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Seventy-Year Record of Changes in the Composition of Overstory Species by Elevation on the Bartlett Experimental Forest

William B. Leak and Mariko Yamasaki

Abstract

Remeasurements over a 70-year period (1931-1932 to 2002-2003) on 404 cruise plots on the Bartlett Experimental Forest in New Hampshire provided a record of landscape-level changes in the composition of overstory species over time by elevation and d.b.h. (diameter at breast height) classes. Typically, early to mid-successional species declined while late successional species, especially hemlock, increased. The exception was at upper elevations (2,000 feet and higher), where natural wind disturbance maintained a variable component of paper and yellow birch. There is no evidence of species decline or migration that is inconsistent with natural succession or natural disturbance.

The Authors

WILLIAM B. LEAK is a research forester, and MARIKO YAMASAKI is a research wildlife biologist, with the USDA Forest Service's Northern Research Station at Durham, New Hampshire.

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Cover Photo

Upper, Middle, and Lower Haystack Mountains on the Bartlett Experimental Forest. Photo by U.S. Forest Service.

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INTRODUCTION

Over the past several centuries, the forests of New England have been subjected to many threats and disturbances including heavy timber harvesting and fires coupled with possible environmental threats such as acid rain, climate change, and nutrient depletion (Leak 2009). Long-term information on the forest resource can be used to evaluate these disturbances. In 1931-1932, a systematic series of about 500 cruise plots (mostly ¼-acre) was established on the Bartlett Experimental Forest in central New Hampshire (Fig. 1). Elevations on these plots ranged from about 600 to 2,700 feet. All trees 1.5 inches in diameter breast height (d.b.h.) and larger were tallied by species. Remeasurements were made in 1939, 1991-1992, and 2002-2003, and subsets of the plots were measured in the 1950s and 1960s.

The Bartlett Experimental Forest, an area of 2,600 acres when the cruise plots were established, consists of three elevation zones that vary in history, management activity, and site conditions. Most of the lowest zone, about 600 to 1,100 feet, was cleared around 1890 for railroad fuel and limited agriculture; some softwood stands were left intact. The soils consist of water-worked granitic material supporting red maple/beech types along with imperfectly drained basal till supporting softwoods (hemlock, red spruce, and some balsam fir[1]). This lower zone has received partial harvests associated with a study of growth related to stand density as well as some group/patch harvests and one shelterwood cut (these heavier cutover areas were eliminated from this analysis).

[1] Common and scientific names of all trees listed in this report can be found in the Appendix on page 12.

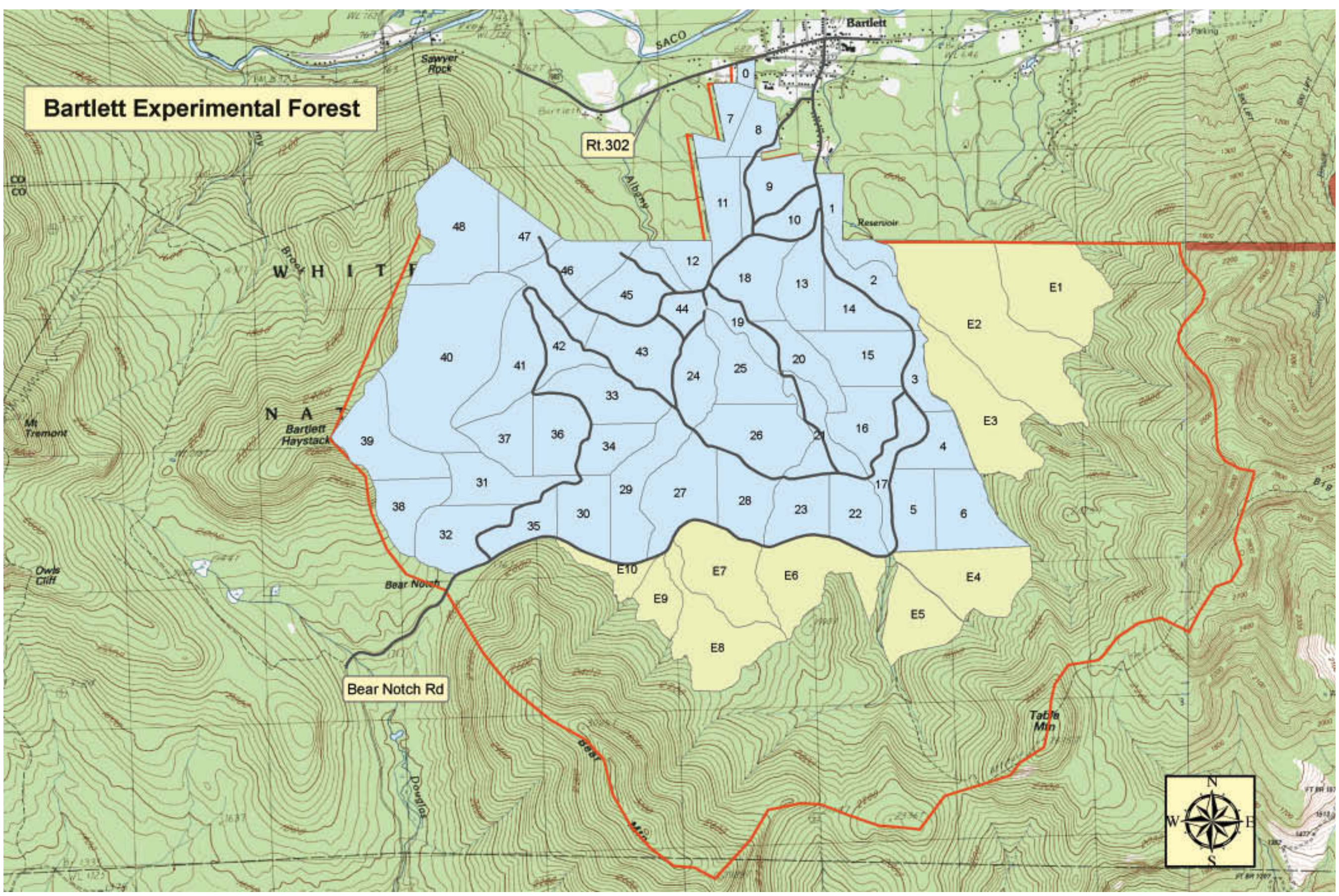

Figure 1.—Location and compartments. Original compartments are in blue; managed expansion area compartments are in pale yellow.

The middle zone, ranging in elevation from about 1,100 to 1,800 feet, may have received light partial harvests for the best softwoods before 1900, but this area never was cleared. Much of the middle zone was harvested by single-tree selection one to three times between the 1950s and early 1990s. The soils are mostly fine tills supporting typical mature/old-growth northern hardwoods. Some areas of softwood (hemlock with some spruce) are associated with heavily washed materials along the drainages. Clearcuts and shelterwoods since the 1980s were omitted from this analysis.

The upper zone, 1,900 to 2,900 feet (available cruise plots up to 2,700 feet), is unmanaged except for some light harvests at the lower extremes. Some of the best softwoods might have been removed before 1900. Much of this area is shallow to bedrock supporting spruce with some fir and very few hemlock, though there are pockets of fine till with a stronger hardwood component. A few small areas of shallow bedrock, facing southerly, support some red oak and white pine.

The plot information has been analyzed for various purposes (Jensen 1941a; Filip et al. 1960; Leak 1961a, b; Leak and Smith 1997) including estimates of growth rates and changes in species composition. Understory changes (trees 1.5 to 4.5 inches in d.b.h.) between 1931-1932 and 2002-2003 were analyzed to determine whether there were measurable effects of climate change. Results showed that understory hemlock, a climatically limited species, was not replacing red spruce at upper elevations (1,900+ feet) (Leak 2009). These two species occupy similar sites apart from the elevation difference. The conclusion was that climate change was having no effect on species distribution in the Bartlett Experimental Forest or adjacent regions.

This analysis addresses spatial and temporal changes in overstory species composition by elevation class. It shows which species/size classes are increasing or declining, and suggests reasons for these changes based on numerous research studies on the Forest. Comparisons are at the landscape scale and include unmanaged and lightly managed stands, except at upper elevations, i.e., the upper unmanaged zone.

METHODS

The cruise plots were laid out in 1931-1932 on a regular grid of 5 by 10 chains. Nearly all were square ¼-acre plots with a very few of 1/10-acre. All trees 1.5 inches and larger in d.b.h. were tallied by species and 1-inch d.b.h classes. All remeasurements followed the same procedure. The most recent complete remeasurement (2002-2003) included marking dead trees with three axe marks. This allows recognition of new dead trees during each ensuing remeasurement as well as an estimation of periodic mortality.

The number of trees per plot by species and 1-inch d.b.h. classes was recorded from the original tally sheets; live trees tabulated as defective were included. The original tally sheets were faded but mostly legible. The trees per plot then were tallied from the electronic records available from the 2002-2003 survey. Plot records from recently regenerated areas and records that seemed flawed (no understory, excess numbers of trees, etc) were eliminated, leaving 404 plots comprising 47.3, 37.0, and 16.0 acres in the low, middle, and upper elevation zones, respectively. Elevation per plot (100-foot classes) was determined from a base map showing both contours and the plot grid. Numbers of trees by 100-foot interval were summarized by species and d.b.h. groups: 5 to 10 inches, 11 to 16 inches, and 17+ inches. Species composition (percent of trees) was calculated by d.b.h group, 100-foot elevation class, and year (designated 1932 and 2003). Species composition in Figs. 2-27 is based on number of trees by d.b.h. group and elevation class. For example, in Figure 2, 37 percent beech in the 5- to 10-inch d.b.h. class at an elevation of 1,150 feet in 2003 means that beech comprises 37 percent of the stems in that size class relative to the stems of all other species. Note that the vertical scale varies among the figures.

RESULTS AND DISCUSSION

Beech

Over the 70-year period, beech poletimber (5 to 10 inches, Fig. 2) increased or maintained its composition at all elevations but was most predominant between about 1,200 to 2,000 feet where it attains a maximum composition of nearly 40 percent. Above that point, spruce-fir becomes the predominant type. Below 1,200 feet (in the low elevation zone) species such as eastern hemlock, eastern white pine, red maple, and paper birch predominate. These areas, underlain with water-worked soils and compact till, are less suitable for northern hardwoods. This trend with elevation is similar in the larger d.b.h. classes (Figs. 3 and 4). The 11- to 16-inch stems maintained an essentially constant composition over time, while the larger stems generally declined, no doubt due to the combined effects of the beech scale-Nectria disease and the timber-sale marking of defective/risky beech. However, 17+-inch beech increased somewhat at 2,000+ elevations where there was little or no management. Composition of the larger beech at mid-elevations maintained at about 30 to 40 percent. Long-term results on one managed compartment, harvested three times beginning in 1952, showed a minor decline in the proportion of beech from 53 percent basal area in 1952 to 49 percent in 2000. But there were increases in the proportion of sawtimber-size trees and significant increases in quality, indicating that management can produce a healthy, productive component of beech despite the beech-bark disease (Leak and Sendak 2002).

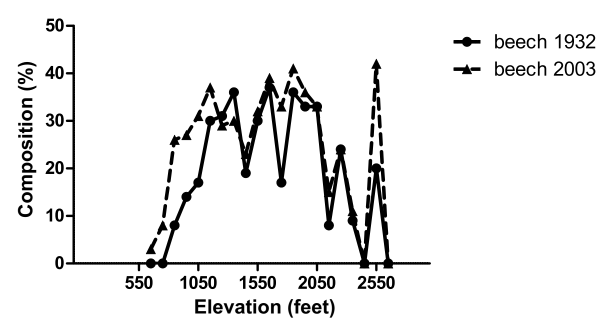

Figure 2.—Percent composition of 5- to 10-inch beech in 1932 and 2003 by elevation.

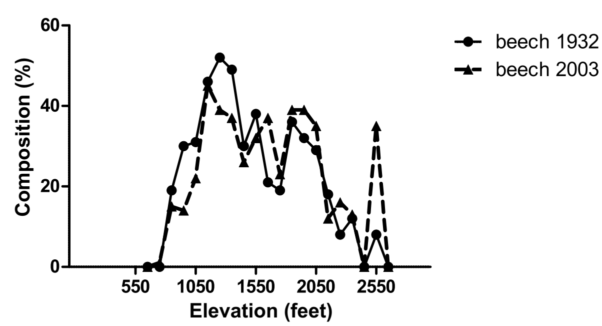

Figure 3.—Percent composition of 11- to 16-inch beech in 1932 and 2003 by elevation.

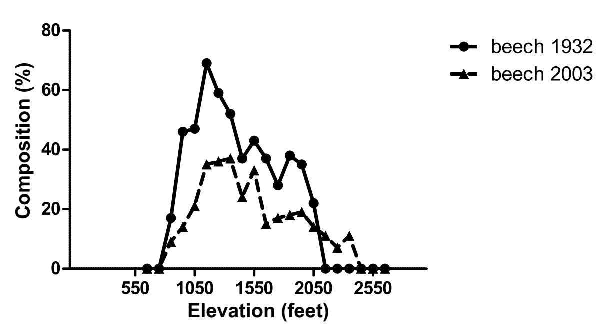

Figure 4.—Percent composition of 17+-inch beech in 1932 and 2003 by elevation.

Yellow Birch

Composition of 5- to 10-inch yellow birch declined appreciably over time at and slightly above mid-elevations (1,000-2,000 feet) from about 25 percent to about 10 percent (Fig. 5). Smaller stems of this mid-successional species are beginning to decline due to a lack of regeneration openings. Yellow birch will be reduced to a minor component without regeneration openings provided by timber harvests or intense natural disturbance. However, at elevations above 2,000 feet, pole-size yellow birch is maintaining its composition (though in variable fashion) due to the heavy natural disturbance that characterizes these shallow-bedrock, higher elevation sites (see Jensen 1941b for details on the 1938 hurricane). Apparently, yellow birch, and paper birch in some areas, can be considered components of the upper elevation, late successional forest due to their continued maintenance by natural disturbance (Leak 1975). Larger stems have maintained at 10 to 20 percent or slightly declined in composition at mid-elevations (Figs. 6 and 7). However, the composition of these larger stems will decline over time due to lack of ingrowth from smaller trees. Again, note the positive effects of natural disturbance on 11- to 16-inch stems coupled with a loss in the 17+-inch class at upper elevations.

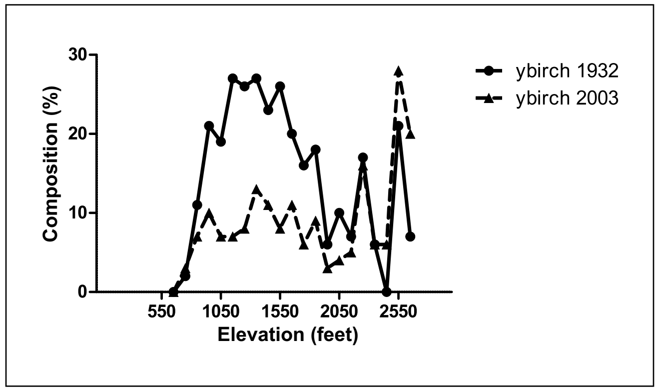

Figure 5.—Percent composition of 5- to 10-inch yellow birch in 1932 and 2003 by elevation.

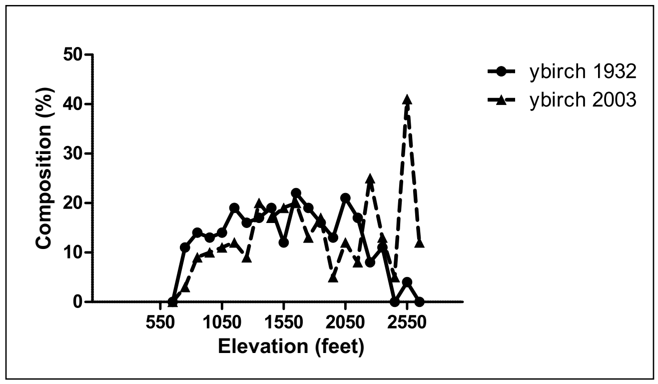

Figure 6.—Percent composition of 11- to 16-inch yellow birch in 1932 and 2003 by elevation.

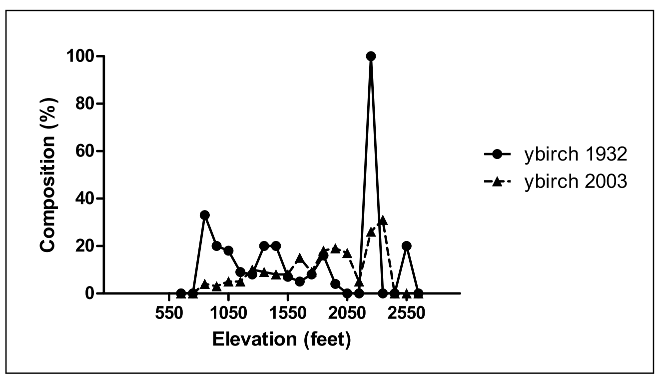

Figure 7.—Percent composition of 17+-inch yellow birch in 1932 and 2003 by elevation.

Sugar Maple

Somewhat similar to yellow birch, sugar maple shows a decline in 5- to 10-inch composition (down to about 5 percent) over much of the midrange (Fig. 8). Although a tolerant, late successional species, there is some evidence that regeneration of sugar maple in this region is aided by disturbance (Leak 2005). This may be true especially on poorer soils derived from low-nutrient, granitic bedrock. An earlier study based on 101 cruise plots in mid-elevation compartments treated with single-tree selection showed a decline (about 50%) in sugar maple understories (2-, 3-, and 4-inch trees) between 1931-1932 and 1991-1992 in compartments harvested once, but only a minor decline in compartments harvested twice; increases in beech understories were moderate to slight, respectively. There were major increases in hemlock and especially in striped maple (Leak 2006).

The 11- to 16-inch sugar maple stems, though variable in percent composition, appear to maintain at about 15 percent. The 17+-inch stems show increases over time, some to nearly 50 percent, apparently replacing the larger beech (Figs. 9 and 10). However, stems in both of these larger classes decreased at the highest elevations due to intense natural disturbance. There seems no evidence of the decline in maple that has been of concern farther west (Horsley et al. 2002). However, regeneration and continued ingrowth of sugar maple is the primary concern in maintaining this species.

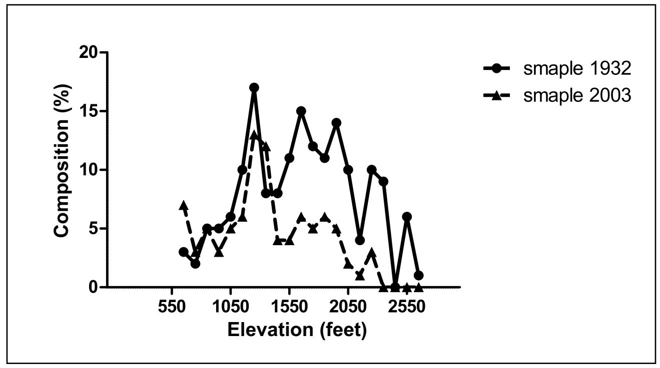

Figure 8.—Percent composition of 5- to 10-inch sugar maple in 1932 and 2003 by elevation.

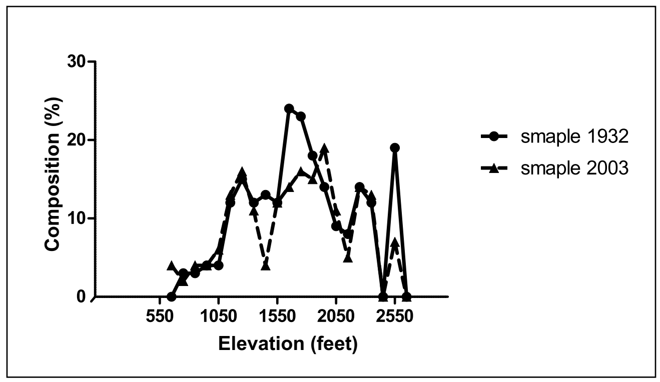

Figure 9.—Percent composition of 11- to 16-inch sugar maple in 1932 and 2003 by elevation.

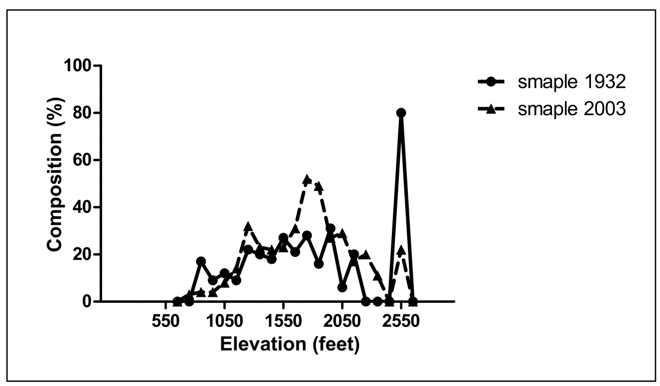

Figure 10.—Percent composition of 17+-inch sugar maple in 1932 and 2003 by elevation.

Red Maple

Apparent increases in red maple in the eastern United States have caused concern (Alderman et al. 2005), though this species is much more marketable in recent years. Red maple of all sizes at the Bartlett Forest maintains a composition of about 30 percent at elevations below about 1,000 feet (Figs. 11-13). Some of the heavily water-worked or compact soils are conducive to softwood species, and red maple is a common associate in softwood types. At the middle and upper elevations, this species maintains a moderate composition (about 10 percent). Moderate proportions of 5- to 10-inch stems at these elevations indicate that red maple probably will not increase appreciably in the future.

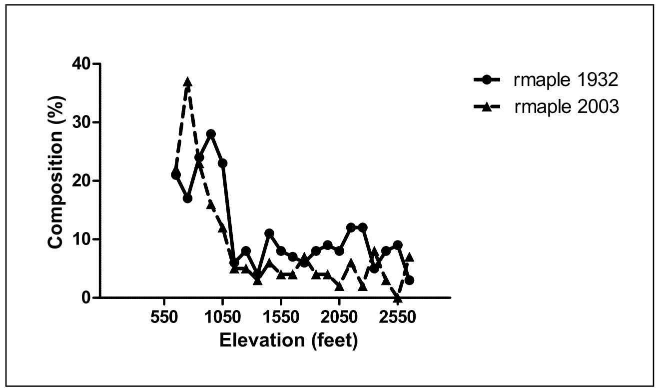

Figure 11.—Percent composition of 5- to 10-inch red maple in 1932 and 2003 by elevation.

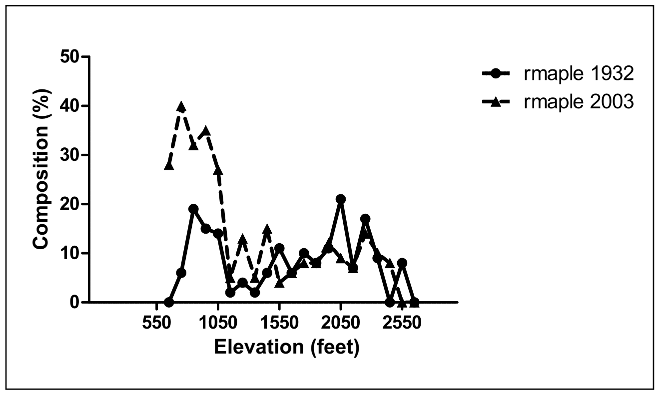

Figure 12.—Percent composition of 11- to 16-inch red maple in 1932 and 2003 by elevation.

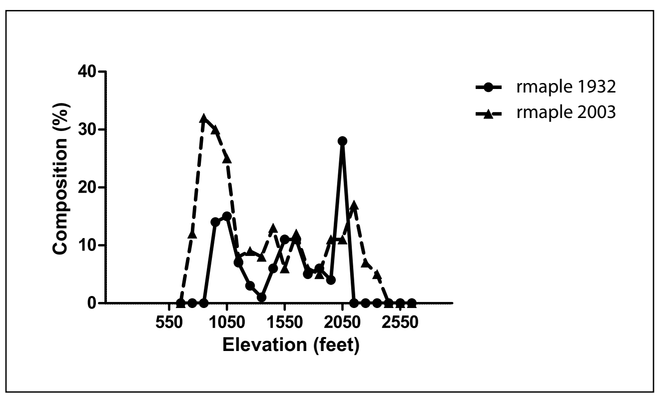

Figure 13.—Percent composition of 17+-inch red maple in 1932 and 2003 by elevation.

Paper Birch

An early-successional species, paper birch declined to less than 5 percent in all size classes at mid-elevations. There was less decline in trees larger than 5 to 10 inches in d.b.h. at elevations below about 1,000 feet, where there are younger stands; and there was appreciably less decline on sites at upper elevations due to continued natural wind disturbance (Figs. 14-16). Similar to yellow birch, paper birch remains a component of upper elevation spruce-fir stands (Leak 1975). Over time and without management, only areas at these upper elevations will have a significant component of paper birch.

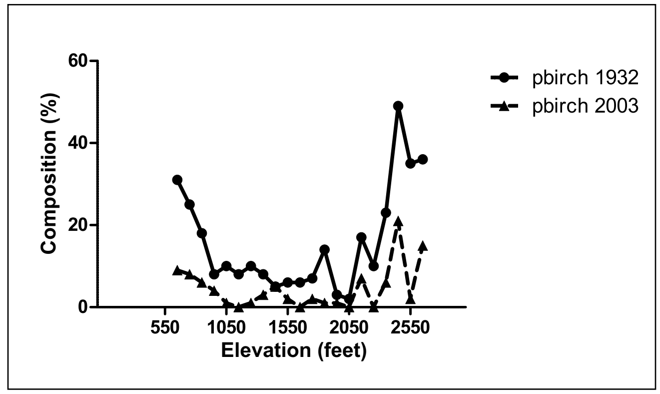

Figure 14.—Percent composition of 5- to 10-inch paper birch by in 1932 and 2003 by elevation.

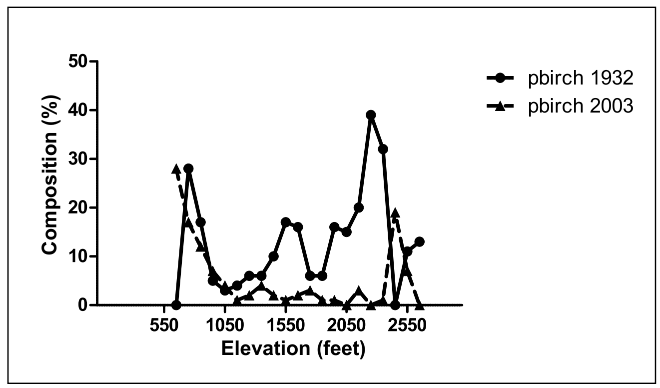

Figure 15.—Percent composition of 11- to 16-inch paper birch by elevation in 1932 and 2003.

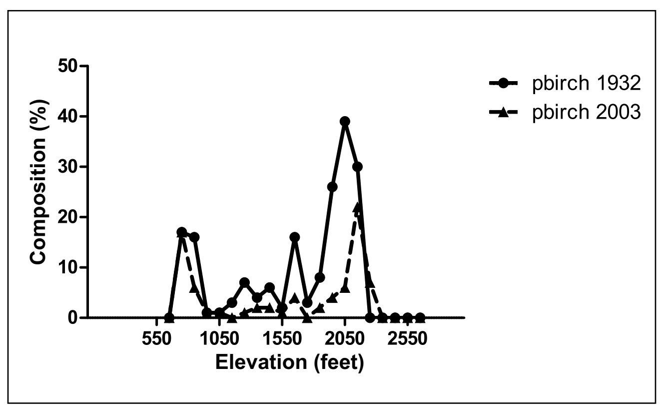

Figure 16.—Percent composition of 17+-inch paper birch in 1932 and 2003 by elevation.

Aspen

Aspen once accounted for as much as 30 percent of the 5- to 10-inch class at low elevations and about 9 percent of the 11- to 16-inch class (Figs. 17 and 18). By 2003, aspen was virtually absent from the lightly managed or unmanaged areas except for an ephemeral component of 11- to 16-inch trees at low elevations. Unlike the birches, aspen is not a component of the naturally-disturbed stands at upper elevations.

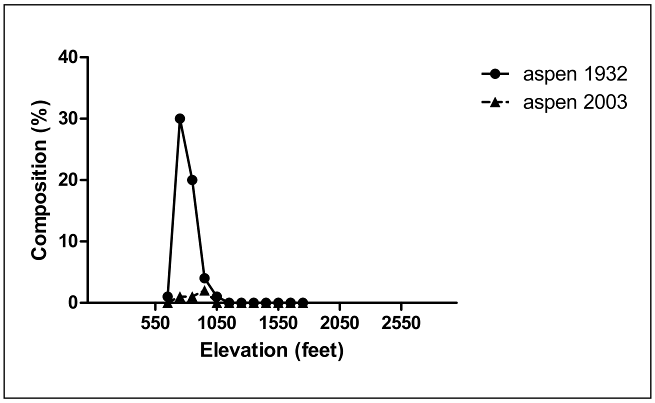

Figure 17.—Percent composition of 5- to 10-inch aspen in 1932 and 2003 by elevation.

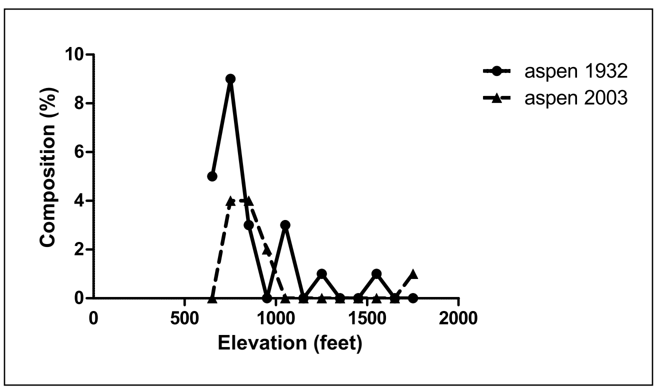

Figure 18.—Percent composition of 11- to 16-inch aspen in 1932 and 2003 by elevation.

Red Spruce and Eastern Hemlock

Except for an increase in the 5- to 10-inch trees on softwood sites at low elevations, the upper elevations remain a stronghold for red spruce where it accounts for more than 50 percent in all sizes despite variability due to natural disturbance (Figs. 19-21). Eastern hemlock, which grows on similar soils as red spruce (e.g., shallow bedrock) is increasing rapidly at lower elevations, but is nearly absent in the small and medium classes at elevations above 2,000 feet (Figs. 22 and 23). The small component of larger hemlock above 2,000 feet apparently is not being replaced (Fig. 24).

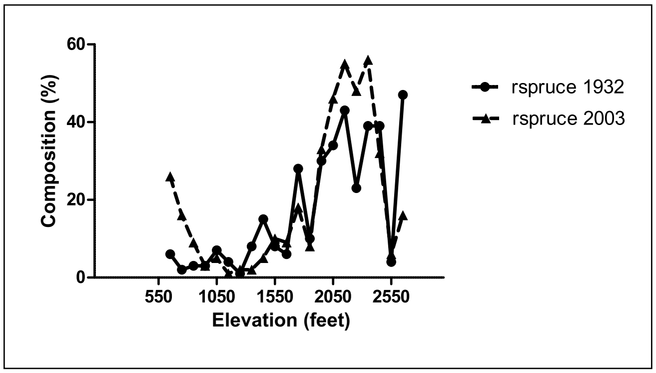

Figure 19.—Percent composition of 5- to 10-inch red spruce in 1932 and 2003 by elevation.

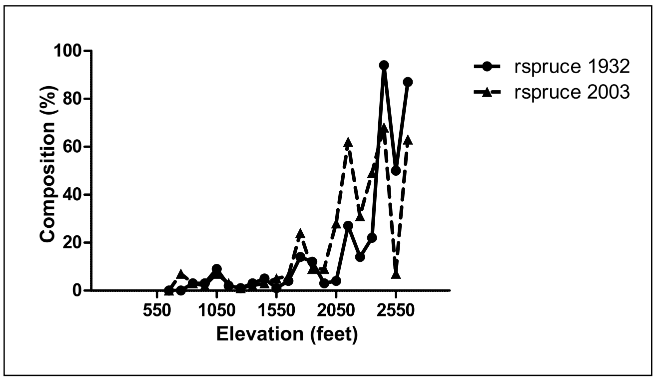

Figure 20.—Percent composition of 11- to 16-inch red spruce in 1932 and 2003 by elevation.

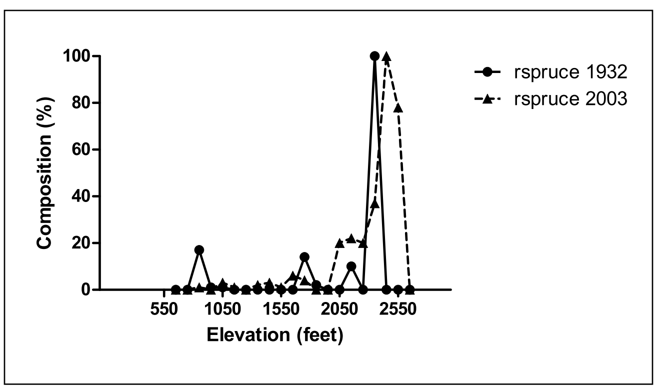

Figure 21.—Percent composition of 17+-inch red spruce in 1932 and 2003 by elevation.

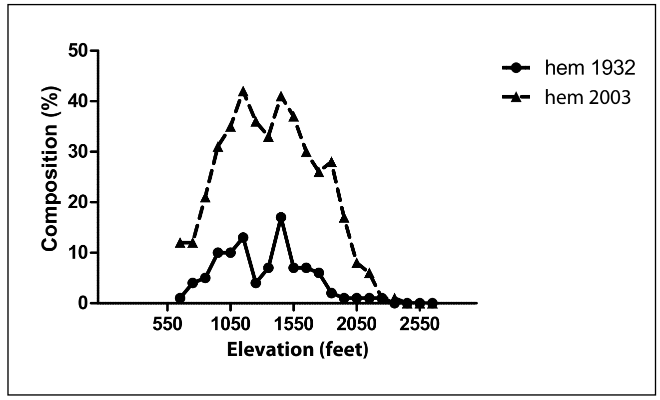

Figure 22.—Percent composition of 5- to 10-inch hemlock in 1932 and 2003 by elevation.

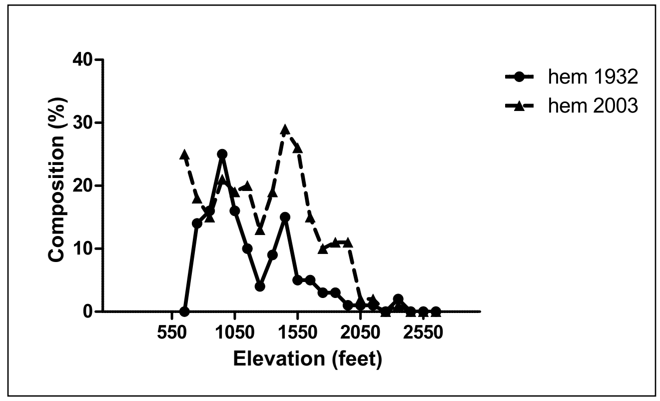

Figure 23.—Percent composition of 11- to 16-inch hemlock in 1932 and 2003 by elevation.

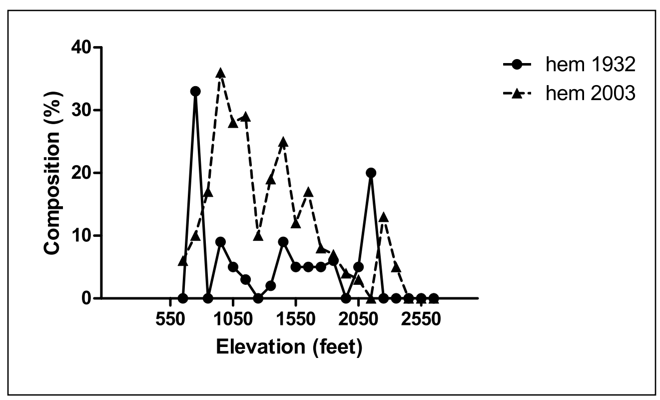

Figure 24.—Percent composition of 17+-inch hemlock in 1932 and 2003 by elevation.

Eastern White Pine and Northern Red Oak

Eastern white pine remains a major component of the 17+-inch stems at the lowest elevations (Fig. 27), but there have been moderate to substantial declines in smaller trees over time (Figs. 25 and 26). Early clearing and perhaps agriculture, are responsible for the presence of white pine. Without such disturbances, this species should decline over time and be replaced by hemlock and some spruce on softwood sites, and by red maple/beech on sandy tills. Of interest is the continued presence of a small component of white pine, especially in the 17+-inch class, at higher elevations along with a small amount of northern red oak. These species are common in small numbers on shallow bedrock, often on slightly southerly/westerly-facing slopes. Regeneration is minimal. It may be that historical fires are responsible for their presence.

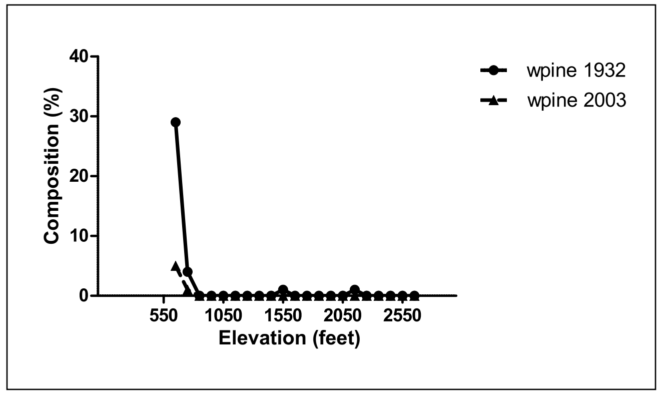

Figure 25.—Percent composition of 5- to 10-inch white pine in 1932 and 2003 by elevation.

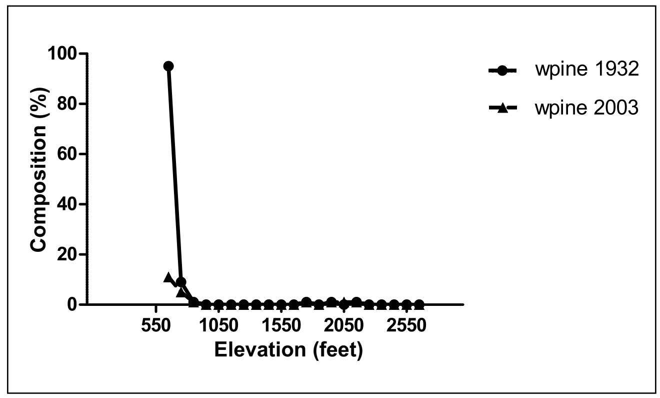

Figure 26.—Percent composition of 11- to 16-inch white pine in 1932 and 2003 by elevation.

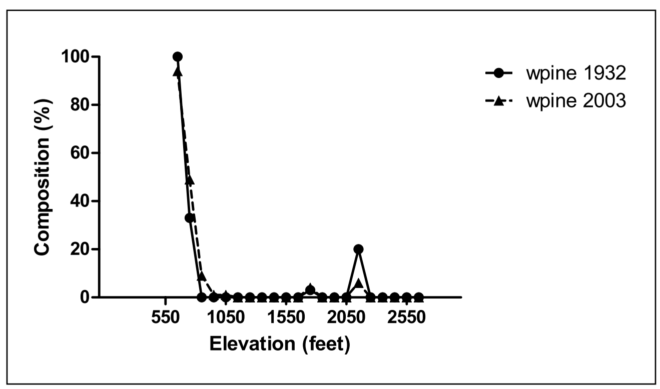

Figure 27.—Percent composition of 17+-inch white pine in 1932 and 2003 by elevation.

CONCLUSION

This 70-year analysis of changes in species composition over time by elevation class reveals fairly typical changes due to natural selection and natural disturbance. Generally, early to mid-successional species declined while late successional species, such as hemlock, increased. However, there were exceptions: 1) at elevations above about 2,000 feet, paper and yellow birch are maintained by natural wind disturbance; 2) hemlock, a rapidly increasing species at low to mid-elevations, did not materially invade elevations above 2,000 feet, where red spruce remains as the dominant softwood; i.e., there is no evidence of elevational redistribution due to climate change. This conclusion was reinforced by an earlier analysis of understory species composition (Leak 2009); 3) although beech remains as a common, aggressive species, there is some indication of a decline in large beech at midslope due to the beech bark disease and subsequent timber marking of defective, risky trees. There is no evidence of decline in sugar maple, red spruce or other species except for changes due to natural succession. However, without management disturbance, the proportion of sugar maple poletimber (5 to 10 percent) seems inadequate to maintain current levels of sawtimber-sized stems (15 to 30 percent or more) at mid-elevations on the Bartlett Experimental Forest.

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APPENDIX

Common and scientific names of tree species referred to in this report.

Common Name	Genus	Species
American beech	*Fagus*	*grandifolia*
Yellow birch	*Betula*	*alleghaniensis*
Sugar maple	*Acer*	*saccharum*
Red maple	*Acer*	*rubrum*
Paper birch	*Betula*	*papyrifera*
White ash	*Fraxinus*	*americana*
Red spruce	*Picea*	*rubens*
Eastern hemlock	*Tsuga*	*canadensis*
Balsam fir	*Abies*	*balsamea*
White pine	*Pinus*	*strobus*
Northern red oak	*Quercus*	*rubra*

Leak, William B.; Mariko Yamasaki. 2010. **Seventy-year record of changes in the composition of overstory species by elevation on the Bartlett Experimental Forest.** Res. Pap. NRS-13. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 12 p.

Remeasurements over a 70-year period (1931-1932 to 2002-2003) on 404 cruise plots on the Bartlett Experimental Forest in New Hampshire provided a record of landscape-level changes in the composition of overstory species over time by elevation and d.b.h. (diameter at breast height) classes. Typically, early to mid-successional species declined while late successional species, especially hemlock, increased. The exception was at upper elevations (2,000 feet and higher), where natural wind disturbance maintained a variable component of paper and yellow birch. There is no evidence of species decline or migration that is inconsistent with natural succession or natural disturbance.

KEY WORDS: northern hardwoods, hemlock, spruce, natural succession, elevation, tree species migration.


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RESEARCH STATION
USDA Forest Service