THE EFFECT OF ACID PRECIPITATION ON TREE GROWTH IN EASTERN NORTH AMERICA[1]

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ABSTRACT

Detailed study of the history of forest tree growth by tree-ring analysis is used to assess the effect of acid precipitation. The pattern and historical trends of acid precipitation deposition are compared with growth trends from mature forest stands in New Hampshire and Tennessee. No clear indication of a regional, synchronized decrease in tree growth was found. The residual variation of relative tree growth responses, after removal of variation due to weather, shows no recent time-dependent trend. Due to the unknown initiation date of acid precipitation and to the large variation of tree growth estimates, a correlation of forest growth and acid precipitation in eastern North America cannot be established at the present time.

INTRODUCTION

Although the interaction between acidic precipitation and actual forest growth is complex, involving many types and extents of interaction, it is useful to look at forests for several reasons. First, they are widespread and constantly exposed, second, they contain a growth history in tree-rings, and third, they are economically and biologically important. I have studied tree growth in order to

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determine if acidic precipitation and forest growth histories are correlated (see Jonsson and Sundberg 1972, Whittaker et al. 1974). The nature of the interaction is undefined, but could involve depletion of soil nutrients (Overrein 1972), fertilization effects, foliage leaching (Eaton et al. 1973), metabolic disruption in leaf tissue (Wood and Bormann 1974), and/or other effects.

SITES AND METHODS

Two forest sites were carefully selected for old aged, mature stands with a minimal history of disturbance. A New Hampshire site was located in the Bowl Natural Area of the White Mountain National Forest. Boring for tree-ring analysis (Fritts 1961) was carried out in August 1972 by W. B. Leak in the northern hardwood plots described in Leak (1973). A Tennessee site was in the Great Smoky Mountains National Park and increment cores were taken in June 1973 in the spruce-fir forest around Newfound Gap. Both sites are in mountainous areas, on acid soils, and in isolated areas removed from local sources of pollution. Yearly growth chronologies for the dominant species were derived from increment cores obtained from scattered trees in each stand.

One site (the Bowl) is near the center of the acid precipitation region while the other site (Smokies) is at the periphery of the acid pattern. The Bowl site was probably acidified (pH <4.52) sometime before 1955 and today has an average acidity in precipitation of pH 4.10. Meanwhile, the Smokies site has become acidified from an annual average pH of about 5.2 in 1955 to a present-day pH of 4.4 (Cogbill and Likens 1974).

Response indices (ratio of yearly growth to previous 10 year average) give an indication of relative growth of a stand (Fritts 1961). These indices are then used as the dependent variable in a multiple stepwise linear regression against precipitation and temperature variables in the growing season. The residual variation of these regressions indicate growth trends not accounted for by weather variables.

RESULTS

The radial growth chronologies for beech (*Fagus grandifolia)*, birch *(Betula lutea)*, and maple *(Acer saccharum)* at the Bowl are shown in Figure 1. Beech growth shows a maximum in the 1940's, possibly in response to release by the hurricane of September 1938. Growth in

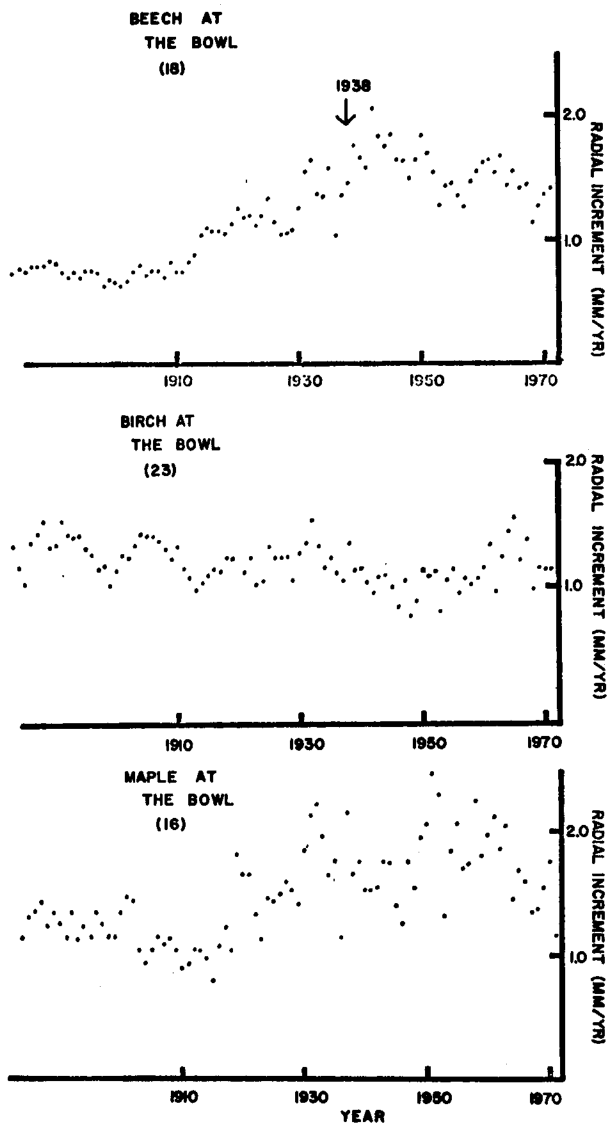

Figure 1. Tree-ring chronologies at the Bowl. The number of trees included in the chronology is in parentheses.

beech was significantly decreasing ($p<.001$ for a linear fit) from 1940 to 1970, but not significantly different from 0 slope ($p>.05$) from 1950 to 1970. Birch had fairly consistent growth with significant increases ($p<.05$) both from 1940 to 1970 and from 1950 to 1970. Maple had irregular growth which was not significantly decreasing ($p>.05$) from 1940 to 1970, but was statistically decreasing ($p<.05$) from 1950 to 1970.

The inclusion of different size trees in chronologies and the general tendency to decrease radial increment as a tree becomes older and larger somewhat biases trends gleaned from radial increment curves. Since basal-area increment is a fair estimate of total productivity regardless of tree size, the basal-area increment chronologies for the

Bowl are shown in Figure 2. All species show a general increase in

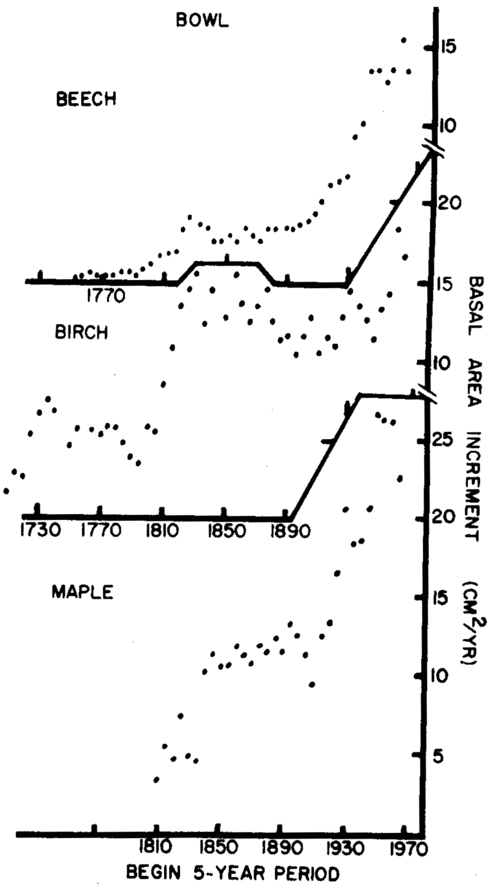

Figure 2. Basal area growth at the Bowl.

basal-area increment with time, as all trees are growing in size. Recent irregular growth has no consistent breakpoint, particularly any downward shift originating before 1955.

The chronology for red spruce *(Picea rubens)* in the Smokies (Figure 3) is similar to those seen in the Bowl, particularly on birch. Irregular decreasing growth is statistically significant ($p<.05$ different from 0 slope) from 1910, 1940, and/or 1950 to 1970. Despite being affected by acid precipitation since 1955, there seems to be no unusual change in growth pattern after this time.

Although both the magnitude and time sequence of acid deposition vary from New York to Tennessee no substantial difference in forest growth was found. At neither site was there a residual downward trend in the response indices after reduction of weather variance by multiple regression techniques. The auto-correlation of these

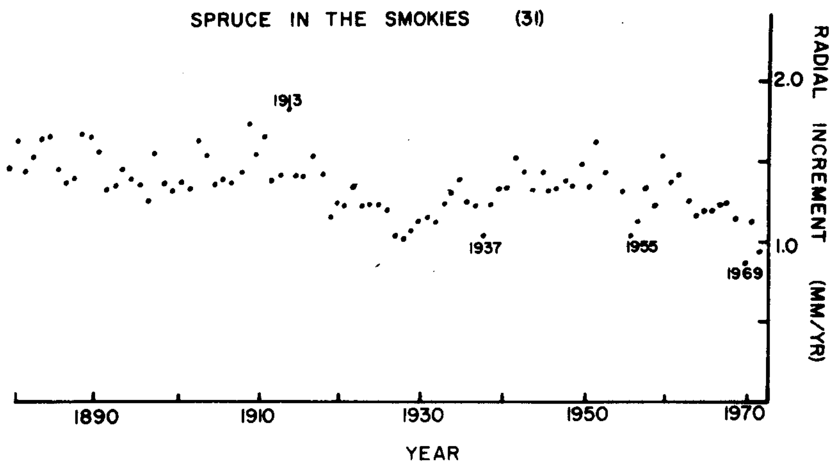

Figure 3. Tree-ring chronology for spruce in the Smokies. The number of trees included in the chronology is in parentheses.

residual indices were not significant ($p > .05$), indicating that no unaccounted for time-dependent variable was left after growth response and weather variance were taken into account.

CONCLUSIONS

No regional, synchronized decrease in radial increment growth was evident in the two mature stands studied in the eastern United States. Despite different acid precipitation regimes, these two stands displayed similar growth patterns. Slight recent decreases in basal area increment in the mature stands were neither dramatic nor without precedent, but acid precipitation cannot be eliminated as their cause. Weather, stand dynamics, and determination error are probable contributory causes. Thus, due to the unknown initiation date of acid precipitation and to the large variance of tree growth estimates with no breakpoint, a correlation of forest growth and acid precipitation in eastern North America cannot be established at the present time.

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