

A COMPARISON OF THREE DENDROECOLOGICAL METHODS FOR ASSESSING GROWTH TRENDS IN RED SPRUCE (*PICEA RUBENS*) NEAR SPRUCE KNOB, WEST VIRGINIA

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Introduction

The red spruce (*Picea rubens* Sarg.) of West Virginia form pure regenerating stands at elevations above 3,000 feet. Historically, these stands covered about 200,000 hectares (ha) of the Allegheny Mountains (Hornbeck and Kochenderfer 1998; Stephenson 1993b). Red spruce also forms the dominant tree in the subalpine coniferous spruce-fir forest of the region. Stephenson (1993b) reported yellow birch (*Betula alleghaniensis*), red maple (*Acer rubrum*), and hemlock (*Tsuga canadensis*) as other canopy species with importance values greater than 10 in this forest type in the Alleghenies.

Following the logging era of the late 19th and early 20th centuries, fewer than 24,000 ha of pure red spruce stands remain in the region on the Monongahela National Forest (Stephenson and Adams 1993). Some studies suggest that red spruce has been in decline since the 1960s throughout the eastern United States (Hornbeck and Kochenderfer 1998; Stephenson and Adams 1993), but other studies do not find such evidence (Goelz et al. 1999). Signs of potential decline include accelerated decrease in ring-widths during 1965-1981 and surveys that indicate 33% of West Virginia red spruce forests contain declining and dead trees (Hornbeck and Kochenderfer 1998).

Several explanations have been given for the possible decline in high-elevation red spruce (Figure 3). Shortle et al. (1997) used dendrochemical and biochemical markers to link growth stress in healthy red spruce populations to acidic deposition. Acid rain mobilizes soil-bound calcium, magnesium, and aluminum, that initially may enhance growth due to increased essential cation availability, but may eventually lead to aluminum toxicity and leaching of calcium and magnesium. David et al. (1998) suggest that high elevation nitrogen deposition (atmospheric) may increase the total N pool in the forest floor, thus changing the biogeochemical environment away from ideal red spruce habitat. Biotic agents (i.e. *Valsa kunzei* Fr., an ascomycetic fungus occurring in damaged red spruce crowns) may also be implicated in the possible decline of this forest type (Hornbeck and Kochenderfer 1998). Finally, historical notes and old-growth chronologies indicate a period of growth decline during the 1880s, after which red spruce populations seem to have recovered (Stephenson and Adams 1993).

The principal objective of this project is to compare three methods of analyzing dendrochronological data to estimate growth trends in the latter part of the 20th century in red spruce. The methods include calculating basal area increment using (1) randomly located samples of dominant/codominant red spruce trees within a stand (Hornbeck and Kochenderfer 1998) and (2) a complete census of all red spruce trees within a measured plot, and (3) using a standardized ring-width chronology to indicate growth trends over time. The purpose in analyzing red spruce data, specifically, is to determine if a growth decline exists in the selected high elevation red spruce stand.

Methods

A pure stand of red spruce was located near the campus of The Mountain Institute (38 degrees 41' Lat., 79 degrees 33' Long., 3950 Feet Elevation), West Virginia, USA. Annual precipitation is about 120 cm, and annual average temperature is 9.4 Celsius (Stephenson 1993a). Cow pastures and hardwood forest composed of American beech (*Fagus grandifolia*), red maple, yellow birch, hawthorn (*Crataegus* sp.), and hemlock surround the study area.

A 20x20 meter (0.04 ha) plot was randomly located within the stand to complete a census of all red spruce trees. Two cores were removed with standard increment borers at opposite sides of each tree

greater than 3 m in height at 0.3 m above the ground to obtain the earliest tree-rings possible. To increase the sampling area and compare results with Hornbeck and Kochenderfer (1998), an additional 15 dominant/codominant red spruce trees were randomly located outside the perimeter of the plot and were cored in the same manner. Bark width of each core and tree diameter at core height were measured and recorded on each core container.

Red spruce trees less than 3 m in height were considered regeneration and were sampled to complete a total cover census for the 0.04 ha plot. Ten 1-m² plots were randomly selected within the larger plot, and all trees less than 3 m were measured and tallied into one of three 1-m interval height classes. Total number of regeneration trees were extrapolated to the 0.04 ha plot. Stems from five trees in each height class were randomly selected and destructively sampled within the 0.04 ha plot.

Tree cores were prepared, cross-dated, and used to create a master chronology according to standard dendrochronological techniques (Stokes and Smiley 1968). At least one core's ring-widths were measured from each tree using a Digital Measuchron (Bangor, Maine). Ring-width measurements from each series were evaluated for errors against the master chronology with COFECHA. Using ARSTAN (Cook), individual chronologies were standardized, and raw ring-width measurements (Figure 1) were power transformed and fit to negative exponential or linear curves; 4 series required fitting by a flexible smoothing spline to address right skew heteroscedacity and negative values of for the best fit growth curve. ARSTAN was then used to create the standardized, ARSTAN, and residual ring-width chronologies.

Response functions of growth to precipitation and temperature were created using PRECON (Fritts). Climate data through 1996 were correlated to the standardized chronology to indicate relationships between growth and climate patterns.

Results

Cores from 29 trees were removed from within the 0.04 ha plot, and cores from 15 trees were removed from trees adjacent to the plot. Of the 29 plot cores, 5 cores were not usable due to tree rot, twisted cores, and double stems above 0.3 m, leaving 24 usable cores from within the plot. The master chronology dated sampled trees from 1929-1998.

Utilizing the methods of Hornbeck and Kochenderfer (1998), we detected a growth trend similar to their published results (Figure 2). A general decline in annual basal area increment (BAI) occurs beginning in the late 1950s to around 1980, while an increase in BAI is detectable from 1985 to present. However, our data showed a somewhat later timing in growth decline and a greater annual sensitivity to variations in BAI than that found by Hornbeck and Kochenderfer (1998). This may be due to the greater accuracy of cross-dated ring series used in this study than ring width series that have not been cross-dated.

Utilizing the plot census method, which incorporated all trees greater than 3 m in height within the 0.04 ha plot, the general growth trend was similar to the Hornbeck and Kochenderfer (1998) method but expressed more variance over time (Figure 3). A larger plot size might have reduced this variance to some extent. Growth trends prior to 1935 were not compared due to insufficient sample depth.

The standardized ring-width chronology, which includes ring-widths from all sampled trees, expressed much variance over time but also indicated a decline in growth through the 1960s and 1970s with an increase in growth beginning in the mid-1980s (Figure 4). This general growth trend supports the results of Hornbeck and Kochenderfer (1998) and the plot census method.

Red spruce regeneration in the 0.04 ha plot was most numerous in the 0-1 m height class (Figure 5). Based on extrapolations from subplot size, 90 trees were in the 0-1 m height class, 67 trees were in the 1-2 m height class, and 23 trees were in the 2-3 m height class. A total of 30 trees were censused in the

greater than 3 m height class. The basal area increment trend for regeneration within the 0.04 ha plot is located in Figure 6.

The climate response function indicates a significant ($\alpha=0.05$) positive relationship between growth and temperature in July of the previous growing season. In addition, there was also a positive relationship between growth for the previous two years and growth for the current growing season. No significant correlation was found between precipitation and growth throughout the standardized chronology.

Discussion and Conclusion

Our results suggest that all three methods provide a similar analysis of general growth trends of red spruce over time. However, we believe that the plot census method should provide a better indicator of general growth trends via basal area increment because this method includes all contributions to stand level growth. If plot sample size were increased, variance of basal area increment should decrease and provide a more realistic approximator of stand dynamics.

Our regeneration data suggest that there is a sufficient level of regeneration to maintain and renew the stand in the case of harvesting, disease in mature trees, or natural disaster. In addition, the lack of hardwood undergrowth would probably result in the stand remaining as a predominantly red spruce stand.

The response function indicates that red spruce in this region respond positively ($\alpha=0.05$) to July temperature from the previous growing season and to growth during the previous two growing seasons. In addition, a high, yet non-significant, negative correlation was observed between current June temperature and growth. These trends suggest that early season high temperatures suppress growth, probably during or prior to the bud break phase, which usually occurs in mid-June. The significant relationships indicate that needles and secondary growth from previous years may act as a buffer for new growth until new needles emerge and are able to photosynthesize. Essentially, good growth during the prior two years should produce good growth during the current year.

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