A COMPARISON OF THE STATUS OF SPRUCE IN HIGH-ELEVATION FORESTS ON PUBLIC AND PRIVATE LAND IN THE SOUTHERN AND CENTRAL APPALACHIAN MOUNTAINS

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Abstract.—Red spruce (*Picea rubens* Sarg.) is the most important component of the high-elevation forest ecosystems of the southern and central Appalachian Mountains. These communities are characterized by mixed hardwood/coniferous forests often with overstory dominance by red spruce. Due to their restricted geographic and elevation ranges, all community types in this ecological group are rare. Red spruce forests provide the only viable habitats for the northern flying squirrel (*Glaucomys sabrinus fuscus*), a federally and state-listed endangered species, as well as for other animals of global and regional significance. Due to a variety of stressors, including exotic pests and pathogens, airborne pollution, wind shear, and climate change, these high-elevation spruce forests face an uncertain future. We use U. S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) plot data from Tennessee, North Carolina, Virginia, West Virginia, and Pennsylvania to analyze the distribution of the red spruce trees, saplings, and seedlings across forest types, elevation classes, and ownerships. Most of the area classified as the red spruce forest type is public land (~90 percent), but only 72 percent of red spruce trees are on public land so there are significant numbers of red spruce trees in other forest types as well. Spruce regeneration is abundant relative to other species within the spruce/fir forest-type group, indicating that spruce is likely to maintain its dominance in those stands, but spruce regeneration is also an important component of seedling and saplings species composition in the maple/beech/birch forest-type group. One-third of stands in the maple/beech/birch forest-type group have a large red spruce component present as regeneration, indicating the potential for red spruce to increase its importance in future forests.

INTRODUCTION

Red spruce (*Picea rubens* Sarg.) is the most important component of the high-elevation forest ecosystems of the southern and central Appalachian Mountains. These communities are characterized by mixed deciduous/coniferous forests, often with overstory dominance by red spruce. All community types in this ecological group are rare because of their restricted geographic and elevation ranges. Most of these relict forest communities suffered severe compositional and structural degradation during the late 19th and early 20th centuries from heavy logging and burning and have never returned to previous conditions (Stephenson and Clovis 1983, Schuler et al. 2002). The geographic extent of red spruce communities has also been greatly reduced.

Restoration of red spruce-dominated forests has been explored in several studies (Schuler et al. 2002, Rentch et al. 2007), but a variety of biotic and abiotic stressors, including exotic pests and pathogens, airborne pollution, wind shear, land-use change, and climate change, currently threaten the health and sustainability of high-elevation spruce forests and potential restoration sites. Restoration of red spruce communities could increase the extent of this rare forest type and the amount of available habitat for characteristic species such as the endangered northern flying squirrel (*Glaucomys sabrinus fuscus*). Forests with a large red spruce component provide some of the best habitat for the northern flying squirrel (Odom et al. 2001, Ford et al. 2004) and other animals of global and regional significance.

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We use Forest Inventory and Analysis (FIA) plot data from Tennessee, North Carolina, Virginia, West Virginia, and Pennsylvania to analyze the distribution of red spruce trees, saplings, and seedlings across forest types, elevation classes, and ownerships. Some stands currently classified as another forest type but with a red spruce component in the overstory and/or understory, could convert to the red spruce type either through succession or silvicultural intervention.

The goal of this study is to summarize the distribution of red spruce on public and private lands in the central and southern Appalachian Mountains. Specific objectives are: 1) differentiating the distribution of red spruce forest-type from the distribution of red spruce trees; and 2) quantifying the proportion of red spruce trees, saplings, and seedlings in different forest-type groups to use as an indicator of future forest composition.

METHODS

The FIA program of the U.S. Department of Agriculture, Forest Service, the only congressionally mandated national inventory of U.S. forests, conducts a three-phase inventory of the forest attributes of the country (Bechtold and Patterson 2005). The FIA sampling design is based on a tessellation of the United States into hexagons of approximately 6,000 acres, with at least one permanent plot established in each hexagon. In Phase 1, the population of interest is stratified and plots are assigned to strata to increase the precision of estimates. The intent of Phase 1 is to classify the land into various remote-sensing classes for the purpose of developing meaningful strata. A stratum is a group of plots that have the same or similar remote-sensing classifications. Stratification is a statistical technique used by FIA to aggregate Phase 2 ground samples into groups to reduce variance when stratified estimation methods are used (Bechtold and Patterson 2005). In Phase 2, site attributes, such as forest type and stand size, and tree attributes, such as species and diameter, are measured for forested plots established in each hexagon. Phase 2 plots consist of four 24-foot fixed-radius subplots on which standing trees greater than 5 inches diameter at breast height (d.b.h.) are inventoried, and four 6.8-foot fixed-radius microplots on which saplings 1 inch to 4.9 inches d.b.h. and seedlings greater than 1 foot tall are inventoried.

In this study we utilized plot data from Tennessee, North Carolina, Virginia, West Virginia, and Pennsylvania. Plots were included in the analysis if at least one red spruce tree or seedling was sampled. Inventory data from 2002-2006 were used, and 86 inventory plots were included in the analysis. Annual net growth and mortality estimates, based on two sequential measurements, were computed using only plots from West Virginia. Annual net growth is computed as annual gross growth minus annual mortality (Bechtold and Patterson 2005). The FIA MapMaker 3.0 program was utilized to generate area, number of trees, volume, basal area, growth, and mortality estimates (Miles 2009). In the FIA forest-typing system, forest types are nested within forest-type groups. For example, the red spruce forest type (50 percent or more of the stocking in red spruce) is in the spruce/fir forest-type group. This terminology is used throughout the body of this paper. The proportion of the total number of red spruce trees, saplings, and seedlings on each FIA plot was computed from the raw FIA data to ascertain the importance of red spruce in the species composition of different tree size classes.

RESULTS

Distribution of the Red Spruce Forest Type

The majority of the area classified by FIA as the red spruce forest-type is in stands more than 60 years old (78 percent). Concentration in this age class resulted from widespread harvesting and burning of red spruce-dominated forests prior to the 1940s followed by decades of virtually no harvesting of red spruce (Steer 1948).

Nearly all of the 90,000 acres of the red spruce forest type is on public land (~90 percent). The majority of this land is administered by the Forest Service (35,000 acres), but the National Park Service (13,000 acres) and the states (26,000 acres) are major owners as well. Virginia and Pennsylvania have the largest amount of state-owned red spruce forest with 6,000 and 14,000 acres, respectively. Nearly 50 percent of the area of red spruce forest type is located in West Virginia; almost all is growing on federal land administered by the Forest Service.

About half of the red spruce forest-type acreage is classified by FIA as reserved status. This classification means the forest land is withdrawn by law, prohibiting management for wood products. Most of the reserved land is wilderness areas in the Monongahela National Forest in West Virginia and the Great Smokey Mountains in Tennessee. By contrast, the majority of nonreserved land is under private and state ownership in North Carolina, Pennsylvania, and Virginia.

It is well documented that red spruce grows at high elevations in the southern Appalachians (Burns and Honkala 1999a). FIA estimates that 83 percent (75,000 acres) of red spruce forest type occurs at elevations greater than 3,000 feet, but small areas are found at less than 3,000 feet in Virginia (1,500 acres) and Pennsylvania (14,000 acres).

Distribution, Growth, and Mortality of Red Spruce Trees

Although 90 percent of the area of the red spruce type is located on public ownerships, there are significant numbers of red spruce trees on privately owned land in other forest types; only 72 percent of red spruce trees are on public land. In fact, 52 percent of the red spruce volume (44 percent of red spruce basal area) is in the maple/beech/birch forest-type group. Only 34 percent of the red spruce volume (32 percent of red spruce basal area) is in the spruce/fir forest-type group.

Based on percentage of total live volume, the most important species growing with red spruce at elevations above 4,000 feet are yellow birch (*Betula alleghaniensis* Britton), 9 percent; sweet birch (*B. lenta* L.), 8 percent; American beech (*Fagus grandifolia* Ehrh.), 5 percent; northern red oak (*Quercus rubra* L.), 13 percent; red maple (*Acer rubrum* L.), 11 percent; black cherry (*Prunus serotina* Ehrh.), 5 percent; and eastern hemlock (*Tsuga canadensis* [L.] Carr.), 7 percent. The birches, particularly yellow birch, are the most common associates with red spruce above 5,000 feet in elevation. Annual growth estimates from West Virginia show that red spruce is growing faster than American beech and yellow birch (Fig. 1). Similarly, estimates from West Virginia show that red spruce has a lower annual mortality rate than American beech and yellow birch (Fig. 2).

Distribution of Red Spruce Trees, Saplings, and Seedlings

The proportion of the total number of red spruce trees, saplings, and seedlings on each FIA plot was computed and each mean is presented by FIA forest-type group (Fig. 3). The spruce/fir forest-type group has the highest proportion of red spruce trees, saplings, and seedlings, but the maple/beech/birch forest-type group has a surprisingly large component of red spruce saplings and seedlings. Although only 11 percent of trees tallied in the maple/beech/birch forest-type group are red spruce, 32 percent of tallied saplings and seedlings are red spruce. By contrast, red spruce is a much smaller component of stands in the oak/hickory forest-type group. One-third of stands in the maple/beech/birch forest-type group have a large red spruce component present as regeneration (greater than 40 percent of seedlings and saplings in red spruce). A more detailed look at the maple/beech/birch forest-type group reveals that red spruce regeneration is a larger component of the seedling and sapling tallies on federal land than on private land (Fig. 4).

DISCUSSION

Red spruce is the most important component of the high-elevation forests of the southern and central Appalachian Mountains and previously dominated forests over hundreds of thousands of acres. It currently makes up a large enough component of the species composition to qualify as the red spruce forest type on only approximately 90,000 acres. The majority of those forests (90 percent) are on public land, are mature (78 percent are in stands more than 60 years old), and at high elevation (83 percent at greater than 3,000 feet). Red spruce is also a significant component in other forest-type groups, particularly in the maple/beech/birch forest-type group, where approximately 52 percent of the red spruce trees are growing.

Concerns about the decline of red spruce were raised in the 1980s because of observed higher mortality rates, foliage loss, and a decrease in growth rates (Johnson 1983, McLaughlin et al. 1987). Potential causes of this decline include climatic change, insect pests, pathogens and diseases, stand dynamics, and atmospheric deposition. In contrast to studies reporting declining red spruce growth, current estimates from West

Virginia FIA data indicate that red spruce is growing faster and dying at a slower rate than its major competitors. Both sweet and yellow birch are susceptible to disease and decay at an early age (Burns and Honkala 1990b) and sweet birch is a short-lived species (Hicks, Jr. 1998). In addition, exotic pest activity has been linked to growth loss and mortality of two other species associated with red spruce in the central and southern Appalachian Mountains: American beech and eastern hemlock (Houston 1994, McClure et al. 2001, Morin et al. 2005).

Although crushing by hardwood litter is generally expected to cause seedling mortality in red spruce (Burns and Honkala 1990a), summaries by forest-type group indicate that 32 percent of the saplings and seedlings tallied in the

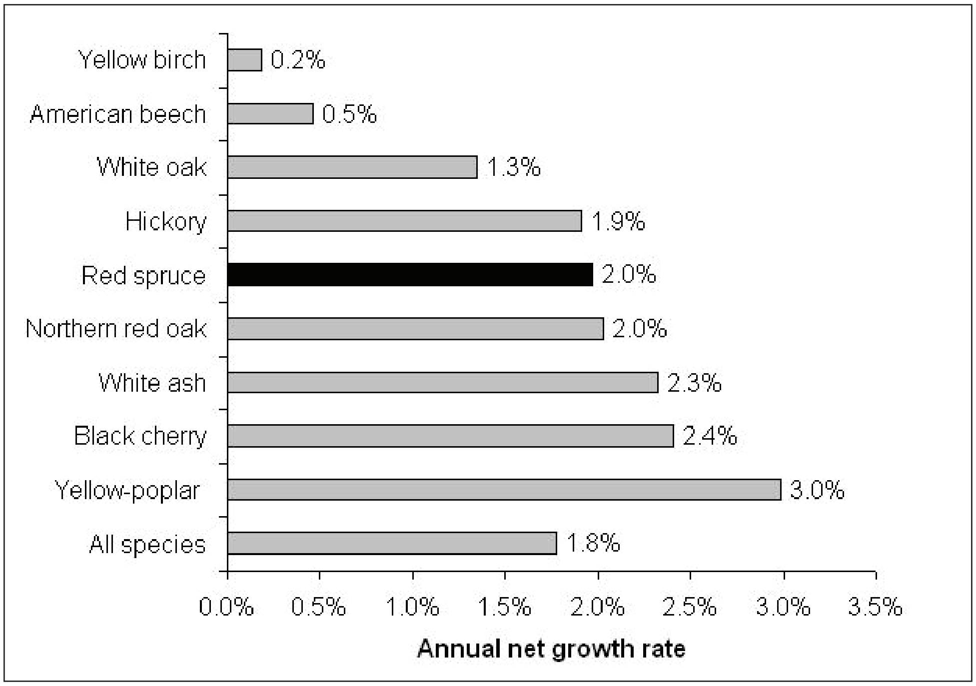

Figure 1.—Annual net growth rate of live volume for selected species on forest land, West Virginia, 2006.

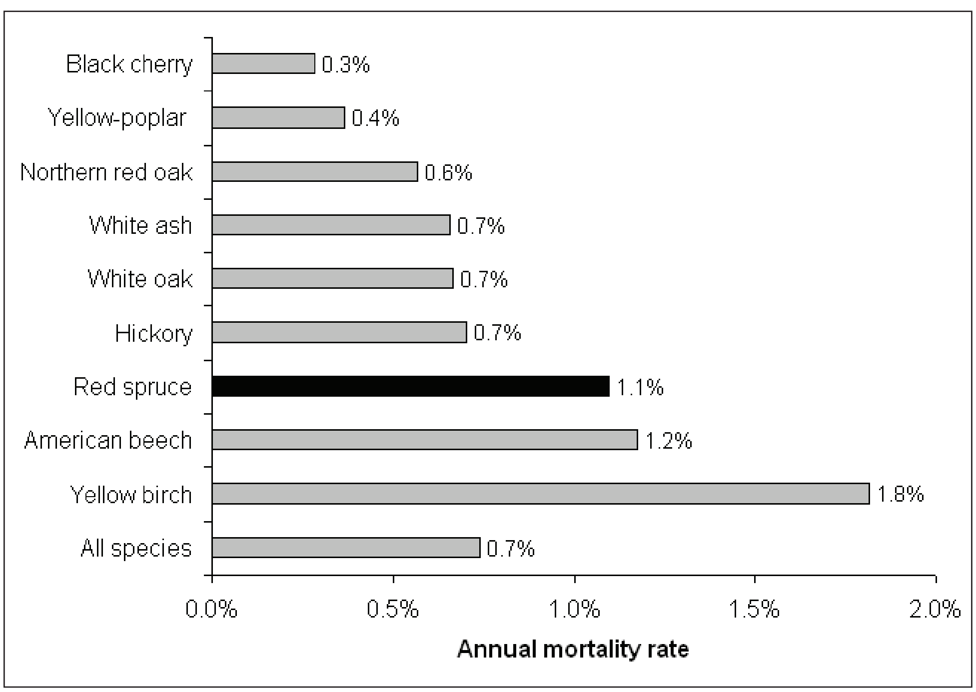

Figure 2.—Annual net mortality rate of live volume for selected species on forest land, West Virginia, 2006.

maple/beech/birch forest-type group were red spruce. In addition, one-third of stands in the maple/beech/birch forest-type group have a large red spruce component present as regeneration (greater than 40 percent of seedlings and saplings in red spruce). A more detailed look at the maple/beech/birch forest-type group reveals that red spruce regeneration is a larger component of the seedling and sapling tallies on federal land than on private land. Therefore, much of the restoration opportunity for red spruce occurs on federal lands where management options might be limited due to regulations.

Two factors indicate that red spruce may increase its distribution in the southern and central Appalachian Mountains in the coming years: the reproductive success of red spruce and the net growth and mortality estimates of red spruce and associated species. This is especially the case in the maple/beech/birch forest-type group, where the trend in levels of red spruce regeneration points toward the natural succession of more red spruce in future forests. Succession potentially could be accelerated through the use of silvicultural treatments, such as the release of understory spruce through the removal of overstory hardwoods (Rentch et al. 2007), but

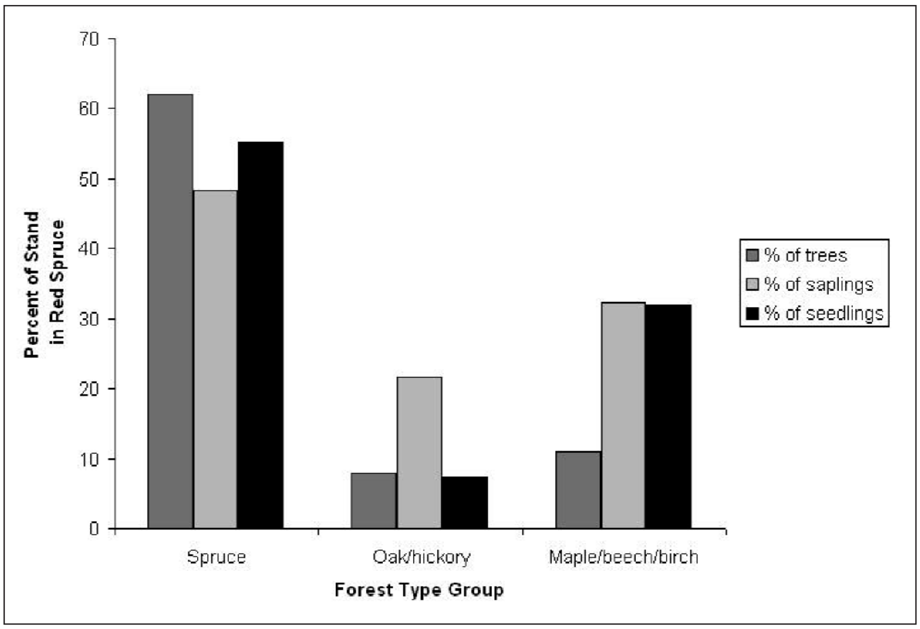

Figure 3.—Percent of tallied trees, saplings, and seedlings in red spruce by forest-type group, North Carolina, Pennsylvania, Tennessee, Virginia, West Virginia, 2006.

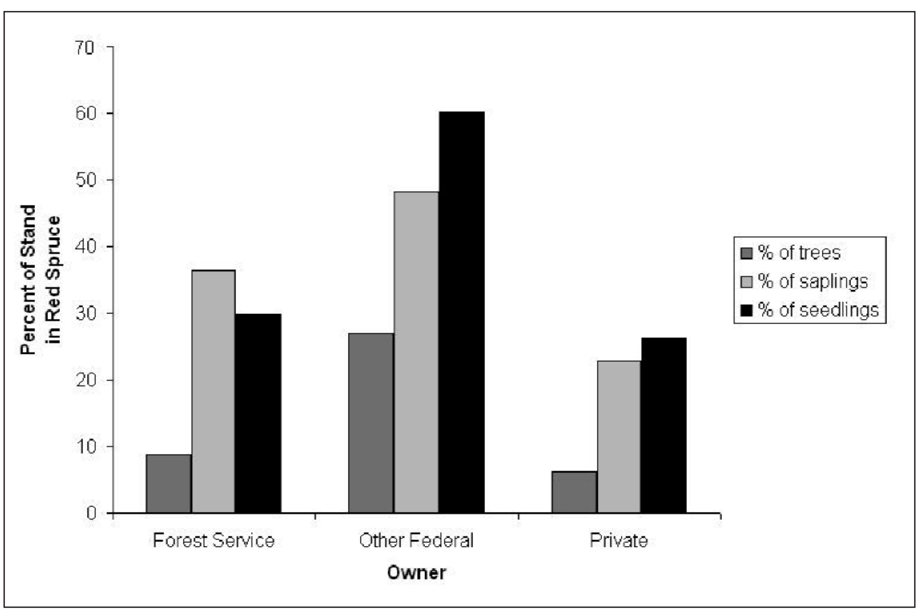

Figure 4.—Percent of tallied trees, saplings, and seedlings in red spruce in the maple/beech/birch forest-type group, North Carolina, Pennsylvania, Tennessee, Virginia, West Virginia, 2006.

management activities may be limited on much of the area where restoration might be appropriate.

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