Reference Stands for Silvicultural Research: A Maine Perspective

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Silvicultural experiments should have untreated stand replicates in which development can be tracked over time. Unfortunately, field studies are seldom ideal. This article is one of six in this issue addressing experimental controls. Our focus is the Penobscot Experimental Forest (PEF) in Maine, where a 55-year-old experiment in northern conifer silviculture has an unreplicated, somewhat atypical control. The identification of stands that represent desired endpoints or natural states is another consideration and may be difficult if based on rare conditions. Big Reed Forest Reserve and Maine's Ecological Reserve System are discussed as possible benchmarks for management on the PEF and serve as examples of the opportunities and challenges associated with the identification of benchmark ecosystems.

Keywords: silviculture, experimental control, old-growth, benchmark, reserve

Silviculture is the art and science of managing forests for desired outcomes. These outcomes are myriad and range from biodiversity maintenance to timber production. Within this context, treatments or harvests are the tools that foresters use to achieve their goals. Silvicultural treatments often are modeled after natural disturbances. Knowledge about the stand development patterns of unmanaged forests thus is important to the development of effective sequences of treatments or systems.

However, there are substantial gaps in our knowledge. In particular, information is needed about ecosystem response to natural and harvesting disturbances, acknowledging inherent differences between the two. Long-term and large-scale perspectives are important because trees live a long time and the return interval between natural disturbance events at any one location may be quite long. Both factors constrain the rate of change in forested ecosystems. Thus, it is imperative that silvicultural research encompass large spatial and temporal scales and that adequate controls are identified.

In 2003, a technical session at the Society of American Foresters' National Convention in Buffalo, New York focused on the topic of experimental controls. We were asked to discuss challenges associated with defining controls for long-term silvicultural research in our region (for other perspectives, see Asbjornsen et al., Dibble and Rees, Goebel et al., and Stephens and Fulé, this issue). This article reviews the control associated with a 55-year-old experiment on the Penobscot Experimental Forest (PEF) in Maine and explores the challenges associated with identifying benchmarks for the unmanaged condition.

Experimental Controls

There are numerous controls that can be used in silvicultural experiments. One of the simplest is preharvest or pretreatment inventory, which allows pair-wise comparisons (pretreatment versus posttreatment) for a given stand. Although this provides a temporally restricted view of the untreated condition, it usually is better than inferring preharvest conditions from untreated stands in a retrospective study. A second type of control is untreated replicate stands. Here, a stand intended for treatment is paired with a similar stand that remains untreated and, if monitored through time, allows differences to be attributed to treatment. These are better than a single pretreatment inventory because they provide information about stand development and natural disturbances in the absence of management. The ideal silvicultural experiment would combine these two types of controls, including randomization of plot locations and treatment allocations, with adequate replication and long-term monitoring. Such studies are quite uncommon. A third type of control, which has appeared more recently in the literature, is provided by old-growth forests, which often are assumed to be benchmarks to which management activities can be compared.

Study Area

This study was conducted in the Acadian region, which stretches from Maine into eastern Canada. The Acadian forest is an ecotone between the eastern broadleaf and boreal forests. Species composition is diverse and common species include spruce (*Picea* spp., especially *Picea rubens* Sarg.), eastern hemlock (*Tsuga canadensis* [L.] Carr.), balsam fir (*Abies balsamea* [L.] Mill.), and northern white-cedar (*Thuja occidentalis* L.) in combination with other softwoods and hardwoods such as red maple (*Acer rubrum* L.), American beech (*Fagus grandifolia* L.), birch (*Betula* spp.), and aspen (*Populus* spp.). Natural disturbances are predominantly small scale, resulting in mortality of single or few trees, with periodic disturbances of higher severity, such as cyclic outbreaks of the spruce budworm (*Choristoneura fumiferana* Clemens). The return interval for natural stand-replacing disturbances in this re-

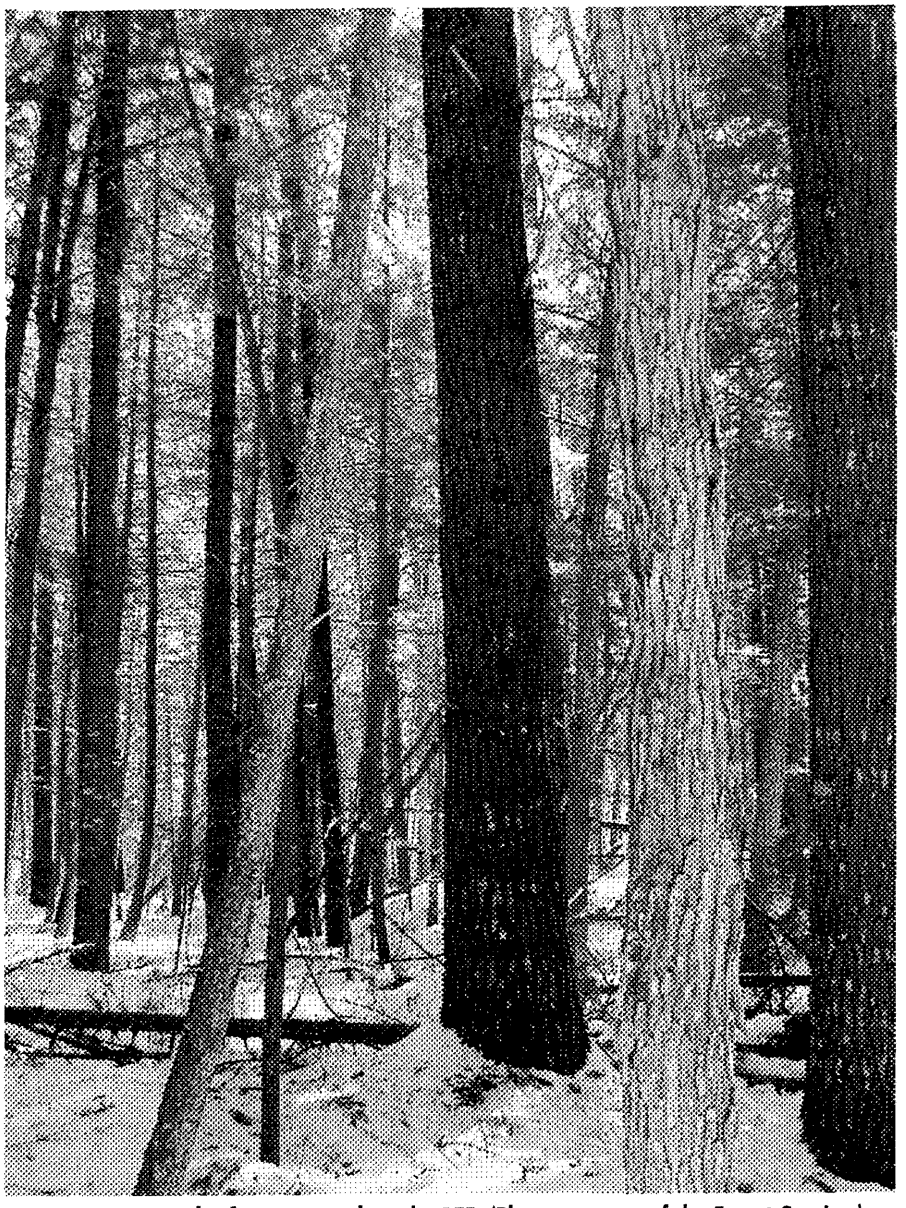

Figure 1. Untreated reference stand on the PEF. (Photo courtesy of the Forest Service.)

gion can exceed 1,000 years (Lorimer 1977) but varies considerably with forest type and topographic position (Lorimer and White 2003).

The PEF occupies approximately 4,000 ac in central Maine. It was purchased in 1950 by a number of pulp and paper and landholding companies and leased to the USDA Forest Service, Northeastern Research Station, for a long-term silvicultural study. Ownership transferred to the University of Maine in 1994 but the Forest Service retained control of its research areas. The largest study is the 600-plus-ac silviculture experiment, which began in 1950 and provides more than 50 years of data.

The objective of the PEF experiment was to determine the effects of silvicultural treatment on a number of response variables, including growth and yield, species composition, growing stock quality, stand structure, and regeneration. Treatments include even-aged silviculture (uniform shelterwood with two- and three-stage overstory removal, with and without precommercial thinning), uneven-aged silviculture (5-, 10-, and 20-year single tree and group selection cutting), and exploitative cuttings (fixed and flexible diameter-limit and commercial clearcutting or unregulated harvest). Each treatment is replicated twice at the stand level with an average stand size of 25 ac. Data are collected before and after every harvest and at 5-year intervals between harvests for regeneration and numbered trees larger than 0.5 in. dbh on permanent inventory plots. Thus, treatment application and data collection are unusually intensive.

Interpreting the Data

The PEF experiment provides an excellent example of the usefulness, and limitations, of controls. The experiment includes an untreated or "natural" area, which is used as a control for the entire study (Figure 1). Spruce composition (percentage of basal area [BA] for trees more than 0.5 in. dbh) in years 0 (pretreatment) and 45 of the experiment in the 20-year selection stands (Figure 2) suggests that selection cutting resulted in an increase in the proportion of spruce. A decline in the percentage of spruce in the untreated area during the experiment supports this conclusion. Without the untreated area, it would be difficult to determine if the changes during the last 50 years in the selection stands were due to natural disturbance (which is not precluded from the experiment), stand development, succession, or periodic harvest.

Unfortunately, the inventoried untreated area is not replicated, which complicates statistical analysis. It was not originally included in the experimental design but was instead designated a natural area and, fortunately, inventoried on the same schedule as the treated stands. Furthermore, the stand chosen to represent the untreated condition is somewhat atypical in drainage and composition. For example, the percentage of eastern white pine (*Pinus strobus* L.) in year 0 of the experiment was higher in the untreated area (20%) than in the areas used for the partial harvest treatments (less than 5% each; Figure 3). This suggests meaningful differences in site or disturbance history.

Additionally, the PEF untreated area, like the rest of the forest, was repeatedly partially harvested before the 20th century. Although no harvests are believed to have been conducted between 1900 and the initiation of the experiment in 1950, the forest was used for many purposes before that time. In fact, a water-powered sawmill was located on the site in the late 1700s and likely motivated harvesting of timber throughout the forest. Although never cleared for agriculture, there is evidence of cutting throughout the property, as well as fencing and homesteading in some areas. Thus, although the untreated area serves as an index of what

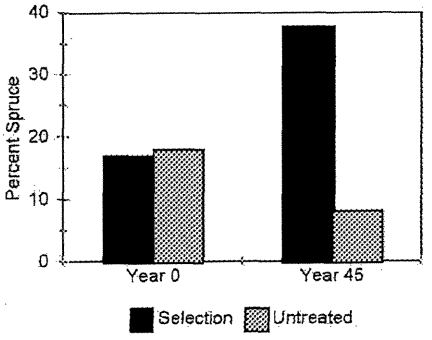

Figure 2. Spruce composition of the selection cut and untreated areas on the PEF.

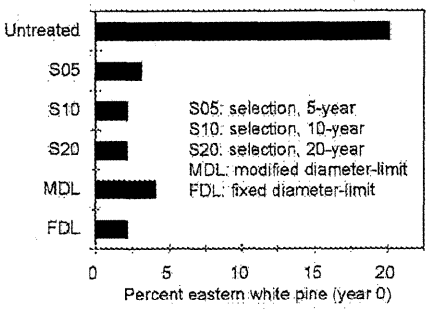

Figure 3. Pretreatment eastern white pine composition in the silvicultural experiment on the PEF.

may have happened between 1950 and the present without management, it does not indicate what an unmanaged stand would look like.

Reference Conditions

What constitutes an appropriate reference condition, benchmark, or desired future condition? One possible answer is old-growth forests. However, their use depends in part on the answers to the following questions:

- Do they exist on sites comparable with those being treated?
- Are they large enough to allow natural disturbance processes?
- Is the historical range of variation in disturbance history, composition, and structure known?

One example of a potential benchmark or reference condition for the PEF silviculture study is the Big Reed Forest Reserve (Figure 4). This 5,000-plus-ac old-growth forest in northern Maine is owned by The Nature Conservancy. It has diverse topography and composition ranging from forested wetlands to ridge hardwoods and includes many of the stand and site types on which forestry is practiced in northern Maine. University of Maine researchers have been studying Big Reed for nearly 10 years and have amassed data on composition and structure, dead wood, and disturbance history.

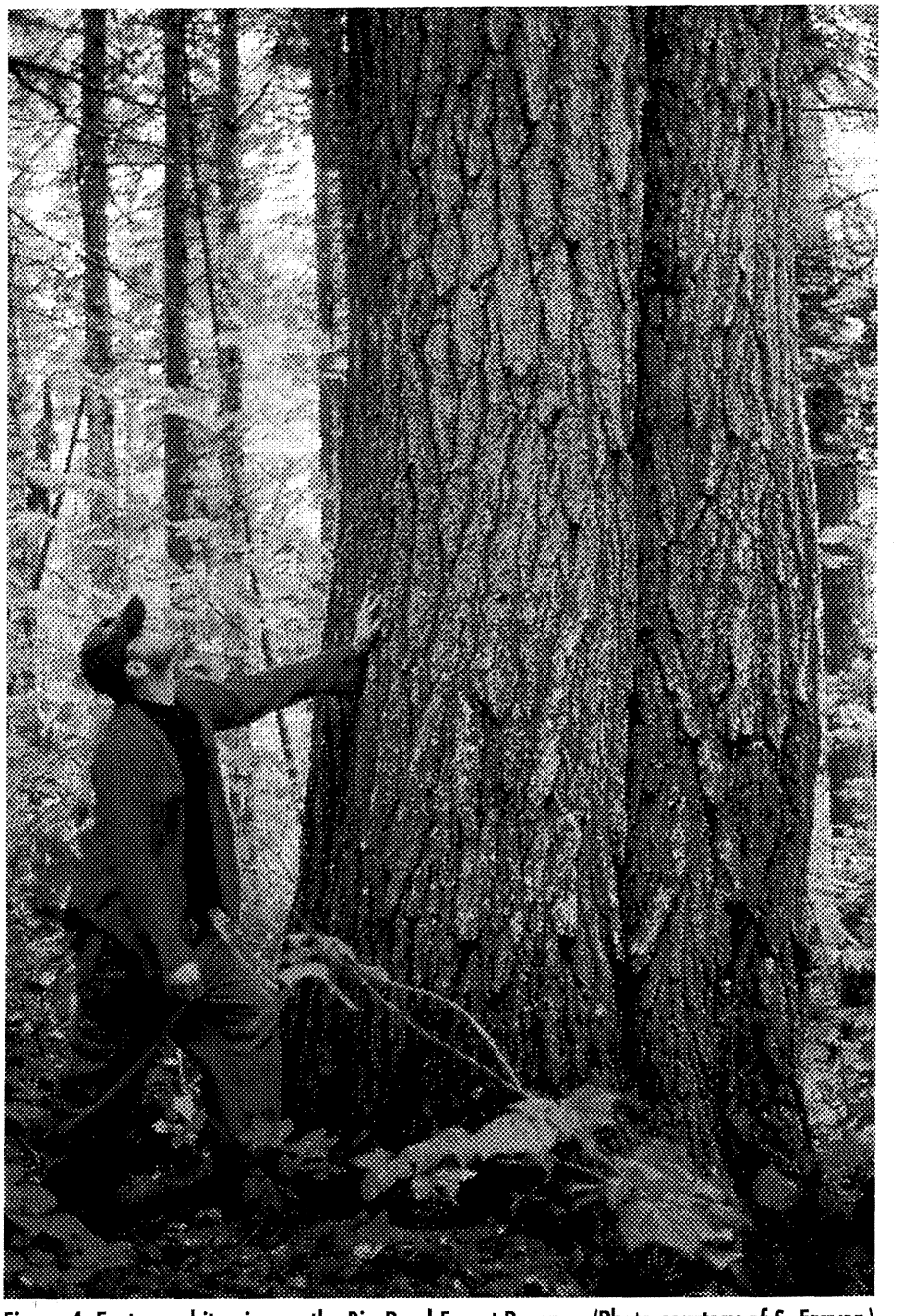

Figure 4. Eastern white pine on the Big Reed Forest Reserve. (Photo courtesy of S. Fraver.)

Maine's Ecological Reserves serve as another source of reference conditions. In 2000 the Maine legislature created the system of Ecological Reserves on the state's public lands. According to the enabling legislation, the purposes of the Reserves include serving "as a benchmark against which biological and environmental change may be measured, as a site for ongoing scientific research, long-term environmental monitoring, and education." The Reserves were established as one initiative of the Maine Forest Biodiversity Project, a collaborative effort of landowners, researchers, and environmental groups interested in exchanging and promoting information on biodiversity in Maine's working forests. Fifteen tracts totaling more than 77,000 ac have been designated, with individual Reserves ranging

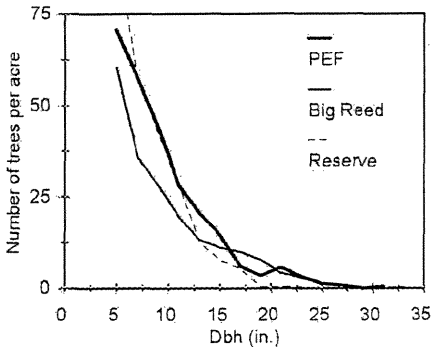

Figure 5. Comparison of current diameter distributions in the PEF untreated area, Big Reed mixed wood stands, and Ecological Reserve mixed wood plots.

from 750 to more than 11,000 ac. Most of these lands were acquired from private companies that had managed them for timber production, and many areas were subsequently harvested by the state before they were designated as Reserves. Reserves also include substantial acreage that burned in the past century. Although the Reserves are scattered throughout the state, they contain a disproportionate amount of inoperable land such as steep slopes, alpine areas, and wetlands.

A long-term Ecological Reserve Monitoring Plan has been developed with the joint goals of (1) measuring change over time and (2) comparing Reserves with managed forests. To date, 179 permanent plots have been established by the Maine Natural Areas Program on six of the Reserves.

Data Comparisons

Density and diameter distribution data serve as examples of valuable comparisons that can be made between the PEF, Big Reed, and Ecological Reserve data. Figures 5 and 6 compare Big Reed data (calculated as the mean of 21 plots in mixed wood stands) and Ecological Reserve data (from 63 mixed wood plots) with that from the inventoried untreated area on the PEF. Note the similarity in the shape of the diameter distribution, although maximum tree size is lower in the Ecological Reserves than in the PEF untreated area or Big Reed, likely because of more recent management. There appear to be more small trees on the PEF and Ecological Reserves (Figure 5), a conclusion supported by stem density data (Figure 6a). This may be due to a large portion of the PEF untreated area and Ecological Reserves that remain in the stem exclusion stage of development, i.e., without the canopy gaps that are associated with reductions in overstory stem density. BA also is higher in the PEF untreated area (Figure 6b), perhaps for the same reason, but more likely due to an intense windstorm that affected many of the Big Reed mixed wood stands in 1983 and the past harvesting and fire history of Ecological Reserves.

Other Considerations

Although the foregoing data provide useful examples of the types of comparisons that can be made, the range of variation in time and space also must be considered. At Big Reed we only have composition and structure data to address the latter. The stem density and BA data provide us with an example (Figure 6, vertical lines show the range of variation among sample plots, i.e., stands). The unreplicated natural area on the PEF falls within the range of variation at Big Reed and may represent densities and stockings included within old-growth mixed wood. It is interesting that the range of data from Ecological Reserves is greater than that found in Big Reed, and is likely due to the greater variety of Ecological Reserve stand

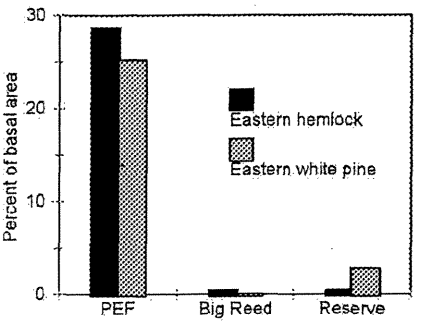

Figure 7. Eastern hemlock and eastern white pine composition of the PEF untreated area, Big Reed mixed wood stands, and Ecological Reserve mixed wood plots.

types, histories, and locations. We do not have sufficient data to compare the full range of conditions across all sites.

The distance between study areas must be considered. Big Reed, approximately 110 miles northwest of the PEF, is the best large-scale example of old-growth in the state. The six Ecological Reserves referenced in this study range from eastern to northern Maine, with some sites more than 150 miles from the PEF. Consequently, there are differences in latitude, elevation, biophysical zone, distance from maritime influence, and species abundance. For example, the current percentages of eastern hemlock and eastern white pine in the Big Reed and Ecological Reserve mixed wood stands are very low compared with the PEF natural area (Figure 7). These compositional differences between the sites potentially have important impacts on stand dynamics, disturbance regime, and response to treatment. Thus, it is especially important to choose reference stands that are comparable with the treated areas in as many parameters as possible. Although this may seem obvious, there is always the temptation to use the most complete reference data available, even if those references are not entirely appropriate.

It is also important to recognize that old-growth stands and the type of stands represented in the Maine Ecological Reserves serve as quite different types of references, even if site conditions and other parameters match well with a treated stand. Properly chosen, old-growth stands and their range of variation provide examples of what type of stand a treated site might have supported in the absence of significant human influence since European settlement. In contrast, if Ecological Reserve stands and treated stands were paired on the basis of a similar human history of disturbance and

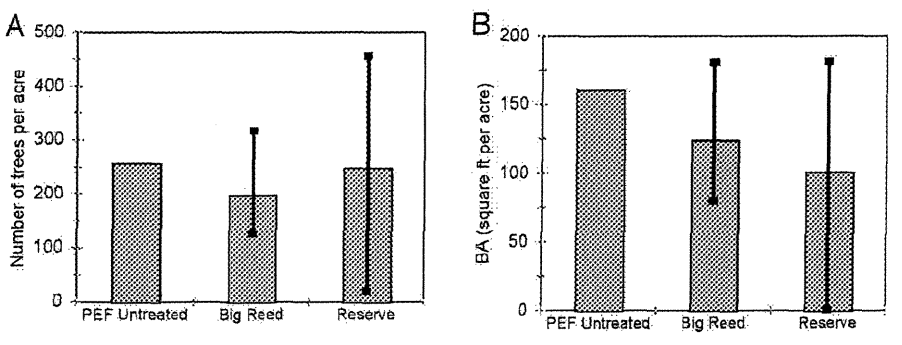

Figure 6. (a and b) Mean stem density, BA, and range of variation in the PEF untreated area (n = 1), Big Reed mixed wood stands (n = 21), and Ecological Reserve mixed wood plots (n = 63).

followed in parallel over time, the Reserve stands might better reflect how a treated stand would have developed if left untreated. This is in essence an untreated replicate with the benefit of existing in an already-protected Reserve. This example illustrates the importance of specifying the role the reference stand is to play in the silvicultural experiment; one or both could have a place.

Summary

There are different types of controls or reference conditions, including preharvest inventory, untreated replicates, and benchmark conditions. We feel it takes more than one kind of control to evaluate adequately silvicultural treatments. Additionally, both mean condition and range of variation are important considerations. These include temporal and spatial variation and necessitate a large-scale, long-term perspective to evaluate optimally silviculture treatments. We are fortunate to have excellent data from more than 600 ac for more than 50 years on the PEF and are well on the way to building a similar database at Big Reed and the state's Ecological Reserves. Understanding the histories of human and natural disturbance on control sites is critical to evaluating the appropriateness of those sites as references. Despite the limitations of the controls discussed in this paper, we are fortunate to have more information for a longer period than most studies provide.

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