The Vegetation of Grassy Balds and Other High Elevation Disturbed Areas in the Great Smoky Mountains National Park

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The vegetation of grassy balds and other high elevation disturbed areas in the Great Smoky Mountains National Park[1,2]

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LINDSAY, M. M. and S. P. BRATTON (Dept. Interior, Nat. Park Serv., Uplands Field Res. Lab., Great Smoky Mountains National Park, Gatlinburg, Tenn. 37738). The vegetation of grassy balds and other high elevation disturbed areas in the Great Smoky Mountains National Park. Bull. Torrey Bot. Club 106: 264–275. 1979.—Plot sampling was conducted in high elevation disturbed communities in Great Smoky Mountains National Park. Sites included grassy balds, fields, wooded balds, burn scars, mowed roadsides and shelter clearings. The areas presently mowed, trampled or grazed were found to be very similar, their flora little influenced by topographic position. Balds and burn scars had many species in common but the structure of the communities was very different, grasses being of lower importance on the burns. Communities with no current anthropogenic disturbances were undergoing woody plant succession and becoming more similar to the surrounding forest. The flora of the grassy balds appears to be partially an artifact of past human influences.

Of all the non-forested plant communities in the southern Appalachians, the grassy balds are the most famous and their origins the most historically obscure. These open, high elevation, grassy areas have great aesthetic appeal and offer some of the best displays of flowering shrubs and vistas of surrounding peaks from the otherwise tree covered ridges. When these areas are protected from disturbances, they slowly change to first a shrub, then a forest community (Bruhn 1964, Gilbert 1954). Since the grassy balds are popular hiking goals, the management of their disturbance regime has become an administrative problem for organizations such as the National Park Service and Forest Service, which oversee them.

The Great Smoky Mountains National Park (GRSM), the largest preserve area in the southern Appalachians, contains several types of high elevation disturbed communities, including landslides, burn scars, grassy balds, roadsides, and shelter clearings. Some of these, such as landslides, are clearly natural while others, such as roadsides and back country shelter clearings are certainly man-caused. The origin and continued existence of the grassy balds, however, have been much debated. Some authors (see literature review in next section) have suggested natural phenomena, including a wide variety of disturbances and climatic factors, as the cause of these openings in the forest canopy. Others have found evidence for anthropogenic interference. The relative role of man in the fire history of the park has also never been definitely determined.

The purpose of this study was to investigate the grassy balds and to compare them floristically to those of other high elevation disturbed communities with different histories of human interference. The intention was to answer several questions of importance to park management, including:

(1) are the grassy balds "natural communities?

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3 We thank all those who helped with the field work for this project, especially Chris Cunningham, Jim Graves, Jill Baron, and Dave Eissenstat, and all the staff of Great Smoky Mountains National Park, especially Boyd Evison, Mike Meyers, and Don Defoe. We are grateful to R. H. Whittaker, who provided his productivity data, and to Peter Marks, Peter White and Lawrence Barden, for reviewing versions of the manuscript.

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(2) were grassy balds or could the grassy balds be maintained by a "natural" disturbance such as fire?

(3) what is the probable future of the grassy balds and other high elevation openings under present park management policy (including fire suppression)?

A brief history of disturbance in GRSM. Over the past 300 years the amount and type of disturbance in the present GRSM has varied tremendously. In pre-Columbian times, Indians occupied the lower creek flats and established hunting camps, following the streams to the higher elevation gaps (Bass 1977). It is not known at present if they purposefully burned the higher elevation forests, but one might guess that campfires escaped occasionally and thus, unlike lightning, the Indians would have been a source of fire during drier weather.

During the late 1700's, white settlers moved into the lower valleys, slowly displacing the Indians. First entry rights were issued to Cades Cove in 1794, for instance, and the first legal grant was in 1821 (Shields 1977). Land was cleared for farming to about 720 m on the north facing Tennessee side and to about 950 m on the south facing North Carolina side of GRSM. Burning of the forest understory was widely practiced. The oak-chestnut and pine forests of the higher ridges were ignited to clear leaf litter when gathering nuts or to improve the berry crop (Lindsay 1976, Lindsay and Bratton, in press). Fire frequencies for more xeric sites were as high as 8 per 100 years before the establishment of the park (Mark Harmon, unpublished data). At some point in time the settlers began to drive cattle and sheep to the high ridges for the summer. Grazing in the woods was common except on the steeper slopes and in the spruce-fir zone (Lindsay 1976).

The disturbance pattern changed again with the advent of commercial logging and the logging railroads in the late 1800's. Rather than the selective and woodlot-type cutting practiced by the settlers, whole watersheds were cut, leaving piles of slash and severely disturbed soils. Large fires on slash were common during this period and a number of these caused crown fires in adjoining stands or burned to the ridgetops (Lambert 1958).

When the park was established in 1936, grazing and other agricultural practices ceased on the high ridges. All fires, including those started by lightning, were suppressed as quickly as possible. New roads were constructed and a trail and shelter system was added for hiker use. Two exotic species, the European wild boar and the balsam woolly aphid, have invaded the park during the last 30 years and are causing severe disturbance to some high elevation plant communities. The woolly aphid is killing almost all the mature Fraser fir (*Abies fraseri*) within its range, and the wild boar is rooting the understory of high elevation beech (*Fagus grandifolia*) forest and turning the turf on the grassy balds and burn scars (Bratton 1975, Hay *et al.* 1978).

Besides the changing human impacts, the frequencies of natural disturbances have also been variable. Lightning fires are very prevalent during some decades and almost absent during others (Barden 1974; Mark Harmon and Juliet Covell, unpublished data). Landslides and blow-downs accompany particularly severe storms. In 1951, for instance, a thunderstorm poured 7 cm of rain on Mount LeConte in a single hour and caused over 40 landslides (Bogucki 1970).

The grassy balds have received far more scientific attention than all the remaining open successional communities in the park combined, and hypotheses on their origin include:

(1) ecotonal position (Mark 1958, Billings and Mark 1957)

(2) xeric conditions or retraction of tree line during the xerothermic period (Camp 1931, Brown 1941, Whittaker 1956)

(3) fire (Clements 1936)

(4) ice and frost damage (Harshberger 1903)

(5) windthrow (Brown 1941)

(6) gall wasps (Gates 1941)

(7) burning by Cherokee Indians (Wells 1936, 1937, 1938, 1946, 1956)

(8) clearing by early settlers (Gershmehl 1970).

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
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
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
Other mature forest sites near the disturbed areas listed above			

They were extensively grazed in the 19th and early 20th centuries but there is little evidence for the use of fire (Lindsay 1976).

The dates of disturbances for most other types of high elevation open communities are known, but little floristic work has been completed. Ramseur (1976) looked at balds and burn scars in spruce-fir forests. Baron *et al.* (1975) investigated the distribution of exotic plants along park roads.

The pattern of disturbance in GRSM has been variable in the past, going through several phases. Some communities may therefore be artifacts of past human influences or present management practices. Considering the total amount of past human interference, the question, "What is natural?" can be difficult to answer for communities like the grassy balds. In a National Park where natural ecological processes should be allowed to operate with as little human interference as possible, an understanding of disturbance histories is critical to sound management.

Study sites. This study investigated the vegetation of several nonforested high elevation communities and the forests around them. A few undisturbed forests were included for comparison. The elevations and aspects of the sites are shown in Table 1, and the geographic locations are shown in Fig. 1.

The disturbed sites were divided into the following classes:

1. ''True'' balds are grassy areas whose origins are not known with certainty. 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, and Mount Sterling Bald. All of these sites were grazed but abandoned before 1936. Herders probably cut trees around the edges of Gregory Bald, and Andrews and Silers may have been cleared before the Civil War (Lindsay 1976, Lindsay and Bratton, in press). One bald, Hemphill, which is on the boundary of the national park and half of which is still grazed by cattle, was also included.

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, probably about 1870, are Spence Field and Russell Field (Lindsay 1976, Lindsay and Bratton, in press). Neither ''true balds'' or ''fields'' were burned during the period of intensive grazing.

3. 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.

4. Areas otherwise affected by pre-park agriculture. 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.

5. 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 west slope of Clingmans Dome.

6. Shelter clearings, cleared areas around shelters along the Appalachian Trial. 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).

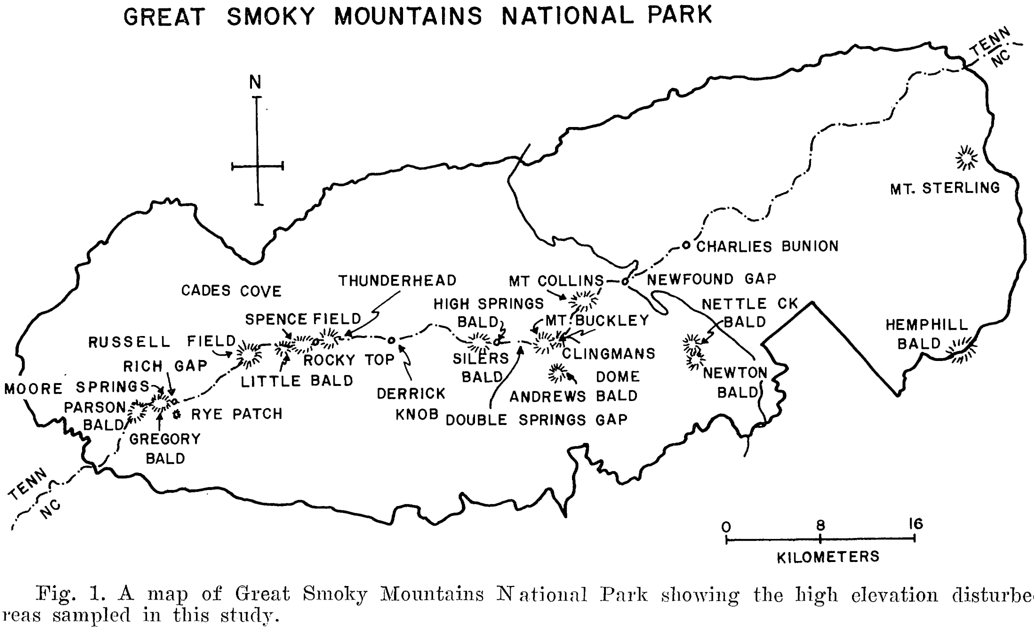

Fig. 1. A map of Great Smoky Mountains National Park showing the high elevation disturbed areas sampled in this study.

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

Methods. FIELD SAMPLING. On two balds, Gregory and Andrews the vegetation was sampled by 10 m × 20 m plots laid out along measured transect lines so that the plots could be relocated to record changes resulting from management. Plots were placed at regular (20 to 50 m) intervals except when a transition such as the edge of a bald was reached. In such places, successive plots were placed at closer intervals (10 m) or adjacent to each other. The plots covered about 15% of the area of Gregory Bald and 5% of Andrews Bald.

On other sites, an attempt was made to sample areas that were still open, forest that had grown up since the cessation of disturbance, and forest that was present before and during the disturbance. (Records, tree cores, and the size of the trees could be used for determining these categories.) If aspect seemed to have a significant effect on the vegetation, different slopes were included in the sample to try to encompass the range of variation on and around a particular site. On sites other than Gregory and Andrews Balds, circular plots with a radius of 8 m (201 m^2) were used because they could be laid out more rapidly. (Hereafter 200 m^2 and 201 m^2 plots are referred to as 200 m^2).

Within each 200 m^2 plot, all trees were identified and their diameter at breast height (1.4 m) was measured. Percent cover of herbs and shrubs was estimated visually in 10 one-square-meter plots. In the 10 × 20 m rectangular plots, the herb plots were located 1 m apart on alternate sides of a line through the center of the plot. In circular plots, eight herb plots were placed along a diameter and one on each side of the diameter 4 m from the center (10 plots total). In shelter clearings and along roadsides, 6 one-square-meter quadrats were placed at each site. Quadrats in shelter clearing 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 m^2 plot. To avoid distortion of the data by exceptionally dense growth of a particular species, 150% was set as the maximum percent cover that could be recorded for any herbaceous 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 m^2, 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 species names used here follow Fernald (1970) where possible, but Radford *et al.* (1974) 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. hirsutum* could be distinguished without fruit or flowers. The deciduous *Rhododendron* species ("azaleas") are grouped as one taxon.

Principal Components Analysis (PCA) ordination of these samples was done with Cornell Ecology Program 23 (Gauch 1973) on the IBM 360 computer. The herb and shrub species with the lowest percent cover, averaged over the stands in which they occurred, and values which did not represent well defined species were 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, 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 is 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.

Results. THE HERBACEOUS VEGETATION. *Open sites.* On all the "natural" balds, *Danthonia compressa* was a major dominant. *Rumex acetosella* and *Potentilla canadensis* were also present in all stands. *Rubus canadensis, Vaccinium vacillans,* and *Viola rotundifolia* were present on almost all balds. All balds had at least one species of *Aster, Solidago,* and *Carex. Agrostis alba, Carex normalis, Dryopteris intermedia, 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, Leachea 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 laciniata, Angelica triquinata, Aster acuminatus,* and *Solidago glomerata* were typical of high elevation balds. (The flora of the grassy balds has been previously studied in detail by Mark 1959, Bruhn 1964, Whittaker 1956, 1966. More extensive species lists can be found in these sources.)

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

The cleared fields, Russell Field and Spence Field, lie near the lower and upper limit of high elevation red oak forest, respectively. Their vegetation is similar to that of the balds in oak forest. They also are dominated by *Danthonia compressa*; and *Potentilla canadensis, Rumex acetosella,* and *Aster* spp. occur 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 found 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% 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% 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% of those present on burn scars.

Roadsides and shelter clearings are under constant disturbance from mowing or trampling. They are dominated by the exotics, *Plantago* spp., *Poa annua, Trifolium* 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% 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, is very similar to the roadsides and shelters. *Plantago, Taraxacum, Poa,* and *Trifolium* dominate the vegetation. *Danthonia* is 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 has not grown up into a *Danthonia* sward as the other balds or fields did after grazing ceased. Instead, there is a dense stand of tall forbs such as *Agastache scrophulariaefolia, Blephilia hirsuta, Rudbeckia laciniata, Geum* sp., *Monarda clinopodia,* and *Campanula americana,* under young forest dominated by high elevation hardwoods. There is no obvious reason why a dense sward of *Danthonia* did not become established; perhaps this did not happen because the part of the bald that is inside the park boundary is on a north slope and therefore much more mesic that most balds and fields. The percentage of exotic species in the sample on Hemphill Bald is extremely high, 59.1%. 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 seems 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* are present but do not attain high coverage. Ferns and more mesic species are more important than in the open areas.

The oak forests seem to have more species in common with the open areas they surround than do beech or spruce-fir forest. Some stands even have higher coverage of *Danthonia* than some open areas. No species occurs in young forests that is absent from balds except *Arisaema triphyllum*. The only species that have a higher coverage in the oak forest than in open areas are *Eupatorium rugosum* and *Dryopteris noveboracensis* (which are also present on balds).

Beech forests differ from the balds they surround in having more sedges and fewer grasses. Except around Hemphill Bald, no species occur in the forests that do not occur on the nearby balds. Some of the more important species are *Angelica triquinata, 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 contain no species not found on the open areas which they surround. The main difference is the much greater coverage of *Oxalis montana* and the lower coverage by grasses.

The only species common to all young forests at all elevations are *Rubus canadensis, Dryopteris intermedia,* and sedges. The occurrence of exotic species is low; 8.6% of the species in oak forests, 3.3% in beech forests, and 5.4% in spruce-fir forests are 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 is very low, less than 5%.

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

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

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

WOODY VEGETATION. Tree data were averaged together over all stands in a particular stand type. The samples on which the summarized tree data were 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 would distort data greatly. However,

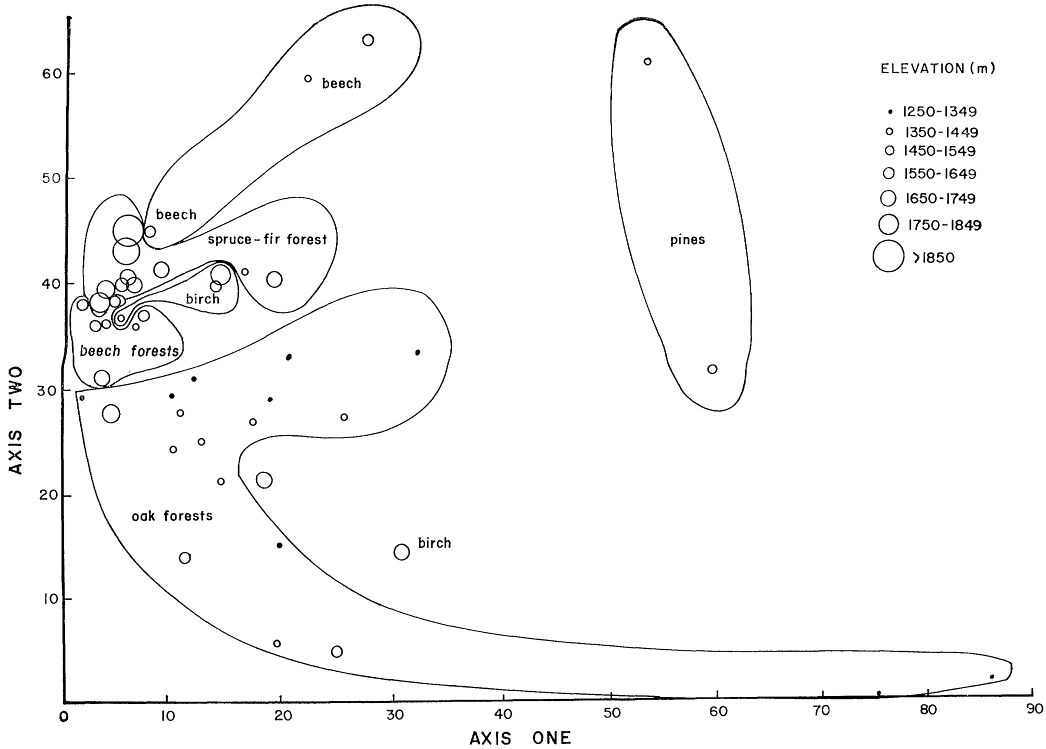

Fig. 2. An ordination of all stands by the relative basal area of trees. Even the successional stands tend to group by the surrounding forest type. Stand positions relate strongly to topography. The effect of elevation is shown in the figure. Axis one and two are artificial coordinates generated by the PCA analysis. Moisture tends to decrease along axis one and elevation tends to increase along axis two.

the average of several stands probably showed general trends fairly accurately.

Balds and fields had the lowest basal areas, less then 10 m^2 per ha. Hawthorn, *Crataegus macrosperma;* serviceberry, *Amelanchier laevis;* and black cherry, *Prunus serotina,* occurred at all elevations. Table Mountain pine, *Pinus pungens*; white pine, *P. strobus*; and pitch pine, *P. rigida,* were common on the balds in oak forests and on the fields but were rare elsewhere. Tree species of the surrounding forest were common on balds in oak and spruce-fir forests, but very few beech trees occur on balds in beech forests except around the edges. This is because beech reproduces mainly by sprouts and not by seeds at the higher elevations (field observation and Huff 1977) ; 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 cm) individuals of species from the surrounding forests. Red oak, *Quercus rubra,* and sourwood, *Oxydendrum arboreum,* were the most important species. Basal areas were about 8 m^2 per ha.

The burn scars are all above 1,600 m and are on sites surrounded by spruce-fir forests. Fraser fir and red spruce are the principal invaders of these sites, and yellow birch, *Betula lutea*; mountain ash, *Pyrus americana*; and fire cherry, *Prunus pensylvanica,* are also common. Basal area was about 7 m^2 per hectare.

No sample plots on Hemphill Bald included trees. However, yellow buckeye, *Aesculus octandra*; black locust, *Robinia pseudoacacia,* and hawthorn could be seen near the top of the bald, and sugar maple, *Acer saccharum,* and beech are at the lower edges.

All young forests sampled had basal areas averaging from 14 to 24 m^2 per hectare for the various types. Over half the basal area in the oak forests was red oak.

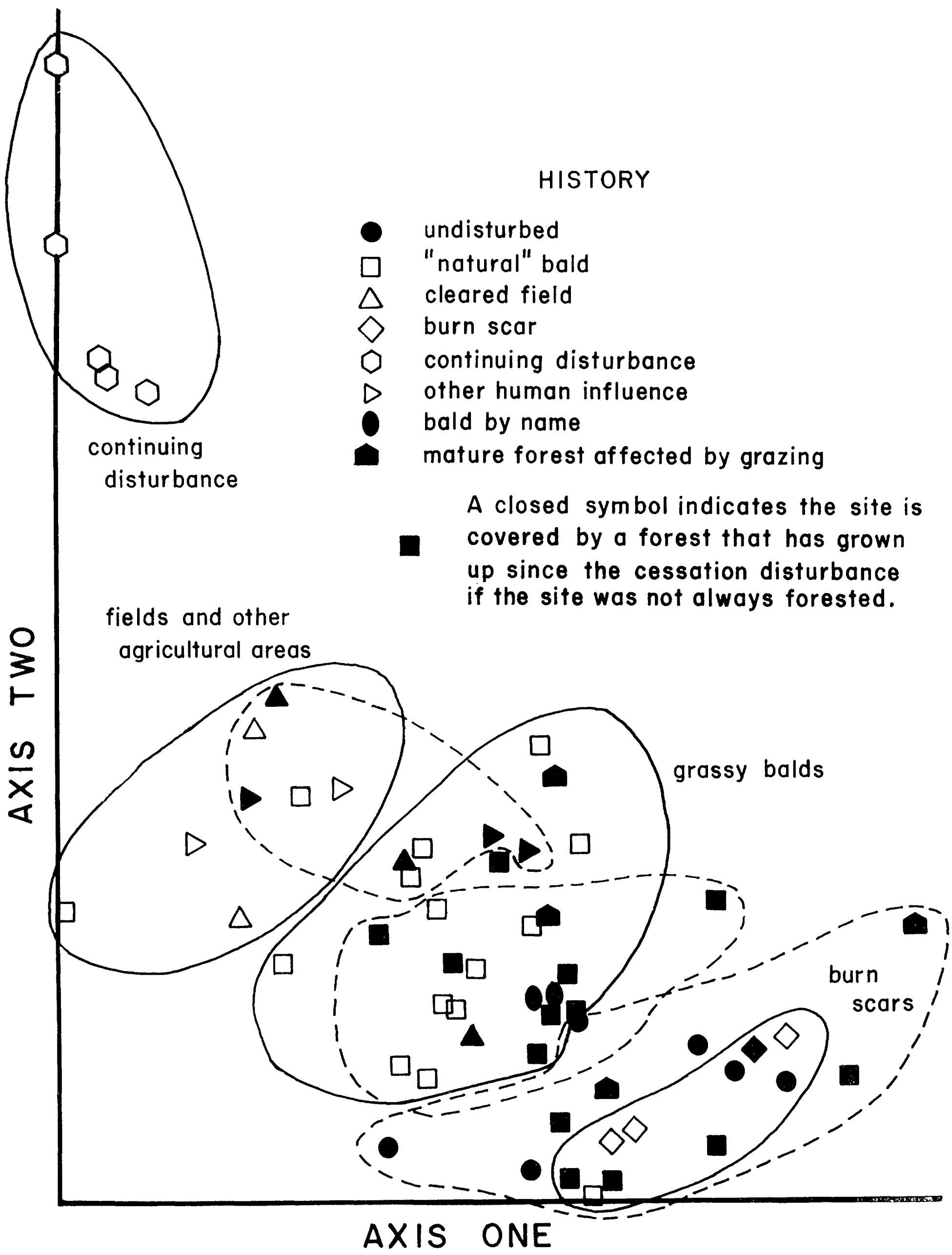

Fig. 3. A principal components ordination of all stands by the relative percentage of herbs. The shapes indicate the history of the stand and a closed symbol indicates the site is now forested. The solid lines show the groupings of the sites which are still open—continuing disturbance at the left of axis one, followed by the fields and other agricultural areas, then by grassy balds, and burn scars to the right. The dashed lines define the relative positions of the closed communities—first fields to the left, grassy balds and then mature forest to the right. Note that burn scars are more closely related to mature forest communities, and that as grassy balds grow in they also approach the mature forests.

Serviceberry, sourwood, and red maple were next in importance. Sixteen other species were also found. Beech made up about 60% of the basal area in beech forests and yellow birch about 20%. 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% in mountain ash, and 20% in yellow birch. Five other species were also present.

Ordination. When woody data from all stands were ordinated, the results suggested that elevation is the most important factor. However, the grouping of plots also indicates that the ordination has bent any axis that might correspond to elevation into a sharp curve. Thus, while the stands that are low on the first axis show a more or less linear relation between elevation and position on the second axis, the stands that are high on the first axis show an opposite relation of elevation and position on the axis (Fig. 2). However, this curving of axes is common in PCA (Whittaker and Gauch 1973). The first axis seems to correspond to moisture. The stands at the high end of the axis are the only ones where pines are important and they lie at low elevations, whereas the stands at the low end of the axis are on moist sites. Basal area, which corresponds roughly with age, site, or species, seems to be relatively unimportant. Forest type corresponds fairly clearly to the curved elevation axis. The odd position of stand 37 probably results from the presence of black locust, a species associated with lower elevations. Five axes were needed to account for 50% of the variance.

Ordination of the herb species suggests that elevation and disturbance are important (Fig. 3). Elevation tends to increase along axis 1. The stands undergoing continuing disturbance, Hemphill Bald, the roadsides, and the shelter clearings, are grouped at the top end of the second axis, whereas most of the undisturbed forests are at the lower end. Nine axes were required to account for 50% of the variance.

The grassy balds plots are scattered through the ordination. The open fields 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 successional plots from balds at the same elevation and also were more closely associated with the mature forest plots than those from other open sites. 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 is also related to axis 1, suggesting that age of the forest and shade influence herbaceous vegetation.

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

Although the "true" balds do not separate as dramatically as the continually disturbed communities, they tend to group between the continually disturbed areas and the burn scars and mature stands. Whatever their origin, the grazing of cattle by white settlers continued for perhaps as long as 150 years on the "true" balds and for 60 years on the cleared fields. This impact probably selected for trampling resistant species, such as *Danthonia compressa*. In the absence of grazing disturbance, *Danthonia* and other pasture species have 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 ordinations than corresponding samples taken 15 years later. Presumably, the balds and fields were most similar to each other when they were being grazed. Species of the surrounding forests are now becoming increasingly important on the balds, and the areas are slowly acquiring the communities which are characteristic of their topographic position.

The burn scars were disturbed greatly at a single point in time, but since the disturbance did not continue, they did not grow into *Danthonia* like the balds. This (and lack of burning by herders (Lindsay

1976)) suggests that the balds are not a pyric-disclimax, at least under natural fire frequencies. The vegetation on the burn scars is typical of what Ramseur (1976) describes for secondory successional communities at high elevations. Succession in oak and beech forests has not been studied, but field observation indicates ericads such as *Vaccinium* and *Kalmia* typically occupy openings in oak forest, and *Rubus* typically occupies openings in beech forest. Grass does not normally become established after a single disturbance.

The data imply that, from a floristic point of view, burn scars and grassy balds are not very similar and that a change in park fire management policies to permit lightning fires to burn would not result in further development of grassy balds, all of which are presently being overtaken by woody succession (Lindsay and Bratton, submitted), losing about 1% of their area per year. Since all of the large burns at high elevations are the result of logging fires, this type of community is also becoming more restricted in area. Lightning has ignited fires in spruce-fir forest, but in recent years all of these have been suppressed.

If the National Park Service were to mow or graze the balds to maintain them as open successional communities, their flora would become more similar to that of the roadsides or of Hemphill Bald, and exotic species would probably become more prominent. All of the high elevation communities with an historic anthropogenic factor important in their origin or maintenance are slowly disappearing from the park.

Conclusion. (1) Although the origin of the grassy balds may have been natural, their present flora is partially an artifact of anthropogenic interference.

(2) Burn scars are not very similar to grassy balds, and allowing an occasional large fire would probably not maintain the grassy balds as a community type.

(3) With the exception of roadsides and shelter clearings, the area of open successional plant communities is decreasing in the park and the present openings are slowly succeeding to the communities typical of their topographic position.

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