Successional Trends in an Ungrazed, Arid Grassland Over a Decade

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Abstract

A study has been made of the vegetational condition of a formerly grazed area, Chesler Park, in Canyonlands National Park. A comparison was made with the same area 10 years earlier. The 10-year successional changes are also compared to baseline data of 10 years earlier from Virginia Park, an adjacent ungrazed area. Because of inaccessibility and long isolation from disturbances, Virginia Park is presumed to be in climax condition and is the control for this study. Chesler Park shows a successional trend after 10 years toward the vegetational condition of Virginia Park. This is exemplified, with only one major exception *(Hilaria jamesii)*, by responses of the perennial grasses *(Stipa comata, Oryzopsis hymenoides, Sporobolus cryptandrus, Bouteloua gracilis)* and the cryptogamic community, particularly the moss, *Tortula ruralis*. Species frequency, cover, vegetational characteristics, and stand classification support this conclusion. Prevalence of perennial grasses has declined and cryptogamic species have increased significantly.

West et al. (1979) noted the dearth of data dealing with perennial plants in arid and semiarid environments. In another study (West 1979) few significant differences were found between the survival of plants in grazed versus ungrazed plots in southwestern Utah over 33 years.

In 1967, a vegetational and soils analysis was conducted in Chesler "Park." A 389-ha area in Canyonlands National Park (Kleiner and Harper 1972). Although largely enclosed by a high rock wall, Chesler Park had been lightly grazed for many years during winter months prior to the creation of Canyonlands National Park in 1964. The last known livestock grazing in Chesler Park was in early 1962 when 30 to 35 horses were kept there for about a month; other areas of Canyonlands had been variously grazed in prior years.

The initial study compared the vegetation and soils of Chesler Park with those of an adjacent, but smaller (97ha) ungrazed area, Virginia "Park." The access to Virginia Park is impassable for cattle or horses due to high rock walls and therefore the area remains relatively undisturbed. For this reason results of this initial study provided an invaluable source of baseline data against which future vegetational changes in grazed areas can be compared.

Gross environmental characteristics vary little between the two parks. The climate of the area is semiarid to arid. It is a country of extremes with an annual temperature range of as much as 55° C. Annual precipitation is generally from 20 to 25 cm, of which warm season rainfall constitutes from 55%–75% of the total.

Although overall park attendance has increased significantly during the decade (Wylie 1981) the study areas have remained relatively isolated—Chesler Park was closed to vehicular traffic in 1971, and Virginia Park, because of its inaccessibility, has never been subjected to such traffic. Both areas are now accessible only by foot and, because of their remoteness, this usage is considered to be moderate.

The purpose of this study was to investigate vegetational and floristic changes over a decade in an area which had been formerly grazed and to compare the decade-end condition with that of a similar, adjacent area which had not been formerly grazed.

Data were collected in 1977 from 20 sites in Chesler Park for comparison with those from 20 Chesler sites in 1967. The 1977 composition is also compared with the undisturbed and presumably climax condition of Virginia Park in 1967.

Methods

To ensure comparable data, the same methods of vegetational analysis were used in 1977 as in 1967. Permanent, circular plots, each .005 ha (50.58m²) in size, were established. This paper includes analysis of data from a total of 80 such plots, including 40 in Virginia Park from 1967, and 20 each from 1967 in 1977 in Chesler Park. Stands were selected subjectively; the criteria used were homogeneity of vegetation and environment. An attempt was made to distribute stands uniformly throughout the parks. Twenty-five small quadrats (0.125m²) and 100 point samples were placed in each stand. Both the quadrats and the point samples (5 samples per setting of the frame sampler) were distributed as uniformly as possible by dividing each circle into approximately equal sectors. Plant species (both cryptogamic and vascular) in each quadrat were noted, and hits on individual species, litter, or soil were recorded for each point sample. In 1967, sampling was done during July, and in 1977 during June.

Prevalent species were selected on the basis of a constancy-times-frequency (C × F) index (Curtis 1959). The index has a possible range of 0 to 10,000. A Chi-square test based on quadrats of occurrence of each species (with $P<.05$ as the limit of significance) has been used to determine if a species is unequally represented in either year.

Based on this index a comparison is made between Chesler and Virginia Parks in 1967, and between Chesler Park in 1977 and Virginia in 1967. Chi-square analysis based on presence or absence of each species in quadrats (frequency) was used as the test criterion for relative abundance. Similar comparisons of species relative abundance were made by Chi-square analysis utilizing precent species cover. Selected vegetational characteristics such as litter cover, cryptogamic cover, total cover, and hits per stand were also compared by Chi-square analysis for both sets of data.

All stands have been assigned to one of three groups arbitrarily named Hilara (H), Stipa (S), or Intermediate (I), depending on whether the quadrat frequency of H or S was at least 2 times, or more, greater than that of the other species. For example, if the frequencies of *Hilaria jamesii* and *Stipa comata* are 50% and 25% respectively in a given stand, that stand would be designated H. All stands not classified as H or S by this criteria were placed in the Intermediate class. On the other hand, if the frequencies were 35% and 25% respectively, the stand would be designated I. The H, S, or I designations will be used hereafter to characterize individual stands. A 10-year comparison of proportionate distribution of stands among H, S, or I classification was made.

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Species nomenclature follows Hitchcock (1950) for grasses, and Holmgren and Reveal (1966) for other vascular plants. Cryptogamic nomenclature follows Fink (1935).

Results

Prevalent species and their abundances are shown in Table 1. The C × F values of prevalent species in Chesler Park in 1977 are arranged in decreasing magnitude. Values run from 6,900 to 1.

Significant changes in Chesler Park vegetation during the decade include a decline in abundance of the 4 major perennial grasses: needle-and-thread *(Stipa comata),* galleta *(Hilaria jamesii),* Indian ricegrass *(Oryzopsis hymenoides),* and sand dropseed *(Sporobolus cryptandrus).* Blue grama *(Bouteloua gracilis)* also decreased significantly. Among the cryptogams, the moss *(Tortula ruralis)* increased by more than tenfold, whereas black lichen *(Collema tenax)* showed a modest (12%), although statistically significant, decrease. Three other cryptogams, white lichen *(Buellia papillata),* pink lichen *(Lecidea decipiens),* and yellow lichen *(Fulgensia bracteata),* have increased, although not significantly since, 1967. Two of the other 5 species, joint fir *(Ephedra viridis)* and cheatgrass *(Bromus tectorum)* show no significant change during the decade. Six-weeks fescue *(Vulpia octoflora)*[1] decreased significantly, while winterfat *(Eurotia lanata)* significantly increased.

A comparison of data from Chesler Park in 1977 with the baseline data from Virginia Park in 1967 showed no significant differences in abundance among the 4 major perennial grasses,[1] with the exception of galleta, which is significantly more abundant in Virginia Park (Table 1). The 1967 abundances of cryptogams in Virginia are all significantly higher than those for the same species in 1977 in Chesler even though their total C × F values have increased by more than 9% in Chesler during the decade.

Table 2 displays percent species cover and selected vegetational characteristics for 1967 and 1977 in Chesler Park. A Chi-square test based on point samples has been used to determine significance of percent cover differences between the years.

The two most prevalent cryptogams—moss and black lichen—had significantly greater cover in 1977 than 10 years earlier. White lichen was recorded in 1977 whereas it, and the two other cryptogams, were not recorded in 1967.

The 4 major perennial grasses, as well as blue grama, occurred in Chesler with a lower percent cover in 1977, although the difference in the case of sand dropseed is not significant. Winterfat had significantly higher coverage in 1977, although the percentage for both years was very low.

[1]Formerly *(Festuca octoflora).*

Table 2. Prevalent species, relative abundance by per cent cover, and selected vegetational characteristics of Chesler Park (test criterion for cover was Chi-square analysis based on 100 point samples taken in each stand).

Species	Cover (%) 1967	Cover (%) 1977	X^2 value	Year of greater percent cover
[1]*Tortula ruralis*	1.35	4.0	25.97**	1977
[1]*Collema tenax*	3.8	6.65	15.83**	1977
Stipa comata	9.15	7.3	4.29*	1967
Hilaria jamesii	4.65	1.35	36.3**	1967
Oryzopsis hymenoides	2.95	0.95	19.89**	1967
Sporobolus cryptandrus	1.15	0.55	3.59^{NS}	1967
Bouteloua gracilis	4.25	1.45	27.31**	1967
Eurotia lanata	0.6	1.95	13.43**	1967
Ephedra viridis	1.2	0.9	.6^{NS}	1967
Vulpia octoflora	0.05	0.1	0 ^{NS}	1977
[1]*Buellia papillata*	0	0.05	0 ^{NS}	1977
[1]*Lecidea decipiens*	0	0		
Bromus tectorum	0	0		
[1]*Fulgensia bracteata*	0	0		
Litter cover (%)	9.8	25.75	172.08**	1977
Soil (%)	68.4	55.45	70.58**	1967
Cryptogamic cover (%)	5.15	10.7	41.46*	1977
Average total living cover (%)	21.8	18.85	4.66*	1967
Total cover (%)	31.6	44.55	70.58**	1977
Average no. hits/stand on living vascular tissue	25.6	9.6	48.2**	1967

[1]Cryptogams
** = highly significant; * = significant; NS = not significant

Among vegetational characteristics of Chesler (Table 2), litter cover, cryptogamic cover, and total cover increased 162%, 107% and 41% respectively, all significantly higher in 1977, while average total living cover, and hits/stand on living vascular tissue and percent soil were higher in 1967.

Table 3 shows the 1977 percent cover in Chesler Park and that of Virginia Park in 1967. The cryptogams all revealed greater coverage in Virginia Park in 1967. Percent cover of 3 of the major perennial grasses was lower in Chesler (1977) than in Virginia, although that of needle-and-thread was not significant. Blue grama, winterfat, and joint fir showed increased coverage over that of 1967 in Virginia Park, although very low in all cases.

Table 1. Prevalent species and their relative abundance (C × F index) in 1967 and 1977 (test criterion for relative abundance was Chi-square analysis based on presence and absence of each species in quadrats).

Species	Chesler Park 1977 C(%)	Chesler Park 1977 F(%)	Chesler Park C × F 1977	Chesler Park C × F 1967	X^2 value	Virginia Park C × F 1967	X^2 value (Virginia 1967, Chesler 1977)
[1]*Tortula ruralis*	100	69	6900	660	329.25**	9130	137.23**
[1]*Collema tenax*	100	48.8	4880	5548	8.88**	9710	502.15**
Stipa comata	95	41.2	3914	4902	6.42*	3626	2.27^{NS}
Hilaria jamesii	90	32.6	2934	3553	8.67**	5206	65.0**
Oryzopsis hymenoides	75	10.4	780	1343	5.45*	1141	.3^{NS}
Sporobolus cryptandrus	45	9.0	405	1530	13.45**	663	.49^{NS}
Bouteloua gracilis	35	8.0	280	522	19.09**	16	41.96**
Eurotia lanata	50	5.5	275	90	8.33**	3	51.98**
Ephedra viridis	35	6.6	231	360	.53^{NS}	3	45.05**
Vulpia octoflora	35	4.4	154	2890	139.29**	1876	88.75**
[1]*Buellia papillata*	45	3.2	144	99	.61^{NS}	6450	519.27**
[1]*Lecidea decipiens*	10	0.4	4	0	.5^{NS}	2040	146.15**
Bromus tectorum	5	0.4	2	9	0.0^{NS}	183	16.11**
[1]*Fulgensia bracteata*	5	0.2	1	0	0.0^{NS}	4533	389.94**

[1]Cryptogams
**=highly significant ($P<.01$); *significant ($P<.05$); NS=not significant

Percent of both litter cover and bare soil has increased in Chesler relative to Virginia in 1967 (Table 3), while other vegetational characteristics are all much greater (from 48% to 255%).

As an additional indicator of species abundance changes over the decade, characterization of stands as H, S, and I is compared to that of 1967 (Table 4). While of little significance for demonstration of species pattern, Table 4 does reveal a trend during the decade toward a higher percentage of sites dominated by galleta and needle-and-thread, the 2 dominant perennial grasses in both parks.

Climatic data (Climatological Data) are provided in Table 5 from the weather station nearest the study site (Canyonlands-The Needles), for 1966-1977 inclusive. Average annual precipitation (rain and snow, expressed as total centimeters water) for the 12-year period was 21.6. A division of the 12 years' data into 2, 6-year sequences shows the later period (1972 through 1977) as somewhat drier, with an annual average of 19.0 cm. compared to 24.1 for 1966 through 1971.

Warm-season (May through October) rainfall, which historically accounts for a larger proportion of total annual precipitation than the cold-season, averaged 59.2% for 1966–71 and 56.1% for 1972–77.

Discussion

Previous investigations (Kleiner and Harper 1972, 1977a, 1977b) have provided baseline data on vegetational, floristic, and soil conditions in a pristine area (Virginia Park) and in a grazed area (Chesler Park). Although the 2 areas were similar in gross environment and vascular plant cover, cryptogamic vegetation and community structure differed markedly between the parks. Many vascular species occurred in greater abundance in one park than the other. Floristically, Virginia was much richer, and cryptogamic cover was about 7 times greater than in grazed Chesler Park.

Table 3. Prevalent species, relative abundance by percent cover, and selected vegetational characteristics of Chesler and Virginia Parks (test criterion for cover was Chi-square analysis based on 100 point samples taken in each stand).

Species	Cover (%) Chesler Park (1977)	Cover (%) Virginia Park (1967)	X^2 value	Area (Park) of greater % cover
[1]*Tortula ruralis*	4	18	225.51**	V
[1]*Collema tenax*	6.65	19	159.56**	V
Stipa comata	7.3	8.4	1.86^{NS}	V
Hilaria jamesii	1.35	8.4	115.88**	V
Oryzopsis hymenoides	0.95	1.8	5.6*	V
Sporobolus cryptandrus	0.55	0.48	.04^{NS}	C
Bouteloua gracilis	1.45	0.2	31.98**	C
Eurotia lanata	1.95	0.2	50.31**	C
Ephedra viridis	0.9	0.2	1.21**	C
Vulpia octoflora	0.1	0.08	.02^{NS}	C
[1]*Buellia papillata*	0.05	0.48	6.03*	V
[1]*Lecidea decipiens*	0	0.18	2.16^{NS}	V
Bromus tectorum	0	0.15	1.69^{NS}	V
[1]*Fulgensia bracteata*	0	0.1	.78^{NS}	V
Litter cover (%)	25.75	12	187.15**	C
Soil (%)	55.45	33	267.24**	C
Cryptogamic cover (%)	10.7	38	470.76**	V
Average total living cover (%)	18.85	55	703.55**	V
Total cover (%)	44.55	66	242.21**	V
Average no. hits/stand on living vascular tissue	9.6	23	147.56**	V

[1]Cryptogams
** = highly significant; * = significant; NS = not significant

Two kinds of comparisons were made. The first comparison is species prevalence in Chesler Park at the beginning and end of 10 years of isolation from domestic grazers. The other provides the decade-end species prevalence with that of pristine conditions in Virginia Park. Results of the study indicate several significant changes. With few exceptions however they follow a successional pattern toward the conditions suggested by those of Virginia Park in 1967.

In view of the historical absence of domestic grazing or other major disturbances in Virginia Park, the presence of a climax community is presumed. Furthermore, use of the 1967 Virginia Park data for comparative purposes in this paper presumes no significant vegetational changes during the decade in that area. Ten years after gathering baseline data, and 15 years after cessation of grazing in Chesler Park, a trend toward the more stable climax condition of pristine Virginia Park might be anticipated. Some minor variation could be expected from the fact that the 1977 stands (Chesler Park) were placed adjacent to the 1967 stands. The stands were offset in order to nullify any effects of the relatively heavy disturbance caused by sampling in 1967; however, a close compositional similarity may be expected due to homogeneity of vegetation and environment. Furthermore, it could be expected that, under the harsh arid conditions of Canyonlands Parks, with its limited growing season, vegetational changes—particularly pattern development as might be indicated by degree of positive association (correlation coefficients) among prevalent species (Kershaw 1964, Kleiner and Harper 1972)—might be slow in developing.

Climatic factors, for example a few particularly dry or wet years before 1977, could influence results. Average annual precipitation of the first 6 years of the study period was 5.1 cm or 21% higher, than the latter 6-year period. Two years in the first sequence, 1966 and 1969, were unusually wet. The lesser percent of warm-season rainfall during the second period (56.1% compared to 59.2%) may have played a role in reproductive and survival success of these grasses also. The temperature data shows only minor monthly fluctuations from year to year.

Succession in Chesler Park toward the pristine condition is indicated by a decline in prevalence of the perennial grasses. The trend is revealed by both species frequency and cover. With the exception of galleta, the original 1967 data comparing the 2 parks

Table 4. Comparison of stands in Chesler Park, 1967 and 1977, based on assignment to H, S, and I category. For designation as H or S the frequency of *Hilaria jamesii* or *Stipa comata* must be two times or more greater than that of the other species; all other stands are classed Intermediate.

1967 Stand Number	1967 H,S, or I	1977 Stand Number	1977 H,S, or I
41	I	41A	S
42	I	42A	I
43	I	43A	S
44	S	44A	S
45	S	45A	I
46	S	46A	S
47	S	47A	I
48	S	48A	S
49	I	49A	I
50	I	50A	I
51	I	51A	I
52	H	52A	H
53	I	53A	I
54	I	54A	S
55	S	55A	H
56	H	56A	S
57	I	57A	I
58	I	58A	S
59	I	59A	H
60	I	60A	S

(Kleiner and Harper 1972) showed these species occurred with significantly lower abundance in the pristine area, Virginia Park. One might therefore expect a general decline in the prevalence of perennial grasses in Chesler during the decade of non-disturbance. By 1977, a comparison of these 5 species frequencies in Chesler Park with those of 1967 in Virginia Park (Table 1), 3 of them, needle-and-thread, Indian ricegrass, and sand dropseed, showed no significant differences, while galleta and blue grama were significantly lower and higher, respectively, in 1977. The prevalence of galleta, however, rather than increasing, declined significantly further in 10 years, even below the 1967 prevalence. Although blue grama declined significantly during the decade, its prevalence is still far above that of 1967 in Virginia. Decreasing prevalence of the perennial grasses in Chesler Park during the decade constitutes a trend toward vegetational similarity of the 2 areas.

The abundance of cryptogamic species was significantly greater in 1967 in the ungrazed park, and cryptogamic cover was 7 times greater (Kleiner and Harper 1972) (Tables 1, 2, 3).

The vegetational and floristic condition of Chesler Park in 1977 more closely resembles that of Virginia Park (1967) than it did in 1967. Based on the assumption that Virginia Park is the climax stage, then it may be said that Chesler Park is generally succeeding toward that condition. The exception, however, is galleta, whose behavior, although consistent with that of the other perennial grasses in Chesler Park, is inconsistent with expectations based on control data of 1967. Perhaps, under environmental conditions such as those of Canyonlands Park, galleta is more sensitive than other perennials to light grazing pressure and has continued to decline even though domestic grazers have been withdrawn. It may simply be that more time is necessary for galleta to increase in abundance. The higher prevalence of galleta in 1967 in Virginia compared to Chesler was exceptional among the perennial grasses, suggesting superior competitiveness in undisturbed conditions. However, galleta has a reputation for resistance to heavy grazing and to drought on arid ranges (U.S. Department of Agriculture 1937). This is corroborated by Vallentine (1961) and Van Dyne (1964), who report that galleta is quite resistant to grazing and is frequently found in areas where other desirable plants have been eliminated by overuse. Galleta is consistently classed as an increaser on the Colorado Plateau of Utah and Arizona (Utah Agricultural Experiment Station 1972). At the same time, Chesler Park has been less heavily grazed than typical southwestern grasslands. It is possible the response of galleta under these isolated, unique conditions is not typical of that expected under conditions following heavy grazing. The autecology of such species under conditions such as those of Chesler Park has been little studied. This study suggests it may be less competitive than other species under a light grazing history.

Other significant changes during the decade involve the cryptogamic species. The 1967 studies revealed a significantly greater prevalence and cover of 5 species (Tables 1, 2) in Virginia Park. Light grazing in Chesler was suggested as the disturbing factor which had contributed to the differences in vegetational characteristics between the 2 sites. One might expect a trend during the decade in Chesler Park toward those conditions found in Virginia, that is, an increase in frequency and cover of cryptogamic species. Results indicate this to be the case. Total cryptogamic C × F and percent cover values approximately doubled in Chesler Park during the decade, due primarily to extensive moss growth. While the relatively faster growing moss increased tenfold, the slow growing black lichen has slightly decreased, albeit significantly. Percent cover of both, however, has increased significantly (Table 2). The 3 other cryptogamic species, which hardly appear (frequency) in 1967 in Chesler, were recorded, at least, in 1977 although the frequency increase was not significant.

Increase in prevalence of cryptogams between 1967 and 1977 in Chesler points to the earlier abolition of grazing as the key factor.

The results of 10-year vegetational characteristics changes (Table 2) are consistent with data from species analysis. Increased litter cover could be expected for example, following the sharp decline in perennial grass prevalence; although cover of cryptogamic species doubled in the period, total percent cover is insufficient to compensate for the reduction in grass prevalence.

Table 5. Climatic data for 1966–1977.

Year	Precipitation (cm. water) Annual	Warm season-May thru October (%)	Temperature averages (°C) Annual	Warm season	Cold season
1966	30.66	42.5	11.9	20.5	3.3
1967	19.58	63	11.7	20	3.4
1968	20.22	58.8	11.1	19.6	2.5
1969	29.69	58.5	12	20.3	3.9
1970	24.77	62.3	11.7	19.7	4.1
1971	19.63	70	11.4	20	2.8
1972	24.31	80.1	11.8	20.2	3.5
1973	19.53	50	10.9	20.2	1.7
1974	18.06	37.2	11.5	20.6	2.4
1975	21.77	40.3	10.5	18.8	2.2
1976	14.43	65.6	11	19.5	2.4
1977	16.1	63.3	12.4	21.2	3.7
	$\bar{x}$=21.56	57.6	11.5	20.1	3.0

In 1967, distribution of stands (Table 4) was 10%, 30%, and 60% as H, S, and I, respectively; the 1977 distribution was 15%, 45%, and 40%, respectively. The 5% and 15% increases in galleta and needle-and-thread dominated stands, respectively, involve 1 stand only for galleta and 3 for needle-and-thread. At first glance, this might appear inconsistent. But, while these species and others declined overall in frequency, variations in stand-to-stand individual frequencies could account for such seeming discrepancies.

Distribution of the 3 types (H, S, I) of stands in Virginia Park in 1967 was 37.5%, 32.5%, and 30% respectively. During the decade in Chesler, there appears to be a trend toward increasing prevalence of both galleta and needle-and-thread relative to other species as indicated by a concomitant decline in the number of stands labeled Intermediate.

Conclusions

A single decade may be insufficient time to draw firm conclusions regarding successional processes under harsh environmental conditions such as those of Canyonlands. The results of this study, however, strongly suggest that several trends, generally consistent with those expected, are underway. These trends reflect a successional sequence toward the more stable conditions found under long-undisturbed conditions within the park.

The perennial grasses have declined in prevalence over 10 years and, with the exception of galleta, have responded with the limits to be expected judging from the 1967 baseline data. Galleta appears to be continuing to decline in abundance and at an accelerated pace relative to other perennial grasses.

A remarkable feature of the vegetational cover in Chesler Park over the 10 years is the rate of growth of the moss. Without even the light grazing pressure of prior years, its frequency and cover increased markedly. Although rapid recovery of this species was expected, the extent of its increase was surprising.

Past studies have indicated that cryptogamic cover is important in stabilization of these highly erodable, sandy soils against wind and water action. The results of this study would suggest that restablization of such arid land crusts by cryptogamic growth occurs more rapidly than earlier believed.

Analysis at the end of a second decade in 1987 should provide additional data regarding vegetational trends.

Literature Cited

Climatological Data, Utah, NOAA, National Climatic Center, Asheville, N.C.

Curtis, John T. 1959. The vegetation of Wisconsin. Univ. Wisconsin Press, Madison.

Fink, Bruce. 1935. The lichen flora of the United States. Univ. Michigan Press, Ann Arbor.

Hitchcock, A.S. 1950. Manual of the grasses of the U.S. 2nd ed. USDA Misc. Publ. No. 200.

Holmgren, Arthur H., and James J. Reveal. 1966. Checklist of the vascular plants of the Intermountain Region. U.S. Forest Serv. Res. Paper Int. 32. Intermountain Forest and Range Exp. Sta., Forest Service, Ogden, Utah.

Kershaw, Kenneth A. 1964. Quantitative and dynamic ecology. Edward Arnold Publishers (Ltd.), London, England.

Kleiner, Edgar F., and K.T. Harper. 1972. Environment and community organization of grasslands of Canyonlands National Park. Ecology 53:299-309.

Kleiner, Edgar F., and K.T. Harper. 1977a. Soil Properties in relation t cryptogamic groundcover in Canyonlands National Park. J. Rang Manage. 30:202-205.

Kleiner, Edgar F., and K.T. Harper. 1977b. Occurrence of four majc perennial grasses in relation to edaphic factors in a pristine communit J. Range Manage. 30:286-289.

U.S. Dept. of Agriculture. U.S. Forest Service. 1937. Range plant hanc book. PB168589.

Utah Agricultural Experiment Station. Western Regional Technical Com mittee W-90. 1972. Galleta: taxonomy, ecology, and management c *Hilaria jamesii* on western rangelands. Bull. 487.

Vallentine, J.F. 1961. Important Utah Range Grasses. Utah State Univ Ext. Circ. 281.

Van Dyne, G.M. 1964. Ranges and range plants. Montana State Col Bookstore.

West, Neil E. 1979. Survival patterns of major perennials in salt dese shrub communities of southwestern Utah. J. Range Manage. 32:442-44

West, N.E., K.H. Rea, and R.O. Harniss. 1979. Plant demographic studie in sagebrush-grass communities of southeastern Idaho. Ecology 60:37 388.

Wylie, Thomas. 1981. Personal communication.