3B2v8.06a/w (Dec 5 2003).51c +model YJARE : 1619 Prod.Type:FTP pp.1–13(col.fig.:1–2) ED:SabithaRD PAGN:anu SCAN:v4soft

ARTICLE IN PRESS

ELSEVIER

Journal of Arid Environments ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Journal of Arid Environments

www.elsevier.com/locate/jnlabr/yjare

Effects of camel grazing on the ecology of small perennial plants in the Dubai (UAE) inland desert

D.J. Gallacher*, J.P. Hill

Zayed University, P.O. Box 19282, Dubai, United Arab Emirates

Received 6 April 2005; received in revised form 29 November 2005; accepted 5 December 2005

Abstract

Camel grazing is recognized as a primary cause of ecological degradation in the UAE. A study of perennial plant species <1 m in height was conducted along a fence separating continuously camel grazed land from land in which camels had been replaced by oryx and gazelle species for 5 years (Al Maha). Vegetation regeneration in Al Maha in the absence of camels was considerable on all substrates (gravel, stable sand, and semi-stable sand) but was greatest on the gravel substratum, indicating that ecology in this habitat is most at risk. Observed regeneration was primarily through vegetative reproduction and growth of existing plants, showing that existing species can tolerate heavy grazing. Therefore, an equilibrium grazing model of continuous and reversible vegetation dynamics is most suitable for management of this ecological zone. Species richness was greater in Al Maha due to the greater number of plants, but biodiversity was unaffected. There was some evidence of localized dune stabilization within Al Maha due to increased vegetative cover. Further recovery of vegetation within Al Maha is discussed. This study highlights the need for reduced grazing pressure throughout the Dubai inland desert, and in particular on gravel substrata.

Keywords: Conservation; Desertification; Rangeland; United Arab Emirates; Vegetation dynamics

1. Introduction

Camel grazing affects over 90% of land on the Arabian Peninsula, of which 44% is severely or very severely degraded (Ferguson et al., 1998). Heavy stocking rates reduce

*Corresponding author. Tel.: +971 50 755 3439; fax: +971 4 2640854.
E-mail address: David.Gallacher@zu.ac.ae (D.J. Gallacher).

0140-1963/$ - see front matter © 2006 Published by Elsevier Ltd.
doi:10.1016/j.jaridenv.2005.12.007

overall forage production, and consequently reduce livestock production (Holechek et al., 1999a). Ghazanfar (2004) suggested that it has increased the proportion of unpalatable shrubs and dwarf-shrubs throughout central Oman. In Northern Kuwait, Brown and Porembski (1998) suggested that the current dwarf shrub ecology probably arose through tens or hundreds of years of excessive grazing, replacing a savannah of Acacia trees and perennial grasses. In Saudi Arabia and Kuwait, livestock exclosures were reported to show a rapid recovery in plant biomass (Zaman, 1997; Barth, 1999), and similar observations have been made in the United Arab Emirates (Khan, 1980, 1981; Oatham et al., 1995). Nevertheless, ecology of the region in previous centuries included grazing by camels and other large herbivores. Some grazing may be required to maintain plant biodiversity and maximize biomass production (Oba et al., 2000; Zaady et al., 2001).

Excessive grazing by camels is now recognized as the single greatest threat to the inland desert ecology of the UAE (Hellyer et al., 2001), due to a rapid increase in their numbers since unification of the Emirates. The national camel herd actually dropped from around 100 000 head in 1961 to a low of 39 500 in 1976, but then climbed steadily to approximately 250 000 in 2004 (FAOSTAT, 2004). There are 2.99 camels/km^2 in the UAE, compared to 0.12 camels/km^2 in Saudi Arabia. Other livestock populations have seen similar expansion, including goats (125 000–1 450 000 head) and dairy cattle (5000–115 000 head) over the period from 1961 to 2004. However, only camels are allowed to wander freely throughout the desert to graze. A cultural reverence for camels has so far prevented any legal restrictions being placed on their movement. Goats, on the other hand, must be kept permanently in pens in the Dubai emirate. Economic policies that subsidize livestock production have exacerbated overgrazing by keeping camel numbers high.

The Dubai Desert Conservation Reserve (DDCR) offers a unique opportunity to study regeneration of the Dubai inland desert under two management systems; one containing oryx and gazelles (Al Maha) and the other containing camels (DDCR). This is preferable to study livestock exclosures, since exclosures are neither natural nor preferable for managing plant ecology. The aim of this study was to investigate how these two different management systems have affected the ecology of dwarf shrub, sedge and grass species. Trees, large shrubs and gourds will be considered in separate studies.

Camels are allowed to graze the desert each day on an 'open-access' land use basis that is common throughout West Asia (Ferguson et al., 1998). The UAE desert is now divided into several open-access zones, demarcated mainly by fenced highways and urban encroachment. Farms therefore impact a much wider area than that of the buildings and irrigation plots. It is arguable whether the farms should be considered part of the natural ecosystem, or whether they should be removed to favor wildlife. The purpose of the DDCR is to preserve a part of the natural desert for future generations, while at the same time providing a resource for the tourism industry.

2. Methods

2.1. Study site

The Al Maha enclosure within the DDCR is approximately 70 km southeast of Dubai (24.82°N; 55.66°E) in the inland desert, 5–15 km from the Hajar mountain range. The soil has not been described, but is likely to be poor in organic matter and nitrogen (Western, 1988), available phosphorus (Melone, 1986), and possibly several micronutrients. Low

Table 1
Free ranging livestock held in the Dubai Desert Conservation Reserve, most of which are in the Al Maha inner enclosure (April 2005)

Species	Common name	Herd size
Oryx leucoryx	Arabian oryx	225
Oryx dammah	Scimitar-horned oryx	24
Gazella subgutterosa marica	Sand gazelle	15[a]
Gazella gazella cora	Arabian gazelle	150[a]
Gazella dorcas saudiya	Dorcas gazelle	30[a]
Gazella thomsonii	Thompson's gazelle	8

[a]Estimated number, based on the number introduced and frequency of sightings.

salinity is indicated by the presence of *Cyperus conglomeratus* (Dickinson and Furley, 1980; Boer and Sargeant, 1998) throughout the study site, and by the presence of *Calligonum comosum* (Brown, 1978; Khan, 1979) within Al Maha.

The Al Maha fence was completed as two enclosures that are now used as one, in January and July 1999. The combined enclosure surrounds 27.09 km^2 of desert within the DDCR, containing one plain of gravel substratum through the centre but mostly containing dune, and stocked at 0.092 oryx ha^{-1} and 0.075 gazelles ha^{-1} (Table 1). These livestock are given externally sourced feed, which supplies probably about half of the oryx's dietary requirement. Gazelles rarely make use of this feed.

The DDCR fence, completed July 2003, surrounds 225 km^2 (4.7% of the emirate) of sand and gravel substrata. The area contains 14 active farms with a combined herd of approximately 960 camels (0.043 camels ha^{-1}) and 4000 goats (contained within pens at all times). Livestock are given feed from irrigated crops, some of which are produced in the DDCR, but most camels are also allowed out of the farms each day to forage in the desert. Grazing intensity appears to vary across the DDCR, being greatest in the immediate vicinity of the farms. This variation has not yet been quantified.

Rainfall in the UAE was very low from before the Al Maha fence was completed, until the 2004/5 winter, which was very wet. This study was mostly completed before the first rains of this winter, and was fully completed before germination occurred. Accurate weather data for the site are unavailable, since there is no weather station in this ecological zone. However, records from the Dubai International Airport indicate an average annual rainfall of 93.8 mm that falls mostly between December and April (World Meteorological Organization, 2005), but which shows large temporal and spatial fluctuation.

The fence under study is 24.12 km in length, of which 150 m crosses gravel substratum. The natural botany of the DDCR is what Ghazanfar (2004) described as a Prosopis–Calligonum vegetation type, which extends through much of the inland dune desert of the UAE and Oman, and parts of Saudi Arabia.

2.2. Experimental design and data collection

Plots were sampled in 43 pairs, one on each side of the Al Maha fence, at roughly equal intervals along the fence. Initial intervals between plot pairs were set at 300 m, but this was later extended to 600 m as the total number of potential plot pairs became known.

Anthropogenically affected areas on the north fence were excluded (road, power line and buildings), as were high camel traffic areas at the southeast and northwest corners. Three plot pairs were sampled at close intervals on the gravel substratum on the western fence, to enable greater representation of this small area.

Specific coordinates of each plot were chosen visually to ensure that similar environments were sampled on each side of the fence. This technique reduced sampling variation caused by large micro-environmental differences, in which a relatively dense stand of vegetation would be bordered by unstable sand with no vegetation at all. The technique was chosen to lower the risk of statistical bias, particularly where the fence was parallel to active dunes, and to increase the statistical power of the analysis. Plot coordinates were chosen to exclude established *Calotropis procera*, *Leptadenia pyrotechnica*, *C. comosum* and *L. schawii* shrubs, as well as the gourd *Citrullus colocynthis*, since these will be studied separately using spatially broader sampling. The densest vegetation within a similar micro-environment (e.g. stable sand, active dune, semi-active or stable slope) was chosen. The sampling technique provides an efficient indication of biodiversity and enables a comparison of maximum local plant cover, but overestimates total plant cover.

Species name, diameter, and plant status (dead, alive, alive and sprouting) were recorded for each plant within a plot (18 m diameter, 254.5 m^2). Plants were ignored only if they were dead and easily removed from the soil. Species names used are those described in Jongbloed et al. (2003).

2.3. Statistical analysis

Statistical analysis was performed using SPSS 12.0.1 for Windows. Box plots were used to assess distribution. Most variables (plant canopy, total plot canopy, number of plants in a plot, and number of *C. conglomeratus* plants within a plot) exhibited a lognormal distribution, and only two (number of species within a plot, and inverse Simpson's index) were left untransformed. The inverse Simpson's index is a measure of diversity that takes account of species abundance within the plot. It estimates the likelihood that two plants selected randomly from the plot would be different species (Brower et al., 1997).

The main factor of interest in analysis was the type of grazing (i.e. camel grazed DDCR versus oryx and gazelle grazed Al Maha), but other factors were also considered when sufficient data were available, including vegetation differences along different fence lines (west, south, east, north) and ground surfaces (gravel, sand), and differences in plant status (dead, alive, alive and sprouting). χ^2 homogeneity tests were used to test for a difference in the presence of each species among plots in each enclosure. A two-way analysis of variance was used to test the effects of enclosure, fence and their interaction. A one-way analysis of variance (t-test) was then used to test other factors on a dataset that was reduced to prevent bias.

3. Results

3.1. All plant species

As expected, the analysis of plot cover and biodiversity measurements showed clear differences between enclosures. Al Maha plots contained almost three times the median plant cover, an average of one extra species, a more even balance among species as measured by the Simpson Index, and 36% higher median number of plants when compared to DDCR plots (Table 2). When the most common species, *C. conglomeratus*, was removed from the dataset, median plants per plot and plant cover in Al Maha rose to 3.1 and 3.4 times higher, respectively, but the difference in the Simpson's Index became insignificant. The biggest difference among enclosures was observed on the gravel substratum, where Al Maha plots contained more than 100 times the cover of DDCR plots. The active dune area along the south fence showed the least difference, but even here there was 1.8 times more cover in Al Maha plots.

The natural log of *C. conglomeratus* cover showed a highly significant negative correlation with several cover and biodiversity indicators. The most significant of these were the total number of species in a plot ($P = 0.000$, Pearson's correlation $= -0.385$) and the natural log of the number of other living plants ($P = 0.000$, Pearson's correlation $= -0.445$).

C. conglomeratus was present in all plots, and comprised 47% of all plants surveyed. Approximately two thirds of these plants were in the DDCR (Table 3) though total plant cover was the same between enclosures ($P = 0.280$). The DDCR contained many more small plants than Al Maha, and a lower proportion of dead plants ($P = 0.000$). The small plants (5 cm or less diameter) were mainly plants that had recently resprouted from rootstock. When these were removed from the dataset, the difference between Al Maha and the DDCR disappeared.

3.2. Species found mainly on the gravel substratum

All but four of the 169 observed *Heliotropium kotschyi* plants were growing either on the gravel substratum or close to it. All plants were alive and 91% were in Al Maha. Plants on the gravel substratum were much larger in Al Maha than the DDCR, resulting in a thousand-fold difference in plot plant cover. Plants that were growing on sand tended to be large, whereas on gravel there was a wider range of sizes. Only four *Fagonia indica* plants were observed in the survey, all of them on the Al Maha gravel substratum. This merely reflects the small sample size on the gravel substratum, as the species was abundant elsewhere on the Al Maha gravel substratum.

3.3. Species found mainly on sand

Most of the species that were common on sand were observed to show considerable recovery within Al Maha (Table 3). *Crotaleria aegyptiaca* and *Limeum arabicum* were found on a larger number of plots, while *L. arabicum* and *H. digynum* occurred in higher densities within plots. Individual plants of almost all species had a larger canopy cover within Al Maha. Only two species, *Dipterygium glaucum* and *Haloxylon salicornicum*, showed no significant differences between enclosures in any of these three categories, despite what appeared to be a large difference in median cover of individual plants. These two species were less common in the study site and variation among plant sizes was relatively large. *D. glaucum* plants were more likely to be dead inside the DDCR ($P = 0.005$).

Individual plants of *Moltikoliopsis ciliata*, *C. aegyptiaca* and *H. digynum* had a larger canopy when growing on sand rather than gravel. *L. arabicum*, *H. salicornicum*, *Indigofera*

Table 2
Summary of statistical differences in vegetation samples between the Al Maha enclosure and the Dubai Desert Conservation Reserve (DDCR)

	Median		Data transformation	Enclosure			*P*-values		
	Al Maha	DDCR		Mean		SE	Enclosure	Fence	Fence × encl.
				Al Maha	DDCR				
Data including Cyperus conglomeratus									
Number of plants per plot	87	64	Ln	4.25	3.94	0.11	0.046	0.000	0.056
Canopy of all plant species (m^2)	6.21	2.21	Ln	1.82	−0.02	0.15	0.000	0.000	0.000
Number of species	5	4	None	5.24	4.16	0.25	0.004	0.000	0.192
Inverse Simpson's Index	3.06	1.92	None	3.04	2.26	0.14	0.000	0.000	0.014
Data excluding Cyperus conglomerates									
Number of plants per plot	55	18	Ln	3.72	2.80	0.18	0.001	0.000	0.067
Inverse Simpson's Index	2.40	1.94	None	2.50	2.13	0.21	0.216	0.072	0.278
Canopy of all other plant species (m^2)	5.64	1.65	Ln	1.71	−0.48	0.21	0.000	0.000	0.000

Table 3
Summary of statistical differences in cover and density of plant species in the Al Maha enclosure and the Dubai Desert Conservation Reserve (DDCR)

Species	Number of plots in which the species was observed (of 43 plots)			Number of plants observed on all plots			Median canopy of individual plants (cm^2)		Canopy size of plants (natural log of cm^2)				
	Al Maha	DDCR	*P*-value[a]	Al Maha	DDCR	*P*-value[b]	Al Maha	DDCR	Al Maha		DDCR		
									Mean	SE	Mean	SE	*P*-value[c]
Species that were significantly affected by grazing													
Crotaleria aegyptiaca	16	2	0.000	118	6	0.234	3904	208	7.814	0.153	5.833	0.919	0.006
Limeum arabicum	26	13	0.009	292	43	0.011	1257	177	7.013	0.066	4.969	0.252	0.000
Heliotropium digynum	29	28	1.000	362	136	0.000	452	28	5.447	0.108	3.512	0.152	0.000
Cyperus conglomerates	43	43	1.000	1096	2283	0.019	20	7	3.302	0.059	2.184	0.043	0.000
Heliotropium kotschyi	7	4	0.520	154	15	0.219	133	3	4.697	0.189	1.673	0.375	0.000
Moltikoliopsis ciliata	24	22	0.829	574	345	0.123	79	7	4.290	0.060	2.166	0.060	0.000
Indigofera colutea	12	8	0.444	58	38	0.753	113	28	4.598	0.196	2.900	0.187	0.000
Pennisetum divisum	35	37	0.771	769	768	0.231	201	154	5.352	0.067	4.950	0.072	0.000
Indigofera intricate	2	4	0.676	14	27	0.389	44	7	3.415	0.460	2.263	0.239	0.018
Species that were not significantly affected by grazing													
Dipterygium glaucum	8	3	0.195	50	23	0.775	1626	962	7.165	0.222	6.708	0.222	0.209
Haloxylon salicornicum	4	5	1.000	33	19	0.575	3848	8659	8.131	0.292	8.700	0.412	0.256
Species that occurred in numbers too small for analysis in the survey													
Citrullus colocynthis	1	2	1.000	1	2	0.125	70686	25957	11.166	N/a	9.374	1.427	0.601
Leptadenia pyrotechnica	3	0	0.241	3	0	N/a	1963	N/a	7.992	0.859	N/a	N/a	N/a
Fagonia indica	2	0	0.494	4	0	N/a	215	N/a	5.101	0.697	N/a	N/a	N/a
Tribulus pentandrus	2	1	1.000	2	1	N/a	108	7	4.412	0.762	1.956	N/a	0.314

[a]Calculated using χ^2 homogeneity test.
[b]Calculated using a *t*-test of logarithmically transformed plant density in plots with one or more plants.
[c]Calculated using a *t*-test on logarithmically transformed data.

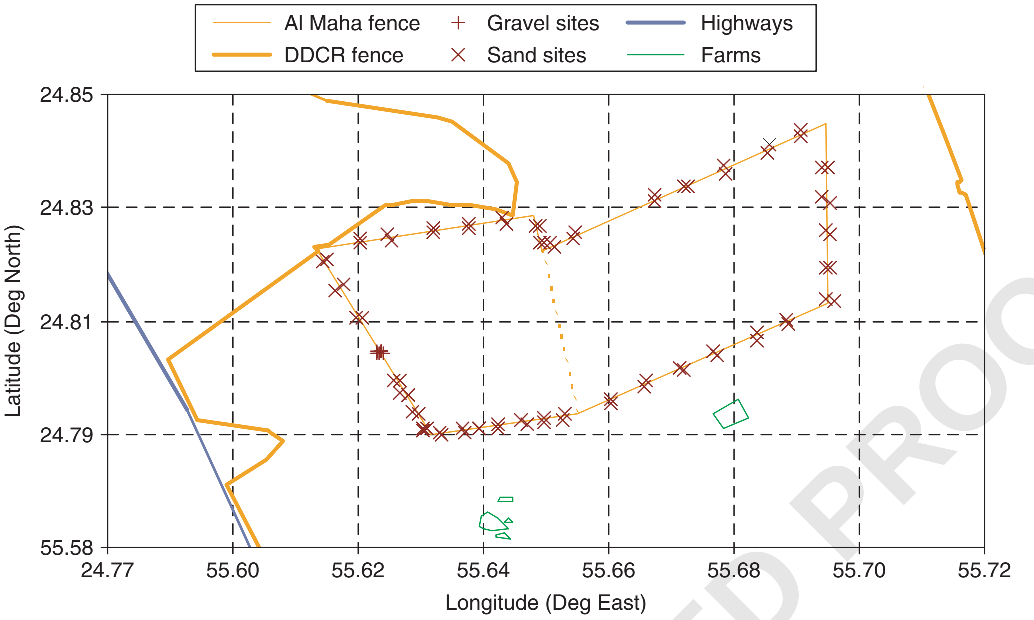

Fig. 1. Map of Al Maha enclosure within the Dubai Desert Conservation Reserve, showing proximity of plot pairs to camel farms, the DDCR fence and to the Dubai–Al Ain highway. North fence: Lower altitude dune with larger zones of stabilized sand and low camel grazing pressure. East fence: Mostly active, high altitude dunes and medium grazing pressure. South fence: Mostly active, high altitude dunes and high grazing pressure. West fence: Mostly low to medium altitude dunes but with 150 m of gravel substratum, and medium to high camel grazing pressure.

colutea and *L. pyrotechnica* were observed only on sand, though this may have been due to the small sample size on the gravel substratum.

Despite avoiding *L. pyrotechnica* shrubs during plot selection, three young plants were observed within Al Maha sand plots. It is possible that conditions within Al Maha are more suitable for regeneration, but the number of observations was not statistically significant (Fig. 1).

4. Discussion

4.1. Plant cover

The difference in gravel substratum vegetation between the DDCR and Al Maha is visually obvious (Fig. 2). This study showed that this increase is not limited to gravel substratum vegetation, but exists also in active and inactive dune areas. The vegetation increase affected most species (Table 3) and the percentage increase was similar to that in exclosure studies in Saudi Arabia (Barth, 1999) and Kuwait (Zaman, 1997).

Al Maha vegetation cover was 170% greater on sand plots and 9900% greater on gravel plots, due to vegetation being almost completely grazed to the ground on the gravel substrata. This shows that camels preferentially graze the gravel substrata vegetation and

Fig. 2. Vegetation growth on the gravel substrata in Al Maha (right) and the Dubai Desert Conservation Reserve (left).

that these habitats are most in danger of overexploitation. The reason may be nutritional (Milton et al., 1992), behavioral (Newman et al., 1994), or due to the energy cost of movement (Murray, 1991). According to the latter theory, larger animals expend more energy in moving and can therefore be less selective than smaller herbivores. On gravel, camels have an easier walking surface and a direct line of site to the next vegetation. Having spent the energy, camels then harvest a higher proportion of a plant than smaller herbivores. The main change in the study area was the recovery of *H. kotschyi*, though other species were important elsewhere within Al Maha.

There appeared to be a higher concentration of semi-stabilized sand areas in Al Maha, though this was not measured directly. This indicates that the increased vegetation had stabilized some active dune areas.

4.2. Biodiversity and regeneration

Al Maha plots had a greater species richness, but biodiversity was similar if *C. conglomeratus* was ignored. Species richness and biodiversity in an equilibrium system are both expected to peak under moderate grazing (Fernandez-Gimenez and Allen-Diaz, 1999), though grazing exclusion may still increase species richness when biomass production is less than 500 g/m^2 (Oba et al., 2001). Moderate grazing can be defined as one in which palatable species can maintain themselves but cannot usually increase their forage production (Klipple and Bement, 1961). The similarity in biodiversity can be explained by the regeneration that has occurred during the existence of the Al Maha enclosure. Of the 7236 plants observed during this study, not a single plant could be classified as a seedling. DDCR employees reported that germination did occur in April 2003 following a single storm, but was mainly apparent on the gravel substratum. Therefore, most of the regrowth that occurred in Al Maha came from plants that could survive the camel grazing that still occurs in the DDCR. This indicates that rootstock for regeneration is present in the DDCR, whether through rhizomes or through plants that have been grazed to a small stump.

4.3. Models of grazing and recovery

Overgrazing has often been blamed for ecological degradation, but its effect on vegetation is often overrated (Dean and Macdonald, 1994). Heavy grazing in arid and semi-arid environments can alter the ratio of individuals among plant species and modify plant form (Todd and Hoffman, 1999), but these factors are usually reversible through a change in land management. The main cause of irreversible decline is a change in soil structure (Wilson and Tupper, 1982) and soil infiltrability, to which sand substratum habitats are relatively resistant (Scoones, 1992). This study indicates that stabilized sand areas have been reduced through overgrazing, but this process occurs naturally and can be reversed. Number and size of phytogenic mounds under dwarf shrubs have been reduced, affecting the frequency and amount of fine particulate sand and patches of concentrated nutrients (El-Bana et al., 2003), but this process also occurs naturally. There is no evidence of extinction among plant species of this habitat, but the Arabian ostrich (*Struthio camelus syriacus*) was hunted to extinction in the 1940s (Gross and Jongbloed, 1996). Irreversible ecological degradation has occurred through the loss of this animal, and probably also in the genetic erosion of other animal species.

The ecology of the DDCR could be described as non-equilibrium model, since it is strongly affected by localized and highly variable rainfall events (Oba et al., 2000) and also by dune movement. This classification implies that recovery from external disturbances is unpredictable and has the potential to reach two or more relatively stable equilibriums (Briske et al., 2003). The study site has two important considerations for the model: (1) the relative importance of fog and dew to plant growth, which is unsubstantiated but could be a relatively consistent water source for some species (Malik et al., 1999; Jacobs et al., 2002), and (2) a stocking rate that is artificially supported through supplementary feed. This study indicates that existing plant species are adapted to heavy camel grazing and can recover quickly. The life-span of most plant species is longer than the normal duration of climatic extremes. Also, spatial variation at the local scale may cancel out within a scale of tens of square kilometers. Therefore, temporal change in species mix is probably more affected by grazing than climatic variation, as was observed in Egypt (Ayyad and El-Kady, 1982). The usual balance between livestock density and feed availability is disrupted by supplementary feed. Plants are still grazed heavily in good years, as livestock substitute desert plants for supplementary feed. These factors all indicate that a more traditional model of continuous and reversible vegetation dynamics following stress may be more useful for management of the DDCR.

It is clear on the gravel substrata that annual forage production has been reduced in the DDCR, due to reduced size and number of plants. This is also likely to be true of the sand substrata. More controlled grazing that allows desert plants to recover would enable farmers to reduce their reliance on supplementary feed. Studies in southwestern U.S.A. have indicated an optimal stocking rate for desert rangelands as one in which 30–35% of average annual forage production is removed by grazing (Smith et al., 1996; Holechek et al., 1999b). Although the rate of removal in the DDCR is not known, it is likely to be much higher than this.

Overgrazing by livestock affects the population of smaller herbivores, which are an important resource for wild carnivores (Hayward et al., 1997). The population of ‘dhub’ lizards (*Uromastyx aegyptius microlepis*) on gravel substrata has shown a clear recovery within Al Maha. Recovery of rodents, Cape hare (*Lepus capensis*), lizards and insects requires investigation. Reduced grazing pressure by camels in the DDCR should increase smaller herbivore populations and the populations of species that depend on these herbivores.

4.4. Vegetation recovery

It may take 20 to 50 years for natural vegetation states to emerge after changed grazing management, in habitats that are dominated by perennial species and dwarf shrubs (Allen-Diaz and Bartolome, 1998; Todd and Hoffman, 1999). The species mix currently in Al Maha is likely to represent a seral transitional state with succession time determined by the life-span of the plant species. Observations of early seedling growth following the 2004/5 winter rains (not yet published) have indicated that species composition within Al Maha will change as perennial seedlings emerge. Germination events do not occur every year, and their frequency may also affect emergence of vegetation states.

Potential vegetation recovery is not known, but could be substantial. An abandoned farm on the gravel substratum within the Al Maha enclosure contained 11% plant cover, compared to 1.8% in the plain bordering the farm and 0.02% in the DDCR gravel plots. Vegetation cover in the abandoned farm was dominated by a dense stand of smaller *H. kotschyi* dwarf shrubs, indicating that this species is an early colonizer of disturbed land and that the vegetation is in a transitional state. However, it also indicates that the plant cover of the Al Maha gravel substratum could increase another five-fold.

Grazing in an arid pastoral system is managed to maintain cover of palatable vegetation, which typically refers to perennial grasses (Archer, 1996). These grasses are intolerant to heavy grazing, compared to both woody shrubs and annual grasses (Jeffries and Klopatek, 1987; Beeskow et al., 1995; Todd and Hoffman, 1999). Annual species at the study site are limited to ephemeral species that were only present in seed form during the study and which, after rainfall, still represented a small fraction of the total biomass (unpublished data). Recovery of *Pennisetum divisum* (a perennial grass) in Al Maha was considerably less than recovery of the dwarf shrub species, and was limited to an increase in canopy size of existing plants (Table 3). Plants in both enclosures were being grazed and seed production was probably limited. It is likely that an increase of perennial grass plants will be a secondary stage of recovery under present conditions, as these plants can produce seeds more easily under the protection of woody shrubs such as *L. shawii*. Displacement of perennial grasses by woody plants has been well documented in heavily grazed arid rangelands (Archer, 1996). It is not known if such displacement has occurred in the DDCR, as suggested by Brown and Porembski (1998) for a similar habitat.

Dwarf shrub vegetation is likely to face increased competition from trees and shrubs with reduced camel grazing. The shrubs *L. pyrotechnica* and *C. comosum* have already increased in Al Maha though *C. procera* has probably decreased. The native tree *Prosopis cineraria* is preferred by camels, and thus may also return.

All plant species are grazed to some extent in the DDCR, even though most have either physical or chemical protection from grazing. Grazing of *C. conglomeratus* is an indicator of excessive grazing pressure in some locations (Ferguson et al., 1998) due to its low palatability (Ould Soulé, 1998). Archer (1996) mentions *Prosopis* spp. as unpalatable woody invaders, but DDCR farmers consider *Prosopis cineraria* to be one of the better sources of livestock feed. Although species of higher palatability might have been removed through grazing, it is possible that they never existed in the first place.

Acknowledgements

The authors would like to thank Greg Simkins and Husam el Alqamy, Dubai Desert Conservation Reserve, for their advice, cooperation and support. This work was made possible through the financial and administrative support of Zayed University, for which the authors are grateful.

References

Allen-Diaz, B.H., Bartolome, J.W., 1998. Understanding Sagebrush-Grass vegetation dynamics. Ecological Applications 8, 795–804.

Archer, S., 1996. Assessing and interpreting grass-woody plant dynamics. In: Hodgson, J., Illius, A.W. (Eds.), The Ecology and Management of Grazing Systems. CAB International, Wallingford, Oxon, U.K., pp. 101–134.

Ayyad, M.A., El-Kady, H.F., 1982. Effect of protection and controlled grazing on the vegetation of a Mediterranean desert ecosystem in northern Egypt. Vegetatio 49, 129–139.

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

Beeskow, A., Elissalde, N.O., Rostagno, C.M., 1995. Ecosystem changes associated with grazing intensity on the Punta Ninfas rangelands of Patagonia, Argentina. Journal of Range Management (U.S.A.) 48, 517–522.

Boer, B., Sargeant, D., 1998. Desert perennials as plant and soil indicators in Eastern Arabia. Plant and Soil 2, 261–266.

Briske, D.D., Fuhlendorf, S.D., Smeins, F.E., 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. Journal of Applied Ecology 40, 601–614.

Brower, J.E., Zar, J.H., von Ende, C.N., 1997. Field and Laboratory Methods for General Ecology, Fourth ed. WCB/McGraw-Hill, U.S.A.

Brown, J.N.B., 1978. Natural Vegetation and Reafforestation in Abu Dhabi. Emirates Natural History Group Bulletin 4, 31–32.

Brown, G., Porembski, S., 1998. Flora and vegetational aspects of miniature dunes in a sand-depleted *Haloxylon salicornicum* community in the Kuwait desert. Flora 193, 133–140.

Dean, W.R.J., Macdonald, I.A.W., 1994. Historical changes in stocking rates of domestic livestock as a measure of semi-arid and arid rangeland degradation in the Cape Province, South Africa. Journal of Arid Environments 26, 281–298.

Dickinson, P., Furley, C.W., 1980. Plants palatable to the Arabian Oryx. Emirates Natural History Group Bulletin 12, 4–6.

El-Bana, M.I., Nijs, I., Khedr, A.-H.A., 2003. The importance of phytogenic mounds (Nebkhas) for restoration of arid degraded rangelands in Northern Sinai. Restoration Ecology 11, 317–324.

FAOSTAT, 2004. FAOSTAT—Agriculture http://www.fao.org.

Ferguson, M., McCann, I., Manners, G., 1998. Less water, more grazing. ICARDA Caravan 8, 9–11.

Fernandez-Gimenez, M.E., Allen-Diaz, B.H., 1999. Testing a non-equilibrium model of rangeland vegetation dynamics in Mongolia. Journal of Applied Ecology 36, 871–885.

Ghazanfar, S.A., 2004. Biology of the central desert of Oman. Turkish Journal of Botany 28, 65–71.

Gross, C., Jongbloed, M., 1996. Traditions and wildlife. In: Vine, P.J., Al-Abed, I. (Eds.), Natural Emirates: Wildlife and Environment of the United Arab Emirates. Trident Press, London, U.K.

Hayward, B., Heske, E.J., Painter, C.W., 1997. Effects of livestock grazing on small mammals at a desert Cienaga. Journal of Wildlife Management 61, 123–129.

Hellyer, P., Al-Abed, I., Vine, P., 2001. United Arab Emirates: a new perspective. Trident Press, U.S.A.

Holechek, J.L., Gomez, H., Molinar, F., Galt, D., 1999a. Grazing studies: what we've learned. Rangelands 21, 12–16.

Holechek, J.L., Thomas, M., Molinar, F., Galt, D., 1999b. Stocking Desert rangelands: what we've learned. Rangelands 21, 8–12.

Jacobs, A.F.G., Heusinkveld, B.G., Berkowicz, S.M., 2002. A simple technique to estimate effects of fog deposition on dew measurements.

Jeffries, D.L., Klopatek, J.M., 1987. Effects of grazing on the vegetation of the Blackbrush Association. Journal of Range Management (U.S.A.) 40, 390–392.

Jongbloed, M., Feulner, G.R., Boer, B., Western, A.R., 2003. The Comprehensive Guide to the Wild Flowers of the United Arab Emirates. Environmental Research and Wildlife Development Agency, Abu Dhabi, UAE.
Khan, M.I.R., 1979. Taming the Abu Dhabi Desert. Emirates Natural History Group Bulletin 8, 19–22.
Khan, M.I.R., 1980. Al bujair nursery in the western region. Emirates Natural History Group Bulletin 10, 16–18.
Khan, M.I.R., 1981. Al babha plantation. Emirates Natural History Group Bulletin 13, 17–19.
Klipple, G.E., Bement, R.E., 1961. Light grazing—is it economically feasible as a range improvement practice? Journal of Range Management (U.S.A.) 14, 57–62.
Malik, E., McCurdy, G., Giles, B., 1999. Dew contribution to the annual water balances in semi-arid desert valleys. Journal of Arid Environments 42, 71–80.
Melone, J.-C., 1986. Common landscape plants in the UAE. Emirates Natural History Group Bulletin 29, 23–27.
Milton, S.J., Dean, W.R.J., Marincowitz, C.P., 1992. Preferential utilization of pans by springbok (*Antidorcas marsupialis*). Journal of the Grassland Society Southern Africa 9, 114–118.
Murray, M.G., 1991. Maximizing energy retention in grazing ruminants. Journal of Animal Ecology 60, 1029–1045.
Newman, J.A., Parsons, A.J., Penning, P.D., 1994. A note on the behavioural strategies used by grazing animals to alter their intake rates. Grass and Forage Science 49, 502–505.
Oatham, M.P., Nicholls, M.K., Swingland, I.R., 1995. Manipulation of vegetation communities on the Abu Dhabi rangelands. I. The effects of irrigation and release from longterm grazing. Biodiversity and Conservation 4, 696–709.
Oba, G., Stenseth, N.C., Lusigi, W.J., 2000. New perspectives on sustainable grazing management in arid zones of sub-Saharan Africa. Bioscience 50, 35–51.
Oba, G., Vetaas, O.R., Stenseth, N.C., 2001. Relationships between biomass and plant species richness in arid-zone grazing lands. Journal of Applied Ecology 38, 836.
Ould Soulé, A., 1998. Mauritania Country Profile. FAO Crop and Grassland Service, Rome, Italy.
Scoones, I., 1992. Land degradation and livestock production in Zimbabwe's communal areas. Land Degradation and Rehabilitation 3, 99–113.
Smith, G., Holechek, J.L., Cardenas, M., 1996. Wildlife numbers on excellent and good condition Chihuahuan desert rangelands: an observation. Journal of Range Management (U.S.A.) 49, 489–493.
Todd, S.W., Hoffman, M.T., 1999. A fence-line contrast reveals effects of heavy grazing on plant diversity and community composition in Namaqualand, South Africa. Plant Ecology 142, 169–178.
Western, R.A., 1988. Adaptations of plants to a desert environment. Emirates Natural History Group Bulletin 36, 17–23.
Wilson, A.D., Tupper, G.J., 1982. Concepts and factors applicable to the measurements of range condition. Journal of Range Management (U.S.A.) 35, 684–689.
World Meteorological Organization, 2005. World Weather Information Service—Dubai www.worldweather.org.
Zaady, E., Yonatan, R., Shachak, M., Perevolotsky, A., 2001. The effects of grazing on abiotic and biotic parameters in a semiarid ecosystem: a case study from the Northern Negev Desert, Israel. Arid Land Research and Management 15, 245–261.
Zaman, S., 1997. Effects of rainfall and grazing on vegetation yield and cover of two arid rangelands in Kuwait. Environmental Conservation 24, 344–350.