MANAGING STANDS OF MIXED NORTHERN CONIFERS: 40-YEAR RESULTS FROM THE PENOBSCOT EXPERIMENTAL FOREST

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Abstract

This long-term experiment in Maine was designed to provide information on the best silvicultural practices for managing stands of mixed northern conifers in northeastern North America. We evaluated growth and yield and changes in species composition, quality, and structure during the first 40 years of the experiment. Replicated treatments include the selection system, uniform shelterwood, unregulated harvesting, and diameter-limit cutting. The new cohort established under three-stage shelterwood was subsequently left untreated or precommercially thinned. Between-treatment differences in net volume growth were not significant ($\alpha = 0.10$), though gross volume growth differed managed vs., unmanaged, selection vs. shelterwood, and shelterwood vs. diameter-limit treatments. The three-stage shelterwood method with precommercial thinning 10 years following final overstory removal resulted in good control of hardwoods and hemlock and a large increase in the proportion of spruce and fir. The selection system on a 5-year cutting cycle resulted in an increase in hemlock, spruce, and fir, with a decrease in hardwood species. If the primary goal were production, even-aged management would most likely be preferred. We recommend two-stage shelterwood as applied in this experiment with some modification to improve species composition and stand quality. Stand quality (proportion of stand volume in cull trees) and species composition were influenced by treatment.

Introduction

The experiment reported here represents a half-century of effort by a number of USDA Forest Service researchers. This report covers the first 40 years of the study representing about one-half of a sawtimber rotation for even-aged red spruce (*Picea rubens* Sarg.) stands in the northeastern U.S. At the time that this experiment was established, there were thousands of hectares of clear-cut and partially cut stands of mixed northern conifers in the northeastern US cut primarily for their spruce and fir timber. Westveld (1953) proposed an approach to managing these forests based on ecological principals advocating the selection system as the preferred option in most spruce-fir stands. Heavily influenced by Westveld's ideas, this study was designed to provide information on the best silvicultural practices for managing operable and developing stands of mixed northern conifers. Our analysis was based on an experiment established from 1952 to 1957 on the Penobscot Experimental Forest (PEF) in east-central Maine.

This report evaluates volume growth and yield, changes in species composition, quality, and to a limited extent, structure of mixed northern conifer stands managed under eight different silvicultural techniques for a period of 40 years. The study experiment primarily was designed to study treatments applied to operable stands. However, precommercial thinning was applied to a portion of the new stand resulting from one of the treatments. The main hypothesis tested was that growth and yield was affected by treatment. Changes in species composition and stand quality and structure were examined but not subject to statistical testing.

Materials And Methods

Site Description

The 1619-ha Penobscot Experimental Forest is located near Bangor, ME. The treatments were installed on approximately 170 ha located in the northern half of the PEF. The PEF is located in the Acadian Forest, an ecotone between the eastern broadleaf and boreal forests. Mixed northern

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conifers dominate the PEF, including mostly red spruce, balsam fir (*Abies balsamea* (L.) Mill.), eastern hemlock (*Tsuga canadensis* (L.) Carr.), northern white-cedar (*Thuja occidentalis* L.), and eastern white pine (*Pinus strobus* L.). The most common hardwoods are red maple (*Acer rubrum* L.) and paper birch (*Betula papyrifera* Marsh.). The predominant cover types on the research compartments were red spruce-balsam fir and eastern hemlock (Eyre 1980). The study area is predominantly spruce-fir flat, characterized by thin, shallow, often wet soils. The research compartments were mostly classified as somewhat poorly to poorly drained and mediocre in productivity.

Long-term Study

Replicated treatments, established from 1952 to 1957 include the selection system on 5- (S05), 10- (S10), and 20-year (S20) cutting cycles, uniform shelterwood with two- (SW2) and three-stage (SW3) overstory removals, unregulated harvesting (URH), and two variations of diameter-limit cutting, fixed limits (FDL) and modified limits (MDL). The new stand established under three-stage shelterwood was subsequently left untreated or precommercially thinned (SW3p). The experiment also included an unmanaged natural area (NAT). A network of 307 systematically located permanent points (with random start) was established. Measurements were taken before and after each cutting treatment and approximately every 5 years following each harvest. Species, DBH, and condition were recorded on plots. Volume, cull volume, basal area, growth, number of trees, mortality, species composition, and diameter distribution were determined from the plot data. Yield was calculated as the difference between pre- and post-harvest inventories. Each compartment was managed as a unit and commercially logged by an independent logging contractor. Volume growth was the principal concern of the study. One-way analysis of variance was used to test the hypothesis of no difference between treatment means for net volume growth, gross growth, accretion, ingrowth, and mortality. A series of planned comparisons of treatment means for net and gross volume were part of the statistical analysis. Details of the study can be found in Sendak et al. (2003).

Results and Discussion

The ANOVA of net volume growth indicated no difference between treatment means (Table 1). Gross volume growth for the MDL and NAT treatments was greater than that for the SW3p and SW3 treatments. Pairwise comparisons between similar treatments (i.e., the two diameter limits, three selection treatments, and three shelterwood treatments) showed no differences between treatment means.

For accretion in volume, there was a significant difference between the two extremes: MDL with the greatest accretion and SW3 with the least (Table 1). For ingrowth, there was a difference between SW2 with the greatest ingrowth and SW3p and SW3 with the least. For mortality, there were no significant differences between treatment means. Differences between treatment yields from the harvested compartments were not significant ($\alpha = 0.10$). Overall mean harvested volume for the study was 171.7 m^3 ha^{-1}, which does not include the zero harvest in NAT.

Average annual net growth in volume on the PEF based on 40-year data was 2.6 ± 0.2 m^3 ha^{-1}. The results indicated that the average of all treatments on the PEF was statistically the same as what might be expected regionally, 2.9 ± 0.1 m^3 ha^{-1}, in natural extensively managed stands (Safford 1968). For the first 40 years of the experiment, harvests have been of trees that were there before 1950. In most treatments, they have been removed in two or three cuttings, but for some, like S10 and S05, removals were extended through several cuttings during the period. The next few cycles of cuts (in 5 to 20 years) in most treatments will probably be the first to harvest trees regenerated during the experiment. Future comparisons of net growth may show that some treatments will achieve greater net growth in volume. This is especially true for the even-aged treatments.

Table 1.—Average annual growth in volume (m^3 ha^{-1} yr^{-1}) by components and treatment in order of decreasing net growth for trees >11.4 cm DBH.

Treatment	Accretion	Ingrowth	Gross growth	Mortality	Net growth
S05	3.21ab	0.58ab	3.79ab	0.40	3.40
MDL	3.64a	0.62ab	4.27a	0.99	3.27
FDL	3.12ab	0.73ab	3.85ab	0.80	3.05
S20	3.06ab	0.48ab	3.54ab	0.74	2.79
S10	3.02ab	0.69ab	3.71ab	0.99	2.72
SW2	2.30ab	0.86a	3.16ab	0.63	2.52
SW3p	2.32ab	0.34b	2.66b	0.40	2.25
SW3	2.10b	0.41b	2.51b	0.41	2.09
URH	2.29ab	0.67ab	2.96ab	0.95	2.01
NAT	3.56ab	0.21ab	4.08a	2.49	1.59

Note: Means followed by the same letter within a column are not significantly different by Tukey method ($\alpha = 0.10$). Means in columns with no letters are not significantly different. S05, 5-yr selection; MDL, modified diameter-limit; FDL, fixed diameter-limit; S20, 20-yr selection; S10, 10-yr selection; SW2, two-stage shelterwood; SW3p, three-stage shelterwood with precommercial thinning; SW3, three-stage shelterwood; URH, unregulated harvest; NAT, natural area.

After 40 years, the experiment represents about half a sawtimber rotation for an even-aged stand in the Acadian Forest. As the even-aged stands regenerated in the shelterwood treatments begin to mature, questions about commercial thinning strategies need to be answered. Are specified *BDq* goals in the uneven-aged treatments still appropriate or do they need to be revised? What is the best way to control hemlock reproduction to decrease the proportion of hemlock?

If production were the primary goal of management, some form of even-aged management would most likely be preferred. A recommendation, based on analysis of the treatments in this experiment so far, would be two-stage shelterwood as applied on the PEF, but with the addition of removing all remaining trees >5-6 cm DBH during the final overstory harvest to eliminate competition from overtopping residual trees. Precommercial thinning should also be considered as the new stand develops, depending on density and species composition objectives. The treatment should result in good to excellent control of species composition and percentage of cull volume, which would have a positive effect on revenue. The cost to apply this treatment would be moderate compared with the other treatments. If favoring spruce over fir was an important management objective, removing the overstory in more than two cuts, and thereby releasing the new cohort more slowly, may be worthwhile.

Literature Cited

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