Rangeland Ecol Manage 60:680–684 | November 2007

Research Note

Livestock Grazing Impacts on Desert Vegetation, Khirthar National Park, Pakistan

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ABSTRACT

The impact of livestock grazing on desert vegetation in Khirthar National Park, Pakistan, was investigated by comparing dry and wet season plant species composition, richness, cover, and a grazing index for quadrats outside (''open'') and inside (''exclosed'') native mammal breeding enclosures that had excluded livestock for 6 years. A total of 93 plant species were recorded in the dry season, 88 species in exclosed quadrats and 50 in open quadrats. While only 5 species were unique to open quadrats, 43 species were found only in the exclosed quadrats. Species richness was higher in the exclosures because of the presence of more grass and herb species, while grazing was higher in the open. After rain, species richness and cover were significantly higher than in the dry season because of the growth of summer ephemeral herbs and grasses, but richness was no longer different between the exclosure and open treatments. Although some herbaceous species may have been adversely affected by livestock grazing, overall species richness suggests strong ecosystem resilience to grazing, with levels no different after seasonal rains regardless of grazing level. Many grass and herb species absent from open sites during the dry season reappeared after rain, which suggests that livestock grazing may eliminate them as the dry season proceeds, but that a soil seed or bud bank persists.

RESUMEN

Se investigó el impacto del apacentamiento del ganado sobre la vegetación desértica del Parque Nacional Khirthar de Pakistan comparando la composición botánica en las estaciones seca y lluviosa, la riqueza de especies, cobertura y un índice de apacentamiento. La comparación se realizó en cuadrantes localizados dentro (excluidos) y fuera (abiertos) de exclusiones para reproducción de mamíferos que tenían seis años de excluidas del ganado. En la estación seca se registró un total de 93 especies, 88 especies en los cuadrantes excluidos y 50 en los abiertos. Mientras que solo cinco especies se localizaron solo en los cuadrantes abiertos, 43 especies se encontraron solo en los cuadrantes excluidos. La riqueza de especies fue mayor en las exclusiones, debido a la presencia de más especies de zacates y hierbas, mientras que el apacentamiento fue mayor en las áreas sin excluir. Después de la lluvia, la riqueza de especies y cobertura fueron significativamente mayores que las registradas en la estación seca, debido al crecimiento de hierbas y zacates efímeros de verano, pero la riqueza de especies ya no fue diferente entre los tratamientos de exclusión y las áreas abiertas. Mientras que algunas especies herbáceas pudieron ser afectadas adversamente por el apacentamiento del ganado, la riqueza de especies general sugiere una fuerte resiliencia del pastizal al apacentamiento, sin diferencia en los niveles posteriores a las lluvias estaciónales, sin importar el nivel de apacentamiento. Muchas especies de zacates y hierbas ausentes de los sitios abiertos durante la estación seca reaparecieron después de la lluvia, sugiriendo que el apacentamiento del ganado puede eliminarlas conforme la estación seca progresa, pero el banco de semillas o yemas del suelo persiste.

Key Words: desert vegetation, exclosures, grazing, species richness, vegetation cover

INTRODUCTION

The distribution and abundance of plant species and communities in desert environments has been related to a range of physical environmental variables associated with water availability and anthropogenic disturbance. Human impacts associated with livestock grazing are a major potential influence on vegetation patterns and relative abundances of palatable and unpalatable species, of woody and herbaceous cover, and of soil physical and chemical properties (Dasti and Agnew 1994; Perelman et al. 1997).

The effects of overgrazing by livestock may include desertification through the loss of vegetation cover and erosion of soils (Barth 1999) and increased dominance of woody species, with impacts assumed to represent long-term changes to vegetation composition and structure (Illius and O'Connor 1999; Brown and Al-Mazrooei 2003). A contrary view (Sullivan and Rohde 2002) is that livestock may have only a limited impact on vegetation because of the inability of grazing and browsing animals to overturn a system where dynamics are controlled largely by a combination of rainfall variability, which determines plant productivity, and life history attributes of species that place regenerative plant parts out of their reach.

Exclosure studies have been used to investigate the grazing/browsing impacts of animals for many vegetation types by controlling animal access to plant resources (Holechek et al.

Research was funded by Shell and Premier Oil Consortium and The University of Melbourne.

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Manuscript received 29 October 2006; manuscript accepted 1 July 2007.

2003). While the interpretation of exclosure studies may be complicated by factors such as the pretreatment condition of the vegetation, the duration for which exclosures are in place, and the environmental variability experienced over that period (Allen et al. 1984), they remain an important source of information concerning the impact of grazing and browsing animals if results are interpreted with care.

Here we compare dry and wet season plant species richness and cover for open and exclosed sites at Khar Center, Khirthar National Park, Pakistan, to identify vegetation differences between areas subject to uncontrolled livestock grazing (primarily by goats), and those where livestock is excluded. Results are interpreted in relation to current ideas about degradation versus resilience of arid ecosystems subject to overgrazing by livestock (Sullivan and Rohde 2002). An understanding of the extent of change in the vegetation caused by livestock, and of the capacity for vegetation recovery following livestock removal, will also facilitate better planning for park management and plant species conservation strategies by local authorities.

METHODS

Study Area

Khirthar National Park is located in Sindh Province, Pakistan, 80–150 km north of Karachi. The park is characterized by the rugged mountains of the Khirthar Range and the presence of several threatened indigenous mammals, including the Sindh ibex (*Capra aegagrus*), urial (*Ovis vignei*), and chinkara (*Gazella bennettii*). Median annual rainfall is 140–163 mm (for nearby Hyderabad and Karachi, respectively), most falling in the summer monsoon. The 5 years (1995–1999) prior to the vegetation surveys described here each had annual rainfalls less than half the median.

The park is dominated by open vegetation with cover rarely exceeding 20% during the dry season (Enright et al. 2005). Common species include the trees *Prosopis cineraria* (L.) Druce, *Acacia nilotica* (L.) Delile, *Tamarix aphylla* (L.) Krst., and shrubs *Salvadora oleoides* Dcne. and *Ziziphus nummularia* (Burm. f.) Wight & Arn. Human activity within the park includes the production of agricultural crops in irrigated fields and the grazing of goats and sheep.

Field and Analytical Methods

Six fenced native mammal breeding areas, varying in size from 30 to 50 ha, were established in the southwest of Khirthar National Park near Khar Center in 1994. A total of 57 quadrats, each 30×30 m in size, were sampled during the dry season in February to April 2000, inside ($n = 36$) and outside ($n = 21$) the fenced areas. Hereafter we refer to the fenced breeding areas, and quadrats within them, as "exclosed" (i.e., sheep and goats excluded), and those outside as "open" (herds of sheep and goats not excluded). Exclosure quadrats were located at random and distributed equally across the six fenced areas. Exclosures carried 15–20 head of a single native ungulate species, with stock rotated among the six areas so that some were occasionally empty. They were free of goats and sheep for the 6 years from 1994 to 2000. Open quadrats were located at random based on distance along and away (to 300 m) from the exclosure fence lines.

The identity and cover of plant species in each quadrat was recorded using the Braun-Blanquet cover-abundance scale (Mueller-Dombois and Ellenberg 1974). Plant species nomenclature follows Akhter (2003). The level of grazing impact was recorded for each plant species using a semiquantitative scale ranging from 0 to 3: 0, no evidence of damage; 1, lightly damaged ($< 25\%$ of plant affected); 2, moderately damaged (25%–75%); 3, heavily damaged ($> 75\%$). The frequency of grazing was calculated based on the number of quadrats in which evidence of grazing was present, and an impact of grazing index was calculated for each species as the mean score across sites.

Twelve randomly selected quadrats, including at least one from each of the 6 exclosure areas, were remeasured after the end of the summer monsoon.

Analysis of variance (ANOVA) and Student's t test was used to test for difference between open and exclosed treatments for species richness, cover, and grazing level (and paired t tests for quadrat comparisons before and after the monsoon). Expected plant species richness in open and exclosed areas was calculated using the second-order Jacknife estimator (PC-ORD; McCune and Mefford 1999), which predicts the number of species that remain unsampled in an area based on the frequencies of singletons and doubletons. Multiresponse permutation procedure (MRPP; PC-ORD; McCune and Mefford 1999) was used to test for difference in species composition between open and exclosed quadrats. The procedure identifies the probability that between-group heterogeneity in ecological distance is significantly greater than within-group heterogeneity.

RESULTS

A total of 93 plant species was recorded in the dry season survey: 50 species in open quadrats and 88 in exclosed quadrats. Although only five species were unique to open quadrats, 43 species were unique to exclosed quadrats. Estimated community species richness (second-order jacknife) for open quadrats was 56 ± 4 (SE), only six more than were found in the 21 quadrats sampled (Table 1). The second-order jacknife estimate of community richness for exclosed quadrats was 152 ± 23 species, which indicates that many more species might be encountered if the number of such quadrats was further increased.

Open quadrats had an average plant species richness of 13.3 ± 1.2 species and mean cover (sum of Braun-Blanquet scores) of 5.6 ± 0.8 (Table 1). On average, 39% of species in open quadrats showed evidence of grazing, and the mean grazing index was 1.12. Mean species richness for exclosed quadrats was 16.7 ± 1.1, significantly higher than for open ($t = 2.07$, $P < 0.05$). The mean grazing index (0.37) and percentage of species grazed (21%) for exclosed quadrats were significantly lower than for open quadrats (Table 1). The most heavily grazed species were the grasses *Pennisetum divisum* (Gmel.) Henr., *Chrysopogon aucheri* (Boiss.) Stapf., *Ochthochloa compressa* (Forssk.) Hilu, and *Cymbopogon jwarancusa* (Jones) Schult. The most heavily browsed woody species were *P. cineraria, Z. nummularia, Capparis decidua* (Fossk.) Edgew., and *Grewia tenax* (Forssk.) Fiori.

Table 1. Comparison of plant species richness, cover, and grazing levels for sample quadrats in open versus exclosed treatments at Khar Center, Khirthar National Park, Pakistan during the dry season. Error terms are SE. Differences between treatments (*t* test, $P < 0.05$) were significant for richness, percentage of species grazed, and grazing index, but not cover (see text for details).

	Exclosed	Open
No. of quadrats	36	21
Total species richness	88	50
2nd-order jacknife richness	152 ± 23	56 ± 4
Species unique to treatment	43	5
Mean richness	16.7 ± 1.1	13.3 ± 1.2
Cover[1]	7.6 ± 0.8	5.6 ± 0.8
Mean % species grazed[2]	21.6 ± 4.4	38.8 ± 6.0
Mean grazing index[2]	0.37 ± 0.08	1.12 ± 0.10

[1]Number refers to the sum of Braun-Blanquet cover scores for species in each quadrat.
[2]Average of site totals.

Both open and exclosed quadrats were dominated by the tree *Acacia senegal* (L.) Willd. and the shrubs *G. tenax*, *Z. nummularia*, and *Euphorbia caducifolia* Haines, with no significant difference in frequency or cover between treatments for these species (Table 2). Significant differences between treatments were found for the climber *Pentatropis spiralis* (Forssk.) Dcne., with higher frequency and cover in exclosed quadrats, and for the climber *Cocculus pendulus* (J.R. & G. Forst.) Diels, the shrub *Rhazia stricta* Dcne., and grass *C. aucheri*, all with higher cover in exclosed quadrats (Table 2). Only the common large shrub *Commiphora wightii* (Arn.) Bhandari showed higher frequency of occurrence in open quadrats. Overall a major difference between open and exclosed quadrats was in the contribution to total cover by grasses, with just 3% of the total cover score contributed by grass species in open quadrats compared to 22% for exclosed quadrats. Nevertheless, MRPP analysis showed no significant difference in species composition for open versus exclosed treatments based on overall ecological similarity among quadrats ($A = 0.003$, $P = 0.44$).

Mean vegetation cover was significantly higher after the monsoon than in the dry season (paired *t* test, $t = 5.2$, $P < 0.001$), but did not differ for open (15.6 ± 4.3) versus exclosed (20.1 ± 1.8) quadrats (Table 3). Mean richness was significantly higher than in the dry season at 37.9 ± 3.6 species per quadrat ($t = 6.2$, $P < 0.001$), an average of 25 more species per quadrat at this time, but did not differ significantly between open and exclosed treatments. However, because of small sample size the power of these tests was low (0.08 for cover, 0.23 for richness). A total of 130 species were recorded after the monsoon, with 80 found in open quadrats and 110 in exclosed quadrats. Of these, 60 species were ephemerals recorded post-monsoon only: 28 were found in both treatments, 13 were found only in open quadrats, and 19 only in exclosed quadrats.

In the dry season there were many more shrub, herb, and grass species in exclosed than in open quadrats, while after the monsoon, the number of grasses was almost identical for both treatments. Although about 20 new (ephemeral) herb species were recorded for both open and exclosed quadrats after the monsoon, the initial (dry season) difference in number of herbs was approximately maintained, with 10 more species in exclosed than in open quadrats.

DISCUSSION

This study sought to identify whether 6 years of livestock exclusion has led to a difference in vegetation properties in open versus exclosed quadrats at Khar Center, Khirthar National Park that might inform the debate concerning the resilience of desert ecosystems to livestock grazing. A major

Table 2. Relative frequency (%F) and cover (%C) of the 15 most frequently encountered plant species in open versus exclosed quadrats for the dry season at Khar Center, Khirthar National Park, Pakistan. Species are ordered by %F. Species with high cover but low frequency are shown at the end of the table. Bolded values indicate significant differences ($P < 0.05$) in frequency and cover for species in open versus exclosed treatments (the higher score is indicated in all cases). Grasses (*) and climbers (#) are indicated.

Exclosed	%F	%C	Open	%F	%C
Acacia senegal	94	*35.7*	*Acacia senegal*	95	36.8
Grewia tenax	86	3.3	*Grewia tenax*	86	3.2
Pentatropis spiralis#	**81**	**1.5**	*Commiphora wightii*	**76**	3.4
Euphorbia caducifolia	69	7.4	*Seddera latifolia*	76	< 0.5
Seddera latifolia	64	< 0.5	*Cadaba farinosa*	71	3.2
Zizyphus nummularia	56	7.8	*Euphorbia caducifolia*	57	6.7
Lycium ruthenicum	56	2.8	*Ochthochloa compressa**	52	< 0.5
Cadaba farinosa	56	< 0.5	*Lycium ruthenicum*	43	4.8
*Ochthochloa compressa**	56	< 0.5	*Zizyphus nummularia*	43	2.7
Rhazia stricta	56	**0.9**	*Pennisetum divisum**	43	0.8
*Chrysopogon aucheri**	50	**7.0**	*Blepharis sindica*	43	< 0.5
Cocculus pendulus#	50	**0.8**	*Salvadora oleoides*	38	10.0
Blepharis sindica	50	< 0.5	*Chrysopogon aucheri**	*38*	1.2
Lasiurus scindicus	50	< 0.5	*Lasiurus scindicus*	38	< 0.5
Commiphora wightii	44	< 0.5	*Vernonia cinerascens*	33	0.6
*Saccharum griffithii**		5.5	*Prosopis cineraria*		13.4
Prosopis cineraria		4.9	*Tecomella undulata*		3.8

Table 3. Mean vegetation cover, species richness, and total number of ephemeral species for open versus exclosed treatments at Khar Center, Khirthar National Park, Pakistan, after the monsoon (September 2000). Error terms are SE. Differences between quadrat locations for richness and cover were not significant (t test, $P > 0.05$).

	Exclosed	Open
Cover[1]	20.1 ± 1.8	15.6 ± 4.3
Mean richness	42.3 ± 3.7	33.0 ± 6.3
Total richness	110	80
Total ephemerals	45	39
Ephemerals unique to treatment	19	13

[1]Number refers to the sum of Braun-Blanquet cover scores for species in each quadrat.

constraint on the ability of this study to provide unequivocal results is that there was no pretreatment vegetation data for the exclosures. This means that results do not measure change in vegetation directly and are dependent upon the assumptions commonly associated with space for time substitution experimental designs. Nevertheless, a number of significant differences in vegetation properties for open versus exclosed samples were observed.

Lower vegetation cover and plant species richness is recorded for open quadrats in the dry season, which suggests a possible grazing impact on species occurrence in unfenced areas of the park. Similar grazing effects are reported by Barth (1999) for Saudi Arabia, Peer et al. (2001) for steppe vegetation in Pakistan, and Holochek et al. (2003) for the Chihuahuan Desert. They interpret this as an overgrazing impact leading to land degradation. However, variation among species in the frequency and intensity of grazing is substantial. The most heavily grazed species were the grasses. All of them had mean grazing scores of ~2 in the open quadrats and showed evidence of grazer impact in ~90% or more of quadrats. Saleem and Call (1993a, 1993b) report that *C. aucheri* is highly palatable to grazers, while *C. jwarancusa* is not, the former having higher quality tillers and the latter essential oils that may represent a herbivory defence. In the present case, results suggest that dry season livestock grazing may be high enough to move grazer pressure on to nonpreferred species. The highly palatable *C. aucheri* had a dry season cover score of 7% in exclosed quadrats, but only 1.2% in open quadrats, supporting the contention that grazing pressure was much reduced inside the exclosures. Friedel et al. (2003) and Gonnet et al. (2003) report decreased vegetation cover with increasing livestock grazing pressure in central Australia and Argentina, respectively, but note that trends vary depending on the palatability of the species and may be related more to changes in soil conditions for plant growth and recruitment than to direct livestock grazing effects, issues that may be pertinent here also.

That there was no significant difference in species composition between treatments in the dry season was largely due to the overriding importance of large woody perennials such as *A. senegal, C. wightii, E. caducifolia,* and *G. tenax,* which were present in most quadrats, while the many additional species found in exclosed quadrats were infrequent, contributing little to ecological distance between samples. The high species richness of infrequent grasses and herbs in exclosed quadrats during the dry season suggests that the major effect of livestock exclusion may be to slow the seasonal decline of such species. After the monsoon, both open and exclosed quadrats revealed much higher species richness, and ecological distance between quadrats decreased, which indicates that many of the ephemeral species that emerged following the monsoon rains were common to quadrats regardless of their location.

IMPLICATIONS

Sullivan and Rohde (2002) argue that grazing alone is unlikely to lead to degradation of arid ecosystems since plant productivity is limited by rainfall, and large annual variability in rainfall sets limits on the extent to which grazers can reduce biomass. Sullivan (1999) found no difference in vegetation between open and exclosed sites in Namibia during periods of drought regardless of the presence of grazers because there was little plant growth, while Brown and Al-Mazrooei (2003) report high regenerative power for apparently degraded sites when grazing was removed, or following years of above-average rainfall, with sites showing strong resilience through the recovery of individuals from protected vegetative parts.

In the present study drought was persistent for the 6 years up to and including the year in which vegetation data were collected, so that plant productivity and biomass availability to grazers and browsers was consistently low. Species cover was lower in open quadrats in both the dry and wet seasons, while species richness was lower in open quadrats in the dry season, but not after the monsoon. The higher cover in the exclosed quadrats in the dry season was mostly of grasses and climbers and suggests a reduced grazer impact. However, species richness did not differ between treatments after seasonal rains regardless of grazing level. These results provide elements of support for both the degradation and resilience paradigms and suggest that not all vegetation property responses need necessarily conform to a single model.

ACKNOWLEDGMENTS

The authors acknowledge the logistical support of the Sindh Wildlife Department and logistical and financial support of the Premier and Shell Oil Consortium in making this study possible. Dr Rubina Akhter of the Pakistan National Herbarium provided plant identifications. The helpful comments of anonymous reviewers and journal editors are also acknowledged.

LITERATURE CITED

Akhter, R. 2003. A plant Guide to Khirthar National Park and adjoining areas. Islamabad, Pakistan: Premier-KUFPEC Pakistan B.V. 188 p.

Allen, R. B., I. J. Payton, and J. E. Knowlton. 1984. Effects of ungulates on structure and species composition in the Urewera Forests as shown by exclosures. *New Zealand Journal of Ecology* 7:119–130.

Barth, H. J. 1999. Desertification in the Eastern Province of Saudi Arabia. *Journal of Arid Environments* 43:399–410.

Brown, G., and S. Al-Mazrooei. 2003. Rapid vegetation regeneration in a seriously degraded *Rhanterium epapposum* community in northern Kuwait after 4 years of protection. *Journal of Environmental Management* 68:387–395.

Dasti, A., and A. D. Q. Agnew. 1994. The vegetation of Cholistan and Thar deserts, Pakistan. *Journal of Arid Environments* 27:193–208.

Enright, N. J., B. P. Miller, and R. Akhter. 2005. Desert vegetation and vegetation-environment relationships in Khirthar National Park, Sindh, Pakistan. *Journal of Arid Environments* 61:397–418.

Friedel, M. H., A. D. Sparrow, J. E. Kinloch, and D. J. Tongway. 2003. Degradation and recovery processes in arid grazing lands of central Australia. Part 2, Vegetation. *Journal of Arid Environments* 55:327–348.

Gonnet, J. M., J. C. Guevara, and O. R. Estevez. 2003. Perennial grass abundance along a grazing gradient in Mendoza, Argentina. *Journal of Range Management* 56:364–369.

Holechek, J., D. Galt, J. Joseph, J. Navarro, G. Kumalo, F. Molinar, and M. Thomas. 2003. Moderate and light cattle grazing effects on Chihuahuan Desert rangelands. *Journal of Range Management* 56:133–139.

Illius, A., and T. O'Connor. 1999. On the relevance of non-equilibrium concepts to arid and semi-arid grazing systems. *Ecological Applications* 9:798–813.

McCune, B., and M. J. Medford. 1999. PC-ORD 4, Multivariate analysis of ecological data. Version 4.10. Gleneden Beach, OR: MjM Software. 237 p.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. New York, NY: Wiley. 547 p.

Peer, T., A. Millinger, J. P. Gruber, and F. Hussain. 2001. Vegetation and altitudinal zonation in relation to the impact of grazing in the steppe lands of the Hindu Kush Range N-Pakistan. *Phytocoenologia* 31:477–498.

Perelman, S. B., R. J. C. Leon, and J. P. Bussacca. 1997. Floristic changes related to grazing intensity in a Patagonian shrub steppe. *Ecography* 20:400–406.

Saleem, M., and C. A. Call. 1993a. Ecology of *Chrysopogon aucheri* and *Cymbopogon jwarancusa.* I. Germination response. *Pakistan Journal of Forestry* 43: 4–9.

Saleem, M., and C. A. Call. 1993b. Ecology of *Chrysopogon aucheri* and *Cymbopogon jwarancusa.* III. Morphology and defoliation response. *Pakistan Journal of Forestry* 43:106–118.

Sullivan, S. 1999. The impacts of people and livestock on topographically-diverse open woodlands in arid north-west Namibia. *Global Ecology and Biogeography Letters* 8:257–277.

Sullivan, S., and R. Rohde. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography* 29:1595–1618.