Effects of Grazing on Desert Vegetation

B. E. Norton

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EFFECTS OF GRAZING ON DESERT VEGETATION

B. E. Norton and D. J. Bermant
Utah State University

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ABSTRACT

Since 1935 the United States Department of Agriculture Forest Service has conducted a sheep grazing experiment on winter rangeland at the Desert Experimental Range, southwestern Utah. From an initial value of about four percent in 1935, the cover of perennials in grazed and exclosed vegetation has increased steadily to nearly 9 and 11 percent, respectively. Heavy grazing did not affect the general trend in plant cover or species composition. Under both grazed and protected conditions: 1) the least palatable shrub, Shadscale, exhibited a short-term rise in total cover followed by a steady decline; 2) the more palatable co-dominant shrub, Winterfat, consistently increased in cover; 3) the perennial grasses more than trebled their cover. Plant replacement studies indicated that Shadscale and Budsage engage in a competitive relationship in which Budsage tends to replace Shadscale, but the interaction is weakened by grazing pressure. In general, successional processes were most pronounced on old plant locations rather than in historically bare patches of the vegetation. Contrary to accepted range management theory, the vegetation changes in dominant palatable and unpalatable species were not a function of grazing pressure as mediated by interspecific competition. Inherent plant longevity, opportunity for plant replacement and differential response to climatic pattern may be more influential factors than grazing stress. Some theoretical implications of these phenomena are discussed.

INTRODUCTION

The classical successional process of autogenic changes in community structure is often obscure in arid or semiarid situations. By contrast, the impact of a severe desert climate that is highly variable from year to year finds conspicuous expression in drought periods of low productivity and high mortality, or in "wet" seasons when the desert blooms with a flush of annuals, extensive germination of perennial seeds and substantial increment to the perennial plant biomass. These dramatic effects of climatic pattern suggest an influence overriding the comparatively modest modification of local habitat mediated by the desert biota. At present the relative importance of biotic and abiotic factors, and the conditions prescribing the relative roles of climate and biota as causal factors determining composition and trends of desert communities, still constitute a dilemma. The uncertainty has been highlighted by the pictorial essay of long-term changes in the Sonoran Desert published by Hastings and Turner (1965), where the authors can often only guess at why the structure of a particular community was drastically altered—sometimes involving a change in dominant life form as occurs with the invasion of grassland by mesquite. One approach to exploring these kinds of questions is to look at long-term change on a small patch of ground, at the scale of the habitat occupied by an individual perennial plant. At the Desert Experimental Range operated by the U.S. Forest Service in salt desert shrub vegetation of southwestern Utah, maps of permanent plots have been taken periodically since 1935, showing outlines of individual plants. This data record permits an analysis of the history of plant replacement over a forty-year period, which can shed some light on successional processes in this vegetation type.

In addition to furnishing information on natural successional processes, the permanent plots at the DER provide data comparing vegetation change under the influence of winter sheep grazing, which is the principal commercial use of salt desert rangeland. In the Great Basin region of the western United States, livestock are forced from mountain pastures in the autumn and spend the winter months of November through April on desert shrublands. The hayed-off perennial grasses offer limited nourishment during this dormant season, but the shrub foliage is more nutritious and when palatable provides adequate maintenance forage, especially for sheep (Cook et al. 1959). The salt desert shrub vegetation type of Branson et al. (1967) containing communities dominated by Winterfat (*Ceratoides lanata*) and Budsage (*Artemisia spinescens*) in association with Shadscale (*Atriplex confertifolia*), covers extensive areas of the Intermountain region and has been consistently utilized as winter range for a hundred years or more. By 1935 the heavy grazing by both sheep and cattle had caused chronic range deterioration (McArdle et al. 1936). This was particularly evident in the desert valleys of southwestern Utah which had just experienced eight years of drought. Stewart et al. (1940) report evidence of widespread soil erosion in Wah Wah and Pine Valleys: pedestaled plants in deflation zones and embryonic dune formation on the loci of individual shrubs in areas of windblown soil accumulation.

Much of the range deterioration was arrested when passage of the Taylor Grazing Act in 1934 permitted government regulation of stocking rates on federal lands, which comprise the majority of rangeland in the Intermountain region. In order to determine optimum stocking rate for winter sheep range, a portion of Pine Valley was appropriated in 1933 for grazing studies, and some of the data collected in the course of these grazing experiments form the basis of our investigations.

OBJECTIVES

By studying permanent plot records taken in 1935-37, 1958, 1969 and 1975, the following questions will be addressed:

1. What changes have occurred in salt desert shrub vegetation at the site between 1935 and 1975?
2. Do changes in spatial configurations of perennial plant populations appear to occur in a random fashion, or is there an important biotic component in the plant replacement process?
3. What is the influence of sheep grazing on vegetation change, compared to the influence of other factors in the environment?

METHODS

Site Description

The Desert Experimental Range was established by the Intermountain Forest and Range Experiment Station at the northern end of Pine Valley in the Basin and Range geologic province, characterized by high mountain ridges running north-south, embracing closed drainage systems in the basins in between. Due to isolation and the late introduction of watering facilities, the Valley vegetation in 1935 had suffered less abuse than other winter ranges. The experiment station lies about 75 km west of the township of Milford at an average elevation of around 1600 m. Mean total annual precipitation is 157 mm, of which 45 mm falls largely as snow in the winter (November-March) and 32 mm falls in the spring months of April and May. The wettest period, 52.5 mm, is the summer season (June-August) when high evaporation rates negate the value of all but the heaviest storms. The occurrence of precipitation is highly variable. Salt desert shrub vegetation similar to Pine Valley was described in detail by Fautin (1946) for an area just 80 km north of the Desert Experimental Range. The Range program and its history are described by Holmgren (1975).

The vegetation is characterized by short-statured shrubs and some perennial grasses. The relatively unpalatable Shadscale and the preferred forage species Winterfat are the two dominant shrubs. Budsage, a highly palatable summer-deciduous species, occurs sparsely. Galleta grass (*Hilaria jamesii*) is a sod-forming dominant among the perennial grasses, but it is not as attractive to sheep as Indian Ricegrass (*Oryzopsis hymenoides*). Sand Dropseed (*Sporobolus cryptandrus*) is the third noteworthy perennial grass. *Bouteloua gracilis*, *Sphaeralcea grossulariifolia* and *Aristida fendleriana* (*A. purpurea* Nutt.) are minor vegetation components. Introduced halophytic annuals are prominent in favorable years. Indigenous annuals are usually not conspicuous.

The main grazing study tested the effects of three levels of grazing pressure (averages of 25, 35 and 42 sheep-days per ha) at early, middle and late winter periods and combinations of these periods. Stocking rates on the 100- to 130-ha fenced pastures were adjusted each year on the basis of available forage in order to maintain fairly uniform utilization from year to year within each treatment. The experiment is being continued today, one of the longest-running long-term grazing studies in the world. Grazing impacts were assessed on the basis of plant productivity by a weight estimate method (Pechanec and Pickford 1937) and foliage cover by the point-observation-plot method (Stewart and Hutchings 1936). The results have been published and discussed by Hutchings and Stewart (1953), Hutchings (1966) and Holmgren and Hutchings (1972).

Data from the permanent plot maps have received relatively little attention, however, apart from the thesis study by Harper (1959). This present report is concerned only with the permanent plot records.

PROCEDURE

When the experimental area was being fenced in 1934-35, two 0.4-ha (one acre) exclosures were set up in sixteen of the twenty pastures. Each exclosure was matched by a permanently-staked area of equal dimensions nearby which was subject to grazing. In each exclosure and its companion grazed area two permanent plots were established and the enclosed vegetation mapped periodically. The plots are 9.3 m^2 (5 x 20 ft) and were mapped according to the procedure of Pickford and Stewart (1935) in 1935-37, 1958, 1968-69 and 1975. The vertical projection outlines of all perennial plants are drawn to scale on grid paper and the dead plants or plant parts are shaded. The resolution of the map grid is a 9.3-cm^2 (one-hundredth square foot) of plot area. All the field map-work was done in the summer by the U.S. Forest Service personnel. Figure 1 shows the map record over forty years for one end of plot 1 in Exclosure 1 of Pasture 13. This example was selected to illustrate the persistence of shrub plants and indicate the level of resolution of the gridded graph paper on which the permanent plot maps were drawn.

The field technique consisted of laying over the plot a wooden-framed quadrat (5 x 2 ft) resting on poles temporarily fixed to steel stakes near the corners of the plot. These support poles ran along the 20-ft length of the plot, and the portable 5 x 2-ft quadrat was moved progressively down the plot and the vegetation mapped in 10 stages. Cross-wires on the 5 x 2-ft quadrat defined the area into units of 6 in. by 6 in., or one-quarter of a square ft. A floating square ft quadrat partitioned into one-hundredth square ft units was employed where necessary for detailed mapping. The map sheets were specifically prepared in advance by the U.S. Forest Service. A rectangle representing the 5 x 20-ft plot was gridded to the appropriate resolution, and the remainder of the form devoted to relevant information for plot identification and to notes on the vegetation, a key to the use of symbols or abbreviations on the map, etc.

The map record was quantified by summary data per plot on cover and density.

Plant cover was calculated from the maps by counting the squares within the outlines of living plants and expressing the total as a percentage of ground area. This measure of cover differs sharply from the cover estimate in the point-observation-plot method, which assesses the vertical projection of foliage assuming it is compressed to form a complete unbroken layer. Cover values by the latter technique obtained at Pine Valley are reported by Stewart and Keller (1936), Stewart et al. (1940), Hutchings and Stewart (1953) and Holmgren and Hutchings (1972).

Plant density was determined from the maps in terms of plant units, which could conceivably represent more than one individual. The point at which the main stem of each plant entered the ground was marked on the maps for only one year—1958. The main objective of the plant density analysis was to trace consecutive records of a plant from one map-year to the next and thereby determine persistence of individuals. By examining contemporary plant clumps and studying the 1958 map record, it seems that about 5 percent of the plant units consist of two or more individuals living so close together that, for ecological purposes they can be viewed as one plant.

RESULTS

Plant Cover

Vegetation trends according to plant cover values are shown in Figure 2 for all 64 plots in the 32 exclosures.

Total plant cover has increased dramatically since 1935, rising from a total of 4.5 % to over 10 %. Cover of shrubs has doubled over the 40-year period, but total perennial grass cover quadrupled. All three grasses exhibit increases in cover, although *Hilaria* and *Sporobolus* developed much faster than *Oryzopsis* (Fig. 3). By focusing only on the shrub species (Fig. 4), it is clear that the depression in shrub cover evident between 1958 and 1969 is seen to be due entirely to a collapse of the Shadscale component. Winterfat shows the most pronounced growth, followed by Budsage.

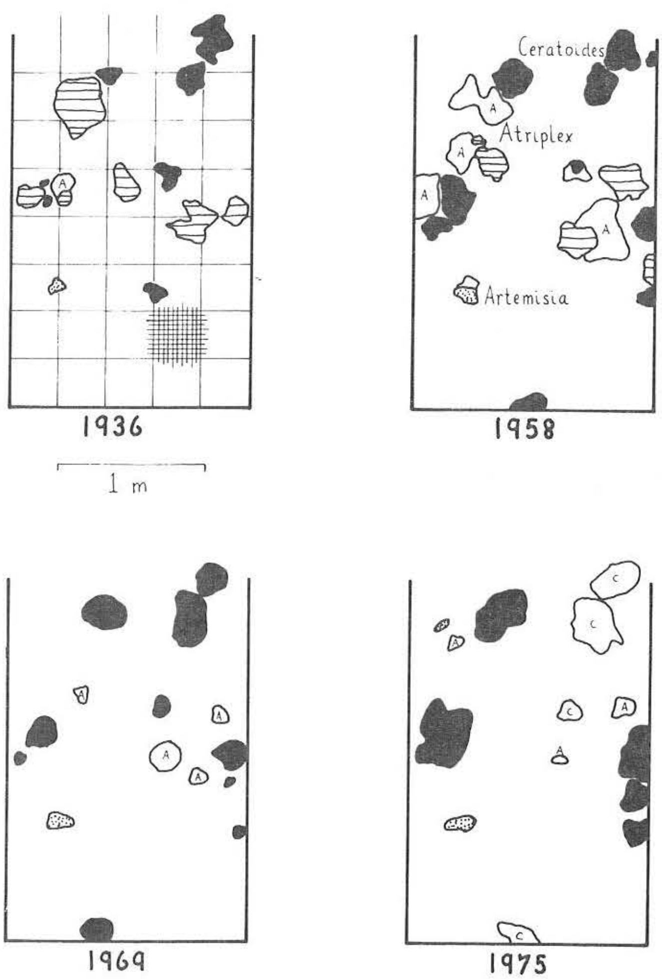

Figure 1. Permanent plot map record for half of plot 1, exclosure 1, pasture 13. *Ceratoides* is represented by solid black, *Artemisia* by stippling and *Atriplex* by horizontal hatching. Empty outlines signify dead plants. Note the longevity of the *Artemisia* plant and several *Ceratoides* plants. The fine grid on the top left figure represents the finest division of grid lines on the mapping paper.

The data presented in Figures 2-4 were taken from all exclosure plots spread over an area of about 25 km^2. Close inspection of the plot trends and sorting by species dominance indicated that there are basically two vegetation types on which the experimental pastures were established (Fig. 5). The "grassy" plots (pastures 2, 3, 4, 5, 6, 10, 11 and 12) are on a southeast facing slope, with somewhat skeletal and shallow soil and higher elevation than the remaining area. The vegetation is distinguished by a steady increase in total plant cover, increasing prominence by perennial grasses, a modest depression of Shadscale after 1958, and only a small component of Winterfat in the community even after the 40 years of protection. The "shrubby" plots (pastures 1, 7, 8, 9, 13, 14, 15 and 16) are generally at lower elevation on deeper soil with many plots having a northeast aspect. The vegetation here exhibits a substantial decline in Shadscale after 1958, reflected in a dip in the total cover value; the perennial grasses do not assume any prominence but Winterfat establishes dominance within 30 years and still continues to increase in plant cover. For the remainder of the Results, only data from plots in the "shrubby" vegetation type will be considered.

Plant Succession

Successional processes were analyzed in the exclosed vegetation by the plant replacement technique. The procedure involved identifying individual square feet (929 cm^2) on the map grids of 1935 plot maps which contained a plant of a particular species, with no other plants encroaching onto the 1-square ft map quadrat. The plant cover on each specific square ft was then traced through successive mapping periods. For Winterfat and Shadscale a total of 100 quadrats were sampled; in the case of Budsage only 40 suitable quadrats could be found.

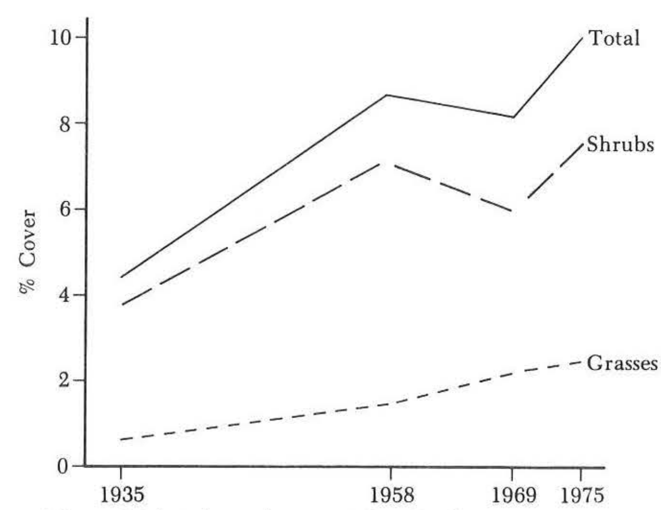

Figure 2. Trends in plant cover for shrubs, grasses and total perennials, 1935-1975. Data are derived from 64 plots in exclosures.

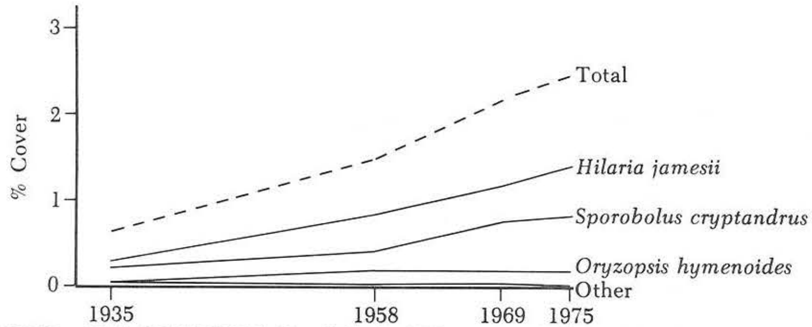

Figure 3. Trends in plant cover for individual perennial grass species, 1935-1975. Data are derived from 64 plots in exclosures.

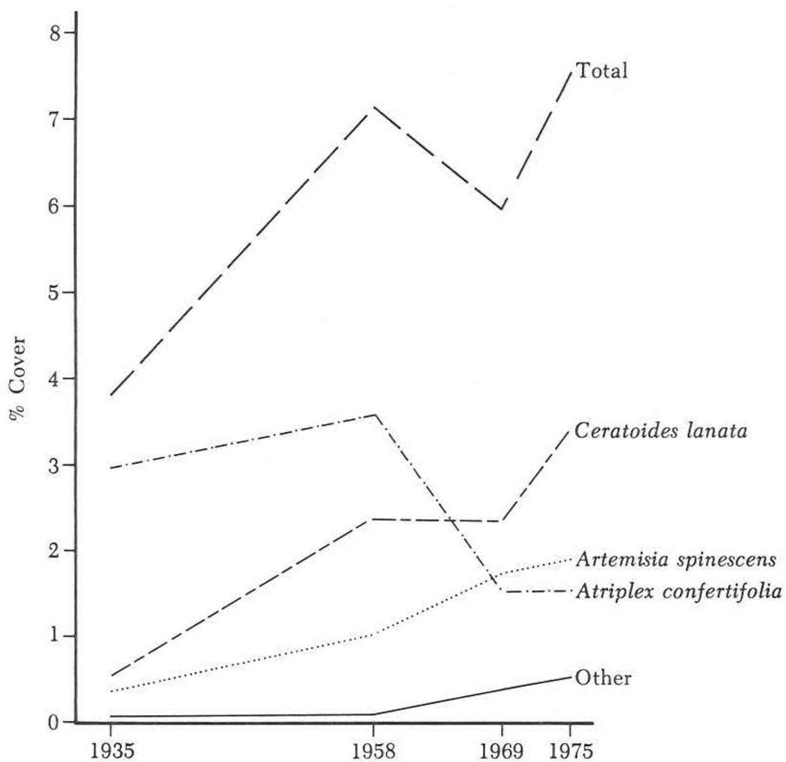

Figure 4. Trends in plant cover for individual shrub species, 1935-1975. Data are derived from 64 plots in exclosures.

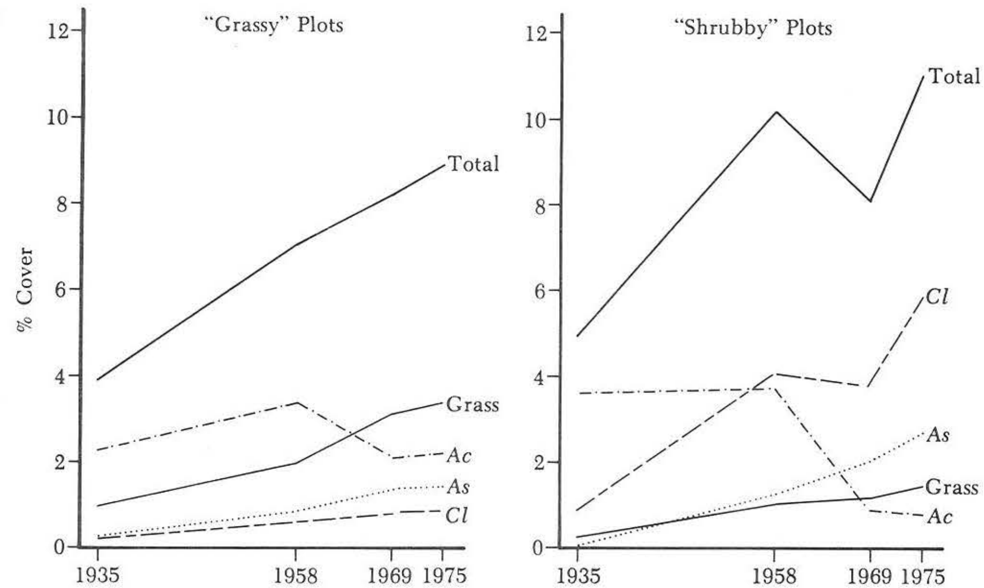

Figure 5. Analysis of cover data from exclosure plots in two vegetation types. Data for each type are derived from 32 plots in exclosures. (See text for pasture numbers.)

Table 1. Successional pattern on locations initially occupied by *Ceratoides lanata*. Area of one location is 929 cm^2 (1 ft^2), n = 100, and units represent % cover

Year	*Artemisia*	*Ceratoides*	*Atriplex*	Grass	Total
1936	—	18.8	—	—	18.8
1958	.4	23.4	1.5	.2	25.5
1969	1.0	21.1	.2	.6	22.9
1975	1.9	25.4	.6	.8	28.7

Table 2. Successional pattern on locations initially occupied by *Artemisia spinescens*. Area of one location is 929 cm^2 (1 ft^2), n = 40, and units represent % cover

Year	*Artemisia*	*Ceratoides*	*Atriplex*	Grass	Total
1936	6.9	—	—	—	6.9
1958	18.2	.5	2.8	1.7	23.2
1969	21.6	.4	.7	3.4	26.1
1975	19.2	1.7	1.2	3.6	25.7

Table 3. Successional pattern on locations initially occupied by *Atriplex confertifolia*. Area of one location is 929 cm^2 (1 ft^2), n = 100, and units represent % cover

Year	*Artemisia*	*Ceratoides*	*Atriplex*	Grass	Total
1936	—	—	40.1	—	40.1
1958	1.6	.8	11.6	.6	14.6
1969	4.3	1.4	1.4	1.6	8.7
1975	4.7	2.9	1.9	1.9	11.4

Table 4. Retrogressive history of locations occupied by isolated *Artemisia spinescens* plants in 1975. Area of one location is 929 cm^2 (1 ft^2), n = 91, and units represent % cover

Year	*Artemisia*	*Ceratoides*	*Atriplex*	Grass	Total
1975	48.2	—	—	—	48.2
1969	34.8	.4	<.1	.6	35.8
1958	19.9	.6	2.0	.5	23.0
1936	3.3	.7	3.9	1.2	9.1

Succession on locations originally occupied by Winterfat (Table 1) indicates that over the 40-yr period the Winterfat was fairly tenacious, permitting a little replacement by the other species but not to a threatening degree. The Budsage invasion of the Winterfat quadrats reached only 1.9%, while Budsage cover for the plots as a whole was 2.7% in 1975. The grasses achieved 0.8% cover in originally pure Winterfat locations, but mean grass cover for the plots is close to 1.5%.

Budsage also displayed considerable tenacity (Table 2), managing to increase its cover from 7 to 20%. Perennial grasses, however, did show a preference for these locations and an ability to establish a foothold, reaching 3.6% cover on the Budsage quadrats when their overall cover is only 1.5%. Winterfat, on the other hand, did not exhibit strong competition with Budsage: 1.7% vs 5.9% cover for Budsage plant sites vs the average for the plots. Shadscale had modest success invading Budsage sites: 1.2% vs 0.8% for the plot as a whole.

The least persistent species was Shadscale (Table 3). Plant cover on quadrats originally dominated by Shadscale fell from 40% to 2%. Grasses established themselves on these quadrats with slightly better success than on a quadrat selected at random, 1.9% vs 1.5% cover, while Winterfat did not show a strong ability to replace Shadscale, 2.9% vs 5.9%. Budsage, on the other hand, invaded the Shadscale plant sites very successfully. While for the plot as a whole, Budsage plant cover was only 2.7% in 1975, on quadrats formerly dominated by Shadscale it was 4.7%. This particular competitive ability of Budsage was tested by tracing the successional history of Budsage plants in a retrogressive fashion. Ninety-one locations of 1 square ft on the 1975 grid maps were located which contained one plant of Budsage, relatively isolated from other plants. These quadrats were examined for plant cover in preceding years and the results appear in Table 4. Although the quadrats had a strong component of Budsage in 1936, as would be expected, they also had a slightly larger component of Shadscale, some grass and a little Winterfat. The Shadscale component of 3.9% is similar to the cover of Shadscale over the whole plot in 1936 (3.6%). While the Budsage cover soared to nearly 50% in these locations, the Shadscale was virtually gone within 30 years.

While examining these selected quadrats, it occurred to us that the low total plant cover in 1935,(4.5%) left large areas of bare ground that would provide attractive establishment sites for species recovering from overgrazing. Our hypothesis was that over the 40-yr period plant invasion into the vacant areas would be largely responsible for the substantial increase in total cover that we had observed. Bare patches, as of the 1936 mapping time, were marked out on tracings of the plot maps. A minimum size for a bare patch was 2 ft (60 cm) in diameter and the boundaries of the patches were drawn no closer than 6 in. (15 cm) to the edge of a mapped plant. The total area covered by these bare patches amounted to 36.8% of the total area of the plots. Figure 6 shows an example of bare patches marked on a plot map for 1935 and the same plot in 1975.

The extent of plant invasion into the bare patches is shown in Table 5. Although for the plots as a whole, plant cover had reached a total of 10.9%, in the bare patches it had achieved only 5% in 40 years! The grasses and Shadscale were the most successful invaders, but not one of the shrub species nor the grasses could establish as much cover in those vacant patches of 1935 as they did for patches selected at random.

The converse of this is that most of the growth of the vegetation occurred in locations already occupied by plants back in 1935. On these "vegetated" areas, evaluated separately from the bare patches, plant cover rose from nearly 8% to 14.6% (Table 6).

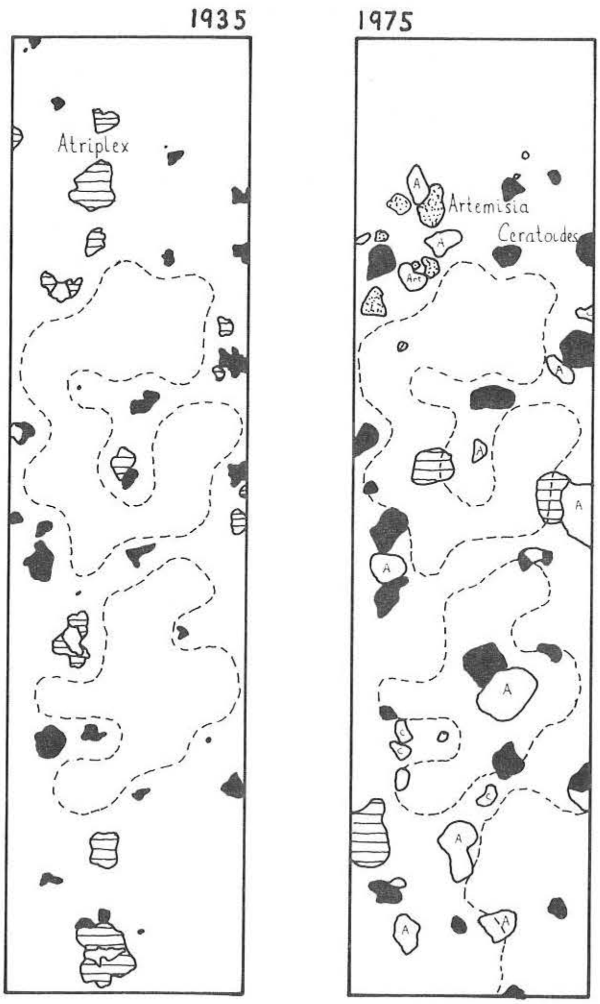

Figure 6. An example of the bare area described for a permanent plot in 1935, and the corresponding plant distribution for the same plot in 1975.

Table 5. Invasion of patches bare in 1935. Mean patch size is 1.1 m^2, $n = 99$, and units represent % cover. Bare patches represent 36.8% of total area

Year	*Artemisia*	*Ceratoides*	*Atriplex*	Grass	Total
1935	0	0	0	0	0
1958	.49	.71	1.81	.67	3.68
1969	1.00	1.00	.76	.71	3.47
1975	1.25	2.02	.55	1.15	4.97
		Mean Cover Over 32 Plots in 1975			
1975	2.72	5.90	.80	1.48	10.9

Table 6. Total cover development in bare vs vegetated areas

Year	Bare Patches (37% of total area)	"Vegetated" Areas (63% of total area)
1935	0	7.88
1958	3.68	14.02
1969	3.47	10.82
1975	4.97	14.62

Impact of Grazing

The cover trends in the exclosed plots and their grazed counterparts are compared in Figure 7. Both grazed and exclosure curves show an increase in total cover, and the parallel is sustained when the shrubs and grasses are examined separately. For perennial grasses, in fact, there is no significant difference in the cover increase between the grazed and protected condition. The separation between the two curves for the shrubs may be simply a function of the initial difference in cover between grazed and protected plots. A covariance analysis should clarify this question. A striking feature of the shrub curves in Figure 7 is not simply that they follow such a parallel course but that this course involves two changes in direction. This phenomenon may be related to the similarity in density record of Figure 9.

When the total shrub picture is broken down into its three contributing components, the compositional trends become more complex. The cover record for the three principal shrub species, which together make up more than 95 percent of the total shrub cover, is depicted in Figure 8. The only species which shows a substantial decline after 1958 is Shadscale, which accounts for the dip in the total cover curve in Figure 7. Winterfat in exclosure plots suffered a mild setback at the same time, but while Shadscale is unable to recover its status in the community the Winterfat appears to have grown more vigorously during the last six years than in any earlier period.

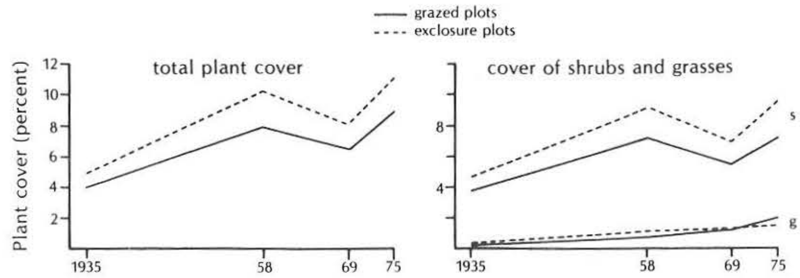

Figure 7. Change in total plant cover, and the shrub (s) and perennial grass (g) components, since 1935. Each curve represents the mean of 32, 9.3-m² plots.

The 40-yr trend in plant density of total shrubs shows little differentiation between the exclosed and grazed plots (Fig. 9). In view of the steady increase in total cover, the population of shrubs must have consisted of rather small plants on the whole in 1935. Density records for the three major shrub species are depicted in Figure 10. For Shadscale, the trends in plant cover parallel the trends in plant density. In the case of Winterfat, however, while plant cover is increasing plant density shows a steady decline. In the process of studying the demographic data, the survival of individual shrub plants was examined by checking matching grid coordinates at successive map periods. This procedure was confined to exclosures and grazed plots in four heavily grazed pastures (numbers 1, 8, 14 and 15; Figs. 9-11). The data in Figures 10 and 11 indicate that the size of the average Winterfat plant has increased significantly over forty years from an average 30 cm² in area to 217 cm², with half the 1975 population being plants at least 40 years old and probably much larger than this mean value. It is apparent in Figure 4 that this size increase is largely due to aging. In the exclosure plots, 52% of the plants alive in 1975 were part of the 1935 population. The other two species have relied heavily on regeneration under conditions of more rapid turnover to build their contemporary populations. Under both grazed and control treatments, respectively, nearly 67% and 77% of the 1975 Shadscale population is derived from plants less than 17 years old.

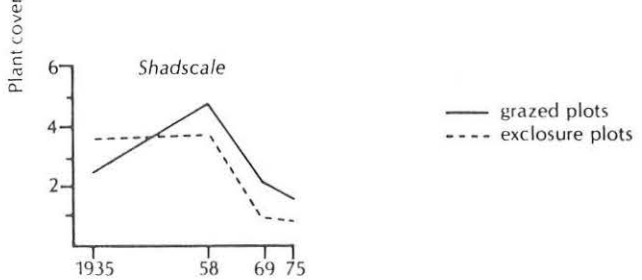

Figure 8. Trends in plant cover of the three principal shrubs in grazed and control plots from 1935-1975.

DISCUSSION

The study of plant replacement activity over the forty-yr period of records suggests that the perennial plants have a significant role in the successional processes of this desert area. The trends of increasing total plant cover and establishment of dominance by Winterfat with decline in Shadscale, have been most pronounced on sites originally occupied by plants in 1935. The increase in cover of Budsage has also been associated with occurrence of specific plants, with preference for sites formerly dominated by Shadscale or the Budsage itself. The interaction between Budsage and Shadscale is obvious in the demographic data illustrated in Figure 11. Winterfat remains somewhat independent of the competition between Budsage and Shadscale, but whether or not the vegetation is heavily grazed is an important factor in the interaction. The relative prosperity of Budsage when protected from grazing contrasts with the adversity of this circumstance for Shadscale. The fortunes are reversed for the grazed populations, indicating a competitive relationship between these two species whose interaction can be controlled by severity of grazing.

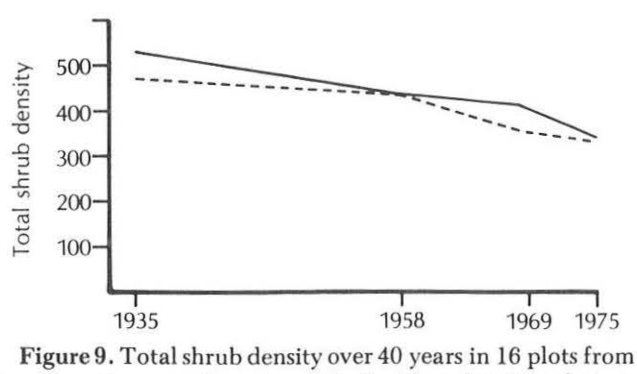

Figure 9. Total shrub density over 40 years in 16 plots from four heavily grazed pastures (1, 8, 14 and 15) and their matching 16 exclosure plots.

If Winterfat was interacting with Shadscale during the 40-yr experiment, the interference is not reflected in the dynamics of the Winterfat population. The increase in cover of the main forage species and the decline of the less palatable Shadscale have occurred independent of interspecific competition. The strong correlation between trends inside and outside the exclosures suggests that climate or some other overriding environmental factor was responsible for vegetation change and not the grazing treatment. Within this general picture, suppression by grazing of the minor shrub, Budsage, benefited Shadscale but did not affect the overall successional pattern.

Heavy grazing did not have a marked impact on Winterfat plant density (Fig. 10) nor on persistence or recruitment of individuals (Fig. 11), even though this species is probably the principal forage resource for sheep grazing in the eight paddocks under study (Holmgren and Hutchings 1972) and received more than 70 percent utilization (inferred from Hutchings (1966). Not only has Winterfat been relatively indifferent to heavy grazing, it supplanted Shadscale as the dominant species under treatment. I suggest three possible explanations for this phenomenon. (1) The rate of turnover of the Winterfat population is so slow, and the proportion of

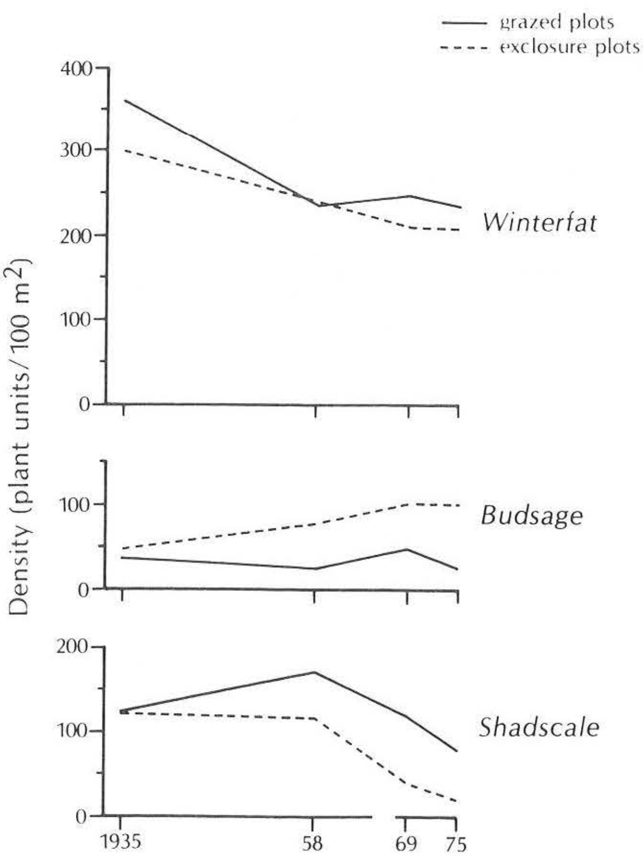

Figure 10. Forty-year record of plant density (expressed as plant units per 100 m^2) of the three main shrub species. Data were taken from four heavily grazed paddocks, with exclosures. Each curve is the mean of 16 plots.

Winterfat forage on large established plants so high, that the experimental grazing pressure has not had an opportunity to express itself. (2) The designated heavy stocking rate is well within the carrying capacity of Winterfat vegetation, with insufficient grazing pressure to influence natural mortality. (3)Forage utilization was maintained near constant within treatments as part of the experimental design by adjusting stocking rate annually, which avoided the magnified intensity of utilization in drought years of low forage production. This third factor was also a feature of a long-term grazing study at the Jornada Experimental Range, New Mexico, where persistence of the preferred forage species, Black Grama Grass (*Bouteloua eriopoda*), was not reduced by heavy grazing (Paulsen and Ares 1961).

The most unexpected result of the data analysis is the collapse of the Shadscale population between 1958 and 1969. This generally unpalatable species lost its dominant rank in both the grazed and protected communities, and to an almost equal degree in each. Under heavy grazing, however, Shadscale plants are less than half the size of their counterparts in exclosures. The response of Shadscale to grazing is less obvious in plant cover changes than in the plant population dynamics illustrated in Figure 11. Plants already established at the beginning of the experiment were not very sensitive to the treatments, but thereafter plant recruitment was much more successful in the grazed community in terms of both number and longevity. By 1975 there were three times more Shadscale individuals in the heavily grazed vegetation. Their smaller size partially compensates for higher density so that the plant cover is only twice the control value.

Theoretical Considerations

A basic principle of range science is that injudicious grazing is responsible for regression of vegetation away from climax. Such range deterioration is normally expressed on the basis of the perennial component of the vegetation, because perennials as measured in terms of basal area or density are relatively stable elements of the vegetation under a wide range of seasons. Perennials are a reliable index of range condition and trend in response to long-term stocking intensities or prolonged drought. A range manager is inclined to expect that when he sees a lot of livestock on the range, and there is a change in the vegetation, then that change is largely due to grazing pressure. He is inclined to believe that palatable perennial species will decrease under grazing while the less palatable perennials increase. A corollary of this theory is that the heavier the grazing pressure, the more pronounced the impact will be.

It is not difficult, however, to find exceptions to these axioms, and the vegetation trends at Pine Valley provide a good example. Norton and Michalk (1978) have initiated on inquiry our basic concepts in range science to see what theoretical development is necessary so that our principles will embrace not only those cases where the traditional decreaser and increaser species behave predictably, but also the growing number of special cases where the old rules do not apply.

To begin with, they suggest that range scientists need to look beyond plant cover data and also deal with measures of community change based on demographic parameters such as plant density, age structure and dispersion. When demographic data on the three salt desert shrubs are compared, it is clear that while Shadscale plants live for only about 20 years, in the case of Winterfat about half the 1975 population consists of individuals that were alive in 1935. Over this period, however, Winterfat plant cover has multiplied several times while its plant density has declined. The average ground cover per plant in 1935 was 30 cm²; in 1975 it was 217 cm². The sphere of influence of the average plant has been greatly enhanced by this size increase, and until those large plants die, the rate of change in vegetation is impeded. Norton and Michalk proposed, therefore, that rate of change in vegetation composition is a function of population turnover rather than cover trends. The opportunity for plant succession is reduced by the inherent long life of Winterfat. For Shadscale on the other hand, more rapid turnover provides more opportunity for successional events, such as replacement by another species, like Budsage.

If, when a plant dies in a community, it is always replaced by a member of the same species, the vegetation will be perfectly stable, even though cover may fluctuate due to irregular recruitment of juveniles. An important component of vegetation stability (or conversely, rate of change) is the probability that a species can maintain occupancy of a plant site over several generations. The plant replacement studies discussed earlier show that Winterfat has a probability of about .7 for species/plant site fidelity, while the probability that Shadscale will replace itself is only .1. It was proposed, therefore, that rate of community change is inversely related to the probability of a dead or dying plant being replaced by a member of the same species (Norton and Michalk 1978).

The complementary component is the probability of a species occupying a new plant site, either through competition with another species or as the result of invading a bare patch in the vegetation. The rate of change in vegetation is directly proportional to the probability of the challenger or invader being successful in establishing new plant sites for the species, all other things being equal.

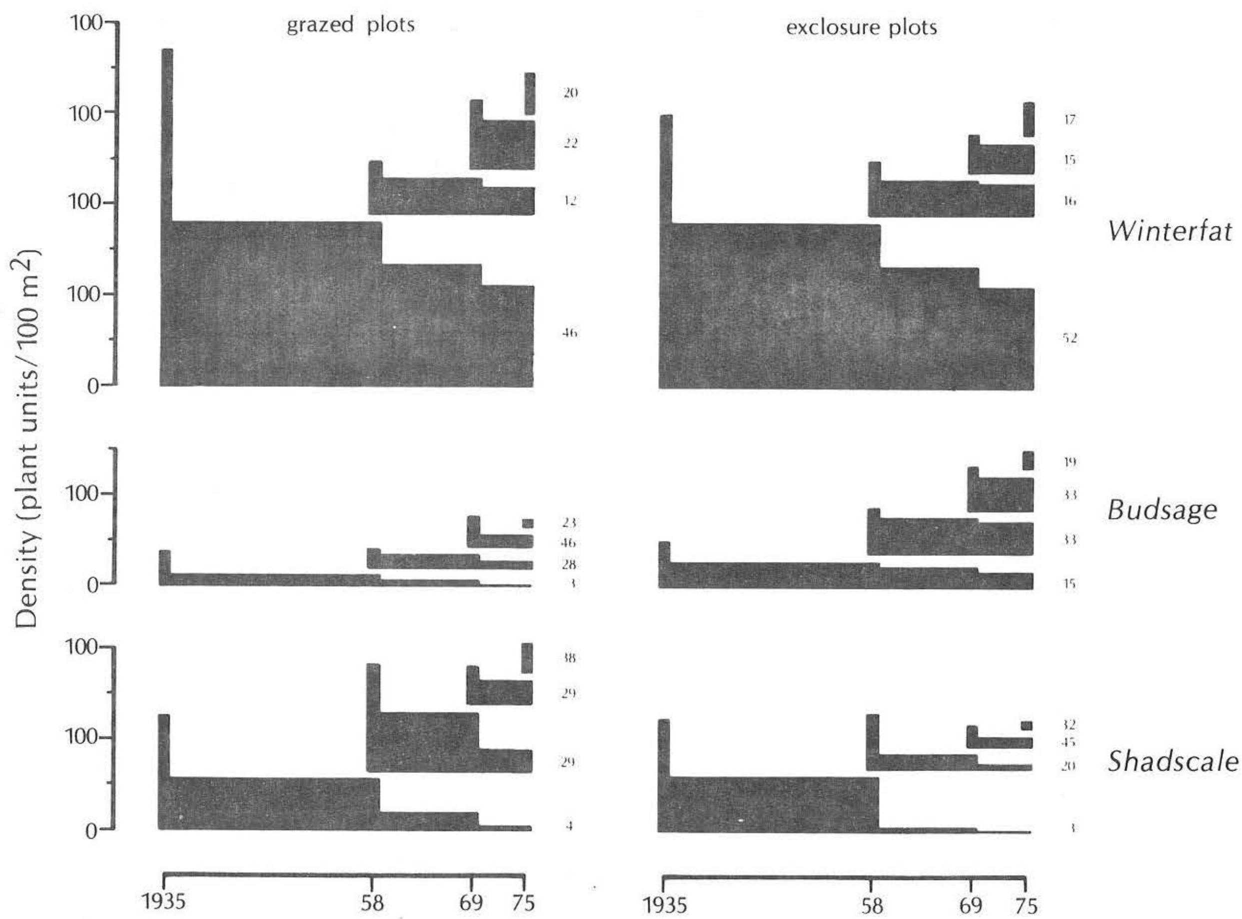

Figure 11. Persistence and introduction of individual plant units by shrub species, comparing heavily grazed and ungrazed plots. Vertical bars indicate density at the year of mapping; solid horizontal bars show persistence of plants from one map-year to the next. Each bar was drawn from the data of 16, 9.3-m² plots. The percent contribution from each age class to the 1975 population is given by the columns of numbers.

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