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Tom Henry
Bryce Canyon National Park
Bryce Canyon, Utah
84717

1981

Dear Tom,

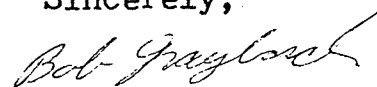
Enclosed is the report of my past summer's excursion in Bryce Canyon. It should be regarded as preliminary, as I am sending a copy to Dr. for review. I wanted, however, to make this available to seasonal naturalists for the upcoming summer, so feel free to distribute copies. My apologies for the total failure to use common names; it saved a good deal of time to do otherwise. If the paper is read with a copy of the checklist on hand there should be no difficulty.

I tried to be brief without loss of information; however, if you feel it is too brief please advise. I can expand the descriptions of the communities and include considerable more data if desired.

I hope you find this thing of some use. I plan on preparing a second report describing the distribution of the endemic species in Bryce Canyon and a speculation on the origin of the bristlecone type. I will forward a preliminary report, but it should be about 6 to 8 months before I get to it.

Thanks again for the opportunity to work at Bryce. We are enjoying our stay in Iowa, with the exception of a dreadful winter. Best wishes.

Sincerely,



Bob Graybosch

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A Vegetative Survey of the Main Amphitheater,
Bryce Canyon National Park

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INTRODUCTION

The first investigation on the vegetation of Bryce Canyon National Park was that of Buchanan (1960). In this work, six major plant communities were delimited, these being: montane forest of spruce-fir, submontane forest of ponderosa pine, sagebrush openings, meadows of grasses and sedges, pinyon-juniper woodland, and the "breaks." The lattermost refers to a narrow band of vegetation occurring on the badlands or "breaks" formed largely by the Red beds of the Claron (Wasatch) formation along the eastern border of the Paunsaugunt Plateau. While conducting a floristic inventory of Bryce Canyon (Buchanan and Graybosch, 1981), I noticed that the "breaks" were possibly divisible into component vegetative units. This paper presents the results of a study on a portion of the "breaks", the primary intent of which is to determine whether or not it is composed of discreet vegetative units.

The present study was undertaken in that portion of Bryce Canyon referred to as the Main Amphitheater (description of which follows). This area encounters the greatest density of the thousands of visitors that annually converge upon the park. Hence, knowledge of its biota would be useful in interpretive and educational activities. Also, the flora of Bryce Canyon is rich in species endemic to

the High Plateaus of southern Utah (Welsh and Thorne, 1979; Buchanan and Graybosch, 1981). I have found that populations of these plants are concentrated in the Main Amphitheater. Establishment of the preferred habitats of such species is essential to their preservation. It is also desirable to assess the impact of intense visitation on the environment of rare species. The aim of this study, then, is threefold: to determine whether or not the "breaks" is divisible into plant communities, to study the typical habitats of the endemic plants, and to note the impact of visitation on the area.

DESCRIPTION OF THE STUDY AREA

Bryce Canyon National Park is located on the eastern margin of the Paunsaugunt Plateau, in south-central Utah. The Main Amphitheater is delimited by the following boundaries: Sunrise Point, southeastward along the rim of the Paunsaugunt Plateau to Bryce Point, then northward to the border of the drainages of Bryce Wash and Campbell Canyon. Lindquist (1977) considered the Main (or Bryce) Amphitheater as extending only as far northward as Sunset Point (1 km south of Sunrise Point). I have elected to extend the boundary northward in order to include the entire headwaters of Bryce Wash. Thus, it occupies an area of approximately 4.5 km². Bryce Wash is an ephemeral stream tributary to the Paria River. Elevations within the area range from 2200 m to 2530 m (7250 ft - 8300 ft). The study area lies along the western border of the Kaiparowits Basin, the flora of which was reported by Welsh et al. (1978).

The predominant geologic formation exposed in the study area is the Claron limestone, a Tertiary deposit. It has been previously referred to as the Wasatch formation (Anderson and Rowley, 1975; Doelling, 1975; Lindquist, 1980). The Claron formation is divisible into two major components, the Red (Pink) beds and the White beds. The former are Eocene deposits; the latter were formed in the Oligocene (Anderson and Rowley, 1975). Besides time of origin, the two differ in chemical and physical features. The Red beds are composed of a mixture of clay, silt and carbonates with minimal quantities of sand. They range from calcareous mudstones to pure limestone or dolomite (Lindquist, 1980). The reddish or pinkish coloration results

from high concentrations of oxides of iron and manganese (Brox, 1961). The White beds have largely been eroded from the surface of the Paunsaugunt Plateau, but they do occur in the southern half of the study area. They are coarser than the underlying Red beds, ranging from pure limestone to limestone mixed with sandstone and conglomerates. Brox (1961) found the White member to be as much as 25% sand, while the Red beds rarely exceeded 5%.

For most of its distribution the Claron formation overlies the Kaiparowits formation. However, in the study area the Kaiparowits is absent, the underlying stratum being the Wahweap sandstone (Brox, 1961; Doelling, 1975). Lining the larger canyons in the Main Amphitheater are Quarternary alluvial deposits derived from the Claron formation (Doelling, 1975).

The Claron formation does not present a uniform profile along the eastern rim of the Paunsaugunt Plateau. In the study area, it is characterized by a vertical slope that falls for as much as 70 m from the plateau rim before assuming a more gradual slope on the Red beds (Lindquist, 1980). Gullies extend the length of the formation adjacent to the rim. These converge to form numerous narrow canyons, these uniting to form Bryce Wash. Ridge lines are often delimited by spires and pinnacles called "hoodoos", these being eliminated as the tributaries enlarge. On the summit of some of the wider ridges, rolling badlands of clay-limestone are formed.

The Claron formation is characterized by a fairly rapid rate of erosion. The average loss of material normal to the slope was determined by Lindquist (1980) to be 3.3 mm per year. Erosion is largely a function of creep resulting from winter freeze-thaw activity. Material is delivered in this fashion to gullies, these

being washed clear during summer thunderstorms. Freeze-thaw cycles are more pronounced on south-facing slopes. Soil development is limited, occurring only on north-facing slopes of the larger canyons (Lindquist, 1980).

Climatic features of the study area may be inferred from weather records kept at Park Headquarters, 2 km from the Main Amphitheater. The average annual precipitation is 41 cm, falling largely in the form of winter snowfall and August thunderstorms. Mean January maximum temperature is 2°C; mean July maximum temperature is 27°C. The mean January and July minimum temperatures are -13°C and 7.6°C, respectively. The Main Amphitheater may be more xeric than these values indicate. Buchanan (1960) maintained a weather station at a site on the "breaks" (Oastler Castle), located at 2350 m, 2 km north of the study area. Temperatures were found to average about 5.5°C warmer at Oastler Castle than at Park Headquarters. Although precipitation was nearly equal at these two sites, the evaporative capacity of the air was considerably higher on the "breaks." Predominantly clay substrates, along with subsequent low infiltration rates and high runoff, diminish water availability. However, it is not possible to say that the entire Main Amphitheater is more xeric than the adjacent plateau. The diverse topography leads to much climatological variation that can only be assessed through a more detailed study.

METHODS

The vegetation of the area was surveyed by means of 100 100 m² plots. Plots were placed in areas of homogeneous vegetation and enclosed with similar vegetation to minimize edge effects. Topography prevented the use of larger plots. Within each plot, density and basal area were recorded for all mature trees (those with a d.b.h. of 5 cm or more). Only density was recorded for juveniles (d.b.h. of less than 5 cm). An importance value was formulated for mature trees by summing the relative values of density and basal area. Understory vegetation (shrubs and herbs were taken together) was surveyed through the use of four 10 m line intercepts, placed at 2 m intervals. Importance values for understory species were determined through the summation of the relative values of density, dominance and frequency. Species present in plots but failing to contact the survey lines were recorded as being present; this information was used in determining the relative frequency values.

Using the importance values of dominant species, plots of similar composition were grouped together to define vegetative types. The mean importance values for all species in each type were then determined. Similarities between types were assessed through the use of Sorensen's Index of Similarity (Sorensen, 1948), defined as:

$$IS = \frac{2W}{A + B} \times 100$$

where A and B are the totals of the importance values for all species in each type and W is the sum of the lesser importance

values for the species common to the two types. In actuality, importance values for all species from each type were not used. To facilitate calculations, comparisons were made using all trees, the five most important shrubs, and the seven most important herbs (or only those having a mean importance value of greater than 1.0) from each type. Admittedly, this probably underestimates the absolute differences, though the relative values should remain unchanged.

Much of the area consists of steep slopes that are not easily accessible. Such areas were surveyed for floristic composition, but community structure could not be analyzed. All species present in the study area were recorded and assigned to vegetative types when possible. Voucher specimens are on file in the herbarium of Bryce Canyon National Park. Nomenclature employed is that of Welsh et al. (1981).

RESULTS AND DISCUSSION

A complete list of species occurring in the Main Amphitheater given in the Appendix. Two species, Puccinellia nuttalliana and Schizachyrium scoparium, are additions to the flora of Bryce Canyon as reported by Buchanan and Graybosch (1981). Additions to the flora of the Kaiparowits Basin, based on Welsh et al. (1978), are noted in the Appendix.

Data to be presented below allows the division of the "breaks" (as it occurs in the Main Amphitheater) into the following vegetative types. Some of these are variable and are further divided into phases. Each shall be discussed in turn.

1. Pinus ponderosa - Arctostaphylos patula type (Pipo-Arpa type)
2. P. ponderosa - A. patula type, Cercocarpus montanus phase (Pipo-Arpa type, Cemo phase)
3. P. ponderosa - Pseudotsuga menziesii type (Pipo-Psme type)
4. Mixed Coniferous type, Picea pungens phase (MC type, Pipo phase)
5. Mixed Coniferous type, Abies concolor phase (MC type, Abco phase)
6. Pinus longaeva type (Pilo type)
7. Washes, clay and talus slopes

Table 1 summarizes the dominant species of each type in terms of mean importance values. Stem densities of trees are given in Table 2 as an indication of the nature of the canopy. A similarity matrix is given in Table 3, comparing the various types and phases.

Description of types and phases

Table 1

Dominant species (in terms of mean importance value) in each type and phase. Species are designated by the first two letters of each half of the binomial listed in the Appendix. Types and phases are given the numerical designation employed in the text.

Species		1	2	type or phase		5	6
				3	4		
Trees							
Abco	mean s.d.						81.7 33.3
Jusc		29.3 37.9	27.2 24.2	13.0 21.4	24.2 27.2	25.8 29.7	
Pipu		2.3 8.1			89.7 36.3	25.3 29.7	
Pifl		7.6 23.6		17.2 23.1	22.5 31.5	3.0 6.6	44.9 48.4
Pilo,		1.0 5.9			4.0 19.2		128.3 71.3
Pipo		158.8 43.9	172.8 24.2	102.1 45.6	35.2 36.0	35.5 29.6	8.6 16.8
Psme		1.0 4.4		67.6 48.1	25.9 25.1	28.8 24.9	
Shrubs							
Acgl			3.2 7.9	19.4 29.8	19.1 25.9	19.8 23.9	
Amut			20.2 31.3	1.3 4.7	1.8 5.1		
Arpa		85.6 32.0	14.1 18.6	70.9 58.1	57.9 40.7	19.7 40.5	76.8 43.7
Cema		12.2 13.0	4.5 7.3	7.0 7.9	8.9 9.2	2.0 4.5	2.2 7.3
Cemo		5.4 13.8	138.0 49.7		23.6 50.2	30.1 46.8	2.2 7.2
Juco		2.1 6.9			19.1 25.9	34.4 46.8	4.4 7.2

Table 1 contd.

Species			type or phase		5	6
	1	2	3	4		
Mare	35.7 27.3	15.9 26.2	46.7 39.6	50.3 40.5	89.6 60.1	1.5 3.3
Putr	1.0 2.5	1.2 2.9		1.4 4.4	16.1 46.1	
Rice.			1.7 5.6			
Xasa	1.9 4.9					1.0 1.7
Grasses and Forbs						
Aske					1.0 1.7	
Ciar	6.4 6.7		3.9 6.5	4.0 6.6	1.4 4.7	3.9 5.8
Clco	1.9 4.4		2.1 3.3	4.0 6.6		
Crab	2.7 4.6	3.5 3.5				
Cypu						7.2 7.4
Elsa	34.4 34.8	4.0 9.9	36.6 32.9	13.7 19.7		5.3 10.5
Erpa						11.8 10.4
Haar	5.9 11.0	2.6 6.2	2.0 7.1	1.0 2.6		6.4 8.8
Hyfi						7.9 13.8
Ivsa						14.2 19.4
Liki						17.9 14.7

Table 1 contd.

Species			type or phase		5	6
	1	2	3	4		
Limu	6.7 8.9	1.3 3.1	2.0 3.2			
Magr						6.7 7.0
Oebr	4.4 4.4		1.5 2.5			
Orhy	13.6 10.2	1.7 4.2	4.8 10.1	11.1 12.9	1.0 3.2	10.7 9.6

Table 2

Stem densities of trees (per hectare). J = juvenile, M = mature.
Types and phases numbered as in text.

Species		1	2	type or phase		5	6
				3	4		
Abco	J	2				180	
	M					270	
Jusc	J	175	280	20	60	45	20
	M	64	70	40	96	130	
Pipu	J	2		15	160	20	
	M	8			420	145	
Pifl	J	25		62	50	10	90
	M	17		85	96	20	73
Pilo	J						230
	M	3			5		250
Pipo	J	60	120	180	20	20	70
	M	310	280	320	156	100	30
Psme	J	11	20	250	20	20	20
	M	3		220	120	120	

Table 3

Matrix comparing Vegetative Types and Phases through use of Index of Similarity (Sorensen, 1948). Consult text for information on the numbering system.

	1	2	3	4	5
1					
2	58				
3	70	40			
4	51	31.5	61		
5	32.5	31	42	60	
6	33	9.6	32	30	11

1. Pipo-Arpa type

Occurrence: Canyon bottoms and south-facing slopes between elevations of 2200 m and 2400 m, continuing to lower elevations outside of the study area. Occurs on substrates derived from both the Claron formation and Quarternary alluvium.

Vegetation: The dominant tree is P. ponderosa with Juniperus scopulorum and Pinus flexilis as common associates. Thickets of Quercus gambelii occur, although infrequently. The shrub layer is dominated by A. patula with Mahonia repens and Ceanothus martinii of secondary importance. The most common herbs are Elymus salina and Oryzopsis hymenoides. In contrast to the ponderosa pine forests of the adjacent plateau, Purshia tridentata is rare. A total of 65 species occur in this type, several being restricted to it. These are largely taxa (l.e. Mahonia fremontii, Streptanthus cordatus and Euphorbia fendleri) that are nearing their upper elevational limits in the study area.

Relation to other types and phases: Closest resemblance is seen between this type and the Pipo-Psme type and the Pipo-Arpa type, Cemo phase. It forms ecotones with all other types, as well as with as with a woodland of Juniperus osteosperma, Pinus edulis and Quercus gambelii at the lower elevational limits of the study area.

2. Pipo-Arpa type, Cemo phase

Occurrence: Adjacent to washes, on alluvium, between elevations of 2200 m and 2300 m.

Vegetation: The dominant trees are P. ponderosa and J. scopulorum with an understory dominated by Cercocarpus montanus. Amelanchier

utahensis is an additional frequently encountered shrub. A. patula is infrequent and variable in importance values. Herbaceous vegetation is uncommon.

Relation to other types and phases: This particular phase exists only in narrow bands lining washes and is generally surrounded by the Pipo-Arpa type in its typical manifestation. Possibly recognized as a distinct type if more widespread, it is most closely related to additional types dominated by P. ponderosa. The importance values of P. ponderosa and J. scopulorum are nearly identical in plots assignable to this phase and those in the typical Pipo-Arpa type (Table 1). This phase probably exists as a result of periodic flooding with subsequent alteration of the physical features of the substrate. This provides a microhabitat that evidently favors C. montanus over A. patula, but does not influence the nature of the canopy.

3. Pipo-Psme type

Occurrence: North-facing slopes of the Claron formation between elevations of 2285 m and 2380 m. Soil development is extensive due to limited winter freeze-thaw activity.

Vegetation: Dominance is shared by P. ponderosa and P. menziesii; Pinus flexilis is occasionally encountered. The principle shrub is A. patula, with M. repens a common associate. In several plots, however, the density of trees was of sufficient magnitude to exclude most understory species. A significant increase in the abundance of more mesophytic species (i.e. Acer glabrum, Clematis columbiana) is noted when this type is compared to the Pipo-Arpa type. A total of 38 species was found in this type.

Relation to other types and phases: Most closely related to the

Pipo-Arpa type, this type also shows affinities with the phases of the MC type. Ecotones are formed with these communities.

MC type

Occurrence: Canyon bottoms and steep north-facing slopes; substrates occupied are derived from both Red and White members of the Claron formation. Elevational distribution is between 2285 m and 2450 m; the lowest elevation corresponds to the furthest extension of hoodoos. Ill-defined and somewhat polymorphic, this type is best described in terms of its two phases. Fifty-five species occur within this type.

4. MC type, Pipo phase

Vegetation: This phase is recognized by the consistent dominance of P. pungens in either pure stands or in mixed associations with additional conifers, the most common of these being P. ponderosa, P. menziesii, P. flexilis and J. scopulorum. The understory varies from sparse along washes (where both C. montanus and C. ledifolius are frequent) to dense in plots not subjected to inundation. In the latter, A. patula, M. repens, Juniperus communis and A. glabrum predominate.

Relation to other types and phases: This phase is most similar to the MC type, Abco phase. The differences between the two lie largely in the paucity of herbs and grasses in the Abco phase. Both are characterized by a high diversity of conifers, the primary difference between the two canopies being the identity of the dominant tree. Ecotones occur with the Pipo-Arpa type, the Pipo-Arpa type, Cemo phase and the Pipo-Psme type. On upper slopes this phase gradually thins to relatively isolated individual trees.

5. MC type, Abco phase

Vegetation: Consistent dominance by A. concolor, and lack of dominance by P. pungens, is the hallmark of this phase. Most of the other conifers are common. Table 1 indicates P. ponderosa as having the second highest mean importance value. However, this phase is present on the White limestone where P. ponderosa is infrequent. In such stands, P. menziesii and P. pungens are the most common associates. Dominant shrubs are largely those of the Pipu phase, although P. tridentata is more common.

Relation to other types and phases: This phase is most closely allied to the MC type, Pipu phase. The two are separated spatially; the Abco phase occurs only on north-facing slopes and canyons east and north of the Wall-of-Windows, with an isolated stand in the Queen's Garden. It is possible that the Pipu phase represents an earlier seral stage of the Abco phase, although no juveniles of A. concolor were found in plots assignable to the Pipu phase. More likely, the two phases represent points along a moisture gradient. P. pungens seems able to exist in situations that are too dry to allow growth of A. concolor. The two phases do not form ecotones, except in the Queen's Garden. Here, A. concolor is found in a nearly pure stand in the shade of some isolated hoodoos. On more exposed sites at higher elevations in the same canyon it is absent, the area being dominated by P. pungens. Ecotones are recognizable between this phase and both the Pipo-Psme and Pipo-Arpa types.

6. Pilo type

Occurrence: This type is well defined only on badlands of the Claron formation, especially on the ridgeline dividing the drainages

of Bryce Wash and Campbell Canyon. There is no soil development; the substrate is generally clay-limestone overlain by gravels or larger particles. The type ranges in elevation from 2200 m to 2400 m. Bailey (1970) reports the lowest elevational record of P. longaeva as being 2200 m.

Vegetation: P. longaeva in open stands is the usual appearance of this type. P. ponderosa and P. flexilis may also occur, all trees being twisted and stunted. It should be noted that P. longaeva does not attain the wide girth that one usually associates with the species (the largest specimen had a d.b.h. of 22 cm). Because of this it is doubtful that it reaches the extreme ages of 4000-5000 years that have been reported (Cronquist et al., 1972). LaMarche (1969) mentions that the oldest reported bristlecone pine in Bryce Canyon is 1560 years of age; the number of trees and their specific location was not given.

Shrubs are uncommon; only A. patula is of any real abundance. Understory vegetation generally covers less than 10% of the plots. The forb component differs from that of all other types; Linum kingii, Ivesia sabulosa and Eriogonum panguicense var. panguicense being the most common. A total of 48 species was recorded for this type, several of which are typical of subalpine zones. Based on the distributions given by Cronquist et al. (1972), Dixon (1935), Ellison (1954), Harrington (1954), and Welsh and Moore (1973) these are: Agropyron scribneri, Aquilegia scopulorum, Aster glaucodes, Erigeron simplex, Monardella odoratissima, P. longaeva, Potentilla fruticosa, Senecio attratus and Silene pettersonii.

Relation to other types and phases: As seen from the similarity matrix, this type has little in common with any others, the highest IS being 33. Ecotones are formed only with the Pipo-Arpa type which extends up narrow washes draining the badlands.

7. Washes, clay and talus slopes

Much of the Main Amphitheater is devoid of vegetation or contains only infrequently encountered individuals of numerous species scattered about the eroding Claron formation. Structured plant communities tend to cluster in canyon bottoms, on the slopes of the wider canyons, or on rolling badlands. Species found on these barren areas have been recorded and are cited in the Appendix. Most of these slopes are not easily accessible, hence, the list may be incomplete. Plots were not used to survey such areas; if any pattern exists in the distribution of species it has not been determined. The White beds form only vertical cliffs in the study area; plots were placed only on the Red member.

Environmental factors influencing the distribution of types.

At this point, I can only speculate as to which environmental parameters are most critical in determining species' distribution. Moisture availability and solar insolation may be critical, but variation in substrates may also warrant consideration. Based on topography, substrate and exposure, I believe that moisture availability in communities increases in the order presented in Tables 4 and 5. Mean importance values for all trees and the most common shrubs are plotted as a function of increasing moisture availability. Certain trees cluster at a given end of the spectrum;

Table 4

Distribution of trees as a function of moisture availability. Types and phases are given in order of most xeric to most mesic. A = Pilo type; B = Pipo-Arpa type; C = Pipo-Arpa type, Cemo phase; D = Pipo-Psme type; E = MC type, Pipu phase; F = MC type, Abco phase.

Mean i.v.	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF
0	+++++	+	+ ++	+	++ +		+ +
1-10			+	+ +	+ +	+	+
11-20		+		+			
21-30		++ ++	+	+			++
31-40						++	
41-50				+			
51-60							
61-70							
71-80							+
81-90	+		+				
91-100							
101-110						+	
111-120							
121-130					+		
131-140							
141-150							
151-160						+	
161-175						+	
species	Abco	Jusc	Pipu	Pifl	Pilo	Pipo	Psme

Table 5

Distribution of most abundant shrubs as a function of moisture availability. Types and phases given as in Table 5.

Mean i.v.	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF	ABCDEF
0	++	+++			+	++	
1-10	+	++		+	++++	++	+
11-20	+++	+	+	+		++	+
21-30						++	
31-40							+
41-50							++
51-60			+				
61-70							
71-80			+	+			
81-90			+				+
91-100							
100-110							
111-120							
121-130							
131-140					+		
	Acgl	Amut	Arpa	Cema	Cemo	Juco	Mare

A. concolor, P. pungens and P. menziesii are common only in moist situations. P. longaeva is restricted to the most arid sites. J. scopulorum and P. flexilis occur at somewhat constant levels throughout, although both diverge from this pattern by decreasing in a given area. P. ponderosa, although uncommon in the most xeric area, generally decreases with increasing moisture levels.

For shrubs the pattern is similar though more complex. A. glabrum, J. communis and M. repens increase with moisture levels; A. patula decreases, C. martinii remains constant. However, A. utahensis and C. montanus both demonstrate substantial increases in the Pipo-Arpa type, Cemo phase, apparently at the expense of A. patula and M. repens.

From this we can gather that gradients of moisture availability are involved in sorting species into communities. However, moisture is not always the factor of paramount importance. Differences in substrate may be responsible for part of the pattern, especially in the increased abundance of A. utahensis and C. montanus in one given type. Only a complete ecological survey of the area will provide an answer to this question.

Distribution of Endemic Species.

Species endemic to southern Utah and found within the Main Amphitheater are listed in Table 6, along with their ecological distribution within the study area. Also given for each species is its current status (Federal Register, Dec. 15, 1980, Vol. 45, No. 242). No status is given for E. panguicense var. panguicense, which, although restricted in range (Reveal, 1965), is apparently not rare (Welsh et al., 1975; Welsh and Thorne, 1979). Status is

Table 6

Distribution of Endemic Species in the Main Amphitheater

Species	Status ¹	Distribution in Utah (Counties) ²	Geologic Distribution ³	Ecologic Distribution in Main Amphitheater
<u>Castilleja revealii</u>	1	Garfield	R; W	Pilo type; washes, clay-limestone slopes
<u>Cryptantha ochroleuca</u>	1	Garfield	R; W	Pilo type; clay-limestone slopes
<u>Draba subalpina</u>	3c	Garfield, Iron, Kane, Millard	R; W; QA	Pipo-Arpa type, Pilo type, MC type
<u>Eriogonum panguicense</u> var. <u>panguicense</u>	-	Garfield, Iron, Kane, Sevier, Washington	R; W ⁴	Pilo type, clay-limestone slopes
<u>Lesquerella rubicundula</u>	2	Garfield	R; W; QA	Pipo-Arpa type, Pilo type, clay-limestone slopes
<u>Lomatium minimum</u>	1	Garfield, Iron, Kane	R; W	Pilo type, clay-limestone slopes
<u>Oxytropis jonesii</u>	3c	Emery, Garfield, Uintah	W; Flagstaff limestone, Green River shale	Sand-limestone slopes
<u>Penstemon bracteatus</u>	1	Garfield	R	Pilo type, clay-limestone slopes
<u>Psoralea pariensis</u>	1	Garfield, Kane	R; alluvium & sandy alluvium	clay-limestone slopes

Table 6 contd.

Species	Status	Distribution in Utah (Counties)	Geologic Distribution	Ecologic Distribution in Main Amphitheater
<u>Silene pettersonii</u> var. <u>minor</u>	1	Garfield, Iron	R	Pilo type, clay-limestone slopes
<u>Townsendia minima</u>	2	Garfield, Kane	R; W; QA	Pilo type, Pipo-Arpa type, MC type

¹ See text for discussion.

² From: Reveal, 1965; Welsh et al. 1975; Welsh, 1978a; Welsh and Thorne, 1979.

³ Refers to the entire range of species. From: Welsh, 1978a; Welsh and Thorne, 1979; personal observations. R = Red beds of Claron formation, W = White beds, QA = Quarternary alluvium

⁴ Reveal (1965) defines the typical substrate of the species only by the designation "clay slopes." With its wide geographic range it probably occurs on substrates other than those derived from the Claron formation.

defined by the following categories.

- Category 1. Information is presently on hand to support listing as Endangered or Threatened species.
- Category 2. Information is available that indicates a probable appropriateness of listing, but sufficient information is not yet available to support listing as Endangered or Threatened.
- Category 3c. Taxa proven to be more abundant or widespread than previously considered. Not under consideration at the present time.

From Table 6 it may be seen that nine of the eleven species listed occur in the Pilo type, 3 are found in the Pipo-Arpa type, and 2 occur in the MC type. Two species, Oxytropis jonesii and Psoralea pariensis, were not found in a recognizable vegetative type. Species that occur only in the Pilo type have the narrowest geographic distributions, although Eriogonum panguicense var. panguicense is an exception. It evidently has broader ecological tolerance as it has been observed in several additional portions of Bryce Canyon. The narrow distributions of most of these species is no doubt a function of the uncommon occurrence of P. longaeva communities or other similar habitat throughout the High Plateaus.

Within Bryce Canyon, most of these endemics are restricted to the Claron formation. In this study, however, Draba subalpina, Lesquerella rubicundula, and Townsendia minima were observed on Quarternary alluvium, a formation from which they have not previously been reported. O. jonesii, P. pariensis and E. panguicense are not limited to the Claron formation throughout their geographic range. The remainder of the endemics have been reported only from the Claron formation.

The majority of the vast number of endemic species found in southern Utah are restricted to substrates derived from a specific

geologic formation (Welsh, 1979). Welsh notes that most of these taxa are found in areas of exposed parent material; soil development provides a barrier between plant and substrate. In the Main Amphitheater, soils are well defined only in the Pipo-Psme type. It is significant that this type contains not a single endemic species.

The distribution of endemic species in Utah is not a random one; fine textured substrates support more species than coarser ones, desert and foothill vegetation is richer in endemic species than montane communities (Welsh, 1978b; 1979). Based on these observations, Welsh has developed a "predictive model for establishing priority areas for the study of endangered and threatened plants of Utah," in which the highest priority is assigned to fine textured soils supporting pinyon-juniper or desert shrub vegetation. A similar model may now be established for endemics of the Claron formation. Outcrops of this formation supporting communities of bristlecone pine are most likely to contain endemic species. Based on this assumption, I have been able to locate populations of these species at several locations in Bryce Canyon. Species generally restricted to such habitat are likely to be less common and less widely distributed than those capable of invading other communities on the Claron limestone. Higher priority for listing as Threatened or Endangered species should be assigned to those taxa concentrating in such habitat. The protection of sites containing populations of bristlecone pine promises to be the most productive strategy for ensuring the continued survival of these plants.

Stands of P. longaeva within Bryce Canyon National Park are of critical importance to botanical science. In addition to rep-

representing the preferred habitat of several endemic species, they are of interest as subalpine vegetation found at atypical elevations. Additional investigation of such areas is likely to be fruitful in studies of the population biology of endemic species and the environmental factors that govern plant distribution.

Within the Main Amphitheater, the heavy use by visitors does not seem to present any danger to plant populations. The only activities are hiking and horseback riding, both restricted to established trails. Few seem to stray from the trails; the diverse topography makes getting lost a relatively simple task. By preventing expansion of the existing trail system, species populations will likely be maintained at the present levels.

SUMMARY

An investigation on plant community structure in the Main Amphitheater of Bryce Canyon National Park has shown that the vegetative community previously referred to as the "breaks" is divisible into discreet vegetative types. Although most of the area consists of sparsely vegetated cliffs and slopes, well defined communities are found on gentle lower slopes, rolling badlands and canyon bottoms. Four major types are recognized, some being further divided into phases. Each has been characterized as to canopy, understory vegetation and relationship to other types. A checklist of all species found in the area is given in the Appendix.

The ecologic distribution of several endemic species of southern Utah is given. The Pinus longaeva type is shown to be the richest in rare plants. This habitat is also unique in that it contains species normally found at subalpine elevations. It is predicted that endemic species of the Claron formation will tend to cluster in similar habitat. Protection of bristlecone pine communities is urged as the simplest means of providing protection for these rare plants.

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Appendix

Checklist of species and their ecological distribution in the Main Amphitheater, Bryce Canyon National Park. I = Pipo-Arpa type, II = Pipo-Psme type, III = MC type, IV = Pilo type, V = washes, clay and talus slopes. * = additions to the flora of the Kaiparowits Basin.

Species	I	II	III	IV	V
Aceraceae					
<u>Acer glabrum</u> Torr.	+	+	+		+
Apiaceae (Umbelliferae)					
<u>Cymopterus purpureus</u> Wats.	+	+	+	+	+
<u>Lomatium minimum</u> (Mathias) Mathias				+	+
Apocynaceae					
<u>Apocynum androsaemifolium</u> L.		+		+	+
Asclepidaceae					
<u>Asclepias asperula</u> (Decne) Woodson	+				
Ericaceae (Compositae)					
<u>Erigeron glaucodes</u> Blake	+	+	+		+
<u>Gnaphalium nauseosus</u> (Pallas) Britt.	+				+
<u>G. parryi</u> (Gray) Greene	+				+
<u>Cirsium arizonicum</u> (Gray) Petrak	+	+	+	+	+
<u>Erigeron simplex</u> Greene*				+	+
<u>Haplopappus armerioides</u> (Nutt.) Gray	+	+	+	+	+
<u>Hymenopappus filifolius</u> Hook.	+	+	+	+	+
<u>Hymenoxys acaulis</u> (Pursh) Parker	+			+	+
<u>H. richardsonii</u> (Hook.) Cockerell					+
<u>Leucelene ericoides</u> (Torr.) Greene	+				
<u>Machaeranthera grindelioides</u> (Nutt.) Shinnars	+	+	+	+	+
<u>Petradoria pumila</u> (Nutt.) Greene	+		+		+
<u>Senecio attratus</u> Greene*			+		+
<u>S. multilobatus</u> T. & G. ex Gray	+	+		+	

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Appendix contd.

Species	I	II	III	IV	V
<u>Solidago sparsiflora</u> Gray	+	+	+		
<u>Stephanomeria tenuifolia</u> (Torr.) Hall	+				+
<u>Tetradymia canescens</u> DC.	+				+
<u>Townsendia exscapa</u> (Richards) T. C. Porter					+
<u>T. minima</u> Eastwood	+		+	+	+
<u>Xanthocephalum sarothrae</u> (Pursh) Shinners	+			+	
(= <u>Gutierrezia sarothrae</u> Pursh)					
Berberidaceae					
<u>Mahonia fremontii</u> (Torr.) Fedde	+				
(= <u>Berberis fremontii</u> Torr.)					
<u>M. repens</u> (Lindl.) G. Don.	+	+	+	+	+
(= <u>B. repens</u> Lindl.)					
Betulaceae					
<u>Betula occidentalis</u> Hook.			+		+
Boraginaceae					
<u>Cryptantha abata</u> Johnst.	+		+	+	
<u>C. ochroleuca</u> Higgins*				+	+
<u>Lithospermum multiflorum</u> T. & G.	+	+	+	+	
Brassicaceae (Cruciferae)					
<u>Arabis pendulina</u> Greene	+				
<u>Descurainia sophia</u> (L.) Webb. ex Engler & Prantl.					+
<u>Draba subalpina</u> Goodmn. & Hitchc.	+		+	+	
<u>Lesquerella rubicundula</u> Rollins	+			+	+
<u>Physaria chambersii</u> Rollins	+		+	+	+
<u>Streptanthus cordatus</u> Nutt. ex T. & G.	+				
<u>Thlaspi arvense</u> L.					+

Appendix contd.

Species	I	II	III	IV	V
Caprifoliaceae					
<u>Sambucus caerulea</u> Raf.	+	+	+		+
<u>Symphoricarpos oreophilous</u> Gray	++	+			+
Caryophyllaceae					
<u>Arenaria fendleri</u> (Rydb.) Fern.			+		
<u>Silene pettersonii</u> Maguire var. <u>minor</u> Hitchc. & Maguire				+	+
Cornaceae					
<u>Cornus stolonifera</u> Michx.*					+
Cupressaceae					
<u>Juniperus communis</u> L.	+	+	+	+	+
<u>J. osteosperma</u> (Torr.) Little	+				+
<u>J. scopulorum</u> Sarg.	+	+	+	+	+
Ericaceae					
<u>Arctostaphylos patula</u> Greene	+	+	+	+	+
Elaeagnaceae					
<u>Shepherdia canadensis</u> (L.) Nutt.		+	+		
Euphorbiaceae					
<u>Euphorbia fendleri</u> T. & G.	++				
<u>E. lurida</u> Engelm. ex Ives*	+	+	+	+	+
Fabaceae (Leguminosae)					
<u>Astragalus convallarius</u> Greene*	+	+	+		
<u>A. kentrophyta</u> Gray			+		+
<u>A. megacarpus</u> (Nutt.) Gray	+		+		+
<u>Oxytropis jonesii</u> Barneby					+
<u>Psoralea pariensis</u> Welsh & Atwood*					+
Fagaceae					
<u>Quercus gambelii</u> Nutt.	+	+	+		

Appendix contd.

Species	I	II	III	IV	V
Gentianaceae					
<u>Gentianella tenella</u> (Rottb.) Borner*		+		+	+
(= <u>Gentiana tenella</u> Rottb.)					
<u>Swertia radiata</u> (Kellogg) Kuntze*	+	+	+	+	
Lamiaceae (Labiatae)					
<u>Monardella odoratissima</u> Benth.				+	+
Linaceae					
<u>Linum kingii</u> Wats.	+		+	+	+
<u>L. perenne</u> L. var. <u>lewisii</u> (Pursh) Eat. & Wright	+		+		+
Onagraceae					
<u>Calylophus lavandulaefolia</u> (T. & G.) Raven	+			+	+
(= <u>Oenothera lavandulaefolia</u> T. & G.)					
<u>Oenothera brachycarpa</u> (Gray) Britt.	+	+	+	+	+
Pinaceae					
<u>Abies concolor</u> (Gord. & Glend.) Lindl. ex Hildebr.	+		+		+
<u>Picea pungens</u> Engelm.	+	+	+	+	+
<u>Pinus edulis</u> Engelm. & Wislitz.	+				+
<u>P. flexilis</u> James ex Long	+	+	+	+	+
<u>P. longaeva</u> D. K. Bailey	+		+	+	+
<u>P. ponderosa</u> Dougl. ex Lawson	+	+	+	+	+
<u>Pseudotsuga menziesii</u> (Mirb.) Franco	+	+	+	+	+
Poaceae (Gramineae)					
<u>Agropyron cristatum</u> (L.) Gaertn.					+
<u>A. scribneri</u> Vasey*				+	+
<u>A. trachycaulum</u> (Linke) Malte					+
<u>Calamagrostis scopulorum</u> Jones			+		+
<u>Elymus salina</u> Jones	+	+	+	+	+

Appendix contd.

Species	I	II	III	IV	V
<u>Oryzopsis hymenoides</u> (R. & S.) Ricker ex Piper	+	+	+	+	+
<u>Poa compressa</u> L.*					+
<u>Puccinellia nuttalliana</u> (Schult.) Hitchc. ex Jeps.					+
<u>Schizachyrium scoparium</u> (Michx.) Nash ex Small*	+				
<u>Sitanion hystrix</u> (Nutt.) J. G. Smith	+				+
<u>Stipa columbiana</u> Macoun*	+				+
Polemoniaceae					
<u>Phlox austromontana</u> Cov.	+			+	+
Polygonaceae					
<u>Eriogonum corymbosum</u> Benth.					+
<u>E. panguicense</u> (Jones) Reveal var. <u>panguicense</u>				+	+
Ranunculaceae					
<u>Aquilegia scopulorum</u> Tidestr.	+		+	+	+
<u>Clematis columbiana</u> (Nutt.) T. & G.	+	+	+	+	
(= <u>C. pseudoalpina</u> (Kuntze) A. Nels.)					
Rhamnaceae					
<u>Ceanothus martinii</u> Jones	+	+	+	+	+
Rosaceae					
<u>Amelanchier utahensis</u> Koehn	+	+	+		+
<u>Cercocarpus ledifolius</u> Nutt.*			+	+	
<u>C. montanus</u> Raf.	+	+	+	+	+
<u>Holodiscus dumosus</u> (Nutt.) Heller			+	+	+
<u>Ivesia sabulosa</u> (Jones) Keck	+			+	+
<u>Potentilla fruticosa</u> L.*				+	+
<u>Purshia tridentata</u> (Pursh) DC.	+	+	+	+	+

Appendix contd.

Species	I	II	III	IV	V
Salicaceae					
<u>Populus angustifolia</u> James ex Torr.			+		+
<u>P. tremuloides</u> Michx.					+
<u>Salix exigua</u> Nutt.					+
Saxifragaceae					
<u>Ribes cereum</u> Dougl.		+	+		+
Scrophulariaceae					
<u>Castilleja linariaefolia</u> Benth. ex DC.		+	+		+
<u>C. revealii</u> N. Holmgren					+
<u>Pedicularis centranthera</u> Gray ex Torr.		+	+	+	+
<u>Penstemon bracteatus</u> Keck					+

