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Diets and Resource Sharing Among Livestock on the Saiq Plateau, Jebel Akhdar Mountains, Oman

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ABSTRACT

A standard method of fecal plant cuticle analysis was used to determine the diets of goats, sheep and feral donkeys on the Saiq Plateau of Oman during a year of below average rainfall. Feces were collected monthly from 8 localities. Twenty-three thousand four hundred digital cuticle images of the feces and the plant reference collection were stored in a Microsoft Access© database. This computer-assisted system greatly increased the speed and efficiency of plant identification, data manipulation and analysis. Goats, sheep and donkeys consumed 37, 32 and 30 species respectively, consisting mostly of plants that have high to moderate coverage in the community (*Helianthemum lippii, Sideroxylon mascatense, Cymbopogon sp., Olea europaea, Teucrium mascatense, Juniperus excelsa*). A few species with low coverage had a moderate occurrence in the diets (*Farsetia sp., Eragrostris barrelieri, Cenchrus ciliaris*). Goats and sheep ate more species of dicots than monocots, but donkeys consumed them in equal proportions. No notable seasonal changes occurred in the diets during the brief dry period. Diet overlap among goats, sheep and donkeys was high (median O_{jk} = 0.836) and asymmetrical; a moderate number of plant species eaten by donkeys are also eaten by goats and sheep (O_{jk} = 0.63), but most plants consumed by goats and sheep are also eaten by donkeys (O_{jk} = 0.85 and 0.82, respectively). Depending on stocking levels, this high degree of diet overlap may be decreasing the productivity and reproduction of the food plants as well as that of the goats and sheep, which commonly require supplemental feeding. *Juniperus excelsa*, a threatened tree, was moderately common in the diet of goats and sheep. Several possible impacts of domestic animals on wild species are discussed. Range productivity and stocking levels need to be quantified as a first step toward developing a sustainable animal industry on the Saiq Plateau.

Key Words: Goat, Sheep and Donkey Grazing, Middle East Mountain Ecology, Oman Animal Husbandry

INTRODUCTION

The Saiq Plateau is an elevated region of the eastern Jebel Akhdar Mountains of northern Oman. The horizontal surface area of the plateau is approximately 300 km^2 (slope surfaces may double the area), the elevation varies between 1800 to 2300 m, and the climate is semi-arid. Annual rainfall is quite variable (127-900 mm, mean 331mm), mostly occurring in early spring and again in mid-summer (Figure 1a). The principle vegetation is an open woodland dominated by trees (*Juniperus excelsa* M. Bieb., *Olea europaea* L.), widely spaced shrubs (*Dodonaea viscosa* (L.) Jacq., *Sideroxylon mascatense* Falc.), *Ephedra pachyclada* Boiss., *Helianthemum lippii* (L.) Dum-Cours.), grasses (*Cymbopogon schoenanthus* (L.) Spreng., *Cenchrus ciliaris* L., *Chloris gayana* Kunth.) and a variety of forbs.

For millennia, people of the mountain villages have depended on goat (*Capra hircus* L.) production as their primary source of meat and income. The Jebel Akhdar goat breed is large (40-55 kg), and the meat is esteemed by Omanis. Sheep (*Ovis aries* L.) were introduced into the grazing system quite recently and constitute a minor component of the mixed grazing

herds. In 2006, 12,293 goats and 663 sheep were vaccinated on the Saiq Plateau by the Ministry of Agriculture and Fisheries. Feral donkeys (*Equus asinus* L.) are the second most abundant domestic species, and Ministry of Agriculture and Fisheries personnel believe between 2 and 6000 animals graze the plateau area. Whatever their actual population size may be, local people agree that the number of donkeys is increasing. Less than 50 cattle are kept in pens.

Zaibet et al. (2004) analyzed the economic performance of the Jebel Akhdar goat production system in relation to recent social changes that have occurred on the mountain. They concluded that: the major source of income was not from goat husbandry but from monies derived outside the farm; flock sizes were relatively large and required supplemental feeding to compensate for the declining range productivity; in some cases resource use was inefficient.

There has been no previous research on the plants consumed by the domestic livestock of the Jebel Akhdar Mountains of Oman. The objectives of this research are to: describe the diets of goats, sheep and donkeys on the Saiq Plateau; quantify the degree of diet overlap among them; suggest how this information can be used to improve management of the animal industry.

MATERIALS AND METHODS

Plant species eaten by goats, sheep and donkeys were identified from cuticles (Table 1) in their fecal pellets. Cuticles provide an accurate estimate of the botanical and dry weight composition of herbivore diets. Details of this methodology and its validation are described by Alipayo et al. (1992) Holechek (1982), Holechek and Gross (1982) and references therein. We isolated cuticles by first grinding dry fecal material and then soaking it in warm water for 10 min, followed by 5 minutes in sodium hypochlorite (bleach). This solution was rinsed with water several times to remove all bleach and then mounted with Hoyers solution on glass microscope slides. Five slides were made from each species at each sample locality, and 20 microscope fields were digitally photographed at 100X. A total of 23,400 images were stored on CDs and provide a permanent record of the cuticles. A reference collection was made that contains cuticle images of 95 species (78 dicots and 17 monocots) collected on the Saiq Plateau. For each monthly sample, 5 microscope fields were randomly selected on each of the 5 slides for identification of the plant cuticles (Table 2). Cuticles with no distinguishing features were classified as "not determined" (Indet) and comprised 14.74% of the cuticles. Fecal samples were collected monthly from 8 localities on the Saiq Plateau from December 2004 to

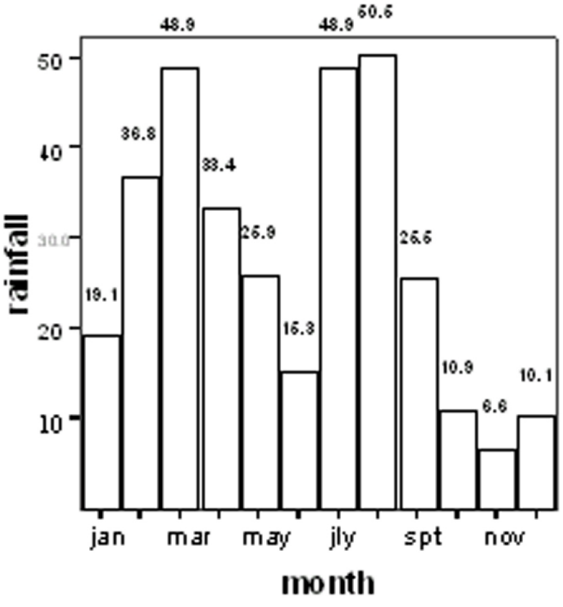

Figure 1A. Long- term (1971- 2005) mean monthly rainfall at Saiq, Jebel Al Akhdar, Oman.

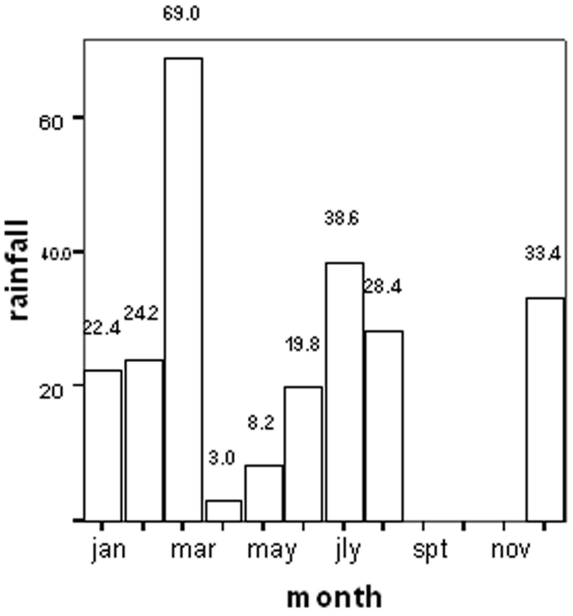

Figure 1B. Monthly rainfall for the period December 2004 to November 2005. 1755 m asl. Data from Directorate General of Civil Aviation and Meteorology.

Table 1. Sample localities and number of monthly fecal collections on the Saiq Plateau, Jebel Akhdar for the period of December 2004 to November 2005. R = range sample, P = pen.

Site	Location (latitude/longitude)	Elevation (m)	Goat	Sheep	Donkey	
Hail Yemen	23° 04, 523' N	057° 42.185' E	2027	7 R + 4P	0	0
Shnoot	23° 06.724' N	057° 39.531' E	2260	12 R+12P	12R + 11P	12R
Juniper Bowl	23° 07.438' N	057° 36.971' E	2295	12 R	0	12R
Wadi Rahba	23° 08.105' N	057° 35.903' E	2240	12 R	6 R	12 R
Hail Hadap	23° 08.207' N	057° 34.317' E	2201	12 P	12 P	0
Al Ghaleel	23° 06.996' E	057° 34.835' E	2268	12R + 12P	10 R	12 R
Al Aleena	23° 06.847' N	057° 34.665' E	2237	12 P	12 P	0
Aqbat Al Beyoot	23° 07.051' N	057° 31.411' E	1820	12 P	0	12 R

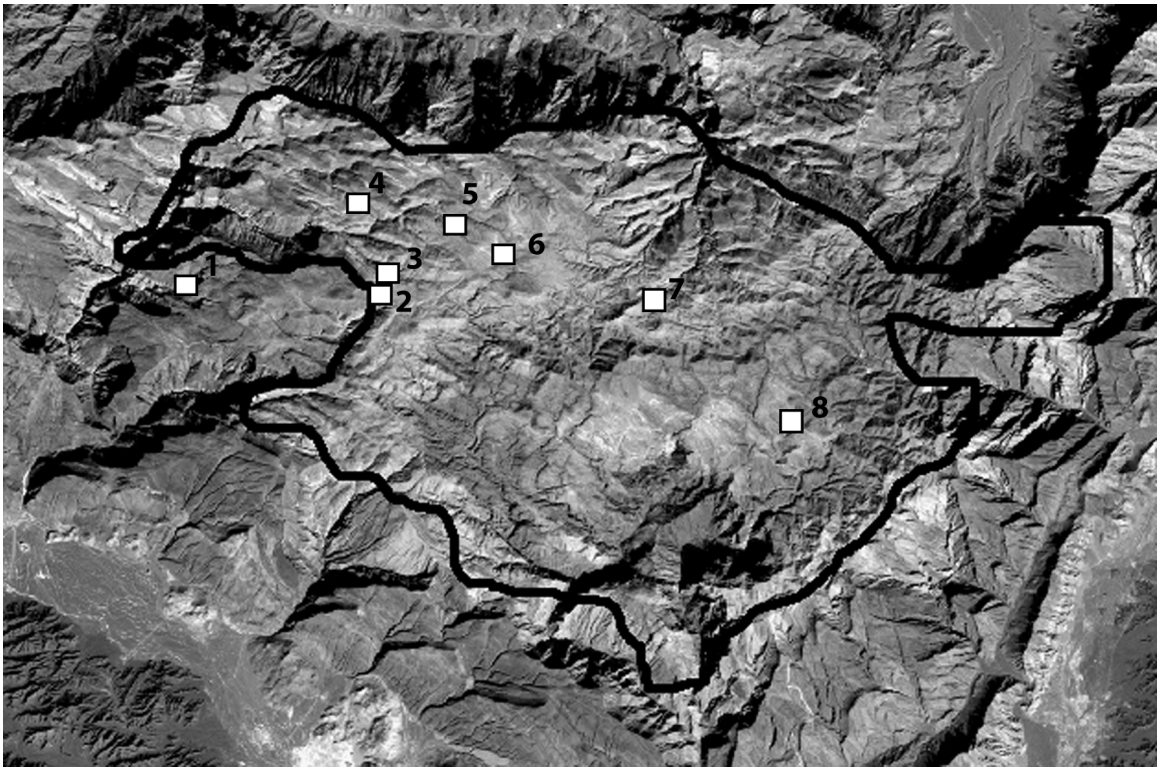

Figure 2. Fecal collection sites on the Saiq Plateau, Jebel Al Akhdar, Oman. Numbered localities are: 1. Aqbat Al Beyut, 2.Al Aleena, 3. Al ghaleel, 4. Hail Hadap, 5. Wadi Rabba, 6. Juniper Bowl, 7. Schnoot and 8. Hail Yemen

November 2005 (Table 1, Figure 2). Samples were taken from open range and from pens where free-ranging animals are retained at night. Fresh feces were generally available from the pens, but some range samples were probably deposited several weeks prior to our collection. Consequently some range samples may not correctly reflect monthly changes of diet, and this aspect is not emphasized here. Goat feces were collected monthly from 8 sites, sheep from 6 and donkey from 5 sites. Goats are the primary domestic species on the Saiq Plateau, and the number of potential collection sites is greater than for sheep or donkeys.

A computer-assisted system was developed to identify the cuticles and store other relevant data. Images in the reference collection were grouped according to distinguishing characteristics (e.g., monocot or dicot, hairs, stomata, surface architecture). Using a split screen one can rapidly compare the fecal cuticle morphology with those in the reference collection. Identifications and other data (locality, month, animal and sample type) were entered into a Microsoft Access© data base. This allowed rapid manipulation and analysis of data in several ways. Only summaries are presented here, but all digital photographs and an extensive data base are available to researchers from the authors through the Centre of Environmental Studies and Research (CESAR), Sultan Qaboos University.

Cuticle counts in Table 4 were used to calculate the extent of diet overlap among the three species. The asymmetrical index of MacArthur and Levins (1967) quantifies the overlap of food resources, where $O_{jk} = \sum p_{ij}p_{ik} / \sum p^2_{ij.}$ O_{jk} is the extent of overlap of species k on j, and p_{ij} and p_{ik} are the proportions of plant species i in the diet of herbivores j and k. The index varies from 0, no similarity, to 1, complete similarity. With only three rainy months (June-August) and three dry months (September-November; Figures 1 a, 1b), it was not possible to statistically test for seasonal shifts in the diets. Instead, a qualitative assessment was made by comparing the rank order of the abundance of those species forming the bulk of the diet (80-90% of total monthly counts) during the wet and dry periods.

RESULTS

During the study rainfall totaled 247.6mm, about 25% below the long-term average (331.1mm). From December 2004 to March 2005 precipitation was slightly above average, but less than normal during April and May and rainless from September to November 2005 (Figure 1b). The long-term annual average air temperature is 18.1ºC with a minimum of -3.6ºC and a maximum of 36.3ºC (Department of Civil Aviation and Meteorology).

Twenty-seven dicots and 12 monocots were identified in the feces of goats, sheep and donkeys. Two species had distinctive cuticles but were not in the reference collection and could not be identified. Eleven plants occurred commonly (occurrence > 1%) in the feces of the three livestock species (Table 3). Cuticles of *Helianthemum lippii* (25.5%), *Sideroxylon mascatense* (22.13%), *Cymbopogon* sp. *(*probably *schoenanthus*) (10.5%) and *Olea europaea* (7.86%) were dominant, and their respective monthly frequencies did not vary greatly. Four grasses and 2 dicots were less frequent but occurred throughout the year. *Juniperus excelsa*, a threatened tree (IUCN, ver. 2.3, 1994), occurred 101 times in goat feces (1.7%), 40 times in sheep feces (1.3%), and once in donkey feces (0.04%). Goats, sheep and donkeys took a variety of grasses, principally *Cymbopogon* sp., *Eragrostis barrelieri* Daveau, *Enneapogon persicus* Boiss., *Cenchrus ciliaris* and *Chloris gayana*. Overall, goats consumed 37 plant species, sheep 32 and donkeys 30. More goat fecal samples were analyzed (Table 2), which may account for the greater species richness of their diet.

Table 2. Data relevant to feces collection and their analysis. R = range sample; P = pen.

	Goat	Sheep	Donkey
Sample Sites	8	5	5
Monthly Samples	119 (48R+71P)	63 (28R+35P)	60 R
Slides Photographed	11900	6300	6000
Fields Analyzed	2975	1575	1500
Proportion of all fields	0.492	0.260	0.248

Table 3. Plants commonly (>1%) consumed by goats, sheep and donkeys on the Saiq Plateau for the period December 2004 to November 2005. Indet indicates species not determined. Percent occurrence is based on 11,900 cuticles.

Species	Class	Percent	Count
Helianthemum lippii	Dicot	25.5	3035
Sideroxylon mascatense	Dicot	22.1	2633
Cymbopogon sp.	Monocot	10.5	1248
Olea europaea	Dicot	7.7	935
Teucrium mascatense	Dicot	2.7	325
Eragrostis barrelieri	Monocot	2.7	322
Cenchrus ciliaris	Monocot	2.1	248
Farsetia sp.	Dicot	1.6	186
Chloris gayana	Monocot	1.3	160
Enneapogon persicus	Monocot	1.3	155
Juniperus excelsa	Dicot	1.2	142
Indet	Dicot	7.5	890
Indet	Monocot	7.3	864

Table 4. Most common plants (>1%) in the diet of goats, sheep and donkeys on the Saiq Plateau from December 2004 to November 2005. Percent occurrence is based on 6056 cuticles for goats, 3084 for sheep and 2760 for donkeys.

Species	Class	Goat		Sheep		Donkey	
		%	Count	%	Count	%	Count
Sideroxylon mascatense	Dicot	28.6	1729	22.9	707	7.1	197
Helianthemum lippii	Dicot	28.1	1701	25.7	791	19.7	543
Olea europaea	Dicot	8.1	490	10.7	329	4.2	116
Cymbopogon sp.	Monocot	7.0	425	6.9	213	22.1	610
Teucrium mascatense	Dicot	2.7	162	3.0	92	2.6	71
Farsetia sp.	Dicot	2.2	130	1.7	53	-	-
Eragrostis barrelieri	Monocot	1.9	116	1.8	57	5.4	149
Enneapogon persicus	Monocot	-	-	-	-	3.7	103
Cenchrus ciliaris	Monocot	1.9	114	1.7	51	3.0	83
Juniperus excelsa	Dicot	1.7	101	1.3	40	-	-
Chloris gayana	Monocot	-	-	1.5	45	2.5	70
Indigofera sp.	Dicot	-	-	1.2	38	-	-
Aristida abnormis	Monocot	-	-	-	-	1.3	36
Cynodon dactylon	Monocot	-	-	-	-	1.0	28

Table 5. Number of monocot and dicot species consumed by goats, sheep and donkeys on the Saiq Plateau for the period December 2004 to November 2005. Ratio is Dicots/Monocots.

	Goat			**Sheep**			**Donkey**		
	Monocot	Dicot	Ratio	Monocot	Dicot	Ratio	Monocot	Dicot	Ratio
December	10	14	1.4	6	10	1.67	10	6	0.6
January	8	14	1.75	8	11	1.38	8	10	0.8
February	10	12	1.2	10	10	1.0	8	7	0.88
March	10	8	0.80	6	7	1.17	9	7	0.78
April	9	15	1.67	8	9	1.13	9	6	0.67
May	9	17	1.89	8	13	1.63	9	8	0.89
June	8	15	1.88	6	15	2.5	10	12	1.2
July	6	13	2.17	7	14	2.0	8	8	1.0
August	8	14	1.75	6	8	1.33	7	6	0.86
September	10	15	1.50	9	9	1.0	9	8	0.89
October	9	9	1.0	8	8	1.0	6	8	1.33
November	8	9	1.13	6	9	1.50	8	7	0.88
Mean	8.75	12.92	1.51	7.33	10.25	1.44	8.42	7.75	0.88

Seven grasses and four dicots occurred commonly (>1%) in donkey feces, sheep droppings had 4 grasses and 7 dicots and those of goats contained 3 grasses and 6 dicots (Table 4). The monthly ratios of the number of species of dicots and monocots in the diets varied. On a yearly basis, donkeys consumed both types of plants equally (Table 5, ANOVA, $F = 1.19$, $P = 0.286$, $n = 12$), but goats and sheep ate significantly more species of dicots than monocots (ANOVA, $F = 21.8$, $P = 0.000$, $n=12$; $F= 12.4$, $P= 0.002$, $n = 12$, respectively).

DISCUSSION

Rainfall on the Saiq Plateau may occur in any month, but generally it is more concentrated during winter and again in summer. In environments with prolonged dry seasons livestock typically rely more on dicot plants, presumably because of their higher nutritional quality and water content. During this study there was an uncharacteristic 3-month rainless period (Fig 1b), but marked shifts in diet were not noted for any of the three species. Possibly the moderate temperature regime allows most perennial and some ephemeral species to retain foliage even during the drier months.

When herded together, goat and sheep diets are usually less similar than they were on the Saiq Plateau. In Spain they consumed in common 64% of the 111 plants identified in their feces (Bartolome et al. 1998), but sheep ate graminoids more consistently and goats favored dicot shrubs. In tropical deciduous woodland of Brasil, goats selected more browse species, and sheep ate more grasses (Kronberg and Malechek 1997). Under excellent range conditions in Texas, sheep diets were dominated by grasses, but goats ate grass and browse species in near equal proportions (Bryant et al 1979). Hanley and Hanley (1982) believe that sheep generally prefer grasses because they have a very large rumen in proportion to their body weight, an adaptation for digesting plants high in cellulose. In their study of 5 sympatric herbivores in the Great Basin region of the United States, sheep ate moderate quantities of grasses (47-68%) complimented with forbes and browse species. On the Saiq Plateau, cuticle fragments of forbes and browse plants were considerably more abundant in the feces of goats (86.8%) and sheep (84.8%) than were grasses (Table 4).

Donkeys are usually considered to be grazers, but in dry lowland habitats their diets are more varied. In the Sonoran Desert of southwestern California, donkeys consumed 39 plant species consisting of browse (61.1%), forbes (30.1%) and grasses (3.8%) (Woodward and Ohmart 1976), and in the Death Valley, California their diet contained similar plant types and proportions, but with slightly more grass (10%; Browning 1960). However, in the Grand Canyon of Arizona, donkeys consumed some browse (27.5%), and forbes (11.5%) but ate mostly grasses (61%) (Hansen & Martin 1973). Only Woodward and Ohmart (1976) sampled throughout an annual cycle. Süß (2005) found 54% overlap in the species ingested by sheep and donkeys in the Rhine Valley of Germany. On the Saiq Plateau donkey feces contained almost equal numbers of cuticles from browse and forbes (46.2%) and grasses (53.8%) (Table 4).

The cuticle analyses revealed that diet overlap is extensive among goat, sheep and feral donkeys (median O_{jk} = 0.836). Goats and sheep have nearly identical food niches, and their diets comprise a large subset of the species eaten by donkeys (Table 6). If stocking rates are above range capacity then this high degree of diet overlap could reduce goat and sheep productivity, decrease vegetative cover and accelerate degradation of the range. Since donkeys are no longer economically important to the people of Jebel Akhdar, regulating their numbers should be a management priority.

Table 6. The asymmetrical index (MacArthur and Levins 1967) of diet overlap among goats, sheep and feral donkeys on the Saiq Plateau. Calculations are based on counts in Table 4.. Values indicate the degree of diet overlap of species in the left column with those in the top row.

	Goat	Sheep	Donkey
Goat		0.974	0.854
Sheep	0.922		0.818
Donkey	0.631	0.639	

With the exception of *Helianthemum lippii,* the most common plants in the feces (Table 3) also have the greatest average coverage on the rangeland (> 2.5%; Dr. Annette Patzelt, personal communication). *Helianthemum* has moderate coverage (1.3%) but is the most common species in the feces (25.5%). Animals may be consuming plants in proportion to their abundance and less on the nutritional value. *Cymbopogon* is considered an unpalatable or little-grazed grass on Sahelian ranges (Le Houerou 1989), and in Oman it is relatively low in crude protein (El Kharbotly et al. 2003). However, it was very common in the diets, but more palatable and nutritious grasses like *Aristida, Cenchrus* and *Chloris* sp. occurred at lower frequencies (Tables 3 and 4). The predominance of chemically-defended and thorny species in the vegetation (e.g.,*Dodonaea viscosa, Calotropis procera* Ait., *Solanum* sp., *Datura* sp., *Teucrium mascatense* Boiss., *Sideroxylon mascatense*) also signals overstocking (Le Houerou 1989). Canopy profiles of trees and shrubs indicate heavy browsing, and herders

cut fodder from trees that animals cannot reach. Large spaces of barren soil between perennials imply loss of vegetative cover. Le Houerou (1995) suggests that poor range conditions in the Near East have resulted mainly from grazing sheep with goats, and from the willingness of governments to subsidize costs for supplementary feeding. However, the impacts of feral donkeys grazing the same ranges as small stock have not been addressed.

Donkeys impact vegetation differently from goats and sheep. Because of their larger size and caecal fermentation system, donkeys generally forage more continuously on fibrous plants, and based on their metabolic weights ($mass^{0.75}$) they require approximately 3 times more energy day^{-1} than goats or sheep (Le Houerou 1989). Donkeys eat the stems and leaves of small dicots, but goats and sheep usually consume only leaves, and donkeys will dig with their hooves to remove and consume the entire plant including the roots (Canacoo and Avoryno 1998). Donkeys can reduce dominant grass species, which opens gaps of bare ground, and during prolonged drought they strip bark from trees, giving them the reputation of being destructive herbivores. However, by digging and wallowing (sand bathing) in sandy areas donkeys create patches of disturbed soil that enhance the germination and growth of some annual plants. Donkeys revisit sites to defecate and urinate. These latrine soils are nitrogen-rich and are often colonized by ruderal species (Süß 2005). In contrast, sheep and goats eliminate while grazing spreading the faeces and urine more evenly across the grazing area. Taken together these studies imply that the substantial populations of donkeys on the Saiq Plateau probably contribute significantly to the degradation of the environment and may be affecting livestock production.

Domestic and feral animals may have direct and indirect impacts on wild species by reducing the quantity of food and by their behavioral interactions. In Trans-Himalayan mountains free-ranging horses, goats and sheep limit food and habitat space of the Himalayan Ibex (*Capra sibirca*), and goats and sheep exclude them from certain pastures (Bagchi et al. 2004). In the same area, Mishra et al. (2004) found that grazing by seven species of domestic herbivores reduced the forage of the Bharal (*Pseuodis nayar*), and presumably this lowered its population density by 63%. Food competition and interference by donkeys have been implicated (Seegmiller and Ohmart 1981) in contributing to the decline of Desert Bighorn Sheep (*Ovis canadensis*) in the southwestern United States. The Arabian Tahr (*Hemitragus jayakari* Thomas), is a threatened species (IUCN 2002) endemic to Oman and the United Arab Emirates. Its habitat of steep slopes and cliffs is limited on the Saiq Plateau, but within the reach of free-ranging goats. In Wadi As Serin, Tahr consume a variety of grasses, forbes and browse, of which 30 species are shared with goats (Al Majani 1999, Munton 1985). Behavioural research documenting the interactions between domestic animals and the Arabian Tahr should be included in future management planning.

Animal herding has existed in the Jebel Akhdar region for about 5000 years (Schreiber 2004). With recent human population growth and implementation of modern husbandry practices in Oman, herds have increased beyond their natural limits causing land degradation (Al Harthi 2003). The current condition of the vegetation, the erosive nature of the soils, and the growing need for supplemental feeding on the Saiq Plateau all point to an ecosystem stressed from overstocking. Any attempt to establish a self-sustaining animal industry must begin with a rigorous assessment of livestock numbers, vegetative cover, plant productivity and soil quality. Monitoring through periodic assessments is needed to assist management in bringing the system toward sustainability. No management plan is likely to succeed without understanding the social and economic aspects of animal husbandry, and Zaibet et al. (2004) have made a commendable start in that direction.

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