Natural Resource Network

Connecting Research, Teaching and Outreach

"Getting the Regeneration You Want" Workshop Proceedings

Granite State Division Society of American Foresters
UNH Cooperative Extension
NH Division of Forests and Lands
October 27 and 31, 2000

UNH Cooperative Extension
55 College Road, 108 Pettee Hall, Durham, NH 03824

Forest regeneration was cited in the 1999 forester education survey as one of the top topics of interest. These proceedings were prepared as a supplement to workshops entitled **"Getting the Regeneration You Want"** held in West Milan on October 27 and Kingston on October 31, 2000. Each session provided an overview of the regeneration picture with a spruce-fir emphasis in the north country and a red oak emphasis in the south. Papers submitted were not peer-reviewed or edited. They were compiled by Karen P. Bennett, Extension Specialist in Forest Resources. Readers who didn't attend the workshop are encouraged to contact authors directly for clarifications. Workshop attendees received additional supplemental materials.

NORTH COUNTRY AGENDA
October 27, 2000
West Milan Town Hall

The State of the State's Regeneration- Worthen Muzzey, NH Division of Forests & Lands

Regen 101- Bill Leak, USDA-Forest Service and Ken Desmarais, NH Division of Forests & Lands

Wildlife Effects- Mariko Yamasaki, USDA-Forest Service

Logging System Effects- Andy Egan, University of Maine

Spruce–Fir Specific: What Works- Bob Frank, USDA Forest Service, Retired

Field Trip to the Enman Tree Farm and Thirteen Mile Woods, Mead Corporation

KINGSTON AGENDA
October 31, 2000
Kingston Town Hall

The State of the State's Regeneration- Worthen Muzzey, NH Division of Forests & Lands

Regen 101- Bill Leak, USDA-Forest Service and Ken Desmarais, NH Division of Forests & Lands

Wildlife Effects- Mariko Yamasaki, USDA-Forest Service

Logging System Effects- Ken Desmarais

Oak Specific: What Works- Steve Drawbridge, MDC Forester and Ken Desmarais

Field Trip to the Kingston State Park and the J.D. Eaton State Forest

The State of the State's Regeneration

Review of FIA Seedling & Sapling Data

by Worthen Muzzey, NH Division of Forests and Lands

Stand Size Distribution
1950 - 1997

	Sawtimber	Poletimber	Seedling/Sapling
1997	52%	39%	9%
1983	42%	53%	5%
1973	38%	44%	18%
1960	36%	47%	14%
1950	39%	37%	11%

Seedling Abundance

- 1. Balsam Fir 3,134,909,000
- 2. Sugar Maple 2,512,525,000
- 3. Red Maple 2,470,614,000
- 4. Beech 1,683,458,000
- 5 Yellow Birch 1,227,134,000
- 6. Spruce 871,809,000
- 7. Paper Birch 864,817,000
- 8. White Pine 828,771,000
- 9. Red Oak 714,222,000
- 10. Hemlock 594,291,000

Sapling Abundance

• 1.	Balsam Fir	442,424,000
• 2.	Red Maple	394,474,000
• 3.	Beech	224,770,000
• 4.	Yellow Birch	167,682,000
• 5.	Sugar Maple	166,378,000
• 6.	Hemlock	162,420,000
• 7.	Spruce	140,338,000
• 8.	White Pine	123,972,000
• 9.	Paper Birch	104,134,000
• 10.	Red Oak	80,565,000

Pole & Sawtimber Abundance

• 1.	Red Maple	168,598,000
• 2.	White Pine	106,318,000
• 3.	Hemlock	87,035,000
• 4.	Balsam Fir	79,466,000
• 5.	Sugar Maple	66,884,000
• 6.	Paper Birch	66,831,000
• 7.	Red Oak	65,049,000
• 8.	Spruce	55,184,000
• 9.	Yellow Birch	50,824,000
• 10.	Beech	50,445,000

White/Red Pine Forest Type Group
Seedling/Sapling Abundance

• 1.	Red Maple	659,421,000	(879 stems/acre)
• 2.	Hemlock	326,783,000	(436 stems/acre)
• 3.	White Pine	319,745,000	(426 stems/acre)
• 4.	Red Oak	186,960,000	(249 stems/acre)
• 5.	White Ash	166,065,000	(221 stems/acre)
• 6.	Yellow Birch	153,138,000	(204 stems/acre)
• 7.	Paper Birch	152,465,000	(203 stems/acre)
• 8.	Black Cherry	134,239,000	(179 stems/acre)
• 9.	Beech	125,229,000	(167 stems/acre)
• 10.	Balsam Fir	90,408,000	(120 stems/acre)

Spruce/Fir Forest Type Group
Seedling/Sapling Abundance

1.	Balsam Fir	1,587,406,000	(3,871 stems/acre)
2.	Spruce	457,275,000	(1,115 stems/acre)
3.	Paper Birch	129,406,000	(316 stems/acre)
4.	Yellow Birch	107,706,000	(263 stems/acre)
5.	Red Maple	99,017,000	(241 stems/acre)
6.	Black Cherry	54,595,000	(133 stems/acre)

Oak/Pine Type Group
Seedling/Sapling Abundance

1.	Red Maple	123,737,000	(603 stems/acre)
2.	Red Oak	92,688,000	(452 stems/acre)
3.	Black Cherry	89,133,000	(434 stems/acre)
4.	White Pine	59,258,000	(289 stems/acre)
5.	Hemlock	56,452,000	(275 stems/acre)
6.	Beech	55,559,000	(271 stems/acre)
7.	White Ash	52,979,000	(258 stems/acre)
8.	Balsam Fir	42,780,000	(208 stems/acre)
9.	Sugar Maple	40,294,000	(196 stems/acre)
10.	White Oak	24,401,000	(119 stems/acre)

Oak/Hickory Type Group
Seedling/Sapling Abundance

1.	Red Maple	557,236,000	(933 stems/acre)
2.	White Pine	331,626,000	(555 stems/acre)
3.	Red Oak	225,048,000	(377 stems/acre)
4.	Beech	214,822,000	(360 stems/acre)
5.	Black Cherry	179,262,000	(300 stems/acre)
6.	Sugar Maple	143,391,000	(240 stems/acre)
7.	Balsam Fir	100,180,000	(168 stems/acre)
8.	Paper Birch	86,955,000	(146 stems/acre)
9.	Hemlock	71,119,000	(119 stems/acre)
10.	White Oak	59,565,000	(100 stems/acre)

REGENERATION BASICS: Regeneration Workshops 10/27 and 10/31 in N. and S. New Hampshire. By W.B. Leak.

A number of steps or factors are involved in the regeneration process (Overhead 1). I'll talk mostly about seed production, competing vegetation, seedbed conditions, and site. Most of the other topics will be covered by the other speakers.

<u>Seed</u>:

It's well-known that seed production varies greatly from year-to-year (Overhead 2). In northern hardwoods, you can count on fairly adequate seed at least half the time; beech is a little less reliable. Viable seed comprises about half the total crop. In really poor seed years, viability often is reduced. In birches, even a moderate seed year produces millions of seeds (Graber and Leak 191992).

Red oak seed production appears more variable and less reliable (Overhead 3) (Auchmoody et al 1993, Downs and McQuilkin 1944). In a 4-6-year period, probably there will be one good seed year. Intervening years may be moderate or very slim. There is great variation from location to location. Numbers of acorns range up to about 250 M/acre during the best years (as compared to millions of birch). Thinning to produce large-crowned trees increases the production per acre, and this holds true for pine and probably most species. White pine may produce 1.5-2 million viable seed per acre (Graber 1970). Good crops are said to occur every 3-5 years, however some locations (e.g. S. Maine) have experienced up to 10 years with minimal crops. Red spruce is listed as producing good crops every 3-8 years; not much information available on this species.

Some species stump sprout profically: red maple and red oak in particular. Others root-sprout, notable beech and aspen. In addition, some species are quite dependent on advanced regeneration – the presence of established seedlings prior to removing much or all of the overstory; these species include beech, sugar maple, red oak, tolerant softwoods, and to some extent, white pine. The purpose of harvesting techniques such as shelterwood cutting is to establish required advanced regeneration.

In general, because of variable seed production and predation, we are most concerned about seed production and timing of seed years in oak and pine.

<u>Competing Vegetation</u>

There have been some detailed studies in northern hardwoods on competing vegetation involving over 1500 milacres (Overhead 4) (Leak 1988). The results are mixed and somewhat inconclusive. Under partial cutting systems, the presence of hobblebush does significantly lower the stocking of commercial species. Milacres dominated by striped maple, however, support a range of commercial species similar to milacres with no weed species.

On clearcut areas, milacres dominated by weed species still support a range of other commercial species somewhat similar to milacres with no dominating weed species. Other studies have shown, however, that weed species (such as dense stands of pin cherry) will affect the stocking and growth rate of commercial stems.

Excess beech is a major concern, since observation shows that understories under partial cutting systems can become almost wholly dominated by beech. Overhead #5 shows percents of total basal area per dbh class in beech vs yellow birch-paper birch-white ash combined in an area that has been managed by group/patch selection for 60 years (Leak 1999). In larger size classes (areas not yet patch cut), up to 45% of the basal area is in beech (another 36% is hemlock and red maple). In the 6-9-inch classes, the percent of beech and YB-PB-WA are nearly the same at 20-25%; this is the effects of the group/patch cuts. Since much of the beech in these classes is in the uncut areas whereas all the YB-PB-WA is in the cutover areas, the proportion of valuable species will rise as more of the tract is harvested.

We are hearing more these days about the inhibiting effects of ferns (mainly hayscented and New York) on regeneration. Fern cover seems most prevalent on old fields where there is significant deer browsing. Most commercial species of regeneration seem to be inhibited in both numbers and growth. However, results from Pennsylvania indicate that birches (black and yellow) are perhaps less affected than other species. In Overhead #6, note that black cherry under the fern-fenced treatment (fenced for deer protection but with a heavy fern cover) showed poor height growth after a shelterwood removal cut. Birches, however, grew well on fenced plots with a heavy fern cover (Horsley and Marquis 1983). It appears that one way to deal with ferns is to attempt to regenerate birch through openings or clearcuts, maintenance of a seed source, and provision of some ground disturbance. We are trying to get some observations on this possibility in the New England area.

Striped maple can become a very dominant understory species in northern hardwoods on good sites. I don't believe it will complete inhibit other regeneration, but it no doubt limits both numbers and growth of better species. A series of shelterwood cuts were made ranging in residual crown cover from uncut (100%) to 0%; understory saplings were removed as well. Eight years later, sugar maple predominated over striped maple only in low density plots with crown covers of 20-40% or less. Under denser canopies, striped maple was more abundant (Tubbs and Lamson 1991).

<u>Scarification</u>:

Scarification to disturb litter layers and expose some mineral soil helps maintain moisture and mediate high temperatures. In addition, if done after seedfall, it helps bury seed so it will be less exposed to predation. Scarification also helps eliminate competing vegetation – an effect sometimes hard to separate from its influence on seedbed conditions. Overhead #8 shows some stocking characteristics of 3-year-old patch cuts as related to seedbed condition. Birch (PB and YB) certainly is more dominant and/or free-to-grow on skidroads or disturbed areas (some mineral soil exposed) (Marquis 1965).

Ideally, scarification should mix humus and mineral soil rather than expose large patches of mineral soil. The reason is (Overhead 9) that seedlings grow poorly in pure B- and C-horizon material as compared to the nutrient-rich humus (Hoyle 1965).

Since scarification has a positive effect with many species, it would seem that the effects of summer vs winter logging would be apparent. Overhead #10 shows that season of cut has less effect than we might suppose on the dominant commercial species per milacre 5 years after logging. Clearcuts had more birch, while shelterwoods had more sugar maple, but the overall differences between summer and winter harvests were small (Tubbs and Reid 1984). Because of these somewhat variable or inconclusive results, we don't urge special scarification operations in northern hardwoods – hoping that logging operations can be designed to achieve the desired results (for example, the use of strip cuts to remove undesirable understories and promote ground disturbance). However, it is still logical that winter operations will help protect advanced regeneration while summer/fall operations will provide more ground disturbance. For oak and pine, with their limited seed and high predation, specific scarification-disturbance-seed covering measures are advisable.

Site:

Keep an eye on site conditions when planning a regeneration operation. Overhead # 11 lists a range of site (habitat conditions) and the species that predominate on those sites (Leak 1982) . Sugar maple and ash are good options only on the better soils, especially those derived from nutrient-rich bedrock. Softwoods are the natural cover on soils that are drier, wetter, or shallower than average. Pine is a good choice on sandy/gravelly outwash, and with some additional effort can be reproduced on sandy till soils. Oak is common on outwash, but is probably less desirable than pine in terms of volume and quality. Sandy tills are likely oak sites, but with effort, we seem to be able to regenerate oak on better tills as well.

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REGENERATION

Flowering

Seed production

Seed losses

Germination and survival

Seedbeds, site prep

Competing vegetation

Light requirements

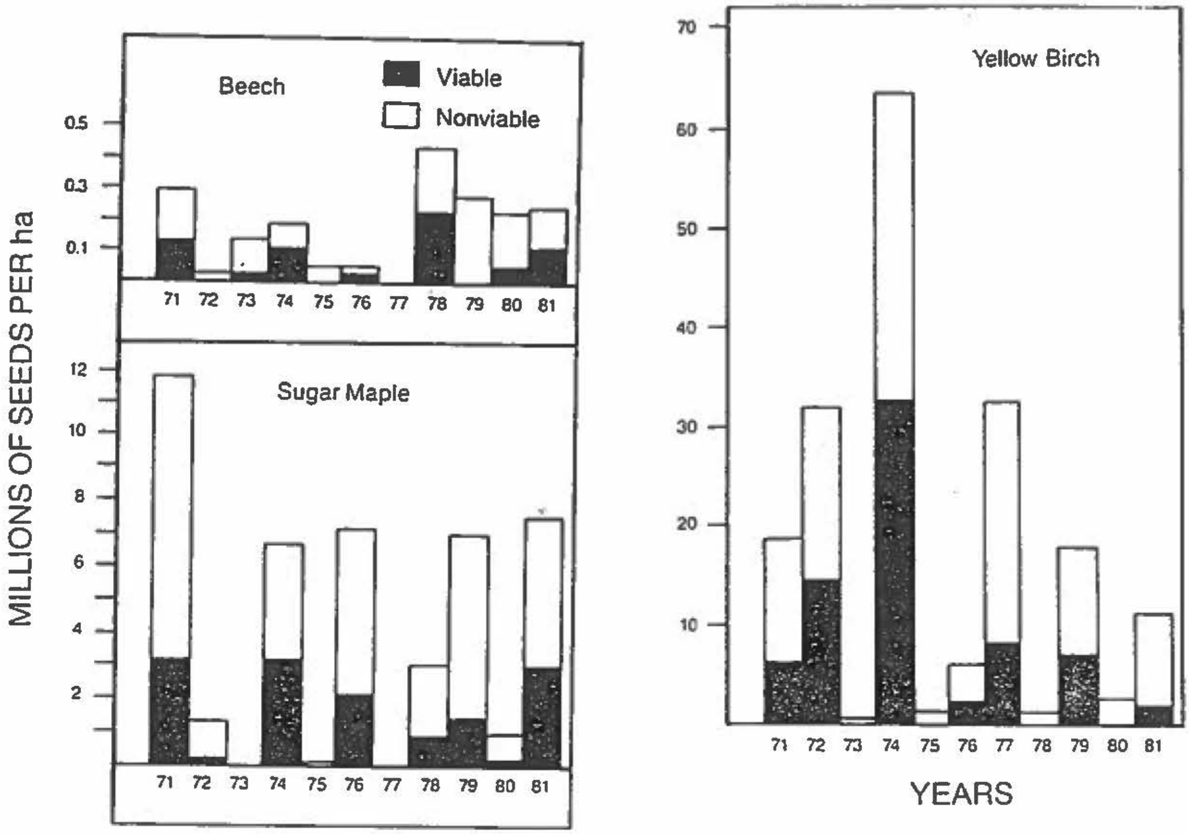
Establishment, growth

Vegetative reproduction

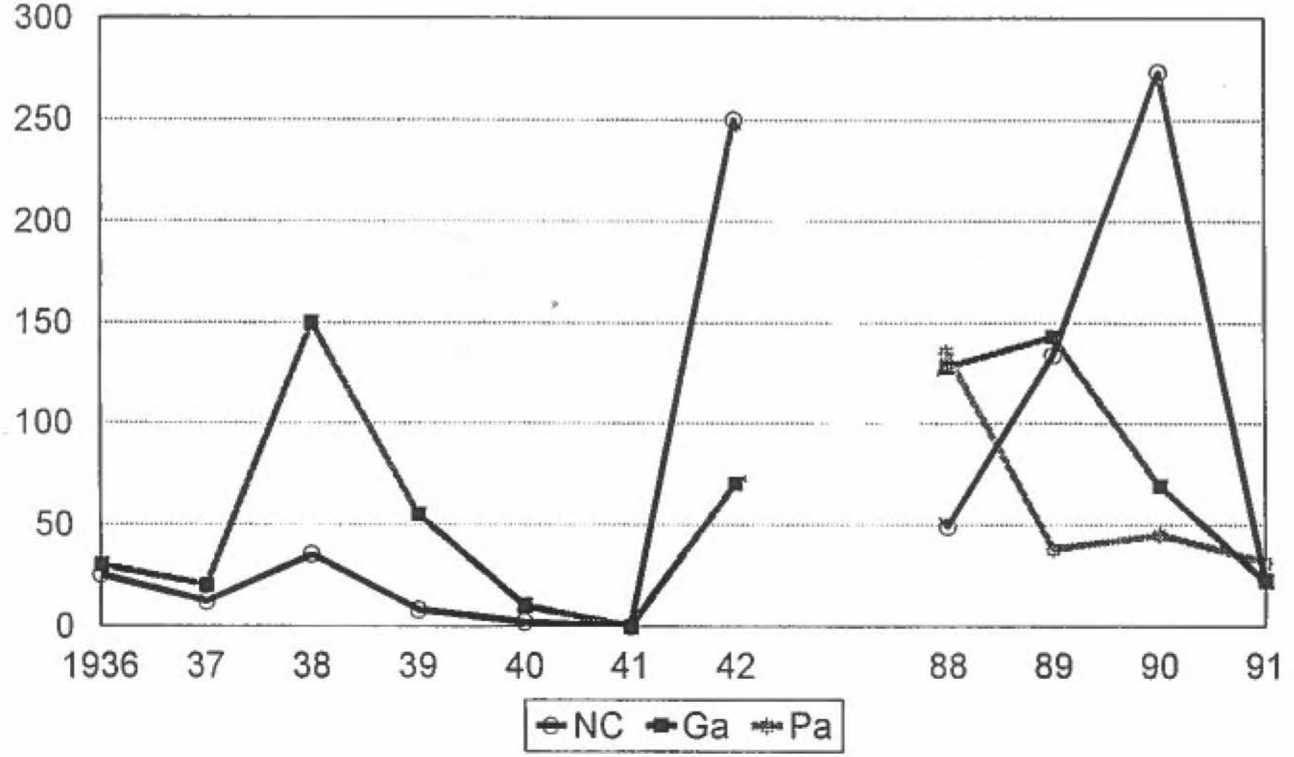
Site relationships

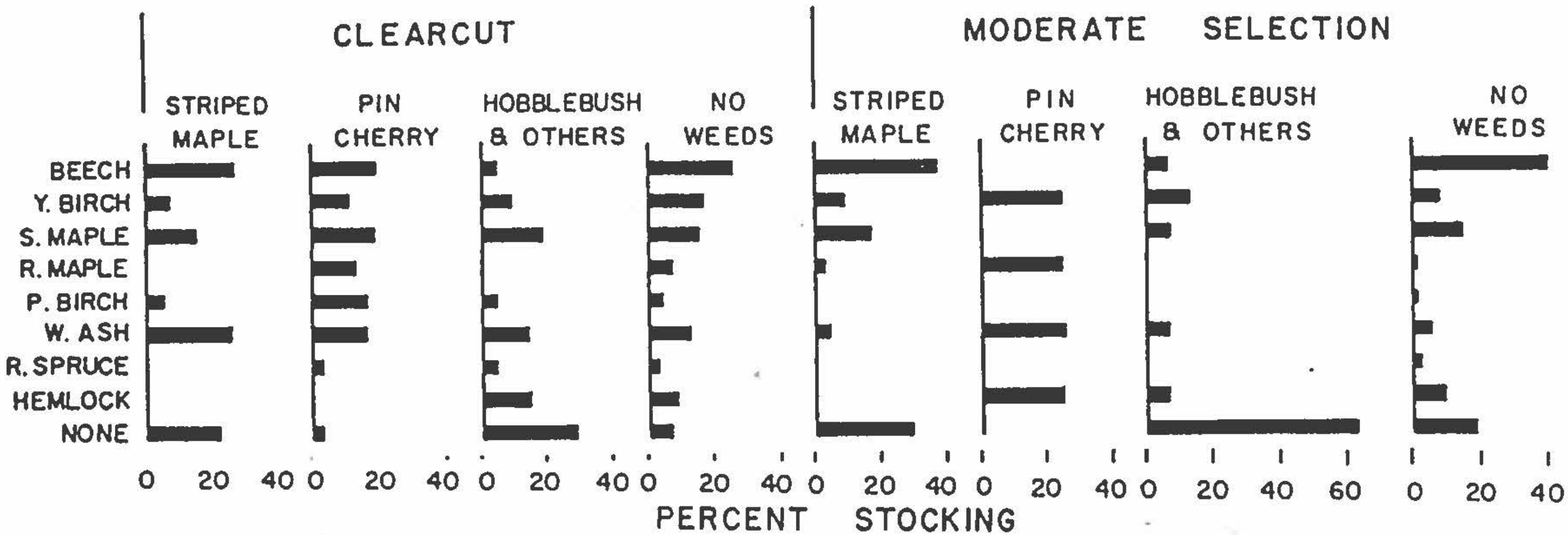
Regen. Sampling

Harvest methods


Beech
Viable
Nonviable
Sugar Maple
Yellow Birch
MILLIONS OF SEEDS PER ha
YEARS
71 72 73 74 75 76 77 78 79 80 81

Acorns (M) per acre by year -- several locations





[redacted] Percentage of stocking of the tallest commercial species on 0.001-ac plots dominated by weed species or no weeds 8 years after cutting by four methods.

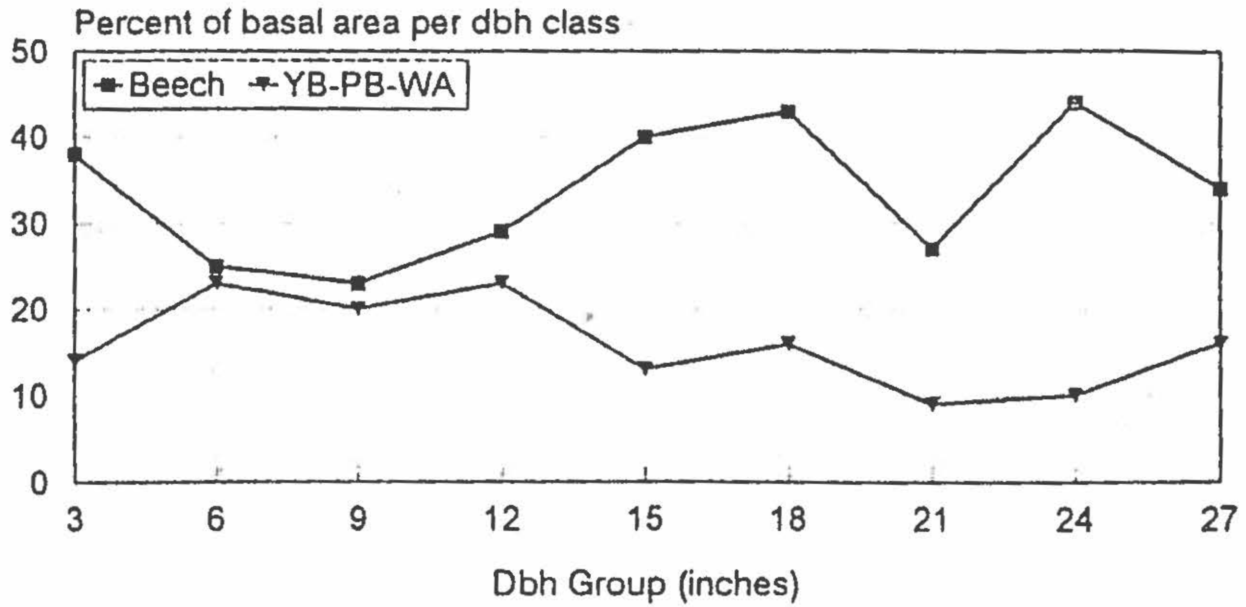


Figure [redacted]. Percent of basal area by dbh class (3 in. classes) in beech, as compared to yellow birch, paper birch, and white ash combined.

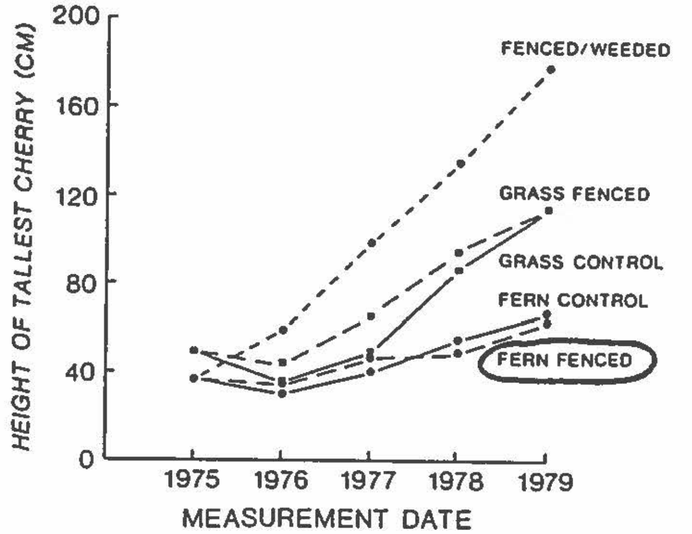


FIG. 1. Height of the tallest black cherry seedling over time on control, fenced, and fenced–weeded plots in a shelterwood removal cut stand.

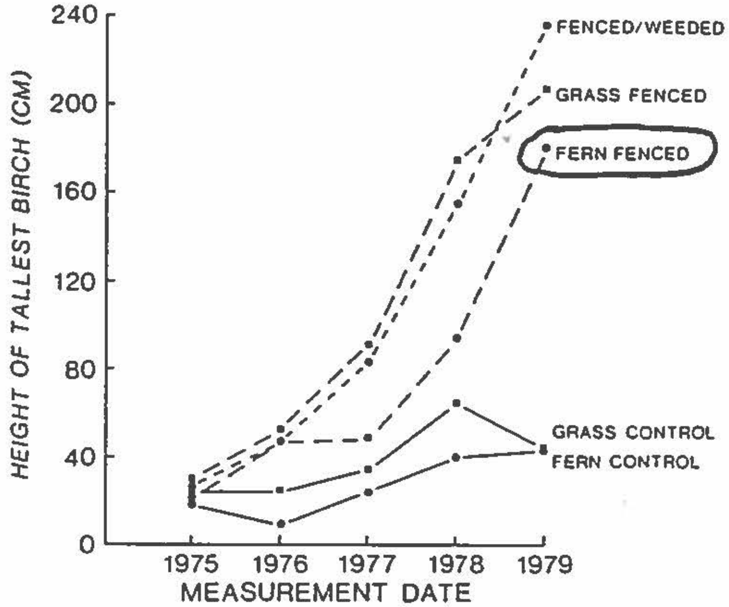


FIG.[redacted] Height of the tallest birch over time on control, fenced, and fenced–weeded plots in a shelterwood removal cut stand.

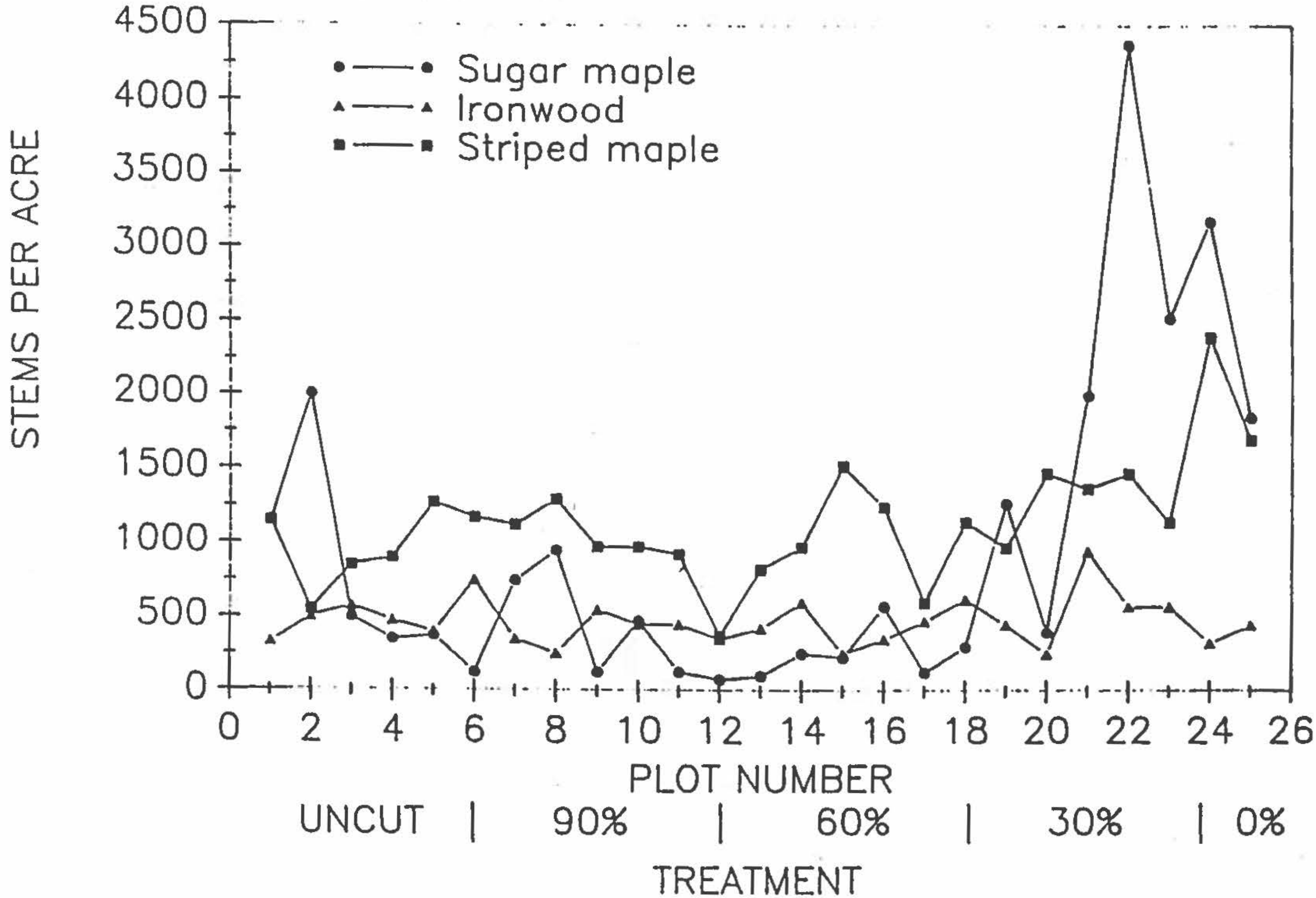


Fig. [redacted] Stems per acre, 4.5 ft tall to 1 in. dbh, in 1988, by species, canopy density, and plot number.

Table [illegible]—Stocking in 3-year-old patch cuttings, by seedbed condition, in percent of 1/4-milacres stocked

Condition	Any woody species	Dominant merchantable species	Dominant merchantable species of seedling origin	Dominant birch	Free-to-grow birch	Any birch
			COMPARTMENT 31			
Skidroad	100	39	22	18	35	91
Disturbed	100	37	22	5	12	95
Undisturbed	100	53	22	3	9	47
Slash	83	43	20	3	0	17
All seedbeds	99	46	22	9	16	60

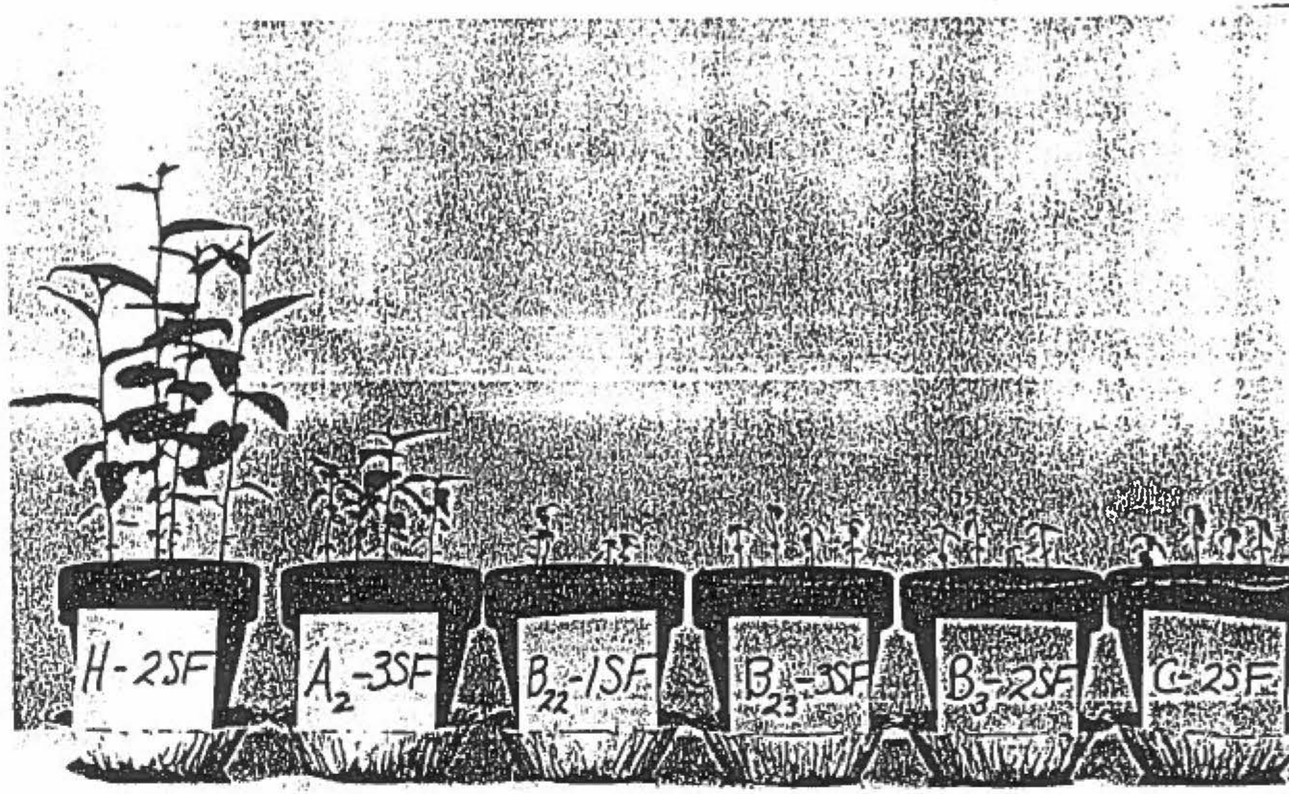


Figure [redacted] — Comparative growth of yellow birch seedlings at 53 days in the various horizons of a Hermon series, podzol soil.

Table [redacted] Average 5-year stocking (%) of stocked plots after logging northern hardwood stands in Vermont, 1973-82.

Season or kind of cut	Stands (*N*)	Tree species					
		Yellow birch	Sugar maple	Am. beech	Red spruce	Other	All commercial species
Summer	15	40	26	14	5	15	88
Winter	21	48	32	11	4	6	91
Shelterwood	9	29	48	15	1	7	
Clearcut	21	49	17	14	5	15	

11

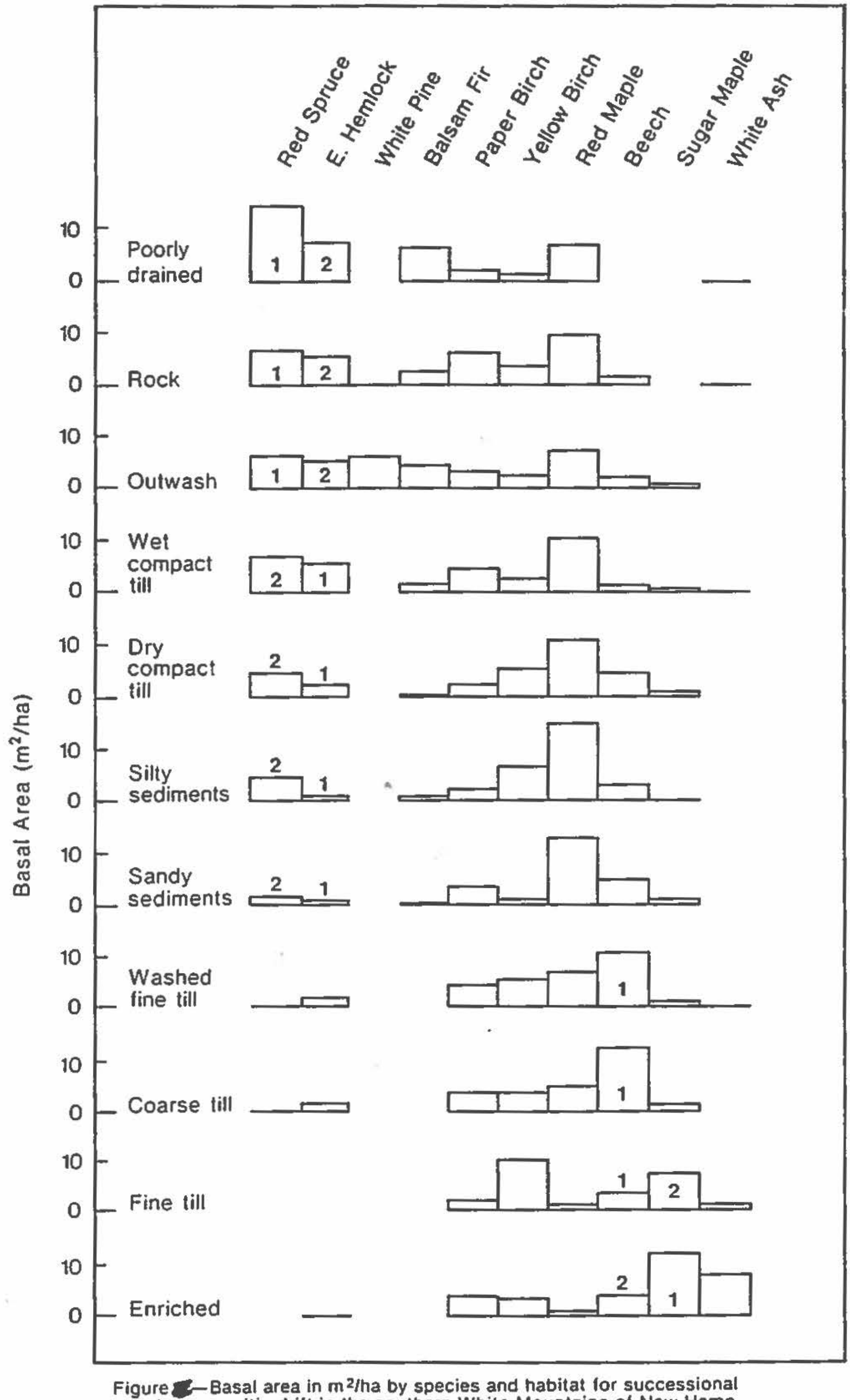


Figure —Basal area in m²/ha by species and habitat for successional stands on granitic drift in the southern White Mountains of New Hampshire. Number 1 refers to the most abundant and number 2 refers to the second most abundant species in older, climax stands.

REGENERATION ASSESSMENT

by
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State of NH – DRED
Division of Forests and Lands – Forest Mgt Bureau
Caroline A. Fox Research and Demonstration Forest

Traditionally, regeneration assessments have dealt with stem counts and estimates of the number of seedlings and saplings per acre. Usually fixed area plots are chosen with mil-acres being common. Good estimates of the number of stems per acre can be obtained from this type of sampling.

This approach has some drawbacks that silviculturists have tried to address. First, counting stems is time consuming and consequently regeneration sampling becomes expensive if a reasonable degree of confidence is to be expected. Depending on plot size and the smallest size class of seedlings considered countable, much time may be spent on a single plot. Reasonable confidence estimates often require 20 plots at a bare minimum, and a hundred or more for better certainty.

Second, the number of stems per acre is not necessarily a good indicator of regeneration success. For example, the probability of small seedlings someday becoming manageable timber is considerably less than for tall or thick callipered stems. Also, stems per acre estimates do not necessarily address the distribution of stems within the stand. Heavily stocked plots can offset scantily stocked plots to yield a misleading estimate that may look good on paper but inadequate in the field. Clues to bad distributions can be found in variability statistics such as the standard deviation and coefficient of variation but such statistics can be difficult to interpret and few practicing foresters seem to be interested in these statistical tools for everyday work.

Finally, there are few data available as guidelines for adequate stocking.

Stocked Plot Concept

A more pragmatic approach to regeneration assessment may be found in the stocked plot approach. Plot size is fixed, based on the size of the tree the plot will eventually supply growing stock for (Maass 1991, Marquis et al 1992). For example, if it were desired to assess if the regeneration will supply adequate stems to fully stock a poletimber stand, then the area used by a single poletimber tree is calculated and used for the plot. In the field, the plot is simply evaluated for being adequately stocked or not.

Initially, circular plot radii for hardwood regeneration were about 6 feet, the area used by a 5-inch dbh tree in a well-stocked stand. Probability tables were constructed to predict the chances that a specific sized stem would eventually make it to the overstory following the removal of the mature stand (clearcutting or shelterwood cutting). In evaluating the plot, the forester simply calculates if there are enough stems to insure the plot will be stocked at the desired point in the future such as at poletimber size.

Naturally, aggressive species will have higher probabilities than other species. For example, beech sprouts are highly likely to populate plots after cutting compared to say hemlock, which does not sprout and is not aggressive. Probabilities for commercially valuable species have been prepared in other regions of the United States but there seems to be little available at the present time for New England.

If 100 % of the sampled plots are considered adequately stocked with regeneration stems, it is assumed that the stand will be 100 % stocked at the designated future point. If 50% of the plots are considered adequately stocked with regeneration of desirable species, then it is assumed that 50% of the stand area will be stocked with desirable species at the designated future point.

Practical Applications

It may be advantageous to note the species of the dominant stem within each plot. It is reasonable to assume if a stem is dominant at the regeneration stage, it will probably be dominant at some future stage. Although desirable species may be present at the designated future point, they will probably be at a subordinate position if they do not dominate at the regeneration stage. More work needs to be done on this subject.

Choosing a plot size should be given careful consideration. For example, species such as red oak and sugar maple do not have a higher value than other species until they reach sawtimber specifications. Consequently, plot size may be better if calculated from sawtimber stocking requirements. For example, poletimber stands carry about 360 stems per acre so plots are 1/360 acre. Red oak stands entering the sawtimber stage may only carry 70 to 80 stems per acre. It may be more advantageous to evaluate 1/70 or 1/80 acre plots (a plot radius of about 13 feet).

Spruce/fir and white pine poletimber stands are completely stocked (A-line) at about 1000 trees per acre, so a mil-acre plot may be appropriate if the forester is interested in sufficient stocking for softwood pulp management. A high percent of stocked mil-acre plots will permit softwood pulp to be thinned at the first treatment. However, softwood sawtimber stands are adequately stocked (B-line) at about 250 stems per acre, so a 1/250 acre plot may work better for this type of management. Be advised that two different approaches are being considered here. The first looks at whether enough softwoods will be present at the end of a growth period (poletimber stage), the second looks at whether enough softwoods are present at the beginning of a growth period.

In practice, we must choose a single plot size to sample a single stand. Larger plots tend to be less variable than small plots. Also, since stocking guidelines can be very flexible, plot sizes can be also. Although a mil-acre is commonly used for softwood regeneration assessment, I see no reason why the plot radius could not be rounded to the nearest foot (4 feet) as long as it is used consistently within a single stand. It would also be important to use the same plot radius if stands were to be compared with other stands. Large plot sizes are generally more generous in evaluating stocking, consequently it can be difficult to make comparisons using different plot sizes. Table 1 gives my suggestions for plot sizes based on forest types and product goals.

Table 1
Suggested Plot Size by Forest Type and Product Goal. Plot radii in parentheses

Forest Type	Pulpwood	Sawtimber
Hardwood	1/385 ac. (6 ft)	1/100 ac. (11.8 ft)
Mixedwood	1/555 ac. (5 ft)	1/150 ac. (9.6 ft)
Softwood	1/1000 ac. (3.7 ft)	1/250 ac. (7.4 ft)

Probability tables cannot anticipate what level of damage the regeneration will receive. If harvesting operations are more severe than usual on advanced regeneration, the probability of stems to reach the anticipated stage may be substantially lower. For example, this author has experienced complete failures of sugar maple regeneration following harvesting. I attribute the failures in part to tough logging conditions that severely damaged the regeneration.

How to Decide if a Plot is Stocked

For spruce and fir mil-acre plots, Frank (1973) suggests that a stocked plot should contain at least 2 spruce and/or fir seedlings 6 inches tall or taller, -OR- 1 spruce or fir seedling 6 inches or taller and 1 or more other commercial species, -OR- 2 seedlings of some other commercial species. Hatcher (1962) found that fir seedlings between 1 and 2 feet tall grew the fastest after logging.

White pine is not as shade tolerant as spruce-fir and consequently I suggest the advanced regeneration be at least 18 inches tall to be considered under the guidelines used for spruce-fir. However, white pine stems become less flexible and are more likely to break as they exceed 3 feet in height.

Marquis et al (1992) working with Allegheny hardwoods made the following suggestions for red oak in areas with low deer browsing pressure:

1. Count each oak stem between 2 inches and 1 foot tall within the plot as one seedling.
2. Count each oak stem greater than 1 foot tall as two seedlings.
3. The sum of the counted seedlings in each plot should equal or exceed 10 to consider the plot stocked.
4. Plots with 2 or more oak stems between 0.5 and 2 inches dbh are considered stocked.
5. Plots with 1 or more oak stems between 2 and 6 inches dbh, that are distinctly younger than the overstory, are considered stocked.

How Many Plots

Marquis (1987) suggests using a minimum of 20 plots per stand with an additional plot for each 5 acres over 20 acres. Barrett, In: Desmarais (1997) provides an equation for calculating the number of plots required for percent stocking:

Where n = # of plots required, t = confidence limits multiplier from a t-value table, S = square root of [p*(1-p)] where p is the estimated % of plots stocked, E = allowable error.

$S = \sqrt{p*(1-p)}$, and $n = [(t*S)/E]^2$

$S = \sqrt{p(1-p)}$ $\quad n = \left[\frac{t \cdot S}{E}\right]^2$

Example

To calculate the number of plots required with a 95% degree of confidence, an estimate of 50% of plots stocked with a allowable error of 20%, the calculation would be:

$S = \sqrt{0.5(1-0.5)} = 0.5$ So, $n = [(2*0.5)/.2]^2 = 25$ plots.

Freese (1962) offers an equation to roughly estimate the confidence limits from a regeneration cruise, where $Sp = \sqrt{[p(1-p)]/(n-1)}$, then the confidence limits are computed as:

$p \pm [t * Sp + 1/2n]$ $Sp = \sqrt{\frac{p(1-p)}{n-1}}$

He also gives another method to calculate a more precise estimate of the confidence limits, which require more space than this paper can provide.

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Harvesting Methods for Regenerating Quality New England Forests

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Harvesting operations in a stand should consider regeneration. To leave regeneration considerations until the end of a rotation is like waiting until your car runs out of gas to decide where your destination is. Each harvest in the forest leads to a set of conditions that effect regeneration in some form in most cases. Silvicultural systems may not be a "cook book recipe" for management but they do try to establish a series of steps that lead to successful management over a rotation period. Mis-application of some steps can lead to a "can't get there from here" situation.

Advanced vs. New Regeneration

Forests generally regenerate by two methods, establishing advanced regeneration for future release and establishing new regeneration after some disturbance event. New regeneration is the easiest form for land managers because it basically entails simply removing the present forest and letting natural seedlings grow in. This works best with intolerant species such as birches and cherries, which establish from seed, and aspens, which establish from suckers.

Other species establish themselves in the understory of a higher forest. Seeding in under lower light conditions than a clearcut, they slowly add root and shoot growth in preparation for release at a later time. These species are more tolerant of shady conditions and include the maples, oaks, white ash, beech and most conifers. Slower growing than the intolerants, these species need to build up resources in their stems and roots to be able to compete with other plants when better light conditions become available. Most hardwood species are crushed by logging equipment and re-sprout at the time of release, developing a new stem of good form and vigor. Most softwoods however, do not re-sprout, so logging operations must be careful not to damage these stems.

Mid-Rotation Cutting

Most commercial cutting does not begin until mid-rotation. Typically, at the first thinning, the forest floor is nearly vacant of seedlings and saplings because of low light levels from overstory shade. These cuttings often establish regeneration by opening the canopy and permitting light levels to increase. Good regeneration can be established if a seed source is present.

Timing a cut with a good seed year appears to be greatly under-appreciated in the region. This may be the single most important factor in establishing quality species. When harvesting during "off-years", advantage is given to undesirable species such as red maple and beech. Red maple can bear seed as early as age 4 and large crops can occur a year apart and beech produces seed as early as age 40 and large crops can occur every 2-3 years (Schopmeyer 1974). Consequently, these two species are regularly producing seed by the time of the first thinning.

Timing the thinning with a seed year for the desired species helps incorporate the seed into the mineral soil, which improves the moisture conditions and minimizes insect and other predatory attacks.

I suggest cutting mostly overstory stems during mid-rotation cutting. The understory helps sustain shady conditions and is more likely to provide a competition-free environment for regeneration when the stand is mature. Thinning overstory stems also encourages better growth of the co-dominant and dominant crop trees. Finally, maintaining the understory will provide a useful means of establishing regeneration at a future point in the rotation.

Late Rotation Cutting

Cutting towards the end of a rotation should focus on establishing advanced regeneration if it is desired to establish species that regenerate best from this source. Advanced regeneration is a primary source of quality stems in New England (Smith 1991). Oaks, sugar maple, white ash, pines, spruces and balsam fir all do well as advanced regeneration. This is accomplished best by removing the understory in the cutting operation (shelterwood cutting). The understory provides the most discouraging shade for advanced regeneration. Often, leaving a heavy overstory of desired species for a source of seed and removing the understory during a good seed year will encourage sufficient advanced regeneration for the stand.

Mechanized harvesting works well for this job because it can harvest small stems in the understory more efficiently and the machinery often travels from tree to tree increasing the amount of scarification that occurs, mixing seeds with the mineral soil and organic matter.

It seems to take about 10 years or more for advanced regeneration to reach a size where it can be completely released by removing the overstory. Softwoods seem to be best released when between 1 and 3 feet tall. Hardwoods are a different story. Although probability tables have been constructed for some species, I have had the best results with advanced regeneration that either has a stump diameter between 1 to 4 inches or a minimum height of 4 ½ feet.

Removing the overstory from softwoods is addressed in another paper as part of this workshop. Hardwoods, however, are quite easy. Most re-sprout well after being cut. Re-sprouts from hardwoods between 1 and 4 inches at stump diameter are usually very vigorous attaining their pre-cut height in a few years, but with much better form. In my regeneration cuttings, I explain to the loggers that it is desired that the advanced hardwood regeneration be cut or crushed to encourage a new sprout. Often, re-sprouts will outgrow established larger advanced regeneration that has been suppressed for many years (often flat-topped).

Occasionally, stands regenerate themselves (natural shelterwood or 1-cut shelterwood) and the forester only needs to remove the mature overstory to regenerate the stand. An example is when spruce and fir to regenerate under a birch, aspen, or other stand. Also, oaks commonly regenerate under white pine stands and white pine regenerates under oak stands.

Problems

Problems arise when a sapling understory of undesirable species has been established by the time regeneration cutting is wanted. This is often associated with heavy cutting and removal of the understory in mid-rotation. To establish new, quality regeneration, this sapling stratum of unwanted species, needs to be removed because it provides the regeneration-discouraging shade described above. Removing this stratum is very expensive and is probably never done. Some work has been done with burning it with prescribed fire, but burning can be expensive and is a new and difficult technology to New England.

I suggest planning silvicultural treatments accordingly to address the sapling stratum development. First, if heavy cutting in the overstory will take place, do it early in the rotation, say, late pole or early sawtimber stage to encourage rapid growth of the crop trees and to permit the accompanying sapling stratum to reach a merchantable size by rotation's end. This lower stratum needs about 40 years or more to reach merchantable size. For white pine, rotations are suggested to be between 75 and 100 years, so any heavy cutting must be done by age 35 to 60 years, about the time that first cuts really are conducted in pine stands. For northern hardwoods, suggested rotation ages range from 100 to 120 years (Leak et al 1987), so heavy cuts must be made no later than age 60 to 80 years. Oaks would also be in this range.

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Preserving Advance Forest Regeneration: A Logging Systems Approach

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A logging system involves more than felling and skidding wood. In particular, "getting the regeneration you want" during harvesting requires planning, implementing appropriate logging practices, and selecting the best equipment and crew for the situation.

This paper outlines elements of a systems approach to harvesting that may help ensure better regeneration survival. Some of the observations offered below are based on experiences while the author was a full-time New Hampshire logger and forester; others are based on results of research.

Harvest planning

If maintaining existing regeneration during harvesting is a forest management goal, the following pre-harvest planning elements may be considered:

- identifying areas of adequate, too much, or too little advance regeneration of the desired species;
- marking trees to harvest or leave (e.g., whole tree chipping operations), as well as areas to avoid;
- skid trail designation; and
- communication among the landowner, logger, and forester (if any) involved in the operation.

It should be noted that these harvest planning elements may take place both before *and* during harvest operations, as the need arises or as conditions change as harvesting progresses.

Regeneration assessment. This does not necessarily imply a formal, scientific regeneration inventory. However, those areas on a logging chance that contain regeneration concerns and challenges may be identified.

Marking. Designating trees to be harvested/left may be particularly important for logging operations that involve both mechanized felling and regeneration concerns. Although there are a variety of reasons for marking/not marking trees to be harvested/left, when foresters do mark trees for harvest, they do so primarily to control the quality of the residual stand, including already established regeneration (Table 1). Feller-bunchers, harvesters, and processors generally approach a tree to be felled from one side; a timber marker on foot can better evaluate the entire tree bole, tree crown, and surrounding regeneration more effectively. In addition, cab visibility is often limited, making stand-level and regeneration decisions very difficult (more on this later). Moreover, by concentrating on marked trees, operators can generally be more productive when operating in marked stands, thereby enhancing logging efficiency. It is critical, however, that the forester performing the marking is familiar with the capabilities of the machine and its operator.

Finally, a forester may consider not marking/felling single, isolated trees of marginal quality, as well as other trees, that, when felled and extracted, may damage regeneration that is considered to be of higher value.

Table 1. Summary and chi-square analysis of responses of Maine foresters to questions related to (a) why respondents mark trees prior to harvest, and (b) why respondents do not mark trees prior to harvest.

	forestry employment subgroup				
	consulting forester	industry forester	public forester	chi-square	p-value
	percents				
(a) Why do you mark trees prior to harvest?					
Quality of the residual stand	**90.1**	**69.5**	**94.3**	**25.99**	**<0.001**
Logger prefers it	32.4	18.3	31.4	8.91	0.012
(b) Why do you NOT mark trees prior to harvest?					
Loggers do a good job without marking	57.9	68.3	37.1	12.61	0.002
Too expensive	22.7	23.8	14.3	1.60	0.450
Not enough time	10.5	39.6	20.0	36.11	<0.001

Underlined p-values indicate that the response is dependent on a respondent's forestry employment subgroup at alpha = 0.05.

Skid trail designation. At the risk of stating the obvious, when thinking about regeneration, skid trails may be planned to: (a) avoid areas of satisfactory regeneration; (b) be located so that there are bumper trees on inside curves for conventional tree-length skidding; and (c) have adequate bumper tree protection on both sides of the trail for whole tree skidding.

Communication. Studies in many northeastern states (e.g., ME, PA, WV) have shown that most NIPF owners do not communicate with a forester when they conduct timber sales on their lands. In addition, although NIPF owners often have a written logging contract when they harvest, these agreements rarely contain performance standards related to regeneration. Moreover, when foresters are involved in timber sales, their communications with loggers are increasingly constrained by liability concerns.

If regeneration is to be protected during logging, the landowner must (a) identify this as a priority/objective; (b) communicate this to the forester/logger. If there is a timber sale agreement, it may set performance standards for regeneration. The results of the pre-harvest regeneration assessment may be communicated to all parties involved, and a strategy developed to conduct harvest practices that mitigate damage.

Harvest practice

There are several harvest practices that may help mitigate damage to existing regeneration: directional felling; pulling cable vs. driving to the stump; bunching vs. multiple trips; and influencing the decisions of logging equipment operators through supervision, payment type, and incentives. Several (perhaps all) of these practices have obvious implications for regeneration, and they all require teamwork and some level of priority assigned to maintaining the integrity of advance regeneration. Importantly, these elements have as much to do with attitudes as they do with the capabilities of machines, operators, or forest managers.

For example, using directional felling in this context implies that preserving regeneration is considered a high priority by the timber faller when s/he is deciding the best lay for a tree. Under some circumstances, the skidder operator may also contribute to the goal of preserving regeneration by pulling more cable to the felled tree, rather than backing directly to the stump to set a choker on felled wood. Attempting to bunch wood and fill as many chokers as is practicable before returning to the landing may save additional trips into the woods to yard the same felled stems; fewer trips may result in less damage to regeneration (as well as to soils).

How may attitudes and behaviors be influenced? Some research has suggested that payment type and incentives may help. For example, research from Canada and Sweden suggests that piece-rate wages (vs. time-based wages) results in too much emphasis on production, and less on workmanship. Monetary incentives to operators for maintaining regeneration during harvesting has been suggested by some Canadian researchers as a way of encouraging more attention to regeneration. Foresters and landowners should understand, however, that these strategies generally increase logging costs.

Finally, a 1993 FERIC report found that the amount of understory protected during logging was influenced by several factors: pre-harvest density of the understory; harvesting patterns; equipment and operating techniques; work practices of the crew; and levels of supervision and planning. Note that most of these variables relate directly to the priorities and decision-making of forest managers and/or loggers.

Equipment selection

Choosing the most appropriate equipment for the job is really a harvest planning activity. However, it is presented separately here because of its importance to the regeneration/harvesting relationship. Although other equipment-related variables may be relevant, some of the more important ones in the context of preserving forest regeneration include: control over felling direction; type of felling head; agility; and visibility.

Felling direction can be controlled through mechanized felling, particularly feller-bunchers that can fell, lift, accumulate, and bunch wood in a way that minimizes damage to regeneration. The type of felling head used may also be important: continuously-rotating disc saw felling heads may do more damage than intermittent-rotation disc saw heads, shears, or chain saw type heads.

The agility of the equipment may also be important in some applications. Smaller equipment and 3-wheelled feller-bunchers, and zero tail swing excavator-type machines with extendo ("squirt") booms, for example, have the potential to either maneuver or reach to avoid established regeneration. Shovel logging in the western US and in Appalachia has been shown to minimize vegetation and ground disturbance under some circumstances. This has yet to catch on in the northeastern US.

Finally, it should be realized that, despite advances in cab visibility, what an operator can see -- especially when in a production mode -- may be very limited. The position of the cab relative to the rest of the machine, scratched safety glass surrounding the cab, and the challenge associated with adequately evaluating either tree crown or regeneration conditions on a stand level often make it very difficult for the operator to give appropriate attention to preserving advance regeneration if s/he is making cutting decisions. This re-emphasizes the importance of planning, harvest control, and communications.

Summary

Preserving forest regeneration during logging requires consideration of a harvesting "system" that includes:

- harvest planning: including regeneration assessment, harvest control, and communication among all parties involved in the harvest;
- harvest practices: including felling and skidding techniques, as well as operator and logging crew considerations; and
- equipment selection: including felling direction, type of felling head, agility, and visibility.

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REMOVING OVERSTORY TREES TO RELEASE SOFTWOOD ADVANCED REGENERATION

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INTRODUCTION

Eastern white pine is generally considered by silviculturists to be intermediate in shade tolerance. Due to this biological ability to inhabit shady areas, white pine advanced regeneration often occurs as a heavy "carpet" under substantial overstory forest canopies. This ability to exist under shade is only temporary, and the regeneration must eventually receive increased light from above to begin acceptable growth rates for timber management. On state lands, I have casually observed a growth rate without release of approximately 2 to 6 inches in height growth per year. With release from the overstory however, I have observed a regeneration growth rate of 12 to 24 inches in height per year.

Releasing pine advanced regeneration can be a difficult task. The pine should be established enough to quickly respond to the increased light and competition, but if too tall, the reproduction can be brittle and prone to excessive damage.

OBSERVATIONS FROM CONVENTIONAL OPERATIONS

Over the past decade, I have watched conventional operations and their impact on advanced pine regeneration. The operators struggled to carefully cut and remove the overstory trees without damaging the young pines. Often, although an adequate number of reproduction stems remained after logging, they were distributed in very dense, small clumps. If plots were taken throughout the logging unit, less than half the plots would be stocked with advanced regeneration, suggesting that the new stand would contain less than half the pine crop trees desired.

I observed three substantial problems which needed to be corrected to successfully leave a fully stocked stand of regeneration behind, (1) minimize crushing the advanced regeneration from felling overstory trees, (2) minimize sawing off the advanced regeneration during limbing operations, and (3) minimize breakage from skidding (extraction).

Felling - When a tree is felled during a harvest operation it strikes the ground with tremendous impact. It seems the larger a tree is, the more damage it can produce when striking the ground. These "*final removal*" operations were harvesting mature timber and so most of the trees cut were quite large. Even small, flexible regeneration gets excessively damaged from conventional felling operations (pounding). Pine stands can

On State lands it is common to lay out the skid trails in a parallel pattern about 66 feet apart for this kind of work. Since final crop trees in the new stand will eventually be about 20 feet apart at maturity, we get 3 rows of crop trees between skid trails. Most excavator type harvesters that I have worked with have a maximum reach of about 20 feet. In order to reach the center of a felling strip, we have the excavator turn its tracks adjacent to the skid trail. The machine can now efficiently move back and forth over the same path to cut trees within the cutting strip and back out to the skid trail to drop the trees.

Rubber tired feller bunchers also seem to move around within the felling strip with little damage when the advanced regeneration is less than 3 feet tall. The regeneration is flexible and bends and springs back as needed. The rubber tired machines that worked well all have the capability of carrying the stem before initially felling it.

I have not worked with small, tracked, boomless feller bunchers in white pine advanced regeneration stands as yet. A few companies manufacture these small, nimble machines that do not have a mounted boom for reaching into the woods.

Protective residuals - One problem with mechanized harvesting is the fanning out of the twitch during skidding operations. The fanning can destroy the advanced regeneration ten or fifteen feet into the felling strip. To remedy this situation I leave bumper trees every twenty to fifty feet along both sides of the skid trail to funnel in the skidded tree tops. The bumpers can either be left until the next future cutting, or removed when a majority of this operation is completed. If bumpers are harvested at the end of this operation, I have the operators leave a high stump of about 4 feet tall on all pulpwood quality bumpers to continue to protect the regeneration from the last of the skidding.

Big Trees - Trees too big for feller-bunchers to handle can be a problem. These trees tend to be greater than 20 inches in diameter ***at stump height*** or 16+ inches in diameter at breast height. The operators generally cut these by hand with a chainsaw at the conclusion of the timber sale or they approach and cut the tree from several directions with the shear or sawhead. If a large number of these trees are harvested, serious impacts to the advanced regeneration can occur. I have not found any satisfactory way of handling these stems except by (1) felling them into areas without advanced regeneration, if present, (2) careful felling into skid roads, or (3) leaving them until the new stand can tolerate their harvest in about 30 to 40 years.

OTHER BENEFITS FROM MECHANIZED HARVESTING

When I began showing this kind of silvicultural application to logging operators, they were apprehensive about trying it. They often thought the job may require too much extra effort to be cost effective. Only one experience is needed to convert a logging operator to this method. First of all, production remains high or increases due to the heaviness of the cut. Because the stand is being harvested, the good trees are cut too, so quality yield increases. Once a logger does this kind of treatment, they gain a specialized knowledge that makes them more valuable to a local forester or landowner. Finally, this kind of operation helps provide quality white pine stands for the future.

carry a large number of trees per acre. If the impact of a single tree were increased by 100 trees per acre, it is easy to understand how the regeneration could be destroyed from felling. At the time it seemed that damage was proportional to the amount of volume felled. Even excellent directional felling was problematic because the trees can't hit the exact spot every time. So, reproduction gaps became larger and larger.

Limbing - Removing the limbs from felled trees with chainsaws often resulted in many of the advanced regeneration stems being cut also. The felled tree bends many regeneration stems over into an arch shape. The arch shape exposes many stems to injury and breakage because of the tension and compression forces within the stem. If not cut, the increased weight of the felled stem as limbing removes support structures along the bole, can crush and break the arched regeneration.

Extraction - Advanced regeneration less than about 3 feet tall can be very flexible and withstand considerable bending. Rubber tires seem to be able to travel among the regeneration without producing much damage. Tracks seem to produce more damage to regeneration, but in dense regeneration areas there still seem to be plenty of undamaged stems to restock the stand. Taller regeneration stems appear to fare much worse. Both types of machinery tend to push over rather than flex the regeneration stems. Increased height generally leads to increased damage. Also, stouter stems either snap from bending or rip out the root system. So, driving machinery among regeneration over 3 feet tall is not recommended.

More damage seemed to originate from dragging the harvested stem through the regeneration. Again, small flexible regeneration stems bent and rebounded often without problem or much injury. Taller stems snapped, remained bent or had substantial root damage.

The trees being dragged by the skidder to the yarding area (twich) often fanned out behind the skidder. A skid trail initially laid out 10 or 12 feet wide eventually became 20 feet wide or wider. Depending on the concentration of skid trails per unit area this expansion of trail width can be a critical negative characteristic of operation.

TRIALS WITH MECHANIZED HARVESTING

Feller-Bunchers - I looked to mechanized harvesting to solve many of the problems with overstory removal described above. Primarily, I thought that if the overstory trees could be cut and felled only into the skid trails, much of the advanced regeneration between skid trails would be protected. This has worked out well. Excavator type harvesters generally stay on the skid trails and reach into the stand to cut the overstory trees. Shears and chainsaw type harvesters perform exceptionally well for this task. Continuous rotation saw heads require more care because the saw can cut the regeneration when being moved into position to cut the overstory stem. Still, with due care even continuous rotation sawheads can work fine.

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