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Ecology and Management of the Saiq Plateau Rangelands, Oman

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ABSTRACT

The high-elevation rangelands of the Saiq Plateau are degraded and require new management strategies. Three livestock species consume many of the same plants throughout the year, placing continual grazing pressure on the ecosystem. Plant canopy cover is generally low (0-13%) and large areas of bare soil exist between perennial vegetation. Soils are shallow, erosive and low in organic matter. The poor ecological condition of the range poses a threat to endangered and endemic mountain species, contributes to eutrophication of freshwater and decreases animal production and income for local farmers. Feral donkeys must be removed from the environment, goat and sheep herds reduced to levels sufficient to sustain their owners, and traditional livestock-free pastures should be resumed. This or similar management plans could restore the natural vegetation in 10-20 years.

Key Words: Oman Rangeland Ecology; Livestock Management; Soil Management; Saiq Plateau

INTRODUCTION

Archaeologists believe humans began herding animals in the Jebel Akhdar region about 4000 years ago (Schreiber 2004), and until recently animal husbandry has been the most important source of food and income for the local people. Recent publications have described the animal husbandry systems and vegetation on slopes below the Saiq Plateau (Schlecht et al. 2009, Brinkman et al. 2009, Dickhoefer et al. 2010), but the higher elevations have not been systematically assessed. Here we review our previous work on livestock diets and present new data on the condition of soils and vegetation above 1900 meters.

The Saiq Plateau is located on the eastern Jebel Akhdar Mountains, which are the highest sector of the Al Hajar Al Gharbi mountain chain. The horizontal surface area of the plateau is approximately 300 km^2 and the elevation varies between 1800 and 2350 meters. The mountains are a centre of plant endemicity and species richness, having floral affinities with northeastern Africa, Iran and Pakistan (Baluchistan). The high elevation vegetation is an open evergreen woodland dominated by two trees, *Juniperus seravschanica* Kom and *Olea europaea* L. The lower strata consist of large and small shrubs and a ground cover of forbes and grasses (Robinson and Al Busaidi 2009). Much of the surface is exposed bedrock, (Figures 1 and 3).

Compared to the surrounding lowlands, the Saiq Plateau enjoys a cooler, semi-arid climate with moderate temperatures. The only weather station is at the village of Saiq, and this brief summary is based on its 28-year record (1979-2006). The average temperature is 18.1ºC, the summer maximum rarely exceeds 35 ºC, and the coldest winter temperatures are slightly below freezing (-3 ºC). Annual precipitation is variable with peak periods in early spring and mid-summer (annual average 324.04 ± 171.26mm, CV 52.8%). Rain can occur in any month (monthly mean 27.02 ± 15.56 mm; CV 57.6%), but brief dry periods of several months do occur (Figure 2).

Figure 1. An open Juniper (*Juniperus seravschanica*)–Olive (*Olea europaea*) woodland with moderately good vegetation cover.

Figure 3. Badly degraded Olive woodland in the vicinity of Al Gereer. Large areas of exposed bedrock are typical of the Saiq Plateau and greatly reduce the potential for plant establishment.

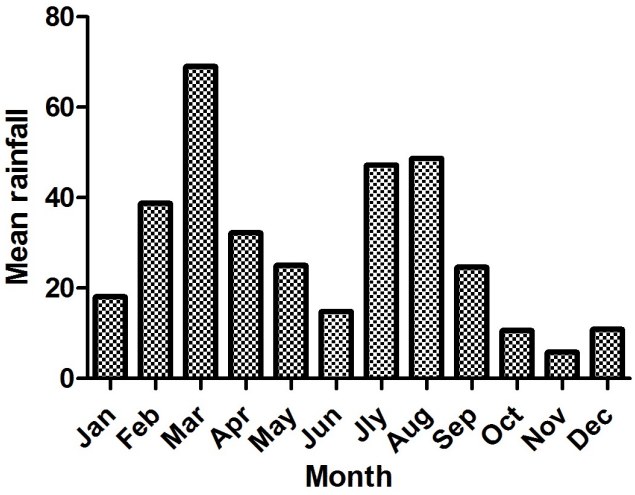

Figure 2. Mean monthly rainfall (mm) at Saiq village, Jebel Akhdar, Oman (1979-2006). Data from Directorate of Civil Aviation and Meteorology, Sultanate of Oman.

Livestock on the Saiq Plateau have not been systematically censused, but some indication of their numbers is available through vaccination records. In 2006, 12,293 goats and 663 sheep were vaccinated by the Ministry of Agriculture and Fisheries. The Jebel Akhdar goat breed is large (40-60 kg) and produces a good quality meat that is esteemed by people in the region. Donkeys, which were once used for transportation, now roam freely, and local governmental agriculturists believe that several thousand feral donkeys live in this mountain sector.

METHODS

Food plants were identified from their cuticles in the feces. Feces were collected monthly from 8 sites that represent a variety of range conditions. Coordinates of the localities are given in Table1. Cuticles were isolated

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 (Al Harthi et al. 2008).

Site	Location		Elevation	Goat	Sheep	Donkey
Hail Yemen	23° 04, 523' N	057° 42.185' E	2027	11	0	0
Shnoot	23° 06.724' N	057° 39.531' E	2260	24	24	12
Juniper Bowl	23° 07.438' N	057° 36.971' E	2295	12	0	12
Wadi Rahba	23° 08.105' N	057° 35.903' E	2240	12	6	12
Hail Hadap	23° 08.207' N	057° 34.317' E	2201	12	12	0
Al Ghaleel	23° 06.996' N	057° 34.835' E	2268	24	10	12
Al Alaleena	23° 06.847' N	057° 34.665' E	2237	24	12	0
Aqbat Al Beyoot	23° 07.051' N	057° 31.411' E	1820	12	0	12

by grinding dry feces and then soaking in warm water for 10 minutes followed by 5 minutes in sodium hypochlorite. This solution was rinsed thoroughly in water several times and then mounted with Hoyers solution on glass microscopic slides. Five slides were made from each animal species at each sample locality, and twenty microscope fields were digitally photographed at 100X from each slide. A total of 23,400 images plus those from a reference collection of 95 species in the range flora form the electronic database from which identifications were made. The cuticle methodology provides accurate estimates of the botanical composition of animal diets (Alipayo et al. 1992). The extent of diet overlap among the three domestic species was estimated by the MacArthur and Levins asymmetrical index:

$$O_{jk} = \sum p_{ij}\, p_{ik} / \sum p^2_{ij}$$

where 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 (MacArthur and Levins 1967).

The Botanical nomenclature follows Cope (1985), Miller and Cope (1996), Adams et al. 2014 and Patzelt (2014).

RESULTS AND DISCUSSION

Livestock Diets

Rainfall during the period of fecal collection (December 2004 to November 2005) was 248 mm, approximately 25% below the long-term average (324 mm), and there was an uncharacteristic rainless period from September to November. This possibly reduced diet diversity and altered the composition compared to years with normal precipitation. No marked seasonal variation occurred in the diet composition of goats, sheep and donkeys even during a three-month rainless period, suggesting that plants are able to retain their foliage throughout dry periods because temperatures are moderate (Al Harthi et al. 2008).

Goats, sheep and donkeys consumed 37, 32 and 30 plant species respectively, and a total of 39 species occurred in their diets (Al Harthi et al. 2008). On an annual basis, 3-4 species of grasses and a similar number of dicots comprised more than 75% of the cuticles that occurred in the feces at a frequency of 0.5% or greater. (Table 2). Although limiting the analysis to the 0.5% occurrence level is arbitrary, it includes more than half of the species identified in the diets. Species with an annual occurrence of less than 0.5% have cuticle counts of less than 12, and are considered uncommon in the diets.

Donkeys consumed 10 grass and 5 dicot species. Two shrubs (*Helianthemum lippii* (L.) Dum Cours and *Sideroxylon mascatense* Falc.) and olive tree (*Olea europaea* L.) accounted for 90.4 % of the dicot cuticles. More than half of the grass cuticles were *Cymbopogon* sp. followed in decreasing order by *Eragrostis barrlieri* Daveau *Enneapogon persicus* Boiss. and *Cenchurus ciliaris* L.(Table 2). *E.persicus* was consumed more frequently by donkeys than by goats or sheep. Rhodes grass (*Chloris gayana* Kunth), a commercial fodder, was also common in the diet (6.2%). An additional 5 grass species were consumed less frequently.

Goats ate 9 species of dicots, of which *H. lippii* and *S. muscatense* contributed 78% of the cuticles. Olive trees were also important (11.2%). The most frequent grass species were *Cymbopogon* sp. (52 %), *E. barrlieri* (14.2 %) and *C. ciliaris* (13.9 %) (Table 2).

Sheep ingested 10 dicots comprised mainly of *H. lippii* (37.7%), *S. muscatense* (33.7%), and *O. europaea* (15.7%). The most frequently consumed grasses were *Cymbopogon* sp. (50%), *E. barrlieri* (13.4%), *C. ciliaris* (12.0%) and *C. gayana* (9.6%). The frequency of two fodder species, Rhodes grass and olive, was highest in sheep diets (Table 2).

The diets indicate that the three livestock species utilize many of the same plants. The MacArthur and Levins Index (MacArthur and Levins 1967) reveals more clearly to what extent this is true. Diet overlap is broad between goats, sheep and donkeys (median $O_{jk} = 0.836$). Goats and sheep ate a moderate number of plant species taken by donkeys ($O_{jk} = .631$ and .639 respectively), but most species eaten by goats and sheep are also consumed by donkeys ($O_{jk} = .854$ and .818 respectively) (Al Harthi et al. 2008). Similar levels of asymmetry and overlap also occurred among these three species in the Spiti Valley of Indian Trans-Himalaya (Mishra 2004). The asymmetry of sharing implies that when food resources are limiting, donkeys will probably have a strong impact on the energy and nutrient intake of goats and sheep. At high stocking levels, this degree of resource sharing may decrease plant and animal production, and partially explain the need for costly supplemental feeding by the herders. This is an important management issue that is addressed later.

Table 2. Species in the diets of donkeys, sheep and goats in the Saiq Plateau, Jebel Akhdar, Oman from December 2004 to November 2005. Numbers below the consumers' names are the count and percent in the diet respectively. Analysis is based on 60 monthly fecal samples from 5 localities for donkeys, 119 monthly samples from 8 localities for goats, and 63 monthly samples from 5 localities for sheep.

Species	Donkeys		Sheep		Goats	
	count	%	count	%	count	%
Dicots						
Berberis baluchistanica Ahrendt					22	0.5
Crotalaria aegyptiaca Benth.	21	2.2				
Daphne mucronata Royle			12	0.6		
Farsetia sp.			53	2.5	130	3
Helianthemum lippii	54	57.3	791	37.7	1701	38.6
Hibiscus micranthis L.F.			18	0.9		
Indigofera sp.			39	1.9	54	1.2
Juniperus seravschanica			40	1.9	101	2.2
Olea europaea	116	12.3	329	15.7	491	11.2
Sideroxylon mascatense	197	20.8	707	33.7	1729	39.3
Teurium mascatense	71	7.5	92	4.4	162	3.7
Ziziphus hajeriense Duling, Ghaz & Prend.			17	0.8	12	0.3
Grasses						
Aristida abnormis	36	3.2	9	2.1	53	6.5
Aristida adscensionis	13	1.2				
Cenchurus ciliaris	83	7.3	51	12.0	114	13.9
Chloris gayana	70	6.2	41	9.6	36	4.4
Cymbopogon sp.	612	54.1	213	50.0	425	52.0
Cynodon dactylon (L. Pers.)	28	2.5	23	5.4	28	3.4
Enneapogon perscius	103	9.1	25	5.9	13	1.6
Eragrosis barrelieri	149	13.2	57	13.4	116	14.2
Fingerhuthia africana	13	1.2			33	4.0
Tetrapogon villosus	24	2.1	7	1.6		

Geographic Variation in Diet

Grasses strongly dominated the diet of donkeys at Aqbat al Beyoot, which is 400 meters lower in elevation than the other fecal collection sites (Table 1). Eighteen taxa were consumed by donkeys, 13 at a frequency greater than 1%. Of these, 9 were grasses and four were dicots. *Cymbopogon* sp. is the dominant grass and Rhodes grass was more common here (23.5%) than at other sites, reflecting the common practice of pen feeding donkeys used for work at this remote location. *S. muscatense* was the most commonly ingested dicot (6.8%). At higher elevations in the Juniper-Olive woodland grasses and dicots co-dominate the diet. The most common grasses were *Cymbopogon, E. barrlieri*, and *E. persicus*, the latter being consumed uncommonly by goats and sheep.

Goats had very similar diets throughout the sampled areas of the Saiq Plateau. *H. lippii* and *S. muscatense* comprised 65-75% of the total cuticle counts, followed by *Cymbopogon* sp. and *O. europaea*. Overall, approximately 6 taxa account for 85-90% of the cuticles counted. Dicots were favoured 2:1 at 6 of the 8 sites. At Wadi Rahba, *J. seravschanica*, a threatened species (Patzelt 2014), was frequently consumed by goats (5.6%) and sheep (1.2%). Sheep diets also showed no marked geographic variation, with *H. lippii*, *S. muscatense, O. europea* and *Cymbopogon* sp. being the most commonly ingested plants. Olive was eaten most frequently (23.5%) at Al Alaleena, but at other sites it was usually third in abundance in the diet, suggesting the greater need for supplemental feeding at some localities.

The geographic homogeneity of the livestock diets reflects the similarity of the elevation and vegetation at all of the sites except Aqbat al Beyoot (Table 1). Rainfall may be less there, and the vegetation is more open with fewer trees and greater grass cover. Thus, with a few exceptions, the same species are grazed each month throughout the higher elevations of the Saiq Plateau, imposing a sustained grazing pressure on the range flora.

Implications for Management

Goats and sheep are generally free-ranging but most return nightly to pens where supplemental feeding of Rhodes grass hay (*C. gayana*), olive tree leaves, dates and sardines are commonly offered (Zaibet et al. 2004), suggesting range plant production is insufficient. The 3 livestock species consumed 39 species of range plants from a woodland flora that contains approximately 150 species (Patzelt unpublished data). The most frequently consumed plants have higher coverage, implying food plant selection is based more on abundance than nutritional quality. For example, *Cymbopogon,* one of the three dominant plants in the diets, has moderate amounts of crude protein (4.4 to 7.7%) (Kharbotly et al. 2003), and is considered unpalatable forage in the Sahel (Le Houerou 1989). More nutritious perennial grasses are generally rare and are eaten in very low frequencies (Table 2).

Research in Arabia's lowlands demonstrates that the vegetation has a strong potential for recovery. North of Jubail, Saudi Arabia, in an area protected from grazing for 25 years, the vegetation has returned to its natural state. Species diversity and cover are 3-5 times that outside the fenced area and production by perennials 3.8 times greater. Plant cover outside the site was extremely low (0.5 to 1%) (Barth 1999). In northern Saudi Arabia the vegetation cover increased from 8.7% to 70.8% after 6 years without grazing, and the density of perennial species increased from 600 plants/ha to 12,000. The change in density also involved a greater proportion of palatable species in the community (Mirreh and Al Diran 1995). In eastern Saudi Arabia after 14 years of protection from grazing and other human impacts plant cover increase 68% and species richness by 33%, and many of the species to reappear were important forage and fuel plants (Shaltout et al. 1996). Long-term research in Kuwait has demonstrated similar levels of recovery for the *Rantherium* steppe vegetation (Al Awadhi et al. 2005, Zaman 1999, Omar 1991).

Compared to the lowlands, Arabia's highlands have received little attention from range scientists. Chaudhary and Le Houerou (2006) believe the devastation of juniper forests of Lebanon, Yemen, Sudan and Saudi Arabia is due to grazing by goats, which 'love juniper leaves and branches' and to shepherds who cut branches to feed them. They also note that goats eat the seedlings and overgrazing removes the understory nurse plants that provide the microclimates for juniper seed germination. Thirty years ago Mandaville (1977) reported that although plant communities on Oman's central Jebel Akhdar were not threatened by excessive grazing, those in the eastern plateau around Saiq village were strongly affected by woodcutting and heavy grazing. At one locality on the Saiq Plateau, Wadi Rahba (2240 masl), where juniper is common, goats consume it at a moderate frequency (5%), but it is less common in the diets of sheep (2%) (Table 2). Intense animal grazing can strongly decrease the establishment of young juniper, and this coupled to longer term climatic warming and drying may be affecting normal reproduction and longevity of mature trees and does not bode well for this relict species adapted to cooler, moister environments.

An insight into the potential for rangeland recovery on the Saiq Plateau without livestock comes from a brief study on Ras al Jabul, a nearby isolated peak that is inaccessible to livestock. There, Schlecht et al. (2009) determined that the weighted average herbaceous biomass of vegetated patches was 753 kg dry wt ha^{-1}, but on the Saiq Plateau near Sayh Qatnah biomass was 35 kg dw ha^{-1} and 62 kg dw ha^{-1} in a wadi. The number of species per plot on Ras al Jabul averaged 25 compared to 15 at a grazed area on the Plateau, and coverage averaged 20%. On grazed ranges at slightly higher elevations of the Plateau (2200 m) canopy cover is generally low, between 0 and 13% (Figure 3), (Robinson and Al Busaidi 2009). Le Houerou (1995) considered coverage on degraded lowland ranges to vary from 0-5% and production between 100 to 200 kg dry matter ha^{-1}.

Grazing can threaten plant survival and result in local extinctions, or in the case of small populations of local endemics total extinction may occur. The flora of the *Juniperus* woodland has 13 range restricted species and 4 rare or threatened taxa, or about 9.5% of the high elevation flora (Patzelt 2014). Nine are community endemics, 9 are regional endemics and 3 species are rare on the Jebel Akhdar but occur elsewhere in Arabia. In addition to juniper, several listed plants occurred in the fecal analysis, although in relatively low frequencies.

Zaibet et al. (2004) concluded that the open access grazing system practiced on Saiq rangelands encourages

large flock size that in turn results in overgrazing and loss of economic benefits. Consequently, farmers must invest heavily in supplemental feed that is mostly paid for from off-farm income. Animal and range scientists (Al Harthi et al. 2008, Dickhoefer et al. 2010, Schlecht et al. 2009) working on the Saiq Plateau agree that the large number of feral donkeys contributes to the loss of small animal production. Their extensive diet overlap with goats and sheep is probably a major factor. Empirical research indicates that past and present animal husbandry practices have damaged soils (Robinson and Al Nabhani 2009) and reduced vegetation cover and species richness of the range communities. Moreover, the natural stocking capacity of the Plateau is considerably reduced due to the large areas of naturally exposed bedrock that limits plant growth (Figure 3).

However, the likelihood that the vegetation can recover is very good. Range vegetation in the lowlands of Arabia has shown remarkable regeneration following livestock exclusion for a decade or less. Given the favorable climate for plant growth on the Jebel Akhdar, similar results can be expected. New systems of animal management should be developed by governmental agencies working through the local farmers. Clearly, the donkeys must be removed, and reducing goat herds to subsistence levels will accelerate the vegetation's recovery. Other options such as establishing traditional livestock-free pastures and seasonal grazing systems should also be considered.

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