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The Rate of Woody Plant Invasion on Two Grassy Balds

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ABSTRACT

Woody plant invasion was investigated on Andrews and Gregory Balds in Great Smoky Mountains National Park. Both balds showed a steady, approximately linear decrease in area. Equations predict that Gregory Bald will be covered by forest about 2007 A.D. and Andrews Bald will be covered by 2042. Blueberries on Gregory Bald have increased from 20% cover in 1964 to 53% in 1975. Most of the regeneration on both grassy balds dates from the cessation of grazing. Hawthorn (*Crataegus macrosperma*) and serviceberry (*Amelanchier laevis*) are the most abundant invaders of Gregory Bald but red oaks (*Quercus rubra*) grow well, once they become established. Serviceberry is the most abundant species on the open portion of Andrews Bald, followed by fir (*Abies fraseri*) and hawthorn.

INTRODUCTION

Grassy balds are treeless grassy areas which occur on ridgetops throughout the southern Appalachian Mountains. Even the highest peaks in the area support spruce-fir forest, so the existence and apparent persistence of the balds are unexpected. In the Great Smoky Mountains National Park (GRSM), a 209,000 ha preserve that straddles the border of Tennessee and North Carolina, the grassy balds were once subject to grazing by livestock, particularly cattle and sheep, and to other man-caused disturbances such as woodcutting. Fire may have been used to clear the areas originally, but was apparently not used to maintain them (Lindsay 1976, Lindsay and Bratton in press *a*, in press *b*). As GRSM was established and land was acquired, all grazing ceased on the ridgetops. Since that time woody plants have invaded the open grass sward and it appears that the grassy balds will eventually disappear from the national park.

The purpose of the present study was to determine the rate of woody plant invasion on two of the best known grassy balds in GRSM, to predict the date when these openings will be completely closed, and to describe the structure of the successional communities. The literature on the grassy balds is already extensive, consisting primarily of papers which discuss their flora or possible origins, including Mark (1958, 1959), Billings and Mark (1957), Whittaker (1956, 1966), Clements (1931), Harshberger (1903), Brown (1941), Gates (1941), Wells (1936, 1937, 1938, 1946, 1956), Gilbert (1954), and Gershmehl (1970).

Several authors have attempted to document successional changes, including Bruhn (1964) and Ramseur (1976).

METHODS

Woody plant invasion was studied on Gregory and Andrews Balds. The former is at 1,495 m elevation and is surrounded by mesic northern hardwoods forest on the north side, and by oak forest on the south. The latter is higher, 1,725 m, and is surrounded by spruce-fir forest on the north and west sides, and northern hardwoods on the south and east sides.

At one time, both balds had a flora dominated by mountain oat grass (*Danthonia compressa*) and forbs such as sheep sorrel (*Rumex acetosella*), and cinquefoil (*Potentilla simplex*) (Whittaker 1956, Billings and Mark 1957, Bruhn 1964). Grazing stopped on Gregory Bald in 1936 and on Andrews in 1931.

On both balds, 20-meter or 10-meter plots were laid out along measured transect lines so the plots could be relocated to record changes. Plots were placed at regular intervals except when a transition, such as the edge of a bald, was reached. In such places, successive plots were placed at close intervals adjacent to each other. The plots covered 15% of the area of Gregory Bald and 5% of the area of Andrews Bald. Within each plot, all trees were identified and their diameter at breast height (1.5 m) was measured. Percent cover of herbs and shrubs was estimated visually in 10 one-square-meter plots, which were located one meter apart on alternate sides of a line through the center of the plot. Percent cover, frequency, and relative cover (the percentage of the total cover of all species combined, that was contributed by the single species) were computed for each herb and shrub

species (maximum cover was limited to 150%). Basal area, abundance, relative basal area, and relative abundance were computed for each tree species. Species names used here follow Fernald (1970) where possible, but Radford et al. (1974) is used for species not given in Fernald.

The first method used to assess the rate of woody invasion was based on aerial photography. Color aerial photographs taken in October 1975 were traced under a stereoscope, distinguishing different types of trees and shrubs on the basis of color and height. The vegetation plots sampled could be easily located on the photographs, since their position relative to major trails and bench marks was measured in the field. Each type and an outline of the entire bald were traced on a separate piece of paper and colored. These tracings were then examined with an International Imaging Systems Digicol Processor 4010-32, which can determine what percentage of the image projected on its screen is of a particular color density. By comparing the areas of the tracings of each type of tree or shrub to the area of a square of known area (the side was the distance between two identifiable points on the bald traced from the photo), the area occupied by each species could be determined.

The second method was to determine the age of trees on the balds. Increment cores were taken from up to 20 trees on each 200-square-meter plot. Cores were taken as close to the ground as possible, generally about 30 cm from the ground for smaller trees. When plots on Gregory Bald were cleared to test management procedures, annual rings were counted on stumps that had been sawed off within 5 cm of the ground. Some trees growing on the bald were sawed at 50 cm intervals and rings were counted at each 50 cm to estimate height growth.

RESULTS

Mapping. Analysis of aerial photographs shows that the area of Andrews and Gregory Balds has decreased considerably since the original surveys were made in 1937 and 1944, respectively. Figures 1 and 2 show the areas that were open and grassy when the original surveys were made. Not only have forests encroached around the edges, but many isolated trees of mature forest species are growing in the center of the balds. Ericaceous

shrubs, mostly blueberries (*Vaccinium* spp.) on Gregory and *Rhododendron catawbiense* and blueberries on Andrews, have taken over large areas. Every one of the 94 200-square-meter plots on Gregory and Andrews Balds had some woody plants in it, though some were only very small seedlings. The areas of Gregory and Andrews Balds, as measured by the original surveys and by Bruhn (1964) are shown in Table 1.

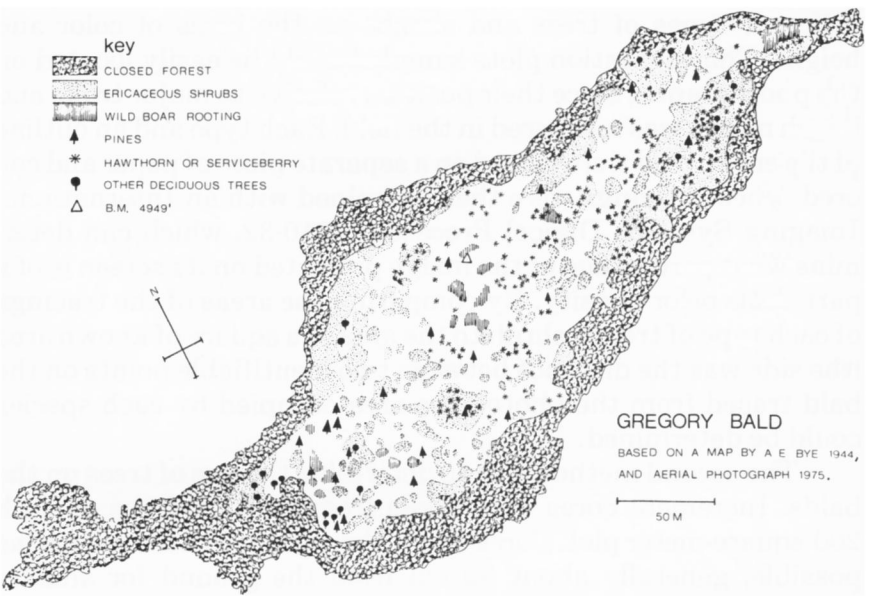


Figure 1. Map of Gregory Bald, Great Smoky Mountains National Park, showing woody plant invasion.

Both balds show a steady, approximately linear decrease in area (Figure 3). The figures (for 1975) count stumps of trees growing outside the continuous forest on the edge as balds, so the decrease in area is greater than the numbers suggest.

Fitting a line to the points graphed in Figure 3 gives the following relation of area to time for Gregory Bald:

$$A = -0.246(T) + 26.4$$

where A is area in acres and T is the year. By extrapolating the line to the abscissa, one can predict Gregory Bald will be covered with forest in about 2007 A.D.

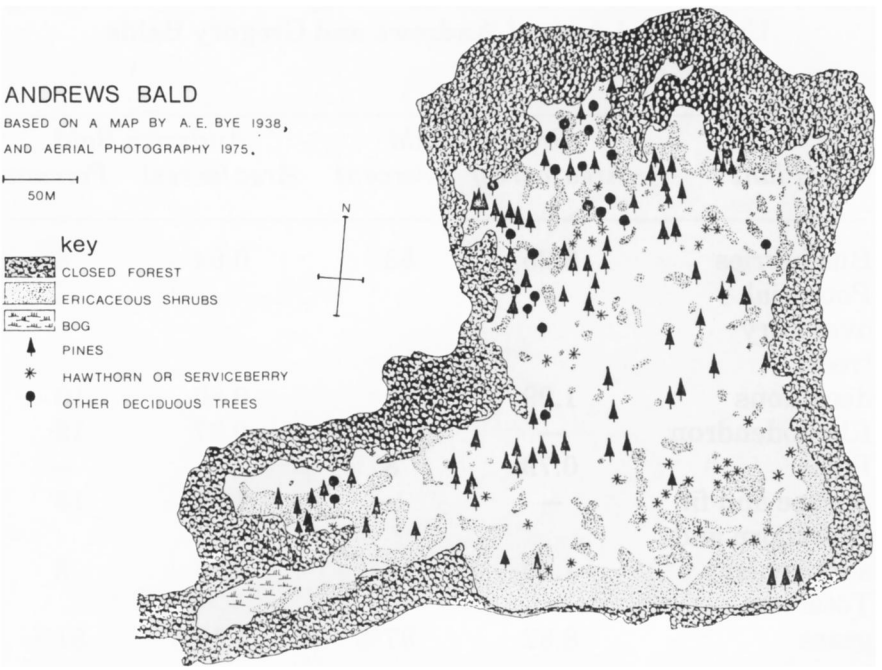


Figure 2. Map of Andrews Bald, Great Smoky Mountains National Park, showing woody plant invasion.

Similarly fitting a line to the data for Andrews Bald gives the equation:

$$A = -.114(T) + 16.3$$

and an x-intercept of the year 2042.

The remaining area of Gregory and Andrews as given here includes the area that has not been covered by forest, continuous with that which originally surrounded them. This "open" area has been invaded by shrubs and trees, and less than half of it is still grass.

The most dramatic change since Bruhn's (1964) study is the great increase in the percent cover of blueberries on Gregory Bald. Bruhn found about 20% cover; we found 53% by a similar method. Using mapping, blueberries form a continuous belt around the edge of the bald and extend quite far under the forest canopy on the south side. Patches of blueberries all over the bald are extending outward by sprouts. Except for a few heavily

Table 1. Percent Cover of Various Woody Plants on Remaining Unforested Area of Andrews and Gregory Balds

Plant	*Gregory Bald*		*Andrews Bald*	
	Area (acres)	*Percent*	*Area (acres)*	*Percent*
Blueberries	5.25	53	0.64	8
Potential overstory trees, deciduous	1.09	11	0.80	10
Rhododendron	—	—	0.97	12
Pines	0.79	8	—	—
Spruce and fir	—	—	1.05	13
Hawthorn and serviceberry	1.49	15	0.64	8
Total non-grass	8.62	87%	4.10	51%

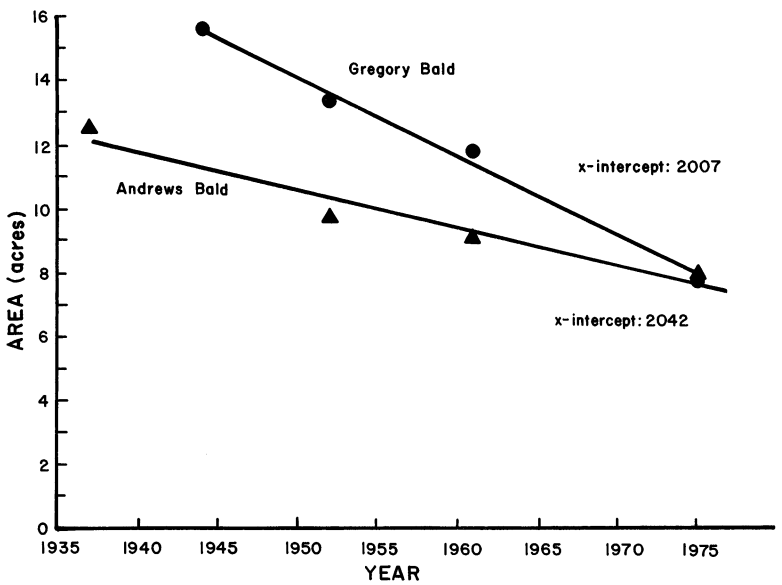


Figure 3. Change in areas of Gregory and Andrews Balds.

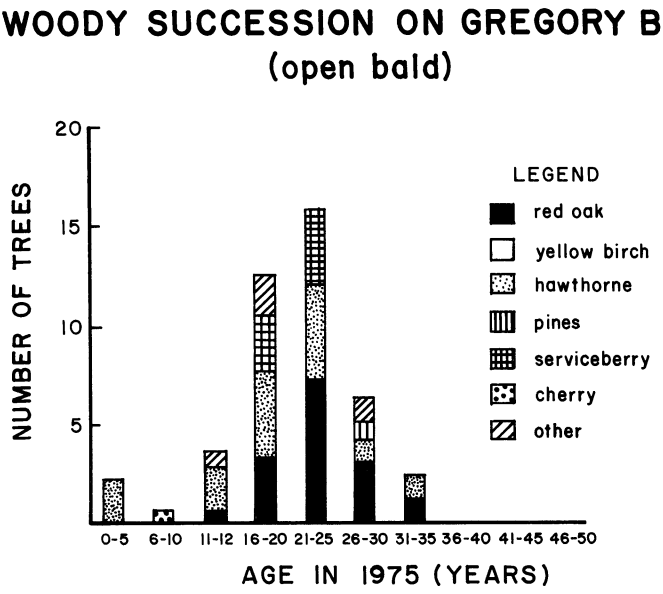
trampled areas, Gregory Bald will probably be completely covered with blueberries in 10 to 20 years; this may have been its presettlement condition. An old resident of Cades Cove (quoted by Gilbert 1954) said that older people had said that Gregory had "always" been a blueberry meadow.

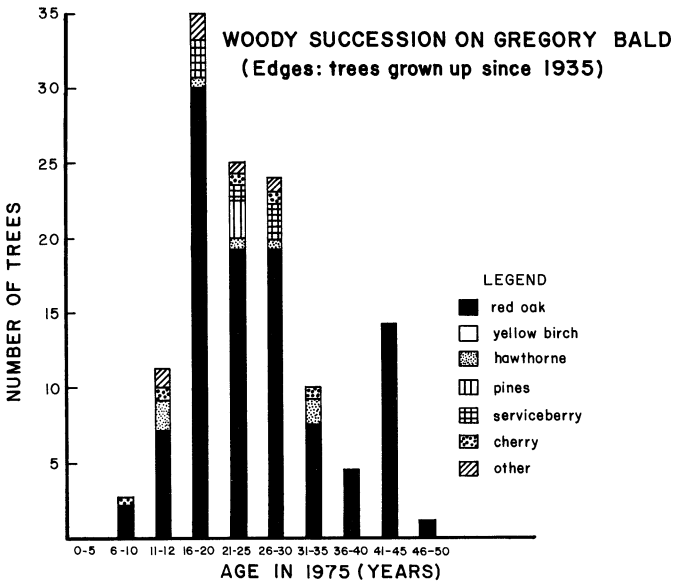
Ring Counts and Plot Data. Age counts of trees on Gregory Bald show that nearly all trees on and around the bald have appeared since the cessation of grazing. Old photographs show an open orchard-type forest of quite large oaks surrounding the bald, but increment cores were taken from very few of these old trees.

Figure 4 shows the age distribution of trees on and around Gregory Bald. Most of the trees on and around the bald became established after grazing was stopped in 1935. Even in the old forest, most of the trees are less than 40 years old. Red oak (*Quercus rubra*) is the dominant species. Tree establishment was most rapid at 10 to 20 years afterward, rather than immediately after the cessation of grazing. Possibly, the thick sod initially made tree establishment difficult. Seedlings are still present, both in the forests around the edges and on the balds. Oak seedlings in the forests are mostly quite small (less than 0.5 m tall), suggesting that the shade there is too dense to allow most of these intolerant seedlings to grow much larger, but seedlings on the bald seem to grow vigorously, especially near the forest margins.

A few oak trees cut on the bald were cut into 50-centimeter segments beginning at ground level. Some of them showed only one annual ring between adjacent 50-centimeter cuts at heights from 1 to 4 cm above ground. Although such ring limits could be in error by as much as two years, this indicates that oaks on the bald can grow 50 centimeters in no more than three years, despite the large amount of production put into side branches. This suggests that the bald is not an extremely marginal habitat for oaks as some have suggested. An oak seedling growing on the bald probably has a better chance of reaching maturity than one starting under the forest canopy. An oak forest may eventually cover the entire bald.

Hawthorn (*Crataegus macrosperma*) is the most widely distributed and abundant invader of the bald, followed by serviceberry (*Amelanchier laevis*) and oak. The forests are dominated by





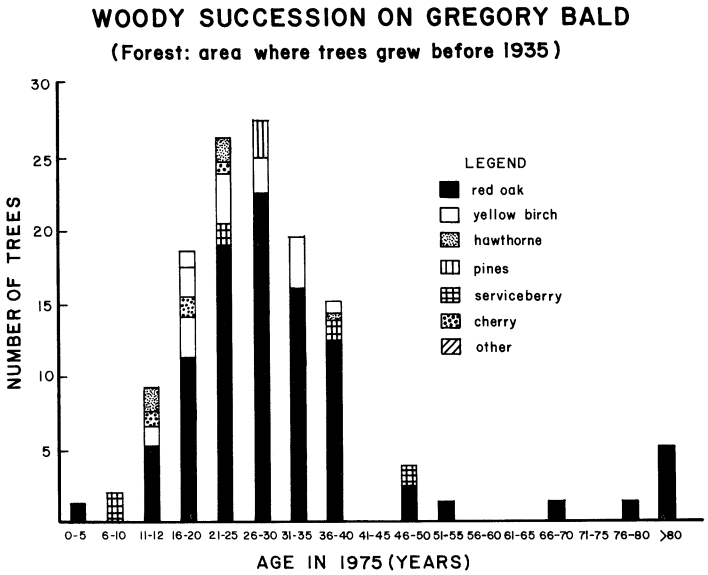


Figure 4. Age distribution of trees on and around Gregory Bald at 20 centimeters above ground, including the open bald, its edges, and the surrounding forests.

oak. The dominance of hawthorn in the forest understory does not mean that hawthorn will be dominant in the future. Hawthorn does not grow tall and cannot become an overstory tree, but it will probably persist a long time in the understory. Chestnut (*Castanea dentata*) will probably persist, but only as an understory tree because all live stems are sprouts from blight-killed trees.

The relative dominance of hawthorn and serviceberry on the bald does not necessarily reflect autogenic successional sequence from grass to hawthorn and serviceberry to oak. The seeds of serviceberry and hawthorn are much more likely to be dispersed all over the bald because the fruits are eaten by birds, and hawthorn also spreads rapidly by vegetative reproduction. Acorns are much less likely to be dispersed up the steep slopes to sites distant from the forest margin. Oak seedlings that get established on the bald grow much more vigorously than hawthorn or serviceberry.

The presence of trees between 40 and 100 years old is difficult to explain. Gregory Bald was clear of forest at least as far

back as 1833 (Gersmehl 1970); hundreds of sheep and cattle were grazed in the area until 1935 (Lindsay 1976), and one would expect them to have suppressed seedlings. Presumably, they missed a few.

The basal areas measured in plots on the bald ranged from 0 to 8.2 m/ha. Plots in the young forest around the edge had basal areas between 10.7 and 17.9 m/ha.

Fewer trees were bored on and around Andrews Bald than on Gregory Bald because most of the cores from spruce and fir trees fell apart into very small fragments and could not be counted. Ramseur's (1976) data show that fir trees started invading Andrews Bald about 1935 and that invasion became more rapid about 1955. Invasion has probably proceeded at least as fast since then; Ramseur avoided coring smaller trees for fear of damaging them.

Hawthorn and serviceberry are the only other common tree species on the open bald but they are less common than on Gregory. Yellow birch, red maple, and chestnut trees are also present.

Beech trees are not invading on the south and east edges, even though beech forest is present. Perhaps the steep, almost cliff-like drop of the edges of the bald make it difficult for the beech to move in by root sprouts. Dense shady thickets of *Rhododendron catawbiense* growing on these two edges might present a barrier to tree invasion.

Serviceberry is the most abundant species on the open portion of Andrews Bald, and the species with the greatest basal area. Fir and hawthorn are the next most important species. Average basal area is only 1.7 m^2/ha.

The spruce-fir forest encroaching on the north and west edges has grown quite dense. The basal area figures may be too high, because large single trees often fell within the small sample plots and raised the basal area for one species to over 60 m^2/ha. However, the forest on the edges is well on its way to becoming a mature forest, and the understory plants are not at all like the bald flora. The forest on the south and east edges has more birch and beech. The low basal area is due to the presence of dense growths of *Rhododendron catawbiense.* If basal area instead of percent cover had been measured for this species, the measured

basal area in these plots would probably have been 5 to 10 m^2/ha. greater.

The woody invasion of the grassy balds began immediately after the cessation of grazing. Establishment of woody plants was most rapid around the edges of the balds, but the isolated trees which grow on balds seem to become centers around which smaller trees become established (Ramseur 1976). This may be due to a more favorable microclimate.

If the present ratio of tree invasion continues, all the balds in the Great Smoky Mountains will probably become covered by forest within 30 to 70 years. Of course, some factors could retard succession or keep parts of the balds clear. Dense growth of blueberries on Gregory Bald could prevent trees from becoming established. An open area may persist along the trail and around the summit because of trampling by visitors. However, if the grass, views, and well-known display of azaleas are overgrown by trees, visitor use may decrease greatly. On Andrews Bald, windthrows have temporarily pushed back the edges in places. The balsam woolly aphid is killing the fir trees (*Abies fraseri*) in the Clingmans Dome area, and its effects are spreading to the bald. If the aphid does kill the firs, the bald may be covered eventually by a forest of very young trees, or it may be covered with rhododendron and become a heath bald of sorts. Birch, beech, serviceberry, and spruce may form a forest on the bald, but encroachment will probably be slower than it would be with healthy fir trees present.

Ramseur (1976) predicted that complete invasion of Andrews Bald would take 200 to 400 years. His data, however, were taken on plots in the central area of the bald and considered establishment of isolated trees there rather than encroachment of forest from the edge (Figure 3). Our data predict faster closure, barring woolly aphid damage.

Most of the tree species surrounding the grassy balds grow vigorously once they become established. Some authors have argued that grassy balds may be ecotonal communities where trees are not effective competitors (Billings and Mark 1957), or that past or present climate was important in their origin (Whittaker 1956), the ridges being too dry or exposed for trees. The growth rate of saplings of species like red oak on or around the

grassy balds implies that climate is not presently limiting and that some sort of disturbance, either natural or man caused, was necessary to clear the areas initially as well as to maintain them.

The rate of woody invasion on the grassy bald is quite slow, however, compared to low elevation communities which were abandoned about the same time and are now completely forested, and, although no quantitative data exist, it appears to be slower than the woody succession on burn scars of similar age and elevation. The burn scars never had an established grass sward (Lindsay and Bratton in press *b*), and woody regeneration probably began immediately after the fire in the more sheltered areas.

An interesting quality of the succession on the grassy balds is the linear function for the rate of closure. One might expect woody invasion to accelerate through time (which it yet may). We can offer no definitive explanation for the curve of invasion rate, but it may be that the resistance of the grass sward to invasion and the pattern of seedling establishment near other woody plants are slowing succession enough to produce a linear function.

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