GROWTH PATTERNS OF RED OAK AND RED AND SUGAR MAPLE RELATIVE TO ATMOSPHERIC DEPOSITION[1/]

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Abstract.--Regional, long-term growth patterns were determined by measuring ring widths on increment cores from 750 red oaks, 687 red maples, and 521 sugar maples. All three species showed generally increasing growth rates from 1900 through the early 1980's. Temporary periods of declining growth coincided with periods of either documented defoliation by insects or below-average precipitation. There are no obvious unexplained growth declines like those reported for red spruce and balsam fir. Separating impacts of atmospheric deposition on hardwood species may be even more difficult than for conifers.

Keywords: red oak, red maple, sugar maple, tree rings, atmospheric deposition, growth decline.

INTRODUCTION

Hardwood species have received considerably less attention than conifers with regard to susceptibility to atmospheric deposition. This is partly because effects of atmospheric deposition are thought to be more severe at higher elevations, where hardwoods are less numerous, and partly because conifers, especially red spruce and balsam fir, have shown more unusual and unexplained symptoms than hardwoods (Johnson and McLaughlin 1986). Consequently, the initial programs to assess the effects of atmospheric deposition have been directed at coniferous species. However, now that these programs are underway, more emphasis needs to be placed on evaluating possible relationships between hardwood forest conditions and atmospheric deposition.

A logical starting point is the examination of growth patterns for major hardwood species. Such an approach using tree-ring measurements proved successful in documenting regional growth declines in red spruce and balsam fir (McLaughlin 1985; Adams et al. 1985; Hornbeck and Smith 1985; Hornbeck et al. 1986). The regional collection of increment cores used by Hornbeck and Smith (1985) and Hornbeck et al. (1986) to document spruce and fir growth declines also includes a large number of cores from hardwood species. Those hardwood cores were used in this study to determine growth patterns for three species commonly found in central and northern hardwood forests: red oak, and red and sugar maple.

METHODS

This study is based on measurements of annual growth of 750 red oaks, 687 red maples, and 521 sugar maples. The sample is composed of groups of four or fewer trees from randomly located plots used in the USDA Forest Service 10-year inventory of forest resources in the six New England states (USDA Forest Service 1985a). All sample trees were growing in forest settings and were dominant or codominant in the canopy.

Annual-ring widths were measured on single increment cores extracted from each tree at about 1.4 m (breast height) above ground. Cores were mounted on wooden blocks, then smoothed by a combination of planing and sanding (Krusic et al. 1987). Ring widths were measured under magnification with a digital micrometer accurate to 0.01 mm. Cross-dating was done using traditional skeleton plotting (Fritts 1976) with some minor adaptions to make the methods more applicable to New England.

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: comparing growth patterns, ring widths nverted to annual basal-area increment ıe formula:

$$BAI = \pi (R^2_n - R^2_{n-1})$$

is tree radius obtained by summing ring and n is year. This conversion was ɜd by Phipps (1983) as a means of showing narrowing ring widths in maturing trees ıts a true growth decline.

compare growth rates across New England, ıple trees were grouped by species by For each year, starting with 1900 and ing to the year of sampling, average basal-area increment ($cm^2\ yr^{-1}$) was ɪ by averaging over all trees in a group. ;h this approach incorporated all sizes s of trees, the standard errors about means were small, ranging from 0.05 to .

RESULTS AND DISCUSSION

Red Oak

d oak samples show a regional trend of ing growth, rising from about 2 $cm^2\ yr^{-1}$ turn of the century to maximums of 10 to ' yr^{-1} by the late 1970's (Fig. 1). However, starting about 1980, red oaks sampled in Connecticut, Rhode Island, Massachusetts, and New Hampshire have shown pronounced growth declines of as much as 37% in a single year. The only exception to this overall pattern is a period of declining growth from 1955 to 1972 in trees sampled in Connecticut and Rhode Island.

The pattern of generally increasing basal area increments from 1900 to 1980 is thought to reflect past land use. Heavy logging and reversion of farmland to forest in the late 1800's and early 1900's structured the ages of many New England forests. Thus, the increasing growth rates may represent the continued development of dominant and codominant red oaks that are of fairly uniform ages.

The marked declines in growth in Connecticut, Rhode Island, Massachusetts, and New Hampshire beginning around 1980 are undoubtedly related to defoliation by the gypsy moth (*Lymantria dispar*). A record gypsy moth outbreak began in New England in 1980 (USDA Forest Service 1985b), and resulted in dramatic increases in defoliated areas in 1981 and 1982 (Table 1).

The declining growth in Connecticut and Rhode Island during 1955 to 1972 is more difficult to explain. Stephens and Hill (1971) reported unusual combinations of drought and defoliation and resulting increases in mortality

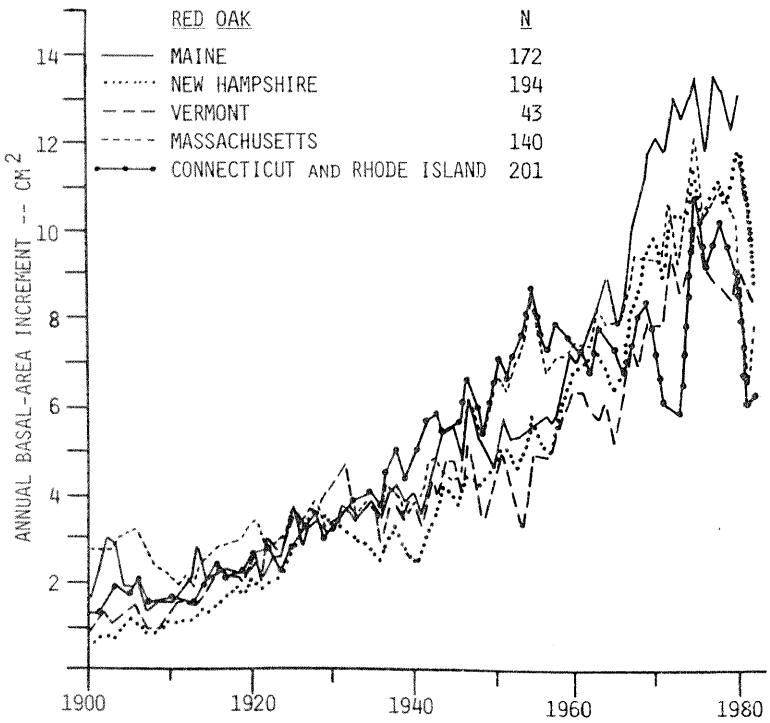

Figure 1. Mean annual basal-area increment for red oak.

Table 1. Gypsy moth defoliation by state, 1979-83 (USDA Forest Service 1985b).

Year	CT	RI	MA	NH	VT	ME
	Hectares					
1979	3,030	265	91,566	2,420	6,237	9,381
1980	110,163	17,738	367,088	74,463	30,390	89,527
1981	599,845	110,302	1,143,705	788,036	19,821	265,415
1982	325,294	266,289	559,800	355,432	3,992	232,511
1983	62,015	21,805	59,949	227	0	6,590

in Connecticut from 1959 to 1970. They pointed out that oaks are a preferred host for many defoliators, and concluded that there is little wonder that oaks often suffer through periods of decline.

Red Maple

Samples from red maples show the most consistent regional growth patterns of the three species studied. Growth rates increased steadily from 2 to 3 $cm^2 yr^{-1}$ in 1900 to current levels of 9 to 11 $cm^2 yr^{-1}$ (Fig. 2). Exceptions are sharp declines in growth in the early 1980's in Massachusetts, Connecticut, and Rhode Island, and a period of declining growth in New Hampshire in the early and mid-1960's.

The temporary growth decline in New Hampshire also was noted by Whittaker et al. (1974) during studies of northern hardwoods at the Hubbard Brook Experimental Forest. They suggested that an abrupt decline in productivity during 1961-65 might be related to several years of below average precipitation, or to increasing acidity of rainfall. The subsequent recovery of growth rates in the late 1960's (Fig. 2) suggests that a drier than average period beginning in July, 1961, and continuing through Autumn, 1966 (Ludlum) 1976, was the more likely factor.

The declines in Massachusetts, Connecticut, and Rhode Island in the early 1980's may reflect defoliation by the gypsy moth. Red maple is well down on the list of species preferred by the gypsy moth (Houston 1979), but heavy defoliation has been reported, especially when maples grow in association with oaks (Campbell 1979). That the growth declines in red maple mirror those in red oaks is further evidence.

Sugar Maple

Only Maine, New Hampshire, and Vermont had adequate samples of sugar maple to construct growth curves (Fig. 3). As with red maple and red oak, the trend was a steady increase in growth from 1 to 2 $cm^2 yr^{-1}$ in 1900 to 9 to 10 $cm^2 yr^{-1}$ by 1980. Trees sampled in Vermont and New Hampshire show a declining trend from 1979-82. There are no data for Vermont beyond 1982, but the 1983 data for New Hampshire show a strong recovery, suggesting that the decline in the previous four years was temporary. This coincides with annual reportings of forest insect conditions in Vermont showing extensive defoliation of maples by gypsy moth, forest tent caterpillar (*Malacosoma disstria*), and saddled prominent (*Heterocampa guttivata*) in 1981 and 1982, followed by a collapse of insect populations in 1983 (Personal communication, Ronald S. Kelley, Forest Protection Specialist, Vermont Department of Forests, Parks, and Recreation).

The 301 sugar maples that make up the Vermont sample were further divided into four age classes (Fig. 4). All age classes show a pattern of steadily increasing growth. However, trees in the youngest age class are growing most rapidly, having reached the same level of growth by 1980 as trees in the older age classes.

Impacts of Atmospheric Deposition

The long-term growth patterns for red oak and red and sugar maple do not show obvious impacts of atmospheric deposition. Growth rates show a generally increasing trend over the past 80 years. Periods of declining growth usually are temporary and coincide with either documented defoliation by insects or periods of below-

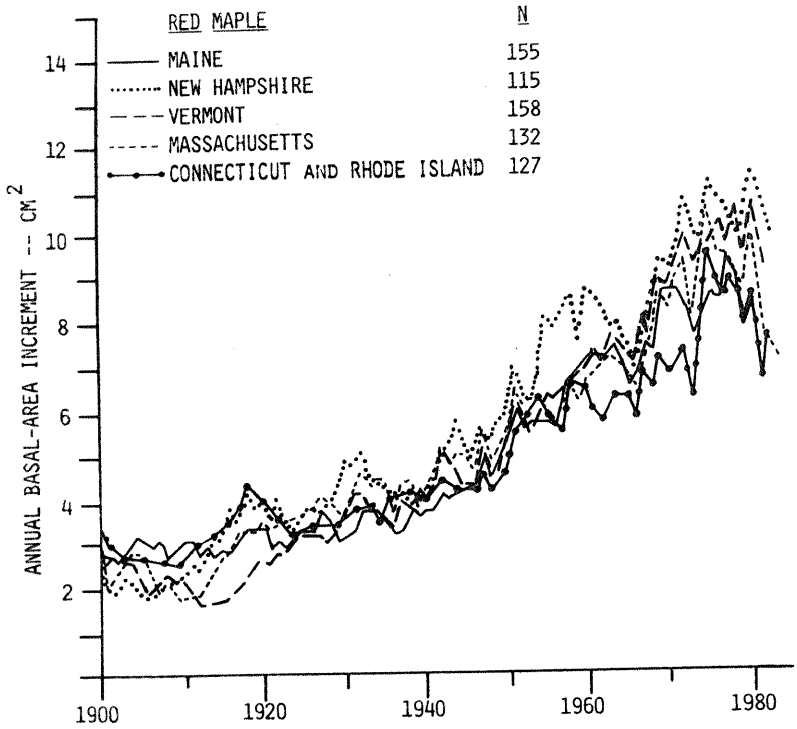

Figure 2. Mean annual basal-area increment for red maple.

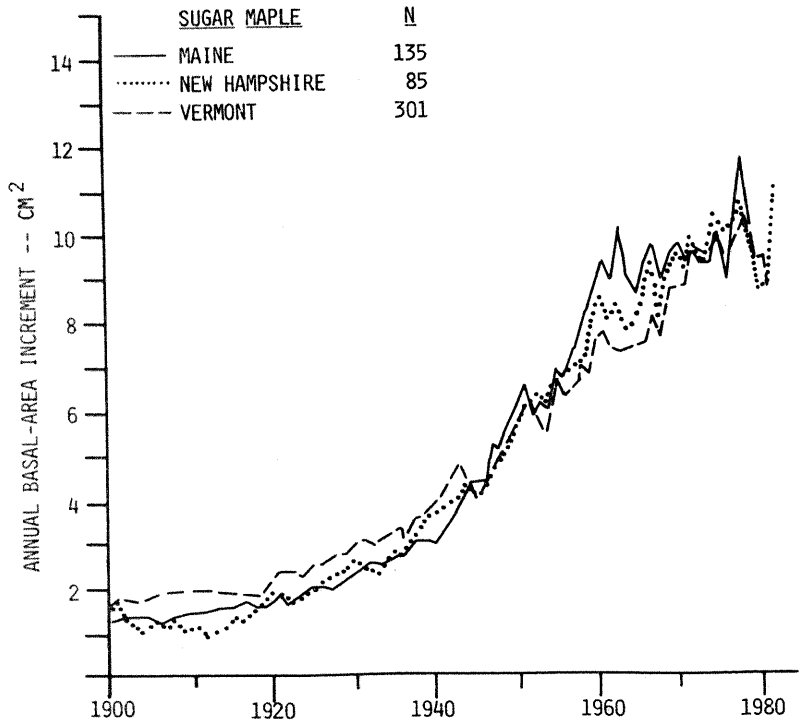

Figure 3. Mean basal-area increment for sugar maple.

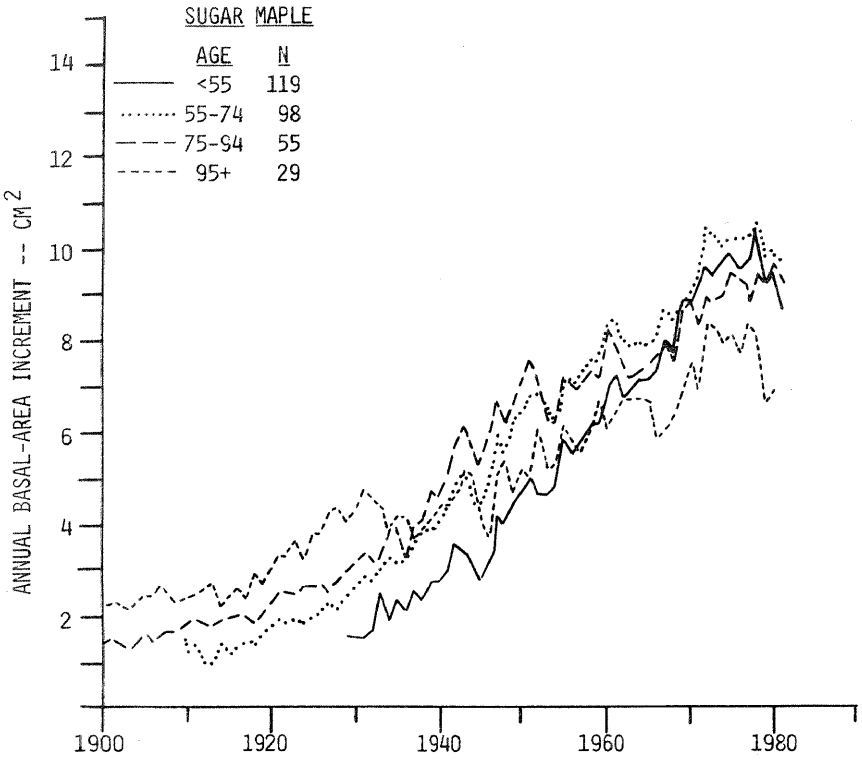

Figure 4. Mean annual basal-area increments, by age class, for sugar maple in Vermont.

average precipitation.

These findings are a marked contrast to those for red spruce and balsam fir obtained from increment cores collected and analyzed by the same methods used in this study. Red spruce showed a steady increase in growth until about 1960, then a regionally consistent decline (Hornbeck and Smith 1985). Depending on location, basal-area increment in 1980 was 13 to 40% less than in the peak growth year around 1960. The growth decline occurred in all size and age classes and was independent of elevation. Balsam fir also showed a decline, but the start varied by tree age (Hornbeck et al. 1986).

Although growth declines in red spruce and balsam fir have been clearly demonstrated, there has been little success in relating them to atmospheric deposition (Johnson and McLaughlin 1986). Other factors, including insect defoliation, climatic change, extreme weather events, and natural aging, severely complicate the problem of isolating impacts of atmospheric deposition. The absence of well-defined growth declines in red oak and red and sugar maple suggests that separating impacts of atmospheric deposition on hardwood species may be even more difficult than for conifers.

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