



ORIGINAL ARTICLE

Plants included in the diet of Arabian Sand Gazelle (Reem) from Saudi Arabia

Peter L. Cunningham *

King Khalid Wildlife Research Center, Thumamah, P.O. Box 61681, Riyadh, Kingdom of Saudi Arabia & Zoological Society of London, Conservation Programmes, Regent's Park, London, NW1 4RY, United Kingdom

Received 21 September 2012; accepted 30 October 2012
Available online 29 January 2013

KEYWORDS

Gazella subgutturosa marica;
Diet;
Saudi Arabia

Abstract Arabian Sand Gazelles are typical intermediate feeders (browsing and grazing) becoming concentrate selectors during the wet season (grazing) with a preference for short grasses and forbs throughout their range. At least, 80 plant species from 23 families have been published as being utilised by reem, mainly from five protected areas throughout Saudi Arabia. Knowledge of the diet of reem is important in assisting wildlife managers with practical decision making, especially with regard to reintroduction.

© 2012 King Saud University. Production and hosting by Elsevier B.V. All rights reserved.

1. Introduction

The Arabian Sand Gazelle *Gazella subgutturosa marica* Thomas, 1897 (reem) are classified as “vulnerable” by the IUCN (2008) with 35% of the global population associated with Saudi Arabia (Dunham et al., 2001). Although the species *Gazella subgutturosa* Guldenstadt 1780 is widespread, occurring from Arabia through the deserts of east and central Asia as far as western China, the subspecies *G. s. marica* is confined to the

Arabian Peninsula (Thouless et al., 1991). Recent evidence indicates that *G. s. marica* is more closely related to the north-African species *Gazella leptoceros* and *Gazella cuvieri*, indicating that *G. s. marica* and *G. s. subgutturosa* have evolved independently (Wacher et al., 2010). In addition to Saudi Arabia, reem is found in small numbers in Oman and the coastal and offshore islands along the Arabian Gulf (e.g. United Arab Emirates, Qatar and Bahrain), although the purity of the Gulf populations is questionable making the Saudi Arabian population of international importance (Thouless et al., 1991). Recently, reem numbers have declined dramatically in the wild in Saudi Arabia (Cunningham and Watcher, 2009) yet very little is known about issues as basic as their diet (Habibi 1991, Mohammed and Saleh 1991). For the effective management of herbivore populations, it is crucial to know the diet (Bookhout 1996) especially when introducing reem as has occurred in two protected areas – Mahazat as-Sayd and Uruq Bani M'arid – in Saudi Arabia.

Reem are predominantly viewed as grazers (Thouless et al., 1991) although dwarf shrubs are important browse throughout their range (Harrison and Bates 1991) with Wacher (1995) indicating their use of bulbs, forbs, grasses and occasionally

* Address: Environment & Wildlife Consulting, 4 Mokke Str, Windhoek, Namibia. Tel.: +264 61 254550.
E-mail address: pckkwrc@yahoo.co.uk.



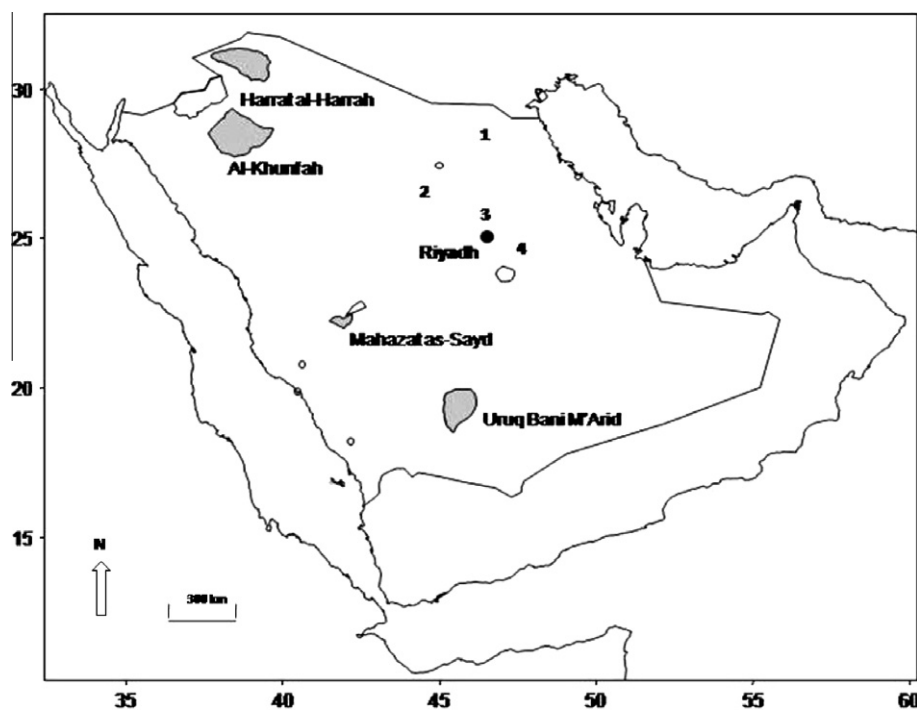


Figure 1 Current distribution of *Gazella subgutturosa marica* in protected areas in Saudi Arabia (shaded). Breeding centres and military areas with gazelle: 1 – Hafar Al Batin, 2 – Qassim, 3 – Thumamah (KKWRC) and 4 – Al Kharj.

trees (i.e. browse) from Saudi Arabia. Haque (1992) confirms reem being grazers, with grazing preference shown towards *Panicum* and *Stipagrostis* grass species in western Saudi Arabia. Plant species utilised by reem in various protected areas in Saudi Arabia have not been well documented with what little is known, published as internal reports and not easily accessible – e.g. Thouless and Al-Bassri (1989) [Al Khunfah]; Robinson et al., (2000) [Harrat al-Harrah]; Haque (1992) [Mahazat as-Sayd]; Wacher (1995) [Uruq Bani M'arid] (See Fig. 1 & Table 1). More recently Cunningham (2009a) confirmed 21 plant species utilised by reem from central Saudi Arabia (Thumamah) indicating the importance of forbs in their diet. This paper attempts to synthesise the plant species known to be included in their diet, from as many unpublished reports as possible, as well as draw some conclusions regarding their diet from Saudi Arabia, in an attempt to assist with future envisaged reintroductions.

2. Materials and methods

A search on the scientific literature, including unpublished reports – i.e. grey literature – by various authors dating back to 1989, were collected for the Al-Khunfah, Harrat al-Harrah, Mahazat as-Sayd, Thumamah and Uruq Bani Ma'arid protected areas known to have reem populations (Table 1). The various reports mainly include *ad hoc* data collection of plants included in the diet of reem either conducted during vehicle wildlife census or general habitat assessments following predetermined or random transects covering the entire areas or sections of areas. The different surveyors' involved and monitoring techniques applied varied between years and were not standardised throughout all the protected areas and thus direct comparisons between years and protected areas cannot

be made. Due to the various techniques used and/or applied over the years by various surveyors no attempt has been made here to describe all of these.

3. Results

Eighty plant species from 23 families have been published as being utilised by reem from five protected areas throughout Saudi Arabia. These consist of Poaceae (17 species), Chenopodiaceae (11 species), Fabaceae (9 species), Zygophyllaceae (8 species), Boraginaceae (5 species), Brassicaceae and Cruciferae (4 species each), Compositae and Convolvulaceae (3 species each), Capparaceae and Polygonaceae (2 species each) and one species each for Amaranthaceae, Aizoaceae, Caryophyllaceae, Cucurbitaceae, Cyperaceae, Ephedraceae, Euphorbiaceae, Geraniaceae, Hyacinthaceae, Neuradaceae, Polagalaceae and Resedaceae. Forty-one plant species have been recorded in the diet of reem from Uruq Bani M'arid, 21 from Thumamah, 19 from Harrat al-Harrah, 17 from Al-Khunfah and 14 from Mahazat as-Sayd (Table 1).

4. Discussion

According to Thouless et al., (1991), reem are predominantly viewed as grazers, feeding on ephemeral plants after rains but generally rely on dry grasses, chenopods and desert melons (i.e. forbs) with a preference shown towards *Panicum* and *Stipagrostis* grasses in the Mahazat As-Sayd in Saudi Arabia (Haque, n.d. (1996)), although distinct seasonal changes mostly related to rainfall being apparent. Grasses, especially *Stipagrostis* species, are utilised widely in Saudi Arabia although forbs (e.g. *Convolvulus lanatus*, *Farsetia stylosa*, *Heliotropium* species, and *Neurada procumbens*) are preferred

Table 1 Plant species known to be included in the diet of *Gazella subgutturosa marica* from Saudi Arabia.

Species	Family	Protected Areas					Reference
		Arabian Peninsula	Al Khunfah	Harrat al-Harrah	Mahazat as-Sayd	Thumamah Uruq Bani M'arid	
<i>Acacia ehrenbergiana</i>	Fabaceae					*	Robinson (2005)
<i>Acacia ramulosa</i>	Fabaceae					*	Robinson (2005)
<i>Acacia oerfota</i>	Fabaceae					*	Robinson (2005)
<i>Acacia tortilis</i>	Fabaceae	*			*	*	Vesey-Fitzgerald (1952), Asmodé (1990), Haque (1992), Wachter (1995), Robinson (2005), Cunningham (2009b), Ul-Islam et al. (2010), Al-Sodany et al. (2011)
<i>Aerva javanica</i>	Amaranthaceae					*	Robinson (2005)
<i>Anabasis setifera</i>	Chenopodiaceae		*				Thouless and Al-Bassri (1989)
<i>Anastatica hierochuntica</i>	Brassicaceae		*				Thouless and Al-Bassri (1989)
<i>Aristida adscensionis</i>	Poaceae			*			Robinson (2005)
<i>Atriplex leucoclada</i>	Chenopodiaceae		*				Thouless and Tatwany (1989)
<i>Atriplex sp.</i>	Chenopodiaceae			*			Robinson (2005)
<i>Cakile arabica</i>	Brassicaceae					*	Cunningham (2009a)
<i>Calligonum crinitum</i>	Polygonaceae					*	Robinson (1999), Robinson (2005)
<i>Cenchrus ciliaris</i>	Poaceae			*			Robinson (2005)
<i>Centropodia forskalii</i>	Poaceae					*	Robinson (2005)
<i>Centaurea fragilis</i>	Poaceae		*			*	Thouless and Al-Bassri (1989), Robinson (2005)
<i>Centuarea pseudo sinaica</i>	Compositae					*	Cunningham (2009a)
<i>Chenopodium sp.</i>	Chenopodiaceae			*			Robinson (2005)
<i>Chrysopogon plumulosus</i>	Poaceae			*			Robinson (2005)
<i>Citrullus colocynthis</i>	Cucurbitaceae		*		*		Thouless and Al-Bassri (1989), Thouless et al. (1991), Haque (1992)
<i>Convolvulus lineatus</i>	Convolvulaceae					*	Cunningham (2009a)
<i>Convolvulus oxyphyllus</i>	Convolvulaceae					*	Cunningham (2009a)
<i>Convolvulus sp.</i>	Convolvulaceae					*	Wachter (1995)
<i>Cornulaca arabica</i>	Chenopodiaceae					*	Robinson (2005)
<i>Crotalaria aegyptiaca</i>	Fabaceae					*	Wachter (1995), Robinson (1999), Robinson (2005)
<i>Cynodon dactylon</i>	Poaceae					*	Robinson (2005)
<i>Cyperus aucheri</i>	Cyperaceae			*		*	Robinson and Wachter (2001), Robinson (2005)
<i>Dichanthium foveolatum</i>	Poaceae					*	Wachter (1995), Robinson (2005)
<i>Dipcadi unicolor</i>	Hyacinthaceae					*	Wachter (1995)
<i>Dipterygium glaucum</i>	Capparaceae					*	Wachter (1995), Robinson (1999), Strauss et al. (2000), Robinson and Wachter (2001), Robinson (2005)
<i>Ephedra transitoria</i>	Ephedraceae			*			Robinson et al. (2000)
<i>Eremobium aegyptiacum</i>	Brassicaceae		*				Thouless and Al-Bassri (1989)
<i>Euphorbia granulata</i>	Euphorbiaceae	*	*				Thouless and Al-Bassri (1989), Kingdon (1990)
<i>Fagonia bruguieria</i>	Zygophyllaceae					*	Cunningham (2009a)
<i>Fagonia sp.</i>	Zygophyllaceae				*		Haque (1992)
<i>Farsetia burtonia</i>	Cruciferae					*	Robinson (2005)
<i>Farsetia longisiliqua</i>	Cruciferae				*	*	Wachter (1995), Cunningham (2009b)
<i>Farsetia stylosa</i>	Cruciferae					*	Cunningham (2009a)
<i>Farsetia sp.</i>	Cruciferae					*	Wachter (1995)
<i>Haloxylon salicornicum</i>	Chenopodiaceae			*		*	Wachter (1995), Robinson et al. (2000), Robinson (2005), Cunningham (2009a)

Species	Family	Protected Areas					Reference
		Arabian Peninsula	Al Khunfah	Harrat al-Harrah	Mahazat as-Sayd	Thumamah Uruq Bani M'arid	
<i>Heliotropium crispum</i>	Boraginaceae		*				Thouless and Al-Bassri (1989)
<i>Heliotropium digynum</i>	Boraginaceae			*		*	Strauss et al. (2000), Robinson and Wacher (2001), Robinson (2005), Wacher (2005)
<i>Heliotropium ramosissimum</i>	Boraginaceae					*	Wacher (1995), Cunningham (2009a)
<i>Indigofera spinosa</i>	Fabaceae	*			*	*	Kingdon (1990), Thouless et al. (1991), Haque (1992), Wacher (1995), Cunningham (2009b)
<i>Kochia indica</i>	Chenopodiaceae					*	Cunningham (2009a)
<i>Lasiurus scindicus</i>	Poaceae				*	*	Wacher (1995), Robinson (2005), Cunningham (2009a), Cunningham (2009b), Al-Sodany et al. (2011)
<i>Launaea cassiniana</i>	Compositae					*	Cunningham (2009a)
<i>Limeum arabicum</i>	Aizoaceae					*	Robinson (2005)
<i>Maerua crassifolia</i>	Capparaceae				*	*	Haque (1992), Robinson (2005), Cunningham (2009b)
<i>Moltkiopsis ciliate</i>	Boraginaceae				*	*	Robinson (2005), Cunningham (2009a)
<i>Monsonia nivea</i>	Geraniaceae				*	*	Cunningham (2009a), Cunningham (2009b)
<i>Moretia parviflora</i>	Brassicaceae				*		Cunningham (2009b)
<i>Neurada procumbens</i>	Neuradaceae		*	*		*	Thouless and Al-Bassri (1989), Robinson (2005), Cunningham (2009a)
<i>Ochradenus baccatus</i>	Resedaceae					*	Robinson (2005)
<i>Ottochloa compressa</i>	Poaceae				*		Cunningham (2009b), Al-Sodany et al. (2011)
<i>Panicum turgidum</i>	Poaceae			*	*	*	Asmodé (1990), Haque (1992), Wacher (1995), Robinson (2005), Cunningham (2009a), Cunningham (2009b), Al-Sodany et al. (2011)
<i>Pennisetum divisum</i>	Poaceae					*	Robinson (2005)
<i>Pituranthos triradiatus</i>	Boraginaceae		*				Thouless and Al-Bassri (1989)
<i>Plantago boissieri</i>	Chenopodiaceae					*	Cunningham (2009a)
<i>Polycarpaea repens</i>	Caryophyllaceae					*	Wacher (1995), Cunningham (2009a)
<i>Polygala sp.</i>	Polygalaceae			*			Robinson (2005)
<i>Rhanterium epapposum</i>	Compositae	*	*			*	Vesey-Fitzgerald (1952), Thouless and Al-Bassri (1989), Kingdon (1990), Harrison and Bates (1991), Cunningham (2009a)
<i>Rhynchosia pulverulenta</i>	Fabaceae					*	Robinson (2005)
<i>Rumex vesicarius</i>	Polygonaceae			*		*	Robinson (2005), Cunningham (2009a)
<i>Salsola spinescens</i>	Chenopodiaceae			*	*		Robinson et al. (2000), Cunningham (2009b)
<i>Salsola sp.</i>	Chenopodiaceae		*	*			Thouless and Al-Bassri (1989), Robinson (2005)
<i>Stipagrostis drarii</i>	Poaceae					*	Cunningham (2009a)
<i>Stipagrostis foexiana</i>	Poaceae					*	Wacher (1995)
<i>Stipagrostis obtusa</i>	Poaceae		*	*			Thouless and Al-Bassri (1989), Robinson et al. (2000)
<i>Stipagrostis plumosa</i>	Poaceae					*	Cunningham (2009a), Al-Sodany et al. (2011)
<i>Stipagrostis sp.</i>	Poaceae		*	*	*	*	Thouless and Tatwany (1989), Haque (1992), Robinson (2005), Cunningham (2009b)
<i>Suaeda sp.</i>	Chenopodiaceae		*				Thouless and Al-Bassri (1989), Thouless and Tatwany (1989)
<i>Tephrosia purpurea</i>	Fabaceae					*	Wacher (1995)
<i>Tragus racemosus</i>	Poaceae					*	Robinson (2005)
<i>Tribulus arabicus</i>	Zygophyllaceae					*	Wacher (1995)
<i>Tribulus macropterus</i>	Zygophyllaceae				*	*	Robinson (2005), Cunningham (2009b)
<i>Tribulus pentandrus</i>	Zygophyllaceae					*	Wacher (1995), Robinson (2005)
<i>Tribulus terrestris</i>	Zygophyllaceae					*	Robinson (2005)
<i>Tribulus sp.</i>	Zygophyllaceae		*	*	*		Thouless and Tatwany (1989), Haque (1992)
<i>Trigonella anguina</i>	Fabaceae		*				Thouless and Al-Bassri (1989)
<i>Zygophyllum simplex</i>	Zygophyllaceae			*			Robinson (2005)

(Thouless and Al-Bassri 1989; Wachter 1995; Strauss et al., 2000; Robinson and Wachter 2001; Cunningham 2009a,b). Mohamed and Saleh (1991) confirm the importance of forbs in their diet from Bahrain. During the dry season in western Saudi Arabia, reem survive by foraging mainly on *Salsola spinescens* shrubs (Cunningham 2009b) and fallen *Acacia tortilis* pods (Asmodé 1990; Haque 1992; Cunningham 2009b), and occasionally even *A. tortilis* gum (Cunningham 2009b). Mowlavi (1978) noted that browsing formed the largest part of the diet (86%) of the *G. s. subgutturosa* – increasing during the drier months – in Iran.

More recent studies conducted by Cunningham (2009b) and Schulz et al., (2012) in Saudi Arabia, indicate that reem are intermediate feeders (browsing and grazing) becoming concentrate selectors during the wet season (grazing) with a preference for short grasses and forbs. These authors indicate that in Mahazat As-Sayd, grasses – including seedlings – that were most heavily utilised, were *Octochloa compressa* (leaves and occasionally inflorescence) followed by, but not necessarily in order of utilisation, *Lasiurus scindicus* (leaves), *Panicum turgidum* (leaves) and *Stipagrostis* sp. (leaves), although no attempt to quantify grass use was made due to general observation difficulties. Although plant part selection was evident, but not studied, it is known to be important for dorcas gazelle (*Gazella dorcas*) in Israel (Henley and Ward 2006). The importance of graze for reem in Mahazat as-Sayd was confirmed throughout the year except during autumn – before the rains – when the use of browse dominated. The period of *Acacia tortilis* leaf drop and height of available foliage would however also affect the use of browse. The movement towards areas that had received rain and an appreciable change in diet from browse to graze during the wet season furthermore indicate the importance of graze. Impala (Stewart 1971; Dunham 1980) and springbok (*Antidorcas marsupialis*) (Liversidge 1970; Bigalke 1972) from southern Africa and dorcas gazelle from North Africa (Grettenberger 1987) and Israel (Baharav 1982) showed a similar trend when the proportion of grasses in the diet reflected the availability of green grass in the habitat.

Forbs were preferred above grasses – i.e. utilised more – although no attempt was made to quantify this, other than confirming the importance of ‘grazing’ which included grasses and forbs (Cunningham, 2009b). Dietary studies of reem from Bahrain (Mohamed and Saleh 1991) and central Saudi Arabia – Thumamah – (Cunningham, 2009a) also showed a preference for forbs. The importance and selection of forbs above grasses for other herbivores – e.g. tortoises – has also been documented (El Mouden et al., 2006; Hazard et al., 2009).

Dwarf shrubs are also important browse (Harrison and Bates 1991) with Wachter (1995) indicating their occasional use of trees – i.e. browse in southern Saudi Arabia. Mowlavi (1978) noted that browsing formed the largest part of the diet of *G. s. subgutturosa* especially during the drier months, in Iran. In Mahazat as-Sayd, males utilised *A. tortilis* and *Maerua carssifolia* more while females utilised *S. spinescens* more while browsing (Cunningham, 2009b). According to Gillet and Launay (1990) new flush *S. spinescens* from Mahazat as-Sayd had a crude protein content of 17.2% and a mineral content of 19% while grasses had lower crude protein contents (e.g. *Lasiurus scindicus* 12.2% & *Panicum turgidum* 4.8–6.8%) probably indicating the reason why females selected for *S. spinescens*. Differences in diet between the sexes for impala and springbok are attributed to their social systems (Van

Rooyen and Skinner 1989; Skinner and Smithers 1990) and male springbok physiology being better able to utilise poorer quality fodder (Davies and Skinner 1986) which is probably similar for reem. Crude protein contents for *A. tortilis* from Sudan indicate lower values between 4.0% and 5.6% although the moisture content is high (48.6–63.7%) making the selection thereof during the dry period’s imperative for the survival of dorcas gazelle (Carlisle and Ghorbail 1968; Grettenberger 1987) and dama gazelle (*Nanger dama* Pallas 1766) in Niger (Ghorbail 1974; Grettenberger and Newby 1986). *A. tortilis* is also an important source of browse for dorcas gazelle in Israel during summer (Baharav 1980, 1982). Baharav and Rosenzweig (1985) suggest that dorcas gazelle in Israel attempt to optimise water intake during summer rather than energy intake with water content differences between *A. tortilis* (winter – 54%, summer – 50%) and grasses (winter – 43%, summer – 5%) indicative thereof. Although *A. tortilis* is not utilised much during summer in Mahazat as-Sayd, as no green leaf flush occurs then, it was replaced by *S. spinescens*, probably serving the same purpose during this challenging season. Although the plants identified in the diet of reem from Saudi Arabia were not analysed for their nutritional parameters, a nutritional study of desert plants conducted in the United Arab Emirates ranked species with the highest nutritional values (e.g. crude protein, dry matter, ash, ether extract & acid detergent fibre) as *Acacia tortilis*, *Convolvulus* sp., *Dipterygium glaucum*, *Farsetia* sp., *Neurada procumbens*, *Panicum turgidum* and *Tribulus* sp. (Wensvoort 1992). These species are also preferred by reem from Saudi Arabia (Thouless and Al-Bassri 1989; Wachter 1995; Cunningham, 2009a,b).

The spines of *Indigofera spinosa*, another shrub utilised occasionally during the extreme dry periods in Mahazat as-Sayd, probably makes it less sought after as indicated by Cooper and Owen-Smith (1986) for other similar spiny browse species. The use and importance of *A. tortilis* pods, of which an individual tree can produce up to 10 kg (Baharav 1980), was noted for dorcas gazelle in Chad (Newby 1978) and Israel (Baharav 1980). *A. tortilis* are as important in Mahazat as-Sayd as pods drop during midsummer (August) when very little else is available (Cunningham, 2009b). According to Baharav (1980) ostrich outcompetes dorcas gazelle for pod use in Israel, something that may put additional stress on ostrich and reem during midsummer in Mahazat as-Sayd.

Other, more unconventional, plants included in the diet of reem include seaweeds, along the Caspian and Aral Sea (Kingswood and Blank 1996), leaves of mangrove (*Aveicennia marina*) (Cunningham 2008) and the desert hyacinth (*Cistanche tubulosa*) (Hornby 2003) in the United Arab Emirates.

Increased knowledge of the diet of reem is expected to assist wildlife managers with determining carrying capacity, assessing viable habitats for future reintroduction programmes, including the overall successful management within protected areas in Saudi Arabia.

References

- Al-Sodany, Y.M., Mosallam, H.A., Bazaid, S.A., 2011. Vegetation analysis of Mahazat Al-Zayd protected area: the second largest fenced nature reserve in the world. World Applied Sciences Journal 15 (8), 1144–1156.
- Asmodé, J.F. (1990). Mahazat as-Sayd Arabian sand gazelle reintroduction project. – Unpublished report, National Wildlife Research Centre, Taif, Saudi Arabia, 10pp.

- Baharav, D., 1980. Habitat utilisation of the dorcas gazelle in a desert saline area. *Journal of Arid Environments* 3, 161–167.
- Baharav, D., 1982. Desert habitat partitioning by the dorcas gazelle. *Journal of Arid Environments* 5, 323–335.
- Baharav, D., Rosenzweig, M.L., 1985. Optimal foraging in Dorcas gazelles. *Journal of Arid Environments* 9, 167–171.
- Bigalke, R.C., 1972. Observations on the behaviour and feeding habits of the springbok *Antidorcas marsupialis*. *Zoologica Africana* 7, 333–359.
- Bookhout, T.A., 1996. *Research and Management Techniques for Wildlife and Habitat*. Allen Press, Kansas, USA, 740 pp.
- Carlisle, D.B., Ghorbail, L.I., 1968. Food and water requirements of Dorcas gazelle in the Sudan. *Mammalia* 32, 570–576.
- Cooper, S.M., Owen-Smith, N., 1986. Effects of plant spinescence on large mammalian herbivores. *Oecologia* 68, 446–455.
- Cunningham, P.L., 2008. Terrestrial Mammals of the United Arab Emirates with Special Reference to the Abu Dhabi Emirate. In: Perry, R.J. (Ed.), *Terrestrial Environment of Abu Dhabi Emirate*. Environmental Agency, Abu Dhabi, pp. 309–378.
- Cunningham, P.L., 2009a. Observations of the seasonal dietary preference of male *Gazella subgutturosa marica* Thomas 1897 along foraging trails of central Saudi Arabia. *Journal of Threatened Taxa* 9, 445–449.
- Cunningham, P.L. (2009b): Feeding ecology of *Gazella subgutturosa marica* (reem) in the Mahazat as-Sayd protected area: seasonal comparisons. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 21pp.
- Cunningham, P.L., Watcher, T., 2009. Changes in the distribution, abundance and status of Arabian Sand Gazelle (*Gazella subgutturosa marica*) in Saudi Arabia: a review. *Mammalia* 73, 203–210.
- Davies, R.A.G., Skinner, J.D., 1986. Temporal activity patterns of springbok *Antidorcas marsupialis* and Merino sheep *Ovis aries* during a Karoo drought. *Transactions of the Royal Society of South Africa* 46, 115–142.
- Dunham, K.M., 1980. The diet of impala *Aepyceros melampus* in the Sengwa Wildlife Research Area, Rhodesia. *Journal of Zoology (London)* 192, 41–57.
- Dunham, K.M., Williamson, D.T., Joubert, E., 2001. Saudi Arabia. In: Mallon, D.P., Kingswood, S.C. (Eds.), *Antelopes Part 4: North Africa, the Middle East, and Asia.. Global Survey and Action Plans. - SSC Antelope Specialist Group., IUCN, Gland, Switzerland and Cambridge, UK, pp. 55–62.*
- El Mouden, E.H., Slimani, T., Ben Kaddour, K., Lagarde, F., Ouhammou, A., Bonnet, X., 2006. *Testudo graeca graeca* feeding ecology in an arid and overgrazed zone in Morocco. *Journal of Arid Environments* 64, 422–435.
- Ghorbail, L.I., 1974. Water relations and requirements of the dorcas gazelle in the Sudan. *Mammalia* 38, 88–107.
- Gillet, H., Launay, C. (1990): Flora analysis of the Mahazat as-Sayd vegetation. – Unpublished Report, National Wildlife Research Centre, Taif, Saudi Arabia.
- Grettenberger, J., 1987. Ecology of the dorcas gazelle in northern Niger. *Mammalia* 51 (4), 527–536.
- Grettenberger, J., Newby, J.E., 1986. The status and ecology of the dama gazelle in the Air and Ténéré National Nature Reserve, Niger. *Biological Conservation* 38, 207–216.
- Habibi, K., 1991. Arabian Gazelles. National Commission for Wildlife Conservation and Development Publication, No 4, Saudi Arabia, pp. 131.
- Haque, M.N. (1992): Preliminary report on the reintroduction of Arabian sand gazelle at Mahazat as-Sayd. – Unpublished report, National Commission for Wildlife Conservation and Development, Riyadh, 31pp.
- Haque, M.N. (n.d.) (1996): Reintroducing Arabian sand gazelle at Mahazat as-Sayd. – Unpublished report, National Commission for Wildlife Conservation and Development, Riyadh, Saudi Arabia.
- Harrison, D.L., Bates, P.J.J., 1991. *The Mammals of Arabia*. Harrison Zoological Museum, England, pp. 354.
- Hazard, L.C., Shemanski, D.R., Nagy, K.A., 2009. Nutritional quality of natural foods of juvenile desert tortoises, *Gopherus agassizii*: energy, nitrogen, and fibre digestibility. *Journal of Herpetology* 43 (1), 38–48.
- Henley, S.R., Ward, D., 2006. An evaluation of diet quality in two desert ungulates exposed to hyper-arid conditions. *African Journal of Range and Forage Science* 23 (3), 185–190.
- Hornby, R., 2003. Island gazelles and Desert Hyacinth. *Tribulus* 13.1, 26–27.
- IUCN SSC Antelope Specialist Group (2008): *Gazella subgutturosa* ssp. marica. In: IUCN 2012. IUCN Red List of Threatened Species. – Version 2012.2. <www.iucnredlist.org> .
- Kingdon, J., 1990. *Arabian Mammals. A Natural History*. Government Press, Ministry of Information, Bahrain, pp. 279.
- Kingswood, S.C., Blank, D.A., 1996. *Gazella subgutturosa*. *Mammalian Species* 518, 1–10.
- Liversidge, R., 1970. Identification of grazed grasses using epidermal characters. *Proceedings of the grassland society of South Africa* 5, 153–165.
- Mohamed, S.A., Saleh, M., 1991. Natural diet of the Arabian Rheem, *Gazella subgutturosa marica*. *Journal of Arid Environments* 20, 371–374.
- Mowlavi, M. (1978): Ecological studies of the goitered gazelle (*Gazella subgutturosa*) in Khosh Yeilagh refuge, Iran. MSc thesis, Michigan State University, In: Habibi K. 1991, editor. *Arabian Gazelles. – National Commission for Wildlife Conservation and Development, Publication No 4, Riyadh, Saudi Arabia.*
- Newby, J. (1978): The ecological resources of the Ouadi Rimé-Ouadi Achim Faunal Reserve, Chad. – Unpublished Report to the FAO.
- Robinson, E.R. (1999): Vegetation and range condition of Uruq Bani Ma'arid. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 12pp.
- Robinson, E.R. (2005): Arabian food plants of gazelles and ostrich. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 3pp.
- Robinson, E.R., Wachter, T. (2001). Response of vegetation in Uruq Bani Ma'Arid Protected Area to rainfall, spring 2001. – Unpublished Annual Report, KKWRC, Thumamah, 9 pp.
- Robinson, E.R., Al-Khaldi, A., Al-Mutairy, M. (2000). Assessment of conditions in the Harrat al Harrah protected area. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 8pp.
- Schulz, E., Fraas, S., Kaiser, T.M., Cunningham, P.L., Ismail, K., Wronski, T. (2012): Food preferences and tooth wear in the sand gazelle (*Gazella marica*). – *Mammalian Biology* <<http://dx.doi.org/10.1016/j.mambio.2012.04.006>> .
- Skinner, J.D., Smithers, R.H.N., 1990. *The Mammals of the Southern African Subregion*. The University of Pretoria, Pretoria, South Africa.
- Stewart, D.R.M., 1971. Food preference of an impala herd. *Journal of Wildlife Management* 35 (1), 86–93.
- Strauss, M., Al-Khaldi, A., Al-Ghamidi, M. (2000): Assessment of the current situation in the Uruq Bani Ma'arid protected area and outline of possible actions to be taken. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 10pp.
- Thouless, C.R., Al-Bassri, K. (1989): Rheem gazelle in Al Khunfah Reserve. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 28pp.
- Thouless, C.R., Tatwany, H. (1989): Sand gazelle in Al Khunfah. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 22pp.
- Thouless, C.R., Grainger, J.G., Shobrak, M., Habibi, K., 1991. Conservation status of gazelles in Saudi Arabia. *Biological Conservation* 58, 85–98.
- Ul-Islam, Z., Ismail, K., Boug, A., 2010. Catastrophic die-off of globally threatened of Arabian Oryx and Sand Gazelle in the fenced protected area of the arid central Saudi Arabia. *Journal of Threatened Taxa* 2 (2), 677–684.

- Van Rooyen, R.J., Skinner, J.D., 1989. Dietary differences between the sexes in impala *Aepyceros melampus*. Transactions of the Royal Society of South Africa 47, 181–185.
- Vesey-Fitzgerald, L.D.E.F., 1952. Wildlife in Arabia. Oryx 1 (5), 232–235.
- Wacher, T. (1995): Sand gazelle monitoring at Uruq Bani Ma'Arif. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, Saudi Arabia, 15pp.
- Wacher, T. (2005): Monitoring results: Uruq Bani Ma'arif, July 2005. – Unpublished Report, King Khalid Wildlife Research Centre, Thumamah, 5 pp.
- Wacher, T., Wronski, T., Hammond, R.L., Winney, B., Blacket, M.J., Hundertmark, K.J., Mohammed, O.B., Omer, S.A., Macasero, W., Lerp, H., Plath, M., Bleidorn, C. (2010): Phylogenetic analysis of mitochondrial DNA sequences reveals polyphyly in the goitered gazelle (*Gazella subgutturosa*). – Conservation Genetics <<http://dx.doi.org/10.1007/s10592-010-0169-6>>.
- Wensvoort, J. (1992): Desert plants and diets for race camels. In: Allen, W.R., Higgins, A.F., Maghew, I.E., Snow, D.H., Wade, J.F. (Eds), Proceeding of the 1st Camel Conference – R&W Publications, Newmarket, pp. 323–326.