

17 Years of Grazer Exclusion on 3 Sites in Pinyon-Juniper Woodland
at Bandelier National Monument, New Mexico

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Community Ecology

Abstract:

In order to determine the effects of grazing on Pinyon-Juniper woodland at Bandelier National Monument, NM, a set of grazing exclosures was established in 1975. Data on the percent basal coverage by species of three grazing exclosure treatments (woven wire, five wire and open), at three different sites, from 1984 and 1992 were compared using canonical discriminant analysis to look for differences between treatments. Plots were compared against themselves (1992 to 1984) using paired t-tests to look for changes in vegetative cover by species and life form (grasses, forbs and woody).

The discriminant analysis shows a clear distinction between the three treatments based on total percentage basal cover. The t-tests show some significant changes (increases or decreases) for some species, but overall seem to indicate that vegetative cover is not changing in any of the treatments.

It is concluded that the grazing exclosures are useful for management decisions because they show that grazing does reduce vegetative groundcover, but that simple release from grazing is not sufficient to cause significant improvement. This implies that more active management is desirable.

Key Words: Pinyon-Juniper, grassland, grazing, exclosures, resource management, Bandelier National Monument, range improvement

Introduction:

Darwin noted that mowing or grazing turf allowed for greater plant diversity because it kept the more competitive plants from dominating (Darwin 1859). Grazing is in many ways equivalent to cutting, yet its effects in many areas are far from clear. In regions of the world where grasslands have evolved with large herbivores, these large grazers play a key role in maintaining the health of the grassland (McNaughton 1988). However, where plants have evolved in the absence of megaherbivores, as some grasses have in the grasslands of southern and central New Mexico, large herbivores may not be necessary, and the grassland may benefit from their absence (Brady et al. 1989).

To investigate the effects of grazing on a particular system, grazing exclosures are often used (Turner et al. 1980). It seems logical that monitoring an exclosure study over a long period of time should allow the researcher to see significant changes in species diversity and abundance. Often, however, no significant differences or improvements are found (West et al. 1984; Holochek and Stephenson 1983). Stranger still are results finding the exclosures do worse in terms of diversity or abundance (Holochek and Stephenson 1983). One cannot decide a priori that a system is being hindered or helped by a grazing regime.

In the present study I examine the effects of grazing by using grazing exclosures in pinyon-juniper grassland habitat. Instead of

presenting new methods or radically different ideas, I look for answers to questions about one particular site: Bandelier National Monument, Los Alamos, New Mexico (BAND). This National Park is located on the Pajarito Plateau in the Jemez Mountains of north-central New Mexico. The Jemez Mountains are the remains of an extinct volcano, and the plateaus surrounding them consist of consolidated ash tuff that was deposited when the extinct volcano erupted 1.4 and 1.1 million years ago. (Allen 1989).

While studying grazing in BAND it is important to understand its land-use history. The area has suffered from anthropogenic disturbance which explains many of its present problems. BAND is plagued by sheet erosion estimated at an unsustainable and relatively recent 0.5m/100 years (Earth Environmental Consultants 1978) and a population of pinyon (Pinus edulis) and juniper (Juniperus monosperma) at an artificially high density compared to what it was in the past.

In the late 1800's and early 1900's the region was subject to heavy cattle and sheep grazing (Allen 1989). In 1948 and 1965 a total of 86 elk were released in the Jemez Mountains (elk were extirpated from New Mexico by 1909) (Allen 1989). Elk continue to increase and expand their range with the Jemez population possibly numbering 10,000 (Allen 1989). The region is home to an increasing population of mule deer, and, until about 10 years ago, feral burros were a significant problem (Allen 1989). Currently, trespass cattle along the southern boundary of the park (The Rio

Grande) are negatively impacting this riparian zone.

Previous to European settlement, fire scars show that this region probably experienced fire intervals of between nine and fifteen years (Allen 1989). These fires served to cycle nutrients and keep the pinyon and juniper populations in check. With the advent of heavy grazing it is believed that tree interspace fuel was removed (eg grasses) which prevented the spread of fires, effectively eliminating them and allowing the tree density to increase. Competition with trees combined with heavy grazing reduced grass populations and allowed increased erosion from the bare soil (Allen 1989). This sort of feedback cycle has been demonstrated in similiar southwestern ecosystems (Schott and Pieper 1987). Anthropogenic and natural history provide the foundation for and influence the effects of the BAND grazing exclosures.

The following questions are addressed in this study: (1) Are the exclosures adequate to demonstrate differences caused by the absence of grazing? (2) Has vegetative cover changed in the exclosures? (3) Are there any particular species which can be used as indicators in this study area to judge the condition of the range?

Study Area:

The southern portion of the Bandelier National Monument (BAND) is characterized by mesas averaging about 1800m in elevation bisected by canyons with an average depth of 150m. Annual precipitation averages 40cm divided between snow in the winter months (usually Nov-March), some spring rains (March- April) and the summer "monsoons" (late June to late August). Mean monthly temperatures range from 28° C (July) to -1.6° C (January) (Allen 1989). For grasses the growing season is effectively divided between the cool season grasses in the spring and the C4 grasses in the hot summer.

The study sites are all within the boundaries of BAND. The first site (Stone Lions) is on the west side of Alamo Canyon, near the Stone Lions Shrine, at an elevation of 1920m. Site 2 (Alamo) is located at the mouth of Alamo and Lummis Canyons at an elevation of 1670m, about 50m above the Rio Grande. It is the lowest of the three sites. Site 3 (San Miguel) is located near San Miguel Ruins in the southwest corner of the park, elevation 1975m.

Soils and thus erosion vary across sites, but they are representative of the area. Earth Environmental Consultants, Inc. classified the soils of BAND in their 1978 report. At Site 1 soils are Hackroy Part, gravelly, sandy loam (USDA). At Site 2 soils are characterized as Nyjack Part, very stony, cobbly, sandy loam (USDA). Site 3 is on the same type of soil as Site 1. Soils are important influences of succession after a disturbance (Schott and Pieper 1987) so it is helpful that the study sites are on similar

soil types. "Characteristic" vegetation also varies across sites, but Koehler (1974) included all three sites in Juniper-Blue grama (*Bouteloua gracilis*) patches. All sites were also characterized by Koehler as very poor and deteriorating.

Methods:

Exclosures were established in July 1975 by David A. Koehler as part of a research program for his Master's thesis to determine the impact of feral burros on vegetation within BAND. Each exclosure consists of three, adjacent plots. Each plot measures 10m x 10m and contains five 8.2m long transects. The ends of the transects are permanently marked with rebar. There are buffer zones of about 1m between transects and the edges of the exclosures and 2m between transects.

At each of the three sites there are eight 2.4m high, 20cm x 20cm, corner posts. The first 4 comprise Plot 3 (woven), and the posts are braced. Woven wire encloses the area from the ground up, and the bottom 1m is further fenced with fine chicken wire which continues into the ground to prevent the entrance of small burrowing grazers. This exclosure is intended to exclude elk, deer, cattle, burros, rabbits and large rodents. Plot 2 (5 wire) shares two of Plot 3's corner posts, and provides Plot 1 (open) with 2 corner posts. Plot 2 is fenced with 5 strands of barbed wire which exclude cattle and burros, probably elk but not deer, rabbits or rodents. Plot 1 (open) is the control which is

delimited by the two posts it shares with Plot 2 and two posts unique to itself.

It should be noted that the exclosure sites were originally located "at locations representative of severe overgrazing" (Koehler 1974), and the three plots at each site were chosen to contain the most comparable vegetation possible (Potter 1985).

The transects were first censused in 1978. These data, unfortunately, are not included in every analysis because the Stone Lions and Alamo sites were read in May while all other data were collected in September or October. In 1978 and 1984 data were collected by stretching a copper wire between the rebar ends of each transect and measuring the basal and foliar intercepts by species (Potter 1985). In 1992 data were collected by stretching a meter tape between the rebar ends and measuring basal and foliar intercept by species and location on the tape. Basal cover was also recorded for bare soil, rock, litter, microphytic crust and other non-species categories to be used in future analysis.

Data for each site are compared between years and treatments as in Potter 1985 (Tables 1-3). Paired t-tests were used to compare each plot in 1992 to itself in 1984 (Sokal and Rohlf 1969). Comparisons are made both by individual species and by growth form (eg grasses, forbs, woody). 1992 data are shown at both the 95% and 90% significance levels. 1984 data from Potter are represented as significant if they were at either the 95% or 90% level.

Canonical Discriminant Analysis (CDA) in a SAS program (SAS Institute, Inc. 1988) was used to look for differences resulting from treatment plots (woven, 5 wire and open), years and locations. Location on the canonical axes allows one to visualize how, in this case, treatment types are the main cause of variation. CDA is a powerful tool to show if there is variation between my study sites because it uses every species in making its comparisons.

The data sets used in the CDA are from the years 1984 and 1992. Several changes had to be made in the data sets to allow for successful analysis in the SAS program. All species values before log transformation are of percent basal cover- the percent being of the 8m total of each transect read for 1984 or the 8.2m read in 1992. Stone Lions "1992" data was actually collected in 1991, and the 5 wire enclosure was not read. It is labelled 1992 to allow for statistical comparison assuming that basal coverage of species will not have changed significantly in one year. All species that did not occur at least 5 times total or comprise a total of 5% basal cover were eliminated. Transects were assumed to be representative of their plots so if a species was not present it was given a zero.

Results:

Paired t-tests for most species showed no change (NC) (See tables 1-3). When species in a plot were combined and compared across years as a growth form, however, a significant increase

Table 1. Paired t-tests for Stone Lions (location 1) comparing percent basal coverage by species and by growth form in each type of plot (1-3). Tests comparing 1978 and 1984 from Potter 1985. 1992 data were collected in 1991.

Spp.	Open (1)					Five Wire (2)					Woven Wire (3)				
	84	d	Sd	95%	90%	84	d	Sd	95%	90%	84	d	Sd	95%	90%
arpu	not present					not present, no 92 data					NC	8.5	6.4	NC	SI
arlo	NP	1.6	3.58	NC	NC	no 92 data					NP	4	6.95	NC	NC
bogr	SD	42	36.45	NC	NC	SD no 92 data					SD	32.6	34.77	NC	SI
hija	NC	12.4	13.9	NC	SI	NC no 92 data					NC	2.4	9.89	NC	NC
lyph	not present					not present, no 92 data					NC	4	9.5	NC	NC
muto	NC	-0.4	0.89	NC	NC	not present, no 92 data					not present				
sihy	not present					not present, no 92 data					NP	2.2	2.86	NC	SI
sprcr	SD	-1.6	2.3	NC	NC	SD no 92 data					NC	0	0	NC	NC
total grass	SD	54.8	45.53	SI	SI	SD no 92 data					SD	44.6	36.23	SI	SI
covi	NC	-0.2	0.45	NC	NC	not present, no 92 data					NC	1.2	2.68	NC	NC
erdi	NC	not present				not present, no 92 data					NC	not present			
gumi	SD	4	3.94	NC	SI	NC no 92 data					NC	3.6	6.8	NC	NC
ecvi	NP	0.2	0.45	NC	NC	not present, no 92 data					NP	0.2	0.45	NC	NC
plpu	NC	0.2	0.45	NC	NC	SD no 92 data					SD	1	1.22	NC	SI
opph	NC	-0.4	0.89	NC	NC	NC no 92 data					SD	-0.2	0.45	NC	NC
oppo	NC	6.8	5.36	SI	SI	not present, no 92 data					NP	2.8	5.72	NC	NC
total forbs	SD	8.6	4.34	SI	SI	SD no 92 data					SD	8.6	3.70	SI	SI
total woody		0.0				0.0						0.0			

NP= not present NC= no change

SI=significant increase (at either 90 or 95% confidence for 84)

SD= significant decrease (at either 90 or 95% confidence for 84)

Table 2. Paired t-tests for Alamo (location 2) comparing percent basal coverage by species and by growth form in each type of plot (1-3). Tests comparing 1978 and 1984 from Potter 1985.

Open (1)						Five Wire (2)					Woven Wire (3)				
spp.	84	d	Sd	95%	90%	84	d	Sd	95%	90%	84	d	Sd	95%	90%
bocu	NC	5.4	7.8	NC	NC	SD	not present				not present				
boer	NC	2.4	7.16	NC	NC	SI	1.2	5.54	NC	NC	NC	2.4	7.16	NC	NC
bogr	SD	13.4	22.69	NC	NC	SD	58	49.95	SI	SI	NC	29.8	24.62	SI	SI
muto	NC	8.6	12.09	NC	NC	NC	-3.0	19.57	NC	NC	NC	0.4	1.52	NC	NC
sihy	NP	not present				NC	-1.6	3.58	NC	NC	NP	3.4	7.60	NC	NC
spr	SD	1.2	2.68	NC	NC	SD	not present				NC	not present			
total grass	SD	32	31.02	NC	SI	SD	56.6	45.01	SI	SI	NC	49.6	19.49	SI	SI
chvi	NP	not present				NC	-0.2	0.45	NC	NC	NC	-0.2	0.45	NC	NC
crja	NP	not present				NC	-0.2	0.45	NC	NC	NP	not present			
gumi	NC	-2.4	2.51	NC	SD	NC	-0.4	0.89	NC	NC	NC	-0.4	2.19	NC	NC
hasp	NP	not present				NP	not present				NC	not present			
leer	NP	-0.2	0.45	NC	NC	NP	not present				NC	-0.4	0.89	NC	NC
opph	NC	-0.8	2.28	NC	NC	NC	4.4	6.69	NC	NC	NC	1.8	4.09	NC	NC
oppo	NP	not present				NP	not present				NP	1.6	3.58	NC	NC
spco	NC	not present				NC	not present				NP	not present			
total forbs	NC	-3.4	4.39	NC	SD	NC	3.6	6.11	NC	NC	NC	2	4.53	NC	NC
chna	NP	not present				NC	62.4	62.33	NC	SI	NC	37.4	83.63	NC	NC
total woody		0.0				NC	62.4	62.33	NC	SI	NC	37.4	83.63	NC	NC

NP= not present NC= no change

SI=significant increase (at either 90 or 95% confidence for 84)

SD= significant decrease (at either 90 or 95% confidence for 84)

Table 3. Paired t-tests for San Miguel (location 3) comparing percent basal coverage by species and by growth form in each type of plot (1-3). Tests comparing 1978 and 1984 from Potter 1985.

Spp.	Open (1)					Five Wire (2)					Woven Wire (3)				
	84	d	Sd	95%	90%	84	d	Sd	95%	90%	84	d	Sd	95%	90%
arpu	NP	0.4	0.89	NC	NC	NC	1	4.3	NC	NC	NC	3	4.58	NC	NC
bogr	NC	-1	2.24	NC	NC	SD	6.2	15.0	NC	NC	SD	15.8	10.21	SI	SI
muto	NC	-0.8	1.79	NC	NC	NP	not present				SI	-0.8	1.1	NC	NC
pobi	NP	not present				NP	not present				NC	1.4	3.13	NC	SI
sihy	NP	not present				NP	not present				NC	2	3.81	NC	NC
spr	NP	not present				NP	not present				SI	-1.4	1.52	NC	SI
gras	NP	not present				NP	not present				NP	1	2.24	NC	NC
total grass	SD	-1.4	4.34	NC	NC	SD	7.2	13.14	NC	NC	SD	21	11.6	SI	SI
covi	NP	not present				NP	not present				NC	not present			
chvi	NP	not present				NP	not present				NP	-0.6	1.34	NC	NC
cowr	NP	not present				NP	0.2	0.45	NC	NC	NP	not present			
gumi	SD	-2.2	3.9	NC	NC	NC	3.2	10.18	NC	NC	SD	7.6	12.46	NC	NC
hyri	NP	1.2	2.68	NC	NC	NP	1.4	1.95	NC	NC	NC	1.2	4.55	NC	NC
kuch	NP	not present				NP	not present				NC	not present			
opph	NP	not present				NC	4	6.93	NC	NC	NP	-0.2	0.45	NC	NC
oppo	NC	-0.4	0.89	NC	NC	NP	-1.4	3.13	NC	NC	NP	not present			
stpa	NP	not present				NC	-0.8	1.79	NC	NC	NP	11.2	10.76	NC	SI
total forbs	SD	-1.4	1.95	NC	NC	NC	6.6	9.24	NC	NC	SI	8.6	12.28	NC	NC
total woody		0.0	(possibly missing data here)				0.0					0.0			

NP= not present NC= no change

SI=significant increase (at either 90 or 95% confidence for 84)

SD= significant decrease (at either 90 or 95% confidence for 84)

appeared more often. A problem that Potter pointed out (1985) is that by giving not-present (NP) species a zero, the null hypothesis of no change is accepted more often. For example if a species that was not present in a plot in 1984 shows up on a small part of one transect in 1992, the t-test will show NC. This may be misleading because the fact that it is now present at all is actually quite significant- if not numerically at least ecologically.

I made simple bar graphs (figures 1-9) comparing the total cm of basal coverage of each species for each treatment plot to look for visual differences. These can be looked at in parallel with the t-tests, and, again, unless the differences are very large few conclusions can be drawn. It is interesting however when, as in fig. 1, 1992 levels are quite close to 1978 levels after 1984 saw a significant decrease.

Another problem using t-tests to compare the treatment plots is that differences between treatments are, for the most part, indistinguishable. Canonical Discriminant Analysis in this situation provides a means for visual analysis of the data set showing me that the treatment plots are in fact significantly different. By teasing apart each point on the canonical graph (Figure 10) I can link it to its original data set and look for what distinguishes it from other sites.

Through this process I have concluded that a plot's position on axis CAN 1 is determined by amount of grass coverage. More

Species List:

Grasses:

arlo Aristida longiligula
arpu Aristida purpurea
bocu Bouteloua curtipendula
boer Bouteloua eriopoda
bogr Bouteloua gracilis
gras unidentified grass
hija Hilaria jamesii
lyph Lycurus phleoides
muto Muhlenbergia torreyi
pobi Poa bigelovii
sihy Sitanion hystrix
sper Sporobolus cryptandrus

Forbs:

assp Astragalus sp.
chvi Chrysopsis villosa
covi Coryphantha vivipera
cowl Cordylanthus wrightii
crja Cryptantha jamesii
erdi Erigeron divergens
gumi Gutierrezia microcephala
hasp Haplopappus spinulosus
hyri Hymenoxys richardsonii
kuch Kuhnia chloralepis
leer Leucelene ericoides
opph Opuntia phaeacantha
oppo Opuntia polycantha
plpu Plantago purshii
spco Sphaeralcea coccinea
stpa Stephanomeria pauciflora

Woody:

chna Chrysothamnus nauseosus
jumo Juniperus monosperma
pied Pinus edulis

Fig 1. S.Lions (1), open (1) basal cover (cm)

by species, years 1978, 1984, 1992

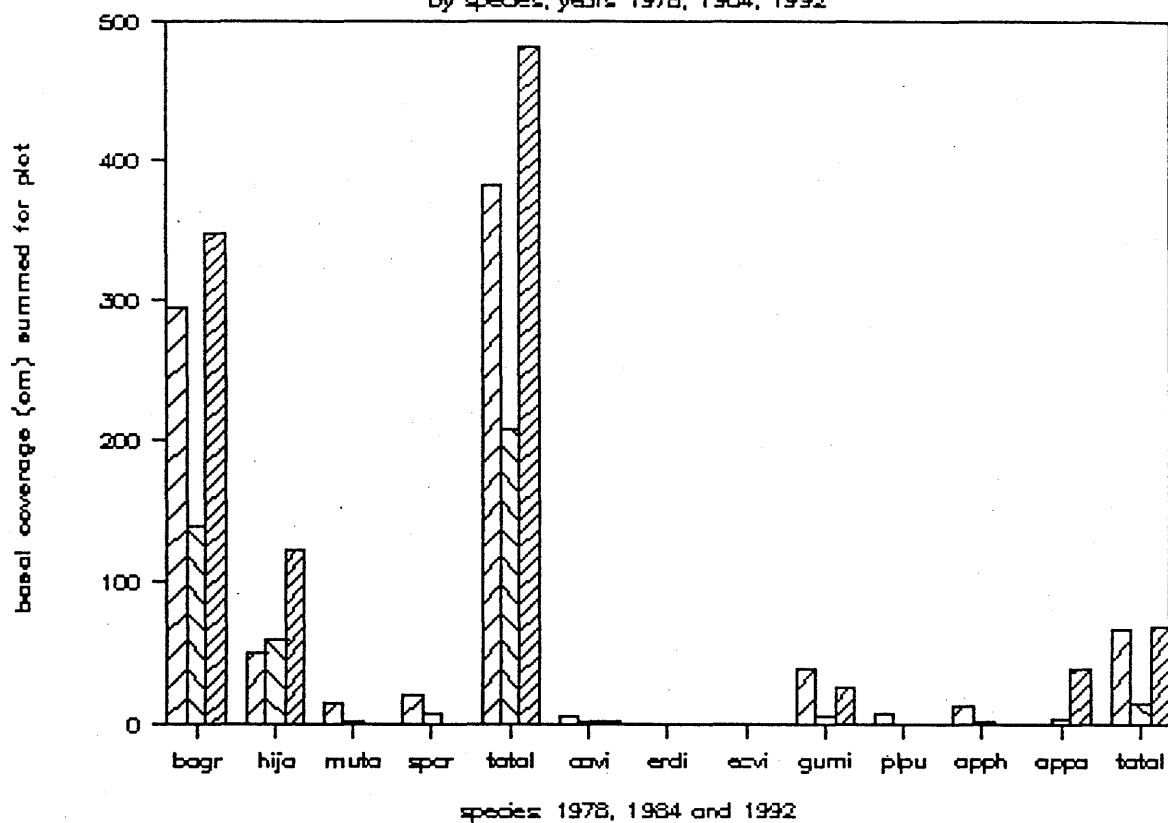


Fig 2. S.Lion (1), 5wire (2) basal cover (cm)

by species, years 1978, 1984, 1992

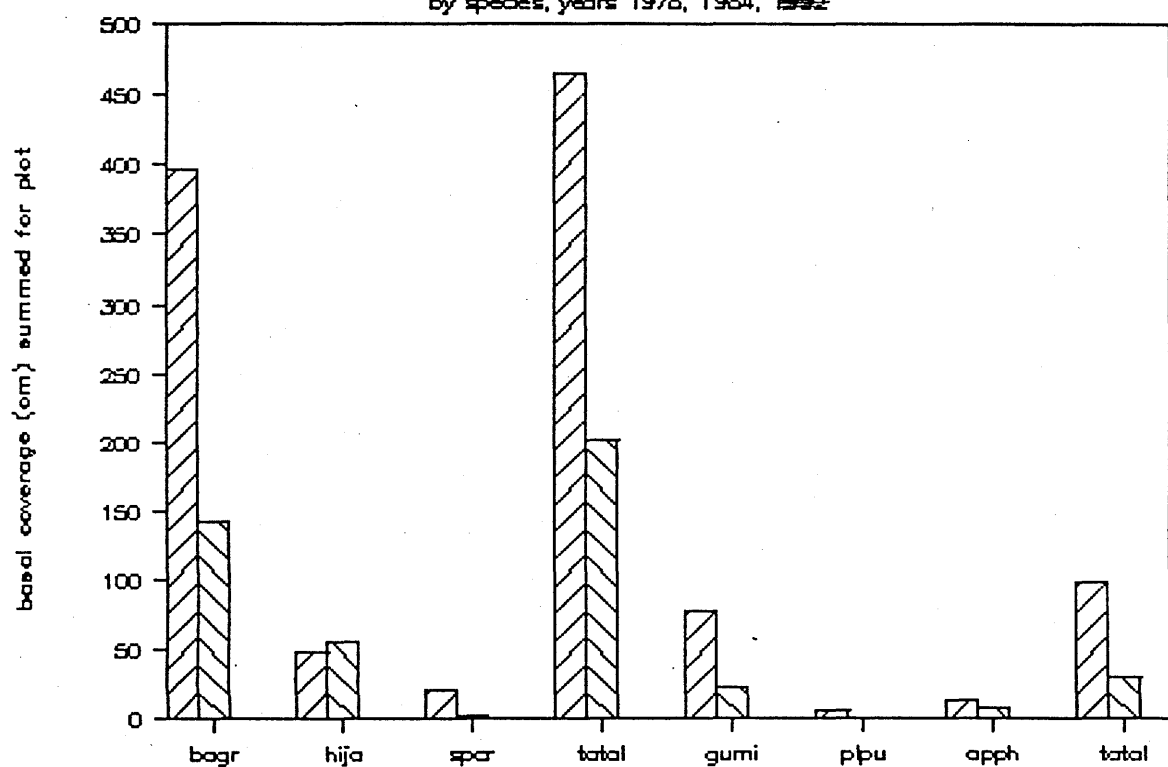


Fig 3. S.Lions (1), woven(3) basal cover (cm)
by species, years 1978, 1984, 1992

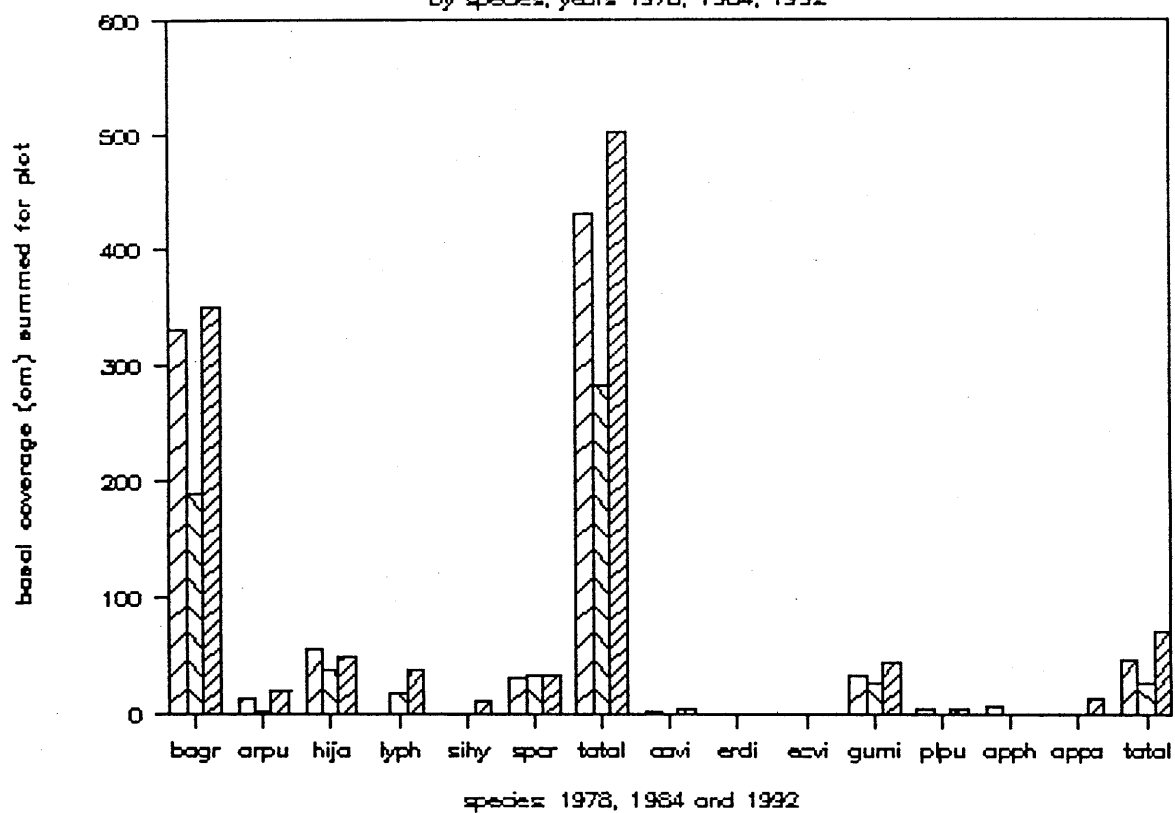


Fig 4. S.Mig (3), open (1) basal cover (cm)
by species, years 1978, 1984, 1992

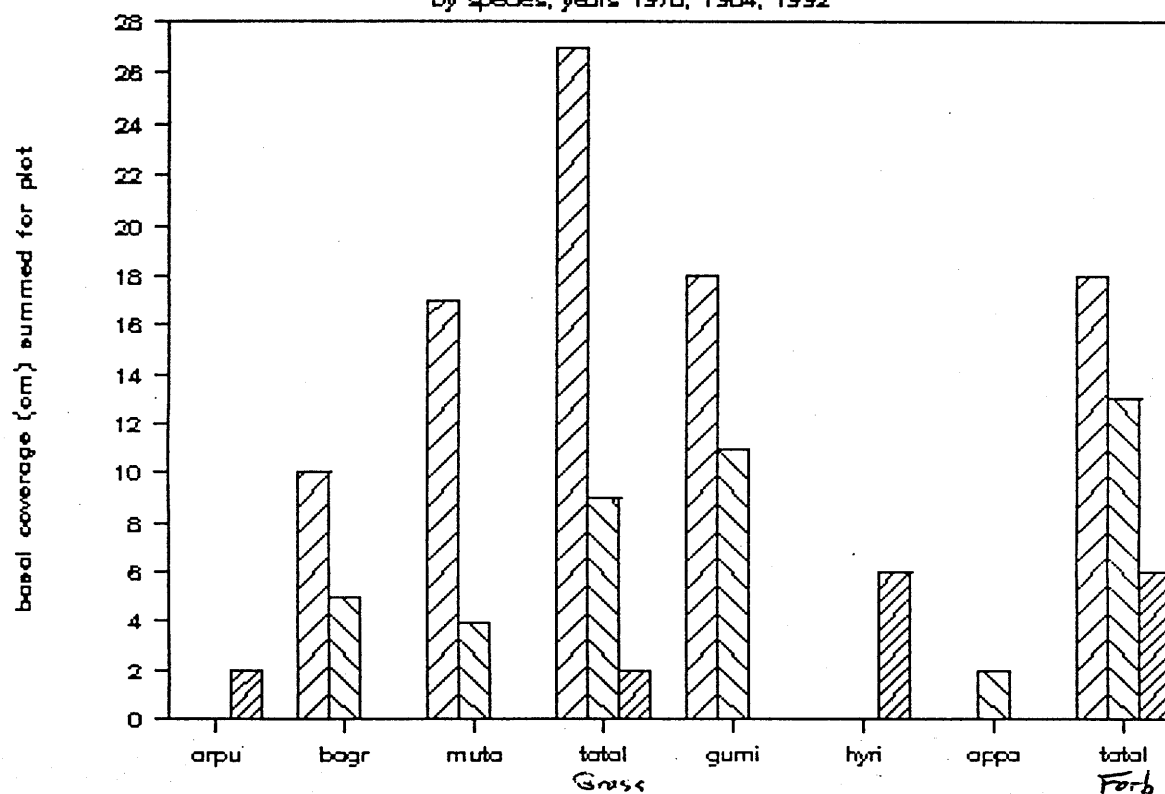


Fig 5. S.Mig (3), 5wire (2) basal cover (cm)

by species, years 1978, 1984, 1992

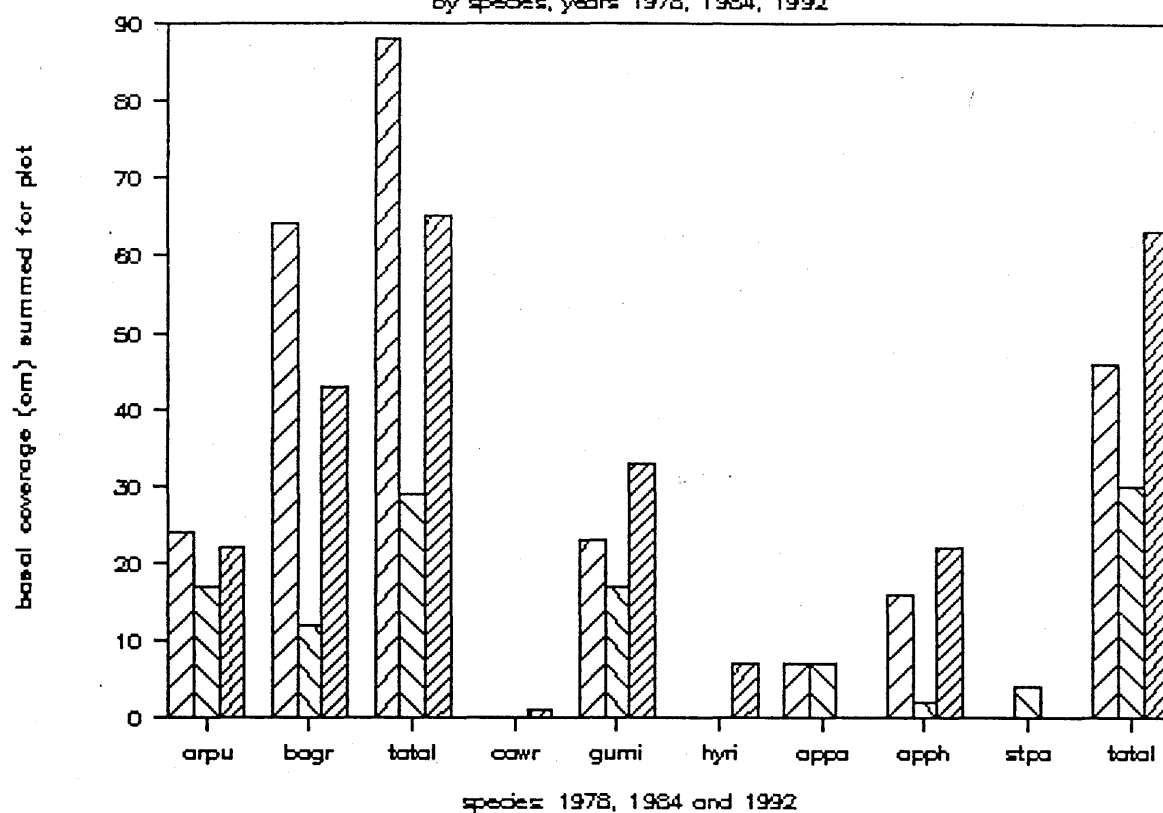


Fig 6. S.Mig (3), woven (3) basal cover (cm)

by species, years 1978, 1984, 1992

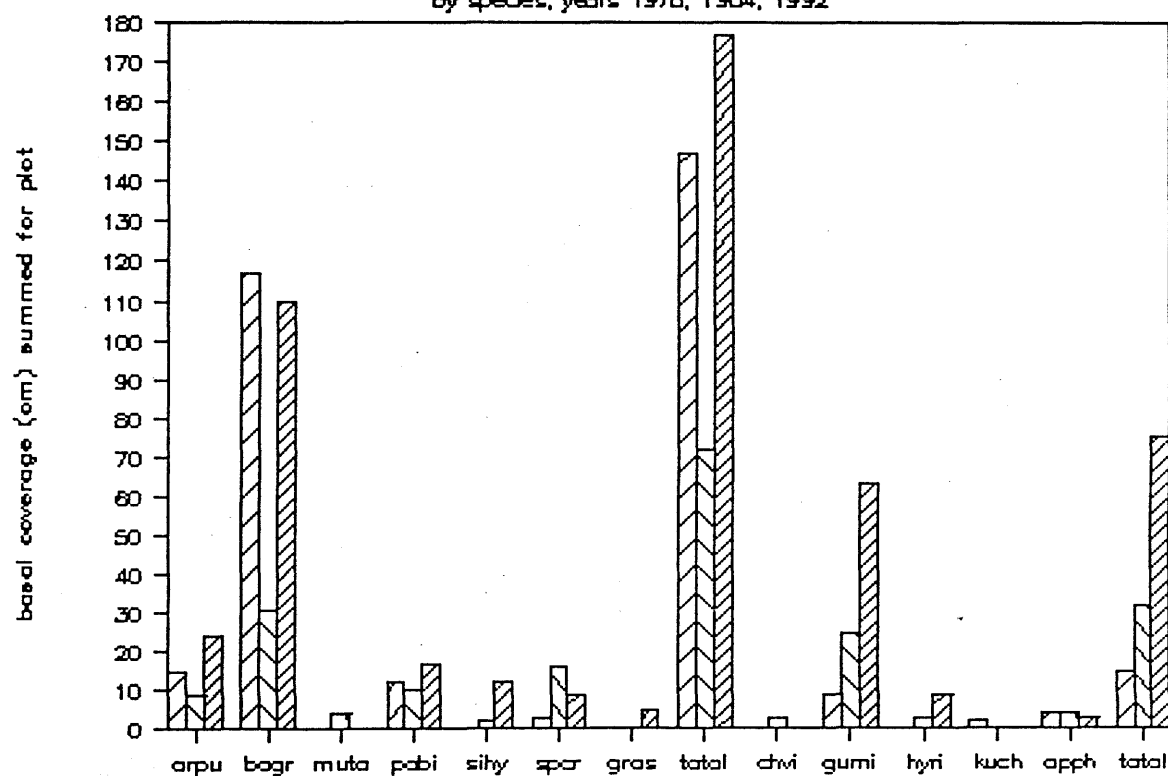


Fig 7. Alamo, line 1, open treatment 78,84,92

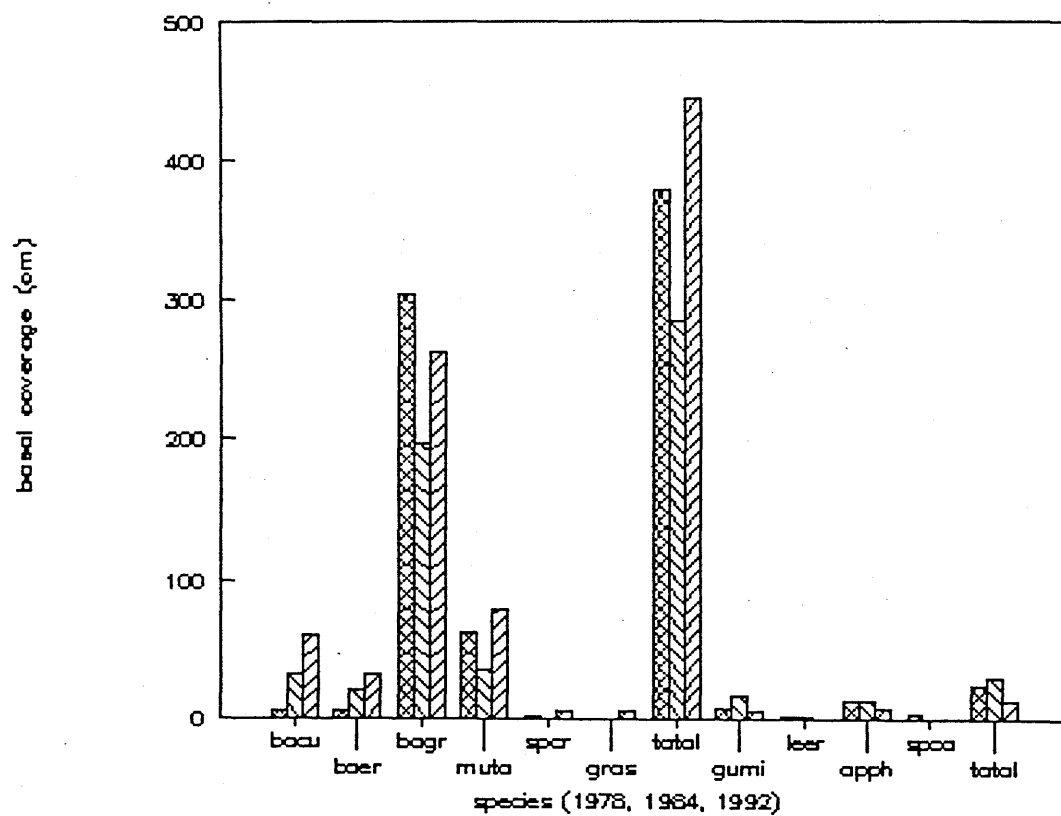


Fig 8. Alamo (2), 5-wire (2) basal cover (cm)
by species, years 1978, 1984, 1992

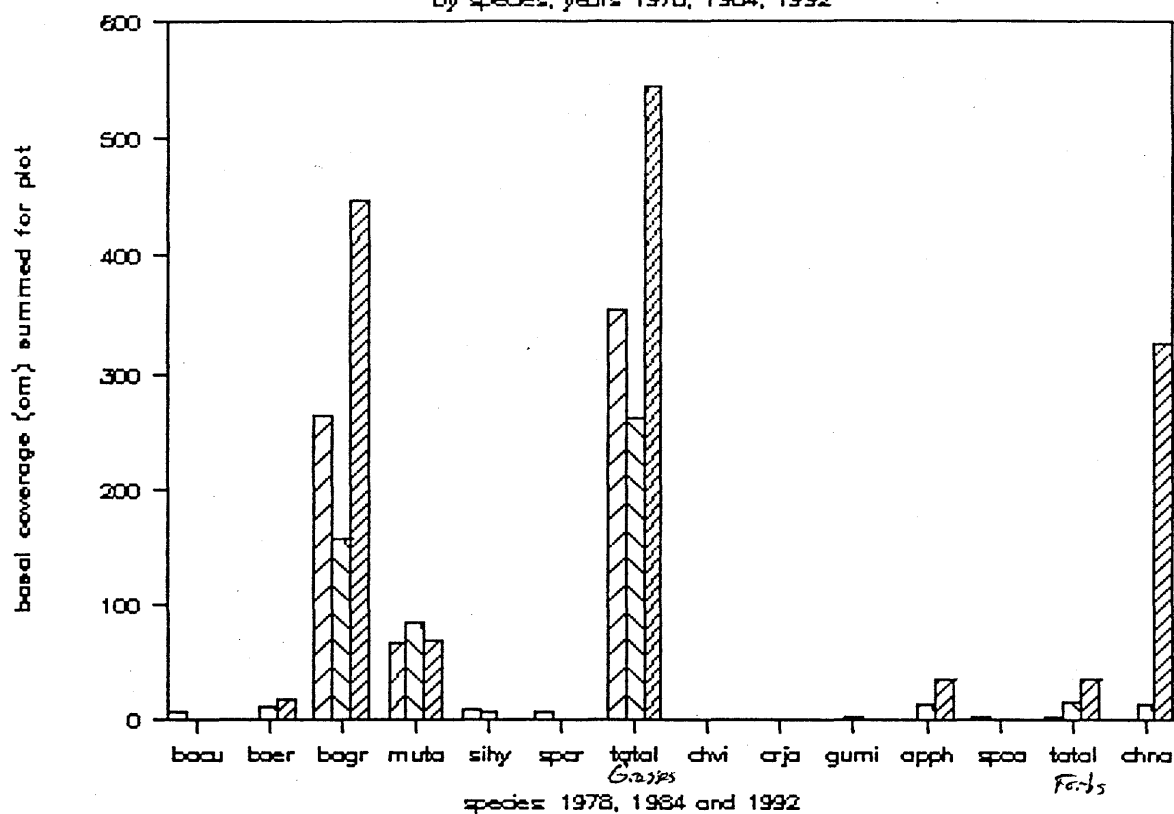
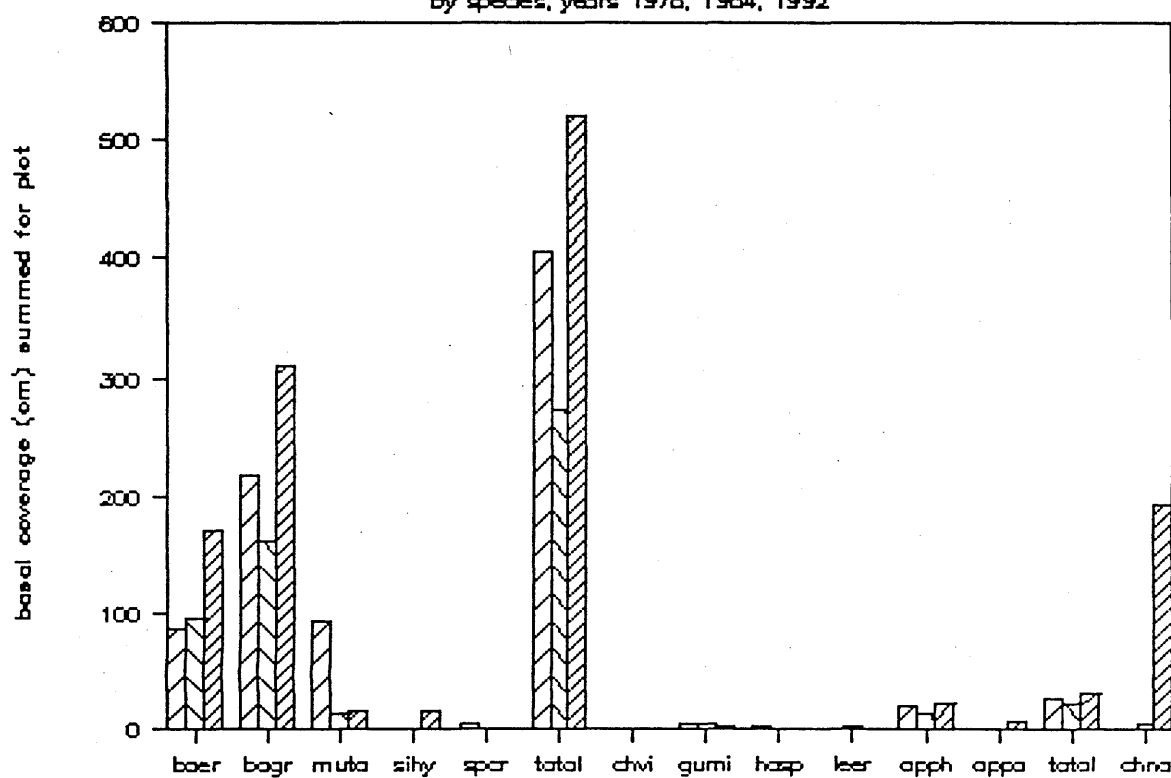


Fig 9. Alamo (2), woven (3) basal cover (cm)
by species, years 1978, 1984, 1992



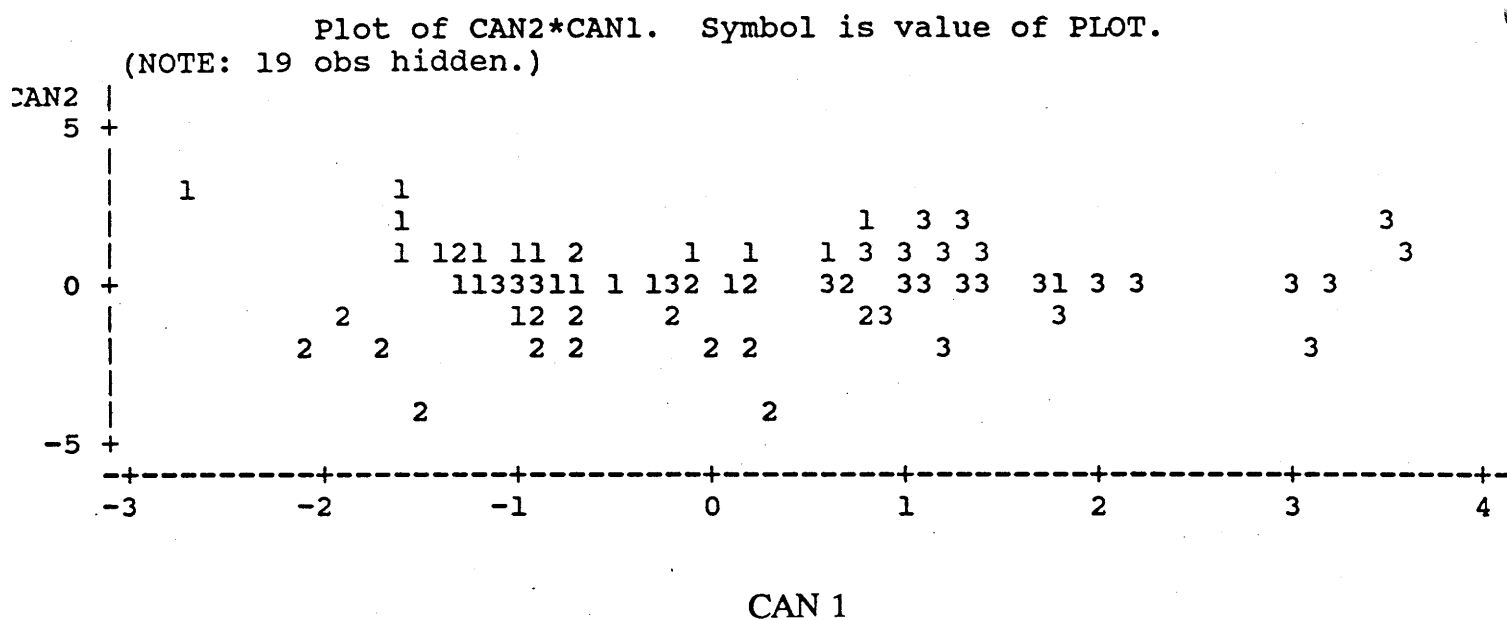


Fig 10. Treatment plots are significantly separated on the canonical axis.

3=woven wire (total exclusion)

2=5 wire (exclusion of burro and cows)

1=open

A plot's position on CAN 1 is determined by amount of vegetative cover, most specifically grass (influenced at the most positive end by five "rare" species: lyph, arpu, sihy, boer, bocu).

specifically, plots at the most positive end have high amounts of grass as a lifeform. They also contain at least one of five "rare" species which exhibited significance at or above the 95% level in the univariate analysis performed in SAS (Lycurus phleoides, Aristida purpurea, Sination hystrix, Bouteloua eriopoda, or Bouteloua curtipendula.) Plots falling in the central area of the graph are intermediate in amounts of vegetative coverage. Plots falling in the most negative regions of CAN 1 have little or no grass coverage at all on some of their transects.

Just looking at the graph (Figure 10), I can see that treatment plot 3 (woven) generally forms a cluster on the positive end of CAN 1 indicating that in fact it does have increased vegetative cover. Plots 1 and 2 are less separated from each other but one tends to clump above 2. This is not unexpected because the five wire (2) treatment allows most grazers in. West et al. in 1984 actually show that 7 rabbits are the grazing equivalent of 1 sheep.

Distances between treatment plots are not large as determined by Eigenvalues, but they are significant. In the CDA the likelihood that the canonical correlations are zero is 0.0001 for CAN 1 and 0.0160 for CAN 2. Combining the actual data with t-tests and a components analysis (CDA) thus provides a more complete picture than any one aspect taken alone.

Discussion:

The grazing exclosures at BAND have been established for 17 years. Though this seems to be a substantial amount of time, studies by West et al. (1984), Beymer and Klopatek (1992) and Holochek and Stephenson (1983) have shown that responses to removal of grazing pressure might not be evident for up to 20 years and that even then responses may not be positive. Some reasons for this include: the loss of nutrient containing top soil; the loss of vegetative and litter cover allowing for increased run-off and more rapid drying of the soil; increased competitiveness and success of deep-rooted tree species; and the loss of the soil seed bank (Kinucan and Smeins 1992; Henderson et al. 1988).

In the case of BAND some managers fear that the land is so deteriorated from the cycle of decreasing herbaceous groundcover that the removal of non-native, destructive grazers, like burros, is not enough. Reasonable management decisions however must be based on more than an unsubstantiated gut feeling. For this reason the information from these grazing exclosures is invaluable. It has been pointed out in the past that removing grazers does not automatically reverse downward trends (West et al. 1984). Results from analyzing the effect of the removal of grazing pressure at BAND can provide valuable insight for future management possibilities.

From the CDA it is apparent that the completely enclosed sites (treatment plot 3) do have more vegetation than the five wire and open plots. It is not clear however if herbaceous groundcover is

currently increasing, or changing at all, in any of the treatments. This tells me two things. First removing the extreme grazing pressure does allow for the presence of increased plant cover. Second, because it is not clear that any of the treatment plots are improving, other management action is desirable.

The five, significant "rare" species: lyph, arpu, sihy, boer and bocu are possible indicator plants for sights that are relatively ungrazed or more "healthy" at sites similar to the ones studied. However, because there is so much variation across the landscape, often on very small scales, it may not be realistic to look for any one set of indicator species to be applicable across the entire park.

Conclusion:

Through CDA it is shown that there are differences between three grazing treatments at BAND in regards to total plant cover. It is also shown, through t-tests and the relatively small separation on the canonical graph, that removal of grazing alone has not caused significant increases of plant cover over time. This lack of response could be due to many factors both abiotic and biotic. Five species were found to be possible indicators of better herbaceous cover for these sites, but they are probably not generally applicable. The results of this analysis may have important consequences for management decisions and implementation.

To halt the widespread sheet erosion taking place on BAND it is necessary to increase herbaceous groundcover. Until this occurs more and more soil will be lost and the harder it will be for plants to establish. Thus the downward cycle continues. At this point there is too much deteriorated land in the park to "treat" all of it even if an effective revegetation treatment were available. However, armed with a clear picture of some of the dynamics occurring between grazing and herbaceous understory, park personnel have a much better chance of making a successful bid for project funding to find appropriate revegetation methods and then implement them.

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