old woods roads, and small openings at low elevation. Broad-winged hawks often locate nests near old woods roads and openings. Red-shouldered hawks often locate their nest sites in moist areas near beaver ponds and wetlands.

The evidence of multiple nesting trees and old nests indicates multiple years of nesting activity, and perhaps a greater choice of potential nest trees than is found in other parts of the country where individual nest trees are used year after year. Bennett (2010) offers recommended practices to minimize disturbance to woodland raptor nesting sites in New Hampshire.

When working near known bald eagle nests, contact the nearest U.S. Fish and Wildlife Service field office to work out appropriate buffer size and configuration and timing of activities. Contact the appropriate state wildlife office where needed.

Bald Eagle Nesting Guidelines

Bald eagles nest in large supra-canopy trees, mostly white pine and some hardwoods, in areas usually a mile or less from lakes, rivers, and marine habitats that provide diverse foraging habitats, and where human disturbance is minimal (Livingston et al. 1990; Ostry et al. 2010; NH Fish & Game 2015). Nests are usually found in the upper live crown, supported by limbs capable of supporting large and heavy nests (5- to 6-feet in diameter; 2- to 4-feet deep; and weighing a ton or more). Supra-canopy white pine also provide perch sites for eagle fledglings waiting for parents bringing food; and adults watching for prey or intruders.

Designations of species rarity
T= state threatened
E= state endangered

Bald eagles were removed from the federal list of threatened and endangered species under the Endangered Species Act in August, 2007. Bald eagles remain protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668-668c), which prohibits the taking or disturbing of bald eagles and their nests (USDI Fish and Wildlife Service 2016). Bald eagles are currently a state-listed species in Vermont (E), Massachusetts (T), Connecticut (T), Rhode Island (E), and New York (T).

The National Bald Eagle Management Guidelines (USDI Fish and Wildlife Service 2007) help landowners, forestry operations, and forest recreation users avoid disturbing nesting bald eagles and their young. (See literature cited for web link).

Voluntary measures include (1) maintaining distance buffers from activities and nests, (2) maintaining forested or natural areas between activities and around nest trees, (3) and avoiding certain disturbances during the breeding season. These buffers act to minimize visual and auditory impacts near the nest sites. These can be seasonal activity buffers as well as physical distance buffers and can depend on the tolerance of the particular nesting eagle pair to human activities. When working near known bald eagle nests, contact the nearest U.S. Fish and Wildlife Service field office to work out appropriate buffer size and configuration and timing of activities. Contact the appropriate state wildlife office where needed.

Winter Bald Eagle Roosting Sites

Winter bald eagle roosting sites typically occur in proximity of known foraging areas where seasonal prey items such as ducks, geese, fish, and roadkill can predictably be found (Bennett 2010). Roosting sites are often near open water and up to ½ mile from water where ducks and geese seasonally congregate; and in uplands with predictable areas of roadkill. Winter night roosts can be consistently used by solitary birds or communally; provide protection from the wind and extreme cold; and need to be accessible to birds with a 6- to 7½-foot wing span that need substantial branches upon which to perch.

Stands of mature conifers, especially white pine, sometimes mixed with large hardwoods, offer sheltered roost sites where bald eagles can find shelter at night and in inclement weather. Roost trees are often found on easterly facing, steeper slopes that are out of the prevailing winds. As an aside, wild turkeys also selected mature white pine stands near water as winter roost sites in Rhode Island (Kilpatrick et al. 1988).

Considerable energy demands on wintering bald eagles means minimizing human activity near night roost sites and shoreline hunting perches from December through March. When working in the vicinity of known roost sites, contact the state nongame wildlife program for assistance in planning recreational and harvest activities.

Other Roosting and Cavity-Nesting Habitat—Bats, Brown Creepers and Other Cavity-Dwellers

Exfoliating plates of white pine bark (as well as other softwoods and hardwoods) provide a chance of covered roosting sites for *Myotis* bats (Sasse and Pekins 1996) in a range of dbh size-classes. Brown creepers use exfoliating bark plates on larger-diameter hardwood and softwood stems in mature forest stands (King and DeGraaf 2000; DeGraaf and Yamasaki 2001). Larger-diameter live and recently dead stems provide secure cavity nest and foraging sites (Gunn and Hagan 2000) for a range of woodpeckers such as downy and hairy woodpeckers, northern flickers, and pileated woodpeckers, as well as winter roost sites for arboreal mammals such as northern flying squirrel (M. Yamasaki, pers. comm.).

Hard Mast

Where oak and other hard mast producers intermix with white pine, the foraging opportunities for wood duck, ruffed grouse, wild turkey, eastern chipmunk, northern and southern flying squirrels, black bear and white-tailed deer among others can be improved with careful identification of abundant mast-producing trees and thinning operations that maintain abundant mast-producers (Healy 1997). See pages 31-33 in Leak et al. (2017) for hard mast information on oak.

Appendix A: Important forest soils groups for New Hampshire

New England soils are complex and highly variable due primarily to their glacial origins. Mapping by the Natural Resource Conservation Service (NRCS) recognizes these complex patterns. In New Hampshire, NRCS organized soils into a useful planning tool—Important Forest Soil Groups. The objective—a simplified yet accurate tool helping natural resource professionals and landowners evaluate the relative productivity of soils; better understand patterns of plant succession; and determine how soil and site interactions influence management decisions. The concepts apply beyond New Hampshire. Soils are grouped into six categories. In this document, we reference groups IA, IB and IC. See *Good Forestry in the Granite State* (Bennett 2010) for a complete treatment.

Group IA are the deeper, loamy, moderately well-drained and well-drained soils. Generally, these soils are more fertile and have the most favorable soil-moisture conditions. Successional trends are toward climax stands of shade-tolerant hardwoods such as sugar maple and beech. Early successional stands frequently contain a variety of hardwoods such as sugar maple, beech, red maple, yellow, gray, and white birch, aspen, white ash, and northern red oak in varying combinations with red and white spruce, balsam fir, hemlock, and white pine. The soils in this group are well-suited for growing high-quality hardwood veneer and sawtimber; especially, sugar maple, white ash, yellow birch, and northern red oak. Softwoods are usually less abundant and best managed as a minor component of predominantly hardwood stands. Hardwood competition is severe on these soils. Successful natural regeneration of softwoods and the establishment of softwood plantations requires intensive management.

Group IB are moderately well-drained and well-drained, sandy or loamy-over-sandy soils, and slightly less fertile than those in group IA. Soil moisture is adequate for good tree growth but may not be quite as abundant as in group IA. Successional trends and the trees common in early successional stands are similar to those in group IA. However, beech is usually more abundant on group IB and is the dominant species in climax stands. Group IB soils are suited for growing less-nutrient and moisture-demanding hardwoods such as white birch and northern red oak. Softwoods generally are scarce to moderately abundant and managed in groups or as part of a mixed stand. Hardwood competition is moderate to severe on these soils. Successful regeneration of softwoods and the establishment of softwood plantations depend on intensive management. The deeper, coarser-textured, and better-drained soils in this group are generally suitable for conversion to intensive softwood production.

Group IC soils are derived from glacial outwash sand and gravel. The soils are coarse textured and somewhat excessively drained to excessively drained and moderately well-drained. Soil moisture and fertility are adequate for good softwood growth but are limiting for hardwoods. Successional trends on these soils are toward stands of shade-tolerant softwoods, such as red spruce and hemlock. White pine, northern red oak, red maple, aspen, gray birch, and paper birch are common in early successional stands. These soils are well-suited for high quality softwood sawtimber, especially white pine, in nearly pure stands. Less site-demanding hardwoods such as northern red oak and white birch have fair to good growth on sites where soil moisture is more abundant. Hardwood competition is moderate to slight. With modest levels of management, white pine can be maintained and reproduced. Although chemical control of woody and herbaceous vegetation may be desirable in some situations, softwood production is possible without it.

Appendix B. Commonly occurring wildlife species with some preference for pine stands in New England (modified from DeGraaf et al. 2005, 2006).

Amphibians
Northern redback salamander (*Plethodon cinereus*)
Reptiles
Northern redbelly snake (*Storeria o. occipitomaculata*)
Eastern hognose snake (*Heterodon platirhinos*)
Eastern worm snake (*Carphophis a. amoenus*)
Northern black racer (*Coluber c. constrictor*)
Eastern ratsnake (*Pantherophis alleghaniensis*)
Birds
Turkey vulture (*Cathartes aura*)
Wood duck (*Aix sponsa*)
Bald eagle (*Haliaeetus leucocephalus*)
Sharp-shinned hawk (*Accipiter striatus*)
Cooper's hawk (*Accipiter cooperii*)
Northern goshawk (*Accipiter gentilis*)
Red-shouldered hawk (*Buteo lineatus*)
Broad-winged hawk (*Buteo platypterus*)
Red-tailed hawk (*Buteo jamaicensis*)
Ruffed grouse (*Bonasa umbellus*)
Wild turkey (*Meleagris gallopavo)*
Mourning dove (*Zenaida macroura*)
Black-billed cuckoo (*Coccyzus erythrophthalmus*)
Yellow-billed cuckoo (*Coccyzus americanus*)
Great horned owl (*Bubo virginianus*)
Barred owl (*Strix varia*)
Northern saw-whet owl (*Aegolius acadicus*)
Whip-poor-will (*Caprimulgus vociferous*)
Red-bellied woodpecker (*Melanerpes carolinus*)
Downy woodpecker (*Picoides pubescens*)
Northern flicker (*Colaptes auratus*)
Pileated woodpecker (*Dryocopus pileatus*)
Eastern wood-pewee (*Contopus virens*)
Least flycatcher (*Empidonax minimus*)
Yellow-throated vireo (*Vireo flavifrons*)
Blue-headed vireo (*Vireo solitarius*)
Blue jay (*Cyanocitta cristata*)
American crow (*Corvus brachyrhynchos*)
Common raven (*Corvus corax*)
Tufted titmouse (*Baeolophus bicolor*)
Red-breasted nuthatch (*Sitta canadensis*)
White-breasted nuthatch (*Sitta carolinensis*)
Brown creeper (*Certhia americana*)
Winter wren (*Troglodytes troglodytes*)
Blue-gray gnatcatcher (*Polioptila caerulea*)
Eastern bluebird (*Sialia sialis*)
Veery (*Catharus fuscescens*)
Hermit thrush (*Catharus guttatus*)
Wood thrush (*Hylocichla mustelina*)
Gray catbird (*Dumetella carolinensis*)
Brown thrasher (*Toxostoma rufum*)
Blue-winged warbler (*Vermivora cyanoptera*)
Chestnut-sided warbler (*Setophaga pensylvanica*)
Black-throated blue warbler (*Setophaga caerulescens*)
Yellow-rumped warbler (*Setophaga coronata*)
Blackburnian warbler (*Setophaga fusca*)
Pine warbler (*Setophaga pinus*)
Prairie warbler (*Setophaga discolor*)
Black-and-white warbler (*Mniotilta varia*)
American redstart (*Setophaga ruticilla*)
Ovenbird (*Seiurus aurocapilla*)
Common yellowthroat (*Geothlypis trichas*)
Canada warbler (*Cardellina canadensis*)
Scarlet tanager (*Piranga olivacea*)
Eastern towhee (*Pipilo erythrophthalmus*)
Chipping sparrow (*Spizella passerina*)
Rose-breasted grosbeak (*Pheucticus ludovicianus*)
Indigo bunting (*Passerina cyanea*)
American goldfinch (*Spinus tristis*)
Mammals
Virginia opossum (*Didelphis virginiana*)
Masked shrew (*Sorex cinereus*)
Northern short-tailed shrew (*Blarina brevicauda*)
Snowshoe hare (*Lepus americanus*)
Eastern chipmunk (*Tamias striatus*)
Gray squirrel (*Sciurus carolinensis*)
Red squirrel (*Tamiasciurus hudsonicus*)
Southern flying squirrel (*Glaucomys volans*)
Northern flying squirrel (*Glaucomys sabrinus*)
Deer mouse (*Peromyscus maniculatus*)
White-footed mouse (*Peromyscus leucopus*)
Southern red-backed vole (*Myodes gapperi*)
Red fox (*Vulpes vulpes*)
Black bear (*Ursus americanus*)
Raccoon (*Procyon lotor*)
Fisher (*Pekania pennanti*)
White-tailed deer (*Odocoileus virginianus*)

Appendix C. Scientific names of species mentioned in the text but not in Appendix B.

Plants—trees
Eastern hemlock (*Tsuga canadensis*)
Black birch (*Betula lenta*)
American beech (*Fagus grandifolia*)
White oak (*Quercu alba*)
Northern red oak (*Quercus rubra*)
Black oak (*Quercus velutina*)
Red maple (*Acer rubrum*)

Plants—shrubs and vines
Common buckthorn (*Rhamnus cathartica*)
Glossy buckthorn (*Frangula alnus*)
Oriental bittersweet (*Celastrus orbiculatus*)

Birds
Great blue heron (*Ardea herodias*)
Osprey (*Pandion haliaetus*)
Merlin (*Falco columbarius*)
Spruce grouse (*Falcipennis canadensis*)
Hairy woodpecker (*Leuconotopicus villosus*)
Black-capped chickadee (*Poecile atricapillus*)
Red-eyed vireo (*Vireo olivaceus*)
American robin (*Turdus migratorius*)
Black-throated green warbler (*Setophaga virens*)
Song sparrow (*Melospiza melodia*)
Pine grosbeak (*Pinicola enucleator*)
Red-winged crossbill (*Loxia curvirostra*)
White-winged crossbill (*Loxia leucoptera*)
Pine siskin (*Carduelis pinus*)
Evening grosbeak (*Coccothraustes vespertinus*)

Mammals
Smoky shrew (*Sorex fumeus*)
Bats (*Myotis* sp.)
Beaver (*Castor canadensis*)
Porcupine (*Erethizon dorsatum*)
Bobcat (*Lynx rufus*)

Insects
White pine bast scale (*Matsucoccus macrocicatrices*)
White pine cone beetle (*Conophthorus coniperda*)
White pine weevil (*Pissodes strobi*)
Gypsy moth (*Lymantria dispar*)
Carpenter ant (*Camponotus sp.*)

Fungal Pathogens
Caliciopsis canker (*Caliciopsis pinea*)
White Pine Needle Damage (*Lecanosticta acicola*)
White Pine Needle Damage (*Septoriodides strobi*)
White Pine Needle Damage (*Bifusella linearis*)
White Pine Needle Damage (*Lophophacidium dooksii*)
Red rot (*Porodaedalea pini*)

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The mission of the Natural Resources Network is to enhance interaction among the natural resource research, teaching, and outreach communities in New Hampshire by providing an ongoing mechanism for identifying, addressing and communicating natural resource issues.

Natural resource professionals are working toward improved ways to conserve and use the natural resources of New Hampshire. The Natural Resource Network was formed to improve the interaction among researchers and those who provide outreach education in many kinds of programs. Teachers, outreach professionals and resource managers can bring research-based education to diverse audiences. At the same time, those audiences, or consumers, identify issues and needs for educational programs which can be addressed by controlled research. Well informed and knowledgeable professionals, free-flowing exchange of information, an advantageous and gratifying professional environment, and natural resource planning are goals of the Natural Resource Network.