Intensification of rangeland grazing in an oil-rich state; causes, consequences and possible solutions.

D.J. Gallacher & J.P. Hill

Zayed University, POB 19282 Dubai, United Arab Emirates

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Over the last 35 years land management and farmer lifestyles have changed dramatically on the rangelands of the United Arab Emirates. The human relationship with rangelands has moved from subsistence to a secondary income or hobby. Both ecological health and indigenous knowledge of rangelands are in decline. Large areas of the inland desert of the country are rapidly becoming urbanized. This paper reviews threats to the 225 km^2 Dubai Desert Conservation Reserve (DDCR) as a model of range and species conservation issues facing the country as a whole. Inland desert rangelands are threatened by groundwater depletion, habitat fragmentation, exotic species introductions and overgrazing. Overgrazing is currently the most serious threat to the inland desert, reducing range species diversity, production and available forage. Reduction of stocking rates requires a revision of pro-agricultural policies and resolving the legal ambiguity surrounding common grazing lands. It can be reasonably expected that environmental attitudes will shift from anthropocentric to ecocentric over time, but a shift in cultural heritage perceptions may also be needed to reassert a balanced approach to rangeland management.

Introduction

Urbanization of Dubai, United Arab Emirates, has spread along the entire coastline of the emirate and may soon cover much of its inland. To counter this, a rangeland conservation zone of 225 km^2, or 4.7% of the emirate, was established in 2003. The Dubai Desert Conservation Reserve (DDCR) has the role of preserving inland sand sea habitats for current and future generations, as well as providing ecotourism for visitors. Fourteen active farms remain in the DDCR, producing livestock, horticultural products and forage crops. Farms contain a variety of penned livestock, and camels which are released from the farm boundaries daily to graze on open reserve rangeland. Rangeland grazing intensity on the DDCR is approximately 0.043 camels ha^{-1}.

Within the DDCR is an inner enclosure of 27 km^2 (Al Maha) bounded by a 24.12 km long fence. Camels were removed on completion of the fence in July 1999, and several species of oryx and gazelle were introduced, some indigenous but others exotic to the area. Al Maha stocking rates in April 2005 were approximately 0.092 oryx ha^{-1} and 0.075 gazelles ha^{-1}. The site provides a unique opportunity to study the recovery of a large expanse of sand desert under different grazing regimes. Previous studies in the Gulf region have reported a rapid regeneration of vegetation in livestock exclosures (Oatham et al., 1995, Zaman, 1997, Barth, 1999b, El-Keblawy, 2003) but exclosure of large herbivores is unviable both socially and ecologically.

Overgrazing is known to be prevalent and damaging. There is sufficient scientific evidence that camel overgrazing in the DDCR severely reduces plant species richness and forage production, and suppresses native animal populations (Gallacher and Hill, 2006b). Overgrazing is often coupled with poverty or marginal incomes, but the UAE has ample

financial resources, and even its poorest citizens are not reliant on rangelands for their primary income. Here, overgrazing persists for social, cultural and political reasons. This paper will review some reasons why overgrazing has not been adequately addressed, despite the financial ability to do so.

Threats to DDCR ecology

Other than overgrazing, DDCR ecology is currently threatened by depletion of groundwater resources, habitat fragmentation, and invasion by exotic species. The threat of extinction continues in the UAE for both plants (ICARDA, 2002) and animals (ERWDA, 2005), but is not currently a serious concern for rangeland species. The extinction of the ostrich subspecies *Struthio camelus syriacus* in late 1940 (Gross and Jongbloed, 1996) is the only known incidence of species loss in this habitat. This section will examine current knowledge of these other three threats.

Groundwater depletion

Groundwater is being rapidly consumed in the UAE, but the effect on rangeland vegetation is unclear. The UAE has almost 60 000 irrigation wells, a tenfold increase over the last twenty years. Within Abu Dhabi emirate the ratio of extraction to recharge is 7:1 (Brook, 2003). Intensive horticultural and livestock industries have rapidly expanded over this time, as have forest plantations, even though the economic return of water used for agriculture is estimated at less that 0.5% of that used for industry (Beaumont, 2000). Measurements of groundwater depth and quality have indicated a severe decline in Abu Dhabi emirate (Brook et al., 2006), but have not been publicly reported in Dubai. The situation in the DDCR is probably less severe since the area is less suitable for agriculture and consequently has a limited history of established farms (UAE University, 1993), and irrigated forestation has been minimal. Farmers in the DDCR reported that groundwater has declined in both depth and quality. Several farmers attributed this to lack of rain, since at the time of the survey they had experienced an uncharacteristic five-year drought (Feulner, 2006). Others attributed it to both lack of rain and high extraction rates. All had stopped drinking groundwater despite its perceived health benefits, due to increased salinity and a preference for bottled water.

Groundwater depletion has caused the incursion of saltwater into freshwater aquifers in parts of the UAE (Aspinall, 2001, Sherif et al., 2005), but frequency may be low. On the east coast, recent aquifer inflows were attributed primarily to agricultural activity (Murad and Krishnamurthy, 2004), while recharge of sabkha groundwater in Abu Dhabi emirate was found to be caused by rainfall (93%) and upward leakage (6.5%) rather than lateral movement (0.5%) (Sanford and Wood, 2004).

Some locations have been artificially recharged with urban waste water and irrigation surpluses. Extent of recharge is likely to increase with expanding urbanization and could affect the DDCR if it continues. However, it would be matched with a continued decline in soil water quality. The cost of desalinized water in GCC countries was approximately US\$0.70 m^{-3} at 2000 international oil prices (Abderrahman, 2000), which is cheap enough for urban usage, but is a prohibitive cost for irrigated agriculture or horticulture. Newer technologies promise to reduce the price to below US\$0.40 m^{-3} (Cruz and Salter, 2006), though prices are also dependent on intake water quality.

Occurrence of healthy vegetation above falling water tables suggests that most perennial plants are not reliant on the water table (Brown et al., 2003). Nor are they directly dependent on rain, dew or fog. Perennial DDCR species tend to not maintain active surface roots on sand substrata, as is common when surface water availability is unreliable (Abd el-Ghani, 2000). The sand surface dries rapidly after rain, but then acts as a protective layer for preserving deeper moisture (Al Wadie, 2002). Water retention is therefore higher in more

porous sand. Dew and fog deposition is more common, but even more temporary. Direct water vapor transfer to soil is a more likely source of plant available water (Agam and Berliner, 2006), which could occur from humid air above, or vapor from the surface of the groundwater table. Root depth knowledge is mainly based on vegetation responses to rainfall rather than direct observation. The only exceptions known by the authors are as follows.

- The highest root density of northern Indian *Prosopis cineraria* was observed at 30 to 60 cm below the surface (Singh, 1994), well below rainfall penetration. The species is a phreatophyte (seeks ground water), with tap root estimates ranging from 20 m (Mahoney, 1990) to 60 m below the surface (Jongbloed *et al.*, 2003), and has an unusually high transpiration rate compared to other desert perennials (Laurie, 1988).
- *Citrullus colocynthis* is a phreatophyte with low tolerance to salinity (Brown et al., 2003 and references within).
- Roots of a small *Leptadenia pyrotechnica* bush were observed to spread throughout 850 m^3 of soil to a depth of 11.5 m. Root density correlated with soil moisture content throughout the depth (Batanouny and Wahab, 1973).
- *Calotropis procera* roots reach 1.7-3.0 m in sandy desert soils, with few to no roots near the surface (Sharma, 1968).

The phreatophytes are probably most at risk from groundwater extraction, though plants may not need the deep source for survival. Whether the bulk of species are at risk depends on the relative importance of upward to downward movement of water into the root zone, which unfortunately is not known.

Habitat fragmentation

Rangeland in the UAE has become fragmented due to road and fence building, farm development and urbanization. Fortunately, the DDCR lies outside the triangle of highways linking Dubai, Abu Dhabi and Al Ain and lies within 10 km of mountain habitats. However, its border fence prevents movement of ungulates and probably reduces movement of cats and foxes. Habitat fragmentation is thought to affect natural populations of mountain (*Gazella gazella cora*) and sand gazelles (*Gazella subgutturosa marica*) (ERWDA, 2005), though captive populations are sustained within the DDCR with minor reliance on artificial feed.

Exotic species invasion

Exotic species can compete with native species for resources, imbalance the food chain, or introduce diseases to native species. Hybridization among similar species is sometimes possible, leading to erosion of the native gene pool as two species merge into one.

Few exotic plant species have become established in rangelands of the UAE, since few introduced species are adapted to hyper arid conditions. One exception is *Prosopis juliflora*, a native tree of South America that is commonly seen around towns and homesteads. Although the species is an aggressive invader, control in the DDCR is easy due to its relatively small size. Hybridization with the native *P. cineraria* has not been reported, though is a possible threat since hybridization occurs with other species of the genus (Pasiecznik et al., 2004).

Gordon's Wildcat (*Felis silvestris gordoni*) is threatened by the spread of feral cats, which occur throughout the UAE rangeland and share several behavioral and phenotypic characteristics (ERWDA, 2005). The wildcat is potentially threatened with genetic pollution (Nowell and Jackson, 1996) and the introduction of exotic diseases (Ostrowski et al., 2003), though there is insufficient information to estimate the severity of these threats (ERWDA, 2005). The mountain gazelle (*Gazella gazella cora*) is also thought to be at risk of genetic pollution through hybridization with Dorcas gazelle (*Gazella dorcas*) (ERWDA, 2005). Both species are currently stocked within the DDCR.

Consequences of overgrazing

Overgrazing is considered the greatest threat to desert ecosystems in the UAE (Hellyer et al., 2001) and is threatening the Arabian plant biodiversity (ICARDA, 2002) of approximately 3500 species (Ghazanfar and Fisher, 1998). An estimated 44% of the Arabian Peninsula is severely or very severely degraded, and 90% of all land is affected in some way. Overgrazing by camels has reduced vegetation throughout the DDCR, with gravel substrata habitats being the most severely affected (Gallacher and Hill, 2006a). Farmer surveys indicated a nine and 19 fold increase in the numbers of camels and goats over the last decade. Farmers reported a decline in most plant species, and their observations were consistent with published literature. However rangeland plant community degradation is usually entirely reversible (Dean and Macdonald, 1994). UAE rangeland ecology has adapted to surviving multiple-year droughts. An irreversible environmental stress is one that changes soil structure or infiltrability (Wilson and Tupper, 1982) or causes a permanent loss of genetic diversity. Sand substrata are relatively resistant to such stresses (Scoones, 1992), and the deep root zone of this environment probably increases this resistance.

Grazing intensity has increased and the mix of grazing species has changed. Up until half a century ago the inland desert was grazed by camels, Arabian oryx (*Oryx leucoryx*), gazelle (*Gazella* spp.), and the Arabian ostrich. Camel numbers increased dramatically while all other species declined, the ostrich to extinction and the oryx to extinction in the wild. Hunting of gazelles was banned in 1983, though enforcing the ban has been difficult (Hellyer, 1996). Populations of smaller species fluctuate with seasonal food availability. Plant species became adapted to grazing by all these herbivores through physical and biochemical defenses, and physiological adaptations. Today in the DDCR, grazing is dominated by the camel, though elsewhere in the UAE other animals are also significant Camel stocking rates are no longer limited by desert plant production since their main feed is produced under irrigation or imported. Therefore, cumulative plant biochemical defenses may no longer be effective.

Botanical consequences

Excessive grazing has led to reduced canopy cover of most perennial plant species in the DDCR. Ephemeral species have been largely unaffected, since they germinate in massive numbers and have a short grazing exposure time. Farmer surveys indicated that no plant species had become extinct in the area, although several had become rare. Significant plant genetic erosion is unlikely, given the area of sand sea rangelands and the frequency of grazing exclosures. This might not be true of species that rely on microhabitats such as the DDCR rocky outcrop. The primary botanical consequence other than a reduction of plant biomass is a modification of species mix.

Livestock typically remove the more palatable plant species such as perennial grasses (Jeffries and Klopatek, 1987, Beeskow et al., 1995, Todd and Hoffman, 1999, El-Keblawy, 2003). DDCR plant cover of the grass *Pennisetum divisum* has been reduced, and vegetative growth of the palatable tree *Calligonum comosum* is almost totally eliminated by grazing. Livestock may also preferentially graze a particular habitat. In the DDCR, camels graze the gravel substrata in preference to the sand substrata relative to oryx or gazelles (Gallacher and Hill, 2006a), probably because this habitat provides a higher ratio of energy gain to energy expenditure (see Murray, 1991).

Three species have been observed to benefit from intensive camel grazing. *Cyperus conglomeratus*, a sedge often mistaken for a grass, has been previously reported as an indicator of excess grazing (Ferguson et al., 1998, Barth, 1999b), though it is also an early colonizer after natural dune movement, limiting its value as an indicator species. The shrub *Calotropis procera* is not eaten by camels due to the adverse effects of its toxic latex (El Badwi et al., 1998), so it benefits from reduced competition in areas of heavy grazing (Khan, 1980, Al Wadie, 2002). Numbers have increased in the DDCR, but are declining again as the

gazelle population increases. Gazelles have learned to remove leaves with their antlers, and then return to eat them later when the leaves have dried and lost most of their toxins. The gourd *Citrullus colocynthis* appears to flourish in areas of high camel traffic, though it is not yet clear why.

Plants have evolved in the presence of herbivory, and have become reliant on it in several ways. Seeds of the tree *Acacia tortilis* are eaten from the tree, scarified, dispersed and then fertilized by animals (Rohner and Ward, 1999). Seeds not eaten from the tree are almost invariably devoured by insects. Plants such as *Leptadenia pyrotechnica* and the numerous dwarf shrub species are likely to reach optimal water balance with light grazing, though this has not been substantiated.

Zoological consequences

Heavy overgrazing directly reduces the feed available to non-livestock herbivores. Natural populations of rodents, lizards, gazelles, herbivorous birds, and the cape hare (*Lepus capensis*) are all likely to be reduced. As a consequence, there is also less food available for carnivores such as cats, the Arabian red fox (*Vulpes vulpes arabica*), and birds of prey. These carnivores are mostly unable to prey on domesticated livestock, due to the larger animal size and to human protection. Evidence of wild carnivore population decline in the DDCR is anecdotal, but nevertheless clear.

Overgrazing also leads to destruction of microhabitats that may be utilized by some animals. Frequency of nebkhas, mounds of dirt that accumulate under shrubs, is reduced. The frequency of very large, dense *Leptadenia pyrotechnica* shrubs is also reduced (Gallacher and Hill, 2006b).

Livestock consequences

The cost of livestock production increases with range degradation, since livestock become dependent on artificial feed sources (Al-Rowaily, 2003). Prolonged overgrazing of perennial shrubs reduces their overall size, and thus their capacity for annual herbage production. Palatable species such as grasses should be managed carefully to avoid removal of whole plants. Overgrazing in Jubail, eastern Saudi Arabia, reduced biomass production from around 300 to 80 kg ha^{-1} (Barth, 1999a). A study of three locations in the UAE estimated livestock biomass consumption to exceed production by a factor of up to three (Shaltout et al., 2006), though much of the biomass consumption recorded in this study was of the trees *Prosopis cineraria* and *Acacia tortilis*. Under favorable circumstances, rangeland biomass production can recover in just 3 to 5 years if grazing pressure is reduced (Barth, 1999a, Gallacher and Hill, 2006a).

Historical Grazing Patterns

Over the last 35 years the human relationship with UAE rangelands has evolved from survival necessity to a source of income, or even a hobby. The current anthropocentric ('what people can get from') relationship is a legacy of this recent past.

Before unification

It is not known if camels were native to the UAE, but they have been a part of the rangeland ecosystem probably for thousands of years. UAE fossil evidence of domesticated camels has been attested for the Iron Age (1200 to 300 BC) (Stephan, 1995), but domestication may have occurred as early as the 4th millennium BC (Peters, 1997). Originally they were used for transport between settlements (Potts, 2001) and so may not have regularly grazed open

rangelands. Nomadic camel herding probably emerged after the spread of settlements, which could still be more than a thousand years ago.

Nomadic camel herders would move camp throughout the season each time feed supply for camels dwindled. Wells were dug in frequently visited places, enabling people to extend their nomadic range. In some places permanent settlements were established, though this is not likely to have occurred in the DDCR. During wet periods camels could get most of their water requirements from plants, and herders could survive by drinking camel milk (Heard-Bey, 2001), but during dry periods they would have to remain close to open water sources. Desert rangeland was therefore grazed more heavily near permanent water sources. *Harim* (preserved natural environments) and *hema* (protected land for grazing in poor seasons) are institutions within *Shari'ah* (Ouis, 2003) that were applied within the UAE (Aspinall, 2001).

After unification

Following unification of the Emirates in 1971, policies to increase agricultural production and to establish permanent settlements and income for nomadic people were instituted. The agriculture sector increased from 0.7 to 3.6% of GDP between 1975 and 1998, and the share of the labor force increased from 4.6 to 7.4% (Shihab, 2001). In general, the policies were as follows:

- Free agricultural land is given to any UAE citizen, including free land leveling and drilling of water wells. Some technical services are also provided for free.
- A 50% subsidy is awarded for production inputs, and interest free credit for purchase of agricultural (and fishing) equipment
- A consistently favorable produce market is guaranteed through a government purchasing scheme

In open rangeland such as the DDCR the number of wells increased, and semi-permanent farms or occasionally used areas became permanent year-round farms. Camel numbers initially waned after unification, falling from approximately 97 000 to 39 500 in 1976, but then steadily increased to 250 000 today (FAOSTAT, 2004). A similar pattern was seen with goats (125 000 to 1 450 000). Within Dubai emirate goats are not legally permitted to graze on open range, but elsewhere they are possibly the primary contributor to overgrazing. Irrigated forage production has also increased, but the livestock sector still relies on imported feed. At 2.99 camels km^{-2}, density in the UAE is second only to Qatar and far higher than that of Saudi Arabia (3.36 and 0.12 camels km^{-2} respectively) (FAOSTAT, 2004). This increase is regional and can be attributed to feed subsidies and improved veterinary services throughout Arabia (ICARDA, 2002).

Current

Today, farms are scattered throughout the rangeland. DDCR farms typically have an employee in residence and an owner who visits occasionally. Throughout the UAE, camel densities are highest around racetracks rather than food or water sources (Yagoub and Hobbs, 2003). Land tenure is not always clear, and is traditionally based on water access rather than geographical boundaries (Wilkinson, 1983). Most camels are allowed to graze the desert on an 'open access' basis that is common throughout West Asia (Ferguson et al., 1998). DDCR farmers typically feed camels at the farm in the afternoon (3 to 4 pm) and maybe in the morning (7 to 8 am), so camels tend to return to the farms at these times. Some camels stay away for days at a time if desert forage is sufficient, and some stay permanently at the farm if it isn't.

Most DDCR farms have appeared since unification in 1971, with only one interviewed farmer claiming prior attachment. All farmers live offsite, often in *shaabeyah*, nearby housing estates provided by the government around 1981. Farms are attended full time by one or

more South Asian employees. Most owners view the farm as a place for relaxation or for entertaining guests, and not as a source of income. It is likely that farms do not make a net profit unless an outstanding racing camel is bred and sold. Most owners expressed gratitude to one or more Sheikhs for giving them housing or farming equipment.

Farmers displayed a sound knowledge of native plants and animals, but only a loose connection with the specific area. Several farmers were able to discuss around 100 individual species of plants, birds and wild animals. Information on plant species was dominated by their use to humans and livestock, and bird species by falcons and their prey. Their knowledge of sustainable stocking rates was poor and, although they had observed the impacts of overgrazing, they attributed these impacts to rainfall patterns.

Causes of overstocking

Through the use of well water, imported feed and feed produced under irrigation, the camel population has grown far beyond historical levels. Elsewhere, overgrazing is exacerbated by the presence of other species. Similar stories occur throughout the Arabian peninsula. Technical knowledge of optimal rangeland management is available, but overgrazing continues for social, cultural and political reasons (Al-Rowaily, 1999).

Agricultural policy and laws

The post-unification agricultural policies appear to have been very successful for social development of the UAE. Previously nomadic and semi-nomadic people were given a source of income, and vastly improved access to social services, such as education and health. These policies have facilitated the equitable distribution of wealth throughout society, as has promotion of the camel racing industry (Khalaf, 1999). Such policies should be temporary as the society transitions, because the economic distortion increases over time. Removal of agricultural subsidies is nevertheless politically difficult in any country.

Federal laws affecting rangeland use are enforced at the Emirate level within the UAE. Primary resource tenure (fresh water, fishing and grazing rights) has a long established political history within and among emirates, and remains a part of their identity. Policies and law enforcement vary, sometimes considerably, among emirates. Consequently there are substantial differences among emirates in the severity of ecological stresses.

Abu Dhabi emirate has recently passed a law on the allocation of grazing rights within the Emirate (WAM, 2006). Hence, there is awareness of overgrazing that is making its way into the legal system.

Land tenure

Open rangeland throughout the Middle East suffers from a tragedy of the commons. Much of Dubai rangeland is openly available for exploitation by any camel herder, and elsewhere by any livestock herder. Horses have also heavily grazed gravel plains surrounding stables. Access to the DDCR is restricted, but the reserve is overstocked from within. Tribal regulation of grazing intensity through annual herder migration and allocation of *harim* land has been abandoned. The industry structure that has emerged is sustainable only through the use of imported feed. Even the use of on-farm irrigated forage would be unfeasible if water were priced on an open market.

Expanding urbanization forces farmers on the city fringe to move further out, as their land is taken for development. Farmers often move only within their emirate for political reasons, which in Dubai has caused stocking rates of the remaining rangeland to become intensified.

Environmental awareness

Emirati people have retained a strong affinity for Bedouin culture, and many urban families have farms, family members or second homes in rural areas. Indigenous people typically have an anthropocentric view of their surrounds, meaning that nature is observed with a view to exploitation. Several DDCR farmers were able to discuss around 100 individual species of plants, birds and wild animals, focusing mostly on exploitability for hunting or grazing. Farmers had observed changes in plant densities and species mix, but frequently attributed changes to low rainfall rather than overgrazing. A study of Saudi male students indicated considerable interest in wildlife and outdoor recreational activities, but the main experience of wildlife was through hunting (Seddon and Khoja, 2003). As UAE society transitions from predominantly rural to urban, a decline in rangeland knowledge and an increase in ecocentric views can be expected. Hence, public support for environmental sustainability can be expected to increase. Commercial awareness of environmental effects also remains low in Dubai (Jahamani, 2003), but many GCC governments have recognized that a 'green' image is important for international prestige (Ouis, 2003).

Heritage

Preservation of rangeland culture has primarily been facilitated through the promotion of camel racing and falconry. Societies tend to conserve the species they value, to the extent that the real environment often becomes a partial reflection of social attitudes (Ouis, 2003). The sport of camel racing employs thousands of people throughout the UAE, is a significant contributor to the wealth of many poorer *Bedu*, and has promoted national and regional identity (Khalaf, 1999). The sport of falconry has had similar effects, though on a smaller scale. Winning races brings prestige to the owner and trainer, and status may also still be given to the owner of a large herd (Brown et al., 2003).

The camel racing industry has become huge. There are 14 000 actively racing camels competing on 15 race tracks throughout the country (Anonymous, 2005), and more camels are brought from throughout the region for race meets (Khalaf, 1999). The camel population is distributed around racetracks rather than food or water sources (Yagoub and Hobbs, 2003). Rangeland grazing is considered beneficial to livestock health, and is included as an essential part of racing camel training (Khalaf, 1999). DDCR farmers explained that rangeland vegetation contains no artificial chemicals, but contains natural chemicals that reduce disease incidence.

The value of promoting both these sports is not under question. However, there has been a disproportionate focus on these industries that has overshadowed the preservation of natural ecology. Falconry led to the decline of the Houbara bustard (*Chlamydotis undulate*) (Tourenq et al., 2005), a species that is now receiving substantial international assistance for recovery. Sustainable rangeland management might require a shift in perceptions of cultural heritage.

Possible solutions

Combating overgrazing requires a reduction of the number of livestock that have open access to rangelands. Rotational grazing patterns may also be necessary for the maintenance of plant species mix (Brown et al., 2003). Several possibilities are available, each with its own political and ecological considerations:

- Reduction of the national herd, through a quota or financial disincentive system. This alone would have no initial impact on vegetation since farmers would reduce supplementary feed accordingly. Camel numbers would probably need to fall by 60% before a difference to vegetation could be expected.

- A quota system for the number of camels allowed daily access to open rangeland would allow people to keep as many camels as they wish, but only allow a sustainable number of camels daily access to rangeland. In fenced areas such as the DDCR this system would be relatively straightforward to enforce, though elsewhere it may not be.
- Protection of specific habitats. In the DDCR, gravel substrata are at greater risk of damage than sand substrata. Creating livestock exclusions through fencing could preserve habitat fragments. Several authors have deemed exclosures in Arabia to be socially unsustainable due to the absence of community involvement, and thus respect for the purpose of the exclosure (Chatty, 1998, Seddon, 2000). However, many small scale exclosures already exist in the UAE in several forms, such as palace grounds and non-commercial forestry, and government ownership of most rangeland makes this option possible throughout the GCC (Brown et al., 2003).
- The application of enclosure laws could eradicate communal over-exploitation, but would further erode cultural heritage. Fencing would also be expensive and may cause further damage through habitat fragmentation.
- Improved public awareness of rangeland issues, either through formal educational systems or the existing agricultural advisory service. Although a long-term and indirect solution, overgrazing will only be fully addressed if the social awareness of rangelands evolves from its current anthropocentric state, and if heritage awareness broadens.

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