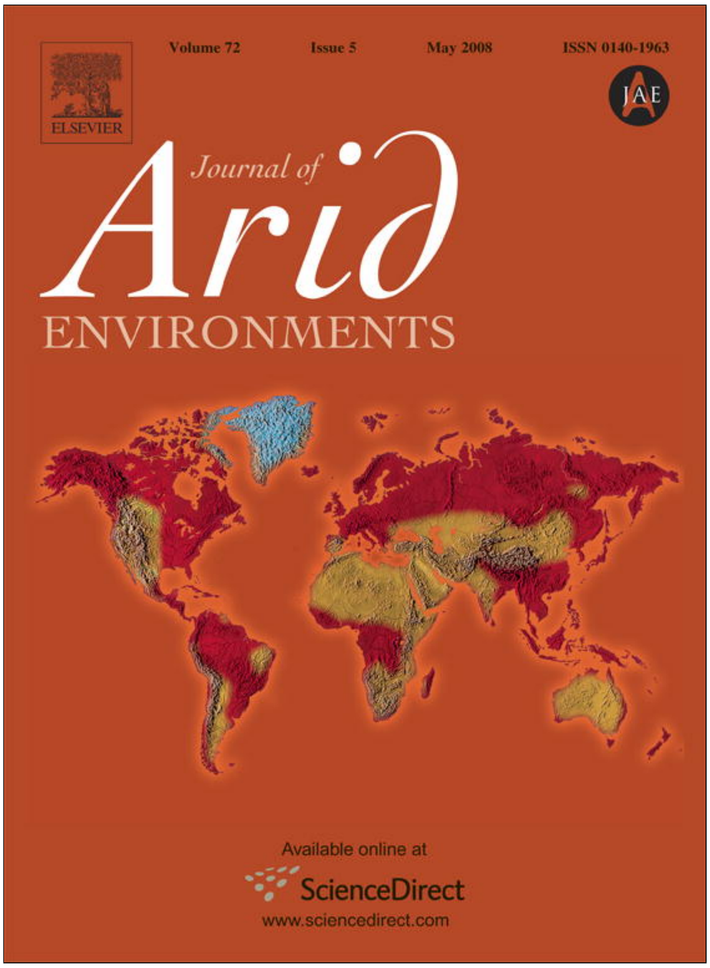
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Short Communication

Effects of camel grazing on density and species diversity of seedling emergence in the Dubai (UAE) inland desert

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Abstract

Germination in the arid rangelands of the UAE occurs as an 'event' following a mid-winter to spring rainfall. A fence line study of germination events was conducted in 2005 and 2006 to identify the response to differential grazing regimes. Fifty-six 1 m^2 seedling plots were destructively sampled each season. Heavy grazing reduced species richness and diversity without significantly reducing seedling density. Both annual and perennial species were impacted, though the reduction in richness of annual species was less pronounced than the natural variation among locations. Direct grazing of seedlings is limited to a few weeks, due to the short annual plant life span. Reduction of perennial seedling density and species richness was likely caused by the reduced size of adult plants under grazing. Recruitment of perennial species could be affected by heavy grazing, leading to loss of habitat, though under moderate grazing levels this could easily be compensated by greater survival.

Keywords: Conservation; Germination; Grazing; Rangeland; Species richness; United Arab Emirates

1. Introduction

Seed germination on the arid rangelands of the United Arab Emirates (UAE) occurs usually less than once a year in a mass event. The resultant seedlings are predominantly of annual species which have a life span of 2–3 months. Plant community structure in the region is considered to be most threatened by excessive livestock grazing (Hellyer et al., 2001), due to observations of perennial plant species. The aim of this study was to determine whether annual plant population structure and germination patterns of both annual and perennial species were influenced by two grazing systems of differing intensity.

Rangeland herbivore populations of the UAE have changed radically in the last half-century. The domestic camel population has expanded, while native herbivore populations have suffered varying degrees of decline (Gallacher and Hill, 2006b). Herbivore populations have thus trended toward a single, large species. Perennial plants use a combination of physical and chemical defenses against herbivory, but annual species rely on the reduced risk of exposure that comes from a short life cycle and coordinated mass germination. Overall grazing

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intensity is thought to be much greater today, and animals are no longer free to move to regions that have experienced localized rainfall.

Plants in arid environments must use highly unpredictable occurrences of soil moisture to grow from seed to reproduction. On average, fewer than half of all desert annual plants reach reproductive maturity (Beatley, 1967), and many reach maturity in poor condition (Went, 1953, 1955). Germination occurs in response to environmental cues that make their survival to reproduction likely (Del Pozo and Aronson, 2000). Arid species generally mature in a shorter time and at a smaller size, and allocate proportionally more synthate to reproductive structures than do wetter climate species (Bell et al., 1979). Germination in the United Arab Emirates is triggered by rain events from mid-winter to spring. All species appear to exhibit seasonal seed dormancy, preventing them from responding to rainfall at other times. Elsewhere, germination percentages were greater in seeds that had undergone dormancy (Boeken et al., 2004; Capon and Asdall, 1967). Amount and timing of rainfall is the most important factor influencing seed germination (Baskin et al., 1993; Brown, 2003; Freas and Kemp, 1983; Gutierrez and Whitford, 1987; Halwagy, 1962; Shreve, 1942) and species composition (Brown, 2003; Guo et al., 2000). Chemical cues are also important (Boeken et al., 2004), such as the presence of soil nitrogen (Skujins 1981; West and Skujins, 1978). Spatially, variable soil water and chemistry could therefore contribute to variable germination patterns over small areas. Seedling density and size in the UAE exhibit wide temporal and spatial variation in both plant density and size. Abundance of a desert species within a season is correlated with frequency among seasons, and rare species are more likely to appear in good seasons (Guo et al., 2000). Most species in Oman had higher germination densities in open spaces, but a few preferred microhabitats under trees such as *Acacia tortilis* (Robinson, 2004).

The objective of this study was to determine whether species abundance, diversity and richness of annual and perennial seedlings differed between the two grazing systems, one characterized by heavy camel grazing and the other by lighter oryx and gazelle grazing.

2. Study site

Observations were made on either side of a 24.12 km looped fence that mainly transects dunes, but also crosses 150 m of gravel substratum. Dunes vary from highly active (Southern fence) to stable and well-vegetated with perennial plants (North Western fence). Outside the fence is the Dubai Desert Conservation Reserve (DDCR) in which the density of camels is approximately 0.05 camels ha^{-1}. Camels are given supplementary feed by their owners, so the effective grazing pressure on desert plants is lower. The inner enclosure (Al Maha) was formed in July 1999 with the completion of the fence under study. The 27.09 km^2 Al Maha enclosure is kept free of camels, but is stocked with approximately 250 oryx and 200 gazelles. Since 2005 these livestock have been free to move between Al Maha and the DDCR. Perennial shrub studies have shown that grazing intensity in the DDCR is much greater than in Al Maha (Gallacher and Hill, 2006a). Hence, 'heavy grazing' will be used to refer to DDCR plots.

Perennial vegetation throughout the research site is dominated by *Leptadenia pyrotechnica*. Although considered a fodder species in the UAE (Khan, 1980), it is only moderately palatable and is often avoided by livestock, particularly cattle (Ould Soulé, 1998). Perennial grasses exist but are rare. Further details of perennial vegetation can be found in other publications from this research (Gallacher and Hill, 2005, 2006a).

Plants recorded in this study were the result of several rainfall events in and around January 2005, and a single downpour on 23 February 2006. Rainfall had been very low for the previous 5 years. Accurate weather data for the site is unavailable, since there is no weather station in this ecological zone. Records from the Dubai International Airport approximately 70 km northeast of the DDCR indicate an average annual rainfall of 93.8 mm that falls mostly between December and April (World Meteorological Organization, 2006).

3. Plant density, species richness and diversity

Four Al Maha and four DDCR 1 m^2 plots were sampled near each of six midpoints of the main fence sections, 6–8 weeks after germination, in 2005 and 2006. Specific plot coordinates were chosen visually to sample patches of high seedling emergence, and to exclude perennial plants with a canopy diameter larger than 10 cm. This sampling was used because seedling emergence is highly spatially heterogeneous (Brown 2003;

Guo et al., 2000; Robinson, 2004), with large areas of little or no germination punctuated by smaller areas of relatively dense germination. Complete random sampling would have been susceptible to outliers, and would not have been reliably analyzable parametrically. Densities and diversity measures in this study are therefore reflective of these denser seedling patches. All plots were at least 20 m from the fence to remove anthropogenic or livestock traffic effects. In addition, eight plots were sampled on each side of the fence on the gravel plain, using two transects (first plot 20 m from the fence, each plot then 10 m further away). This different methodology was due to spatially consistent germination on this substrate. All seedlings within a plot were counted and identified using nomenclature from (Jongbloed et al., 2003). Plants emerging from preexisting rootstock were excluded. Statistical analysis was performed using SPSS 12.0.1 for Windows. Box plots were used to assess distribution, and data displaying a lognormal distribution were transformed. Plant diversity was assessed using the inverse Simpson's index (d_s).

$$d_s = \frac{N(N-1)}{\sum n_i(n_i-1)},$$

N represents the total number of plants, and n_i represents the number of individuals of species i. This diversity index measures the inverse of the probability that two randomly selected plants from the plot will belong to the same species (Brower et al., 1997). Factorial analysis of variance was used to test the effects of season (2005, 2006), enclosure (Al Maha, DDCR), location (each of the six fence midpoints, and the gravel location), and their interactions on plot data. Bivariate correlations were conducted on plot seedling density and species richness, and plot seedling density and diversity.

A total of 24 species, 13 annual or biannual and 11 perennial, were observed to germinate (Table 1). The list is not exhaustive for the DDCR since other species were observed outside the sampled plots (e.g. *Convolvulus cephalopodus*, *Chrozophora plicata*, *Calotropis procera* and *Dipterygium glaucum*). There was a three-fold difference in seedling densities between 2005 and 2006, due mainly to a 10-fold difference in the germination of *Eremobium aegyptiacum* (Fig. 1a,d). Plots with greater seedling density tended to have both a higher species richness ($P<0.001$) and diversity ($P = 0.002$). Nine species were more prevalent in 2005 and six were more prevalent in 2006 (Table 1). This result concurs with previously reported temporal variation (Guo et al., 2000).

Heavy grazing reduced species richness ($P<0.001$) and diversity of seedlings ($P = 0.005$), supporting previous research (Osem et al., 2002), but did not significantly affect overall plant densities in the study ($P = 0.272$, Fig. 1a–c). DDCR plots contained an average of two fewer species than Al Maha plots. Richness of both annual and perennial species was reduced by grazing ($P = 0.004$ and $P<0.001$, respectively), though the impact on annual species was much less pronounced (Fig. 1e,f). Total number of perennial seedlings was 17% lower in the DDCR, falling to 37% lower when *Cyperus conglomeratus* was removed from the dataset. *C. conglomeratus* is a sedge that colonizes disturbed areas in large numbers. A similar decrease in perennial seedlings was observed by West (1979). It is likely that heavy grazing of established perennial shrubs reduces their seed production in comparison to annual plants. Grazing has reduced median perennial plant cover in the DDCR to almost a third of that in Al Maha (Gallacher and Hill, 2006a).

Camels were observed grazing on dense stands of the annual *E. aegyptiacum* 35 days after germination (Fig. 2). Although this study did not include grazing observations, it appears that large herbivores would have had a 3–4 weeks period of grazing on annual seedlings.

4. Conclusions

Rangeland that was exposed to heavy grazing showed reduced species diversity, and species richness of perennial seedlings within the patches of relatively dense germination of the Dubai inland desert. Annual species were less affected by grazing, and possibly not affected at all. The lower recruitment of perennial seedlings is likely due to the reduced size of adult plants leading to lower seed production. Grazing is unlikely to significantly impact annual or perennial plants within the season of germination, due to the short exposure time to herbivores. It is possible that recruitment of perennial species is reduced by heavy grazing, leading to loss of habitat, though under moderate grazing levels this could easily be compensated by greater survival.

Table 1
Presence and density of seedlings observed in lightly grazed Al Maha and the heavily grazed Dubai Desert Conservation Reserve (DDCR) separated by species, preferred substrata (sand or gravel) and season

Species	Season	No. of plots in which species was observed				Plant density across all plots (num m^{-2})			
		Gravel (8 plots)		Sand (24 plots)		Gravel (8 plots)		Sand (24 plots)	
		Al Maha	DDCR	Al Maha	DDCR	Al Maha	DDCR	Al Maha	DDCR
Annual/biennial species									
Gravel substratum preferred									
Monsovia nivea	2005	5	7	2	1	5.3	9.1	0.1	0.0
	2006	8	8	–	1	35.2	18.1	–	0.3
Neurada procumbens	2005	6	8	2	1	1.8	3.3	0.1	0.0
	2006	7	4	2	–	2.0	0.9	0.1	–
Gravel or sand									
Arnebia hispidissima	2005	7	8	12	8	6.0	11.0	8.3	4.4
	2006	5	6	6	4	2.0	3.9	7.4	1.7
Cenchurs spp.	2005	–	–	2	3	–	–	0.1	0.2
	2006	4	5	14	9	1.7	2.5	1.6	1.8
Dichanthium foveolatum	2005	6	6	14	9	2.4	3.3	2.2	1.3
	2006	8	8	9	7	8.0	20.3	1.8	0.9
Sand substratum preferred									
Eremobium aegyptiacum	2005	5	4	23	22	1.4	2.3	9.0	10.4
	2006	7	7	23	24	11.0	32.9	117.7	111.9
Plantago boissieri	2005	1	4	2	6	0.3	0.8	0.8	2.1
	2006	3	2	5	2	1.2	0.5	5.1	3.8
Launaea mucronata	2005	3	–	11	8	0.5	–	1.3	1.0
	2006	2	–	7	5	0.2	–	1.0	0.6
Lotonis platycarpa	2005	–	–	3	4	–	–	0.2	1.0
	2006	–	1	6	3	–	0.1	1.1	0.3
Launaea capitata	2005	–	–	5	2	–	–	0.3	0.1
	2006	–	–	2	1	–	–	0.1	0.2

Gisekia pharnaceoides	2005	–	–	6	2	–	–	0.5	0.2
	2006	–	–	7	4	–	–	1.0	1.5
Silene villosa	2005	–	–	9	5	–	–	3.8	3.0
	2006	–	–	8	6	–	–	1.9	1.5
Schweinfurthia papilionaceae	2005	–	–	6	–	–	–	0.5	–
	2006	–	–	1	–	–	–	0.0	–
Perennial species									
Gravel substratum preferred									
Fagonia indica	2005	3	–	–	–	1.1	–	–	–
	2006	6	1	–	–	2.3	0.1	–	–
Heliotropium kotschyi	2005	2	–	–	–	0.5	–	–	–
	2006	–	–	–	–	–	–	–	–
Gravel or sand									
Heliotropium digynum	2005	4	–	12	5	1.1	–	1.5	0.3
	2006	2	2	10	2	0.2	0.8	1.6	0.1
Pennisetum divisum	2005	1	3	7	3	0.4	0.6	1.4	0.3
	2006	3	–	2	1	0.4	–	0.1	0.1
Haloxylon salicornicum	2005	–	1	1	–	–	0.1	0.0	–
	2006	–	–	–	–	–	–	–	–
Sand substratum preferred									
Tribulus pentandrus	2005	–	–	–	–	–	–	–	–
	2006	1	–	2	–	0.1	–	0.3	–
Cyperus conglomeratus	2005	–	1	18	20	–	0.1	4.6	8.2
	2006	–	–	12	4	–	–	1.0	0.4
Indigofera colutea	2005	4	–	11	3	0.6	–	6.8	9.1
	2006	–	–	4	2	–	–	0.5	0.1
Indigofera intricata	2005	–	–	1	2	–	–	0.3	1.1
	2006	–	–	3	–	–	–	0.3	–
Moltikoliopsis ciliata	2005	–	–	9	6	–	–	2.3	0.3
	2006	–	–	14	4	–	–	2.5	0.3
Fagonia spp. (not *F. indica*)	2005	–	–	1	2	–	–	0.1	0.6
	2006	–	–	–	–	–	–	–	–

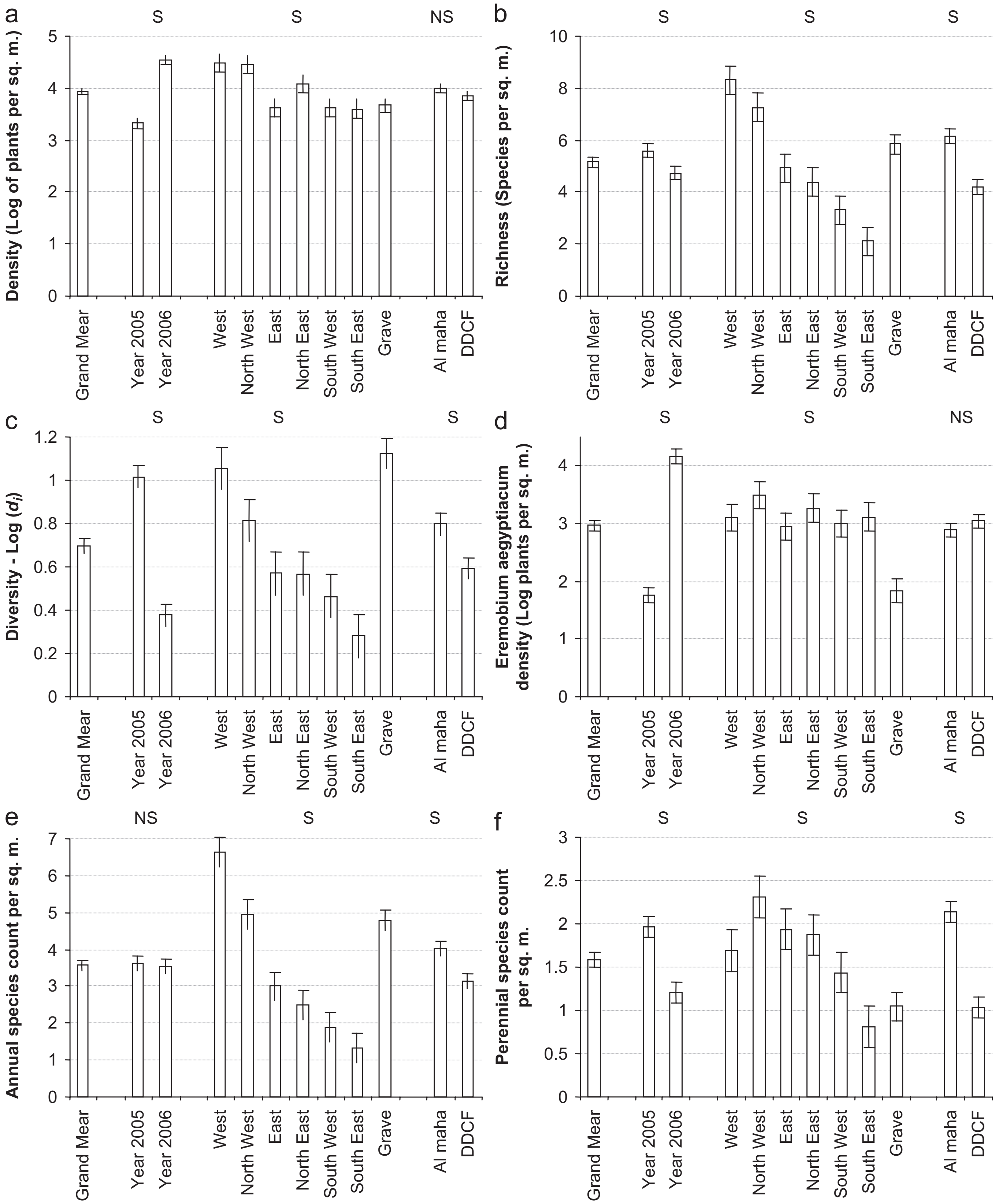

Fig. 1. (a–f) Effects of season (2005 and 2006), location (sand substrata, represented by compass points, and gravel substrata) and grazing system (Al Maha, DDCR) on measures of seedling species abundance and diversity within denser seedling patches. Heavy camel grazing is represented by the DDCR. Error bars indicate standard error. Statistical significance (S) or non-significance (NS) is indicated for variation among seasons, locations or grazing systems.

Fig. 2. Camel grazing on an area dominated by flowering *Eremobium aegyptiacum* 35 days after germination. *E. aegyptiacum* were 5–6 cm tall with roots 6–10 cm deep.

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