

DRAFT

Vegetation Analysis Report
Roan Mountain Grassy Balds
Challenge Cost Share Project

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I. Introduction

The largest and perhaps most biologically significant grass bald ecosystem in the Southern Appalachians is that which occurs on the Roan Mountain massif. Many rare species of plants and animals can be found on the balds and many others occur in the adjacent forest communities of Roan Mountain. A review of the rare plants known from the Roan Mountain massif shows two endangered and two threatened taxa on the Federal list and another 10 that are candidates for listing. In addition there are 66 other plant taxa that appear on Tennessee or North Carolina rare plant lists. The purpose of this report is to present the results and conclusions of intensive vegetational sampling conducted on the balds of the Roan Mountain massif during the summers of 1987 and 1988 by a coalition of agencies and organizations with the assistance of two U. S. Forest Service Challenge Grants.

The purpose of the study was to provide background data prior to active bald management activities by the Forest Service, which owns and manages most of the Roan balds and by The Nature Conservancy, which owns and jointly manages Big Yellow Bald with the Southern Appalachian Highlands Conservancy. Woody plant invasion onto the balds was recognized as a serious management problem at a special Balds Management Symposium convened by the Forest Service in 1986.

While there have been many studies conducted on Southern Appalachian grass balds relating to their flora, vegetation, management and origin over the past six decades, only a few have focused specifically on those of Roan Mountain. Of great historical value is the vegetational survey of Roan Mountain balds done by Dalton M. Brown (1941) at the time the balds were being actively grazed. Other more comprehensive works which included vegetational sampling on Roan Mountain are those of Wells (1937) and Mark (1958). A more recent look at one of the Roan balds involving vegetation sampling and floristic analysis is the work of Weakley (1980) on Big Yellow Mountain.

Recent research focusing on balds vegetation management has been done in the Smoky Mountains, and on Big Meadow and Mount Rogers in Virginia. Recent management research on Roan Mountain is limited to that of Nora Murdock in the 1980's who looked at the effects of fire and manual clipping of blackberry on a portion of Round Bald. The current study attempts to describe and map the 1987-88 vegetation of the mountain balds and to examine

relationships among the balds, the community types recognized, the dominant taxa present, and physical parameters of the bald environment such as slope, aspect, soil depth, and substrate type.

II. Methods

Field methods

On each bald a set of perpendicular transects was laid out at 150m intervals along a centerline which followed the route of the Appalachian Trail (AT) whenever possible. For Big Yellow Mountain and Grassy Ridge side trails from the AT were used as the center line as much as possible. Compass bearings approximating the trail's direction were used to place the center line more accurately. The transects themselves extended from one edge of the bald to the other. Along them sampling plots were randomly located at densities ~~representing one plot per 10m²~~ ~~one plot per 25m²~~ or 50m, depending on the bald. Round, Jane, Grassy Ridge, and Big Yellow balds were sampled at the one plot per 10m² density, whereas on Little Hump and Big Hump the density dropped to one per 25m and one per 50m, respectively. Any random numbers locating a plot within three meters of the center line trail were discarded because the permanent plot markers would be easily seen and subject to vandalism. In this way ~~397 plots~~ were sampled on seven balds of the Roan Mountain massif.

At each sampling point a 1m² grid was laid down. One corner per plot was staked using either plastic or aluminum tubing in 12-(18)-24 inch lengths and tagged with aluminum numbered tags wired into holes drilled into the tubing. Each stake was placed at the meter mark and extended to the next higher meter. The plot frame was always placed on the south or east side of the transect line, depending on its orientation.

Within the grid plants were identified to species or in some cases only to genus. The percent cover of each taxon was estimated by eye to the nearest percent. Substrates were determined, and the percent cover of each was estimated separately from that of the plants. Using a 75cm steel rod, soil depth was measured at four points, each being the center point along one of the four sides of the plot frame. Also recorded were aspect, slope percent, and the maximum height of herbs and shrubs in the plot. A color photograph was made of each plot for Forest Service files. Photo number, date, time, location as "bald, transect, plot", and surveyors were recorded also.

A second set of vegetational data was derived from the above transects using a line-intercept method of sampling. This involved the determination of the length of each of the transects, their orientation on the landscape, and the coverage of apparent communities of plants as judged by observers walking along the transects while the tape measure was still in place. In this exercise the objective was to identify the dominant plant

cover growing under the line and describe in linear units where one association or community ended and another began. Between one and four taxa were recorded as dominant or co-dominant in any one association. This simpler method of sampling was done to provide an independent check on the community classification derived from the plot data and also to aid in mapping the balsds vegetation using aerial photography provided at the end of the 1987 field season by the Forest Service.

Computer methods

Data from the field were subjected to a rigorous exploratory data analysis using the Statistical Analysis System (SAS; SAS Institute 19??). Data on the percent cover of each species from the field plots were screened to determine whether the data were normally distributed. They were not, and so coverages were converted to more nearly normal distributions by the arcsine transformation (Sokal and Rohlf 1969). A composite list of all species recorded was compiled and from that list the 21 most frequently recorded species were selected for analysis. Coverage data for these 21 species were then subjected to a variety of correlation, regression, and multivariate analyses to determine the relationships of plant coverage among species, and between species and blackberry, *Rubus allegheniensis*, a species of management concern. We examined the relationship between coverage of individual species and the balsds on which plots were made.

We attempted to determine the plant communities of the balsds by using cluster analysis techniques. These techniques will always produce a set of clusters from an input set of data, and are thus data dependent. Because they are data dependent techniques, it is very difficult to know whether the communities that appear in the analysis are in some sense real without some additional testing. To deal with this situation, we initially divided the data set into two groups of plots, groups to which each plot had a 50% chance of being assigned. We then produced cluster analyses of each of the groups separately, and compared the apparent composition of the clusters, the distribution of the clusters on the several balsds and bald groups, and made biological judgments concerning the meaning of the clusters from each group independently. Second, we used a discriminant analysis procedure to compare the clusters from one of the subgroups with those from the second subgroup and vice versa. Our belief has been that plant community clusters which are consistent from one subgroup to the next are ones on which managers can place more faith.

We further analysed the relationships between selected plant species and the balsds and the physical environments of the balsds using the same random subgroups. We conducted principal components analysis of the coverage of the most frequent plant species to determine the patterns of variation among the species in relation to balsds, to aspect, to soil depth, and to other

physical parameters. We compared the components from one subgroup to those from the other subgroup. Our belief here has been the same as above, that patterns repeatable in independent subsets of the data are in some sense more real than patterns that appear in analysis of the entire data set. These, therefore, cannot be tested.

We used the data on the position of the plots on the transects to construct computer maps of the distribution of the plots on the balds and then to superimpose information about the distribution of the clusters and other information onto these schematic maps.

We used the 5% confidence level for all the testing that we did. Where feasible we used experiment wide confidence testing such as with Bonferroni intervals or Scheffe simultaneous confidence intervals rather than specific information concerning the individual tests, because the number of tests in each comparison of balds and species were very large, the numbers of plots were very large, and consequently we had enough sample size to achieve numerical significance in almost every case. Numerical significance, however, is not the same as biological significance. We have only accepted numerical significance as indicative of biological significance when the latter seemed to us to be consistent with some biological explanation for the observed results. Others may differ with our explanations; we have attempted to show enough of the data and of the analyses for others to reach their own conclusions.

Mapping method

Vegetation mapping involved the use of the plant communities determined in the analyses of the data. First, each plot was assigned to a particular community. Second, its specific location on the ground, as transect and distance from baseline was recorded. Then, using information about the total length of each transect as the remaining sort of data, schematic maps were drawn using the computer in which each plot was located at its particular location and marked with its particular community type.

III. Results

A. Vegetation and Floristic Analysis

1. Composition of the vegetation and/or flora

Within the 897 plots sampled a total of 197 taxa were identified (Exhibit A). Because some of the taxa are relatively similar in appearance and not always distinguishable in the field, some of the taxa were lumped for the purposes of analysis. An example would be the two oat-grass species, Danthonia spicata and Danthonia compressa, that occur on the balds. It was impractical and often impossible to distinguish them. Thus for general analysis

purposes, the list was condensed to 175 names (Exhibit C). For some specific purposes, such as the community classification work, only the vascular plant taxa with a frequency of at least 90 were used. This short list consisted of 21 taxa (Exhibit H). Although mosses, lichens, and the dominant moss species, Polytrichum commune, which was tallied independently from other mosses, had frequencies above 90, they were not included in the cluster or principal component analyses. Their presence and importance in some of the communities were shown in some of the data summaries though.

The list of 197 taxa for the Roan Mountain grass balds represents the most complete compilation to date for this area and ecosystem. Previous published lists resulting from vegetation sampling (Brown, Mark, etc.) are much briefer. Brown (1941), for instance, listed 29 taxa from his quadrats on Round and Jane balds. Mark (1958) listed only 12 herbs and one woody species from his sampling of Round Bald. The fact that our sampling was more extensive and intensive than in previous studies, no doubt, contributed to our lengthier list. There are no published lists of Roan Mountain plant taxa based either on qualitative searches of the balds or the mountain massif as a whole. Other unpublished lists of Roan Mountain plants, e.g. Weakley (1980) and Gatti (ca. 1979), do not distinguish in all cases whether or not the taxa have been observed on the grass balds. The species area curves (Exhibit I) indicate that our sampling captured most of the bald flora. The fact that the curves are still rising slightly for each testgroup plotted suggests, however, that a few additional taxa would have been encountered with more sampling.

Species richness (total # of taxa) varied considerably among the balds. Sample area, the number of plots sampled, and the intensity of sampling varied among the balds, thus the total number of taxa observed on each can not be compared directly with another. Nevertheless, the totals should be presented here as a basis for further discussion.

BALD	# PLOTS	# TAXA
Bradley Gap	37	73
Grassy Ridge	156	55
Hump Mt.	147	122
Jane	53	48
Little Hump	51	69
Round	191	60
Yellow Mt.	289	94

Some areas such as Bradley Gap are relatively species rich. A large seepage area on the North Carolina side of Bradley Gap, which yielded high numbers of species per plot, is a partial explanation of this. It is interesting that Grassy Ridge and Jane Bald, which are known as sites of several rare species, yielded relatively low species totals for the areas sampled. It can be noted also that Yellow Mountain Bald, which was sampled much more intensively than Hump Mountain yielded fewer taxa. Conversely, however, it can be

said that the Hump Mountain sampling covered a much larger area than that sampled on Yellow Mountain. This illustrates why some caution is needed in interpreting these results.

The presence of rare plant taxa in the plots was infrequent. Out of about fourteen nationally significant rare taxa that have been reported for Roan Mountain (Somers & Schell 1991, Exhibit), only two were observed: Abies fraseri (14 plots) and Lilium grayi (6 plots). Some of the other taxa that are nationally significant such as Geum radiatum, Hedysotis purpurea var. montana, Liatris helleri (only historical on Roan), and Solidago spithamea, which all happen to be Federally listed, occur mainly in high elevation rock outcrops. Like L. helleri, a few of Roan's other national rarities, Astilbe crenatiloba, Delphinium exaltatum, and Senecio millefolium, are known on Roan only from historical records. One taxon in this category that is seen on the grass balds is Geum geniculatum. This candidate for Federal listing was encountered during the rare plant mapping exercise on Hump Mountain and Engine Gap (Jane Bald vicinity) in 1987. It is frequent in the Northern hardwood forests adjacent the grass balds of the Roan Mountain massif but is seldom seen on the balds themselves. The Northern hardwood forest is also the primary habitat for two other Federal candidate taxa, Cardamine clematitis and Carex roansensis. The remaining nationally significant taxa, Saxifraga caroliniana and Juglans cinerea occur at low to mid elevations on the mountain typically.

Of the 65 taxa listed by Somers & Schell as "regionally significant" on Roan, eleven were encountered in the balds sampling. These taxa and their plot frequencies were as follows: Alnus viridis ssp. crispa (93), Arenaria groenlandica (1), Carex trisperma (1), Epilobium leptophyllum (3), Gentiana austromontana (20), Hypericum graveolens/mithcellianum (78), Lycopodium salago (1), Potentilla tridentata (165), Prenanthes roanensis (79), and Senecio schweinitzianus (38). It is also possible that Poa palustris, a rare bluegrass in both Tennessee and North Carolina, was present in one or more of the 240 plots where Poa was recorded. A few other regionally rare plant taxa were observed one or more times during the 1987-88 reconnaissance on the grass balds: Agrostis mertensii, Carex aenea, Carex oligosperma, Carex ruthii, Menziesia pilosa, and Rhynchospora alba. Most of the remaining regionally rare taxa reported for Roan occur in other habitat types.

Exotic plant species are of importance on the Roan Mountain balds from a management perspective, so a few comments should be made about their presence. Twenty taxa were encountered in the plots (Exhibit C), and of these four had frequency values that surpassed the less frequent ones by at least five-fold. Rumex acetosella was the most frequent exotic, occurring in 53% of the plots. The other taxa in descending order of frequency were Hieraceum pratense (30%), Achillea millefolium (25%), and Phleum pratense (22%). These were also the taxa with the higher relative cover values in our analysis. Exotic taxa of secondary importance in our sampling

were Trifolium repens, Holcus lanatus, and Prunella vulgaris; they all had relative frequencies of 4%. The twenty exotic taxa represent about 10% of the total flora observed.

How does our list compare with the previous floristic lists of the balds? Because of the earlier vegetation sampling done by Brown (1941) and Mark (1958) on Round Bald, some direct comparison's can be made of the floras present during their study periods (July-August, 1936 and the summers of 1956-1957, respectively) with what we observed in July-August of 1987-1988. Brown's sampling, which consisted of 200 plots (1x2m), yielded a total of only 28 taxa; Mark's sampling, consisting of 50 plots (0.5x2m), produced an even shorter list of taxa for Round: 12 herbs and 1 woody species. Our sampling, being 200 plots (1x1m), yielded 60 taxa. Most of the taxa reported by Brown and by Mark were observed by us; only three taxa, Phytolacca americana, Potentilla monspeliensis (=P. norvegica) and Veronica serpyllifolia, were not observed during our sampling. All three occurred in very low frequencies and are of little consequence, especially since the latter two are introductions from Europe. All of Mark's taxa were present in our sampling.

Other comparisons can be made between our overall list for Roan and 1) the composite list published by Mark (1959) for many Southern Appalachian balds, 2) the one produced by Ramseur (1960) for high mountain communities of the Southern Appalachians, and 3) the taxa observed in the unpublished research of Nora Murdock on Round Bald.

2. Percent cover PCA of most frequent species.

What are the principal components in the data sets?

Principal components analysis is a multivariate statistical technique in which linear functions of the original data are calculated. Each component is defined to be statistically independent of the other components. In sequence, each component measures the greatest amount of variation left in the data set, given the constraint that each component is independent of all others. In a sense, this is analogous to measuring the dimensions of an object. The components are the dimensions, and each is considered to be the next longest axis of the object, as long as it is perpendicular to each earlier axis. Recent vegetation ecological wisdom is that Principal Components Analysis is less effective than Detrended Correspondence Analysis (DCA) for purposes such as ours. Unfortunately, we had no access to DCA for this work.

The percent cover data for the 21 most frequently encountered taxa in the Roan Mountain data set were subjected to two different kinds of principal components analyses. First, the covariance matrix for the entire data set was analyzed as a whole, and then separate analyses were conducted for all the plots on each bald. Second, within each of the randomly selected subgroups, a principal components analysis of the correlation

matrix was conducted and principal component scores were calculated for each plot in each subgroup. Subsequent to this, the eigenvectors for the first three components in each testgroup were used to calculate separate transformations for each plot in the other testgroup. Comparison of the values for each plot on the component from its own group with the calculated values for the similar component in the other testgroup provides a means by which the repeatability of the components can be assessed. Where the components are repeatable from testgroup to testgroup, confidence in inference about their biological meaning can be gained. If the components are not repeatable, their biological reality is not relevant.

In the full data set, the first 11 principal components account for 95% of the variance in the data set (Table). A test of the individual components, called a sphericity test, indicated that each of these 11 axes measured a distinctly different axis of variation, while the remaining 10 axes could not be distinguished (Pimentel ; Table). In the full data set the major axis of variation, accounting for 36% of the variance, was a contrast between Rubus allegheniensis and Danthonia compressa. Plots with high values of Danthonia had low scores on this component and plots with extensive coverage of Rubus scored high on this component. The second component was a similar contrast between plots with high coverage of Carex pennsylvanica (high scores) and those with high coverage of Rubus (low scores on this component). The third component contrasted plots with high values of Danthonia and Potentilla tridentata (high scores) and those with high values of Potentilla canadensis (low scores). Similar interpretations can be made for each of the remaining 11 components by examining each of the eigenvector loadings in the table; eigenvector loadings greater than 0.3 or lower than -0.3 are the ones that contribute the largest amount to the components.

When the analysis was restricted to the plots from the individual bards, the component values were different depending on the bald. For example, on Little Hump Mountain the first Principal Component was a measure of cover of Rubus and the second component was a measure of cover of Carex pennsylvanica. On Round Bald the first component measured increasing coverage of both of these species and the second component sorted plots with high coverage of one species from those with high coverage of the other. On Big Yellow Mountain the first component measured increasing coverage of Danthonia compressa and Potentilla tridentata and the second component sorted plots with high coverage of the former from those with high coverage of the latter. These results indicate that the patterns of coverage and empirical relations of species to species differed among the bards (Figure). None of the correlations between the components for the full data set and those for the individual bards accounted for more than about 17% of the variance in the data set although 141 of 441 correlations had probability values < 0.05. These results indicate that the patterns in the full data set are

different from those at the scale of the individual balds, and further that patterns of species occurrence on the individual balds are different from each other. The dominant distinction, however, is that of the grass vs shrub cover on the balds indicated by principal component 1. The scale dependence of the relationships between species determined here is perhaps confusing; it is also relevant to an understanding of the management of the balds.

When we compared the analysis of the two random subsets of the data, the results were consistent. The eigenvector loadings on the first three components in each data set were of the same sign for all save one species with loadings > 0.20 , for example, although a larger number of differences in sign and in value occurred in the next three components (Table). We concentrated our examination on the first three components, and calculated two different principal component scores for each plot. The first score was that for the principal component eigenvectors from its own subset and the second was that for the principal component eigenvectors from the other subset. When we conducted a correlation analysis of the scores for the principal components, the very high resulting correlations indicated that the components in each independent subset were measuring the same variation (Figure). The corresponding Group 2 components accounted for 86% of the variation in Group 1 PC1, 92% of that in Group 1 PC2, and 44% of that in Group 1 PC3. Similar values for Group 1 components were 92% for Group 2 PC1, and 71% for each of Group 2 PC2 and PC3 (Table). From this we infer that the components measure the same axes of variation, or themes in species association across the balds. Further work can pick up from this beginning to explore these associations in more detail.

3. Communities from most frequent taxa

What communities were identified?

We conducted a number of preliminary analyses using the FASTCLUS procedure in SAS to identify the vegetation clusters that potentially existed in the Roan Mountain data. Cluster techniques are powerful, and they always assign each data point to a cluster. In order to test the reality of the clusters resulting from the analyses, we employed the two random subsets of the data in two different ways. First we conducted analyses of each group separately. We analysed the cover data for the 21 most frequent species seeking cluster groupings that were interpretable biologically, contained a reasonable number of groups, and were repeatable across the two data sets. For each of a number of clusters from 3 to 9 we compared the results from the two data sets.

We chose the clustering to 6 clusters as that most meaningful, and then examined the resulting clusters in the following way. We assigned each plot to a cluster based on the analysis of its own subgroup data set. We then conducted a

discriminant analysis of each subgroup to determine the extent to which clusters assigned by the cluster analysis were distinct from each other. The clusters were shown to be distinct: 92% of Group 1 observations remained in the cluster to which they were assigned by the cluster analysis; 93% of the plots in Group 2 were correctly assigned to their original cluster. We then extended the analysis to examination of the other test group. In this analysis 78% of Group 1 plots were assigned to the corresponding cluster by the Discriminant Function from Group 2 and 85% of Group 2 plots were assigned to the corresponding cluster by the Discriminant Function from Group 1. Each subset was thus more effective at classifying its own plots than those plots in the other data set, and each subset correctly assigned at least 75% of the plots in the other subset. From this analysis we infer that the clusters as we define them are repeatable and thus definable for management purposes. Five of the six clusters were identical between the two subsets, and the sixth, smaller cluster, was apparently biologically similar across subsets but not as distinct to the discriminant functions as it was to us. We thus left out the sixth cluster in analyses of species distributions across the clusters.

The six clusters and the individual species' relative frequency, relative cover and importance values represent our best set of results for characterizing the 1987-88 plant communities of the Roan Mountain bals. Using the importance value ranks as a way of assessing community dominance, we have compared the results for the two subsets and established an overall picture of each cluster or community. They can be described as follows:

Green alder-blackberry Community (A)

This community was the least common of the six types encountered in the sampling. In the 52 plots classified as this type, 47 taxa were recorded. Two shrubs, Alnus crispa and Rubus allegheniensis, comprised about 44% of the relative cover in the community. Two sedges, Carex pensylvanica and Carex debilis, ranked highest in importance value among the herbs present. Following these taxa in importance were Southern lady fern, Athyrium asplenioides, crinkled hairgrass, Deschampsia flexuosa, and sheep-sorrel, Rumex acetosella. There was less agreement between the two data subsets as to which taxa ranked next in importance, but consistently high in both test groups were common hair-cap moss, Polytrichum commune, violets, Viola spp., mountain aster, Aster acuminatus, and mountain rosebay, Rhododendron catawbiense.

Other noteworthy taxa in the community were rough goldenrod, Solidago patula, a sedge, Carex intumescens, common cinquefoil, Potentilla canadensis, Roan Mountain rattlesnake-root, Prenanthes roanensis, Autumn bentgrass, Agrostis perennans, as well as lichens and mosses. Two of the above species, the community dominant, Alnus crispa, and Prenanthes roanensis, are considered to be regionally rare taxa. The former is disjunct about 500 miles from the Adirondacks of New York; the latter is endemic to upper

elevations of the Southern Appalachians. Other rarities noted in this community were fraser fir, Abies fraseri, Mountain St. John's-wort, Hypericum mitchellianum/graveolens, and Gray's lily, Lilium grayi, all endemic taxa to the region. The latter is a candidate for Federal listing.

Oat-grass--Three-toothed cinquefoil Community (B)

This community type was represented in 133 plots. Sharing dominance among the 57 taxa identified were an admixture of two oat-grasses, Danthonia compressa and Danthonia spicata, and the three-toothed cinquefoil, Potentilla tridentata. Another cinquefoil species, Potentilla canadensis, ranked third in importance value for each test group. For this community, the species' importance value ranks were remarkably similar between the test groups. Other taxa in the top ten rank positions in both groups were Rumex acetosella, hawkweed, Hieraceum pratense, Agrostis perennans, sedge, Carex pensylvanica, primrose-leaved violet, Viola primulifolia, yarrow, Achillea millefolium, and lichens.

Other taxa with relatively high importance values were bluegrass, Poa spp., a sedge, Carex glaucoidea, Path rush, Juncus tenuis, Polytrichum commune, wild strawberry, Fragaria virginiana, Wood rush, Luzula sp., and Whorled loosestrife, Lysimachia quadrifolia. The dominant, Potentilla tridentata, is one of several regionally significant rare plants in this community. Other rare taxa recorded here were Robbin's ragwort, Senecio schweinitzianus, Prenanthes roanensis, and Hypericum mitchellianum/graveolens. Robbin's ragwort, a disjunct from New England, achieved its highest importance rank in this community.

Blackberry--Sedge Community (C)

The second most common community type encountered on the balds, the blackberry, Rubus allegheniensis--sedge, Carex pensylvanica type was found in 218 plots and consisted of 105 taxa. For this community the sequence of five top-ranked species were identical for the two test groups. Ranked below the above dominants in descending order were another sedge, Carex debilis, Southern lady fern, Athyrium asplenioides, and sheep-sorrel, Rumex acetosella.

Other high ranked taxa appearing commonly in both subsets of this community were Polytrichum commune, Potentilla canadensis, Viola spp., Danthonia compressa, Alnus crispa, and moss. Of secondary importance in the community were Autumn sneezeweed, Helenium autumnale, Deschampsia flexuosa, White wood aster, Aster divaricatus, Wild bergamot, Monarda fistulosa, timothy, Phleum pratense, angelica, Angelica triquinata, and Prenanthes roanensis. In addition to Alnus crispa and Prenanthes roanensis, rare taxa in this community were limited to infrequent occurrences of Hypericum mitchellianum/graveolens, Appalachian gentian, Gentiana austromontana, Abies fraseri, and Lilium grayi.

Sedge Community (D)

Carex pensylvanica comprised on average about 42% of the cover in the 136 plots of this community type. A total of 92 taxa were recorded for this community. Taxa which held identical ranks 2 through 4 in each subset were in descending order Rumex acetosella, Rubus allegheniensis, and Potentilla canadensis. Other taxa with relatively high ranks in both test groups were Carex debilis, Phleum pratense, Polytrichum communs, Helenium autumnale, Poa spp., Agrostis perennans, and Danthonia compressa. A few taxa of secondary importance were hawthorn, Crataegus, Hypericum mitchellianum/graveolens, Fragaria virginiana, Hieraceum pratense, and Viola spp.

A number of rare taxa occurred in this community with the ones in the Hypericum complex mentioned above having the highest importance value. Others were Prenanthes roanensis, Gentiana austromontana, Alnus crispa, Abies fraseri, Senecio schweinitzianus, Lilium grayi, and Potentilla tridentata.

Cinquefoil Community (E)

With 304 plots, this was the most common community type encountered. Of the 149 taxa found in the plots Potentilla canadensis had the highest relative frequency and cover in each test group. Holding reciprocal importance value ranks in the test groups for rank positions 2 and 3 were Rumex acetosella and Danthonia compressa. Ranking fourth in both cases was Agrostis perennans. Other high ranked taxa in both groups were Hieraceum pratense, Carex pensylvanica, Fragaria virginiana, Poa spp., Phleum pratense, Carex debilis, moss, and Achillea millefolium. Of lesser importance, but still relatively important in this community ($IV > 0.26$), were Viola spp., Rubus allegheniensis, Polytrichum commune, Helenium autumnale, and lichens.

This relatively common community type included habitat for 13 rare taxa, the most frequent being Prenanthes roanensis, Potentilla tridentata, and Hypericum mitchellianum. Several rare species not reported in any of the above communities showed up, albeit infrequently, in the community; they were the Federally endangered Roan Mountain bluet, Hedyotis rupurea var. montana, dwarf dandelion, Krigia montana, Greenland sandwort, Arenaria groenlandica, willow-herb, Epilobium leptophyllum, and a sedge, Carex trisperma. Of these the first three generally occur on rocky outcrops while the latter two occur in wet seepage areas. The community classification appears, therefore, to have captured a wide variety of habitats in this type. Other rare taxa present but previously cited for some of the other communities were Senecio schweinitzianus, Abies fraseri, Gentiana austromontana, Lilium grayi and Alnus crispa.

Unresolved Community (?)

In the cluster analysis, 54 plots were not classified cleanly into a one of the above community types; the dominant taxa differed somewhat for the two data subsets. The plots contained a total of 79 taxa. Potentilla canadensis held the highest importance value in one subset and was second highest in the other, thus making it the overall dominant. In this regard, they resemble the cinquefoil community just described. One subset, (2), even had Rumex acetosella as the second most important taxon, as in the cinquefoil community, and shared other high ranked taxa with it.

Despite the fact that the two subsets were not as homologous as in the previous five communities, an argument can be made for combining and recognizing them as a community. Looking at importance values, eight taxa shared positions in the top eleven ranks within each subset. Species composition, therefore, was not very different, but the relative frequencies and percentage cover for the top taxa differed between the subsets. Several taxa (Phleum pratense, Agrostis perennis, Poa sp., and Viola sp.) ranked only 1-3 steps apart, but others (Helenium autumnale, Rumex acetosella, and Fragaria virginiana) were 6-7 steps apart. Helenium autumnale, for instance, ranked first in subset 1 but eighth in subset 2.

This community, if it truly existed, consisted of low growing mats of Potentilla canadensis, combined with smaller amounts of Fragaria virginiana, Rumex acetosella and Viola spp., overtopped by tall forbs, mainly Helenium autumnale, and graminoids such as Phleum pratense, Agrostis perennis, and Carex scoparia. Perhaps the layered structure and the presence of many wispy tall graminoids contributed to inconsistencies in the data for this suggested community type. Other moderately important taxa in the community, the data suggests, were Monarda fistulosa, Aster divaricatus, Carex pensylvanica, Achillea millefolium, Bromus purgans, Rubus allegheniensis, Taraxacum officinalis, and Carex debilis. Prenanthes roanensis was the only rare species that appeared in both subsets. Hypericum mitchellianum/graveolens, Senecio schweinitzianus, and Gentiana austromontana were present only in subset 2.

It seems to closely resemble the cinquefoil community (E) and may be just a slightly later sere of it. Danthonia compressa, an earlier successional grass, is less important, and Phleum pratense, a taller grass, along with Helenium autumnale, a tall composite, have replaced it in importance.

How are the communities distributed across the different balds?

See Exhibit F and Maps of Balds.

B. Patterns of variation in the flora

1. Groupings of balds by similarity

Our data show a greater species richness in the eastern balds (Hump Mt.-122, Yellow Mt.--94, Bradley Gap--73, and Little Hump--69) than in the western ones (Round--60, Grassy Ridge--55, and Jane--48). Even when one excludes the 289 plots on Big Yellow and compares the remaining 235 plots of the Hump Mountain complex with the 400 plots of the western group of balds, the number of taxa in the former outnumbers the latter's: 137 to 79. Why this pattern exists is not known; a partial explanation is that the former included a greater land area.

In an attempt to compare the various balds and better study the effects of past and future management, we have looked at our sampling results not only by bald but by bald groups that reflect either proximity or perceived differences in historical management, particularly during the past decade or two. Little is recorded about the historical usage or management of the balds. It is assumed that they were all grazed by cattle, sheep and horses and that fire, both natural and man-initiated, occurred at various levels of frequency on all of them around the turn of the century up until the 1930's or 1940's. Grazing is assumed to have halted or slowed substantially on Round, Jane and Grassy Ridge balds during the 40's and 50's following government acquisition of all or portions of these areas. Grazing and burning is presumed to have continued on the other balds until recently. In fact, active grazing by cattle and horses has continued til the present on Yellow Mountain. Grazing on Hump Mountain, Bradley Gap, and Little Hump, on the other hand, was discontinued in the 1980's. Because fire has been used as a management tool on Little Hump during the 1980's, this bald can be considered distinct from Hump Mt.\Bradley Gap with regard to historical management.

Two tables summarize the data by bald and bald group. One shows the "ranked importance values of dominant plant taxa by bald or bald group" (Table ??); the other depicts the "distribution of plots by clusters. . ." (Table ??). Some general comments on the results are as follows:

a. Vegetation analysis groups

A couple of the balds are distinctive in that nearly all of the plots of a particular cluster can be attributed to it. Yellow stands out from the rest because 96% of the cluster B (oat-grass--three-toothed cinquefoil) plots occur on it. Likewise Grassy possesses the majority (77%) of the cluster A (green alder--blackberry) plots. Jane and Round balds are similar for the most part, both scoring highest in cluster C (blackberry--sedge) and second highest in E (cinquefoil). Hump Mt. and Bradley Gap also scored highest in these clusters, but the pattern was reversed with cinquefoil community plots being more frequent than blackberry--

sedge. Little Hump was highest in C and E also, but had equal numbers of plots in each. Because the number of plots for Jane, Bradley Gap and Little Hump are low, patterns are less discernable for them than the others. Cluster D (sedge), interestingly had its highest frequencies on Round and Hump Mt., where it characterized about 25% of the plots. The undefined cluster (?) occurred mainly on the eastern balds, except 11% of Jane Bald plots; 39% of this type's plots were found on Hump Mt.

b. Historically similar groups

Grouping the balds according to the historical concepts discussed above yields some interesting results. Round-Jane-Grassy captures all but one of the green alder--blackberry plots and a disproportionate share (75%) of the blackberry--sedge plots. Yellow continues to stand out as the primary habitat for oat-grass--three-toothed cinquefoil. The Hump Mt.-Bradley Gap combination confirms the prevalence of cluster E (cinquefoil) on these balds, as well as the majority (54%) of the undefined (?) cluster, which was often comprised of a mix of grasses, sedges and composites, overtopping a groundcover of cinquefoil and sheep sorrel. While these three bald groups separated nicely using plot distribution data, Little Hump still cannot be lumped although it does appear distinct from Yellow. The ranked importance values (Table ??), on the other hand, suggest that Little Hump is more closely aligned with Hump Mt.-Bradley Gap than with the Round-Jane-Grassy. Cinquefoil (POCA) ranks highest for Little Hump, Bradley Gap and Hump Mt., its lowest value being 0.76 on Bradley Gap, whereas on Round, Jane and Grassy Ridge blackberry (RUAL) ranks highest and cinquefoil contributes its highest value of 0.40 on Jane Bald.

3. Relationship between bald vegetation and physical parameters

a. Soil depth

Scores on Principal Component 2 in each subset of the data appear to be related to the mean depth of soil on the plots. In each of the four comparisons, the correlation is positive and very significant. Using data from Group 1: $r = 0.32$ ($P < 0.0001$) for the Group 1 Principal Component function; $r = 0.33$ ($P < 0.0001$) for the Group 2 Principal Component function. Using data from Group 2: $r = 0.22$ ($P < 0.0001$) for the Group 2 Principal Component function; $r = 0.23$ ($P < 0.0001$) for the Group 1 Principal Component function. The consistency of the pattern of relation between soil depth and PC 2 score is strong and very suggestive that species that occur on deeper soils have high values on this component and that species that occur on shallower soils have lower values on this component.

b. Slope

The relationship between slope and Principal Component Scores for the vegetation plots was low and consistent across the test groups. For example, Principal Component Score 1 from Test Group 2 ($r=0.13$,

$P<0.005$) and the Test Group 1 function as applied to Test Group 2 ($r=0.11$, $P=0.02$) were both positive, while the respective scores on PC 3 (Group 2 data, Group 2 function, $r=-0.25$, $P<0.001$; Group 2 data, Group 1 function, $r=-0.20$, $P<0.0001$) were both negative. In either case, however, the slope alone was not able to explain a substantial amount of the variation in the data set. Similarly, weaker than for Test Group 1 data the results were consistent and somewhat correlation was a negative one between Slope and the score on Principal Component 3 (Group 1 data, Group 1 function, $r=-0.16$, $P<0.0001$; Group 1 data, Group 2 function, $r=-0.24$, $P<0.0001$). Further exploration of these results is beyond the scope of this report.

c. Aspect

We used the ranking of aspect categories identified by Day and Monk (1974) to relate aspect of a particular plot to moisture regime. Our analysis of moisture in relation to vegetation on the Roan Mountain balds. We were able to pursue only the initial stages of this analysis in this project. The relationships are suggestive that Principal Component scores are related to moisture regime for a plot and the variation is great. Examination of the Principal Component scores from Test Group 2 Correlation matrix, revealed a maximum of 17% of variation explained by aspect class (Table ??). Similar examination of Test Group 1 correlation matrix revealed a maximum of 16% variation explained by aspect (Table ??). As in other analyses, the groups produced consistent results and the transformations of one test group's data by the component functions from the other group yielded analogous results.

Table ?? Relation between aspect class and Principal Component scores for Roan Mountain vegetation plots.

Data Test Group	Transformation Principal Component	F value	P	R ²
Group 1 N=440 plots	Group 1 PC 1	3.82	0.0001	0.119
	Group 1 PC 2	3.40	0.0001	0.107
	Group 1 PC 3	1.76	0.038	0.059
	Group 1 PC 4	2.96	0.0002	0.095
	Group 1 PC 5	2.26	0.0045	0.074
	Group 2 PC 1	5.31	0.0001	0.158
	Group 2 PC 2	3.11	0.0001	0.099
	Group 2 PC 3	1.63	0.064	0.054
GROUP 2 PC 1		5.18	0.0001	0.150
GROUP 2 PC 2		2.92	0.0002	0.090
GROUP 2 PC 3		2.50	0.0015	0.078
GROUP 2 PC 4		1.21	0.26	0.039
		2.63	0.0008	0.082
		2.19	0.19	0.042

Group 2 PC 7	1.23	0.24	0.040
Group 1 PC 1	6.26	0.0001	0.175
Group 1 PC 2	3.32	0.0001	0.101
Group 1 PC 3	1.93	0.02	0.061

d. Substrate types

A pattern of high Rubus cover with high soil cover was found. Percentages of other substrate types were very low overall, however, making it difficult to detect differences in Rubus compatibility with different substrates.

C. Ecological distribution of selected species

1. Rubus and its occurrence in relation to:

a. other species

The importance of Rubus allegheniensis as a species of management concern is clear in the data analysis of the 1987-88 Roan Mountain vegetation sample. Earlier workers, eg. Mark (1941) do not mention the species as particularly noteworthy, while in our data set this taxon occurs in almost half of the plots. Clear in our data is the relationship between cover of Rubus and soil depth (Table). When we grouped plots by the amount of Rubus cover, soil depths on plots with Rubus were significantly greater than on plots without Rubus. Furthermore, although not statistically significant, the mean depth of soil on plots increased as the amount of Rubus cover increased (Table).

Table. Rubus cover and soil depth on Roan Mountain balds

Mean Soil Depth on Plot, in cm

Rubus presence	Mean	95% Confidence interval	N plots
Absent	27.9	26.5 - 29.3	455
Present summarized	33.3	31.9 - 34.7	442
1-5% cover	31.6	27.1 - 36.1	40
6-25% cover	32.3	29.8 - 34.8	127
26-50% cover	32.7	30.1 - 35.2	100
51-75% cover	33.8	30.3 - 37.3	76
76-95% cover	34.3	30.2 - 38.5	47

Rubus figured prominently in the description of several of the community types we identified in these data, as well as contributing importantly to the axes of variation in the principal components analyses of the data.

The mean soil depths recorded for other frequently recorded species were sometimes different, and sometimes similar to the means recorded for the plots with Rubus. Whether the differences relate to competition between the plants, to preferred substrates, or to the effects of past management practices cannot be determined from these data. (Exhibit K)

Mean soil depths recorded for Rubus cover classes on different balds differ, and the patterns are not as clear as they are in the overall analysis of the data (Exhibit I). This may represent differences in the individual balds, differences in sampling intensity across the balds, or differences in the length of time since the cessation of past management practices, eg. grazing, on particular balds. An important management consideration in this regard may be that Rubus cover in relation to measured soil depth reflects the situation at the time of measurement, 1987-88, and that in future the apparent preference for soil depth may not appear so as the species may be capable of growing on shallower soils than at present appears to be the case. Invasion of Rubus onto the balds is proceeding from areas with deeper to areas with shallower soils. Future work will be required to clarify this issue.

b. by bald

Considerable variation in Rubus correlation with other species as it relates to balds is evident in the data. We believe this is related to differences in the amount of Rubus on the different balds and possibly to differences in recent management history of the balds. Where the amount of Rubus or frequency of plots with Rubus on a bald is high, the correlations are strong and negative, eg. on Round and Jane balds. Where the amount and frequency of Rubus is low, the correlation may be positive, as on Yellow Mountain, indicating the paucity of communities typical of Round and Jane balds on Yellow Mountain and vice versa. The situation may occur either because the sites for Rubus on the different balds are not present on other balds, because the management activities have eliminated the communities in which Rubus grows, or for some other cause.

c. on PC's.

The amount of Rubus in the data set is great, and variation is attached strongly to Principal Components 1 and 2 in each test group data set.

Plots with Rubus had significantly less coverage by rock, lichen, and moss substrates, and significantly more coverage by soil than did plots without Rubus (Table ???). This situation verifies the apparent result of analysis of soil depths that Rubus occurs more often on portions of the balds with deeper soils. Substrate cover of Polytrichum commune was approximately the same on plots with and those without Rubus.

Table ??. Values for Cover¹ of Different Substrate Types on Plots with Different Amounts of Rubus Cover.

Rubus Soil Class Cover	Sample Size Cover	Lichen Cover	Moss Cover	Polytrichum commune Cover	Rock
No Rubus	452	.053 .006	.041 .109 .005 .013		.102 1.27 .012 .020
Plots with Rubus	436	.012 -	.028 .083 - -		.028 1.36 - -
1-5% Rubus	42	.030 .014	.037 .152 .014 .055		.098 1.27 .039 .067
6-25% Rubus	126	.016 .005	.029 .020 .008 .038		.025 1.31 .008 .040
26-50% Rubus	97	.012 .004	.021 .222 .006 .044		.017 1.28 .009 .047
51-75% Rubus	73	.009 .004	.038 .045 .021 .024		.022 1.41 .009 .047
76-95% Rubus	46	0 0	.010 .039 .005 .020		.009 1.52 .007 .020
96-100% Rubus	52	.006 .003	.032 .015 .010 .009		.028 1.48 .016 .036

¹ For each Rubus value, the upper row is the mean value and the lower is the standard error of that mean value. Standard errors were not calculated for the combination of all plots with Rubus.

2. Exotics and their distribution

In general, exotics are much more common on the eastern balds (Hump Mt., Bradley Gap, Little Hump, and Big Yellow) than on the western ones (Round, Jane and Grassy Ridge). This is evident in both species richness and importance values for the taxa on each bald. The number of exotic taxa on the eastern balds ranged from three on Grassy Ridge to four on Round and Jane; the range for the western balds varied from nine on Little Hump to 17 on Hump Mountain.

On all of the balds, four taxa consistently ranked near the top in importance for exotics. They were sheep sorrel (Rumex acetosella), timothy (Phleum pratense), hawkweed (Hieraceum pratense), and yarrow (Achillea millefolium). For Round Jane and Grassy balds, these were the only exotics reported. All of the other 16 exotics, therefore, were sampled only on the eastern set of balds. Rumex acetosella was the dominant exotic on all but Hump Mountain and Bradley Gap where Phleum pratense ranked higher. On the western balds R. acetosella was the only exotic with an importance value greater than 0.10; H. pratense, A. millefolium, and P. pratense were all lower and the latter was actually absent in the Grassy Ridge plots. For each of the eastern balds the four main exotics always had values greater than 0.10. Hieraceum pratense, A. millefolium, and P. pratense consistently ranked higher on the eastern balds than the western ones, whereas R. acetosella varied some east to west. Among the western balds it ranged from 0.35 on Grassy Ridge to 0.75 on Round Bald. Similarly on the eastern balds the range went from 0.32 for R. acetosella on Hump Mountain to 0.72 on Big Yellow. On some of the eastern balds velvet grass (Holcus lanatus) and heal-all (Prunella vulgaris) had ranks ranging from 0.09-0.20, indicating that these taxa are relatively conspicuous there.

What is the relationship between the exotics and the six clusters or community types? All communities had exotics, but some had much more than others. The alder-blackberry community had the least (2), and the cinquefoil community and the undefined community scored highest in species richness (16 and 11, respectively) and cumulative importance values. The four exotics discussed above as dominant on the balds also ranked highest for the community types. Exceptions existed, however, in the case of the alder-blackberry community, where Rumex acetosella and Phleum pratense were the only exotic taxa present, and for the oatgrass--three-toothed cinquefoil community where P. pratense ranked relatively low (0.03) among the exotics. Rumex acetosella (0.35 in the alder community to 0.78 in the sedge community) ranked highest in all communities except the undefined one, where P. pratense outranked it substantially.

3. Selected rare species

Sixteen rare plant taxa were identified in the grass bald plots. Two of them, Alnus crispa and Potentilla tridentata, were described above as community dominants; the other 14 generally occurred very infrequently. Relative frequency values for these 14 taxa in any community testgroup were always less than 0.22, and frequently were absent altogether in a community.

The number of rare plant taxa per community type (cluster) varied from three in the oatgrass--three-toothed cinquefoil community to all 16 in the cinquefoil community. Only one taxon, Hypericum mitchellianum (also includes H. graveolens) occurred in all six community types, but its highest relative frequency values were

found in the sedge and cinquefoil communities. Another taxon, Prenanthes roanensis, was evenly distributed across five of the community types, but was absent from the oatgrass--three-toothed cinquefoil community. Five taxa were found in four community types: 1) Alnus crispa discussed above, 2) Abies fraseri, which had its highest relative frequency values in the green alder--blackberry community, 3) Gentiana austromontana, which appeared most frequently in the sedge community, 4) Lilium grayi, infrequent in all but the oatgrass--three-toothed cinquefoil and "undefined" communities, and 5) Senecio schweinitzianus, which appeared most frequently in the oat-grass--three-toothed cinquefoil community. Potentilla tridentata occurred occasionally in two other communities besides the one in which it shared dominance. All remaining rare taxa made only an infrequent appearance in one community type--the cinquefoil community. The fact that all 16 rare plant taxa occur in this type, including several rock outcrop habitat taxa (Arenaria groenlandica, Lycopodium selago, Paronychia argyrocoma and Hedysotis purpurea var. montana) and a couple seep habitat taxa (Carex trisperma and Epilobium leptophyllum), suggests that this community may really be a composite type.

How were the rare plants distributed across the balds? Six of the 16 taxa were found only on the western set of balds. These were Abies fraseri, Alnus crispa, Arenaria groenlandica, Krigia montana, Lycopodium selago, and Hedysotis purpurea var. montana. The latter is known to occur on Big Yellow, however, even though it was not picked up in the sampling. The majority of the Alnus crispa records were from Grassy Ridge. Taxa confined to the eastern set of balds in the sampling were Carex trisperma, Epilobium leptophyllum, Paronychia argyrocoma, and Gentiana austromontana. The latter, which was sampled only on Hump Mt. and Little Hump, was seen on the western balds about a decade ago, but has been in decline there since then. The vast majority (92%) of plots with Potentilla tridentata in them occurred on Big Yellow, but there were infrequent occurrences of this taxon on Grassy Ridge and Round Bald. Only one taxon was seen on all of the balds, that was Hypericum mitchellianum\graveolens. It was most frequent on Round, Bradley Gap, Hump Mt., and Little Hump. Prenanthes roanensis, while it had its highest relative frequency values on Round Bald, was found on all balds except Bradley Gap. Lilium grayi in our samples was found on only three balds (Grassy, Jane, and Yellow) and always at a low frequency level.

D. Vegetation maps

Using the cluster analysis data, plots were schematically mapped for each of the balds. In the case of Hump Mountain, four maps were generated, each covering a separate portion of the mountain. The letter codes assigned to each cluster can be colored differently to see more easily the vegetation patterns they represent.

IV. Conclusions

The 197 taxa recorded on the grass balds of the Roan Mountain massif during this project should serve as a foundation for future monitoring of changes in floristic richness and species composition on the balds. Although past information on the floras of specific Roan balds is more limited, the new list can be compared to those that do exist, e.g. Brown (1941) and Mark (1958), in order to detect any losses from what was historically known. These comparisons suggest that few, if any, of the taxa recorded by Brown or Mark have disappeared from the floras of Round Bald.

Based upon our analysis of cover data from 897 plots, we have concluded that five or six broadly defined community types were present on the balds during the 1987-88 growing seasons. These community types were not found to be uniformly distributed among the Roan Mountain balds. The relative frequencies of common and rare taxa varied from community to community and bald to bald. The reasons for the many patterns of variation were explored using data on slope, aspect, soil depth, and substrate type, but much more needs to be done to fully explain Roan's vegetative patterns.

The study documented that there are some strong differences between the western group (Round, Jane, Grassy) and the eastern group (Hump Mt., Bradley Gap, Little Hump and Yellow) of balds with regard to species richness, community types, numbers of exotics, and presence of rare species. Big Yellow, in part at least, due to its history of continuous grazing, stood out as very different vegetationally from the other balds. Blackberry, a major component on all of the other balds, was nearly absent on Yellow. Grazing on Big Yellow, it appears, has resulted in reduction of some taxa (e.g., Carex pensylvanica) while favoring others (e.g., Danthonia spicata and Potentilla tridentata).

One of the most exciting aspects of this study was that the data set was large enough to do separate analyses of two data subsets, thus allowing tests of the cluster routines for repeatability. Since we found a very high level of similarity between the testgroups when six clusters were used, we concluded with much confidence that this best represented a community classification for the grass balds of Roan Mountain. Seldom is vegetational sampling done at an intensity that allows this very important testing to be done.

What we have described about the flora and vegetation of Roan's grassy balds in this report must be viewed as a snapshot in time. It represents the vegetation of 1987-1988. Much has been done in the interim to clear blackberries and hawthorns from certain areas and natural succession has wrought changes elsewhere. Our data should serve as a good baseline upon which to measure change resulting from these activities or natural events. While they will be very useful for detecting major changes on the balds, it should not be regarded as a baseline to answer all future management or ecological questions that might be posed. The scale at which we

sampled might present some limitations, as could the types of data we gathered. Our design is not particularly useful, for instance, as a method for carefully monitoring populations of infrequently occurring rare plants on the balds; this was not its intent. A critical part of all future management planning should be to identify research objectives and determine whether or not our data and experimental design are adequate to detect change at a desired level of significance.

The values of this study are that it documented the Roan Mountain balds vegetation of the late 80's, allows comparison to the vegetation types described by Brown from the late 30's and Mark from the late 50's, and provides a data set that can be used to monitor future changes. It can be put to immediate use in formulating management objectives and questions for future research.

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