# The Remarkable Story of the Partial Cutting Study at the Dukes Experimental Forest

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This paper describes our recent and successful efforts to reopen the pioneering U.S. Forest Service "Partial Cutting Study" on the Dukes Experimental Forest in Michigan. This experiment in northern hardwood silviculture was initiated in 1926 and closed in 1966. Although the research conducted there informed the use of uneven-aged silviculture throughout the northern hardwood forest, no one had measured or monumented the plots in more than 40 years. The only clues to plot locations were typewritten memos and hand-drawn schematics in files dispersed across three states. Yet, the Partial Cutting Study remains one of the most influential studies of northern hardwood silviculture in the U.S. and adjacent Canada, and remeasurement of the sample plots is warranted.

Even under the best circumstances, relocating forest inventory plots can prove challenging. This is particularly true in managed forests where sample trees are cut and plot markers are damaged or destroyed by harvest operations. Painted tree numbers become unrecognizable as stems grow and the bark cracks and curls; wooden plot stakes decay and records are misplaced or destroyed. In light of these obstacles, our story about the relocation and remeasurement of the Partial Cutting Study plots is a remarkable one. Furthermore, although earlier scientists had deemed their research complete and closed the study, the Hiawatha National Forest continued to apply the prescribed treatments, resulting in what is now one of the longest-running silvicultural experiments in North America. As a consequence, we are able to generate new findings about the long-term sustainability of management alternatives applied for more than 80 years.

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## Partial Cutting Study, Dukes Experimental Forest

By the early 1900s much of the forestland in upper Michigan and Wisconsin had been cut over and the lumber industry was reevaluating its use of the northern hardwood resource (Zon and Garver 1930). The Lakes States Forest Experiment Station of the U.S. Forest Service was established in 1923, and public foresters advocated the use of partial cutting instead of common exploitive practices such as commercial clearcutting and high grading (Rudolph 1985). Station Director Raphael Zon understood the importance of scientific forest management for maintaining production and forest integrity into the future. Although silvicultural partial cutting had a long history of use in Europe, the approach was new to the U.S. Many questions remained about its application. Zon, who had been instrumental in establishing both the research branch of the Forest Service and the first experimental forest (Price 1976, Ross 2008), had a keen interest in this subject as well as in the use of selection cutting, a form of uneven-aged silviculture, as an alternative to exploitive cutting (Zon and Garver 1930).

Research at the Dukes (also called Upper Peninsula) Experimental Forest (DEF) began in 1926 under Zon's direction. Initially established on a half-section of land donated by the Cleveland-Cliffs Iron Company, the DEF was later expanded to 5,500 acres and incorporated into the Hiawatha National Forest. The portion of the forest used for

early research was late-successional, multi-aged and dominated by sugar maple (Acer saccharum, 80%) in mixture with yellow birch (Betula alleghaniensis, 10%) and small amounts of American elm (Ulmus americana), eastern hophornbeam (Ostrya virginiana) and balsam fir (Abies balsamea) (Eyre and Zillgitt 1953). The first study – the Partial Cutting Study – included eight experimental treatments of varying intensities: reserve (uncut), diameter-limit cuttings, improvement cuttings, overmature and defective (OMD) cuttings and clearcutting. The objective was to devise a method of partial cutting that would prolong utilization of the old-growth hardwood resource while gradually converting them into managed, productive forests (Eyre and Zillgitt 1950).

A monograph describing the ecology and management of northern hardwoods was published based on the first 20 years of research at the DEF and included a recommended structure for managing uneven-aged northern hardwood stands (Eyre and Zillgitt 1953). This diameter distribution was later presented by Arbogast (1957) as a technical publication (commonly referred to as the Arbogast Guide) that served as a tool for single-tree selection silviculture in northern hardwoods. It is still used throughout the Lake States, Northeast and adjacent Canada. Specifically, Arbogast (1957) recommended creating and maintaining uneven-aged stands xwith the empirically derived, reverse-J diameter distribution and residual stocking suggested by Eyre and Zillgitt (1953) (figure 1). This residual target was based on the OMD treatments in the Partial Cutting Study at the DEF, where all overmature and defective trees were removed regardless of diameter. This treatment was believed to provide good residual growth, continuous in-growth and adequate reproduction (Eyre and Zillgitt 1953). Because growth could be harvested periodically without depleting the base structure, stands managed according to the Arbogast Guide (1957) were believed to provide sustained yield of sawtimber volume at the stand level.

Outreach and early publication of the findings from the Partial Cutting Study resulted in widespread adoption of Eyre and Zillgitt's (1953) recommendations. Memos in the Northern Research Station (Station) archives reveal that major landowners were already starting to apply the selection system over clearcutting by the mid 1930s (Kern et al. in press). The Regional Forester in the Lake States required National Forests to use single-tree selection in northern hardwood forests, and the Menominee Indian Reservation adopted selection system marking guidelines based on results from the Partial Cutting Study. Over the years, many landowners based their silvicultural handbooks on the results of this study, including but not limited to state departments of natural resources, Native American natural resource agencies, large industrial landowners, National Forests and provincial lands (Kern et al. in press). Research and management

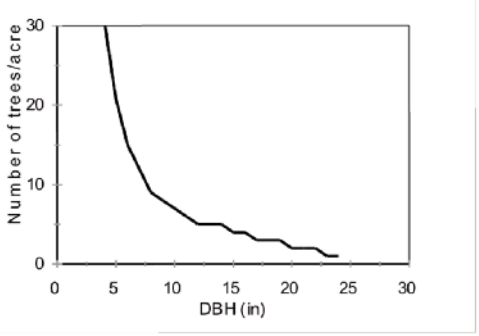



Figure 1. The diameter distribution recommended by Eyre and Zillgitt (1953) and presented as a management guide by Arbogast (1957).

based on the Arbogast Guide (1957) spread into the Northeast (Hansen 1987, Nyland 1987 and 2002) and northern New England (R. Morrill, personal communication, 2010). Moreover, the guidelines were widely used in teaching, short courses, and in extension bulletins. Through references in textbooks over the years (e.g. Westveld 1939, Hawley 1946, Davis 1954, Hawley and Smith 1954, Smith 1962, Barrett 1962, 1980 and 1995, Nyland 1996 and 2002), these guidelines have become as well-known as any work in northern hardwood silviculture.

In the 1920s, few if any large-scale silviculture experiments were replicated. Although replication was often used in early agricultural field trials (Yates 1963), the practice was uncommon in forestry research (Wakeley 1965). Advances in experimental design and statistical analyses, especially by Fisher (1925), motivated interest in applying the same set of treatments to multiple experimental units. To that end, a replicated Stocking and Cutting Cycle Study was initiated on the DEF in 1951 to test Eyre and Zillgitt's (1950, 1953) findings.

Because of changing research objectives, the Partial Cutting Study was closed following the 1966 remeasurement. This was consistent with the conditions of the original deed, which allowed the Forest Service 20 years (later expanded to 40) to return to Cleveland-Cliffs Iron a volume of timber equal to the merchantable volume standing in 1926. A 1951 memo by Zillgitt indicated that this would be accomplished by 1966; we believe this to be the case because Tubbs (1977) described the 1965 harvest in the Partial Cutting Study as "necessary… to complete (the) transaction with Cleveland-Cliffs Iron Company." The remaining studies on the DEF were closed in the 1980s (Adams et al. 2008); some of these were reopened in 2002 under a new Project Leader. We discussed the possibility of re-measuring the Partial Cutting Study during a Station silvicultural meeting in Minnesota shortly thereafter; our work to relocate the plots began in 2007.

## Lost and Found

Efforts to reopen the Partial Cutting Study would have failed except for a series of remarkable circumstances. First, because of the influence of the original study on National Forest management and the potential of the site for demonstration purposes, staff of the Hiawatha National Forest continued to apply the scheduled silvicultural treatments. Without this continuity of management and the availability of associated stand prescription and harvest documents, interpretation of long-term results would not have been possible. In addition, study plans, maps, raw data and memoranda associated with the Partial Cutting Study were still in the hands of Station scientists and National Forest managers. These files had been dispersed throughout the region as offices moved and staff relocated or retired; records were ultimately found at current and former Forest Service facilities in Marquette and Munising (MI), Grand Rapids and St. Paul (MN), Rhinelander (WI) and even in retirees' homes. While this lack of central storage is less than ideal (see Kenefic et al., this volume), most files and data were ultimately recovered. Parallel efforts in the Station to reopen closed studies at other experimental forests have been less successful (see Berven et al., this volume).

The original files and institutional knowledge from Station and National Forest retirees, the Hiawatha National Forest and DEF's local community allowed us to reconstruct the inventories and treatments of the past. Large-format sheets of inventory data were particularly useful (figure 2), although the minimum tree size that was measured changed over time and the list of species codes was lost. Careful scrutiny of decades of "Memos to the File" clarified the specifics of treatment application, including the lowering of the target residual basal area (BA) in the OMD stands after the Eyre and Zillgitt (1953) and Arbogast (1957) publications. Number, orientation and size of sample plots had been sketched (figure 3), and thousands of numbered trees spatially located (figure 4). With this information, the support of our supervisors, and volunteers from the National Forest and universities in Michigan and Minnesota, we traveled to the DEF in 2007 to reestablish and re-measure the Partial Cutting Study plots, only weeks before another cutting was scheduled by National Forest timber and contracting staff.

Difficulties of reestablishing the Partial Cutting Study sample plots cannot be overstated. Remote location and lack of on-site staff and facilities limited the time we could spend in the field, and required expensive travel for staff and cooperators. Although we had initially planned to reassign tree numbers using stem maps from the 1930s, almost none of the numbers painted on the stems were still legible. While re-measurement of some of these numbered trees may be possible in the future, the effort involved in relocating them will likely exceed available staffing and resources. Most of the permanent plot stakes (white wooden posts) had decayed and were either buried under leaf litter or missing. Careful compass and tape work was required to reestablish plot boundaries, and was facilitated by finding some of the original corner posts. In addition, although we were confident in our re-establishment of the 1.0- to 2.0-acre overstory plots, the original seedling and sapling plots had been laid out in a way that proved difficult to re-establish. We therefore installed new subplots for the measurement of small trees and regeneration (figure 5). Once the plots were established, re-measuring them and collecting tree grade information following the 2008 harvest was easier, but still required the participation of more than a dozen cooperators for timely completion (figure 6). The reference (uncut) stand, which had been damaged by a storm and salvaged in 1953, was not resampled.

Data entry and interpretation have been laborious. Fortunately, researchers recorded the minimum tree size sampled in each inventory. Unfortunately, this size varied over the course of the study, from as low as 0.5-inch diameter at breast height (dbh) in some

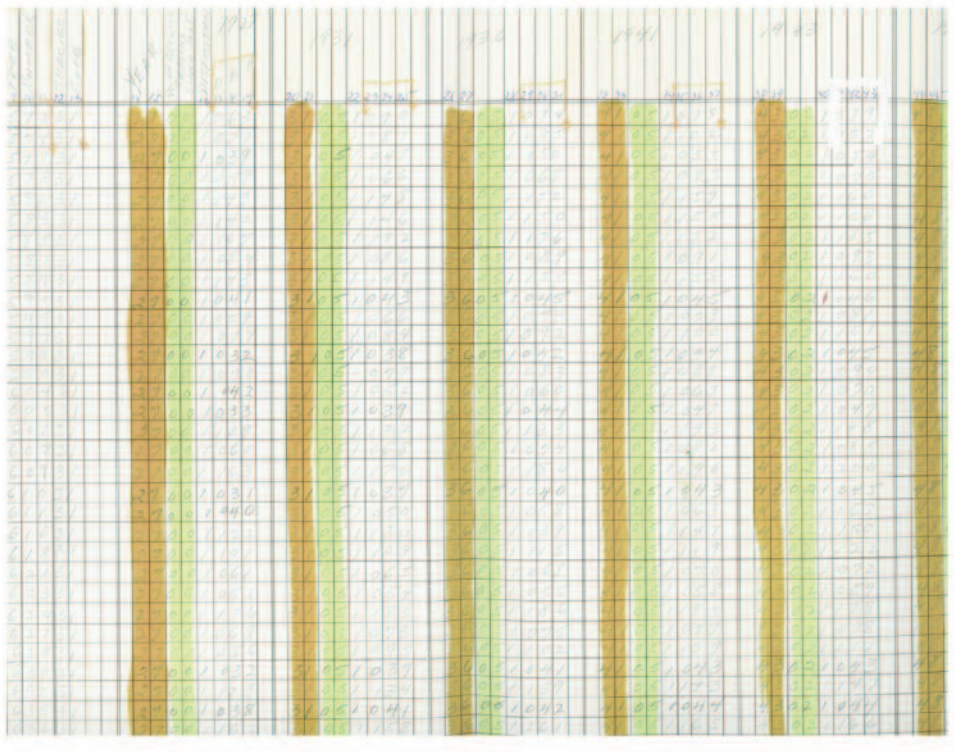
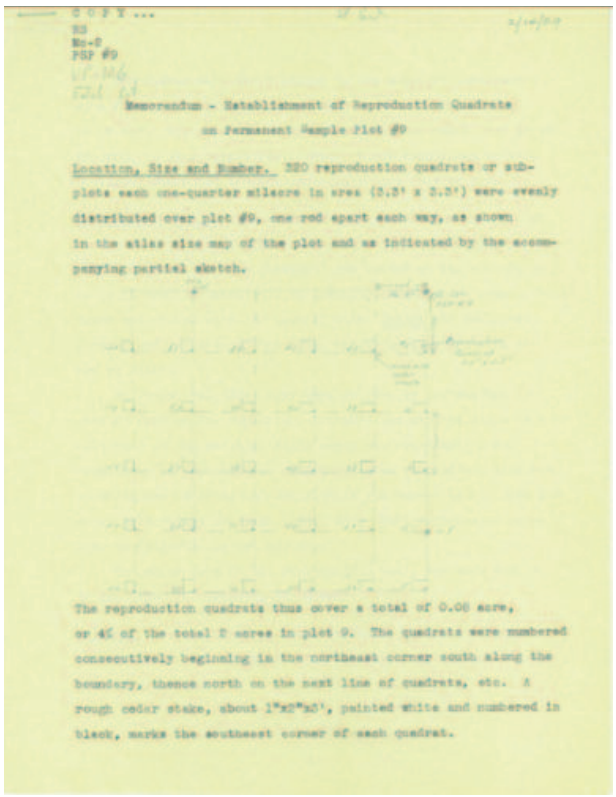


Figure 2. Portion of a data sheet from the Partial Cutting Study, 22-inch Diameter-Limit treatment at the Dukes Experimental Forest, 1926-1966. The key to species and disposition codes is missing.



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Memorandum - Establishment of Reproduction Quadrats on Permanent Sample Plot #9

Location, Size and Number. 320 reproduction quadrats or sub-plots each one-quarter milacre in area (3.3' x 3.3') were evenly distributed over plot #9, one rod apart each way, as shown in the atlas size map of the plot and as indicated by the accompanying partial sketch.

The reproduction quadrats thus cover a total of 0.00 acre, or 4% of the total 2 acres in plot 9. The quadrats were numbered consecutively beginning in the northeast corner south along the boundary, thence north on the next line of quadrats, etc. A rough cedar stake, about 1"x2"x3', painted white and numbered in black, marks the southeast corner of each quadrat.

Figure 3. Example of permanent sample plot layout in the Partial Cutting Study, Overmature and Defective #1 treatment, 1929.

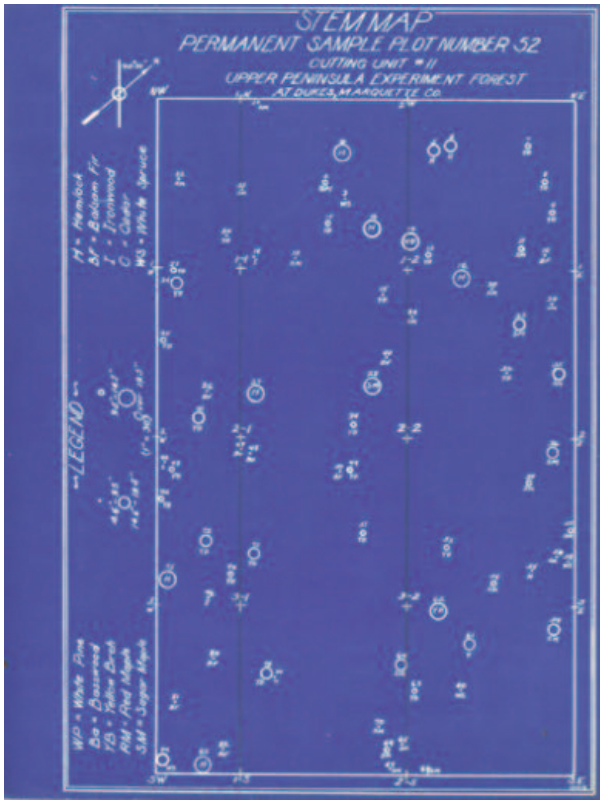


Figure 4. Example of stem map for the Partial Cutting Study, Improvement Cutting treatment, 1932.

inventories to as high as 10 inches dbh in others. As previously mentioned, species codes were recorded but the key is missing. Familiarity with the site and review of interim reports and 1950s publications helped us to identify unknown species. Lastly, the original files are historical documents – some more than 80 years old and signed by Zon himself – and need to be kept secure. Copying and transcribing these files involved many carefully arranged shipments of records from one location to another and three years (and counting) of photocopying, digital scanning, data entry and summary by student workers and technical support staff.

Even with the continuity of treatments and availability of historical records, the Partial Cutting Study would not have been reopened without our unwavering commitment to do so. We are silviculturists who, as young professionals, were mentored by scientists with a strong sense of the value of early research. Also, as part of the culture of Forest Service silvicultural experimentation we feel a responsibility to continue projects initiated by our predecessors. This tradition has been diluted by an increased proportion of grant funding for our work, which generally necessitates shorter-term studies that yield immediate results. Also, the Partial Cutting Study is un-replicated. While we recognize the limitations of this "case study" approach, such studies formed the foundation of modern silviculture and continue to generate meaningful findings. Scientists at the Bartlett Experimental Forest in New Hampshire, for example, have been prolific in generating publications and management guides based on more than 75 years of largely un-replicated stand-level experiments (e.g. see publications by Leak and others). In such cases, the length of the data record and recognized influence of early findings validate continued research. In the Partial Cutting Study, more than 80 years of data with repeated treatment applications give us a unique opportunity to evaluate the success of Eyre and Zillgitt's (1953) recommendations and Arbogast's Guide (1957), using data from the very stands that

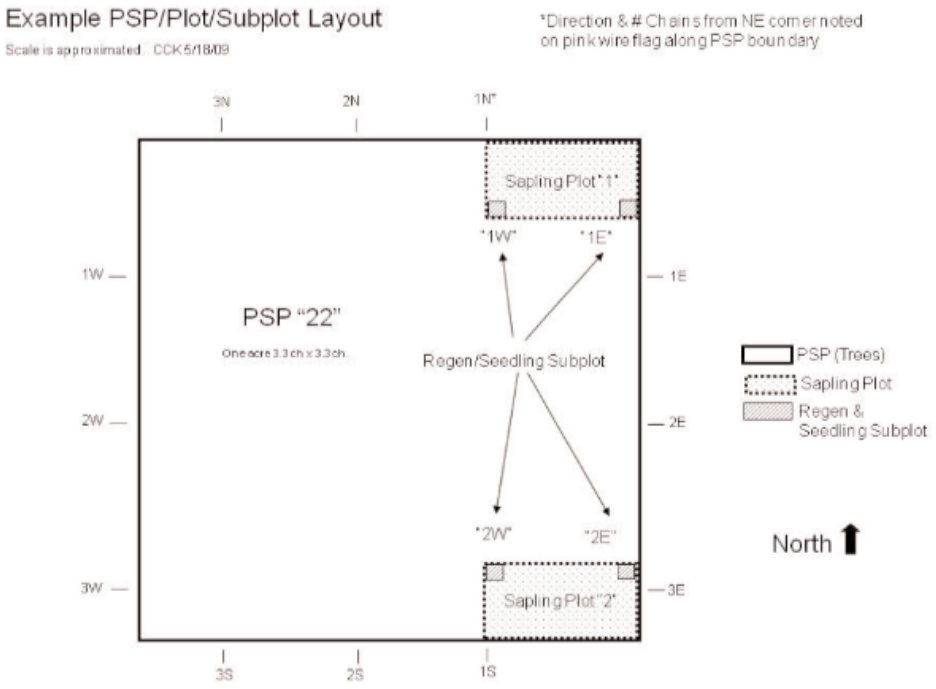


Figure 5. Example of new sample plot layout in the Partial Cutting Study, Group Selection treatment, 2007.

served as the basis for their work. Few if any other studies have as long a period of continuous assessment or degree of influence on northern hardwood management.

**New Findings**

Our efforts at the DEF Partial Cutting Study have focused on the long-term structural development and quality of the OMD stands that served as the basis for Eyre and Zillgitt's (1953) recommendations for uneven-aged silviculture in northern hardwoods, and for Arbogast's Guide (1957). In their 1953 monograph, Eyre and Zillgitt suggested that their proposed diameter distribution and residual stocking would result in a stand that "will remain thrifty and if cut at fairly short intervals (8 to 12 years) will maintain good periodic growth on a continuous basis." Tubbs (1977) investigated stand structure and composition in one of the OMD stands using data from the first 40 years of the Study, and reported that the structure was "reasonably well balanced" and that growth rates (as reflected by age-size relationships) had been improved by treatment.

The foremost question in our minds when re-measuring the Partial Cutting Study 80 years after its initiation was whether the recommended structure had been maintained by periodic cutting over the long term. Although we have not yet compiled the long-term growth data, diameter distributions reveal that Eyre and Zillgitt's (1953) recommended structure, which had limited experimental support (it was based on < 20 years of data from two <15-acre stands), was sustained, despite the fact that the cutting cycle has not been consistently 8 to 12 years as suggested in the Arbogast Guide (1957), but has varied from 10 to more than 30 years. In addition, researchers lowered the target residual BA by 25% in the 1960s; this was not reported in the literature and represents an important adjustment to the management guidelines. Nevertheless, after several selection cutting cycles, current OMD stand structures approximate the distribution proposed by Eyre and Zillgitt (1953) (figure 7).

The 2009 inventory also indicated treatment effects on tree quality. Tree grade data collected 15 years

Figure 6. A Partial Cutting Study post-harvest inventory field crew, consisting of Station researchers and support staff, National Forest staff and university volunteers, 2009. Photo courtesy of R. Nyland.

after the first harvest indicated that 59% of sawtimber trees in the OMD were Grades 1 and 2 (Eyre and Zillgitt 1953); this percentage was 71% in our recent post-harvest inventory. Comparison with one of the diameter-limit treatments (12-inch dbh removal threshold) that was inventoried at the same time shows that Grade 1 and 2 sawtimber decreased from 43% in 1943 to 25% in 2009. These findings support Eyre and Zillgitt's (1953) observation that their recommended management approach produced "good growth on sound, thrifty trees," and that such an approach is preferable to exploitive harvesting. Future research will focus on structural development in all eight cutting treatments, along with regeneration dynamics, tree species composition and growth and yield.

## Conclusion

One of the most remarkable aspects of this story is that the Hiawatha National Forest continued treatments even after researchers closed the Partial Cutting Study. This is a testament to the high value our partners and cooperators place on historic research and the silvicultural recommendations that it provided. Because there were few publications from the study after the Eyre and Zillgitt (1953) monograph, the amount of information that could be gleaned from the literature was limited. Important data about stand dynamics, records of harvest dates and intensities of cutting, and information that could suggest revisions to the original guidelines exist only in the study files. Our predecessors preserved those files and the information essential to continuing the research in the Partial Cutting Study. We are fortunate to have the opportunity to reevaluate one of the oldest and most influential northern hardwood silviculture studies, and to be part of the remarkable and continuing story of the Partial Cutting Study at the DEF.

## Acknowledgements

We thank the scientists and staff of the Northern Research Station (previously the Lakes States Forest Experiment Station, North Central Forest Experiment Station and North Central Research Station) and Hiawatha National Forest who maintained the research and outreach legacy at the DEF over the decades. In particular, we are indebted to Gus Erdmann, Terry Strong, Al Saberniak and Tim Baker for providing institutional knowledge and guidance about the Partial Cutting Study between the 1970s and the present, a period that was largely un-documented in the files. We thank John Brissette and Brian Palik for their support of our time and travel. We appreciate technical assistance provided by John Bennink, and assistance with field work provided by the National Forest System and students from the Michigan Technological

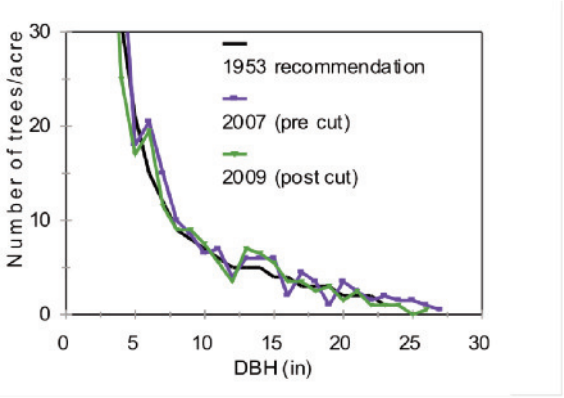


Figure 7. The pre- and post-cut diameter distributions (2007 and 2009) of one of the OMD stands in the Partial Cutting Study, and Eyre and Zillgitt's (1953) recommendation.

University and University of Minnesota. We thank Ralph Nyland for his assistance with data collection and technology transfer during our 2009 field season. Helpful reviews of an earlier version of this paper were provided by Ralph Nyland, Grant Domke and Lloyd Irland. This project is funded by the Northern Research Station in cooperation with the Hiawatha National Forest.

**References**

Adams M.B., L. Loughry and L. Plaugher. 2008. Experimental forests and ranges of the USDA Forest Service. General Technical Report NE-321 revised. U.S. Department of Agriculture, Forest Service. Northeastern Research Station. 178 p.

Arbogast, C., Jr. 1957. Marking guides for northern hardwoods under the selection system. Station Paper 56. U.S. Department of Agriculture, Forest Service. Lake States Forest Experiment Station. 20 p.

Barrett, J.W., editor. 1962. Regional Silviculture of the United States. The Ronald press Company. New York, NY. 610 p.

Barrett, J.W., editor. 1980. Regional Silviculture of the United States (Second Edition). John Wiley & Sons, Inc. New York, NY. 551 p.

Barrett, J.W., editor. 1995. Regional Silviculture of the United States (Third Edition). John Wiley & Sons, Inc. New York, NY. 643 p.

Davis, K.P. 1954. American Forest Management. McGraw-Hill Book Company, Inc., New York, NY. 482 p.

Eyre, F.H and W. M. Zillgitt. 1950. Size-class distribution in old-growth northern hardwoods twenty years after cutting. Station Paper 21. U.S. Department of Agriculture, Forest Service. Lake States Forest Experiment Station. 15 p.

Eyre, F.H. and W.M. Zillgitt. 1953. Partial cuttings in northern hardwoods of the Lake States: twenty-year experimental results. Technical Bulletin 1076. U.S. Department of Agriculture, Forest Service. Lake States Forest Experiment Station. 124 p.

Fisher, R.A. 1925. Statistical methods for research workers. Oliver and Boyd Ltd., Edinburgh.

Hansen, G.D. 1987. Choosing diameter distribution to aid in marking uneven-aged northern hardwood stands. In: Managing Northern Hardwoods. Edited by: R.D. Nyland. Miscellaneous Publication 13, Society of American Foresters Publication 87-03. State University of New York College of Environmental Science and Forestry. Syracuse, NY: 95-112.

Hawley, R.C. 1946. The Practice of Silviculture (Fifth Edition). John Wiley & Sons, Inc., New York, NY. 354 p.

Hawley, R.C. and D.M. Smith. 1954. The Practice of Silviculture (Sixth Edition). John Wiley & Sons, Inc., New York, NY. 525 p.

Kern, C.C., G. Erdmann, L. Kenefic, B. Palik and T. Strong. In press. Development of the selection system in northern hardwood forests of the Lake States: an 80-year silviculture research legacy. In: Research Trajectories in Forest Ecology, Management and Silviculture. Edited by: R. Crawford, D. Hayes and S. Stout. Department of Agriculture, U.S. Forest Service. Washington, D.C.

Nyland, R.D. 1987. Selection system and its application to uneven-aged northern hardwoods. In: Managing Northern Hardwoods. Edited by: R.D. Nyland. Miscellaneous Publication 13, Society of American Foresters Publication 87-03. State University of New York College of Environmental Science and Forestry. Syracuse, NY: 49-80.

Nyland, R.D. 1996. Silviculture: Concepts and Applications. McGraw-Hill, New York, NY. 633 p.

Nyland, R.D. 2002. Silviculture: Concepts and Applications (Second Edition). McGraw-Hill, New York, NY. 682 p.

Price, R. 1976. History of Forest Service Research in

the Central and Southern Rocky Mountain Regions, 1908-1975. General Technical Report RM-27. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 100 p.

Ross, A.T. 2008. Peeling back the bark. Exploring the collections, acquisitions, and treasures of the Forest History Society. Forest History Society. Accessed April 6, 2010. http://fhsarchives.wordpress.com/2008/12/01/december-1-1874-a-red-star-is-born/.

Rudolph, P.O. 1985. History of the Lake States Forest Experiment Station. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 290 p.

Smith, D.M. 1962. The Practice of Silviculture (Seventh Edition). John Wiley & Sons, New York, NY. 578 p.

Tubbs, C.H. 1977. Age and structure of a northern hardwood selection forest, 1929-1976. Journal of Forestry 75 (1): 22-24.

Wakeley, P.C. 1965. The less obvious problems of nursery stock production. In: Proceedings of the Nursery Soil Improvement Sessions. 25-28 January 1965. Edited by: A.L. Leaf. State University of New York College of Forestry. Syracuse, NY: 77-92

Westveld, R.H. 1939. Applied Silviculture in the United States. John Wiley & Sons, Inc., New York, NY. 567 p.

Yates, F. 1964. Sir Ronald Fisher and the design of experiments. Biometrics 20(2): 307-321.

Zon, R. and R.D. Garver. 1930. Selective logging in the northern hardwoods of the Lake States. Technical Bulletin 164. U.S. Department of Agriculture, Forest Service. Lake States Forest Experiment Station. 47 p.

# Long-term Silvicultural & Ecological Studies

## Results for Science and Management: Volume 2

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January 2013
GISF Research Paper 013

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