Stand Structure in Evenaged Northern Hardwoods: Development and Silvicultural Implications

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ABSTRACT: *Stand structure was examined in evenaged northern hardwoods in New Hampshire in terms of diameter distribution (numbers of trees by dbh class) and spatial distribution of basal area by species. Diameter distributions by species and for all species combined were graphed for stands varying in age class from 7–9 yr up to 60–68 yr. Over time, these northern hardwood stands develop a layered canopy structure with the intolerant and short-lived paper birch and aspen dominating the larger size classes and exhibiting a bell-shaped diameter distribution. Longer lived species, most abundant in the smaller size classes, exhibit flat or very skewed bell-shaped distributions. The usual silvicultural recommendation in such stands is to thin to prescribed stocking levels, leaving adequate stocking in larger stems of the longer lived species and gradually removing the intolerants as they reach maturity. However, appreciable spatial variation in the abundance of aspen-birch and longer lived species may prevent uniform application of this approach; i.e., some areas in certain stands do not have adequate stocking of the longer lived species once the aspen-birch is removed. In variable stands such as this, a gradual transition to group selection may be a better tactic. North. J. Appl. For. 16(2):115–119.*

Much of the past work on stand structure has been in unevenaged stands, where the intent is to define forms of diameter distributions (e.g., J-shaped) that will allow for sustained harvests over time. However, the diameter distributions of evenaged stands and the spatial distribution of their component species also are important since they affect silvicultural options, marking practices, and stand growth responses after cutting (Marquis and Ernst 1991, Nowak 1996, Nowak and Marquis 1997). The purposes of this paper are to describe the development over time of diameter distributions in evenaged northern hardwoods in the White Mountains of New Hampshire, to describe the spatial distribution of the component species, and to discuss the silvicultural implications.

Methods

The data on diameter distributions were available from earlier studies. In 1977, a series of plots was taken in evenaged sapling stands that developed following clearcutting in the White Mountain National Forest. There were nine plot clusters in 7–9 yr old stands and five plot clusters in 11–15 yr old stands; each cluster consisted of eight to ten 0.0012 ac (5 m^2) plots where all trees greater than 1 ft tall were tallied by species and diameter. As part of the same study, 24 plot clusters were taken in 60–68 yr old stands; each cluster consisted of four 0.012 ac (50 m^2) plots where all trees greater than 4.5 ft tall were measured. These plots covered a range of sites, but all supported uncut/unmanaged northern hardwoods with a small component of associated tolerant softwoods (Leak 1979). A second set of plots consisted of five 1/4 ac control (untreated) plots from a release study in young, evenaged northern hardwoods on the Bartlett Experimental Forest; measurements were available at 25 yr and 56 yr of age on trees larger than 1.5 in. dbh (Marquis 1969). The basic information is summarized in Table 1.

The analytical approach was graphical, showing how the diameter distributions of entire stands and individual species change with a sequence of stand ages. Because the numbers of stems and the proportions of various species varied greatly within the data set, the diameter distributions are expressed as the percentage of the stems within each dbh class. For example, in a stand where the numbers of stems (for the whole stand or for any given species) consisted of one-hundred 1 in. stems, fifty 2 in. stems, thirty 3 in. stems, and twenty 4 in. stems, the percentages in the graphs would be plotted as 50, 25, 15, and 10%, respectively. We then examined the spatial variation among plots or plot clusters in

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Table 1. Summary of plot data.

Data category	Stand age 7–9	11–15	25	56	60-68
	(yr)				
No. plots or clusters	9	5	5	5	24
Area measured (ac)	0.10	0.06	1.25	1.25	1.19
Stems measured > 1 or 4.5 ft tall	3071	1112	—	—	1266
Stems measured > 1.5 in. dbh	119	83	2353	961	989

species proportions to help draw conclusions about appropriate silvicultural approaches.

Diameter Distributions

Percentages of trees by dbh class (trees >1.5 in. dbh) excluding seedlings progressed over a sequence of stand ages from a steep J-shaped curve in the young stands to a more gradual J-shaped structure in the older stands (Figure 1); regressions of percent of trees (in logarithms) over dbh had adjusted R^2 values of 0.86 to 0.99 in stands 25 yr old or more—this is the classical test of a truly J-shaped structure. This J-shaped tendency results from the mixture of species of varying light tolerances that become established in northern hardwood clearcuts (Wang and Nyland 1996) and the way in which the less tolerant species assume dominant positions over the more tolerant (Wilson 1953, Marquis 1994).

When the total dbh distribution is plotted for all trees including seedlings down to 1 ft tall in sapling stands or 4.5 ft tall in poletimber stands, the curve moves from a J-shape in young stands to a very skewed bell-shaped curve in the oldest stands (Figure 2).

The percent dbh distributions for the individual species follow several shapes (Figure 3). Beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), and sugar maple (*Acer saccharum*) exhibit steep J-shaped curves in the very youngest stands but, over time, develop very skewed bell-shaped curves with the maximum percentage of stems in the 2 in. class, and with a long right-hand tail extending up to 8–14 in. dbh. This variation in tree size results from differences in origin (advanced growth, sprouts, seedlings), crown position/competition, and genetic growth potential. Red maple (*Acer rubrum*), in the older stands, exhibits a very flat, and slightly skewed bell-shaped curve with a poorly defined peak at about 4–8 in. dbh. Paper birch (*Betula papyrifera*) and aspen (*Populus grandifolia* and *tremuloides*) develop well-defined bell-shaped curves with peaks at 8 to 10 in. dbh, respectively, in the 60–68 yr old stands. Pin cherry (*Prunus pensylvanica*) (not shown in Figure 3) quickly shifts from a steep J-shaped to a bell-shaped distribution at an early age, but is a very minor component in the 60–68 yr old stands. White ash (*Fraxinus americana*) had inadequate numbers for a well-defined dbh distribution.

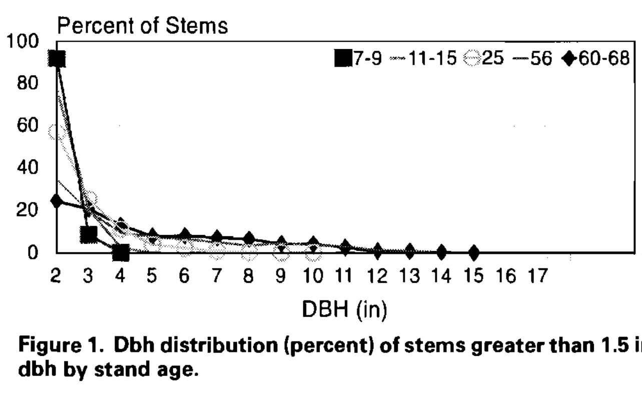

Figure 1. Dbh distribution (percent) of stems greater than 1.5 in. dbh by stand age.

Silvicultural Implications of Canopy Structure and Spatial Variation

Silvicultural approaches for dealing with mixed, layered stands have been described in detail for the Allegheny hardwood type (Marquis 1994) where black cherry is the common intolerant species which develops a dominant, bell-shaped distribution—similar to the aspen-birch component in this study. In general, the suggested evenaged management tactic is to thin (commercially, noncommercially, or a combination of the two) to the stocking levels suggested by available stocking guides, favor the larger dominant/codominant stems of any species as residual crop trees, and remove the early-maturing species (black cherry or aspen/birch) at their appropriate rotation ages while leaving the late-maturing species (sugar maple, yellow birch, white ash, red maple, etc.) for additional growth before regenerating the stand. This approach is sometimes referred to as *extended harvest, double rotation,* or *thin-harvest* (Marquis 1994) to distinguish it from classical thinning, which is the control of tree/stand growth through the manipulation of stand density. Part of the strategy would be to encourage a narrow range in diameters (a sharp, bell-shaped curve) in the final crop by removing about two-thirds to three-quarters of the cut basal area from below the average merchantable stand diameter and the remainder from above. Another part of the strategy is to provide mature trees as a seed source at the end of the rotation

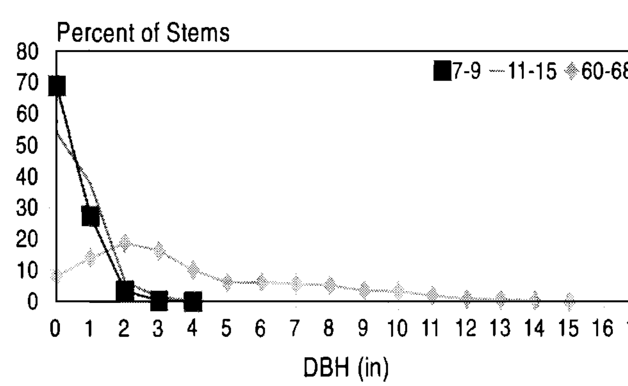

Figure 2. Dbh distribution (percent) of stems greater than 1 ft tall or 4.5 ft tall (60–68 yr old stands) by stand age. The zero dbh class ranges from 1 ft tall to 0.5 in. dbh in the 7–9 and 11–15 year old stands and from 4.5 ft tall to 0.5 in. dbh in the 60–68 year old stands.

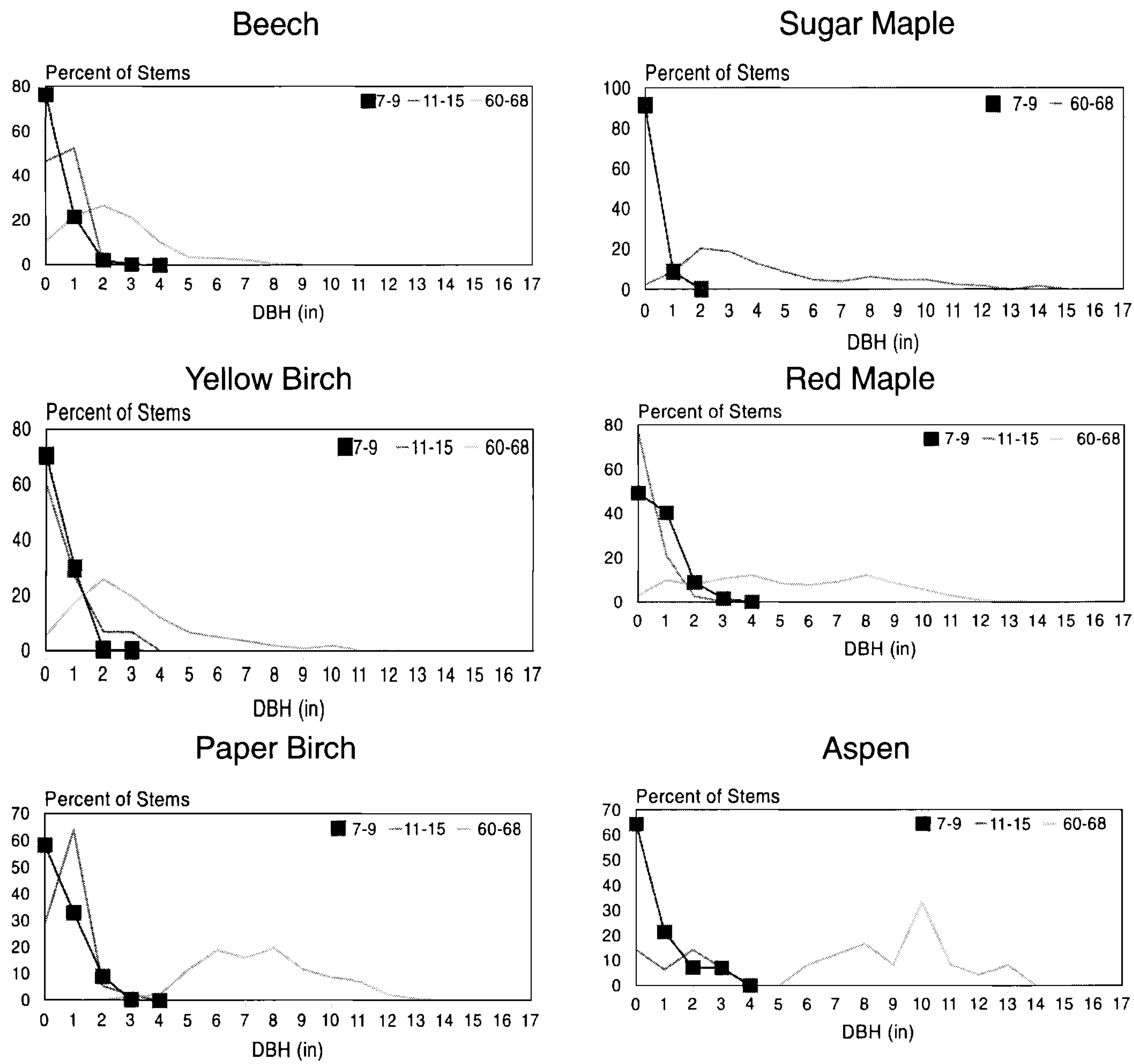

Figure 3. Dbh distribution (percent) of stems greater than 1 ft tall or 4.5 ft tall (60–68 yr old stands) by species and stand age.

for the early maturing species. For example (Marquis 1994), recommendations for a 60 yr old stand with 36% black cherry and a 10 in. mean commercial stand diameter were to thin twice at 15 yr intervals (two-thirds of the cut below the mean diameter) removing poor quality and low vigor stems of any species, harvest the black cherry at age 90, and carry the remainder of the stand for another 30 yr (120 yr rotation) until the red and larger sugar maple reach maturity. However, the authors suggested that the cherry removal be spread out until the final harvest to maintain a seed source and that attempts be made to maintain some cherry advanced regeneration until the final cut.

Some refinements and precautions on this general approach seem appropriate for evenaged northern hardwoods in New England with a component of aspen (a major wildlife species and increasingly important commercial species) and paper birch (a valuable commercial species):

1. Paper birch and aspen mature earlier than black cherry, at about 60–80 yr depending on management intensity, although occasional stems live to about 100; so, the aspen and birch would need to be removed 40–60 yr before the longer lived species reach the usual northern hardwood rotation age of about 120 yr.

2. In a 60–80 yr old stand, few trees of the longer lived species are sawtimber-sized (Figure 3), so removal of two-thirds to three-quarters of the thinned material in trees below the mean stand diameter would result in a low value poletimber harvest. A more economically viable alternative would be to concentrate more of the thinning removals in paper birch boltwood and mature aspen.

3. During a 60 yr period, the longer lived species would grow about 6 in. (sugar maple and yellow birch) to 8 in. (red maple) (Leak and Solomon 1997), so (check Figure 3),

only a few stems of the longer lived species would reach a finally mature size of 18 in. dbh or more at 120 yr; apparently a rotation of longer than 120 yr would be needed.

4. The diameter distributions of the longer lived species are quite broad (Figure 3), making it difficult to form a uniform-sized final crop with a narrow bell-shaped distribution. Earlier intermediate cuts apparently would not help in this regard, since our study shows that broad, somewhat J-shaped structures develop at an early age.

5. Aspen and paper birch do not live for 120 yr or more and do not develop from advanced regeneration under a fully stocked stand; this means that a source of paper birch seed or aspen root suckers must be present at the final harvest if these species are to be perpetuated. Aspen is often eliminated from long-rotation northern hardwood stands. Although paper birch is a prolific seeder, about 90% of the seed falls within two and one-half chains from the stand edge (Bjorkbom 1971), so mature trees must be in the vicinity to maintain high proportions of the species.

The most important concern, however, deals with the spatial variation in species composition within a stand. The Bartlett thinning study is within a 20 ac stand that originated following a very complete clearcut, except for a few large white ash seed trees. However, the five 1/4-ac control plots showed wide variation in species composition and silvicultural opportunities at 56 yr of age (Figure 4). Available stocking guides (Leak et al. 1989) suggest that stands at this stage of development should be thinned to not less than 50 ft^2 basal area per acre in trees over 4.5 in. dbh. Only one plot (Plot 19) would provide the opportunity for removal of the paper birch and aspen while still leaving a residual stocking of 50 ft^2. If the paper birch and aspen were removed in two operations 20–25 yr apart, it is possible that the long-lived species on plots 5 and 12 would develop to the point where the removal of the paper birch and aspen would leave a well-stocked stand of desirable species. However, plots 4 and 7 do not appear to contain sufficient long-lived species greater than 4.5 in. dbh to provide for an adequate stand once the paper birch and aspen are removed.

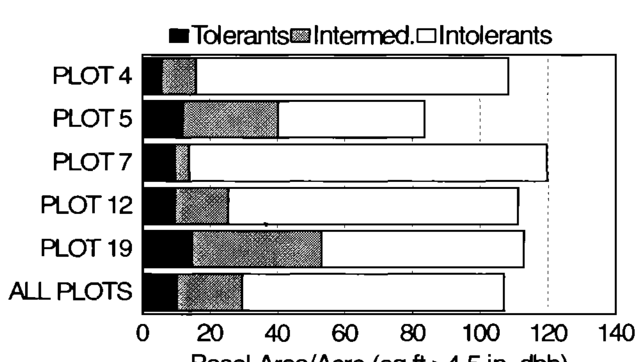

Figure 4. Basal areas per acre (trees greater than 4.5 in. dbh) by tolerance groups for the 5 control plots at age 56 in the release study on the Bartlett Experimental Forest (Compartment 22). Tolerants (beech, sugar maple). Intermediates (red maple, yellow birch, white ash). Intolerants (paper birch, aspen).

There are two ways to deal with this level of variability. First, a uniform thinning prescription, leaving an essentially constant residual density, could be applied to the stand, realizing that areas of 1/4 ac or perhaps larger would not be well marked—i.e., that some paper birch or aspen would be left beyond the point of maturity or that the stand would be lowered below recommended stocking levels. The other alternative is to begin the transition toward an unevenaged group/patch selection stand with openings varying from about 1/4 to 2 ac in size. Under this approach, areas of abundant aspen/birch would be regenerated by group/patch cuts as they mature as well as areas of defective or mature longer lived species. Some of these group/patch cuts would regenerate to a predominance of aspen/paper birch/yellow birch, especially those heavily disturbed by logging; other areas would contain a potentially valuable understory of sugar maple and beech that could be released by group/patch overstory removals. Areas with adequate proportions of longer lived species could be thinned during the same operation, removing aspen/birch as it matures as well as low-potential stems (cordwood) of the longer lived species. This transition toward group selection, described in detail elsewhere (Leak et al 1989), also maintains seed sources of most species. The approach, however, is difficult under high deer populations because of the intense browsing on the small isolated areas of available browse.

Another example of the variability in New England northern hardwoods is provided by the 60–68 year old plots from the White Mountain National Forest. These plots were established in pairs of clusters about 100 ft apart; the data from each pair were combined (a total of eight 0.012 ac plots), representing a spatial area of a little over 150 × 50 feet, about 1/5 ac. In each of several locations or stands, two or more pairs of clusters were established. The variability between and within locations (stands) suggests different silvicultural strategies (Figure 5). Again using the standard of 50 ft^2 basal area as minimum stocking, the "Mudgetts" plots could readily be thinned, removing the intolerant, short-lived component

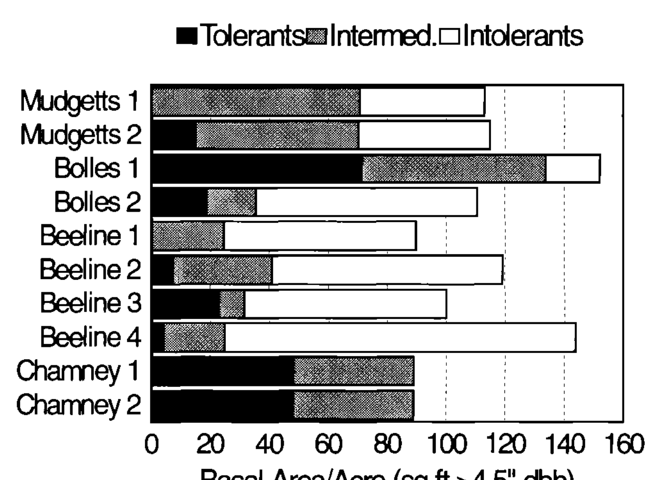

Figure 5.— Basal areas per acre (trees greater than 4.5 in. dbh) by tolerance groups on pairs of plot clusters within four stands on the White Mountain National Forest. Tolerants (beech, sugar maple). Intermediates (red maple, yellow birch, white ash). Intolerants (paper birch, white ash).

and leaving an adequate stand of longer lived species. In the "Bolles" stand, the first plot cluster could be thinned, removing both intolerant and long-lived stems and leaving an adequate residual stand. The second "Bolles" plot would have a minimally stocked stand once the aspen-birch was removed. The "Beeline" plots contain a high proportion of intolerants; "Beeline" 2 is the only cluster that contains sufficient long-lived species to perhaps provide an adequate stand after removal of the aspen/birch. The Chamney plots contain no intolerants; thinning of longer lived species to attempt the development of an even-sized final crop is one option, although most thinning prescriptions in these 68 year old stands will produce mostly 6–10 in. dbh cordwood. Gradual implementation of single-tree or group selection to develop an uneven-size stand is another option, keeping in mind that single-tree selection in this forest type will produce mostly tolerant species.

Many large stands (50–100 ac) in New England northern hardwoods will contain all of the conditions represented in Figure 5. It is possible, however, to define boundaries of smaller stands that would be amenable to uniform evenaged thinning regimes. However, stands that are patchy at a scale of perhaps 1/4 to 2 ac. in size probably are best handled by a gradual transition to group selection. Stands with intimate mixtures of tree sizes and species can be handled by a gradual transition toward single-tree selection if tolerant regeneration is acceptable.

Applications

This study reintroduces the concept that many evenaged northern hardwoods in New England develop a layered structure with a dominant bell-shaped diameter distribution of intolerant, short-lived aspen-birch over a flat or very skewed bell-shaped distribution of more tolerant species. The usual silvicultural approach for treating such stands is thinning to recommended residual stocking levels, leaving the best stems of the longer lived species while removing most of the aspen-birch by about 80 yr of age, and regenerating the stand by evenaged methods when the long-lived species reach an appropriate rotation age. However, northern hardwoods in New England commonly contain such small-scale, within-stand variation that there generally are patches with inadequate stocking of long-lived species once the aspen-birch is removed. In such stands, a better approach is to regenerate by group/patch cutting small areas dominated by mature aspen-birch while continuing to thin areas with an adequate stocking of long-lived species. This approach begins the long-term transition toward an unevenaged stand managed by group selection.

In prescribing silvicultural treatments for young evenaged northern hardwoods in New England, the following suggestions may be useful:

1. Large stands (50 to 100 ac or more) usually contain so much variation in structure and composition that uniform thinning treatments will not leave adequate stocking of long-lived species. These large stands are probably best handled by a gradual transition to group selection. (For details on the method, see Leak et al. 1989.)

2. Smaller stands often can be delineated that will be amenable to uniform thinning treatments although even stands as small as 20 ac may contain appreciable small-scale variability.

3. The broad range in tree sizes among the long-lived species makes it difficult to produce a stand at rotation age with a preponderance of mature trees. Group selection provides a somewhat more flexible means to harvest small areas of mature trees while providing for regeneration of a broad range of species. Single-tree selection in northern hardwoods provides maximum flexibility for harvesting trees at the optimum size or condition, but it leads toward regeneration of primarily tolerant species.

4. In developing silvicultural prescriptions, considerations other than diameter distribution or spatial variation may be dominant: excess deer pressure, the need for certain types of wildlife habitat such as sizable aspen-birch stands, esthetics, and short-term owner objectives.

This study dealt with northern hardwoods containing an aspen/birch component. However, the silvicultural strategies described above may be generally useful in any mixed stands of long- and short-lived species that are spatially variable.

Literature Cited

Bjorkbom, J.C. 1971. Production and germination of paper birch seed and its dispersal into a forest opening. USDA For. Serv. Res. Pap. NE-209. 14 p.

Leak, W.B. 1979. Effects of habitat on stand productivity in the White Mountains of New Hampshire. USDA For. Serv. Res. Pap. NE-452. 8 p.

Leak, W.B., D.S. Solomon, and P.S. DeBald. 1989. Silvicultural guide for northern hardwood types in the Northeast (revised). USDA For. Serv. Res. Pap. NE-603. 36 p.

Leak, W.B., and D.S. Solomon. 1997. Long-term growth of crop trees after release in northern hardwoods. North. J. Appl. For. 14(3):147–151.

Marquis, D.A. 1969. Thinning in young northern hardwoods: 5-year results. USDA For. Serv. Res. Pap. NE-139. 22 p.

Marquis, D.A. (ed.). 1994. Quantitative silviculture for hardwood forests of the Alleghenies. USDA For. Serv. Gen. Tech. Rep. NE-183. 376 p.

Marquis, D.A., and R.L. Ernst. 1991. The effects of stand structure after thinning on the growth of an Allegheny hardwood stand. For. Sci. 37(4):1182–1200.

Nowak, C.A. 1996. Wood volume increment in thinned, 50- to 55-year-old mixed species Allegheny hardwoods. Can. J. For. Res. 26:819–835.

Nowak, C.A., and D.A. Marquis. 1997. Distribution-of-cut guides for thinning in Allegheny hardwoods: A review. USDA For. Serv. Res. Note NE-362. 7 p.

Wang, Z., and R.D. Nyland. 1996. Changes in the condition and species composition of developing even-aged northern hardwood stands in central New York. North. J. Appl. For. 13(4):189–194.

Wilson, R.W. 1953. How second-growth northern hardwoods develop after thinning. USDA For. Serv. Northeast. For. Exp. Sta., Sta. Pap. 62. 12 p.