Management Report

THE VEGETATION OF THE GRASSY BALDS
AND OTHER HIGH ELEVATION DISTURBED AREAS
IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Management Report No. 26

NATIONAL PARK SERVICE
SOUTHEAST REGIONAL
UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS
NATIONAL PARK

NATIONAL PARK SERVICE
Department of the Interior

THE VEGETATION OF THE GRASSY BALDS AND OTHER HIGH ELEVATION DISTURBED AREAS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Management Report No. 26

Mary Lindsay

Uplands Field Research Laboratory
Great Smoky Mountains National Park
Gatlinburg, Tennessee 37738

June 1978

ACKNOWLEDGMENTS

I thank all those who helped me gather data in the field, especially Chris Cunningham, Jim Graves, Jill Baron, and Dave Eissenstat. Great Smoky Mountains National Park staff were very helpful; I am especially grateful to Boyd Evison, Mike Meyers, and Don DeFoe for their assistance. Research Biologist Susan Bratton provided continuous encouragement. Facilities of the Uplands Field Research Laboratory at Tremont and in Gatlinburg were used. R. H. Whittaker made his productivity data available.

I thank Susan Bratton, Peter Marks, Peter White, and Lawrence Barden for their comments on the manuscript.

Research was supported by National Park Service Contracts CX500050207 and CX500061100 with Cornell University.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE | Page

INTRODUCTION

Grassy balds occur throughout the southern Appalachian Mountains. They are treeless grassy areas occurring mostly on ridgetops, both on peaks and in gaps. Even the highest mountains in the southern Appalachians, such as Mount Mitchell and Clingmans Dome, support spruce-fir forest and so are obviously below timberline. Therefore, the existence and apparent persistence of balds are unexpected. Scientists speculated why no trees were found on balds and why woody plants did not invade them. I shall review these theories later.

In the Great Smoky Mountains National Park (GRSM), the grassy balds are being invaded by forest tree species. Many people who have known the GRSM for a long time are concerned about the loss of the unique scenic and historical values of the balds. Therefore, management of a few balds was suggested to restore and maintain the appearance they had when the GRSM was established in 1936.

Concern over the possible disappearance of grassy balds has prompted the National Park Service to support research, including Bruhn's (1964) and the research reported here. Bruhn's results showed the balds were being invaded by trees and would probably not persist without management. Lindsay (1976) indicated that grazing was probably the

main factor responsible for maintaining grassy balds before GRSM was established. A plan for restoring and maintaining Gregory and Andrews Balds was presented in Lindsay (1977).

This report considers the vegetation of the balds -- what its present composition is, how it compares with that of other high elevation communities in the GRSM, how it has changed since GRSM was established, what factors influence it, how rapidly woody plants are encroaching, and what will become of the balds if they are not managed.

Study Sites

I studied the vegetation of several non-forested high elevation communities and the forests around them. A few undisturbed forests were included for comparison (Fig. 1). Table 1 gives the elevation, aspect, and history of each site.

The sites are divided into seven classes:

1. "True balds" are grassy areas whose origin is not known with certainty. The ones included in this study are Parsons Bald, Gregory Bald, Little Bald, Rocky Top, Thunderhead, Silers Bald, a small opening on Welch Ridge (probably originally an extension of Silers Bald), High Springs Bald, Andrews Bald, Mount Sterling Bald, and Hemphill Bald.

Figure 1. Great Smoky Mountains National Park, showing location of study sites.

GREAT SMOKY MOUNTAINS NATIONAL PARK

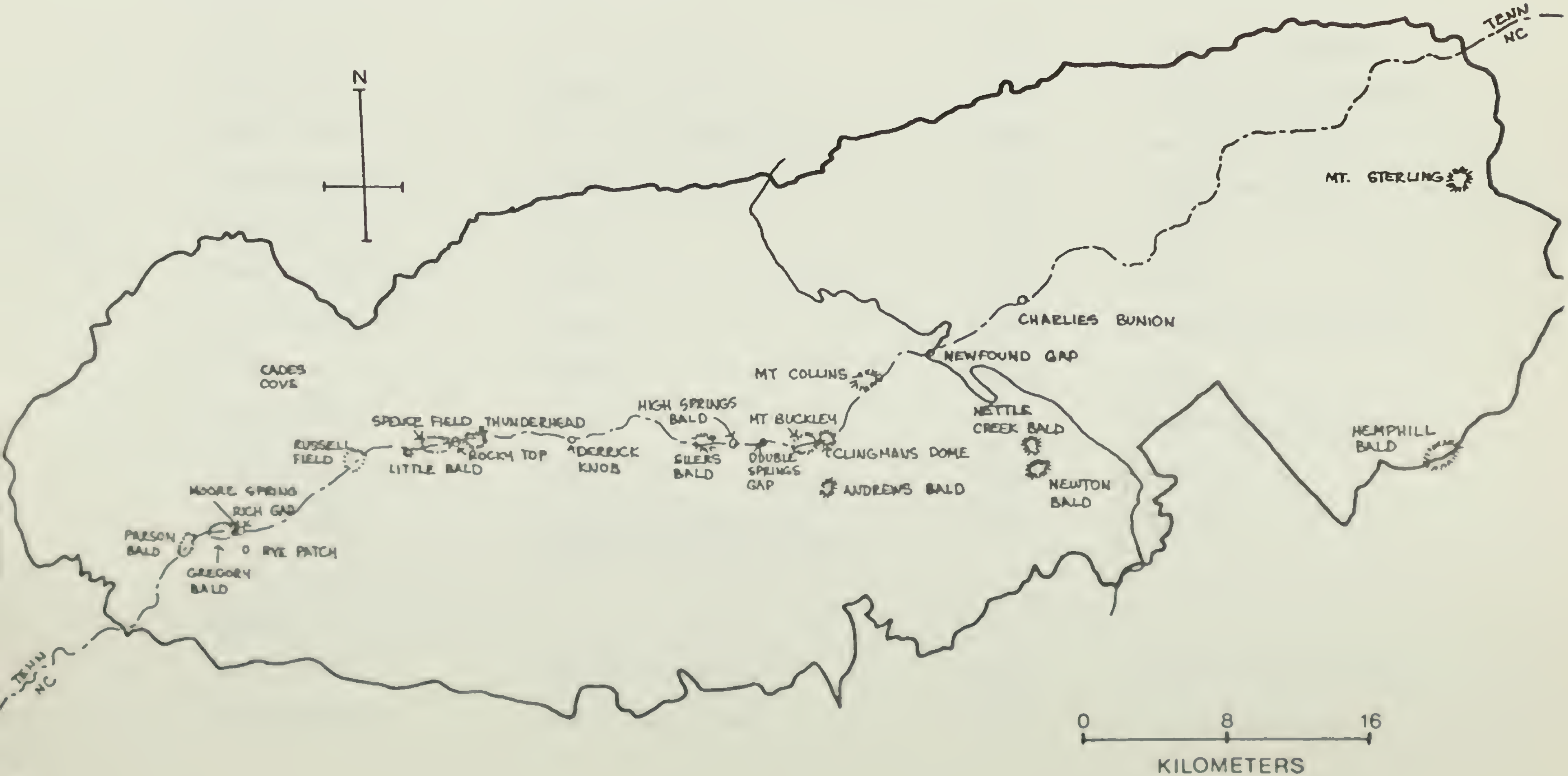


Table 1. Study sites grouped by major type

	History	Approximate altitude (meters)	Aspect
I. True Balds			
Andrews Bald	Grazed until 1931	1,725	South - southwest
Gregory Bald	Grazed until 1935	1,495	Mostly north and south
Hemphill Bald	Half still being grazed	1,680	North and south
High Springs Bald	Probably grazed	1,645	North and south
Little Bald	Grazed	1,510	South
Mount Sterling Bald	Grazed	1,770	West
Parson Bald	Grazed	1,430	Mostly east and west
Rocky Top	Grazed	1,615	West
Silers Bald	Grazed	1,706	South and southeast
Thunderhead	Grazed	1,645	West
Welch Ridge	Probably originally an extension of Silers Bald	1,645	Level
II. Fields			
Spence Field	Cleared and grazed	1,495	Mostly north and south
Russell Field	Cleared and grazed	1,340	All directions

Table 1. Study sites grouped by major type - Cont.

Type and Name	History	Approximate altitude (meters)	Aspect
III. Forested Areas Called Balds			
Newton Bald	May have been grazed	1,570	North and south
Nettle Creek Bald	May have been grazed	1,570	All directions
IV. Other Areas Used by Settlers			
Rye Patch	Site of cabin; was farmed	1,250	Southeast
Rich Gap	Site of gant lot	1,402	Southeast
V. Burn Scars			
Burned area on Clingmans Dome	Burned in 1920's; fire in logging slash	1,890 - 1,950	Southwest
Burned area east of Charlies Bunion	Burned in 1920's	1,615	Southeast
Charlies Bunion	Burned in 1920's	1,615	Southeast

(Cont'd on next page)

Table 1. Study sites grouped by major type - Cont.

Type and Name	History	Appropriate altitude (meters)	Aspect
VI. Shelter Clearings			
Derrick Knob Shelter	Subject to trampling	1,495	West
Mount Collins Shelter	Subject to trampling	1,790	West
Moore Spring Shelter	Subject to trampling	1,405	West
Russell Field Shelter	Subject to trampling	1,345	West
Spence Field Shelter	Subject to trampling	1,490	West
VII. Roadsides			
Clingmans Dome Road	Mowed regularly	1,585 - 1,950	West
Newfound Gap Road	Mowed regularly	1,450 - 1,480	West
Roadcut on Newfound Gap Road	New growth on bare rock and soil exposed in road construction	1,460	West
VIII. Virgin Forest			
Forest on Mount Collins	No known disturbance	1,830	West

2. "Fields" are grassy areas which were cleared by settlers in the late nineteenth century and grazed. The only ones in the GRSM that were certainly cleared by men are Spence Field and Russell Field.

3. Burn scars are areas burned after logging in the 1920's. The two areas studied were Charlies Bunion and the ridge immediately to the east, and the east slope of Clingmans Dome.

4. Shelter clearings, cleared areas around shelters along the Appalachian Trail. Data were taken at Moore Spring, Derrick Knob, Russell Field Shelter, Spence Field Shelter (these four are surrounded by hardwood forest and the data were averaged together), and Mount Collins Shelter (in spruce-fir forest).

5. Places called "bald" which are covered with well developed forests. Newton Bald and Nettle Creek Bald were the ones included in this study. These may have once been open park-like forests, free of underbrush and small herbs, like those which surrounded the true balds while they were being grazed.

6. Mowed roadsides along the Clingmans Dome and Newfound Gap roads.

7. Areas otherwise affected by human activity. Rye Patch on Long Hungry Ridge was farmed. Rich Gap near Gregory Bald was the location of a "gant lot" where the herders penned cattle in the fall so they could be sorted out.

Most of these sites are in the western half of GRSM. Perhaps the spruce-fir forests on the high ridges of the eastern half of the park were less inviting to early settlers interested in grazing or farming. There would probably have been less game and less forage for grazing livestock. The roads and trails into Cades Cove from outside the mountains and from the cove to the high peaks gave better access to the main ridge in the western part of GRSM than anywhere in the eastern part of the GRSM except for the Cataloochee area where most of the balds in the eastern half of the GRSM occur. The reader interested in more details on the vegetation and physiography of the GRSM is referred to Whittaker (1956) and his sources. Climate is discussed in Shanks (1954).

Literature Review

Publications about grassy balds have dealt with two main questions besides the kinds of plants present: Why are there no trees on bald places, and what kept trees from invading? Unfortunately, many writers have not distinguished between these two questions. Seeing trees dying on one site, some have proposed theories that explain the absence of mature trees without explaining what prevented understory trees or dormant seeds from forming a new forest. Others have proposed theories to explain why tree invasion is slow but do not explain the absence of trees or the development of a grassy cover. Moreover, all balds need not have originated by similar means nor have had the same factors maintaining them.

A main difficulty in determining the origin of grassy balds is that no one knows their age. Since the balds are mentioned in Cherokee legends that were collected in the nineteenth century by Mooney (1898), they were assumed to be many centuries old. If balds predated white settlement by centuries, their origin and persistence would have to be explained entirely in terms of natural factors or the work of Indians. If they are less than 300 years old, they might have been formed and maintained entirely by human action.

Several natural factors have been suggested which could have deforested bald areas. Whittaker (1956) suggested that spruce-fir forest was absent from certain peaks because this forest type was restricted to the very highest peaks during a postglacial period of warm climate. During the cooler period that followed, spruce-fir forest remained absent from peaks where it had once grown because none of the high peaks was near enough to be a source of seeds. Therefore, these areas remained open and became grassy. Billings and Mark (1957) suggested that some balds may have originated or become much larger during the same period of cool climate. Conditions on the peaks could have become too cold for deciduous trees. After the deciduous trees died, no spruce or fir tree seeds could reach the peak to generate a coniferous forest to replace them. Therefore, the peak could remain bare. However, this theory cannot account for all the balds in the GRSM. Forest covers sections of the main ridge between Thunderhead and Gregory Bald, which differ in elevation by

200 meters. If both the bald on Thunderhead and Gregory Bald were caused by a downward migration of deciduous forests, why are there no natural balds between Gregory Bald and Thunderhead, other than Little Bald? Andrews Bald is surrounded on two sides by spruce-fir forest and lies on a ridge extending down from Clingmans Dome where spruce-fir forest persisted during the period of warm climate, and Billings' and Mark's theory could not apply here because a seed source was always available.

Other proposed natural causes for the treelessness of balds include fire (Clements 1931), ice and frost damage (Harshberger 1903), windthrow (Brown 1941), gall wasps (Gates 1941), and dry microclimate (Camp 1931; Whittaker 1956; Davis 1930). Fire could have been a factor in creating balds. Areas burned over by fires in logging slash such as the area around Black Balsam Knob in the Pisgah National Forest have become covered with vegetation similar to that of grassy balds. However, in the absence of logging slash, fires severe enough to remove a mature forest canopy are rare at high elevations in the Southern Appalachians (Barden 1974). Very few balds are likely to have been created by fire. Other factors may have been important in one or two places but not for all balds. Frost and ice damage are common on trees around balds, but they have proved to be no hindrance to the growth of young trees on balds. Windthrow may extend edges of grassy balds, but most windthrows start where a forest edge is already bounded by an open

area. Gall wasps could kill oak forest but not beech or spruce-fir forests. Wells (1936, 1937, 1938, 1946, 1956) proposed clearing by the Cherokee Indians as a possible cause of some grassy balds. Although the Indians may have removed the understory by repeated fires in some places, it is unlikely that they could have cleared very many mountain tops.

Being mentioned in Cherokee legends may not mean that the balds are especially old. According to Gersmehl (1970), Cherokee oral traditions were very short-lived, and the legends in which balds were mentioned were variations of an old legend common among related Indian tribes. Cherokee story tellers would mention details of the local landscape to make their stories more believable rather than make up stories to explain features of the landscape. Therefore, even if balds were created by white settlers in the mid-eighteenth century, they could have found their way into Cherokee legends in the next few decades. Early travelers in the region, such as William Bartram, do not mention balds but such lack of mention is inconclusive.

Gersmehl proposed that balds were almost all made by white settlers, mainly through use of fire. The balds were then kept open and growth of _Danthonia compressa_, the dominant grass, was encouraged by grazing. He cites reasons why the settlers could have found it worthwhile to go to the trouble of clearing mountain tops to graze their livestock in the summer: it was part of their cultural

tradition, more land could be made available for crops or hay, and it was difficult to fence livestock out of crops. Several old residents of the area around the GRSM mentioned rumors that a few balds had been cleared by settlers (Lindsay 1976), and the floristic composition of the fields known to have been cleared is very similar to that of the natural grassy balds.

It seems impossible in most cases to determine exactly what caused trees to be removed from balds, and it seems fairly reasonable to suppose that different factors could be important in different places. The next question is why the balds became grassy rather than shrubby or reforested. Jenkins and Ayres (1951) found that *Danthonia compressa*, a native grass which is the dominant and most characteristic species of grassy balds and fields, was present only in areas continually disturbed by man and that the disturbance had to be sufficient to eliminate woody species. This is borne out by my own observations that, off grassy balds, *Danthonia* is found only along edges of trails in a few places. Burned areas in the Great Smoky Mountains are covered with *Rubus canadensis*, ferns, sedges, *Vaccinium* spp., and many forbs, but grass cover is low and *Danthonia* is entirely absent. If the balds were grassy when white man came to the mountains, it was only by continued disturbance, such as burning by the Indians or grazing by native herbivores.

Burning by the Indians seems to have been common, and an open area could have been maintained by fire. Ramsey (1853) mentions a large area in the Cumberlands that, in 1783, was maintained as an open meadow by large herds of deer, elk, and bison. Linzey and Linzey (1968) say that bison and elk were present in the Great Smoky Mountains until the end of the eighteenth century. Such native herbivores might have maintained balds throughout the Southern Appalachians. If no such continuous disturbance existed before white settlers grazed their livestock, grassy balds would probably have been covered with Rubus, Vaccinium, or other shrubby growth rather than grass. Since livestock do not eat much Vaccinium (Lindsay 1977) and are poisoned by other common shrubs that might have invaded cleared areas, such as Laurel (Kalmia) and Rhododendron spp., some human intervention must have been necessary to create the grassy cover if native grazing animals were not present.

Why did grassy balds remain grassy? The encroachment of woody species into balds since the 1940's suggests that balds are not naturally maintained communities. The invasion has become much more obvious in the last 20 years, and most of the work on grassy balds done previously may not have adequately considered the potential rate of succession.

Theories of bald maintenance include climatic factors, grazing, and Billings' and Marks' (1957) ecotone theory. Whittaker (1956) attributes the maintenance of balds to unfavorable southerly and

westerly exposure coupled with high water loss through runoff. High runoff could be as much a result of treelessness as a cause. Camp (1931) and Brown (1941), among others, also cite moisture stress as a factor. Grazing is mentioned by Cain (quoted by Yard 1972), Camp (1942), and Griggs (quoted by Yard, 1942).

Billings and Marks (1957) proposed that the growth on many balds was hindered by their ecotonal location. In the transition zone between two forest types such as hardwood and spruce-fir, neither type would be growing under optimum conditions, so the additional stress of an open site might explain the slow tree growth. This theory could explain the slow invasion by trees of balds where hardwood forests surround balds in a potential spruce-fir zone isolated from seed source. However, many balds do not fulfill these conditions. Andrews Bald is clearly located in an ecotone. Color photographs taken in October 1975 show spruce-fir forest extending down Forney Ridge and bordering the north and west edges of the bald, while hardwood forests border the south and east. Tree invasion is progressing and will eventually result in the forest over the whole area (Ramseur 1976). Competition limits forest types to a narrower range of ecological conditions than the physical tolerance limits of the component species. Therefore, we could expect a forest type to grow beyond the ecotone in the absence of a competitive forest type. Black Balsam Knob in the Pisgah National Forest is surrounded on two sides by spruce forest and is not ecotonal since it extends above this forest. However, tree invasion is very slow.

The most telling argument against any theory that balds were maintained by natural factors is their invasion by woody plants as reported by Bruhn (1964), Gersmehl (1970), Ramseur (1976), and this report. In summary, the removal of trees from balds could have been due to several factors. As Gilbert (1954) pointed out, there is not necessarily a single cause for all balds, and different balds could have come about by different means. Fire, climatic change, gall wasps, and clearing by white settlers or Indians might have cleared trees from at least a few balds. Except for those places where clearing or fire are documented, the explanation for the absence of trees will remain speculative. Grazing or other continuing disturbance seems necessary to cause development of the typical *Danthonia* cover. Although natural factors contribute to maintenance of balds, grazing seems to have been the main factor that kept them open and grassy.

METHODS

Woody Plant Invasion of the Balds

Woody plant invasion was studied only on Andrews and Gregory Balds. Two methods were used.

The first method was based on aerial photography. Color aerial photographs taken in October 1975 were traced under a steroscope, distinguishing different types of trees and shrubs on the basis of color and height. Each type and an outline of the entire bald were traced on a separate piece of paper and colored in. These tracings were then examined with an International Imaging Systems Digicol Processor 4010-32. This image analyzer can tell 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 could be determined.

The second approach was to age 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 centimeters 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 centimeters of the ground. Some trees growing on the bald were sawed at 50-centimeter intervals and rings were counted at each 50 centimeters to estimate height growth.

Present Vegetation of the Balds and Other High Elevation Communities

Field Sampling

The vegetation was sampled in several 200-square-meter plots on most of the study sites. On Gregory and Andrews Balds, 20-meter or 10-meter plots were laid out along measured transect lines so the plots could be relocated to record changes resulting from management. 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 about 15 percent of the area of Gregory Bald and 5 percent of the area of Andrews Bald. Exact locations of the plots have been filed in the GRSM archives.

On other sites I tried to sample areas that were still open, forest that had grown up since the cessation of disturbance, and forest that was present during or before the disturbance. If aspect seemed to have a significant effect on the vegetation, different slopes were included in the sample. No attempt was made to locate plots randomly

or systematically beyond efforts to encompass the range of variation in the vegetation on and around a particular site. On sites other than Gregory and Andrews Balds, circular plots with a radius of 8 meters (201 square meters) were used because they could be laid out much more rapidly.

Within each 200-square-meter plot, all trees were identified and their diameter at breast height (1.5 meters) was measured. Percent cover of herbs and shrubs was estimated visually in 10 one-square-meter plots. In the 10 meter by 20 meter rectangular plots, the herb plots were located one meter apart on alternate sides of a line through the center of the plot. In circular plots, 8 herb plots were placed along a diameter and one on each side of the diameter 4 meters out from the center. In shelter clearings and along roadsides, 6 one-square-meter quadrats were placed at each site. Quadrats in shelter clearings were placed to avoid bare ground.

Percent cover, frequency (percentage of herb subplots in which a species occurred) 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 in every 200-square-meter plot average. To avoid distortion of the data by exceptionally dense growth of a particular species, 150 percent was set as the maximum percent cover that could be recorded for any

species. Basal area, abundance, relative basal area, and relative abundance were computed for each tree species. To simplify the analysis of data from over 200 plots, each measuring 200 square meters, data were averaged from the several plots that occurred in a single vegetation type on a single site. For example, all samples on the open grassy part of Spence Field were placed in one group, samples in young forest on the north slope in another, and so forth. The only exception was on Gregory and Andrews Balds, where samples were grouped on the basis of the results of a principal components ordination. The percent cover, abundance, and basal areas in these summaries are means of the values in the individual plots; the frequency is the percentage of 200-square-meter plots in which a species occurs. These stand summaries are on file in the GRSM archives.

The species names used here follow Fernald (1970) where possible, but Radford et al. (1974) was used to identify plants in the field, and their nomenclature is followed for species not given in Fernald. Many grasses, sedges, and composites could not be identified because they were not in flower or fruit. These are given as "grass", "*Solidago* sp.", "*Carex* sp.", and so forth. Some species of *Vaccinium* were grouped together because they could not be distinguished without flowers or fruit. *Vaccinium vacillans* was combined with other low-growing smooth-leaved species. *V. corymbosum* and *V. constablaei* were combined. *V. erythrocarpum*, *V. stamineum*, and *V. hirsutam*

could be distinguished without fruit or flowers. I did not try to distinguish the deciduous Rhododendron species ("azaleas"). Others (Bruhn 1964, Mark 1959) identified the Crataegus sp. as C. macrosperma var. roanensis.

Ordination of Samples

Ordination is a mathematical technique which attempts to arrange samples in an order that corresponds to some environmental factor or combination of factors. Since an ordination tends to group similar stands, ordination can also be a first step towards classifying samples.

Because so many environmental factors seemed to be important, including some, such as history, that could not be easily identified, direct ordination was not attempted with these data. In direct ordination, samples corresponding with defined values of some environmental factor are arranged in order along the environmental gradient. The response of various species and other characteristics of the samples to the environmental factor can then be analyzed. In indirect ordination, the characteristics of the samples are used to order them along one or more axes, which may then be correlated to environmental factors. Bray-Curtis ordination (Bray and Curtis 1957) is the most straightforward of these techniques and causes least distortion of the axes (Whittaker and Gauch 1973). It was not

practical to use it for these data because many pairs of stands had zero similarity, making it impossible to choose any two particular stands as end points.

Principal components analysis (PCA) was chosen as the ordination technique because PCA distributes the samples along axes of the greatest variation in the data. Although Whittaker and Gauch (1973) criticize PCA for its tendency to distort axes, especially with as great a diversity among samples as in this study, and for its relative computational difficulty, it gave an adequate ordering of the samples and permitted insights into factors affecting the vegetation.

PCA ordination of these samples was done with Cornell Ecology Program 23 (Gauch 1973, 1976) on an IBM 360 computer at The University of Tennessee, Knoxville. The herb and shrub species with the lowest percent cover, averaged over stands in which they occurred, were eliminated because they would have contributed little to the results. Values which did not represent well defined species or genera (such as unidentified grasses) were also eliminated. One hundred species were left. The ordinations were then done using the importance values of these 100 herb and shrub species and 35 tree species. Ordination was done with presence - absence data, raw importance values, or importance values relativized to stands. Raw importance values were percent cover for herbs and shrubs and basal area for

trees. Relative importance value of a species was the proportion of total percent cover or basal area in a stand contributed by that species. Data from Whittaker's (1966) productivity studies were included in the ordinations based on relative importance and presence - absence values; although he measured biomass rather than percent cover, his biomass data could be relativized. The samples ordinated are listed in Appendix Table 2.

RESULTS

Vegetation of the Balds and Other High Elevation Communities

The stand summaries were divided into several groups on the basis of appearance, age, and history. The three main groups were balds, areas that were still predominantly open and free of large trees; young forests, forests that had grown around balds or on burned sites since the cessation of disturbance; and mature forests, areas that had at least a few trees on them before the establishment of GRSM. These three basic types were further divided by altitude to correspond with the prevailing forest types: oak, beech or birch, and spruce-fir.

In addition to the nine types of communities derived above, I distinguished fields, areas known to have been cleared by man in the late nineteenth century; two smaller open areas, Rich Gap, where cattle were penned and sorted out in the fall, and Rye Patch, the site of a small farm, also artificially cleared; mowed roadsides and shelter clearings; a bald (Hemphill) that is still being grazed by cattle; and two sites that are named "bald" but are forested, Newton Bald and Nettle Creek Bald.

Data from all stands in each type were averaged to obtain the results for herbs and shrubs and trees (Appendix, Tables 3 and 4).

The Herbaceous Vegetation

Open Sites

On all the "natural" balds, *Danthonia compressa* was dominant, at least in patches. *Rumex acetosella*, sheep sorrel, and *Potentilla canadensis* were also present in all stands. *Rubus canadensis*, blackberry; *Vaccinium vacillans*, blueberry; and *Violá rotundifolia*, violet, were present on almost all balds. All balds had at least one species of *Aster*, *Solidago*, and *Carex*. *Agrostis alba*, *Carex normalis*, *Dryopteris spinulosa*, *Houstonia purpurea*, *H. serpyllifolia*, *Juncus tenuis*, *Luzula* sp., *Polytrichum* sp., *Prenanthes* sp., and *Stenanthium gramineum* occurred on balds at all altitudes. *Achillea millefolium*, *Aster lateriflorus*, *A. undulatus*, *Lechea racemulosa*, *Senecio smallii*, *Oxalis stricta*, and *Solidago bicolor* were confined to the lower elevation balds. *Vaccinium vacillans* reached its maximum importance on and around balds in oak forest. *Cuscuta* sp., *Rudbeckia lacinata*, *Angelica triquinata*, *Aster acuminatus*, and *Solidago glomerata* were typical of high elevation balds.

Introduced species were most common on the balds in oak forest; 15.7 percent of the species found there were exotic. On the balds in beech forest, 6.2 percent of the species were exotic; and on balds in spruce-fir, 2.1 percent of the species were exotic.

The cleared fields, Russell Field and Spence Field, lie near the lower and upper limit of oak forest, respectively. Their vegetation is similar to that of the balds in oak forest. They were also dominated by Danthonia compressa; and Potentilla canadensis, Rumex acetosella, and Aster spp. occurred frequently. Many herb species on Russell Field occurred on no other site studied, but the low altitude may have been as important as the history of the site in causing their presence. Eleven percent of the species on the cleared fields were exotic.

Rye Patch and Rich Gap had many species in common with the balds in oak forest, but Danthonia was not the dominant species, and other grasses and weedy forbs such as Prunella vulgaris, Desmodium sp., and Eupatorium rugosum were more important on these sites. Twelve and one-half percent of the species were exotics.

The burn scars were quite different from any of the vegetation types described above. Grasses were very low in importance. Rubus canadensis averaged 63.4 percent cover, the highest it attained in any type of community. Angelica triquinata, Athyrium filix-femina, Carex debilis, Dennstaedtia punctilobula, Solidago glomerata, Stachys clingmanii, and Diervilla sessilifolia all averaged 9 percent or higher in cover. Danthonia occurred only in a few trampled places along trails. Nearly all the species on these burn scars were present on and around balds at a similar elevation, but the

proportions were so different that the general appearance was entirely dissimilar. Exotic species made up 3.2 percent of those present on burn scars.

Roadsides and shelter clearings were under constant disturbance from mowing or trampling. They were dominated by the exotics, Plantago spp., Poa annua, Trilolium spp., and Taraxacum officinale. Juncus tenuis was very frequent although its relative cover was always low. These species were very infrequent on balds, being confined to heavily trampled places such as the summit of Gregory Bald along the trail. Exotic species were 29.8 percent of those present. Many of these exotics, such as Cichorium intybus, Galinsoga ciliata, Chrysanthemum leucantheum, and Rumex obtusifolius, were absent or extremely uncommon elsewhere.

Hemphill Bald, which still has cattle grazing on it, was very similar to the roadsides and shelters. Plantago, Taraxacum, Poa, and Trifolium dominate the vegetation. Danthonia was present, but only as very small plants cropped close to the ground. The half of the bald that was included in GRSM and therefore not grazed for over 40 years had not grown up into a dense stand of Danthonia as the other balds and fields did after grazing ceased. Instead, there was a dense stand of tall forbs such as Agastache scrophulariaefolia, Blephilia hirsuta, Rudbeckia lacinata, Geum sp., Monarda clinopodia, and Campanula americana. (This area is averaged in with young beech or birch

forests.) There was no obvious reason why a dense sward of *Danthonia* did not become established; perhaps this had not occurred because the part of the bald that is inside the park boundary is on a north slope and therefore much more mesic than most balds and fields. The percentage of exotic species in the sample on Hemphill Bald was extremely high, 59.1 percent. Since the sample was small, the total number of species may not represent the total number of species on the bald; a larger sample might have revealed more native species. The constant grazing of the cattle keeps the vegetation cropped extremely close to the ground. This disturbance, more severe than even that on the mowed roadsides, may have reduced the diversity and favored alien species so much that the figure is real rather than due to sampling error. Since Hemphill Bald is on the GRSM boundary, there is no surrounding undisturbed forest to stay the migration of exotic species onto it.

Young forests

The herbaceous vegetation of young forests was found to be transitional between that of the balds which they surround and the mature forests of the same type. Species such as *Danthonia compressa*, *Rumex acetosella*, and *Potentilla* were present but do not attain high coverage. Ferns and more mesic species were more important than in the open areas.

The oak forests had more species in common with the open areas they surrounded than the beech or spruce-fir forests. Some stands had higher coverage of Danthoria than some open areas. No species occurred in young forests that was absent from balds except Arisaema triphyllum. The only species that had a higher coverage in the oak forest than in open areas were Eupatorium rugosum and Dryopteris noveboracensis.

Beech forests differed from the balds they surround in having more sedges and fewer grasses. Except around Hemphill Bald, no species occurred in the forests that were not present on the nearby balds. Some of the more important species were Angelica trinquinata, Aster divaricatus, Athyrium filix-femina, Carex pensylvanica, Eupatorium rugosum, Solidago curtisii, and Rubus canadensis. Overall herb cover was often very low because of rooting by European wild boar.

Young spruce-fir forests also contained no species not found on the open areas which they surround. The main difference was the much greater coverage by Oxalis montana and the lower coverage by grasses.

The only species found common to all young forests at all elevations were Rubus canadensis, Dryopteris spinulosa, and sedges. The occurrence of exotic species was low; 8.6 percent of the species in oak forests, 3.3 percent in beech forests, and 5.4 percent in spruce-fir forests were exotic.

Mature Forests

These are areas that were forested before the establishment of GRSM. They may have been affected by grazing. These forests also have few species that are absent from the open communities. The percent cover of grasses was very low, less than 5 percent.

Species found important in oak forests included *Dennstaedtia punctilobula*, *Houstonia serpyllifolia*, *Rubus canadensis*, and *Vaccinium vacillans*. *Angelica triquinata*, *Carex pensylvanica*, *Eupatorium rugosum*, and *Solidago curtisii* were important in beech forests. Relatively few species were found in the spruce-fir forests; *Dryopteris spinulosa*, mosses, *Oxalis montana*, *Senecio rugelia*, *Solidago glomerata*, and *Viburnum alnifolium* made up most of the cover. The total cover was higher than in the oak and beech forests, despite the lower number of species.

Introduced species were uncommon in the mature forests. None were found in the beech or spruce-fir forests, and only 4.6 percent of the species in the oak forests were exotic.

The sampled forested areas called "bald" were relatively open oak forests with a dense and diverse herbaceous cover. The dominant species were *Dryopteris noveboracensis*, *Rubus canadensis*, and *Carex pensylvanica*. Grasses were almost entirely absent, and no exotic species were found.

Trees

Species Composition

Tree data were averaged together over all stands in a particular stand type. The samples on which the summarized tree data are based were often too small or had too high a variance to allow generalizing basal area or relative importance for any one stand. When time allowed only one plot in a forest stand, inclusion of one exceptionally large tree in a plot distorted data greatly. However, the average of several stands probably shows general trends fairly accurately.

Balds and fields had the lowest basal areas, less than 10 square meters per hectare and sometimes less than 1 square meter per hectare. *Craetagus* (hawthorn), *Amelanchier laevis* (serviceberry), and *Prunus serotina* (black cherry) occurred at all elevations. *Pinus pungens*, *P. strobus*, and *P. rigida* (pine) were common on the balds in oak forests and on the field and rare elsewhere. Tree species of the surrounding forest were common on balds in oak and spruce-fir forests, but very few beech trees occurred in balds in beech forest except around the edges. This is because beech reproduces mainly by sprouts and not by seeds; young individuals do not start far from older ones.

The trees growing on Rich Gap and on Rye Patch were mostly rather small (dbh about 10 centimeters) individuals of species from the surrounding forests. Red oak (Quercus rubra) and sourwood (Oxydendrum arboreum) were the most important species. Basal area was about 8 square meters per hectare.

The burn scars are all above 1,600 meters and are on sites surrounded by spruce-fir forests. Fraser fir and red spruce were the principal invaders of these sites, and yellow birch (Betula lutea), mountain ash (Pyrus americana), and fire cherry (Prunus pensylvanica) were also common. Basal area was about 7 square meters per hectare.

No sample plots on Hemphill Bald included trees. However, yellow buckeye (Aesculus octandra), Craetagus, and black locust (Robinia pseudoacacia) were seen near the top of the bald, and sugar maple (Acer saccharum) and beech (Fagus grandifolia) are at the lower edges.

All young forests sampled had basal areas averaging from 14 to 24 square meters per hectare for the various types. Over half the basal area in the oak forests was red oak. Serviceberry, sourwood, and red maple were next in importance. Sixteen other species were also found. Beech made up about 60 percent of the basal area in beech forests and yellow birch about 20 percent. Yellow buckeye and mountain ash were of secondary importance, and 15 other species

were present. Half the basal area of the young spruce-fir forests was in Fraser fir, about 16 percent in mountain ash, and 20 percent in yellow birch. Five other species were also present.

The mature forests had basal areas from 36 square meters per hectare for the dry oak forests to 52 square meters per hectare for mature spruce-fir forest. In oak forests, red oak made up about 40 percent of the basal area, and sourwood, sugar maple, yellow birch, and beech each contributed about 10 percent of the basal area. Ten other species were recorded.

The beech-northern hardwood forests had 33 percent of their basal area in beech. Red oak contributed 32 percent of the basal area, yellow buckeye 23 percent, black cherry 9 percent, and sugar maple 2 percent. The only other species recorded was hawthorn. The large relative basal areas of red oak and yellow buckeye could be due to the presence of a few large individuals in the one 200-square-meter plot taken near Hemphill Bald.

The mature spruce-fir forest had only three important species: Red spruce, which was 39 percent of the basal area; Fraser fir, which was 29 percent of the basal area; and yellow birch, which was 32 percent of the basal area. Mountain maple (*Acer spicatum*) was present.

Newton Bald and Nettle Creek were found to be essentially rather open mature red oak forests. The average total basal area was about 31 square meters per hectare, of which 76 percent was red oak. White oak, yellow birch, red maple, black locust, and hemlock each contributed 3 or 4 percent of the basal area. Eleven other species were recorded.

Woody Plant Invasion of the Balds

Mapping

Analysis of aerial photographs showed that the area of Andrews and Gregory Balds has decreased considerably since the original surveys were made in 1937 and 1944, respectively. Figures 2 and 3 show the area that was 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 out 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 2.

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

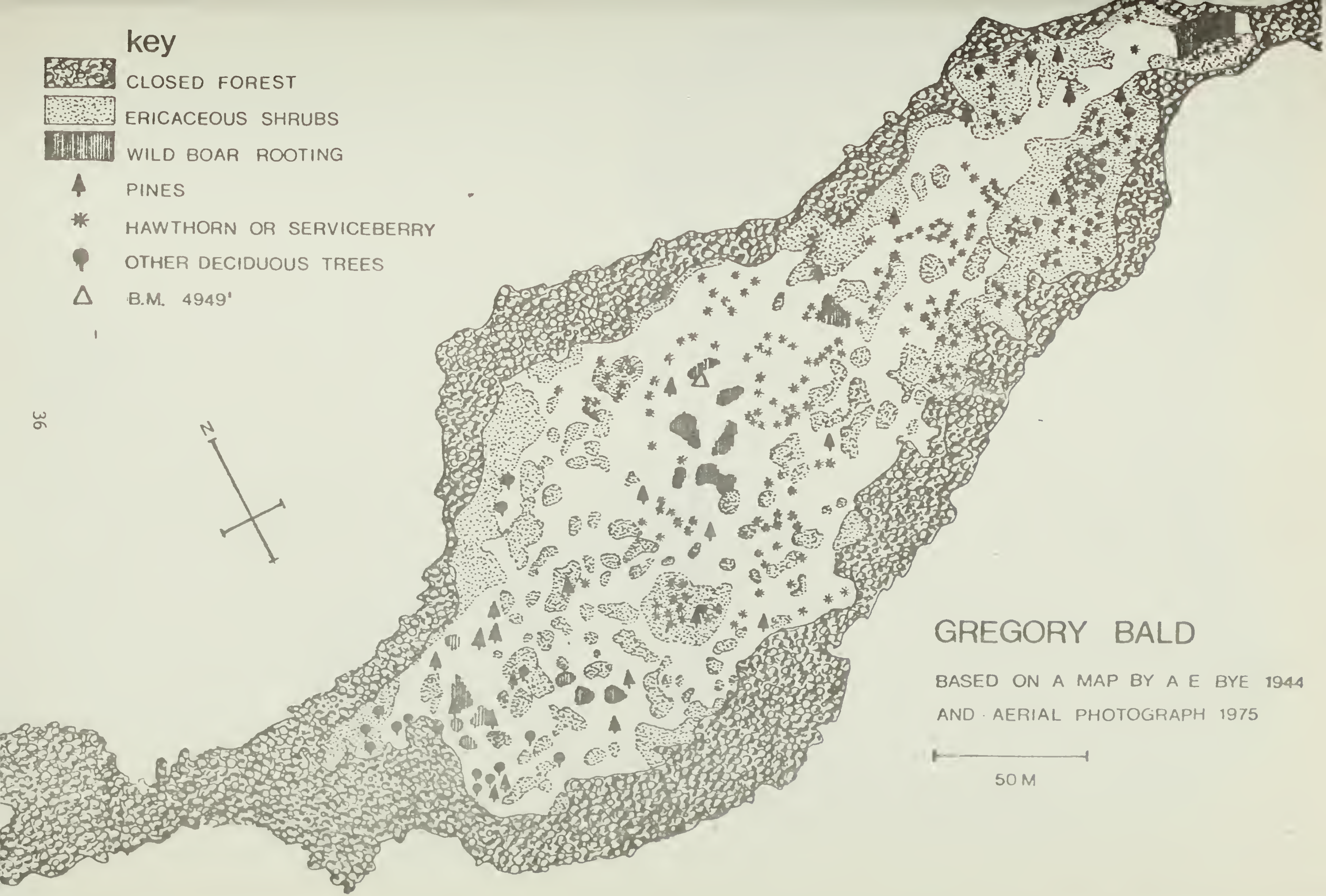

key
CLOSED FOREST
ERICACEOUS SHRUBS
WILD BOAR ROOTING
PINES
HAWTHORN OR SERVICEBERRY
OTHER DECIDUOUS TREES
B.M. 4949'
N
GREGORY BALD
BASED ON A MAP BY A E BYE 1944
AND AERIAL PHOTOGRAPH 1975
50 M

Figure 3. Map of Andrews Bald, Great Smoky Mountains National Park, showing woody plant invasion.


ANDREWS BALD
BASED ON A MAP BY A. E. BYE 1937
AND AERIAL PHOTOGRAPHY 1975
50M
N
key
CLOSED FOREST
ERICACEOUS SHRUBS
BOG
CONIFEROUS TREES
HAWTHORN OR SERVICEBERRY
OTHER DECIDUOUS TREES

Table 2. Changes in area of Gregory and Andrews Balds

Date	Area of Gregory Bald (acres)	Percent of original area	Percent change per year	Area of Andrews Bald (acres)	Percent of original area	Percent change per year
1937*	Not measured	--	--	12.5	--	--
1944*	15.7	--	--	Not measured	--	--
1952+	13.34	85	1.9	9.67	77	1.5
1961+	11.71	74	1.2	9.17	73	0.44
1975	7.91	50	1.7	8.05	64	.68

*Based on surveys by A. E. Bye. Maps are in GRSM archives.

+From Bruhn (1964)

Both balds show a steady, approximately linear decrease in area (Fig. 4). My figures (for 1975) counted clumps of trees growing outside the continuous forest on the edge as bald, so the decrease in area is greater than the numbers suggest.

Fitting a line to the points graphed in Figure 4 gave rise to 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 - 1900

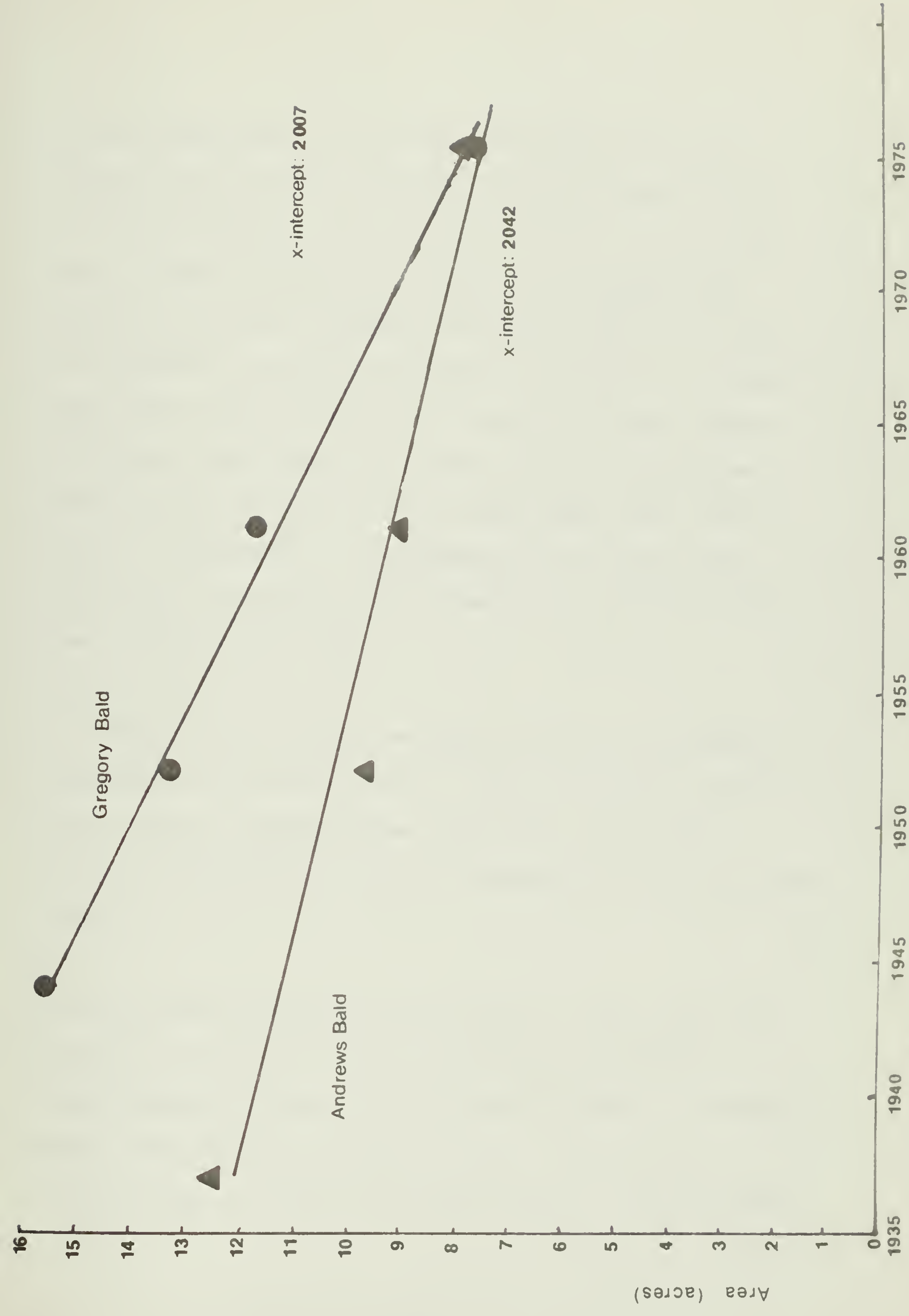
By extrapolating the line to where it intersects the horizontal axis, one can predict that Gregory Bald will be covered with forest in about 2007 A.D. Of course, parts of the bald may resist invasion by trees. Dense growth of blueberries could prevent trees from becoming established. An open area may 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.

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

$$A = -0.114 (T) + 16.3$$

Of course, many factors may keep part of Andrews Bald clear. Windthrows have temporarily pushed back the edges in places. The balsam woolly aphid is killing fir (Abies fraseri) trees in the

Figure 4. Change in areas of Gregory and Andrews Balds.


Gregory Bald
Andrews Bald
x-intercept: 2007
x-intercept: 2042
Area (acres)
Date
1935
1940
1945
1950
1955
1960
1965
1970
1975
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Clingmans Dome area, and its effects will probably spread to Andrews Bald. The death of mature fir trees may greatly retard the rate of invasion by fir or result in a forest of very young trees. Ramseur (1976) predicted that complete invasion would take 200 to 400 years. However, his data were taken on plots out in the center of the bald and considered establishment of isolated trees rather than encroachment of forest from the edge. Ramseur also thought that invasion would become more rapid because many seedlings were becoming established around larger trees already present. The combination of encroachment from the forest edge and invasion in the center would probably result in faster closure than I predict on both balds.

The remaining area of Gregory and Andrews as given here included 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 (Table 3).

The most dramatic change since Bruhn's (1964) study was the great increase in the percent cover of blueberries on Gregory Bald. Bruhn found about 20 percent cover; I found 53 percent by a similar method. Using mapping, blueberries formed a continuous belt around the edge of the bald and extended quite far under the forest

Table 3. Percent cover of various woody plants on remaining unforested area of Andrews and Gregory Balds

	Gregory Bald		Andrews Bald	
Plant	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%

canopy on the south side. Patches of blueberries all over the bald were extending outwards by sprouts. Except for a few heavily trampled areas, Gregory Bald will probably be completely covered with blueberries in 10 to 20 years. This may have been its pre-settlement 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.

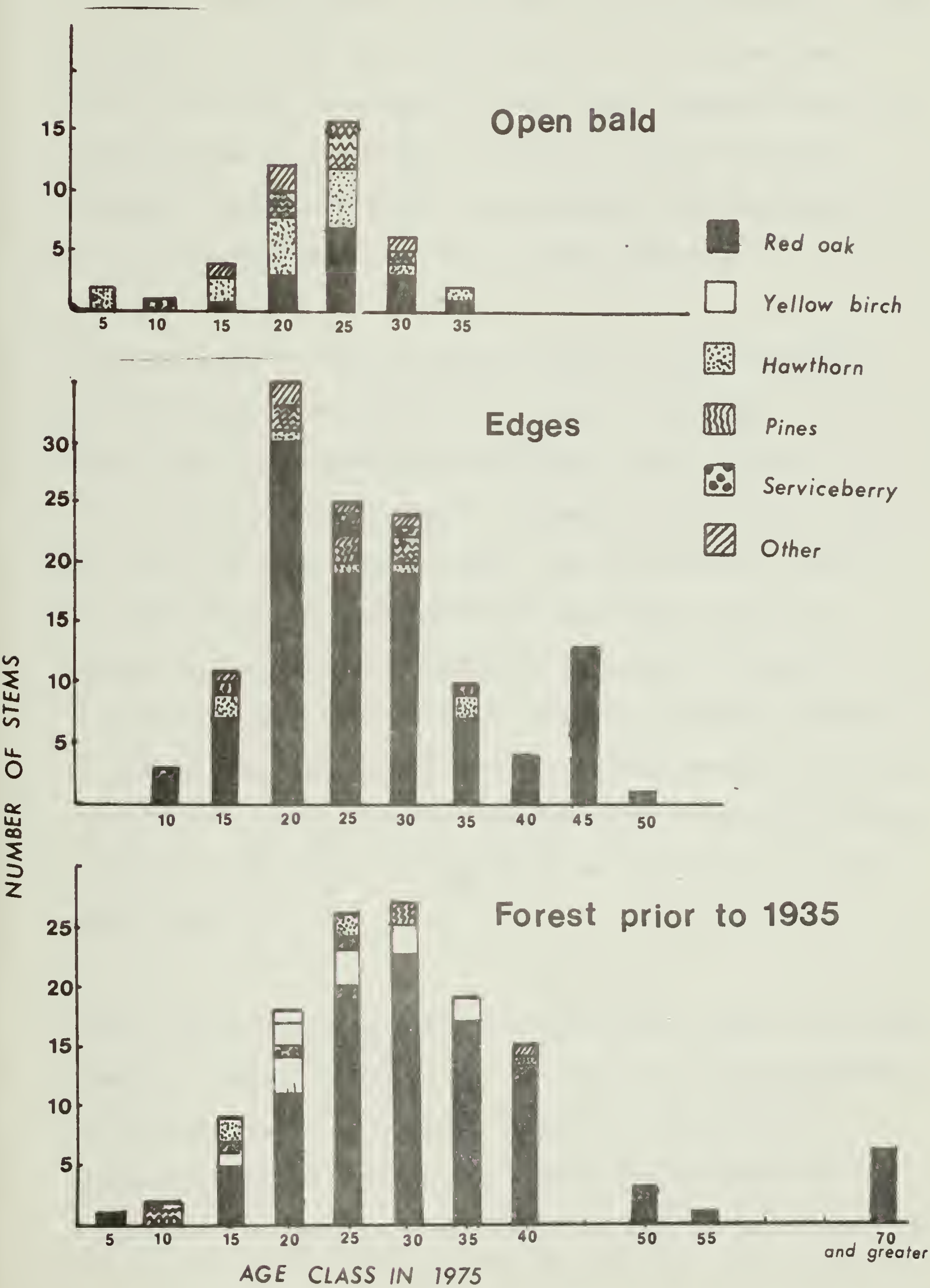
Ring Counts and Plot Data

Age counts of trees on Gregory Bald showed that nearly all trees on and around the bald have grown up 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 5 shows the age distribution of trees on and around Gregory Bald. While the sample was by no means complete or random, several conclusions may be drawn. 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 were less than 40 years old. Red oak (Quercus rubra) was the dominant species. Tree establishment was most rapid 10 to 20 years rather than immediately after the cessation of grazing. The thick sod probably made initial tree establishment

Figure 5. Age distribution of trees on and around Gregory Bald at 20 centimeters above ground. Age classes are five-year blocks with the maximum age shown.

WOODY SUCCESSION -- GREGORY BALD



difficult. Seedlings were still present, both in the forests around the edges and on the balds. Oak seedlings in the forests were mostly quite small (less than 0.5 meter tall), suggesting that the shade there may be too dense to allow most of these intolerant seedlings to grow much larger, but seedlings on the bald seemed to grow vigorously, especially near the forest margins.

A few oak trees cut down 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 centimeters above ground. Although such ring limits could be in error by as much as two years, this indicated 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 suggested that the bald is not an extremely marginal habitat for oaks as some have thought. 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.

Table 4 shows relative abundance of various tree species in two size classes. Hawthorn (Crataegus sp.) was the most widely distributed and abundant invader of the bald, followed by serviceberry (Amelanchier laevis) and oak. The forests were dominated by oak. The dominance of hawthorn in the forest understory does not mean

Table 4. Relative abundances of tree species in different areas of Gregory Bald. The numbers are the percentage of all the trees found in any one area that belong to a given species. Script numbers refer to seedlings and trees less than 2.5 centimeters in diameter at breast height.

SPECIES Total Tree Density (Trees per 200 m with dbh < 2.5 cm	AREA OF GREGORY BALD				
	South Forest	South Edge	Open Bald	North Edge	North Forest
Acer pensylvanicum (striped maple)		1.8		0.7	
Acer rubrum (red maple)	1.9 *6.3*	0.9 *1.9*	*3.2*	1.3 *1.6*	0.9
Acer saccharum (sugar maple)		1.8			0.9
Aesculus octandra (yellow buckeye)			*0.8*		
Amelanchier laevis (serviceberry)	6.9 *2.1*	6.2 *4.2*	24.3 *9.7*	16.8 *3.8*	4.0 *0.6*
Betula alleghenensis (yellow birch)	2.3			2.0 *0.5*	42.0 *3.2*
Castanea dentata (chestnut)	0.5 *37.1*	1.8		1.0 *0.5*	0.6 *0.6*
Crataegus sp. (hawthorn)	5.5 *14.7*	9.8 *54.2*	35.1 *73.4*	12.1 *69.2*	6.8 *72.0*
Fagus grandifolia (beech)	0.9 *7.4*	0		*10.3*	0.6 *8.9*

Table 4. Relative abundances of tree species in different areas of Gregory Bald.- Cont.

SPECIES	AREA OF GREGORY BALD				
Total Tree Density (Trees per 200 m^2 with dbh > 2.5 cm)	South Forest	South Edge	Open Bald	North Edge	North Forest
Fraxinus americana (white ash)			*0.8*		
Oxydendrum arboreum (sourwood)	0.9	0.9		0.5	
Pinus pungens (Table Mountain pine)	0.5	0.9			
Pinus strobus (white pine)	1.4	0.9	8.1		
Quercus alba (white oak)				3.5	
	1.1				*0.6*
Quercus rubra (red oak)	76.4	68.8	29.7	63.1	33.7
	29.5	*34.7*	*10.5*	*11.9*	*11.5*

that hawthorn will be dominant in the future. Hawthorn does not grow tall and cannot become an overstory tree. 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 were found as 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 study found the presence of trees between 40 and 100 years old 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 zero to 8.2 square meters per hectare. Plots in the young forest around the edge had basal areas between 10.7 and 17.9 square meters per

hectare. Basal area of plots in the old forest ranged from 23.3 to 41.8 square meters per hectare (see Table 4 for average value).

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, graphed in Figure 6, showed 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 were the only other common tree species on the open bald but they were less common than on Gregory. Yellow birch, red maple, and chestnut trees were also present.

Beech trees were 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 makes 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.

Table 5 summarizes tree data from Andrews Bald. Serviceberry was the most abundant species on the open bald and the species with the greatest basal area. Fir and hawthorn were the next most important species. Average basal area was only 1.7 square meters per hectare.

Figure 6. Age distribution of trees on and around Andrews Bald. Age classes are five-year blocks with the maximum age shown. Data are from Ramseur (1975).

WOODY SUCCESSION -- ANDREWS BALD

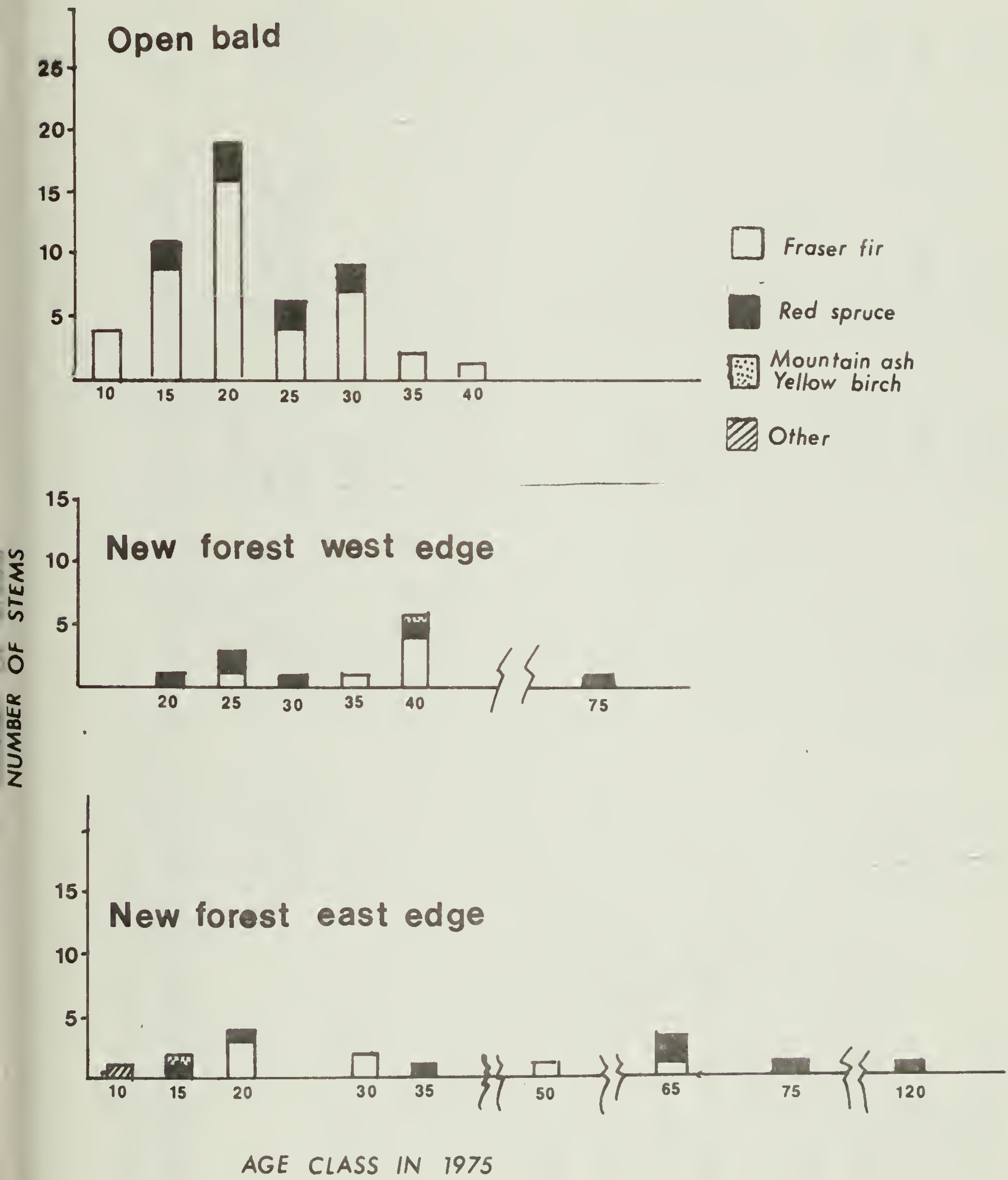


Table 5. Summary of tree data for Andrews Bald.

LOCATION: Open Bald (13 plots) Average basal area (square meters per hectare) - 1.701

SPECIES	Relative density of saplings	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Abies fraseri (Fraser fir)	0.34	0.17	0.306	0.52	0.62
Acer rubrum (red maple)	0.26	0.619	0.0036	0.0062	0.077
Acer saccharum (sugar maple)	--	--	--	--	--
Acer spicatum (mountain maple)	--	--	--	--	--
Aesculus octandra (yellow buckeye)	--	--	--	--	--
Amelanchier laevis (serviceberry)	0.166	0.46	0.69	0.34	0.69
Betula lutea (yellow birch)	0.079	0.019	0.00088	0.015	0.23
Castanea dentata (Amer. chestnut)	0.00	0.019	0.025	0.043	0.077
Crataegus sp. (hawthorn)	0.18	0.21	0.10	0.17	0.31
Fagus grandifolia (Amer. beech)	--	--	--	--	--
Fraxinus americana (white ash)	0.026	0.00	0.00009	0.02	0.077
Magnolia accuminata (cucumber tree)	0.026	0.00	0.00009	0.0015	0.077
Picea rubens (red spruce)	0.026	0.038	0.159	0.27	0.23

Table 5. Summary of tree data for Andrews Bald - Cont.

LOCATION: Open Bald - Cont.

SPECIES	Relative density of saplings	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Pyrus americana (mountain ash)	0.26	0.00	0.00088	0.0015	0.077
Prunus pensylvanica (pin cherry)	0.079	0.019	0.035	0.06	0.15
Quercus alba (white oak)	--	--	--	--	--
Quercus rubra (red oak)	0.026	0.038	0.019	0.41	0.77

Table 5. Summary of tree data for Andrews Bald.- Cont.

LOCATION: New Forest on North and West (10 plots) Average basal area (square meters per hectare - 37.08

SPECIES	Relative density of trees	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Abies fraseri (Fraser fir)	0.44	0.55	0.62	23.17	1.0
Acer rubrum (red maple)	--	--	--	--	--
Acer saccharum (sugar maple)	0.0095	0.0031	0.00073	0.027	0.2
Acer spicatum (mountain maple)	0.029	0.048	0.00013	0.005	0.1
Aesculus octandra (yellow buckeye)	--	--	--	--	--
Amelanchier laevis (serviceberry)	0.67	0.05	0.02	0.70	0.90
Betula lutea (yellow birch)	0.057	0.05	0.083	3.08	0.70
Castanea dentata (Amer. chestnut)	--	--	--	--	--
Crataegus sp. (hawthorn)	--	--	--	--	--
Fagus grandifolia (Amer. beech)	--	--	--	--	--
Fraxinus americana (white ash)	--	--	--	--	--
Magnolia accuminata (cucumber tree)	--	--	--	--	--
Picea rubens (red spruce)	0.29	0.30	0.26	9.58	1.0

Table 5. Summary of tree data for Andrews Bald. - Cont.

LOCATION: New Forest on North and West - Cont.

SPECIES	Relative density of trees	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Pyrus americana (mountain ash)	0.00	0.0093	0.0072	0.268	0.20
Prunus penslyvanica (pin cherry)	0.11	0.043	0.0067	0.25	0.70
Quercus alba (white oak)	--	--	--	--	--
Quercus rubra (red oak)	--	--	--	--	--

Table 5. Summary of tree data for Andrews Bald. - Cont.

LOCATION: New Forest on South and East (12 plots) Average basal area (square meters per hectare - 20.28

SPECIES	Relative density of trees	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Abies fraseri (Fraser fir)	0.36	0.21	0.28	5.76	1.0
Acer rubrum (red maple)	--	--	--	--	--
Acer saccharum (sugar maple)	--	--	--	--	--
Acer spicatum (mountain maple)	--	--	--	--	--
Aesculus octandra (yellow buckeye)	0.00	0.0097	0.00013	0.0027	0.083
Amelanchier laevis (serviceberry)	0.005	0.011	0.064	1.29	0.67
Betula lutea (yellow birch)	0.005	0.012	0.12	2.55	0.67
Castanea dentata (Amer. chestnut)	0.005	0.00	0.0011	0.023	0.083
Crataegus sp. (hawthorn)	0.00	0.0097	0.0021	0.042	0.17
Fagus grandifolia (Amer. beech)	0.56	0.41	0.26	5.27	0.58
Fraxinus americana (white ash)	--	--	--	--	--
Magnolia acuminata (cucumber tree)	--	--	--	--	--
Picea rubens (red spruce)	0.020	0.83	.026	5.32	0.92

Table 5. Summary of tree data for Andrews Bald.- Cont.

LOCATION: New Forest on South and East - Cont.

SPECIES	Relative density of trees	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Pyrus americana (mountain ash)	--	--	--	--	--
Prunus pensylvanica (pin cherry)	0.024	0.029	0.00032	0.0065	0.17
Quercus alba (white oak)	0.000	0.014	0.00083	0.0017	0.083
Quercus rubra (red oak)	0.00	0.0048	0.00064	0.013	0.083

Table 5. Summary of tree data for Andrews Bald.- Cont.

LOCATION: Old Forest (Spruce Fir) (1 plot) Average basal area (square meters per hectare) - 39.98

SPECIES	Relative density of saplings	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Abies fraseri (Fraser fir)	0.33	0.19	0.50	20.14	--
Acer rubrum (red maple)	--	--	--	--	--
Acer saccharum (sugar maple)	--	--	--	--	--
Acer spicatum (mountain maple)	--	--	--	--	--
Aesculus octandra (yellow buckeye)	--	--	--	--	--
Amelanchier laevis (serviceberry)	--	--	--	--	--
Betula lutea (yellow birch)	0.17	0.40	0.24	9.50	--
Castanea dentata (Amer. chestnut)	--	--	--	--	--
Crataegus sp. (hawthorn)	--	--	--	--	--
Fagus grandifolia (Amer. beech)	--	--	--	--	--
Fraxinus americana (white ash)	--	--	--	--	--
Magnolia accuminata (cucumber tree)	--	--	--	--	--
Picea rubens (red spruce)	0.50	0.11	0.031	1.22	--

Table 5. Summary of tree data for Andrews Bald.- Cont.

LOCATION: Old Forest (Spruce Fir) - Cont.

SPECIES	Relative density of trees	Relative density of trees	Relative basal area	Basal area (square meters per hectare)	Frequency
Pyrus americana	--	--	--	--	--
Prunus pensylvanica	0.00	0.30	0.23	9.11	--
Quercus alba	--	--	--	--	--
Quercus rubra	--	--	--	--	--

The spruce-fir forest encroaching on the north and west edges has grown up 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 square meters per hectare. However, the forest on the edges is well on its way to becoming a mature forest, and the understory plants were not at all like the bald flora. The forest on the south and east edges had 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 square meters per hectare greater.

If the balsam woolly aphid, which is killing trees near Andrews Bald, does not kill the mature fir trees, Andrews Bald will be covered with fir-spruce forest in a little over 100 years. If the aphid does kill the firs, the bald will probably be covered with rhododendron and become a heath bald of sorts. Birch, beech, serviceberry, and spruce may form a forest on the bald, but forest encroachment will be slower than it would be with healthy fir trees present.

Too few plots were taken on other balds and fields to allow quantitative estimates of invasion rates, but trends can be noted.

Balds surrounded by beech forest, such as Silers, High Springs, Thunderhead, and Rocky Top, are being invaded by beech sprouts around the edges, and all have become considerably smaller since the establishment of GRSM, especially Silers Bald. Beech sprouts on Rocky Top have formed a stand with the equivalent of 2,300 seedlings, 9,500 saplings, and 2,800 trees per hectare in one sample plot.

Parsons Bald seemed more open than Gregory, probably because fewer hawthorn and serviceberry trees have become established. The oak forest around the edge looked very similar to that on Gregory, and forest encroachment around the edges is probably proceeding as rapidly as on Gregory Bald.

Mount Sterling is being taken over by a birch-fir forest. The woolly aphid is established there so invasion may be slowed down.

Russell Field has been invaded so rapidly that one can scarcely imagine its original extent. Perhaps 90 percent of the original area of the field is covered either by trees seeded from the surrounding forest or by a dense growth of laurel (*Kalmia latifolia*). The rapid invasion is probably due to the low altitude and relatively sheltered position.

Spence Field was being invaded fairly rapidly by a beech - birch forest on the north side but relatively slowly by the oak forest on the south. Trees were scattered over most of the field, and there were laurel and rhododendron thickets on parts of the south edge. Spence Field will probably take longer than Gregory Bald to become completely covered with forest. Bruhn (1964) calculated a slower invasion rate in acres per year for Spence Field than for Gregory or Andrews Balds, and Spence Field is considerably larger than these two balds.

The most obvious evidence of the invasion of balds by woody plants was the change in their appearance between 1935 and 1977. An open, orchard-type forest covered most of the main ridge in 1935. Younger trees have filled the gaps in this park-like forest since the cessation of grazing. The increase in woody growth on the bald is obvious. Similar changes have occurred in the appearance of Andrews Bald.

Without continued disturbance such as grazing that evidently maintained the balds before the park was established, burning, or some kind of management, the balds will probably all be covered by woody plants.

Results of the Principal Components Ordination

PCA was first applied to herb data from the 57 plots on Gregory and the 39 on Andrews Bald to show what influenced the vegetation in and around a single bald. The results are shown in Figures 7A, B, and C, and Figures 8A and B.

In ordination of the plots on Gregory Bald, the first axis extended by PCA accounted for 29 percent of the variance, and only three axes were needed to account for 56 percent.

The first axis seemed to correspond best with basal area. As one can see in Figure 7A, the plots at the left end of the axis have large basal areas compared to those on the right. The plots in group 1 are all nearer the center of the bald, and those in group 3 are in the forest that was present before grazing ceased. Plots in groups 5, 4, and 2 tended to be on the edge of the bald or in patches of trees in the center of the bald. This axis also was inversely related to the cover of Danthonia (Fig. 7B).

The meaning of the second axis was unclear. It was not related to aspect or to the distribution of any major species. It seemed to correspond somewhat to shrub cover (Fig. 7C), but it was impossible to tell what specific environmental factor might cause the variation in shrubbiness. This ordination did put the sample plots in five fairly distinct groups (Fig. 7). When all stands were ordinated

Figure 7A. Principal components analysis ordination of plots on Gregory Bald by relative percent cover of shrubs and herbs. Basal areas of plots included in the ordination are shown. Basal areas are in square meters per hectare.

PCA GREGORY BALD

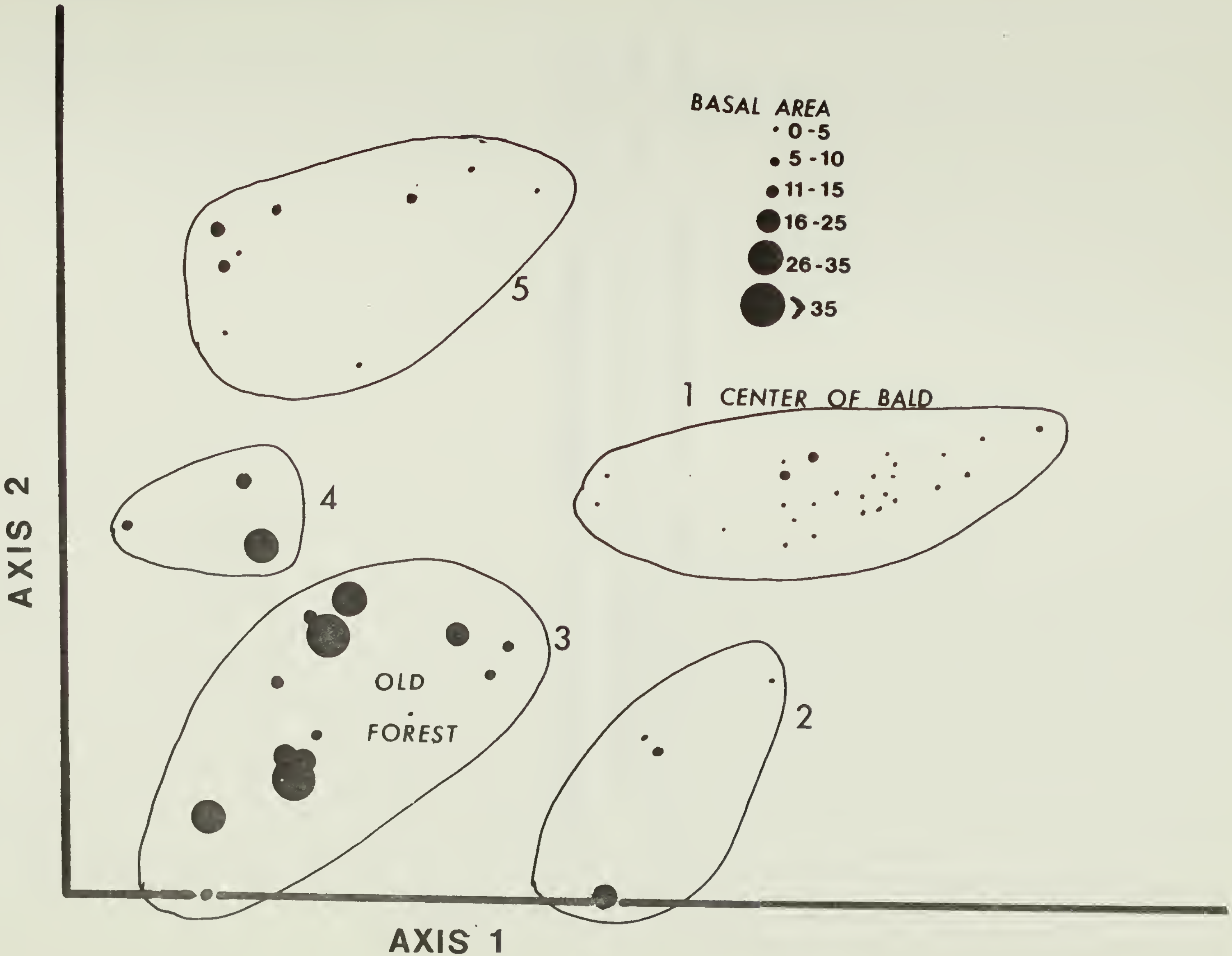


Figure 7B. Principal components analysis ordination of plots on Gregory Bald by relative percent cover of shrubs and herbs. Percent cover of Danthonia compressa on the plots is indicated.

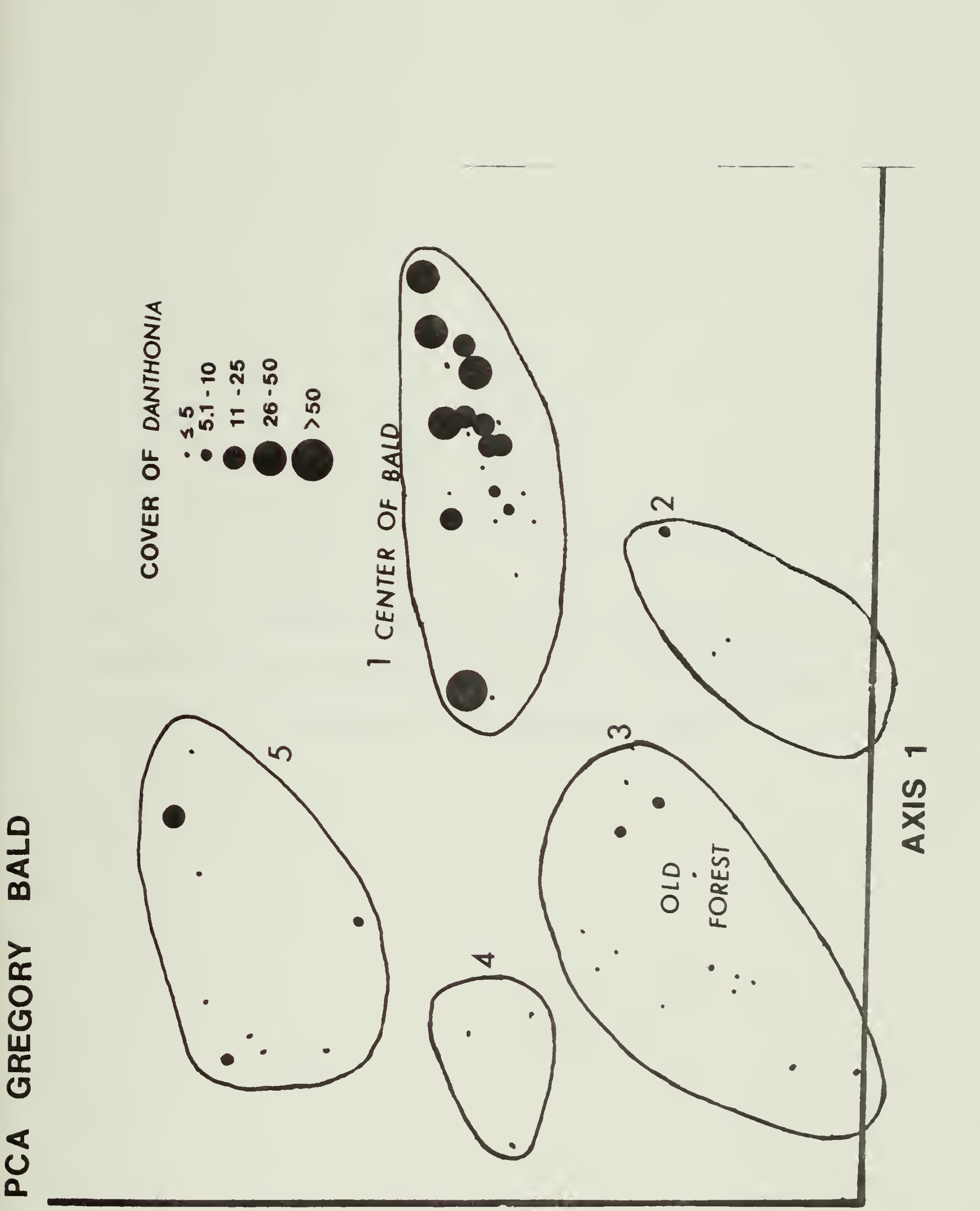

PCA GREGORY BALD
COVER OF DANTHONIA
≤ 5
5.1 - 10
11 - 25
26 - 50
>50
1 CENTER OF BALD
2
3
OLD FOREST
4
5
AXIS 1
AXIS 2

Figure 7C. Principal components analysis ordination of plots on Gregory Bald by relative percent cover of shrubs and herbs. Percent cover of Vaccinium spp. on the plots is shown.

PCA GREGORY BALD

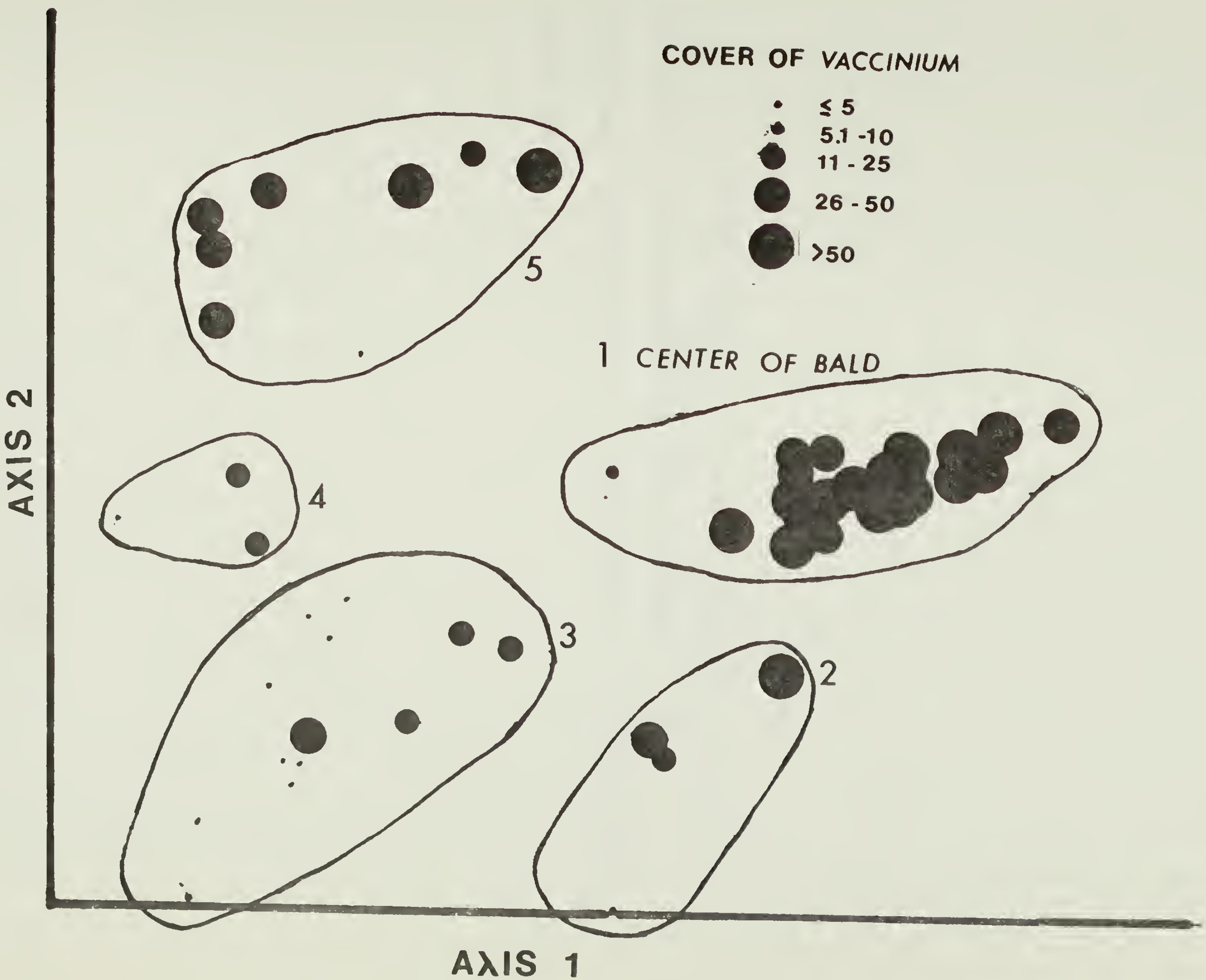


Figure 8A. Principal components analysis ordination of plots on Andrews Bald by relative percent cover of shrubs and herbs. Basal areas of plots are shown. Basal areas are in square meters per hectare.

PCA ANDREWS BALD

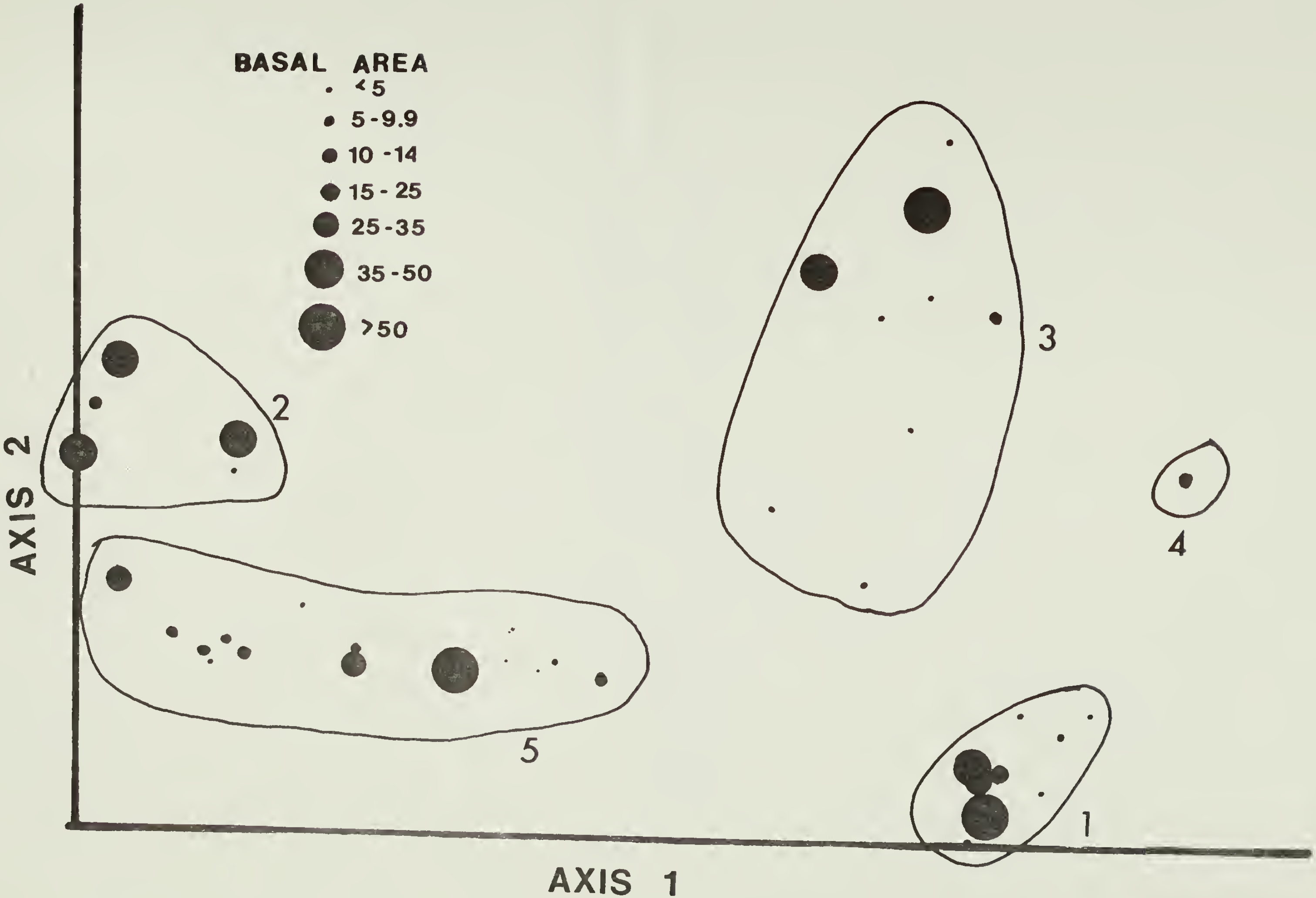
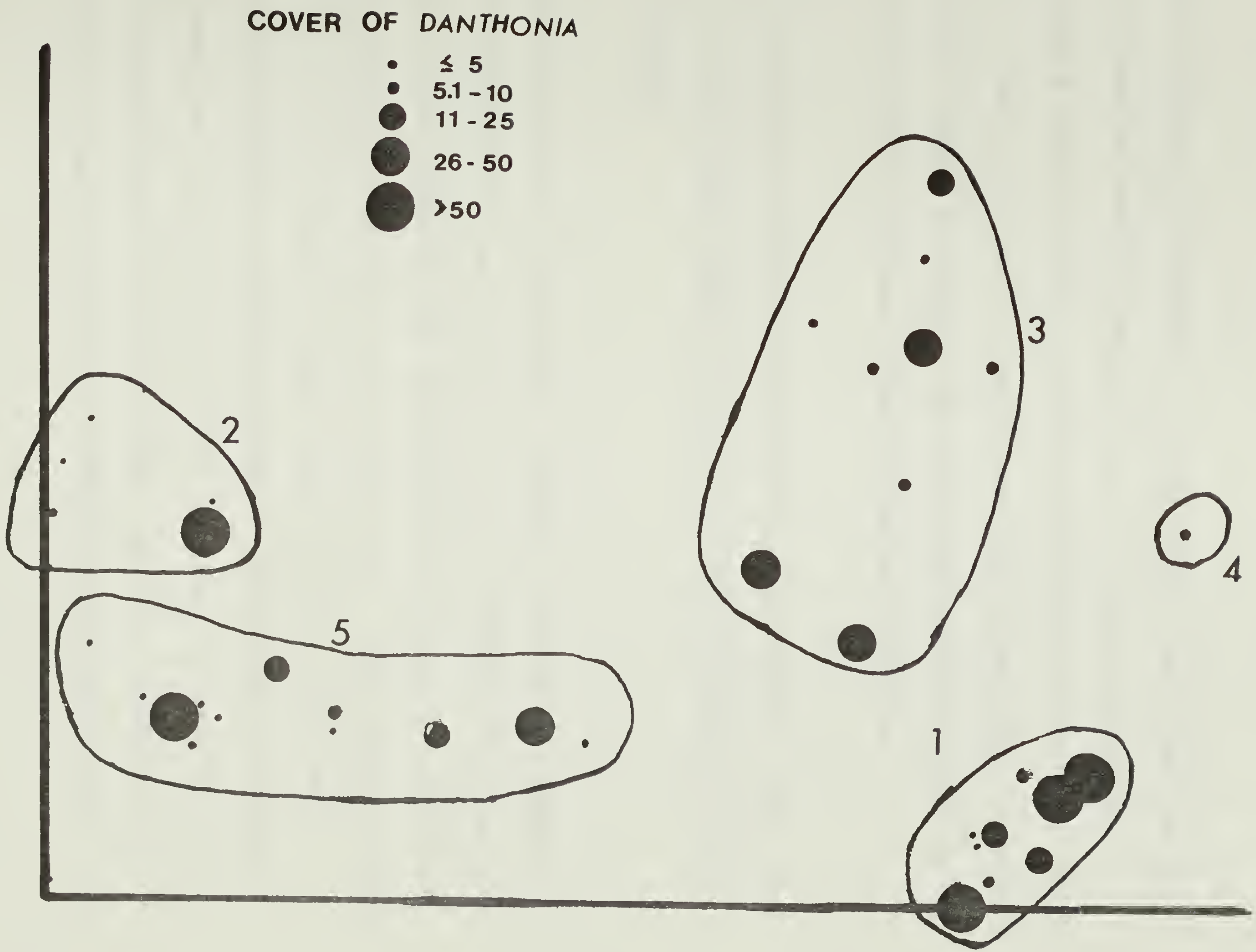


Figure 8B. Principal components analysis ordination of plots on Andrews Bald by relative percent cover of shrubs and herbs. Percent cover of *Danthonia* on the plots is shown.

PCA ANDREWS BALD



each of these groups was considered as a stand, and the groups resulting from the ordination of plots on Andrews Bald were similarly grouped into stands.

The ordination of the plots on Andrews Bald also grouped the plots into several distinct groups (Fig. 8). However, the factors causing plots in a group to fall together were not obvious. Plots from every group can be found on the bald, on the edges, or in the forests around the edges. The first axis, which accounted for 28 percent of the variance, seemed related to basal area.

The meaning of the second and third axis was unclear. Again, the first three axes together accounted for over 50 percent of the variance.

When data from all stands were ordinated, the results suggested that elevation was the most important factor. However, the grouping of plots also indicated that the ordination bent any axis that might correspond to elevation into a sharp curve. Thus, while the stands that are low on the first axis showed a more or less linear relation between elevation and position on the second axis, the stands that are high on the first axis showed an opposite relation of elevation and position on the axis (Fig. 8A. However, this curving of axes is common in PCA (Whittaker and Gauch 1973). The

first axis seemed to correspond to moisture. The stands at the high end of the axis were the only ones where pines are important and they lie at low elevations, whereas the stands at the low end of the axis were on moist sites. Basal area, which corresponds roughly with age, site, or species, seemed to be relatively unimportant (Fig. 9B). Forest type corresponded fairly clearly to the curved elevation axis (Fig. 9A). The odd position of stand 37 probably resulted from the presence of Robinia pseudoacacia (black locust), a species associated with lower elevations. Five axes were needed to account for 50 percent of the variance.

Ordination of the herb species suggested that elevation and disturbance are important (Fig. 10). Elevation tended to increase along axis 1. The stands undergoing continuing disturbance, Hemphill Bald, the roadsides, and the shelter clearings, were grouped at the top of the second axis, whereas most of the undisturbed forests were at the lower end. Nine axes were required to account for 50 percent of the variance.

The grassy balds did not come out very close together in this ordination (Fig. 10C). The open balds tended to fall at the low end of axis 1 compared to natural balds, but this could have been due to their lower elevation. The burn scars fell close to balds at the same elevation despite their vastly different appearance

Figure 9A. Principal components analysis ordination of all stands by relative basal areas of trees. Elevation of stands is indicated. First axis is the abscissa. Second axis is the ordinate.

PCA ALL STANDS

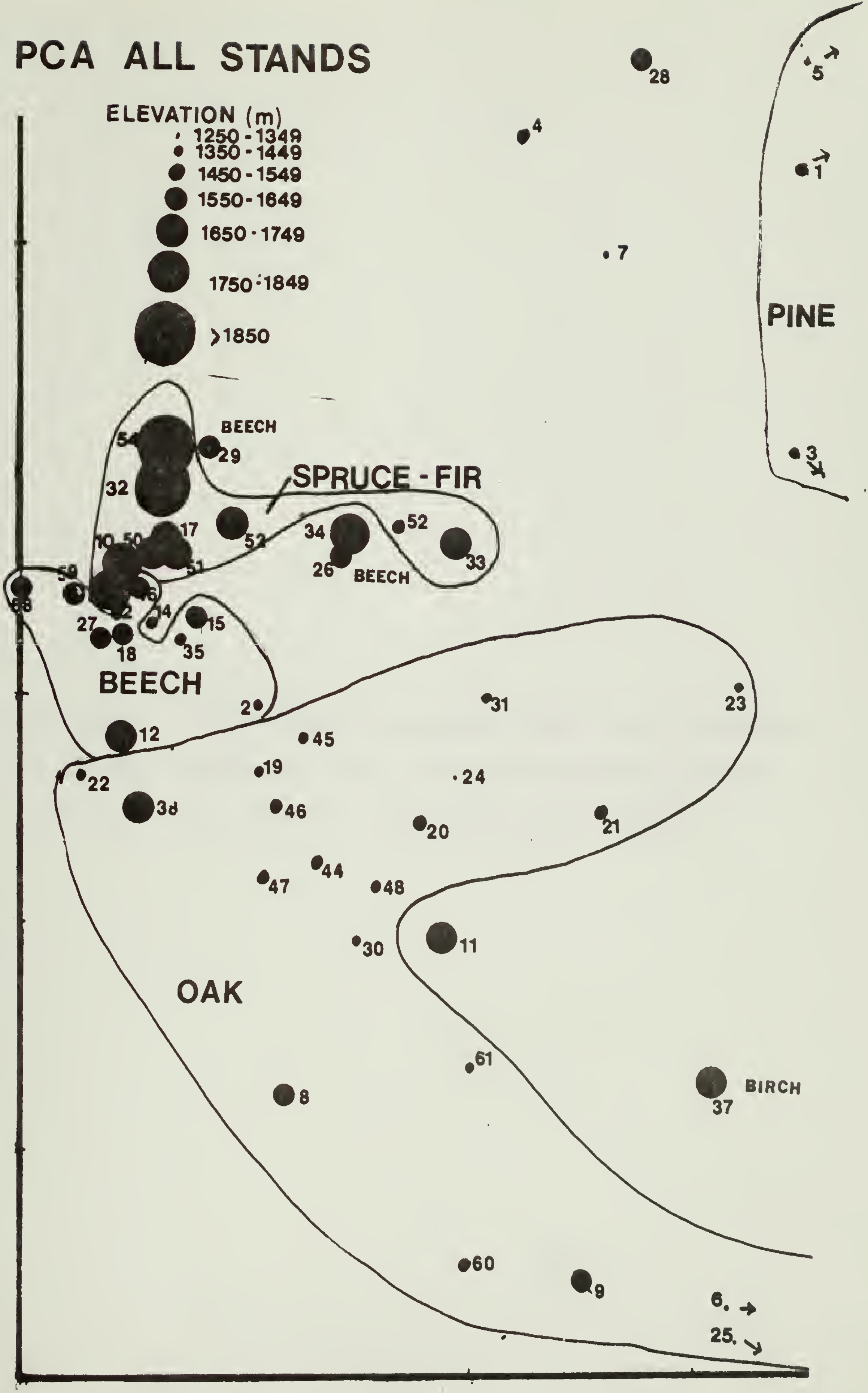


Figure 9B. Principal components analysis ordination of all stands by relative basal area of trees. Basal area of stands is shown. First axis is the abscissa. Second axis is the ordinate.

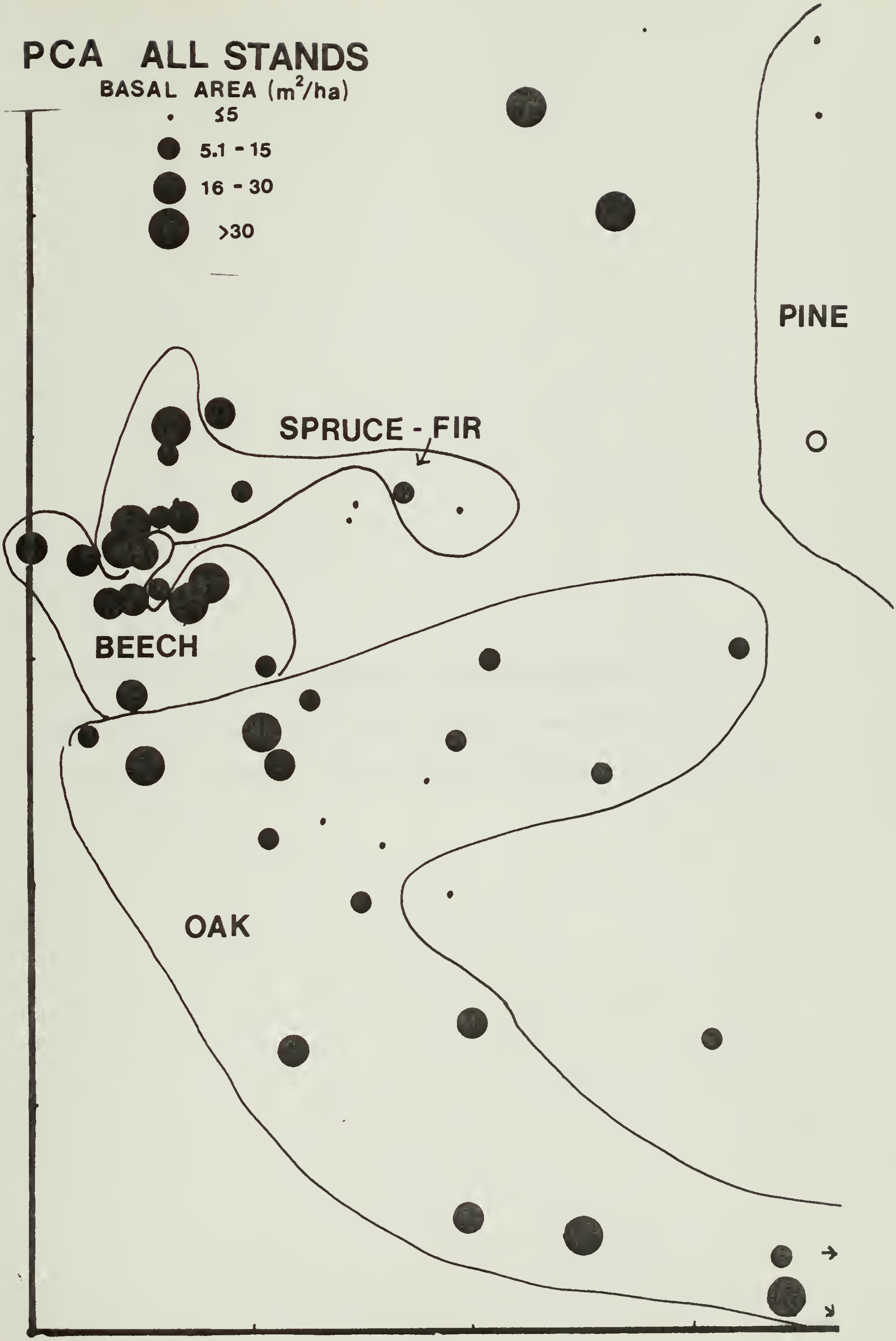

PCA ALL STANDS
BASAL AREA (m²/ha)
≤5
5.1 - 15
16 - 30
>30
PINE
SPRUCE - FIR
BEECH
OAK

Figure 10A. Principal components analysis ordination of all stands by relative percent cover of shrubs and herbs. Elevation of the stands is shown. First axis is the abscissa. Second axis is the ordinate.

PCA ALL STANDS

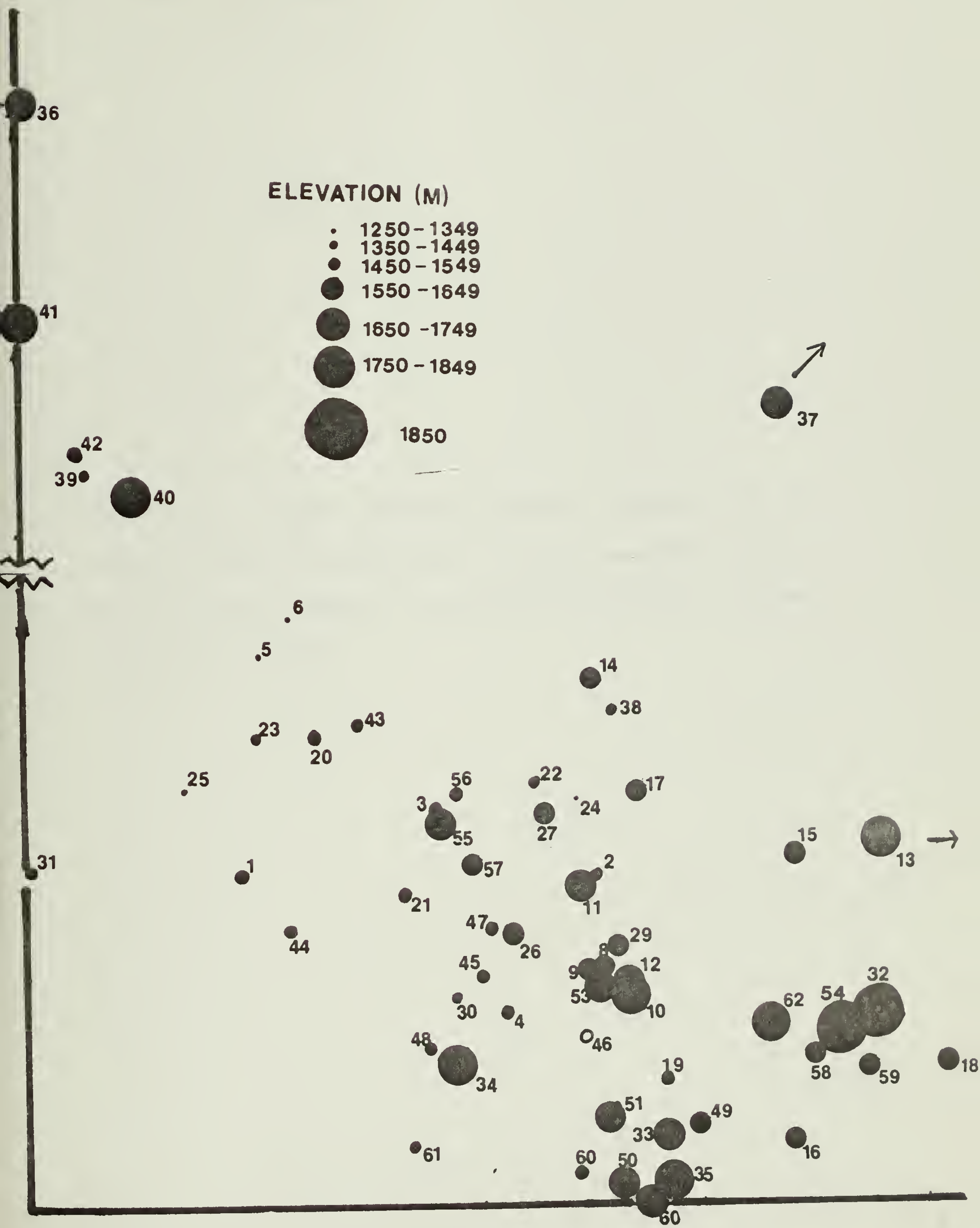


Figure 10B. Principal components analysis ordination of all stands by relative percent cover of shrubs and herbs. Basal area of stands is shown. First axis is the abscissa. Second axis is the ordinate.

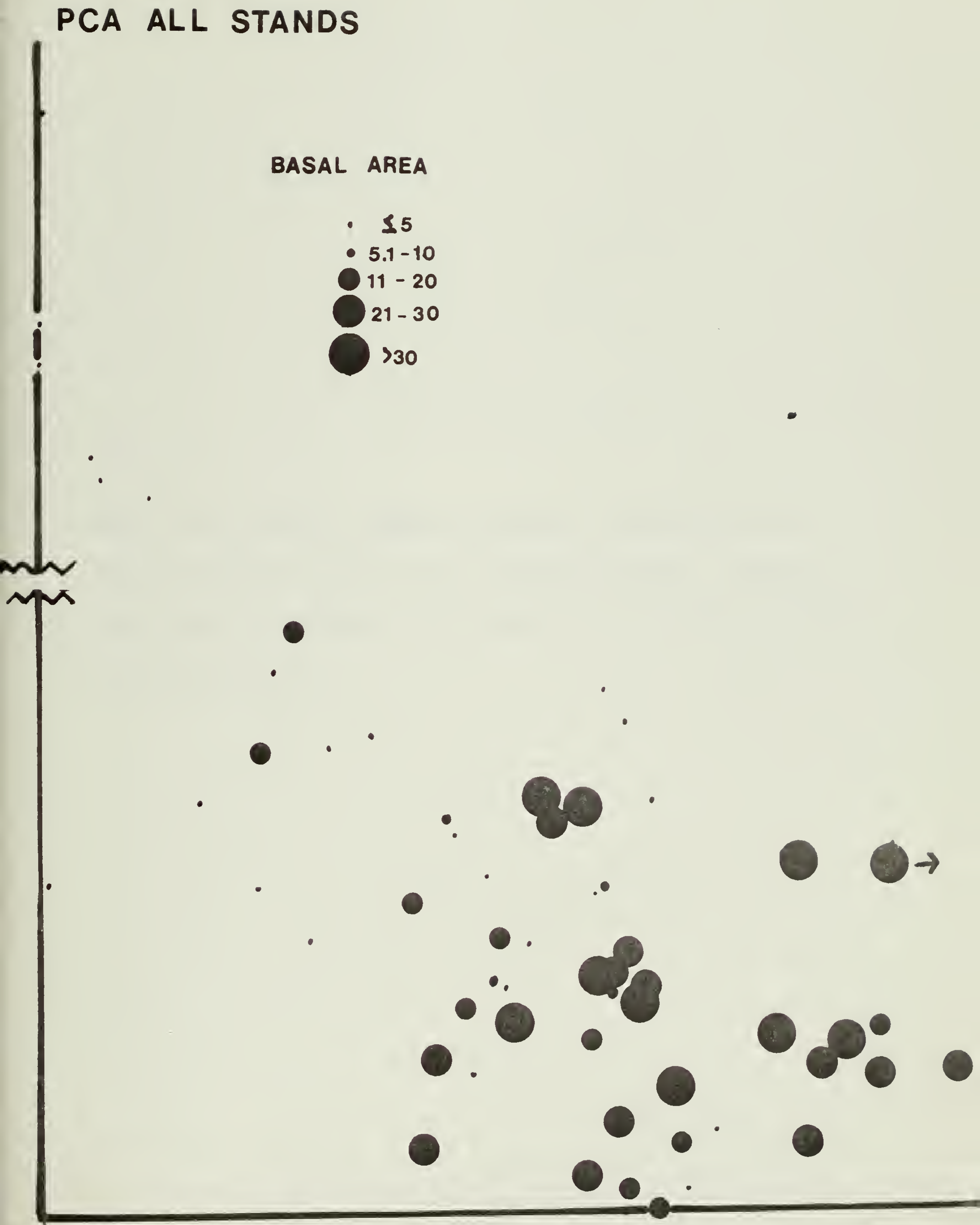
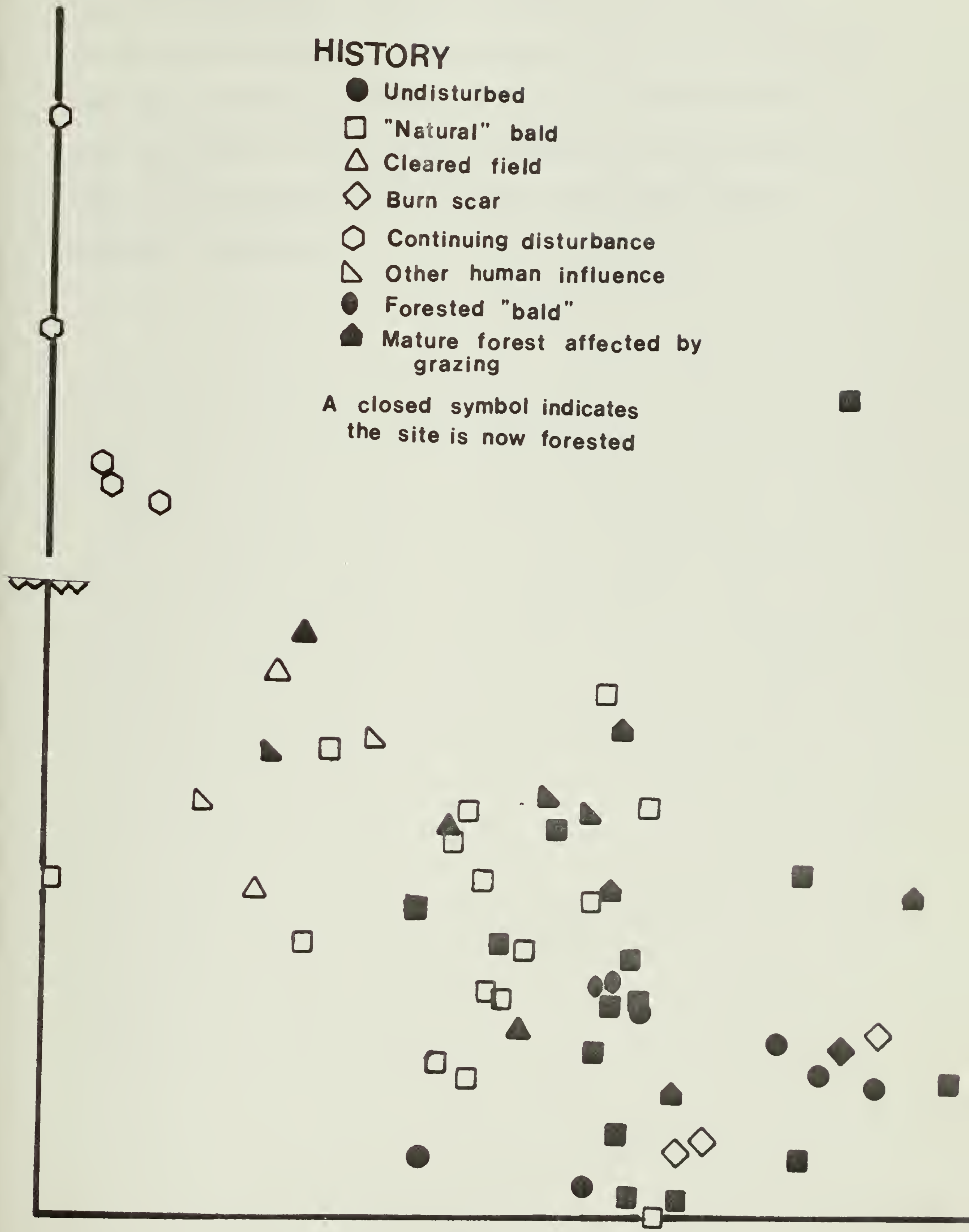

PCA ALL STANDS
BASAL AREA
≤5
5.1 - 10
11 - 20
21 - 30
>30

Figure 10C. Principal components analysis ordination of all stands by relative percent cover of shrubs and herbs. History of all stands is indicated. First axis is the abscissa. Second axis is the ordinate.

PCA ALL STANDS



and lack of Danthonia. Whittaker's (1966) data for Gregory, Silers, and Thunderhead Balds fall among the other balds, indicating that the composition of the herb layer has not changed greatly since he sampled it in the 1950's. Basal area was also related to axis 1, suggesting that age of the forest and shade influence herbaceous vegetation.

DISCUSSION

Based on this investigation, the origin of the grassy balds has not been determined with any certainty. Trees could have been eliminated by any of several factors: fire, climatic change, windthrow, insect damage, or human interference. Different balds could have lost their forest cover by different means.

The dissimilarity between the vegetation of burned areas and that of grassy balds suggests that the development of the characteristic grassy cover on balds is not the normal successional sequence. The vegetation on burn scars in spruce-fir forests in the Great Smoky Mountains is typical of what Ramseur (1960) described for secondary succession communities at high elevations. Succession in oak and beech forests has not been studied. I have observed blueberries and laurels in clearings in oak forests and blackberries in beech forest. Grass is almost certainly not what normally becomes established after a single disturbance.

Jenkins and Ayres (1951) found *Danthonia compressa* limited to heavily and continually disturbed sites. In the Southern Appalachians, the disturbance was grazing by large numbers of sheep and cattle very summer (Gersmehl 1970; Lindsay 1976).

If the balds were cleared before white settlement, native herbivores might have grazed in sufficient numbers to favor *Danthonia*.

The grazing animals not only favored the development of a grassy cover but also prevented or greatly retarded the establishment of woody plants. Griggs (quoted in Yard 1942) and Brown (1953) both pointed out the role of cattle in preventing the establishment of tree seedlings on Roan Mountain.

Some people familiar with the Great Smoky Mountains before the establishment of the national park feel that grazing cattle not only kept the balds clear of invading trees but were gradually enlarging them by suppressing regeneration in the surrounding forests (Carlos Campbell, personal communication). Very few of the trees around Gregory Bald whose ages were determined had become established while the bald was being grazed.

Even after grazing ceased, it probably influenced succession afterwards. Dormant seeds or live stumps or roots would be present after a fire or logging, but livestock would have eaten their sprouts. Small light seeds that the wind might blow onto the bald would be hindered by the grassy sod from reaching the soil. Thus, the establishment of forest would be greatly retarded.

Trees have invaded the balds in the Great Smoky Mountains since the cessation of grazing. Trees are becoming established most rapidly around the edges of balds. Isolated trees which grow on balds seem to become centers around which smaller trees become established (Ramseur 1976). If present ratio of tree invasion continues, all the balds in the Great Smoky Mountains will probably become covered with forest within 30 to 70 years.

Microclimate is probably important in favoring tree establishment near older trees. The beginning of tree invasion corresponds with the cessation of grazing. Therefore, the elimination of grazing rather than regional climatic change is probably responsible for the changing of balds to forest.

The results of the ordinations suggest that the main factors influencing the vegetation are elevation and aspect (related to moisture), as Whittaker (1956) concluded. However, disturbance can override these major influences. The sites that are still undergoing heavy disturbance have very similar vegetation despite their differences in altitude. In all ordinations performed, they fell together regardless of the ordination method or the data transformation.

Although the balds do not separate as dramatically as the continually disturbed sites, they also represent an overriding of the factors of elevation and moisture. The grazing of cattle by white settlers continued for perhaps as long as 150 years on the "natural" balds and for 60 years on the cleared fields. In the absence of this disturbance, Danthonia has decreased and herb species typical of particular elevations are becoming more common. Whittaker's samples of Gregory Bald, Thunderhead, and Silers Bald lie closer together in the ordination space than corresponding samples taken 15 years later (Fig. 10). Species of the surrounding forest dominate the balds and fields in basal area if not in number. These results suggest that the balds will, in time, fit into the pattern determined by elevation and moisture.

The burn scars were disturbed greatly at a single point in time but, since the disturbance did not continue, they did not grow up into Danthonia like the balds. Fir and spruce are invading them, but invasion might be slow because so much soil was washed away soon after the fires. These areas will, however, become forest eventually unless the balsam woolly aphid prevents fir regeneration.

The distribution of trees seemed to be influenced almost entirely by elevation and moisture. Age of the forest had some effect;

species such as hawthorn, fire cherry, and serviceberry were most common on open areas, but even there they are not dominant in basal areas and their occurrence was relatively independent of elevation when compared to species that occurred in older forests. All the areas that are not continually disturbed will probably become forested eventually.

The implications of these results for management are (1) balds in the Great Smoky Mountains will become forested in less than 100 years if they are not managed, and (2) management activities should be continued regularly if maintenance of the open grassy appearance of the balds is desired.

LITERATURE CITED

BARDEN, L. S. 1974. Lightning fires in Southern Appalachian forests. Ph.D. Dissertation, University of Tennessee. 65 pp.

BILLINGS, W. D. and A. F. MARK. 1957. Factors involved in the persistence of montane treeless balds. Ecology 38:140-142.

BRAY, J. R. and J. T. CURTIS. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

BROWN, D. M. 1941. Vegetation of Roan Mountain: A phytosociological and successional study. Ecol. Monogr. 11:61-97.

__________ 1953. Conifer transplants to a grassy bald on Roan Mountain. Ecology 34:614-617.

BRUHN, M. E. 1964. Vegetational succession on three grassy balds of the Great Smoky Mountains. Unpubl. M.S. Thesis, Univ. of Tennessee, Knoxville.

CAMP, W. H. 1931. The grass balds of the Great Smoky Mountains of Tennessee and North Carolina. Ohio J. Sci. 31:157-164.

FERNALD, M. L. 1970. Gray's Manual of Botany. 8th Ed., corrected printing. American Book Company, New York.

GATES, W. H. 1971. Observations on the possible origin of the balds of the Southern Appalachians. Contributions from the Dept. of Zoology, Louisiana State University No. 53, Louisiana State University Press, Baton Rouge. 16pp.

GAUCH, H. G., Jr. 1973. The Cornell Ecology Program Series. Bull. Ecol. Soc. Am. 54:10-11.

GERSMEHL, P. 1970. A geographic approach to a vegetation problem: The case of the southern Appalachian grassy balds. Ph.D. Dissertation, Univ. of Georgia, Athens. 463pp.

GILBERT, V. C. 1954. Vegetation of the grassy balds of the Great Smoky Mountains National Park. Unpubl. M.S. Thesis, Univ. of Tennessee, Knoxville. 73pp.

HARSHBERGER, J. W. 1903. An ecological study of the flora of mountainous North Carolina. Bot. Gaz. 36:241-258, 368-383.

JENKINS, W. R. and M. A. AYRES. 1951. The mountain outgrass communities of the region of Mountain Lake, Virginia. Castanea. 16:92-96.

LINDSAY, M. 1976. History of the grassy balds in Great Smoky Mountains National Park. U.S. Dept. of Interior, National Park Serv., Southeast Region, Uplands Field Research Lab., Manage. Rep. No. 4. 215 pp.

__________ 1977. Management of Grassy Balds in Great Smoky Mountains National Park. U.S. Dept. of Interior, National Park Serv., Southeast Region, Uplands Field Research Lab., Manage. Rep. No. 17. 67 pp.

LINZEY, D. W. and A. V. LINZEY. 1968. Mammals of the Great Smoky Mountains National Park. J. Elisha Mitchell Sci. Soc. 84: 384-414.

MARK, A. F. 1958. The ecology of the southern Appalachian grass balds. Ecol. Monog. 28:293-336.

MARK, A. F. 1959. The flora of the grass balds and fields of the southern Appalachian Mountains. Castanea 24:1-21.

MOONEY. 1898. Myths of the Cherokees. Bureau of Am. Ethnology, 19th Annual Rep., Government Printing Office, Washington, D. C.

MUELLER-DOMBOI, D. and H. ELLENBERG. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 pp.

RADFORD, A. E., H. E. AHLES, and C. R. BELL. 1974. Manual of the vascular flora of the Carolinas. University of South Carolina Press, Chapel Hill. 1183pp.

RAMSEUR, G. 1976. Secondary succession in the spruce fir forest of the Great Smoky Mountains National Park. Dept. of Interior, National Park Serv., Southeast Region, Uplands Field Research Lab. Manage. Rep. No. 7. 35pp.

RAMSEY, J. G. M. 1853. The annals of Tennessee to the end of the eighteenth century: Comprising its settlement as the Watanga Association, from 1769 to 1777; a part of North Carolina, from 177 to 1784; the State of Franklin, from 1784 to 1788; a part of North Carolina, from 1788 to 1790, the Territory of the United States south of the Ohio, from 1790 to 1796; the State of Tennessee, from 1796 to 1800. Philadelphia Daughters of the American Revolution. Reprinted 1926.

SHANKS, R. E. 1954. Climates of the Great Smoky Mountains. Ecology 35:358-59.

WELLS, B. W. 1936. Origin of the southern Appalachian grass balds. Science. 83:283.

__________ 1937. Southern Appalachian grass balds. J. Elisha Mitchell Sci. Soc. 53:1719.

__________ 1938. Southern Appalachian grass balds as evidence of Indian occupation. Bull. Arch. Soc. N. C. 5:2-7.

__________ 1946. Archaeological disclimaxes. J. Elisha Mitchell Sci. Soc. 67:51-53.

__________ 1956. Origin of southern Appalachian grass balds. Ecology 37:592.

WHITTAKER, R. H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monog. 26:1-80.

______________ 1966. Forest dimensions and production in the Great Smoky Mountains. Ecology 47:103-121.

______________ Ed. 1973. Ordination and classification of communities. Handbook of vegetation science, Part V. Junk, the Hague. 737pp.

WHITTAKER, R. H. and H. G. GAUCH, JR. 1973. Evaluation of ordination techniques. Pages 287-321 in R. H. Whittaker ed., Ordination and classification of vegetation. Handbook of vegetation science. Part V. Junk, the Hague, 737 pages.

YARD, R. S. 1942. The Great Smoky wilderness. Living Wilderness. 7:7-19.

APPENDIX

Table 1. Species Codes. Nomenclature follows Fernald (1970).
Introduced species are indicated by *.
Species not treated in Fernald are indicated by +.
Nomenclature for these species follows Radford et al. (1974).

TREES

ABFR	*Abies fraseri*	OXAR	*Oxydendrum arboreum*
ACPE	*Acer pensylvanicum*	PCRU	*Picea rubens*
ACRU	*Acer rubrum*	PIPU	*Pinus pungens*
ACSA	*Acer saccharum*	PIRI	*Pinus rigida*
AEOC	*Aesculus octandra*	PIST	*Pinus strobus*
AMLA	*Amelanchier laevis*	PRPE	*Prunus pensylvanica*
BELU	*Betula lutea*	PRSE	*Prunus serotina*
CADE	*Castanea dentata*	QUAL	*Quercus alba*
COAL	*Cornus alternifolia*	QURU	*Quercus rubra*
CRAT	*Crataegus*	RACA	*Rhamnus caroliniana*
FAGR	*Fagus grandifolia*	ROPS	*Robinia pseudo-acacia*
FRAM	*Fraxinus americana*	SAAL	*Sassafras albidum*
HACA	*Halesia carolina*	SOAM	*Pyrus americana*
LITU	*Liriodendron tulipifera*	TILI	*Tilia*
MAAC	*Magnolia acuminata*	TSCA	*Tsuga canadensis*
MAFR	*Magnolia fraseri*	HAVA	*Hamamelis virginiana*

SHRUBS AND WOODY VINES

CLVI	*Clematis virginiana*	SAHU	*Salix humilis*
DISE	*Diervilla sessilifolia*	SAPU	*Sambucus pubens*
HYAR	*Hydrangea arborescens*	SMHE	*Smilax herbacea*
KALA	*Kalmia latifolia*	SMRO	*Smilax rotundifolia*
LEED	*Leucothoe editorum*	VACO	*Vaccinium constablaei*
LYLI	*Lyonia ligustrina*	VAER	*Vaccinium erythrocarpum*
RHCL	*Rhododendron calendulaceum* and all "azaleas"	VAHI	*Vaccinium hirsutum*
RHCT	*Rhododendron catawbiense* and "rhododendrons"	VAST	*Vaccinium stamineum*
RHRA	*Rhus radicans*	VAVA	*Vaccinium vacillans*
RHUS	*Rhus glabra*	VIAE	*Vitis aestivalis*
RIBE	*Ribes*	VIAL	*Viburnum alnifolium*
RUBU	*Rubus*	VICA	*Viburnam cassinoides*
RUCA	*Rubus canadensis*	VIDE	*Virburnum dentatum*
		VIRO	*Vitus rotundifolia*

Table 1. Species Codes -Cont.

HERBS

ACMI	*Achillea millefolium**
AGAL	*Agrostis alba**
AGGR	*Agrimonia gryposepala*
AGPE	*Agrostis perennans*
AGSE	*Agastache scrophulariaefolia*
AGRO	*Agrostis* spp.
AMBR	*Amphicarpa bracteata*
AMMU	*Amianthium muscaetoxicum*
ANQU	*Anemone quinquefolia*
ANTR	*Angelica triquinata*
ARRA	*Aralia racemosa*
ARTR	*Arisaema triphyllum*
ASAC	*Aster acuminatus*
ASCO	*Aster cordifolius*
ASCU	*Aster curtisii*
ASDI	*Aster divaricatus*
ASLA	*Aster lateriflorus*
ASPA	*Aster patens*
ASPI	*Aster pilosus*
ASPL	*Asplenium* sp.
ASSP	*Aster* spp.
ATAS	*Athryrium filix-femina*
ASUN	*Aster undulatus*
BIFR	*Bidens frondosa*
BITR	*Bidens tripartita*
BLHI	*Blephila hirsuta*
BODI	*Botrychium dissectum*
BROM	*Bromus* spp.
CAAM	*Campanula americana*
CAAT	*Cacalia atriplicifolia*
CADI	*Campanula divaricata*
CARD	*Carduus* spp.
CEHO	*Cerastium holosteoides*+
CHLE	*Chrysanthemum leucanthemum**
CHLY	*Chelone lyoni*
CHMA	*Chimaphila maculata*
CIIN	*Cichorium intybus**
CLBO	*Clintonia borealis*
COAM	*Conopholis americana*
COCA	*Collinsonia canadensis*
COCU	*Commelina communis*
COMA	*Coreopsis major*
CORA	*Corallorhiza* sp.
CUSC	*Cuscuta* sp.
CXAE	*Carex aestivalis*
CXAU	*Carex austro-caroliniana*+
CXCR	*Carex crinita*
CXDE	*Carex debilis*
CXIN	*Carex intumescens*
CXNO	*Carex normalis*
CXMI	*Carex pensylvanica*
CXRU	*Carex ruthii*
CXSP	*Carex* sp.
CXSW	*Carex swanii*
CYPE	*Cyperus* spp.
DACA	*Daucus carota**
DACO	*Danthonia compressa* and *D. spicata*
DAGL	*Dactylis glomerata**
DEPU	*Dennstaedtia punctilobula*
DESM	*Desmodium* spp.
DRRO	*Drosera rotundifolia*
DRYO	*Dryopteris spinulosa*
EPRE	*Epigea repens*
EPVI	*Epifagus virginiana*
ERAN	*Erigeron annuus*
ERCA	*Erigeron canadensis*
EUMA	*Eupatorium maculatum*
EURU	*Eupatorium rugosum*
EUSP	*Eupatorium* spp.
FRVI	*Fragaria virginiana*
GAAP	*Galax aphylla*
GACI	*Galinsoga ciliata**
GALI	*Galium* spp.
GAPR	*Gaultheria procumbens*
GEDE	*Gentiana decora*
GEPU	*Geranium pusillum*
GEMA	*Geranium maculatum*
GEQU	*Gentiana quinquefolia*
GEUM	*Geum* sp.
GEVI	*Gerardia virginica*
GITR	*Gillenia trifoliata*
GLNU	*Glyceria nubigena*
GRAS	Undetermined grasses
GRA1	Undetermined grass
HABE	*Habenaria* spp.

Table 1. Species Codes - Cont.

HIER	*Hieracium* spp.	RANU	*Ranunculus* spp.
HOLA	*Holcus lanatus**	RATU	*Ranunculus tuberosa*
HOPU	*Houstonia purpurea*	RUAC	*Rumex acetosella**
HOSE	*Houstonia serpyllifolia*	RUCR	*Rumex obtusifolius**
HYPE	*Hypericum* spp.	RUHI	*Rudbeckia hirta*
IMPA	*Impatiens pallida* and *I. capensis*	RULA	*Rudbeckia laciniata*
		SAMI	*Saxifraga michauxii*
JUAC	*Juncus acuminatus*	SERU	*Senecio rugelia*+
JUEF	*Juncus effusus*	SESM	*Senecio smallii*
JUTE	*Juncus tenuis*	SIST	*Silene stellata*
KRBI	*Krigia biflora*	SMHE	*Smilax herbacea*
LACA	*Lactuca canadensis*	SMRA	*Smilacina racemosa*
LERA	*Lechea racemulosa*	SOAR	*Solidago arguta*
LICA	*Ligusticum canadense*	SOBI	*Solidago bicolor*
LICH	Lichens	SOCA	*Solanum carolinense*
LISU	*Lilium superbum*	SOCU	*Solidago curtisii*
LOIN	*Lobelia inflata*	SOGL	*Solidago glomerata*+
LUZU	*Luzula* spp.	SOJU	*Solidago juncea*
LYCI	*Lysimachia ciliata*	SOOD	*Solidago odora*
LYCO	*Lycopodium*	SOSP	*Solidago*
LYQU	*Lysimachia quadrifolia*	SPGR	*Spiranthes tuberosa*
MACA	*Maiantheum canadense*	SPHA	*Sphagnum* spp.
MAUN	*Malaxis unifolia*	STCL	*Stachys clingmanii*
MEVI	*Medeola virginiana*	STGR	*Stenanthium gramineum*
MINT	Undetermined mint	STME	*Stellaria media* and *S. pubera*
MOSS	Undetermined bryophytes	SYAN	*Sisyrinchium angustifolium*
MOUN	*Monotropa uniflora*	TAOF	*Taraxacum officinale**
ORCH	Undetermined orchid	THNO	*Dryopteris noveboracensis*
OSCL	*Osmunda claytoniana*	THRE	*Thalictrum revulutum*
OXMO	*Oxalis montana*	THTR	*Thaspium trifoliatum*
OXST	*Oxalis stricta*	TICO	*Tiarella cordifolia*
PALA	*Panicum lanuginosum*	TRCA	*Trautvettaria caroliniensis*
PASP	*Panicum* sp.	TRER	*Trillium erectum*
PECA	*Pedicularis canadensis*	TRIF	*Trifolium repens** and *T. pratense**
PHPR	*Phleum pratense**	TRIL	*Trillium* sp.
PLLA	*Plantago lanceolata**	UNID	Undetermined plants
PLMA	*Plantago major**	UNKN	Undetermined plant
PLVI	*Plantago virginica*	UNK1	Undetermined composite, especially common on boar-rooted sites on Gregory and Parson Balds
POA	*Poa* spp., especially *P. annua**	UVPE	*Uvularia perfoliata*
POAR	*Potentilla argentea*	VEAR	*Veronica arvensis*
POBI	*Polygonatum biflorum*	VESE	*Veronica serpyllifolia*
POCA	*Potentilla canadensis* and *P. simplex*	VEVI	*Veratrum viride*
POLY	*Polytrichum* spp.	VIHA	*Viola hastata*
POVU	*Polypodium vulgare*	VIOL	*Viola* spp.
PREN	*Prenanthes* spp.		
PRVU	*Prunella vulgaris**		

Table 2. List of stands included in ordination

Stand Number	Description	Number of plots
1	Spence Field, open bald	5
2	Spence Field, old forest	1
3	Spence Field, new forest on south	2
4	Spence Field, new forest on north	2
5	Russell Field, open	2
6	Russell Field, new forest	4
7	Russell Field, old forest	1
8	Newton Bald	5
9	Nettle Creek Bald	4
10	Mount Collins, mature forest	2
11	Silers Bald, open area	3
12	Silers Bald, new forest	4
13	Silers Bald, old forest	1
14	Welch Ridge, open area	2
15	Welch Ridge, forest	3
16	High Springs, forest on south	1
17	High Springs, bald	3
18	High Springs, forest on north	1
19	Little Bald, forest on north	1
20	Little Bald, bald	3
21	Little Bald, forest on south	1
22	Rich Gap, forest	2

Table 2. List of stands included in ordination - Cont.

Stand Number	Description	Number of plots
23	Rich Gap, open	4
24	Rye Patch, forest	4
25	Rye Patch, open	4
26	Rocky Top, open	5
27	Rocky Top, forest	1
28	Thunderhead, open	4
29	Thunderhead, forest	2
30	Parson Bald, bald	8
31	Parson Bald, forest	2
32	Clingmans Dome, open	5
33	Charlies Bunion	4
34	Mount Sterling, open	4
35	Mount Sterling, forest	1
36	Hemphill Bald, bald	1
37	Hemphill Bald, new forest	2
38	Hemphill Bald, old forest	1
39	Shelters in hardwood forest	4
40	Collins Shelter in spruce-fir forest	1
41	Roadsides in spruce-fir forest	10
42	Roadsides in hardwood forest	4
43	Road Cut in Gap Road	1
44	Gregory Bald, group one	26

Table 2. List of stands included in ordination - Cont.

Stand Number	Description	Number of plots
45	Gregory Bald, group two	4
46	Gregory Bald, group three	14
47	Gregory Bald, group four	3
48	Gregory Bald, group five	9
49	Burn scars east of Charlies Bunion	3
50	Andrews Bald, group one	9
51	Andrews Bald, group two	18
52	Andrews Bald, group three	9
53	Andrews Bald, group four	1
54	Clingmans Dome, forest	3

Plots 55 through 62 are taken from R. H. Whittaker's 1966 productivity data.

55	Silers Bald	
56	Gregory Bald	
57	Thunderhead Mountain	
58	Gray beech forest, north slope phase, Newfound Gap	
59	Gray beech forest, south slope phase, Newfound Gap	
60	Red oak (-chestnut) forest, Gregory Bald	
61	Red oak-white oak (-chestnut) forest, Parson Bald	
62	Spruce-fir forest, north slope type, Mount Collins	

Table 3. Summary of shrub and herb cover by vegetation types.

Vegetation types are:

1 Balds in oak forest (Parson, Gregory, Little)

2 Balds in beech forest (Silers, Welch Ridge, High Springs)

3 Balds in spruce-fir forest (Andrews, Mount Sterling)

4 Fields (Spence, Russell)

5 Other areas affected by agricultural uses (Rye Patch, Rich Gap)

6 Burned areas (Clingmans Dome, Charlies Bunion, area east of Charlies Bunion)

7 Roadsides and shelter clearings (20 sample sites)

8 Grazed part of Hemphill Bald

9 Young oak forests (5 stands)

10 Young beech forests (7 stands)

11 Young spruce-fir forests (2 stands)

12 Mature oak forests (5 stands)

13 Mature beech forests (2 stands)

14 Mature spruce-fir forests (1 stand)

15 Areas called "bald" that are not (Newton Bald, Nettle Creek Bald)

Numbers in following columns are average percent cover (unweighted average over all stands in a type) and frequency (number of stands in which the species occurred). Species marked with an asterisk indicate the species was present but either not recorded in a sample plot or recorded as having a percent cover less than .001 percent. For identification of species code letters refer to Table 1.

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 (1) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 Burns	7 Roads and Shelter Cleanup	8 Hemphill Bald
CLVI				0.312 1				
DISE			3.91 2			20.4 2		
HYAR								
KALA	0.019 1	1.91 2		0.169				
LYLI	0.770 2		0.208 1					
RHCL	3.36 2	1.14 2	0.462 1		0.750			
RHCT		0.052 1	10.2	0.075		0.402 2		
RHRA	0.053 1							
RHUS								
RIBE						0.113 1		
RUBU							0.008 1	

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
CLVI							
DISE			14.0 1				
HYAR	0.031 1						0.500 1
KALA	0.067 2	0.573 1					
LYLI	0.172 1						
RHCL	1.38 3	0.828 1		2.01 1			1.27 2
RHCT		0.263 1	1.4 1				0.250 1
RHRA							
RHUS	0.007 1						
RIBE			0.312 1				
RUBU							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 (1) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 Burns	7 Roads and Shelter Cleanup	8 Hemphill Bald
RUCA	1.481 2	23.3 5	12.7 2	9.18 2	6.75 2	63.4 3	.025 1	
SAHU	0.689 2							
SAPU						3.14 1		
SMHE		0.218 2						
SMRO	1.82 2	0.080 1			1.11 1	0.093 1		
VACO	0.047 1		0.305 1		1.50 1	0.510 1		
VAER		0.097 1	0.784 1		0.188 1	3.82 3		
VAHI	0.427 2			1.00 1	0.016 1			
VAST								
VAVA	23.82 3	0.295 3	0.442 2	0.005 1	5.18 2			
VIAE		0.080 1						

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
RUCA	5.12 6	11.1 8	23.2 2	18.4 3	0.812 1	0.563 1	22.7 2
SAHU	0.018 2			0.101 1			
SAPU			0.708 1				
SMHE	0.006 1	.021 1		0.019 1			
SMRO	0.146 1						
VACO	1.44 2						2.02 2
VAER	0.225 1	0.172 1		1.31 1		0.813	
VAHI	2.47 3			0.950 1			
VAST	0.004 1			0.167 1			
VAVA	12.0 4			4.28 1			
VIAE							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 (2) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 (3) Burns	7 (20) Roads and Shelter Cleanup	8 Hemphill Bald
VIAL		0.006 1	0.306 1			3.14 1		
VICA			0.454	* 1		0.833 1		
VIDE						0.683 2		
VIRO					0.516 2			
ACMI	0.452 2/3			1.93 2			0.920 9	4.975 1
AGAL		0.303 2						
AGGR		0.088 2						
AGPE		0.012 1			1.14 1	2.85 3	1.50 1	
AGSE								
AGRO	2.36 3/3	0.192 1	0.158 2					
AMBR					3.14 1			

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 (6) Young oak forest	10 (8) Young beech forest	11 (2) Young spruce-fir forest	12 (3) Mature oak forest	13 (2) Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
VIAL						1.68	
VICA	0.021 1						
VIDE							
VIRO							
ACMI	0.204 1						
AGAL							
AGGR							
AGPE	0.175 1	0.047 1	2.07 1				
AGSE		1.38					
AGRO	0.025 1						
AMBR	0.104 1	0.008 1					

Table 3 Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 (2) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 (3) Burns	7 (20) Roads and Shelter Cleanup	8 (1) Hemphill Bald
AMMU								*
ANQU	0.005 1/3							
ANTR		2.73 3	6.202 1			26.9 3	0.002 2	
ARRA								
ARTR			0.050 1			0.486 1		
ASAC			0.633 2			3.54 3		
ASCO	0.094 1			1.16 1			5.11 2	
ASCU	0.630 2/3		1.50 1					
ASDI		0.446 3	2.23 1	0.745 1				
ASLA	0.796 3			3.18 2	8.06 2		0.021 1	
ASPA				0.062 1				
ASPI				0.087 1				

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 (6) Young oak forest	10 (8) Young beech forest	11 (2) Young spruce-fir forest	12 (3) Mature oak forest	13 (2) Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
AMMU		0.191 1			0.125 1		
ANQU	0.021 2	0.116 1		0.152 1			0.096 2
ANTR		4.54 7	8.27 1		13.6 1		C.050 1
ARRA							0.328 1
ARTR	0.026	.053 3	0.429 2	0.003 1			0.078 1
ASAC			3.28 2			0.063	
ASCO		0.111 1					0.078 1
ASCU	3.52 3		0.988 1				
ASDI	0.520 2	1.39 6	0.271 1	0.486 2	0.838 2		
ASLA	0.970 4						* 1
ASPA							
ASPI							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelter Cleanup	8 Hemphill Bald
ASPL	0.219 2	0.075 2	0.187 1	0.194 1	0.031 1			
ASSP	0.219 2	0.075 2	0.187 1	0.194 1				
ASUN	0.537 2/3			2.46 1	2.40 2			
ATAS		0.896 2	1.04 1			17.0 3		
BIFR							0.011 2	
BITR		5.10 2						
BLHI								
BODI	0.031 1	0.129 3		0.012	0.078 2			
BROM							18.2 19	
CAAM				* 1				
CAAT		0.015 1		4.31 1				
CADI			0.034 1					

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
ASPL							
ASSP	0.188 2	0.028 1		0.201 1			
ASUN	0.154 1			0.004 1			
ATAS	0.288 2	1.46 6	10.9 2		2.88 1		1.63 2
BIFR							
BITR							
BLHI		2.81 1					
BODI	0.012 2	0.010 2					
BROM	0.014		0.638 1				
CAAM		0.156 1					
CAAT							* 1
CADI	0.021 1						0.132 2

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 (3) Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
CARD	0.058 2				0.203 1			0.425
CEHO	0.043 2			0.031 1			0.314 12	0.800
CHLE				0.068 1			6.132	.250
CHLY								
CHMA				0.031 1				
CIIN							0.508 1	
CLBO	0.003 1	0.050 1				3.83 3		
COAM								
COCA	1.90 4							
COCU								
COMA	0.013 1							
CORA								
CUSC		0.740 4						

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
CARD	0.021 1						
CEHO							
CHLE	0.098 1						
CHLY		0.008 1	6.35 1				
CHMA	0.004 1						
CIIN							
CLBO	0.051 1					0.625	0.394 2
COAM							0.194 2
COCA		0.523		1.312 1			
COCU							0.062 1
COMA							0.112 1
CORA		0.038 2					
CUSC	* 1	0.026 3	1.28 1	0.025 1			

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
CXAE								
CXAU	0.022 1							
CXDE		2.10 5		0.037 1				
CXCR								
CXDE	0.343 3		9.55 2		0.084 1	11.1 3		
CXIN		0.408 2				6.03		
CXNO	0.444 2	1.57 3	0.058 1			0.810 2		
CXMI	0.039 1	0.810 2	0.998 1	0.350 1				
CXRU								
CXSP	0.054 2	0.931 5	0.278 1	0.344 2	0.306 1	0.090 5		
CXSW	0.137 2			0.107 1	0.425 1	0.015 1		
CYPE						0.006 1		
*DACA						0.031 1		

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
CXAE				0.018 1			
CXAU	0.319 2			0.014 1			
CXDE							
CXCR							
CXDE		0.305 6	1.79 1				
CXIN	0.018 1		1.32 1	1.05 2	0.238 1		
CXNO	0.020 1	0.016 1	0.258 1				
CXMI	0.415	11.4 3		7.91 3	12.6 1		11.3 2
CXRU							
CXSP	0.088 2	3.10 6	1.10 1	0.576 2	0.562 1		
CXSW	* 1						
CYPE							
*DACA							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
DACO	41.4 3	33.3 5	28.09 2	81.6 2	14.0 2	1.594 2	0.868 2	2.95
DAGL	0.090 1							
DEPU		0.583 2	5.58 2	0.350 1	3.10 2	14.3 2	3.22 1	
DESM					0.656 1			
DIOS	0.002 1	0.008 1		0.017 1				
DRRO								
DRYO	0.016 1	0.976 1	0.611 2			0.736 1		
EPRE	0.817 2		0.368 1					
EPVI		0.016 1						
ERAN							0.042 2	
ERCA					0.047 1			
EUMA								

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
DACO	14.7 5	5.91 6	5.45 1	1.63 3	0.675 1		0.047 1
*DAGL	0.008 1						
DEPU	4.28 5	1.32 2	1.94 1	7.65 2			
DESM							
DIOS	0.001 1	0.096 5		0.032 1	0.500 1		3.16 2
DRRO							
DRYO	0.749 2	0.094 1	2.42 2	0.125 1		19.688	
EPRE	1.05 2	.026 1		0.092			0.088 2
EPVI				0.075 1			
ERAN							
ERCA	0.010 1						
EUMA							0.412 2

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
EURU	0.678 2	0.290 2			6.26 2	5.43 3	0.022 4	
EUSP			0.142			0.579 1		
FRVI	0.204 2	0.373 2		1.94 2	1.32 2		1.01 7	
GAAP			0.010 1					
*GACI							0.042 1	
GALI				0.125 1				
GAPR			0.434 1	0.005 1				
GEDE		0.100 1	1.01 1		0.056 1			
GEPU								0.475
GEMA	0.005 2							
GEQU		0.105 1						
GEUM								

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
EURU	7.36 5	1.53 5	0.904 2	2.50 3	14.4 2		4.12 2
EUS	0.021 1	0.074 1					
FRVI	0.088 2	0.038 2					0.042 1
GAAP	0.208 1						
*GACI							
GALI	0.042 1						
GAPR							
GEDE	0.051 2	0.132 2		0.006 1			0.512 2
GEPU							
GEMA							
GEQU							
GEUM		0.089 1					

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
GEVI					0.147 1			
GITR								
GLNU			0.318 1			0.171 2		
GRAS	0.012 1				6.81 2	4.06 2	17.28 7	
GRA1								
HABE	0.0007 1		0.143 1	0.037 1			0.083 1	
HIER	0.038 2	0.370 3	0.200 1			0.046 1	2.49	
HOLA	1.353 1	0.092 1		2.81 1	0.712 1		2.82 13	.025
HOPU	0.441 3	0.283 3	0.006 1	0.812 1	5.54 2		0.333 1	
HOSE	1.46 2	1.79 1	1.39 1	0.031 1	4.77 2		0.215 8	
HYPE	0.021 1	0.466 3	0.765 1		0.006 1		0.015 2	

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
GEVI							0.444 2
GITR							0.325 2
GLNU							
GRAS	0.912 4	0.109 2	0.075 1	0.137 2	1.05 1		
GRA1							
HABE			0.167 1				
HIER	0.045 2	0.098 3	1.26 1				0.558 2
HOLA	0.229 1						
HOPU	0.093 1	0.094 1		0.047 1			0.268 1
HOSE	0.972 5	1.382 6	1.52 1	7.69 3			
HYPE	0.029 1	0.018 2					

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
IMPA		0.015 1				5.83 2	0.0008 1	
JUAC								
JUEF	0.006 1							
JUTE	0.069 2	0.012 1	0.051 2		0.031 2		1.81 12	
KRBI	0.021 1							
LACA	0.028	0.099		0.556	0.094			
LERA	1.373 3							
LICA			0.058 1					
LICH		0.493 2						1.10
LISY		0.007 1	0.487 2			0.509 1		
LOIN					0.122 1		0.476 3	
LUZU	0.377 3	1.36 5	0.391 1		0.206	1.705 3		

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
IMPA	0.208 1	.022 1	4.29 1		26.8 1		
JUAC							
JUEF							
JUTE	0.003 2			0.008 1			
KRBI	0.002 1			0.017 1			
LACA				0.006 1			0.282 1
LERA							
LICA							0.125
LICH							
LISY	0.012 1		0.067 1				
LOIN	0.005 1						
LUZU	0.217 2	1.20 4	3.23 2	0.833 1	2.96 1		

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
LYCI								
LYCO			3.38 1					
LYQU	0.199 3		0.484 1	1.25	0.094			
MACA			0.042 1					
MAUN			0.012 1	0.006 1				
MEVI	0.016							
MINT							0.072 2	
MIRE								
MOCL								
MODI								
MOFI								
MOSS	1.415 2		6.57 2	0.181 1				0.225
MOUN								
ORCH								

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
LYCI		0.602 1					
LYCO			2.74 1				
LYQU	0.262 3		0.688 1	0.269 2			0.397 2
MACA							0.050 2
MAUN				0.001 1			
MEVI	0.072 2	0.031 1		0.210 2			
MINT							
MIRE	0.036 2			0.017 1			
MOCL		0.872 1					
MODI			0.066				
MOFI							0.769 2
MOSS	0.721 2	0.347 2	1.96 2	0.615 2	0.438 1	23.75	
MOUN	0.002 1						
ORCH							

Table 3. Shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
OSCL		0.125 1						
OXMO		0.015 1	0.170 1			0.833 1		
OXST	0.059 2	0.376 1			0.332 2		0.147 10	
PALA	0.041 3				0.088 1			
PASP								
PECA	0.118 1	0.185 1						
*PHPR	1.905 2	4.48 5			0.016 1		0.018 1	0.100
*PLLA							0.533 7	0.025
*PLMA							4.40 19	4.22
PLVI							0.039 3	
POA	1.07 1						20.3 4	21.7
POAR							*0.454 2 0.731 2	

Table 3. Shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
OSCL							
OXMO			14.7 1			73.0	
OXST	0.062 1						
PALA	0.003 1						
PASP							
PECA	0.029 1						0.372 2
*PHPR	0.118 2	0.039 1		0.007 1			
*PLLA							
*PLMA							
PLVI							
*POA							
POAR							

Table 3. Shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
POBI								
POCA	17.6 3	11.2 5	9.81 2	28.0 2	9.72 2		0.090 5	
POLY	.1.191 1	3.21 4	4.86 2	8.35 2	4.23 2	0.589 2	0.308 1	
*POND							0.011 1	
POTR							0.054 2	0.050
POVU		0.015 1						
PREN	0.309 2	0.153 4	1.88 2	0.310 1	0.054 2	0.046 1		
*PRVU	0.008 1	0.213 2		0.094 1	0.348 2		0.512 9	0.100
RANU							1.75 2	
RATU							0.260 1	
RUAC	5.516 3	4.68 5	1.43 2	4.58 2	1.35 2	0.509 1	0.072 9	1.951
RUCR	0.001 1			0.038 1			0.282 2	0.025

Table 3. Shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
POBI							0.125 1
POCA	3.18 5	0.978 5		0.472 1			2.36 2
POLY	0.942 3	1.77 4		0.304 1			6.218 1
*POND							
*POTR							
POVU							
PREN	0.046 2	0.138 2	2.32 2	0.138 2	0.312 1		1.34 2
*PRVU	0.106 1						
RANU							
RATU							
*RUAC	2.53 4	1.20 3	0.225 1	0.044 1			
*RUCR							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
RUHI		0.560 1		0.987 1			0.337 6	
RULA		9.01 3						
SAMI						1.782 1		
SERU			1.28 1			2.85 2		
SESM	0.005 2							
SIST								0.016 1
SMRA	0.007 1							1.79 2
SOAR								0.175 1
SOBI	0.973 2			5.95 1	0.516 1			0.088 2
SOCA	0.196 2			0.188 1	0.053 1			

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
RULA		3.709 3	3.92 1		12.9 1		
SAMI							
SERU						15.0	
SESM							
SIST							0.016 1
SMRA	0.005 1			0.010 1			1.79 2
SOAR							0.175 1
SOBI	0.156 1						0.088 2
SOCA	0.029 1						

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
SOCU	0.793 2	2.44 4		0.656 1	3.89 2			4.85 2
SOGL		0.902 1	2.57 1			51.6 3		
SOJU				0.969 1				
SOOD		0.338 1		6.89 1			0.021 1	
SOSP	5.05 3	0.842 2	4.37 2	7.971 1	0.797 2		2.24 5	0.811 2
SPGR				0.012 1				
SPHA			0.035 1	* 1				
STCL	0.551 2	4.45 5		1.83 1	0.100 1	9.39 1	0.007 2	
STGR	* 1	0.366 2	0.045 1		0.016 1			0.297 2
STME	0.001 1	0.369 3						0.050 1
SYAN		0.110 1						
*TAOF	0.024 2				0.034 2		5.14 16	2.82
THNO		1.53 2	0.100 1					

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Coed	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
SOCU	3.75 5	3.01 7		0.838 3	7.69 2		4.85 2
SOGL		0.024 1	6.10 1			8.875	
SOJU							
SOOD	0.927 1						
SOSP	2.33 4	3.27 2		0.103 1			0.811 2
SPGR							
SPHA							
STCL	2.36 1	1.88 4	1.98 1		0.425 1		
STGR	0.014 1			0.058 1			0.297 2
STME	0.042 3	0.501 5		0.001 1	2.49 1		0.050 1
SYAN							
*TAOF							
THNO	5.85 3	0.724		1.70 1			20.2 2

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
THRE		0.003 1					0.303 2
THTR		0.044 1					0.025 1
TRCA		1.049 3			0.062 1		
TRER							
*TRIF	0.187 1						
TRIL			0.008 1				0.062 1
UNID							
UNKN	0.172 1						
UNK1	0.044 2			0.055 1			
UVPE							0.252 1
*VEAR							

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
THRE		1.91 4						
THTR	0.194 1	3.62 3		0.700 1	0.038 1		0.040 1	
TICO		0.44 1						
TRCA								
TRER								
*TRIF	0.024 2				0.010 1		11.4 17	39.1
TRIL						0.133 1		
UNID	0.006			0.094 1				
UNKN								
UNK1	9.67 2							
UVPE								
*VEAR								4.40

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
VEUF							0.454 4	
VESE							0.0008 1	
VEVI						1.29 1		
VIHA	* 2		0.042 1	0.400 2	0.032 1			
VIOL	0.354 2	0.736 5	0.394 2	0.372 2	1.99 1	0.116 1	0.468 13	0.025
Total number of herb species	70	65	48	54	48	31	57	22
Total number of exotics	11	4	1	6	1	17	3	7
Percent of exotics	15.7	6.2	2.1	11.1	12.5	3.2	29.8	59.1

Table 3. Summary of shrub and herb cover by vegetation types - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
VEUF	0.007 1						
VESE							
VEVI							
VIHA	0.035 3			0.001			
VIOL	1.69 4	0.222 5	0.912 2	3.635 3	0.275 2		0.318 2
Total number of herb species	81	61	37	43	23	14	56
Total number of exotics	7	2	2	2	0	0	0
Percent of exotics	8.6	3.3	5.4	4.6	0	0	0

Table 4. Summary of tree data by vegetation sites. See beginning of Table 6 for list of types. Numbers are average basal area (unweighted average over all shrubs in a type) and frequency (number of stands in which the species occurs).

Species Code	1 (2) Balds in oak forest	2 (4) Balds in beech forest	3 (2) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 (2) Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
ABFR		0.0026 1	3.69 2			5.10 2		
ACPE	0.0012 1				* 1			
ACRU	0.018 2	0.0007 2	0.013 1	0.12 2	0.64 2	0.065 1		
ACSA		0.00097 1		0.0063 1	0.34 1			+
ACSP			0.0026 2					
AEOC								+
AMLA	0.0021 2	0.059 3	0.51 2	0.55 2	1.09 2	0.0078 1		
BELU	0.10 2	0.27 3	2.42 2	0.012 1	0.52 2	0.12 1		
CADE	0.0027 1				0.028 1			
COAL								

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	9 (5) Young oak forest	10 (7) Young beech forest	11 (2) Young spruce-fir forest	12 (5) Mature oak forest	13 (2) Mature beech forest	14 (1) Mature spruce-fir forest	15 (2) Balds by name
ABFR			11.65 2			14.86	
ACPE	0.018 2	0.014 1	0.016 1	0.0018 2			0.088 2
ACRU	0.44 5	0.21 2		0.30 3			1.05 2
ACSA	0.12 4	0.16 3		5.29 4	1.17 1		0.0020
ACSP			0.020 1			*	
AEOC	0.0016 2	0.89 4		1.44 3	12.06 1		* 1
AMLA	1.92 5	0.38 6	0.32 1	0.97 4			0.34 2
BELU	0.92 3	3.71 7	5.21 1	4.58 4		16.8	1.27 2
CADE	0.14 3			0.19 2			0.17 2
COAL		* 1		0.0047			0.0078 2

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	1 (2) Balds in oak forest	2 (4) Balds in beech forest	3 (2) Balds in spruce-fir forest	4 (2) Fields	5 (2) Rye Patch and Rich Gap	6 (2) Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
CRAT	0.14 2	0.12 3	0.0095 1	0.0063 1				
FAGR		0.008 3			0.0078 1			
FRAM	0.0003 1			0.16 2	0.035 1			
HACA								
LITU					* 1			
MAAC			0.0085 1		0.0078 1			
MAFR				0.0039 1				

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	9 (5) Young oak forest	10 (7) Young beech forest	11 (2) Young spruce-fir forest	12 (5) Mature oak forest	13 (2) Mature beech forest	14 (1) Mature spruce-fir forest	15 (2) Balds by name
CRAT	0.048 1	0.19 2	0.079 2	0.0078 1			0.0020 1
FAGR	0.28 1	12.18 6		3.57 4	16.89 1		
FRAM	0.0032 1						
HACA							0.19 1
LITU	0.35 1						
MAAC	0.022 2						
MAFR							

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
OXAR	0.003 1	0.10 1		0.80 2	1.31 2			
PCRU		0.19 1	0.77 2			1.27 2		
PIPU	0.0078 1			0.27 1				
PIRI	0.414 1							
PRPE	0.0009 2	0.0061 3	0.66 2	0.051 1	* 1	0.31 2		
PRSE	0.065 1	0.32 3		0.0016 1	0.73 2			
QUAL	* 1				0.23 2			
QURU	1.56 2		0.16 2	0.0078 1	2.16 2			
RACA		0.0039 2	0.019 2	0.0040 1				
ROPS				0.67 1				+

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	9 (5) Young oak forest	10 (7) Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
OXAR	0.66 3	0.0044 1		4.76 1			
PCRU		0.45 1	3.69 2			20.37	0.16 1
PIPU	0.28 2						
PIRI		0.091 1					
PIST	0.0042 1						
PRPE	0.19 3	0.0039 2	0.29 1	0.0031 1			
PRSE		0.40 4		0.40 1	4.58 2		
QUAL	0.17 4						1.29 1
QURU	7.49 5	0.28 2		14.90 5	16.61 1		23.43 2
RACA	0.004 1	0.052 3		0.13 2			0.037 2
ROPS	0.36 1	0.56 1					0.96 2

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	1 Balds in oak forest	2 Balds in beech forest	3 Balds in spruce-fir forest	4 Fields	5 Rye Patch and Rich Gap	6 Burns	7 Roads and Shelters Cleanup	8 Hemphill Bald
SAAL					0.073 2			
SOAM		0.12 2	0.05 2	0.078 1		0.60 2		
TILI								
TSCA				0.016 1	0.35 1			
HAVA					0.17 2			
Total basal area	2.15	1.11	8.29	2.11	7.93	7.48	--	--
Number of species	14	14	11	15	20	7	N.A.	N.A.

Table 4. Summary of tree data by vegetation sites - Cont.

Species Code	9 Young oak forest	10 Young beech forest	11 Young spruce-fir forest	12 Mature oak forest	13 Mature beech forest	14 Mature spruce-fir forest	15 Balds by name
SAAL	0.13 1						
SOAM		1.07 2	4.11 1				
TILI							0.19 1
TSCA							1.55 1
HAVA							
Total basal area	13.55	20.24	23.28	36.52	51.35	52.06	30.73
Number of species	21	18	9	15	6	4	17