Journal of Arid Environments 73 (2009) 347–354

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Camel grazing affects species diversity and community structure in the deserts of the UAE

A. El-Keblawy [a,*], T. Ksiksi [a], H. El Alqamy [b]

[a] Biology Dept., Faculty of Science, UAE University, P.O. Box 17551, Al-Ain, United Arab Emirates
[b] Terrestrial Environment Research Center, Environment Agency – Abu Dhabi, United Arab Emirates

ARTICLE INFO

Article history:
Received 23 July 2007
Received in revised form
9 September 2008
Accepted 1 October 2008
Available online 25 November 2008

Keywords:
Community structure
Desert
Herbivory
Palatable plants
Species diversity

ABSTRACT

Camel grazing plays a crucial role in the desert ecosystems of the UAE. In this study, we compare areas grazed by small antelope (Al Maha Resort – the AMR) with areas grazed by both camels and small antelope (Dubai Desert Conservation Reserve – the DDCR). A total of 126 plots were selected during the growing season 2006/07 on three soil substrates: gravel plains, sand flats and sand dunes. In each plot, several vegetation parameters were assessed: density, frequency, percent cover and diversity indices. The replacement of camels with wild antelope has significantly increased the number of species on gravel plains, vegetation density on sand dunes and diversity indices on both sand flats and sand dunes, but significantly decreased plant cover on sand flats and sand dunes. The increase in species diversity in the AMR was attributed to moderate grazing by antelope. Replacement of camels by antelope in the AMR has resulted in change in plant community composition of the three substrate types. Species recovered after protection from camel grazing are palatable, especially for camels, except *Heliotropium kotschyi* and *Aerva javanica*. The absence of most of the palatable species from the DDCR was attributed to both selective foraging and overgrazing by camels.

1. Introduction

The effect of large herbivore grazing on plant species diversity has been investigated in various terrestrial ecosystems (Milchunas and Lauenroth, 1993; Proulex and Mazumder, 1998), but few have dealt with the UAE desert ecosystem (e.g., El-Keblawy, 2003; Gallacher and Hill, 2006). Camel grazing affects over 90% of the area of the Arabian Peninsula, of which 44% is severely or very severely degraded (Ferguson et al., 1998). In the inland desert ecosystems of the UAE, excessive grazing by camels has been recognized as the single greatest threat (Hellyer et al., 2001; Gallacher and Hill, 2006). Camels are allowed to wander freely throughout the UAE desert to graze, while other livestock, such as goats, must be kept permanently in pens (Gallacher and Hill, 2006).

The increase in grazing pressures, due to the sharp increase in the number of livestock in many Gulf countries, including the UAE (Oatham et al., 1995; Gallacher and Hill, 2006), has resulted in significant deterioration of desert rangelands (Assaeed, 1997; Brown et al., 2003). Batanouny (1990) indicated that over 30% of the grazing land in the Arab Gulf countries is in a depleted condition due to large numbers of livestock, unrestricted grazing, and destructive gathering of wood and dry farming. The UAE camel herd increased from 39,500 in 1976, to approximately 250,000 in 2004 (FAOSTAT, 2004). Consequently, the camel population density in the UAE is much higher (2.99 camels/km^2), than in other countries of the region, e.g. Saudi Arabia (0.12 camels/km^2) (Gallacher and Hill, 2006). Furthermore, camels represent an important part of the heritage of the UAE, and the government generously subsidizes their production (Cordes and Scholz, 1980; E-Government, 2007).

Camel grazing can affect plant community composition. Camels generally graze on a broad spectrum of fodder plants, including thorny bushes, halophytes and aromatic species, usually avoided by other domestic herbivores (Iqbal and Khan, 2001). In addition, camels are adapted to the poor feeding conditions of deserts by selecting diets of high quality throughout all the seasons. These diets include plants with high digestibility (Rutagwenda et al., 1989) and high crude protein content (Kamoun and Steinmetz, 1995; Woodward and Coppock, 1995). El-Keblawy (2003) showed that overgrazing by camels in the UAE resulted in a significant reduction in the palatable plants *Crotalaria aegyptiaca*, *Indigofera articulata*, *Pennisetum divisum*, *Stipagrostis plumosa*, and *Panicum turgidum*, suggesting that these species constitute an important part of camel diets in arid rangelands. While the above species were abundant inside the enclosures, they were not recorded in the overgrazed areas (El-Keblawy, 2003).

* Corresponding author. Tel.: +971 505432065.
E-mail address: a.keblawy@uaeu.ac.ae (A. El-Keblawy).

0140-1963/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jaridenv.2008.10.004

Understanding the dynamics of arid rangelands is a prerequisite for their proper management (Retzer, 2006). Arid rangelands are often fragile and subject to accelerated soil erosion. Consequently, continuous grazing has ultimately led to loss of vegetation, erosion, desertification, wildlife extinction and a drop in the water table of these lands (Kassas, 1995). In addition, heavy grazing by livestock can change plant community composition, especially in arid regions, where plant communities generally evolved in the absence of a heavy grazing by wild herbivores (Landsberg et al., 1999; Ayyad, 2003). Several studies have shown that heavy grazing results in a more specific compositional shift in plant communities (Ayyad and Elkadi, 1982; Noymeir et al., 1989; Olsvig-Whittaker et al., 1993). In the semi-arid succulent Karoo's biome, Anderson and Hoffman (2007) reported a significant compositional shift away from large woody and succulent shrubs, and an associated increase in dwarf shrubs and herbaceous perennial plants in the communal areas. Heavy grazing not only altered the diversity of the palatable plants but also changed the morphological structure and distribution patterns of dominant species on degraded arid lands of western China (Walker et al., 1981; Zhao et al., 2007).

Protection of vegetation against grazing in desert environments has been suggested as a feasible approach to halting land degradation in order to rehabilitate rangelands (Ayyad et al., 1990; Omar, 1991; Ayyad, 2003). The impacts of protection against livestock grazing on plant communities of arid and semiarid rangelands have been studied in many regions of the world, however with contradictory results. The impact of grazing on desert plant communities is usually moderated by managing grazing intensity, duration, and type of grazing animal. Light to moderate grazing improved plant diversity (Waser and Price, 1981; Ayyad and Elkadi, 1982; Ayyad and Fakhry, 1996; El-Keblawy, 2003), while overgrazing resulted in significant losses in plant cover and diversity (Brady et al., 1989; Shaltout et al., 1996; Eccard et al., 2000). In addition, the duration of protection has significantly affected vegetation recovery in arid deserts. Whereas short term protection from grazing, mainly by camels, resulted in a significant recovery, longer term protection apparently results in deterioration of the biodiversity and biomass of desert vegetation (Omar, 1991; El-Keblawy, 2003). In Kuwait, for example, vegetation protection for three years led to an increase in plant cover, frequency and production (Omar et al., 1990), but when the protection was extended for ten years in the same enclosure, it resulted in a deterioration of plant cover (Omar, 1991). Similarly, in the UAE, a four year program of protection resulted in a significant increase in species richness and abundance, compared to a 15 year program (El-Keblawy, 2003).

The Dubai Desert Conservation Reserve (DDCR) offers a valuable opportunity to study the impact of different types of grazing animals and grazing intensities under the harsh desert conditions of the UAE. This reserve provides two grazing arrangements; one with a low wildlife stocking rate, such as oryx and gazelles (Al Maha Resort, referred to here as the AMR) and an outer perimeter with a high camel stocking rate (referred to as DDCR). Gallacher and Hill (2006) compared the impact of the replacement of camel grazing by oryx and gazelles for five years on vegetation regeneration of small perennial plants in these two grazing systems. They concluded that plant regeneration in the absence of camels occurred on three types of substrates, but was greatest on the gravel substratum indicating that the ecology in this habitat is most at risk. However, their conclusion regarding that substrate type was based only on three closely located plots. The present study aims to compare the impact of the replacement of camel grazing by both oryx and gazelles for seven years on vegetation regeneration in three substrate types within the two grazing systems (i.e., the AMR and the DDCR). Several community attributes, such as species diversity, frequency, density, cover, importance value index and composition of all sizes of perennial plants, including medium and large shrubs, were used to assess plant recovery and community structure in the two grazing systems.

2. Materials and methods

2.1. Study area

The Dubai Desert Conservation Reserve (DDCR – 24°–25° latitude and 55°–56° longitude) is a designated area set aside for protection of the natural flora, fauna and landscape of the desert ecosystem in Dubai, UAE (Fig. 1). It lies within an arid area, characterized by two distinctive seasons: a long dry season (April–November) with very high temperatures, and a short season (December–March) with mild to warm temperatures and light rainfall. The climatic data of Sharjah Airport, which is one of the nearest meteorological stations to the study area, shows that the mean daily temperature ranges between 12.1 °C in January to about 42 °C in June–August. The long-term records (1934–2004) of this metrological station showed an average rainfall of 102.8 mm. However, variations in annual rainfall are considerable. A maximum of 345 mm was recorded in 1957 while a minimum of 3.0 mm was recorded in 1985 (Feulner, 2006).

The DDCR encompasses about 225 km^2 of sand dune desert and covers about 5% of the total area of Dubai Emirate. The DDCR is a fenced area with a perimeter of about 85 km. The reserve was declared in 2002 and the perimeter was completed in late 2003. The DDCR is mainly a sand dune–desert ecosystem. The topography is simple with the landscape dominated by low to medium-high sand dunes. The altitude variation is not profound; the maximum is 260 m above mean sea level in the south and gradually sloping towards the north to reach a minimum of 180 m. Gravel plains and sand flats are also present among the sand dunes. Sand flats are essentially low lying, stabilized sandy areas with intervening sand dunes. Gravel plains are similar to sand flats, but are covered with variously sized pebbles and rocks.

Several farms are still present inside the DDCR and camels are free to roam. The numbers of camels counted in the DDCR is 1209. This yields a density of 5.37 camel/km^2 (DDCR livestock survey 2004). The stocking rate at the DDCR is calculated to be about 8 Animal Unit Equivalents (AUE)/km^2. Incorporated now within the area of the DDCR is the Al Maha Resort (AMR). The AMR is a smaller area of 27 km^2 that was fenced off in 1999, and since that time has been excluded from all livestock grazing practices. Until now the AMR has supported only wild desert antelopes as free ranging animals. These antelopes are given externally sourced feed, which supplies probably about half of the oryx's dietary requirement. Gazelles rarely make use of this feed (Gallacher and Hill, 2006). The herd size at the AMR was estimated as, 225 *Oryx leucoryx* (Arabian oryx), 18 *Oryx dammah* (Scimitar-horned oryx), 28 *Gazella subgutterosa marica* (Sand gazelle), 150 *Gazella gazella cora* (Arabian gazelle), 30 *Gazella dorcas* (Dorcas gazelle), and 2 head of *Gazella thomsonii* (Thompson's gazelle) (Gallacher and Hill, 2006). This represents a stocking rate of about 3 AUE/km^2, setting the AMR stocking rate much lower than for the DDCR.

2.2. Vegetation study

As described above, three substrate types (gravel plains, sand flats and sand dunes) were identified in both the AMR and the DDCR. During January 2007, before the onset of the 2006/2007 rainy season, a total of one hundred and twenty-six plots were randomly selected on the three main substrates: Thirty-six were on sand dunes (twenty-one in the AMR and fifteen in the DDCR), twenty-eight were on sand flats (sixteen in the AMR and twelve in the DDCR) and sixty-two were on gravel plains (forty-nine in the AMR and thirteen in the DDCR).

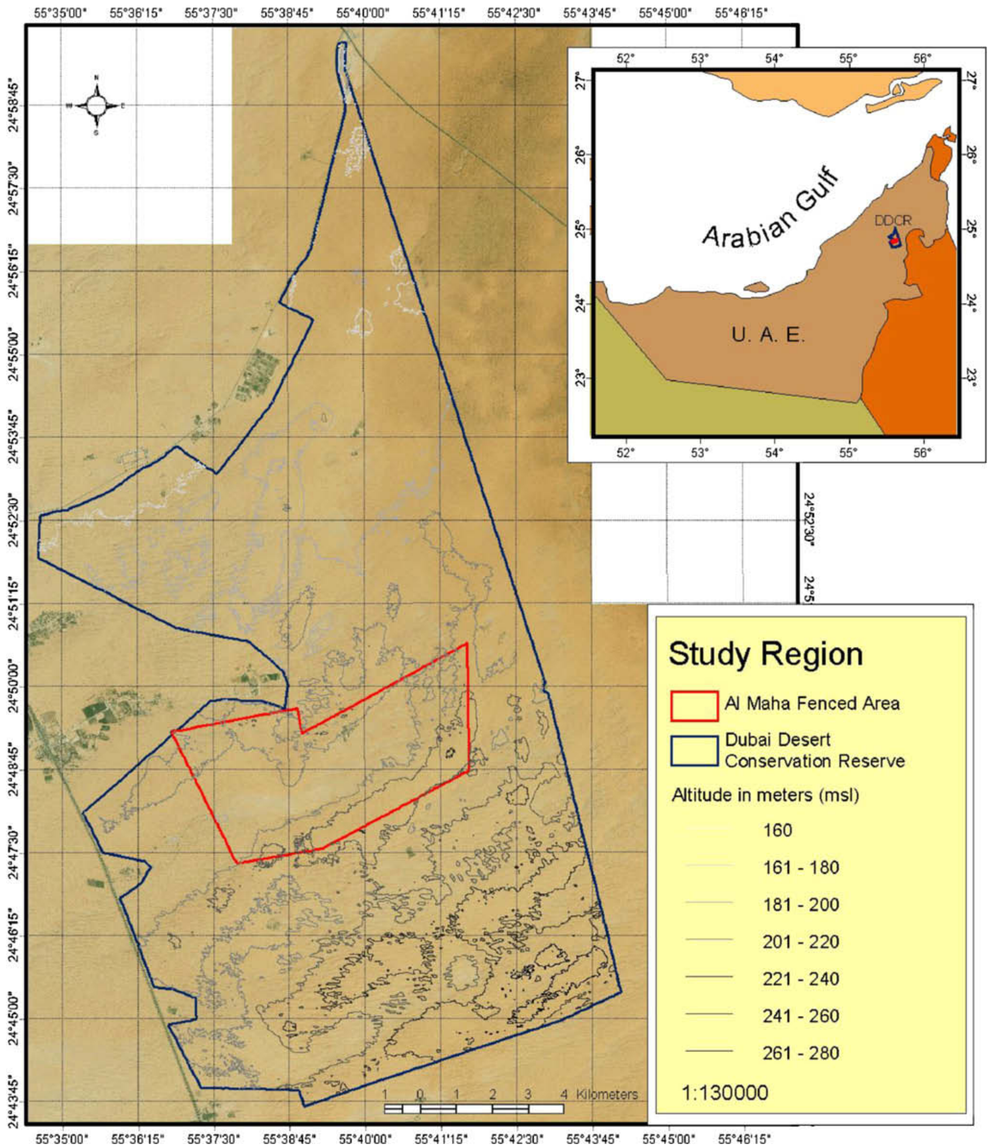

Fig. 1. Location map of the Dubai Desert Conservation Reserve (DDCR), core fenced area of Al Maha Resort (AMR) and the topography as 20 m slope increment contour lines.

The plots were sampled using a method modified from McAuliffe (1990). The strategy of sample selection was somewhat different for the three different substrates. For gravel plains and sand flats, randomly distributed points were generated separately for each of the individual plains and flats. Random sampling extension in ArcView 3.2a (ESRI Inc., 1996) was used to generate the random points in these habitats. The number of points varied in the different plots of these substrate types, according to surface area. Selection of sampling plots was managed subjectively to cover habitat variations. For the sand dunes, a different approach was adopted, in that a 500 m grid was generated over the whole area. Centeroids of grid units were generated and formed a group out of which a subgroup was selected to be sampled using a randomization extension of ArcView (ESRI Inc., 1996).

At the sampling points, circular plots (50 m diameter) were used. In each plot, the following plant community attributes were assessed: density, relative density, frequency, relative frequency, percent cover and diversity indices. The importance value index (IVI), which is the sum of relative values of density, frequency and cover was also calculated for each species. Three species diversity indices (Simpson, Shannon-Weaver and Birllioun) were calculated on the basis of the relative cover of species. The nomenclature of plant species followed Jongbloed (2003).

The significance of the difference of total number of species between the two grazing systems was assessed by χ^2 tests. One-way analysis of variance (ANOVA) was used to evaluate the effect of grazing system on species diversity, density and cover within each substrate.

3. Results

3.1. Effects on species diversity and abundance

The elimination of overgrazing by camels in the AMR reserve has resulted in a significant increase in the number of species in the gravel plains, but not in either of the sand flat and sand dunes substrates. The number of species increased from nine species in the DDCR to fifteen species in the AMR in the gravel plains (Table 1).

The effect of protection against camel grazing on species diversity were gauged by calculating three diversity indices (Simpson, Shannon-Wiener and Birllioun). None of these diversity indices was significantly affected by protection against camel

Table 1
Comparisons of some community attributes between different habitats in the Al Maha Resort enclosure (AMR) and camel grazed Dubai Desert Conservation Reserve (DDCR).

Community attributes	Gravel plains		Sand flats		Sand dunes	
	AMR	DDCR	AMR	DDCR	AMR	DDCR
Number of species	15[a]	9[b]	14[a]	12[a]	8[a]	10[a]
Diversity indices						
Simpson	0.48[a]	0.43[a]	0.70[a]	0.55[b]	0.35[a]	0.32[a]
Shannon-Wiener	0.99[a]	0.82[b]	1.93[a]	1.32[b]	0.91[a]	0.84[a]
Birllioun	0.90[a]	0.63[b]	1.82[a]	1.05[b]	1.05[a]	1.01[a]
Plant density (ind./1000 m^2)	9.9[a]	7.1[a]	12.6[a]	10.0[a]	10.6[a]	4.6[b]
Plant cover (%)	1.13[a]	0.82[a]	0.51[b]	0.91[a]	0.41[b]	0.66[a]

Averages with different letters – within the same row and same soil substrate – indicate significant differences at $P < 0.05$.

grazing in sand dunes. However, two indices (Shannon-Wiener and Birllioun) increased significantly in sand flats and gravel plains, within the AMR as compared to the DDCR. The Shannon-Wiener and Birllioun indices were greater for the AMR, than the DDCR, by 46% and 73%, respectively in sand flats and by 21% and 43%, respectively, in gravel plains (Table 1).

Protection against camel grazing has resulted in a significant increase in the density of individual plant species in the sand dunes, but not on the gravel plains and sand flats. The density was greater in the AMR than the DDCR by 130% on sand dunes, but by only 26% and 39% on sand flats and gravel plains, respectively. Similarly, plant cover was greater in the AMR than in the DDCR on gravel plains, but the reverse was true on sand dunes and sand flats. Cover was greater in the DDCR than in the AMR by 78% and 66% on sand flats and sand dunes, respectively, but was greater in the AMR than in the DDCR by 37% on gravel plains (Table 1). The increase in plant cover on both sand dunes and sand flats of the DDCR is attributed mainly to the dominance of *Cyperus conglomerates* in these habitats. Excluding the cover of this species from the analysis resulted in insignificant differences in plant cover between the DDCR and the AMR in both sand dunes and sand flats.

3.2. Effects on species composition

3.2.1. Gravel plains

In the camel grazed gravel plains in DDCR, *Haloxylon salicornicum* was the dominant species (IVI = 111.5) and *Cyperus conglomeratus*, *Calotropis procera* and *Leptadenia pyrotechnica* were the co-dominant species (IVI = 41.2, 29.5 and 32.6, respectively). However, *H. salicornicum* and *C. conglomeratus* attained very low IVI values within the AMR enclosure in the same substrate type (4.3 and 1.9, respectively, Table 2).

The dominant and co-dominant species on the gravel plains within the AMR enclosure were *Heliotropium kotschyi* (IVI = 96.4) and *L. pyrotechnica* (IVI = 53.8), respectively. The first species was not recorded and the latter attained very low frequency and density in the DDCR. In addition, five other species have recovered in the AMR, as a result of protection from camel grazing. These species are *Limeum arabicum*, *Aerva javanica*, *Dipterygium glaucum*, *Moltkiopsis ciliate* and *C. aegyptiaca* (Table 2).

3.2.2. Sand flats

L. pyrotechnica was the dominant and the co-dominant shrub in the DDCR and the AMR sand flats respectively. In addition, *Rhanterium epapposum*, *C. procera* and *Indigofera intricata* were among the dominant species on sand flats of the DDCR (IVI of these species were 39.5, 39.1 and 38.2, respectively). However, these species attained significantly lower IVI values in the AMR of the same substrate, indicating their deterioration in the presence of small antelope. *R. epapposum* was absent and both *C. procera* and *I. intricata* attained lower IVI values (13 and 2.6, respectively) (Table 3).

Four species attained significantly greater IVI values in the AMR, as compared to the DDCR, indicating their recovery after protection from camel grazing. These were the small shrubs *Heliotropium digynum*, *C. aegyptiaca*, *H. kotschyi* and *Moltkiopsis ciliata*. *C. aegyptiaca* and *H. kotschyi* were not present in the DDCR, but their IVI values were 50.9 and 30.7, respectively in the AMR. *Moltkiopsis ciliata*, which is a very palatable species for camels, attained significantly greater IVI in the AMR (40.5), compared to the DDCR (26.1). It is interesting to note that the sedge *C. conglomeratus* attained significantly greater density and frequency in the AMR sand flats, as compared to the DDCR sand flats, but the reverse was true for absolute cover (Table 3).

3.2.3. Sand dunes

On sand dunes, the dominant species in both the camel grazed DDCR and antelope grazed the AMR was the sedge *C. conglomeratus* (IVI was 99.8 and 94.8, respectively). As was the case with the sand flats, this species attained significantly greater density and frequency in the AMR sand dunes compared to those in the DDCR, but the reverse was true in relation to absolute cover (Table 4). On sand dunes four species were absent from the antelope-grazed area (AMR), but they attained significantly greater IVI values in the camel grazed area (DDCR). These were *Indigofera intricate*, *Lycium shawii*, *D. glaucum* and *H. salicornicum* (IVI values in the DDCR were 5.7, 12.2, 14.4 and 45.8; respectively) (Table 4). However, *C. aegyptiaca*, *L. arabicum*, *M. ciliate* and *H. digynum* attained significantly greater IVI values in the AMR, as compared with the DDCR. This indicates the recovery of these species due to protection against camel grazing. The IVI of these species increased from 0.0, 0.0, 7.7 and 22.4, respectively, in the DDCR to 36.3, 27.4, 27.1 and 40.5, respectively within the AMR (Table 4).

4. Discussion

The results of the present study indicate that protection from camel grazing in the AMR has resulted in an increase in the number of species and species diversity compared with the camel-grazed areas in the DDCR. This was particularly evident on the gravel plains and sand flats. This outcome could be attributed to the more moderate grazing of the antelopes in the AMR versus the overgrazing by camels in the DDCR. The stocking rate is about 3 AUE within the AMR and about 8 AUE in the DDCR. El-Keblawy (2003) suggested that moderate grazing or periodic protection might be necessary to maintain the productivity level in desert rangelands in the UAE. In Ethiopia's rangelands, Tefera et al. (2007) concluded that the pressure of intensive grazing was an important factor leading to species deterioration. In the western Mediterranean region of Egypt, Ayyad and Elkadi (1982) and Ayyad and Fakhry (1996) compared controlled grazing with free grazing and complete protection and found that species diversity was greatest in controlled grazing. Light nibbling and removal of dead shoots by animals can promote vigor and shoot growth in grazed plants

Table 2
Abundance attributes of different perennials in the Al Maha Resort enclosure (AMR) and camel grazed Dubai Desert Conservation Reserve (DDCR) in the gravel plain habitat. *N*, Number of studied plots; LS, Large shrub; MS, Medium shrub, DS, Dwarf shrub.

Species	Life form	Density (ind./1000 m^2)		Frequency		Absolute cover (cm/100 cm)		Importance value Index	
		AMR	DDCR	AMR ($N=49$)	DDCR ($N=13$)	AMR	DDCR	AMR	DDCR
Aerva javanica	MS	3.2	0	15	0	0.02	0.0	8.8	0
Calotropis procera	LS	2.7	2	15	4	0.93	2.60	14.2	29.5
Crotalaria aegyptiaca	DS	10.2	0	21	0	0.63	0.0	20.3	0
Cyperus conglomeratus	Sedge	2	14	1	8	0.01	1.57	1.9	41.2
Dipterygium glaucum	DS	4.56	0	18	0	0.01	0.0	11.1	0
Fagonia indica	DS	9.7	4	8	4	0.0	0.35	10.4	14.9
Haloxylon salicornicum	MS	4	72	3	9	0.01	4.62	4.3	111.5
Heliotropium digynum	DS	3.8	4	13	4	0.02	0.20	8.5	13.8
Heliotropium kotschyi	DS	55.3	0	38	0	6.48	0.0	96.4	0
Indigofera intricata	DS	3.6	2	5	3	0.2	0.1	10.8	4.7
Leptadenia pyrotechnica	LS	8.9	4	26	4	5.84	2.80	53.8	32.6
Limeum arabicum	DS	3	0	2	0	0.07	0.0	3.5	0
Lycium shawii	LS	3.9	6	23	3	0.78	1.10	17.5	22
Moltkiopsis ciliata	DS	7.24	0	21	0	0.02	0.0	14.3	0
Rhanterium epapposum	DS	16.2	12	24	3	1.33	0.65	30.1	23.8

(Pearson, 1965). The above results could also be attributed to difference in diet preferences. Antelopes have been reported to rely heavily on grass species (Tingting, 2006), while camels are known to have a very wide range of dietary preferences.

Under long term intensive grazing, the shift in species composition frequently involves the replacement of palatable species by unpalatable plants, grasses and/or woody perennials (Briske, 1991; Milton et al., 1994). Several studies reported that heavy grazing by livestock could change plant community composition, especially in arid regions (Shaltout et al., 1996; Li and Jiang, 1997; Landsberg et al., 2002; El-Keblawy, 2003; Li et al., 2005; Tefera et al., 2007). For example, in the arid ecosystems of China, Li and Jiang (1997) revealed a declining trend of palatable species with increasing grazing pressures. The palatable *Kochia prostrate*, *Festuca ovina* and *Carex turkestanica* declined, while unpalatable *Salsola collina* increased (Li and Jiang, 1997). Similarly, the increase of grazing pressures after a ten year grazing trial on the Inner Mongolian desert steppe had resulted in a significant reduction of palatable species, such as *Artemisia frigida* (Li et al., 2005). Furthermore, in the arid rangelands of Saudi Arabia, overgrazing resulted in the reduction of the palatable forage plants such as *R. epapposum*, *Ochradenus baccatus*, and *Lasiurus hirsutus* (Shaltout et al., 1996). In the UAE, overgrazing, mainly by camels, resulted in a significant reduction in the abundance and cover of the palatable *S. plumosa* (Oatham et al., 1995), *C. aegyptiaca*, *I. articulata*, *P. divisum*, *S. plumosa*, and *P. turgidum* (El-Keblawy, 2003) but a significant increase in the unpalatable *H. salicornicum* (El-Keblawy, 2003). In the present study, all of the species that recovered following protection from camel grazing are palatable for many types of animals, especially camels, except *H. kotschyi* and *A. javanica*.

Our study indicated that the unpalatable *H. kotschyi* was the most abundant species in the gravel plains and one of the most dominant species of the sand flats of the AMR, but not recorded on the sand dunes of either the AMR or the DDCR (Table 2). This species was not recorded in the study area in an earlier floral survey on Dec. 1997; before the introduction of the wild antelope (Böer, 1997). In addition, two years before our study, Gallacher and Hill (2006) reported a relatively lower abundance for *H. kotschyi*, compared to the other species. This indicates that *H. kotschyi* may have been introduced with the release of the antelope in the AMR (El Alqamy, 2004). Unlike camels, antelope grazing in the AMR do not seem to include *H. kotschyi* in their diets. It is highly recommended, therefore, to monitor the population dynamics of this species in the AMR reserve.

Grazers could influence plant communities directly through selective feeding on some species unto extinction (Proulex and

Table 3
Abundance attributes of different perennials in the Al Maha Resort enclosure (AMR) and camel grazed Dubai Desert Conservation Reserve (DDCR) in the sand flats habitat. *N*, Number of studied plots. LS, Large shrub, MS, Medium shrub, DS, Dwarfshrub.

Species	Life form	Density (ind./1000 m^2)		Frequency (*N*)		Absolute cover (cm/100 cm)		Importance value Index	
		AMR	DDCR	AMR ($N=16$)	DDCR ($N=12$)	AMR	DDCR	AMR	DDCR
Calligonum comosum	LS	2	0	1	0	0.01	0	2	0
Calotropis procera	LS	2	4.8	1	5	0.95	3.76	13	39.1
Crotalaria aegyptiaca	DS	27.1	0	13	0	2.17	0	50.9	0
Cyperus conglomeratus	Sedge	32.3	16.4	12	5	0.21	0.53	29.4	24.9
Dipterygium glaucum	DS	5.3	4	6	3	0.39	0.02	12.9	9.5
Haloxylon salicornicum	MS	19	7	2	2	0.46	2.8	16.3	27
Heliotropium digynum	DS	22.7	14.4	15	5	0.85	0.63	35.4	24.4
Heliotropium kotschyi	DS	34.6	0	7	0	0.65	0	30.7	0
Indigofera coultea	DS	7.3	2	3	1	0.08	0.02	7.3	3.7
Indigofera intricata	DS	2	50	1	1	0.06	1	2.6	38.2
Leptadenia pyrotechnica	LS	8.4	18.8	16	10	1.83	3.41	41	56.9
Limeum arabicum	DS	7.7	4	7	1	0.16	0.35	12.4	7
Lycium shawii	LS	4	2	2	1	0.15	0.02	5.6	3.7
Moltkiopsis ciliata	DS	39.6	16.3	15	6	0.61	0.35	40.5	26.1
Rhanterium epapposum	DS	0	31	0	2	0	2.55	0	39.5

Table 4
Abundance attributes of different perennials in the Al Maha Resort enclosure (AMR) and camel grazed Dubai Desert Conservation Reserve (DDCR) on the sand dunes habitat. *N*, Number of studied plots; LS, Large shrub; MS, Medium shrub; DS, Dwarfshrub.

Species	Life form	Density (ind./1000 m^2)		Frequency (*N*)		Absolute cover (cm/100 cm)		Importance value Index	
		AMR	DDCR	AMR ($N=21$)	DDCR ($N=15$)	AMR	DDCR	AMR	DDCR
Calotropis procera	LS	2.0	2.0	1	5	0.9	1.5	15.4	28
Crotalaria aegyptiaca	DS	6.0	0.0	6	0	1.7	0.0	36.3	0
Cyperus conglomeratus	Sedge	112.3	41.0	17	14	0.57	1.50	94.6	99.8
Dipterygium glaucum	DS	0.0	5.3	0	3	0.0	0.05	0	14.4
Haloxylon salicornicum	MS	0.0	8.0	0	1	0.0	3.8	0	46.8
Heliotropium digynum	DS	19.4	5.33	13	6	0.78	0.13	40.5	22.4
Indigofera coultea	DS	5.33	4.7	3	3	0.71	0.07	17.4	13.8
Indigofera intricata	DS	0.0	2.0	0	1	0.0	0.08	0	5.7
Leptadenia pyrotechnica	DS	6.44	3.4	9	7	1.74	3.2	41.4	49.8
Limeum arabicum	DS	10.8	0.0	12	0	0.30	0.0	27.4	0
Lycium shawii	LS	0.0	2.0	0	1	0.0	0.8	0	12.2
Moltkiopsis ciliata	DS	18.4	4.0	9	1	0.28	0.01	27.1	7.7

Mazumder, 1998). Camels exhibited preference for the herbaceous species, as they became available, but they utilize low quality forage when more desirable herbage is unavailable during the dry period (Mengli et al., 2006). Camel diets were mainly comprised of perennial woody plants throughout the year (Udén and Dereje, 2005). In the present study, many palatable medium and dwarfed shrubs, such as *L. arabicum*, *D. glaucum*, *M. ciliata*, *C. aegyptiaca* and *H. digynum*, attained lower abundances in the DDCR, but recovered after protection from camel grazing in the AMR. This indicates that selective foraging of these species by camel could be responsible for their deterioration within the DDCR. Most of these species are rich in proteins (Ksiksi et al., 2007). Camel forage preference was positively correlated with nitrogen content (Woodward and Coppock, 1995). It has also been reported that camels are able to select plant species with high crude protein content (Kamoun and Steinmetz, 1995).

In general, the response of forage species to grazing varies according to the effect of plant competition, plants' ability to re-grow after damage, abiotic conditions and the type and intensity of herbivory. Some studies have reported that the competitive ability of the palatable species is higher than that of unpalatable species in the absence of grazing (Moretto and Distel, 1997). The dominance of the palatable species on the three substrates of the AMR, where heavy grazing was replaced by moderate or light grazing by wild antelope, could be attributed to greater competitive ability of the palatable over unpalatable plants species. Further studies are needed, therefore, to confirm this assumption under the arid environment of the UAE deserts.

Herbivore induced species replacement appears to be based upon differences among plant species in tolerance or avoidance of repeated defoliation (Briske, 1991). Some plants can tolerate the high intensity of grazing through certain chemical and morphological mechanisms that provide the plants with effective protection against herbivory (Perevolotsky and Seligman, 1998). These plants are usually avoided by herbivores. Other plants resist grazing through the compensation or over-compensation of the consumed parts by additional growth. *H. salicornicum* was the dominant species on gravel plains and the co-dominant species on sand dunes in the DDCR. This indicates that this species is resistant to camel grazing or could be more competitive than the other associated plants. *H. salicornicum* had been shown to be one of the most resistant species to grazing in the arid rangeland vegetation of the UAE (El-Keblawy, 2003) and Iraq (Thalen, 1979), even though it was grazed by camels and has low palatability (Akhter and Arshad, 2006). El-Keblawy (2003) concluded that *H. salicornicum* dominated the overgrazed rangelands of Abu Dhabi, UAE. Thalen (1979) indicated that heavy grazing over an extended period would result in the creation of monospecific stands of perennial plants that are most resistant to grazing pressure.

A comparison of the current survey with a floral survey two-years earlier (Gallacher and Hill, 2006) indicates that some dwarf shrubs, such as *M. ciliate*, *L. arabicum*, *Indigofera coultea*, and *D. glaucum*, recovered more during two extra years of protection in the AMR, but deteriorated more in the camel grazed DDCR. This was especially true in the gravel plain substrate. The results in our study, compared to that of a much earlier floral survey (Böer, 1997), highlight a big change in the community structure on gravel plains. For example, neither *Fagonia indica* nor *H. kotschyi* were recorded in Böer's survey. However, these species are currently the dominant and co-dominant species respectively, in AMR gravel plains. Böer (1997) also reported *P. divisum* as co-dominant species along with the *C. conglomeratus* on sand dunes. However, *P. divisum* is extremely rare in the dunes in the AMR reserve and the few live individuals have little forage. Dead individuals were abundant on the DDCR dunes. This indicates that *P. divisum* is currently endangered on the sand dunes of Dubai. It should be stated that Böer's (1997) findings should be considered here with caution since his document lacks a description of his methodology or any quantitative measures being applied, yet provides the only relatively available long-term comparative study.

On the gravel plains, by contrast with the dune habitat, none of the species deteriorated and six species recovered in the AMR after antelope replaced camels. Gallacher and Hill (2006) reported similar greater vegetation cover in the same substrate within the AMR, compared to the DDCR, which was almost completely grazed to the ground level. This could be attributed to the high preference of camels to spend more time (grazing, resting) on gravel (Ksiksi et al., 2007). Ksiksi et al. (2007) showed a greater number of camel visits to the gravel plains. The high foraging activity in gravel plains would trigger camel to overgraze plants of this substrate in the DDCR (Mengli et al., 2006). Therefore, a stricter grazing management of camels on gravel plains is highly recommended, to avoid sustained overgrazing and minimize the prospects of desertification.

In both sand flats and sand dunes, *C. conglomeratus* attained significantly greater density and frequency in the AMR, as compared to the DDCR, but the reverse was true in relation to absolute cover (Tables 3 and 4). It is believed that the increase in *C. conglomeratus* cover in areas accessible to camel grazing could be attributed to higher camel preferences for new growth. The greater density and frequency of *C. conglomeratus* inside the AMR could be attributed to greater disturbance by wild antelope. It has been documented that *C. conglomeratus* can benefit from such disturbance and it has the capacity to colonize sand habitats before any other species following rain events and overgrazing (Ferguson et al., 1998).

In conclusion, seven years after substituting small antelopes with camels in the AMR, there was a marked recovery of perennial plants, including medium and large shrubs. Recovery was best on gravel plains. In addition, most of the recovered plants are palatable, especially for camels.

Acknowledgements

The investigator would like to express his sincere appreciation to the Research Affairs at the United Arab Emirates University for the financial support of this project under fund grant # 01-05-2-12/03. The authors would also like to express their gratitude to the DDCR, especially Greg Simkins. Mr Ahmed Ramy was crucial to the proper running of this component of the project. Comments from Mr Lotfi Ahmed, Mrs Katera Moore and Dr Abdel-Rahman Fowler are much appreciated in improving the English style of the manuscript.

References

Anderson, P.M.L., Hoffman, M.T., 2007. The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesberg mountain range in the Succulent Karoo. South African Journal of Arid Environments 70, 686–700.
Akhter, R., Arshad, M., 2006. Arid rangelands in the Cholistan Desert (Pakistan). Sécheresse 17, 210–217.
Assaeed, A.M., 1997. Estimation of biomass and utilization of three perennial grasses in Saudi Arabia. Journal of Arid Environments 36, 103–111.
Ayyad, M.A., 2003. Case studies in the conservation of biodiversity: degradation and threats. Journal of Arid Environments 54, 165–182.
Ayyad, M.A., Fakhry, A.M., 1996. Plant biodiversity in the western Mediterranean desert of Egypt. Verhandlungen der Gesellschaft fur Okologie 25, 65–75.
Ayyad, M.A., Elkadi, H.F., 1982. Effect of protection and controlled grazing on the vegetation of a Mediterranean desert ecosystem in northern Egypt. Vegetatio 49, 129–139.
Ayyad, M.A., El Ghareeb, R., Gaballah, M.S., 1990. Effect of protection on the phenology and primary production of some common annuals in the western coastal desert of Egypt. Journal of Arid Environments 18, 295–300.
Batanouny, H.K., 1990. Rangeland Ecology of the Arab Gulf Countries. In: Proceeding of the First International Conference on Range Management in the Arabian Gulf. Kegan Paul International, London, pp. 33–56.
Böer, B., 1997. A Vegetation Survey and Recommendations for Landscape Establishment with Indigenous Plants for the Al Maha Project, Dubai, United Arab Emirates. Unpublished internal document, 16 p.
Brady, W.W., Stromberg, M.R., Aldon, E.F., Bonham, C.D., Henry, S.H., 1989. Response of a semidesert grassland to 16 years of rest from grazing. Journal of Range Management 42, 284–288.
Brown, G., Peacock, J., Loughland, R.A., Aldrami, G.A., 2003. Coastal and Terrestrial Ecosystem Management Requirements in the GCC States. A Background Report. Environmental Research and Wildlife Development Agency, Abu Dhabi, UAE.
Briske, D.D., 1991. Developmental morphology and physiology of grasses. In: Heitschmidt, R.K., Stuth, J.W. (Eds.), Grazing Management: an Ecological Perspective. Timber Press, Portland, pp. 85–108.
Cordes, R., Scholz, F., 1980. Bedouins, Wealth, and Change: a Study of Rural Development in the United Arab Emirates and the Sultanate of Oman. The United Nations University, Tokyo.
E-Government, 2007. Traditional life. <www.uae.gov.ae/government/traditional.htm>.
Eccard, J.A., Walther, R.B., Milton, S.J., 2000. How livestock grazing affects vegetation structures and small mammal distribution in the semi-arid Karoo. Journal of Arid Environments 46, 103–106.
El Alqamy, H., 2004. Vegetation of Dubai Desert Conservation Reserve: Initial Assessment and Baseline Data. Phase 2: DDCR Habitat. Sponsored by Emirates, UAE. Dubai Desert Conservation Reserve. <http://ddcr.org/conservation/common/file/vegetation_survey.pdf>.
El-Keblawy, A., 2003. Effect of protection from grazing on species diversity, abundance and productivity in two regions of Abu-Dhabi Emirate, UAE. In: Alsharhan, A.S., Wood, W.W., Goudie, A.S., Fowler, A., Abdellatif, E. (Eds.), Desertification in the Third Millennium. Swets & Zeitlinger Publisher, Lisse, The Netherlands, pp. 217–226.
ESRI, Inc., 1996. ArcView 3.1. Environmental Systems Research Institute, Inc., Redlands, California.
FAOSTAT, 2004. FAOSTAT—Agriculture. <http://www.fao.org>.
Ferguson, M., McCann, I., Manners, G., 1998. Less water, more grazing. ICARDA Caravan 8, 9–11.
Feulner, G.R., 2006. Rainfall and climate records from Sharjah airport: historical data for the study of recent climatic periodicity in the UAE. Tribulus 16, 3–9.
Gallacher, D., Hill, J., 2006. Effects of camel grazing on the ecology of dwarf shrubs and sedges in the Dubai (UAE) inland desert. Journal of Arid Environments 66, 738–750.
Hellyer, I., Al-Abed, A., Vine, P., 2001. United Arab Emirates: a New Perspective. Trident Press, USA.
Iqbal, A., Khan, B.B., 2001. Feeding behaviour of camel. Pakistan Journal of Agricultural Science 38, 58–63.
Jongbloed, M.V.D., 2003. The Comprehensive Guide to the Wild Flowers of the United Arab Emirates. Environmental Research and Wildlife Development Agency (ERWDA), Abu Dhabi, UAE.
Kamoun, M., Steinmetz, P., 1995. Feeding behaviour, intake and digestion of the *Camelus dromedarious* at pasture. In: Tisserand, J.-L. (Ed.), CIHEAM-IAMZ, Zaragoza, pp. 51–57. Tunisia.
Kassas, M., 1995. Desertification: a general review. Journal of Arid Environments 30, 115–128.
Ksiksi, T., El-Keblawy, A., Al-Ansari, F., Elhadramy, G., 2007. Desert ecosystems vegetation and potential uses as feed sources for camels and wildlife. Proceeding of the 8th Annual Conference for Research Funded by UAE University, Al-Ain, United Arab Emirates, pp. 71–81.
Landsberg, J., O'Connor, T., Freudenberger, D., 1999. The impacts of livestock grazing on biodiversity in natural ecosystems. In: Jung, H.J., Fahey, G.C. (Eds.), Nutritional Ecology of Herbivores. American Society of Animal Science, Savoy, IL, pp. 752–777.
Landsberg, J., James, C.D., Maconochie, J., Nicholls, A.O., Stol, J., Tynan, R., 2002. Scale-related effects of grazing on native plant communities in an arid rangeland region of South Australia. Journal of Applied Ecology 39, 427–444.
Li, J.H., Jiang, P., 1997. The effects of different rotational grazing intensities on the soil, grassland and sheep productions in the northern Tianshan in China. Archivos de Zootecnia 46, 301–310.
Li, J.H., Li, Z.Q., Ren, J.Z., 2005. Effect of grazing intensity on clonal morphological plasticity and biomass allocation patterns of *Artemisia frigida* and *Potentilla acaulis* in the Inner Mongolia steppe. New Zealand Journal of Agricultural Research 48, 57–61.
McAuliffe, J.R., 1990. A rapid method for the estimation of density and cover in desert plant communities. Journal of Vegetation Science 1, 653–656.
Mengli, Z., Willms, W.D., Guodong, H., Ye, J., 2006. Bactrian camel foraging behaviour in a *Haloxylon ammodendron* (C.A. Mey) desert of Inner Mongolia. Applied Animal Behaviour Science 99, 330–343.
Milchunas, D.G., Lauenroth, W.K., 1993. Quantitative effects of grazing on vegetation and soils over a global range of environments. Ecological Monographs 63, 327–366.
Milton, S.J., Dean, W.R.J., du Plessis, M.A., Siegfried, W.R., 1994. A conceptual model of arid rangeland degradation. Bioscience 44, 70–76.
Moretto, A.S., Distel, R.A., 1997. Competitive interactions between palatable and unpalatable grasses native to a temperate semi-arid grassland of Argentina. Plant Ecology 130, 155–161.
Noymeir, I., Gutman, M., Kaplan, Y., 1989. Responses of Mediterranean grassland plants to grazing and protection. Journal of Ecology 77, 290–310.
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 long term grazing. Biodiversity and Conservation 4, 696–709.
Olsvig-Whittaker, L.S., Hosten, P.E., Marcus, I., Shochat, E., 1993. Influence of grazing on sand field vegetation in the Negev desert. Journal of Arid Environments 24, 81–93.
Omar, S.A., 1991. Dynamic of range plants following 10 years of protection in arid rangelands of Kuwait. Journal of Arid Environments 21, 99–111.
Omar, S.A., Taha, F.K., Nassef, A., 1990. Ecological Monitoring of Vegetation in Kuwait's Rangelands. In: Proceeding of the First International Conference on Range Management in the Arabian Gulf. Kegan Paul International, London 57–72.
Pearson, L.C., 1965. Primary production in grazing and ungrazed desert communities of eastern Idaho. Ecology 46, 278–286.
Perevolotsky, A., Seligman, N.G., 1998. Role of grazing in Mediterranean rangeland ecosystems. Bioscience 48, 1007–1018.
Proulex, M., Mazumder, A., 1998. Reversal of grazing impact on plant species richness in nutrient-poor vs. nutrient-rich ecosystems. Ecology 79, 2581–2592.
Retzer, V., 2006. Impacts of grazing and rainfall variability on the dynamics of a Sahelian rangeland revisited (Hein, 2006): new insights from old data. Journal of Arid Environments 67, 157–164.
Rutagwenda, T., Kaske, M., Engelhardt, W.V., Lechner-Doll, M., Schultka, W., Schwartz, H.J., 1989. Adaptation strategies of camels on a thornbush savannah pasture: comparison with other domestic animals. Options Méditerranéennes – Série Séminaires 2, 69–73.
Shaltout, K.H., El Halawany, E.F., El Kady, H.F., 1996. Consequences of protection from grazing on diversity and abundance of the coastal lowland vegetation in eastern Saudi Arabia. Biodiversity and Conservation 5, 27–36.
Tefera, S., Snyman, H.A., Smit, G.N., 2007. Rangeland dynamics of southern Ethiopia: (2). Assessment of woody vegetation structure in relation to land use and distance from water in semi-arid Borana rangelands. Journal of Environmental Management 85, 443–452.
Thalen, D.C.P., 1979. Ecology and Utilization of Desert Rangelands in Iraq. Dr W. Junk Publishers, The Hague.

Tingting, Z., 2006. Feeding the Tibetan Antelope. <http://hyconference.edu.cn/english/2006/Jul/175421.htm>.
Udén, P., Dereje, M., 2005. The browsing dromedary camel. I. Behaviour, plant preference and quality of forage selected. Animal Feed Science and Technology 121, 297–308.
Walker, B.H., Ludwig, D., Holling, C.S., Peterman, R.M., 1981. Stability of semi-arid savanna grazing systems. The Journal of Ecology 69, 473–498.
Waser, N.M., Price, M.V., 1981. Effects of grazing on diversity of an annual plants in the Sonoran desert. Oecologia 50, 407–411.
Woodward, A., Coppock, D.L., 1995. Role of plant defense in the utilization of native browse in southern Ethiopia. Agroforestry Systems 32, 147–161.
Zhao, W.Y., Li, J.L., Qi, J.G., 2007. Changes in vegetation diversity and structure in response to heavy grazing pressure in the northern Tianshan Mountains, China. Journal of Arid Environments 68, 465–479.