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# SIZE-CLASS DISTRIBUTION IN OLD-GROWTH NORTHERN HARDWOODS TWENTY YEARS AFTER CUTTING

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By F. H. Eyre and W. M. Zillgitt

How should old-growth northern hardwoods be managed so as to create stands adapted to continuous yield under the selection system? Since these forests as they occur in the Lake States present an all-aged appearance, it has long been assumed that the single-tree selection could be used in their management. All tree sizes up to 30 inches d.b.h. and larger, and at least several age groups, are normally represented. However, there usually is a considerable excess of larger trees, and plenty of small seedlings and saplings, but often a scarcity of trees in the middle size classes, especially in the heavier merchantable stands. Moreover, there has been no knowledge as to how fast the small trees would grow, once the overstory was opened up, and whether the all-aged character could be maintained and improved.

When selective cutting of northern hardwoods was first initiated on a practical scale, some 20 to 25 years ago, skeptical foresters spoke somewhat as follows: "Yes, we can see where the second cut is coming from, but where will you get the third cut?" This question still remains in the minds of some foresters.

Twenty-year records, now available for a number of cuttings2/ on the Upper Peninsula Experimental Forest, Dukes, Michigan, provide a fairly good answer to this question. In particular they show changes in distribution of diameter classes, basal area, and board-foot volume, which should be useful in evaluating the possibilities of the selection system or variations of it in long-time management.

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1/ Maintained at University Farm, St. Paul, Minnesota, in cooperation with the University of Minnesota.

2/ Acknowledgment is made to Raphael Zon, who planned most of the experiments; to A. E. Wackerman, E. L. Mowat, and J. R. Neetzel, who did the marking and maintained the records during the early years.

The stand where the experimental cuttings were carried out is the maple-birch variant[3] of the general forest type, commonly called northern hardwoods. Sugar maple makes up some 80 percent of the stand by volume and yellow birch about 15 percent. The remainder includes American elm, balsam fir, white spruce, and eastern hophornbeam (ironwood). Hemlock and beech are absent. The site is good for northern Michigan but not up to that found in parts of Wisconsin and southern Michigan. An average dominant tree has about 2½ 16-foot logs. Defect was high in this stand before cutting, with cull running from 25 to nearly 40 percent of gross volume. Net volumes before cutting ranged from 8.5 to 10.5 thousand board feet per acre.[4] Trees up to 300 years and older were present in the stand.

## DESCRIPTION AND TREATMENT OF STUDY AREAS

Permanent sample-plot records for seven cutting[5] units and a reserve area are available for this study, five extending for 20 years, one for 17, and one for 15 years.

Brief descriptions of the various plots[6] follow:

1. Reserve Area.- No cutting. Sample plots of 2 acres established in 1927 in a 9-acre unit. Total basal area in 1927 of 134 square feet per acre (9,290 board feet net). Stand fairly typical of the other units before cutting commenced.

2. 22-Inch Diameter Limit Cutting.- A light cutting in which 29 percent of gross board-foot volume was removed in 1926. Most trees, but not all, over 22 inches d.b.h. were cut; also a little improvement cutting of smaller trees. Four acres of sample plots established in 1927 in a 19-acre cutting unit. Total basal area after cutting, 100 square feet per acre (7,360 board feet net).

3. Light Improvement Cutting.- A very light cutting with only 24 percent of gross board-foot volume being removed in 1928. More emphasis on improving residual stand than in No. 2. One-acre sample plot in an 8-acre cutting unit. Total basal area after cutting, 92 square feet per acre (7,890 board feet net).

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3/ This is the sugar maple-beech-yellow birch type of the Society of American Foresters (Forest Cover Types of the Eastern U. S., 3rd Edition, revised 1940) but is at the extreme western edge of the beech range.

4/ Scribner rule used for all computations in this paper.

5/ Carried out under cooperative agreement with Cleveland-Cliffs Iron Company.

6/ The names of the various cuttings are not in all cases as descriptive as desirable but have been retained as originally assigned in order to provide comparison with other reports dealing with the same plots.

4. <u>Heavy Improvement</u>.- Moderate cutting with 46 percent of gross board-foot volume being removed in 1928. Two-acre sample plot established in an 8-acre cutting unit. Total basal area after cutting, 68 square feet per acre (5,490 board feet net).

5. <u>Overmature and Defective Cutting No. 2</u>.- A moderately heavy cutting in which 59 percent of gross board-foot volume was removed in 1932-33. Emphasis was on removal of defective trees, which left none larger than 22 inches d.b.h. One-acre sample plot in a 13-acre cutting unit. Total basal area after cutting, 61 square feet per acre (5,500 board feet net).

6. <u>Overmature and Defective Cutting No. 1</u>.- A moderately heavy cutting in which 62 percent of gross volume was removed in 1927-28. Two-acre sample plot in a 10-acre cutting unit. Total basal area after cutting, 55 square feet per acre (3,540 board feet net).

7. <u>12-Inch Diameter Limit Cutting</u>.- This was a very heavy cutting -- essentially a commercial clear cutting for sawlogs with the removal of over 90 percent of the gross sawlog volume. Two acres of sample plots in a 5-acre cutting unit. Total basal area left, 26 square feet per acre (410 board feet net).

8. <u>Clear Cutting</u>.- Everything cut down to 5 inches d.b.h. Total basal area left, 4 square feet per acre. Two acres of sample plots in a 5-acre cutting unit.

The general objective in units 2 to 6 was to devise a method of partial cutting that could be used in prolonging the utilization of old-growth hardwoods and gradually converting them into growing forests. The purpose was thus largely economic. It was hoped that the shock of rapid liquidation on communities dependent on the manufacture of hardwoods would be lessened if a practical method of selection cutting could be developed and generally adopted. Then there would be a shorter gap between the depletion of old-growth timber and the time when second growth could reach merchantable size.

Although there were no applicable tree classification schemes (aside from the dominance classification) available at the time the tests were initiated, the tree markers made definite effort to leave trees of good thrift and low risk. Naturally, in the heavier selection cuttings the markers could go further in removing trees of poor risk, high cull, and low vigor than in the very light cuttings.

Units 7 and 8 were established primarily to provide contrast with the various selection cuttings. No attempt was made in either of these operations to select good trees for retention in the future stand. Instead these cuttings were on a straight diameter-limit basis. Although they were not designed as a test of even-aged management, cuttings 7 and 8 provide some indication of how even-aged conditions may be created. This is certainly true of the Clear Cutting (Unit 8), and to a lesser extent of the 12-Inch Diameter Limit Cutting (Unit 7).

The reserve area and units 3 and 4 above are on Chatham loam. All other plots are on soil classed as Trenary sandy loam to loam. These soils seem to be equally good for timber production.

The basal area figures given for the various plots are for the stand left after cutting and include all trees for the total stand 2 inches d.b.h. and up. Before cutting the range in total basal area was from 119 to 143 square feet per acre (table 1). There was reasonable comparability between plots before cutting. After cutting basal areas ranged from 4 to 134 square feet (table 2). Detailed information on stand and stocking immediately after cutting and 20 years later is given in table 2.

## CHANGES IN NUMBER OF TREES, BASAL AREA, AND VOLUME

In the analysis of stand changes since cutting, particular attention has been given to size-class distribution. Emphasis in this paper has been given to that point rather than to board-foot increment or to age classes, because future productivity is largely governed by the proportion of different size classes. Age is a much less important consideration in an uneven-aged forest than in an even-aged forest containing short-lived species. Diameter does, of course, roughly reflect age, and the very large and old trees may be more defective than smaller ones. Cull, however, is spread throughout the stand. Sound thrifty trees in excess of 28 inches are occasionally present. Since sugar maple and yellow birch attain ages in excess of 200 years without necessarily becoming defective, the question of age can be omitted from the analysis. It is the size-class distribution of sound trees that really matters in management of stands of the type described here, and age is not a limiting factor.

Stand structure as reflected by number of trees immediately after cutting, and 20 years hence, has varied a great deal according to treatment (figure 1). The Reserve Area has changed very little. The light partial cuttings, such as the 22-Inch Diameter Limit and the Light Improvement, have gained in saplings, lost in the 10- to 14-inch group, and gained in the larger trees. The overmature and defective cuttings which left a smaller growing stock have gained considerably in number of trees under 9 inches d.b.h. and generally also in larger trees.

Overmature and Defective Cutting No. 1 (Unit 6) gained in all diameter classes. The extremely heavy cuttings, such as the 12-Inch Diameter Limit and the Clear Cutting have made tremendous gains in small trees, but considerably more time will be required to get a good representation among larger sizes.

Table 1.- Basal area per acre before cutting on the various plots for trees 1.6 inches d.b.h. and up

| Unit | Basal area before cutting (by D.B.H. groups) | | |
|---|---|---|---|
| | Under 9.6 inches | 9.6+ inches | Total |
| | | Square feet | |
| 1. Reserve . . . . . . . . | 16 | 118 | 134 |
| 2. 22-inch diameter limit . . . . . . . | 16 | 116 | 132 |
| 3. Light improvement . . | 17 | 107 | 124 |
| 4. Heavy improvement . . | 14 | 105 | 119 |
| 5. Overmature and defective No. 2 . . | 1/ 9 | 127 | 1/ 136 |
| 6. Overmature and defective No. 1 . . | 23 | 104 | 127 |
| 7. 12-inch diameter limit . . . . . . . | 17 | 118 | 135 |
| 8. Clear cutting . . . . | 13 | 130 | 143 |

1/ Does not include trees under 5 inches d.b.h.

Table 2.- Stand and stock table per acre immediatoly after cutting and 20 years lator

| D.B.H. group | Number of trees | Basal area | Board feet (net) | Number of trees | Basal area | Board feet (net) |
|---|---|---|---|---|---|---|
| | **RESERVE** | | | | | |
| | 1927 | | | 1947 | | |
| Inches | | Sq.ft. | | | Sq.ft. | |
| 2 - 4 | 164.0 | 6.55 | - | 157.5 | 6.97 | - |
| 5 - 9 | 37.5 | 9.32 | - | 40.0 | 11.09 | - |
| 10 - 14 | 24.5 | 19.52 | 1,153 | 19.0 | 15.27 | 909 |
| 15 - 19 | 31.5 | 48.13 | 3,788 | 29.5 | 48.02 | 3,900 |
| 20 - 24 | 11.5 | 28.60 | 2,475 | 15.5 | 34.71 | 2,952 |
| 25 - 29 | 6.0 | 22.04 | 1,874 | 5.5 | 27.72 | 2,380 |
| Total | 275.0 | 134.16 | 9,290 | 267.0 | 143.78 | 10,141 |
| | **22-INCH DIAMETER LIMIT CUTTING 1/** | | | | | |
| | 1926 | | | 1943 | | |
| 2 - 4 | 133.0 | 5.42 | - | 196.2 | 8.08 | - |
| 5 - 9 | 44.8 | 10.38 | - | 61.5 | 14.59 | - |
| 10 - 14 | 27.2 | 21.92 | 1,514 | 23.5 | 18.63 | 1,347 |
| 15 - 19 | 23.8 | 36.82 | 3,406 | 26.8 | 41.66 | 4,018 |
| 20 - 24 | 8.0 | 20.46 | 1,978 | 14.8 | 37.24 | 3,784 |
| 25 - 29 | 1.2 | 4.74 | 462 | 3.5 | 12.95 | 1,330 |
| Total | 238.0 | 99.74 | 7,360 | 326.3 | 133.15 | 10,479 |
| | **LIGHT IMPROVEMENT CUTTING** | | | | | |
| | 1928 | | | 1948 | | |
| 2 - 4 | 146.0 | 6.18 | - | 240.0 | 9.48 | - |
| 5 - 9 | 27.0 | 5.59 | - | 60.0 | 13.37 | - |
| 10 - 14 | 16.0 | 14.00 | 1,075 | 14.0 | 11.19 | 827 |
| 15 - 19 | 22.0 | 35.89 | 3,590 | 18.0 | 29.91 | 3,061 |
| 20 - 24 | 12.0 | 30.76 | 3,225 | 20.0 | 52.43 | 5,601 |
| 25 - 29 | - | - | - | 6.0 | 21.63 | 2,321 |
| Total | 223.0 | 92.42 | 7,890 | 358.0 | 138.01 | 11,810 |
| | **HEAVY IMPROVEMENT CUTTING** | | | | | |
| | 1928 | | | 1948 | | |
| 2 - 4 | 79.0 | 3.08 | - | 305.0 | 12.35 | - |
| 5 - 9 | 29.5 | 7.09 | - | 45.0 | 10.68 | - |
| 10 - 14 | 20.0 | 16.97 | 1,297 | 18.5 | 20.93 | 1,018 |
| 15 - 19 | 17.5 | 27.42 | 2,717 | 20.5 | 25.32 | 3,252 |
| 20 - 24 | 5.0 | 11.96 | 1,260 | 14.0 | 34.44 | 3,678 |
| 25 - 29 | .5 | 2.03 | 216 | 2.0 | 7.15 | 767 |
| 30+ | - | - | - | .5 | 2.57 | 275 |
| Total | 151.5 | 68.55 | 5,490 | 405.5 | 113.44 | 8,990 |

1/ 17-year record on this area.

Table 2.- Stand and stock table per acre immediately after cutting and 20 years later (Continued)

OVERMATURE AND DEFECTIVE CUTTING NO. 2

| D.B.H. group | 1932 Number of trees | 1932 Basal area | 1932 Board feet (net) | 1947 2/ Number of trees | 1947 2/ Basal area | 1947 2/ Board feet (net) |
|---|---|---|---|---|---|---|
| Inches | | Sq.ft. | | | Sq.ft. | |
| 2 - 4 | (3/) | (3/) | - | 365.0 | 13.25 | - |
| 5 - 9 | 28.0 | 6.05 | - | 75.0 | 15.55 | - |
| 10 - 14 | 26.0 | 19.86 | 1,558 | 21.0 | 18.31 | 1,560 |
| 15 - 19 | 14.0 | 21.38 | 2,310 | 20.0 | 32.12 | 3,625 |
| 20 - 24 | 6.0 | 14.15 | 1,632 | 13.0 | 34.39 | 4,095 |
| Total | 74.0 | 61.44 | 5,500 | 494.0 | 113.62 | 9,280 |

OVERMATURE AND DEFECTIVE CUTTING NO. 1

| | 1927 | | | 1947 | | |
|---|---|---|---|---|---|---|
| 2 - 4 | 125.0 | 5.06 | - | 282.5 | 9.40 | - |
| 5 - 9 | 27.5 | 7.10 | - | 87.5 | 21.86 | - |
| 10 - 14 | 22.0 | 16.31 | 1,053 | 28.0 | 21.72 | 1,646 |
| 15 - 19 | 12.5 | 18.48 | 1,686 | 18.5 | 29.47 | 2,958 |
| 20 - 24 | 3.5 | 8.14 | 801 | 9.5 | 24.05 | 2,538 |
| 25 - 29 | - | - | - | 1.0 | 3.56 | 378 |
| Total | 190.5 | 55.09 | 3,540 | 427.0 | 110.06 | 7,520 |

12-INCH DIAMETER LIMIT CUTTING

| | 1927 | | | 1947 | | |
|---|---|---|---|---|---|---|
| 2 - 4 | 64.0 | 2.50 | - | 852.0 | 29.15 | - |
| 5 - 9 | 32.0 | 7.60 | - | 82.5 | 19.37 | - |
| 10 - 14 | 19.5 | 15.56 | 410 | 29.0 | 21.72 | 950 |
| 15 - 19 | - | - | - | 16.0 | 23.40 | 2,098 |
| Total | 115.5 | 25.66 | 410 | 979.5 | 93.64 | 3,048 |

CLEAR CUTTING

| | 1927 | | | 1947 | | |
|---|---|---|---|---|---|---|
| 2 - 4 | 20.5 | .95 | - | 1,224.0 | 48.65 | - |
| 5 - 9 | 12.0 | 2.61 | - | 78.0 | 14.33 | - |
| 10 - 14 | - | - | - | 10.0 | 6.94 | 334 |
| 15 - 19 | - | - | - | .5 | .61 | 55 |
| Total | 32.5 | 3.56 | - | 1,312.5 | 70.53 | 389 |

2/ 15-year record on this area.
3/ No trees under 5 inches d.b.h. tallied in this measurement.

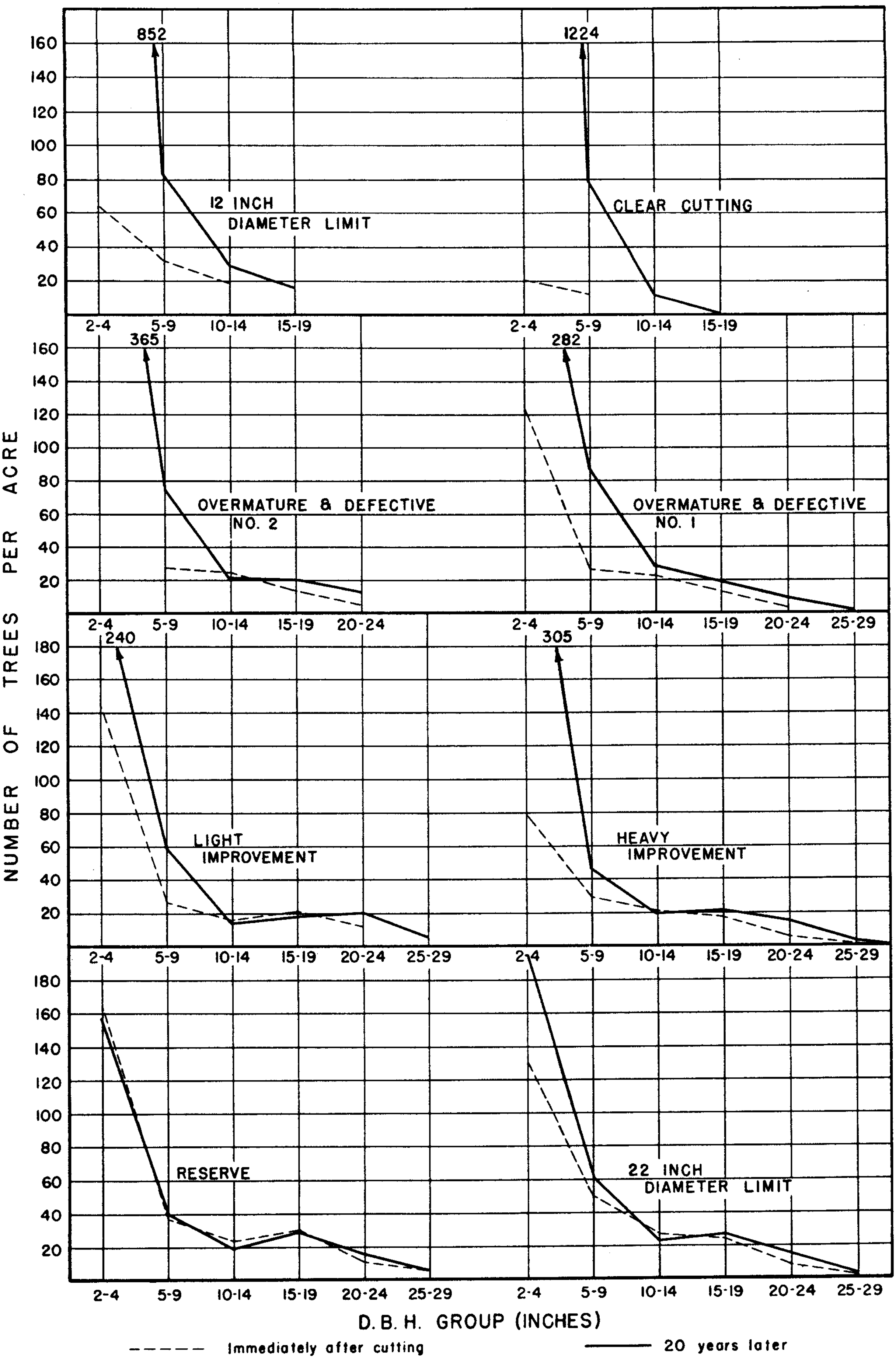


Figure 1 – Number of trees per acre by D. B. H. groups immediately after cutting and 20 years later on different cuttings.

The changes in stand structure can perhaps be better appreciated by studying basal area changes (figure 2 and table 3). The light cuttings have not stimulated much growth in the middle diameter classes, although the larger trees have continued to move into still larger ones. The extreme increase in small trees resulting from the heavy cuttings is striking, but the larger trees are poorly represented and will be for a long time. Growth will, no doubt, be comparatively rapid for sometime to come in the heavy cuttings as ingrowth becomes more pronounced, but there are no large trees and thus this type of cutting is not well suited to sustained production under uneven-aged management. Instead the very heavy cuttings generate a type of stand more even than uneven-aged. Overmature and Defective Cutting No. 1 (Unit 6) shows appreciable basal area increment in all size classes. The Overmature and Defective No. 2 cutting (Unit 5) has a similar pattern in this respect, except for the 10- to 14-inch group. However, the exceptional increment in the next smaller group should iron out this discrepancy at an early date. The two Overmature and Defective Cuttings, taken together, have developed a distribution of size classes that appears likely to continue to produce merchantable timber without any serious lapses. This point will be amplified further on in the paper.

Stand changes may also be appraised in terms of board feet (figure 3). It is evident that the light cuttings (the 22-inch Diameter Limit and both the Light and Heavy Improvement Cuttings), although they have made good growth in the larger diameters have lost in the 10- to 14-inch groups -- the critical point in stand structure in northern hardwoods in this locality. There is likelihood, however, of some future improvement in this respect because of growth in the 5- to 9-inch group (figure 2) but not as much improvement as in the two Overmature and Defective Cuttings.

The Overmature and Defective Cuttings have made excellent board-foot increment -- No. 2 (Unit 5) the best of any cutting. No. 1, (Unit 6) however, seems to have a better distribution of this growth. These stands are still growing rapidly and have not yet reached a point where another cut is needed to stimulate growth. The Clear Cutting is just beginning to show board-foot increment, but the 12-inch Diameter Limit is now doing well. It will, no doubt, continue to do so for some time to come. However, too great a proportion of the stand is in small diameters to represent much quality increment.

## WHAT IS DESIRABLE GROWING STOCK?

The question of how much growing stock to hold and how it should be distributed among size classes is an important one for the manager of a tract of northern hardwoods. The term "desirable growing stock" as here used may be defined as that stocking which will result in satisfactory increment of high-quality material for a given cutting cycle and a size-class distribution that will insure continuous yield. In an earlier paper7/ it was shown that

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7/ Zillgitt, W. M. 1948. Stocking in northern hardwoods under the selective system. Proceedings, Society of American Foresters' meeting, 1947.

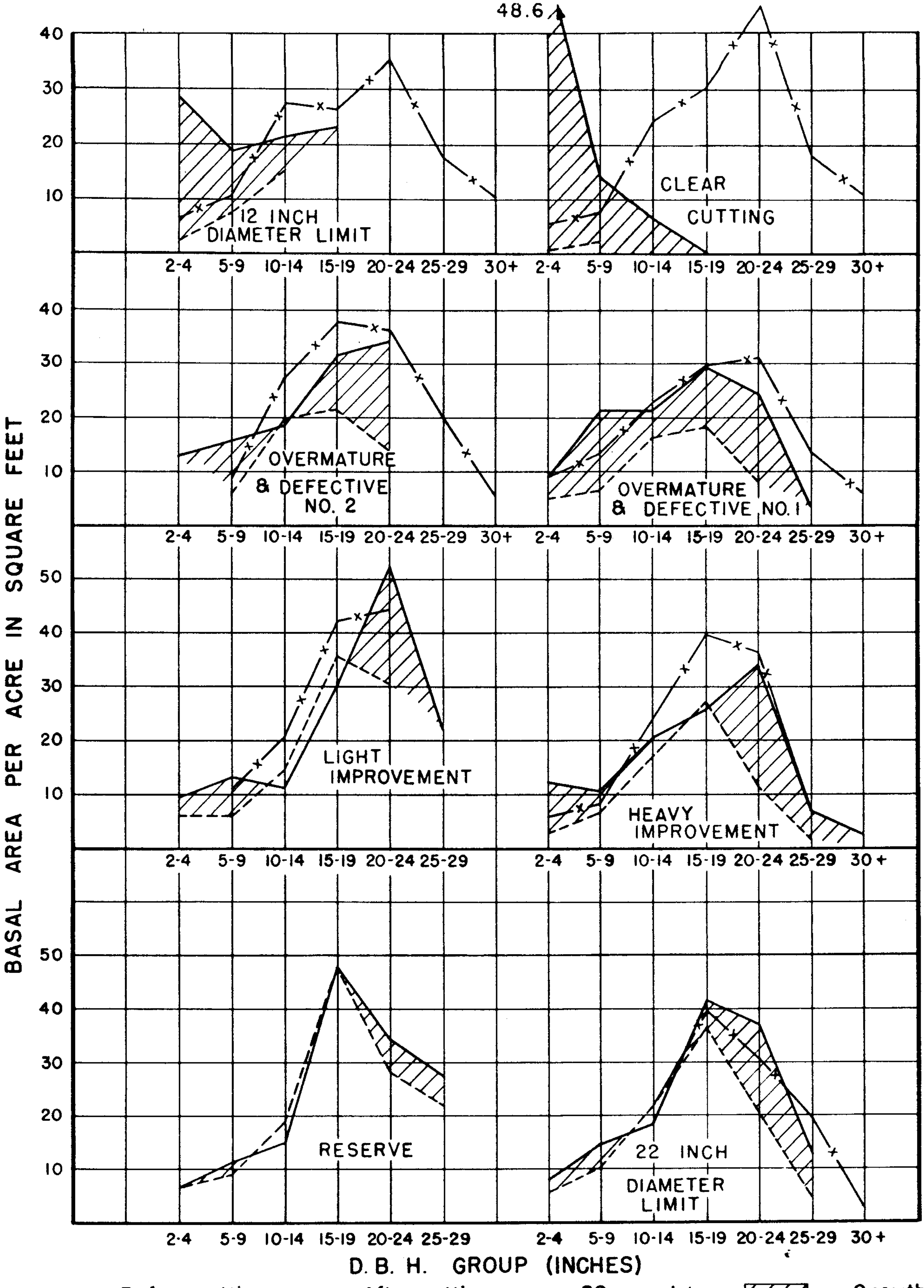


Figure 2 - Basal area per acre by D. B. H. groups before cutting, immediately after cutting, and 20 years later on different cutting plots.

Table 3.- Growth and losses in basal area per acre by d.b.h. groups during 20-year period following cutting, based on stand present immediately after cutting

| Unit | D.B.H. group: 2 to 9 inches | | D.B.H. group: 10 to 14 inches | | D.B.H. group: 15 to 19 inches | | D.B.H. group: 20 inches and up | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | Average annual | Total | Average annual | Total | Average annual | Total | Average annual | For period | Average annual |
| | | | | | Square feet | | | | | |
| 1. Reserve area . . . . . | 2.19 | .11 | -4.25 | -.21 | -0.11 | -.01 | 11.79 | .59 | 9.62 | .48 |
| 2. 22-inch diameter limit 1/ . . . . . . | 6.87 | .40 | -3.29 | -.19 | 4.84 | .28 | 24.99 | 1.47 | 33.41 | 1.96 |
| 3. Light improvement . . | 11.08 | .55 | -2.81 | -.14 | -5.98 | -.30 | 43.30 | 2.17 | 45.59 | 2.28 |
| 4. Heavy improvement . . | 12.86 | .64 | 3.96 | .20 | -2.10 | -.11 | 30.17 | 1.51 | 44.89 | 2.24 |
| 5. Overmature and defective No. 2 2/ . | 3/22.75 | 1.52 | -1.55 | -.10 | 10.74 | .72 | 20.24 | 1.35 | 52.18 | 3.48 |
| 6. Overmature and defective No. 1 . . | 19.10 | .96 | 5.41 | .27 | 10.99 | .55 | 19.47 | .97 | 54.97 | 2.75 |
| 7. 12-inch diameter limit . . . . . . . . | 38.42 | 1.92 | 6.16 | .31 | 23.40 | 1.17 | - | - | 67.98 | 3.40 |
| 8. Clear cutting . . . . | 59.42 | 2.97 | 6.94 | .35 | 0.61 | .03 | - | - | 66.97 | 3.35 |

1/ 17-year record on this area.
2/ 15-year record on this area.
3/ No trees under 5 inches d.b.h. tallied after cutting.

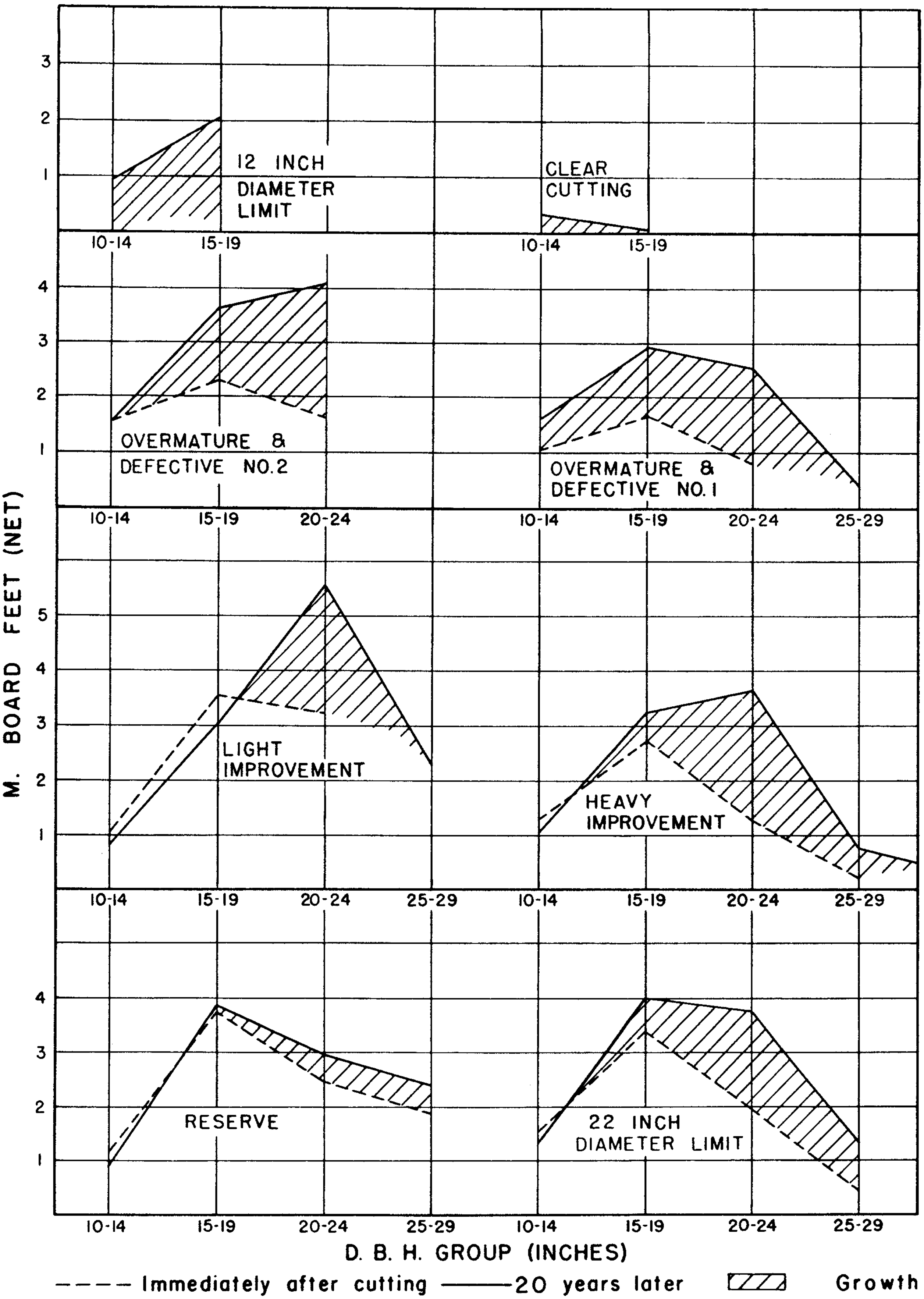


Figure 3 – Board feet per acre by D. B. H. groups immediately after cutting and 20 years later on different cutting plots.

an old-growth stand cut back to 64 square feet of basal area for trees 10 inches d.b.h. and up resulted in greater 15-year increment than stands with heavier or lighter stocking. A slightly higher basal area stocking would probably be advantageous for cutting cycles less than 15 years.

But what should the distribution of diameter classes be? If the growing stock could be so arranged among the various sized trees that the periodic cut could be taken altogether from fairly large trees -- say, those over 22 inches d.b.h. and all of good quality -- that certainly would be a desirable distribution. Thus only trees of high quality would be produced. Unfortunately management is not that simple.

One difficulty is that all trees in the stand are not good trees. Keep in mind that old-growth northern hardwoods contain from 25 to 40 percent defect due to rot and other causes. Rot does not wait until a tree is 22 inches d.b.h., but may start even in small trees 8 to 10 inches d.b.h., and it increases with age.

In order to keep a selection forest in a growing and healthy condition, it is necessary to dip down into the smaller d.b.h. classes every time a cut is made and take out inferior trees or those of high risk. If there is a market only for sawlogs such improvement cuttings may not go lower than trees of 12 to 14 inches d.b.h. If tie cuts and mine timbers can be sold, trees as small as 10 or 11 inches d.b.h. can be removed, and if a market exists for chemical wood or fuelwood, trees down to 5 or 6 inches d.b.h. can be taken out with little or no expense. All this means that there must be some silviculture applied with management and the better the market the more intensive this may be.

But no matter how small the trees that come out in an improvement cutting, it is still the large trees of good form and quality that provide the profit. To make sure that the stand produces them there must be a sufficient number of well-formed trees of small and medium size always present and ready to grow into larger diameters.

How many trees should there be in the various diameter classes to achieve this objective? The evidence in case histories of stand development presented on previous pages provide some clues. The 22-Inch Diameter Limit and the Light Improvement Cuttings (Units 2 and 3) do not give the answer because the leaving of such a heavy stocking in large trees did not permit development of a suitable number of middle diameter classes needed for continued production. However, board-foot increment has been good so far and thus has all been on large trees. The Heavy Improvement Cutting which left a lighter growing stock gave somewhat better distribution. The 12-Inch Diameter Limit and the Clear Cutting (Units 7 and 8) for which the residual stand was very light will probably develop into even-aged stands or something approaching them. These two cuttings look as though they would in time make good stands. As they grow into poles they may be more dense than stands developed under uneven-aged conditions, so should produce clean timber. But there may be more need for thinning as a special operation to maintain good growth than in the selection stands where more stocking is held in larger diameters. At present there is little or no sale generally in the Lake States for small thinning material from hardwoods, but markets may develop in the future. The stands grown under Clear Cutting (Unit 8) or a heavy partial cutting such as 12-Inch Diameter Limit (Unit 7), show no indication as yet of developing a distribution of size classes needed for repeated selective cuts. Instead the distribution, as might be expected, is less desirable for uneven-aged management than is the old-growth forest.[8]

The Overmature and Defective Cuttings (Units 5 and 6) which distributed the cut among all sizes and reduced the growing stock to about 60 square feet of basal area not only have not upset the fairly good stand structure provided by nature, but they decidedly improved it by bringing in classes not well represented in old growth. (It should be emphasized that it is not so much the "methods" as the stocking levels that achieved this result.) At the same time they have provided a good continuous yield.

Using the average size-class distribution of the two Overmature and Defective cuttings (figure 2) as a guide a basal-area curve representing desirable stocking was drawn, based on judgment and the evidence provided by 15- to 20-year growth. It is believed that this curve (figure 4) represents a desirable distribution of size classes and stocking level immediately after cutting. In figure 4 desirable stocking is compared with an uncut old-growth stand based on a tally of 240 acres in the same vicinity. It will be noted that the desirable stocking has more small trees than the old-growth forest. This objective cannot be achieved immediately. The curve of desirable stocking was, in turn, converted into number of trees and basal area per acre (table 4). The desirable stocking as here set forth is somewhat idealized. It will be noted that the residual stand contains no trees over 24 inches d.b.h., as there appears to be no economic justification for growing trees to a larger size. In practice this upper diameter limit may vary and there will probably be an occasional larger tree left, but it seems quite unlikely that under sustained-yield management trees will be grown to as large a size as they were in the original stand.

Also in actual application there is little likelihood that there will be such an even diminution in number of trees in diameter classes from large to small and, of course, there will not be fractional trees unless stand tables representing several acres are used. The following rounding off and grouping of number of trees and basal area should have more application in practice:

Desirable stocking per acre, by size groups

| D.B.H. group (inches) | Number of trees | Basal area (sq. ft.) |
|---|---|---|
| 2 - 4 | 202 | 8 |
| 5 - 9 | 65 | 16 |
| 10 - 14 | 28 | 22 |
| 15 - 19 | 17 | 26 |
| 20 & up | 8 | 21 |
| Total | 320 | 93 |

8/ There is no attempt here to compare the merits of even-aged -vs- uneven-aged management of northern hardwoods as a permanent method of management. More adequate tests designed with that particular objective are needed, especially for the large areas of second-growth stands which are now growing into merchantability.

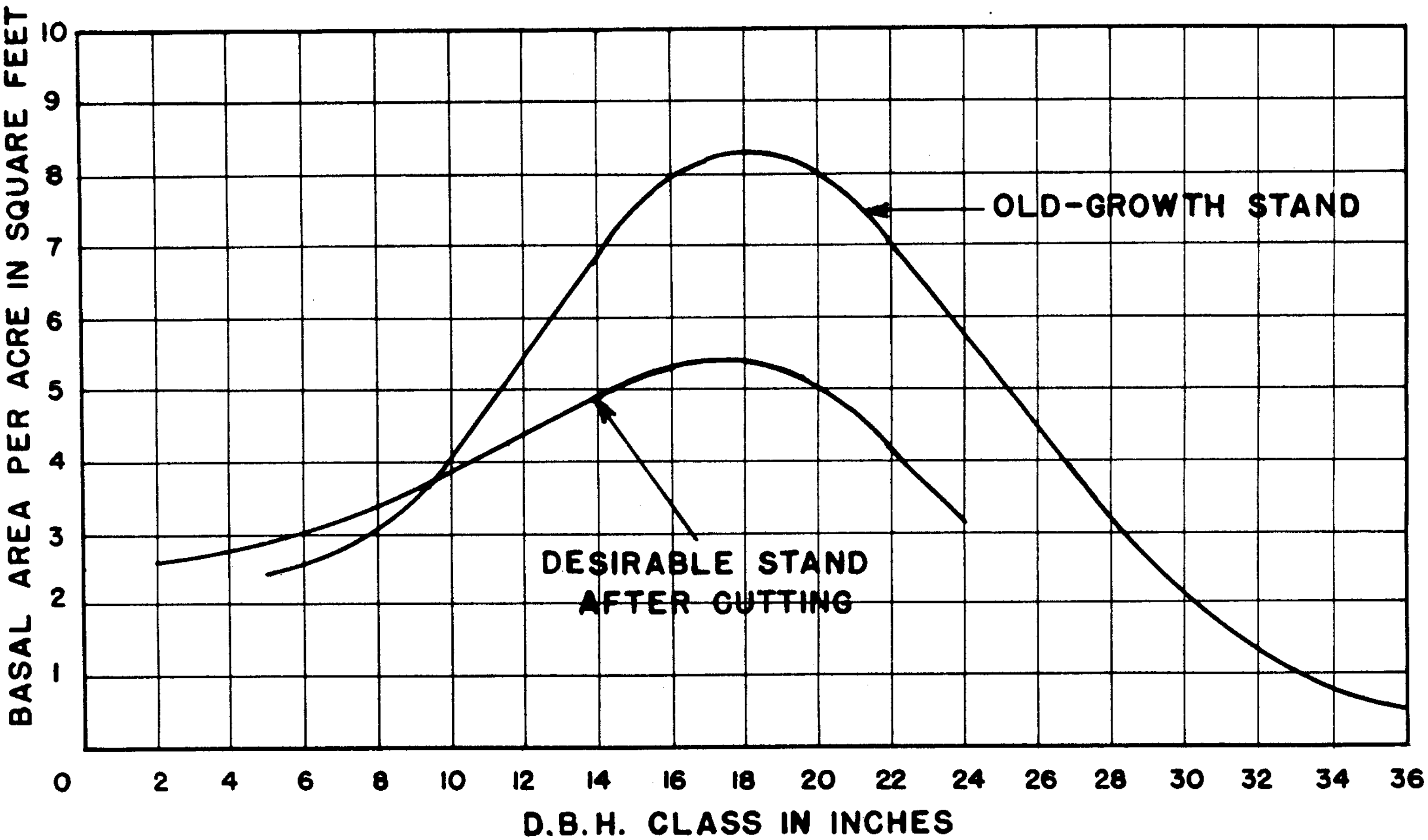


Fig. 4 - Basal area per acre by D.B.H. classes of an old-growth stand compared with a stand having desirable stocking.

Table 4.- Stocking per acre of an old-growth stand compared with one having desirable stocking for good continuous growth

| D.B.H. | Uncut old growth 1/ | | | | Desirable (after cutting) | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of trees | | Basal area | | Number of trees | | Basal area | |
| Inches | | | Square feet | | | | Square feet | |
| 2 | (2/) | | (2/) | | 118.2) | | 2.6) | |
| 3 | (2/) | | (2/) | | 53.1) | 202.3 | 2.6) | 7.9 |
| 4 | (2/) | | (2/) | | 31.0) | | 2.7) | |
| 5 | 17.3) | | 2.4) | | 20.6) | | 2.8) | |
| 6 | 13.4) | | 2.6) | | 15.3) | | 3.0) | |
| 7 | 10.6) | 58.1 | 2.8) | 14.4 | 12.0) | 65.3 | 3.2) | 15.8 |
| 8 | 8.7) | | 3.0) | | 9.5) | | 3.3) | |
| 9 | 8.1) | | 3.6) | | 7.9) | | 3.5) | |
| 10 | 7.3) | | 4.0) | | 7.0) | | 3.8) | |
| 11 | 7.0) | | 4.6) | | 6.1) | | 4.0) | |
| 12 | 6.9) | 34.1 | 5.4) | 26.8 | 5.5) | 28.2 | 4.3) | 21.6 |
| 13 | 6.4) | | 5.9) | | 5.0) | | 4.6) | |
| 14 | 6.5) | | 6.9) | | 4.6) | | 4.9) | |
| 15 | 5.8) | | 7.1) | | 4.2) | | 5.1) | |
| 16 | 5.8) | | 8.1) | | 3.8) | | 5.3) | |
| 17 | 5.0) | 25.5 | 7.9) | 39.7 | 3.4) | 17.2 | 5.4) | 26.5 |
| 18 | 4.7) | | 8.3) | | 3.1) | | 5.4) | |
| 19 | 4.2) | | 8.3) | | 2.7) | | 5.3) | |
| 20 | 3.6) | | 7.9) | | 2.3) | | 5.0) | |
| 21 | 2.9) | | 7.0) | | 1.9) | | 4.6) | |
| 22 | 2.7) | 13.4 | 7.1) | 34.6 | 1.6) | 8.0 | 4.2) | 20.6 |
| 23 | 2.3) | | 6.6) | | 1.2) | | 3.6) | |
| 24 | 1.9) | | 6.0) | | 1.0) | | 3.2) | |
| 25 | 1.7) | | 5.8) | | | | | |
| 26 | 1.3) | | 4.8) | | | | | |
| 27 | 1.0) | 5.3 | 4.0) | 20.4 | | | | |
| 28 | .7) | | 3.0) | | | | | |
| 29 | .6) | | 2.8) | | | | | |
| 30 | .5) | | 2.5) | | | | | |
| 31 | .4) | | 2.1) | | | | | |
| 32 | .2) | | 1.1) | | | | | |
| 33 | .2) | 1.6 | 1.2) | 8.9 | | | | |
| 34 | .1) | | .6) | | | | | |
| 35 | .1) | | .7) | | | | | |
| 36 | .1) | | .7) | | | | | |
| Total | 138.0 | | 144.8 | | 321.0 | | 92.4 | |

1/ Based on tally of 240 acres.
2/ Not tallied.

Assuming an annual diameter growth of .21, .20, .19, .18, and .16 inches respectively for the diameter groups given above (based on another study of these cutting plots), and a reasonable mortality rate among the larger classes the stand would, in 10 years, grow to a volume somewhat less than is present in a virgin stand but one sufficiently well stocked to warrant a substantial commercial cut. Stocking, of course, should never be allowed closely to approach that of a virgin stand, for to do so will reduce growth. It is believed that a stand like that represented in the tabulation will remain thrifty and if cut at short intervals (say from 8 to 12 years) should maintain a structure that will make possible good periodic growth on a continuous basis. In stands where the distributional pattern is undesirable and deficiences exist in one or more size groups, a period of adjustment will be necessary. During this period a variable cutting cycle may be advisable or it may be necessary to pass up a cut or two. At best it may require concentrating the cut in certain d.b.h. groups until better distribution is attained.

These guides should be useful even to the experienced marker. He should find it worth while from time to time to check the residual stocking in number of trees, basal area, and if he wishes, in equivalent board-foot volume. On the experimental forest at Dukes, checks are made by tallying occasional fifth-acre plots as marking progresses. It should be remembered, of course, in applying the interim guides presented here that they were developed in one locality and are based on only 20 years' growth, which is not a long period in the life of a stand. They will no doubt be revised and refined as more data become available.

## SPECIES COMPOSITION

So far consideration has been given only to size-class distribution. It is shown that following moderate partial cutting there is no lack of small trees; on the contrary they are abundant. But the question may be raised as to whether the species represented in the reproduction are those most desired. It has been recognized for sometime that light partial cuttings favor tolerant species to the exclusion of light demanding ones. In the case of the forest under investigation, sugar maple reproduces readily and yellow birch, a more valuable tree, is crowded out by a light selection type of cutting. It has been found, however, that yellow birch can be perpetuated with moderate selection cuttings if some attention is given to creating small openings around yellow birch seed trees.9/ Elm and basswood also are favored by this treatment. Reproduction of mixed species are aided further by exposure of mineral soil through logging during the season when snow is absent. Thus, with some slight modification of the selection method, a suitable mixture can be maintained.

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9/ Zillgitt, W. M. and Eyre, F. H. Perpetuation of yellow birch in Lake States Forests. Jour. For. V. 43: 658-661. 1945.

## TIMBER QUALITY

The abundance and kind of reproduction, important though they are, do not guarantee the formation of a desirable future forest. The quality of the reproduction must be of such a character that well-formed merchantable trees will result. What can be expected in this regard under partial cuttings? This question was recently made the subject of a special study.10/ Moderate cuttings proved to be equal to or better than clear cutting in the number per acre of good trees, based on their origin (seedling -vs- sprout), position in stand, condition and form. Only in the matter of clear length was the reproduction slightly inferior to that resulting from heavier cuttings, probably because of less dense reproduction stands under selective cutting.

The further question may be raised as to whether the quality of the trees will still hold good under selection cutting as they become older and of merchantable size. A study made in 1947 11/ showed that in 15 to 20 years following moderate selection cutting there was no falling off in log grades. But in heavy cuttings, such as the 12-Inch Diameter Limit, there was a decided decrease in quality due to lowering of crowns through development of large branches following epicormic sprouting. Also there was considerable die-back in the tops of residual trees in this heavy cutting, with some mortality as a result. However, many trees have recovered and developed new crowns.

Management considerations should by no means submerge silviculture in the application of selection cutting in northern hardwoods. They should go hand in hand. In fact, the condition of the stand coupled with economic factors such as markets will largely govern what can be done. The problem is how to convert decadent old-growth to vigorous growing forest, and at the same time preserve an all-sized pattern of stand structure. Some cutting must be done in all merchantable size classes because in these wild, untended forests, defect and cull extend through all classes. Timber marking, therefore, must be approached from the improvement-cut angle. After two or three cuttings it should be possible to reduce cull to a relatively small figure.

## SUMMARY

The fairly good distribution of size (and age) classes in old-growth sugar maple-yellow birch forests of the northern part of the Lake States suggests that selection cutting could be successfully applied in their management. These forests normally have an excess stocking of large trees and ample reproduction, but frequently a shortage of trees in the middle sizes, 12- to 14-inch d.b.h. Sample-plot records of six partial cuttings of various intensity, a clear cutting, and a reserve area, records for which extend for most areas over 20 years, provide a test of application.

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10/ Zillgitt, W. M. 1950. Quality of reproduction following partial cutting of northern hardwoods. Jour. of For. 48: 324-325.

11/ Zillgitt, W. M. Log grade following selection cutting in northern hardwoods. Lake States Forest Experiment Station Technical Note No. 285, 1 p., mimeo. 1947.

The light cuttings have not brought about proper stocking in the middle classes, although the larger trees have made good growth. The extreme increase in small trees in the heavy cuttings has been striking, but the distribution of size classes is undesirable. Thus, the heavy cuttings have generated a type of stand more even than uneven-aged. Growth, largely by reason of ingrowth of trees to merchantable size will, no doubt, be high for some time, but size distribution is poor for sustained production from the same area. Moderately heavy selection cuttings show up best with rapid growth and good distribution in all sizes -- an improvement over that provided by nature.

On the basis of the evidence presented by the changes in these stands, a stand table representing desirable stocking for uneven-aged management of northern hardwoods after cutting has been prepared (table 4). It is believed that such a stand, if cut periodically at intervals of 8 to 12 years, will maintain a good structure for continuous yield of merchantable timber.