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CONSERVATION THROUGH RESTORATION: STUDY OF A DEGRADED GRAVEL PLAIN IN SOUTH-EASTERN ARABIA

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Abstract

The cultural set up in Arabia for holding large stocks of camels and goats, and the long history of grazing beyond the carrying capacity of rangelands have left vast areas in south-eastern Arabia highly degraded. Coupled with that, road building, and unsustainable development of amenity parks and resorts has left an indelible mark on the landscape. Not only there is a lack of regeneration of key plant species, there is also a discernable loss of both floral and faunal diversity.

In several countries of the Arabian Peninsula there is now a growing concern for the restoration of damaged landscapes. Through sustainable restoration the loss of biodiversity can be halted, and the species can be brought back and conserved. In order to restore the vegetation of an area, an indepth knowledge of the species present there is necessary. In this paper we describe the vegetation of a gravel plain in south-eastern Arabia and the steps that will have to be taken to restore and eventually conserve this area.

Introduction

A relatively long history of subsistence farming and free grazing on rangelands in the Arabian Peninsula, and the cultural set up to hold large numbers of livestock have resulted in highly degraded rangelands, in some cases beyond recovery. Added to that, the recent expansion of 'good value for money' tourist destinations has led to the fast and unsustainable development of resorts and amenities, which have contributed to the degradation and loss of biological diversity (see also Gardner & Howarth 2009).

In the last two decades there is a growing concern in several countries of the Arabian Peninsula for the loss and degradation of plant and animal life. There are now attempts to conserve and restore damaged landscapes, and to bring back the plant and animal diversity and richness that was once there. Dams have been made in several locations in the mountains of the Sultanate of Oman and the UAE to recharge the aquifers; livestock farms are being fenced so as to reduce grazing pressures on landscapes, and projects to restore degraded land are in place (pers. obs. 2009).

Restoration projects are especially useful as they aim for sustainability. Although these projects are necessarily long term, within a few years restored landscapes can begin to attract the local fauna and habitats are created for many plants, especially the annual species, to return (Ghazanfar 2010, in press).

A full vegetation survey of the area together with the geomorphology, soil and climatic data is mandatory before any restoration work can start. A vegetation survey would list the dominant and associated species, and the dominant plant communities in an area. In many instances if the land is very degraded only the "hardy" or "non palatable" species remain. If imagery prior to degradation is available (e.g. before construction of a building or road, etc.) or a similar area is available that is not degraded or less so, a survey could be carried out there so that a reference for restoration (in terms of species richness and alpha diversity) can be established. Detailed vegetation maps and vegetation profiles are also very useful references in restoration programmes as the key species and their distribution are well recorded and vegetation described in some detail (see for example vegetation maps in: Al-Hubaishi & Müller-Hohenstein 1984; Deil & Müller-Hohenstein 1996; Kürschner 1986; Frey & Kürschner 1986).

Geomorphology and Climate

The proposed site is a gravel desert plain at the foot of the most westerly outlier of the northern mountain range, the Hajar, which extends from the Sultanate of Oman into the United Arab Emirates Geologically it is composed of hard limestone and is classified as an anticline resulting from late Tertiary tectonic activity (Kirkham 2004).

The desert plain is composed of coarse and fine sand and gravel, large and small stones, and silt mixed with sand. The gravely sandy alluvial sediment is a result of numerous wadis that flow through and fan out around the mountain. Three or four major, and several smaller wadis flow out on the gravel plain forming deep and shallow gullies and runnels of varying widths. There is evidence of water flow in these wadis and runnels, but the vegetation present in the wadis shows that the water flow is irregular and is a rare event.

There is no climatic data for the site but that of Buraimi in Oman may be representative (Fig. 1.). The average annual temperature is 27.9^{o} C; May to November are the hottest months, and December to April the coolest months with the lowest average monthly temperatures recorded during December and January; mean annual rainfall is 97 mm which usually falls during the winter months, from December to March but the inter-annual variability of rain is high (Fisher & Membery 1998). An aspect of rainfall fundamental to the timing of growth and flowering is the “spottiness” of desert rainfall. Such rainfall is highly localised, has a high inter-annual variability, and gives the consequent “spottiness” of plant growth and flowering in deserts.

Floristics and vegetation

The number of plant species recorded for the area (including the mountains) is about 390 (Aspinall & Hellyer 2004). The vegetation is typical of much of the sand and gravel deserts in the Emirates and Oman and can be classified as the *Acacia-Lycium-Euphorbia* scrub (Ghazanfar 1991) typical of the foothills and immediate plains of the northern mountains of Oman. The vegetation is typified by an open *Acacia tortilis* scrub with *Lycium shawii* and *Euphorbia larica* as the main associates. Where sand is abundant, *Haloxylon salicornicum* is dominant. As the site is heavily grazed there is a dominance of unpalatable species such as *Calotropis procera*, *Tephrosia apollinea*, *Rhazya stricta* and *Citrullus colocynthis*. A small fenced area of a sandy plain shows un-grazed vegetation (the length of time that the fence has been in place is unknown).

Methods

The area was surveyed with the aim of describing the existing habitats and flora, identifying impacts on the vegetation and advising on potential for remediation. During a detailed vegetation survey a range of habitats across the area were examined systematically, with particular focus on areas with a higher cover of vegetation such as wadis, foothills and low lying sites. A planted area was also surveyed.

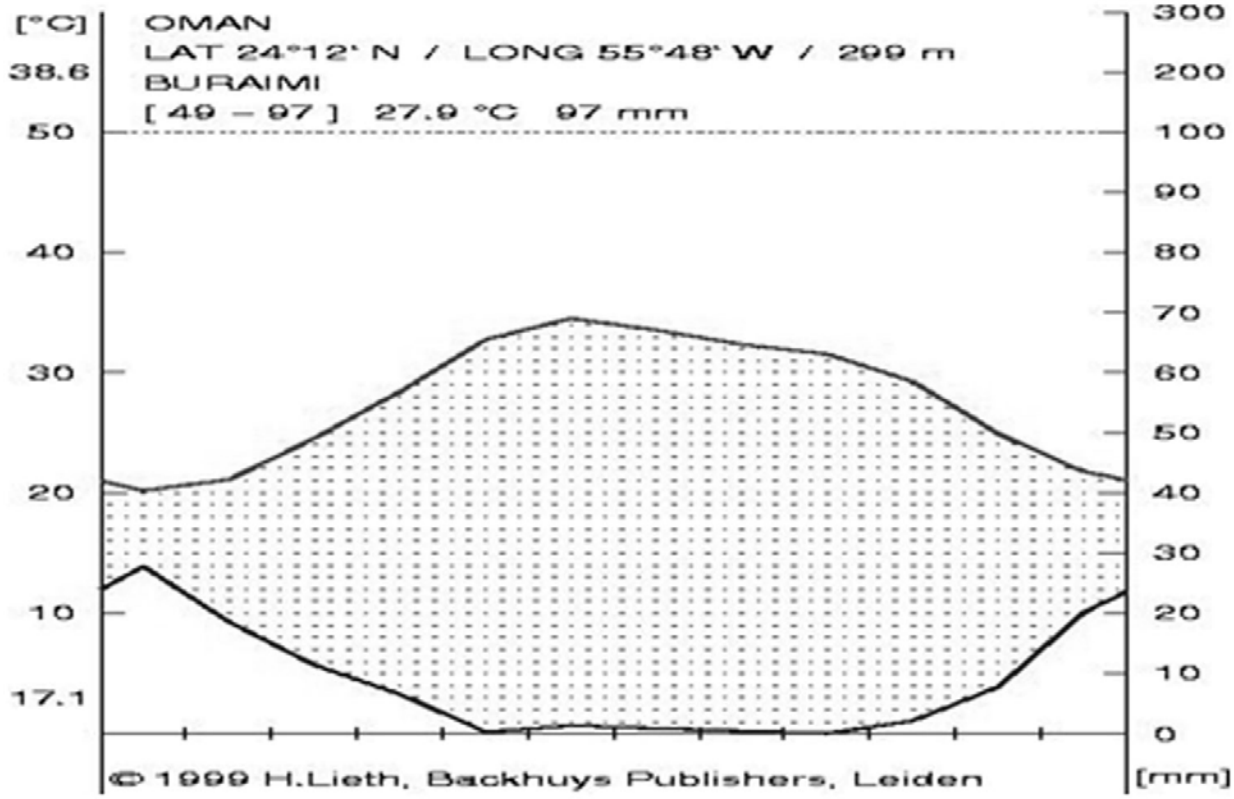

Fig. 1. Climate diagram for Buraimi, Oman.

The survey was carried out by transects laid out parallel to the length of the site in a north/south direction and parallel to the width in a west/east direction. Two transects along the length of the site (N/S) and five transects across the width (E/W) were surveyed traversing wadis and intervening gravel areas across the plain. Quadrats (20 x 20 m) were sampled every 1 km for the N/S transects and at every 500 m for the E/W transects. Presence/absence of species was recorded in each quadrat. In addition all species and their numbers were recorded in a fenced area at the southern end of the site. This area, as far as we could judge had not been grazed for some time (length of time not known) and was a good reference for the potential richness and condition of species in an otherwise degraded desert plain

Results and discussion

The number of plant species recorded at the site is about 60 (Appendix 1). With a detailed survey after rain to include the annuals, the species richness is likely to be higher. This is below the average recorded for a somewhat similar site estimated to be about 200 (Ghazanfar 1998). Very few annuals have been recorded at the site. The reasons are not fully investigated, but the most likely causes are grazing pressures and the depletion of seed bank in the soil. This may be compounded by a lack of rain and changes to the water regime and water flow in the wadis.

The present vegetation at the site consists mainly of a few trees and shrubs that have tolerated grazing pressure and those that are unpalatable to camels and goats. No regeneration is visible around the trees and shrubs and no significant fruiting has been recorded in the two surveys carried out at the site. In contrast, the plants in the fenced area show flowering and fruiting, indicating that flowers and fruits are unable to develop in the degraded area due to the constant browsing and grazing. Figs. 2-8 give the results for each transect showing the number of species in each quadrat. A list of total species is given in Appendix 1.

Vegetation Types

Three vegetation types can be identified in the desert plain. These are related to the topography, substrate and availability of water. Despite the effects of grazing, many distinctive native desert plants were recorded throughout the site. Appendix 1 gives a list of all species recorded.

1.Upper wadi vegetation type

Location: Upper part of wadis.

Substrate: Large and small stones, coarse gravel, sandy pockets.

Species richness: ± 20 perennial species, plus 5-10 annual species.

Dominant species: *Acacia tortilis, Euphorbia larica, Lycium shawii, Gaillonia aucheri.*

Associated species: *Blepharis ciliaris*, *Cymbopogon schoenanthus*, *Chrozophora oblongifolia*, *Heliotropium bacciferum*, *Stipagrostis plumosa* (occasional).

2. Upper gravel plain vegetation type

Location: Upper part of gravel plains.

Substrate: Coarse gravel strewn with large and small stones, sandy depressions and pockets of sand and silt.

Species richness: ± 10 perennial species, plus ± 5 annual species.

Dominant species: *Euphorbia larica.*

Associated species: *Chrozophora oblongifolia*, *Heliotropium bacciferum*, *Blepharis ciliaris*. *Stipagrostis plumosa, Farsetia linearis, Fagonia brugieri*

3.Lower wadi sand and gravel vegetation type

Location: Lower part of wadis and gravel plains.

Substrate: Sandy with fine gravel, occasionally strewn with small stones; sandy/silty depressions and pockets of sand and silt.

Species richness: ± 8 perennial species, plus ± 5 annual species.

Dominant species: *Rhazya stricta*, *Calotropis procera*, *Citrullus colocynthis, Corchorus depressus.*

Associated species: *Tribulus pentandrus*, *Stipagrostis plumosa* (occasional).

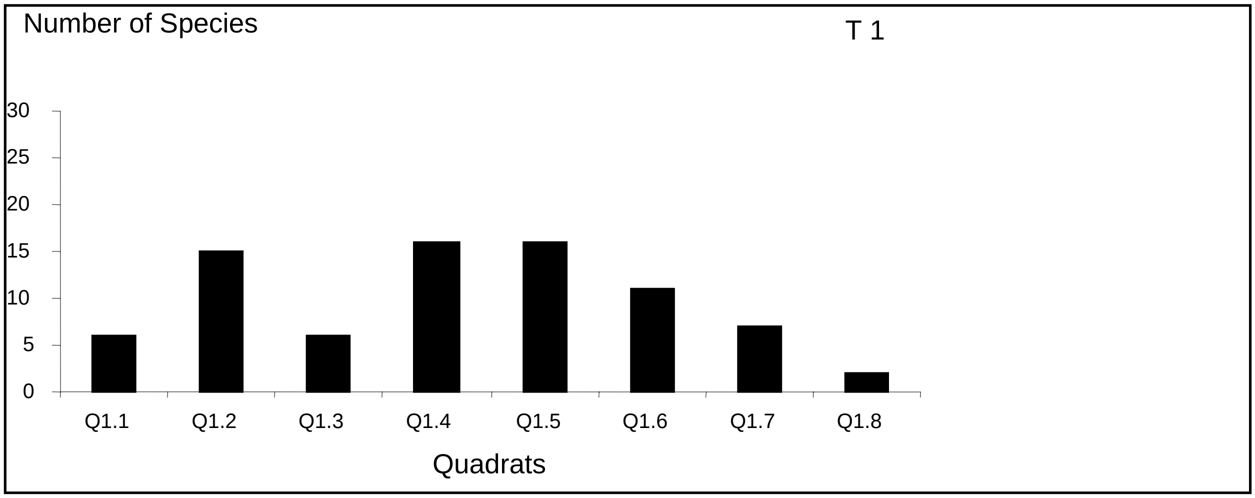

Fig. 2. Transect 1. North-South Transect at the edge of a plantation area beside a track road. Quadrats were surveyed in silty/sand in a depression with coarse gravel. There is evidence of water accumulation and dried annuals in places.

The entire transect demonstrates a very disturbed site where a track road is made and soil excavated from it for the formation of a bund at edge of the site. Perennials are few and those present are unpalatable to livestock such as *Rhazya stricta*, *Calotropis procera* and *Citrullus colocynthis*. Even though the number of annual species are few, they are present where some moisture had accumulated from the last rainfall.

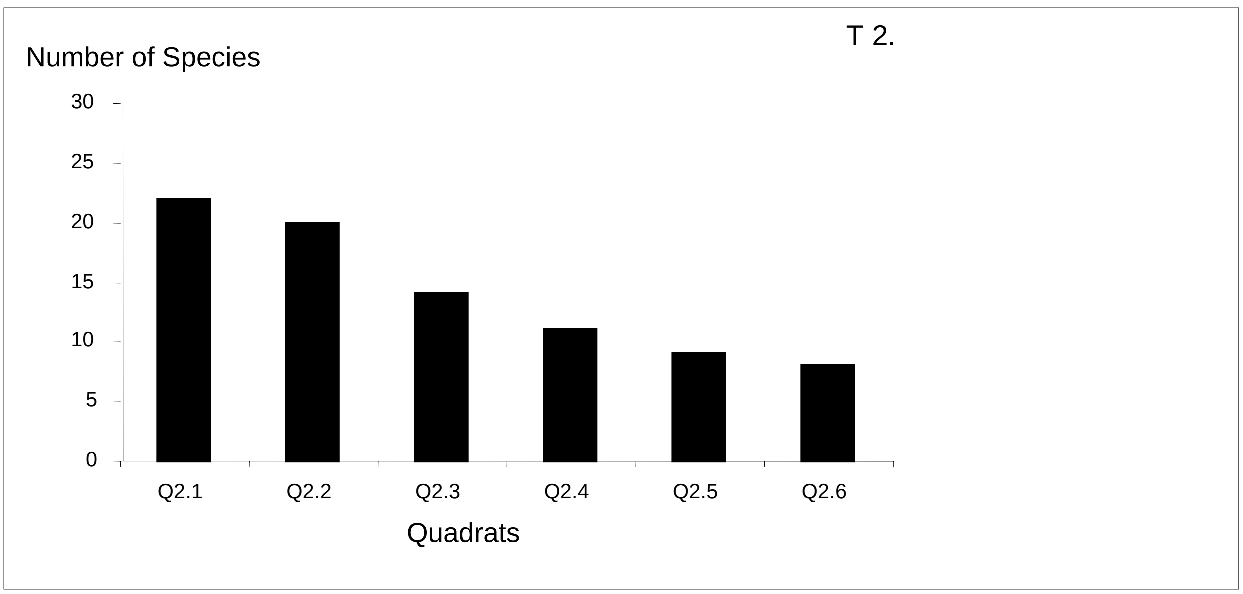

Fig. 3. Transect 2. East-West transect following a small wadi out of the mountain. The wadi is narrow at its upper part, becoming shallow and widening at its lower end. The substrate at the upper end of wadi is of large and small stones with pockets of soil and coarse gravel. The substrate gets finer with smaller stones, gravel and sand, and finally in the lower wadi fan the substrate is coarse and fine gravel with sand. The east-west transect across the desert plain shows the typical perennial species on gravel plains. The transect lacks the usual annuals and the some of the typical perennial species such as *Sphaerocoma aucheri*, *Convolvulus virgatus* that are palatable are lacking in most quadrats. The perennial trees and large shrubs present (*Acacia tortilis*, *Lycium shawii*, *Plocama aucheri*), are heavily grazed. The first two quadrats show the most richness with the number of species decreasing in the lower wadi fan. The entire transect shows predominance of unpalatable species and heavily grazed trees and shrubs. The species richness in the upper wadi may be due to the presence of subsurface moisture in upper wadi and also the protection provided by wadi sides and large stones. Some species such as *Euphorbia larica* are only present in the upper wadi areas. Low shrubby species are seen growing underneath large shrubs and are probably protected by them.

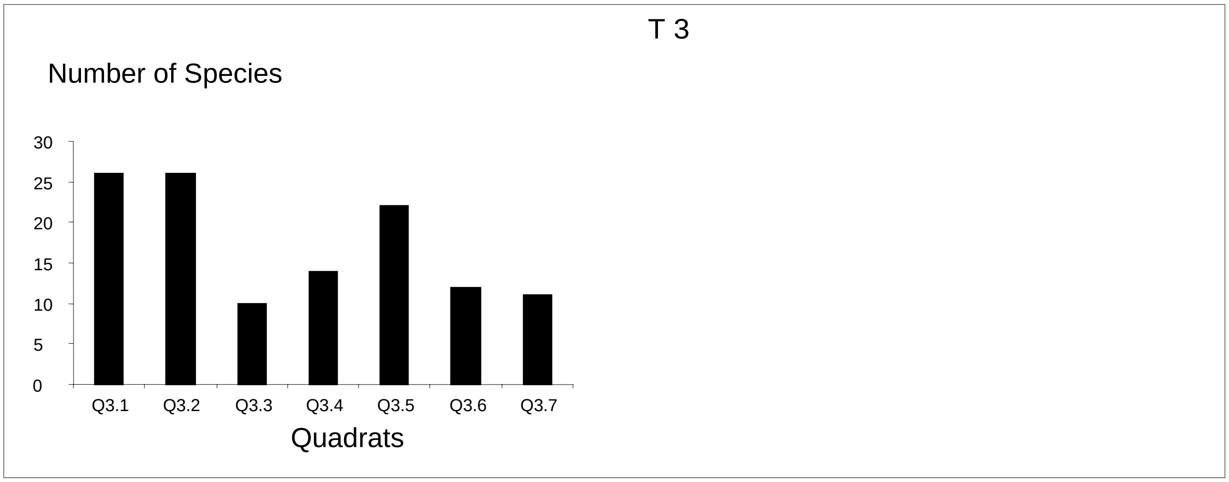

Fig. 4. Transect 3. East-West transect starting at base of the mountain, following a wadi. At the upper end the wadi banks are about 1-1.5 m high and wadi is about 10 m wide. The substrate is sand with coarse gravel, with large and small stones and a few boulders. The vegetation is mostly present in the wadi with the banks and higher ground almost bare of any perennial species. The typical plants are *Acacia tortilis*, *Euphorbia larica*, *Plocama aucheri* and *Lycium shawii*. The species composition is similar to that of Transect 2. As in Transect 2, the most species rich area is the upper wadi with species decreasing in the lower reaches. The species composition changes in the lower wadi with the substrate becoming more sandy and gravel finer. Throughout the transect the vegetation is heavily grazed.

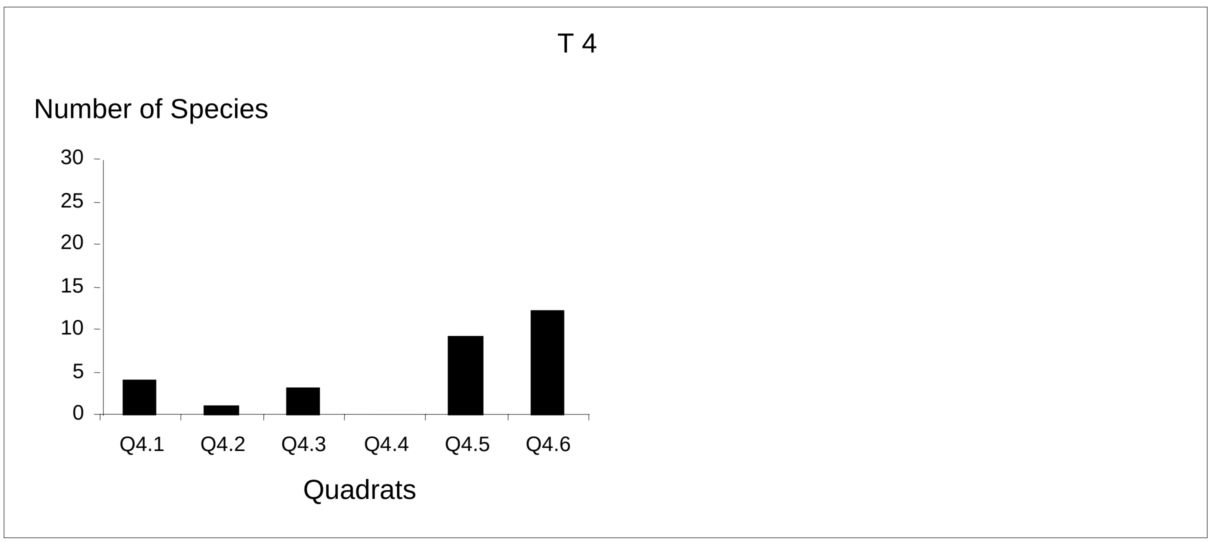

Fig. 5. Transect 4. East-West transect starting at base of the mountain, following a wadi with quadrats made on high ground above the wadi. The substrate at the upper end of the wadi is coarse gravel with sandy pockets and small stones. The almost flat gravel plain is practically bare of vegetation; there is a small rise in species in the lower part of the transect when the gravel plain meets and becomes part of the wadi fan. Here the substrate is sandy with fine gravel, strewn with few stones and supporting species typical of wadi fan (albeit only the unpalatable ones). *Acacia tortilis* and *Euphorbia larica* and associated wadi species such as *Lycium shawii* are lacking in this transect. This is due to the lack of water retention in the high areas above the wadi.

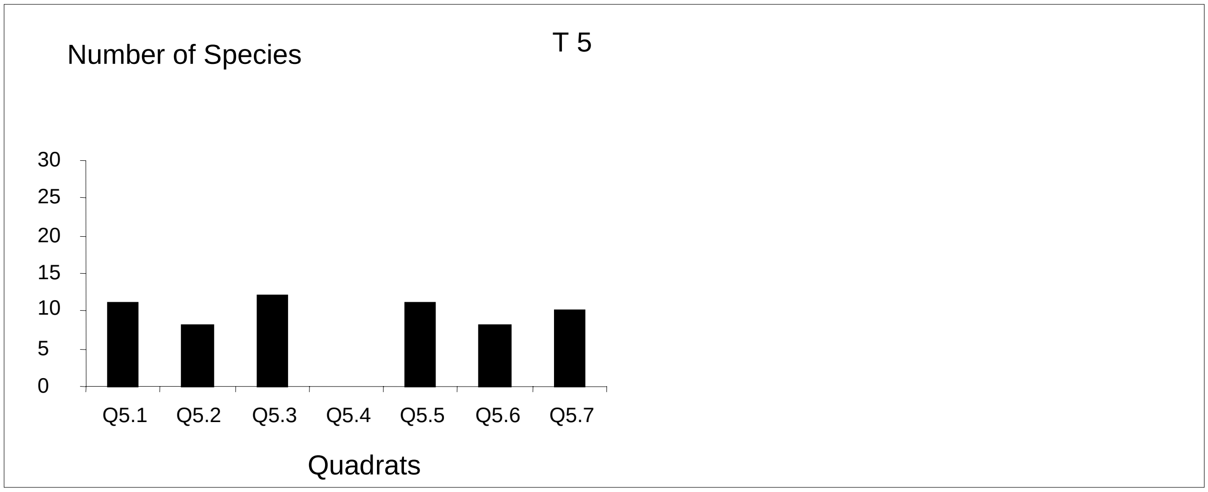

Fig. 6. Transect 5. East-West transect starting at base of the mountain. The transect is made in elevated areas composed of coarse gravel and small stones (5-10 cm across) and sandy depressions. In the upper gravel plain there are no wadis or runnels, but in the lower part a shallow sandy runnel runs across. The upper gravel plains support *Acacia –Euphorbia* plant community with associated shrubs. *Euphorbia larica* is not found in the lower gravel plain, but other species such as *Acacia tortilis*, *Lycium shawii*, *Blepharis ciliaris* are found more or less throughout the transect. In the lower part of the transect a shallow runnel widens out with a sandy substrate dominated by *Rhazya stricta* and *Citrullus colocynthis*.

There is no wadi in this transect and therefore the number of species is low and more or less the same throughout although the composition of the species changes from the upper to the lower parts of the transect.

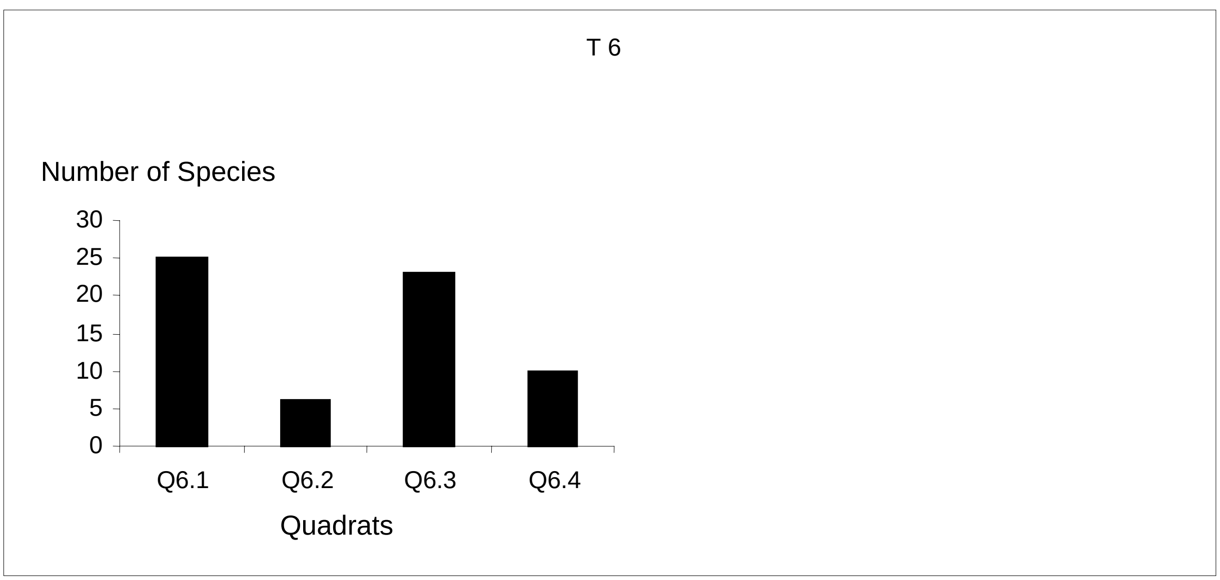

Fig. 7. Transect 6. A North-South transect made at the base of the mountain crossing several wadis and the intervening gravel plains. The purpose in surveying this transect was to show the distribution of species in wadis and the gravel plains between the wadis. The substrate is mainly coarse gravel, fine gravel with sand, in parts strewn with large and small stones.

A high numbers of species was recorded in the wadis and a low number in the intervening gravel plains. The composition of species was similar to the other wadi and gravel plain transects surveyed. The dominant plant community was the *Acacia-Euphorbia* community with associates *Lycium and shawii*, *Plocama aucheri* found more or less throughout.

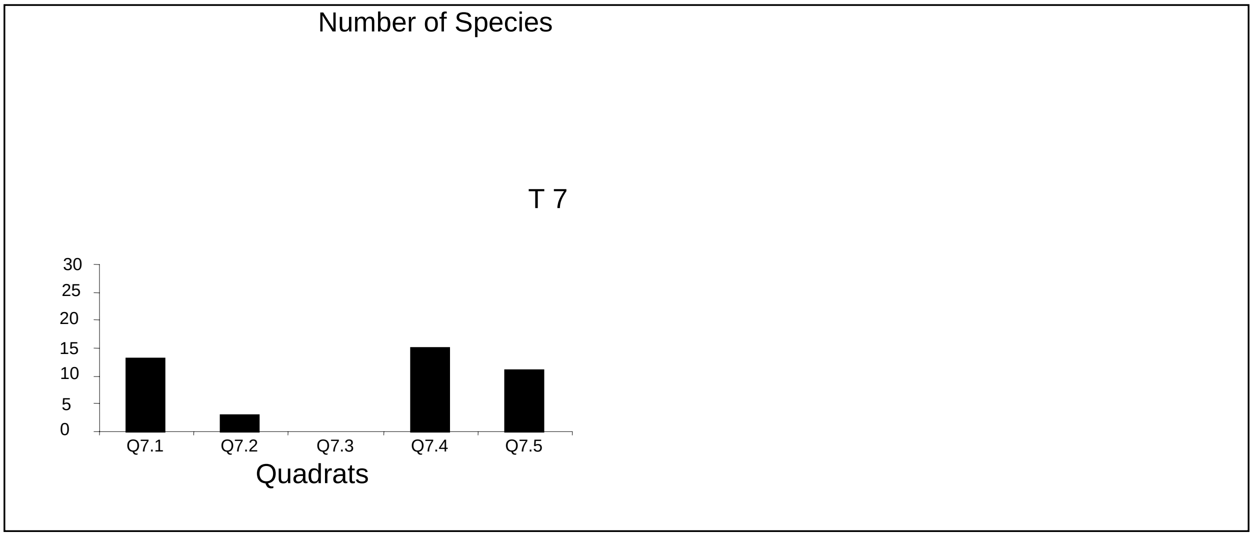

Fig. 8. Transect 7. East-West transect from the base of the mountain to the end of desert plain. The transect is made in the gravel plain which is dominated by *Euphorbia larica* in its upper part. Occasional *Acacia tortilis* and associated shrubs are present throughout. The gravel plain is composed of coarse gravel and small stones (5–10 cm across) with sandy depressions especially in the lower part of the transect. In the upper gravel plain there are no wadis or runnels and the lower part meets the sandy plain close to the bund at the end of the plain. The number of species fluctuates with the topography where small depressions or runnels hold more moisture and consequently support more species; *Euphorbia larica* is dominant in the upper part; *Acacia tortilis* is found throughout. The lower part is dominated by *Rhazya stricta* with occasional *Calotropis procera*.

Conservation and restoration

The paucity of diversity of plant species and vegetation cover in Arabia are inextricably linked with over grazing. The situation is so severe that a survey of rangelands in Oman in 1981 concluded that the rangelands were “highly degraded” (Anon. 1982). In the 1970’s 85% of the rangelands of Saudi Arabia were already estimated to be in a severely degraded state (Kingery 1971).

There are no long term studies available for the Arabian Peninsula where exclosures have been made and monitored to see the effects of protection against grazing. A few recent studies indicate the general effect of protecting rangelands from grazing. A study in eastern Arabia showed that after 11 years of protection by an exclosure in mixed gravel plain and sand dune substrata, there was an increased plant cover with *Stipagrostis plumosa* showing the greatest increase, and a decreased cover of the unpalatable *Zygophyllum qatarense* (Othman et al. 1995). In another exclosure measurable increases in cover compared to adjacent grazed areas occurred after only two years, again with increases in fodder species (Böer & Norton 1996). It has been shown that changes in species composition are higher in areas with long histories of grazing than areas with higher levels of grazing (Milchunas & Lauenroth 1993).

From the available studies on rangelands in Arabia, it is shown (1) that the greatest effect of overgrazing on species composition is likely to be seen in areas of greater productivity, such as mountains, (2) that increases in grazing pressure will decrease species diversity, and (3) that changes in species diversity cannot be necessarily be used to indicate effects of grazing on soil quality (Milchunas & Lauenroth 1993).

Plant recovery and restoration of habitats

Plant recovery requires that natural populations or planted populations (or plant communities) be within a protected, appropriate habitat and be able to maintain themselves over long periods of time. Restoration projects have failed due to several reasons, one of these being the inability of plants to establish and maintain themselves in the wild. Loss of critical habitat quality, or lack of seed of key species may contribute significantly towards this failure. Success for a restoration project requires a good understanding of the soil, landscape and ecosystem.

Species and plant communities should be planted to keep the species composition as natural as possible. Whole plants can be salvaged from development sites and used for restoration, or species propagated from seed or cuttings.

Direct seeding, one method for restoration, can be done at any time, but seeds will be blown away and lost to insects, birds, and rodents over time. Seed quality also declines from exposure, sand blast and desiccation. Although some seeds may persist for years or decades and finally emerge when a heavy rain occurs, direct seeding is most effective if it is done just before significant rain events. However, these are hard to predict. If direct seeding must be done the seed should be put in place when precipitation is most likely or when the soil is already moist. Placing it into pits or depressions can increase success. If seeding must be done when the soil is dry, irrigation is advised. Local, site adapted native seeds should be used for restoration projects. Seeds should be collected from healthy, local populations using a broad genetic base. Collected seeds can also be banked for later use though seed viability should be monitored over time. Species should be identified carefully and detailed records of the collection source should be kept (Bainbridge 2007).

Water is a key factor in desert restoration. The aim is to capture all the rain, reduce plant water loss, and to provide efficient irrigation only when strictly necessary. In a degraded habitat, irrigation may be necessary at first to allow seed to germinate and young plants to establish but it is critical to avoid reliance on irrigation if the restoration is to be sustainable. Plants should be weaned off artificial watering as soon as possible. It is best as a start, to plant in natural depressions, runnels and wadis where there may be some subsurface water or where water accumulates from dew or rain. As plants start to grow they will slowly improve their environment which in turn increases growth leading to site recovery. (Bainbridge 2007).

Container plants grown from local, site adapted seed can be useful for desert restoration projects. Container plants speed recovery of a damaged site because the container plant jumps the biggest hurdle, seed germination and early growth (Bainbridge 2007).

Invasive species

It is important to take especial note of non-native invasive species during the restoration programme. Invasive species of desert habitats are by nature hardy, moderately salinity tolerant, and opportunistic. They are likely take over favourable habitats and impede the establishment and growth of the native flora. At the study site where conditions are suitable, the most common invasive species is *Prosopis juliflora*, native to Central and South America. This tree flowers and fruits profusely and is likely to spread quite rapidly if left unchecked.

Monitoring

Long term monitoring of plants is essential for any restoration programme, and it is recommended that permanent plots are made in each of the vegetation types to monitor progress. If restoration has been done using restoration units or islands as the main disseminating entity, monitoring of plants in these islands is essential. Such monitoring identifies the timing and causes of poor performance and can provide a framework for measures to be taken to improve the project. Changes in the ecosystem should also be monitored as these will have a direct effect on the survival of the plants.

Demographic trend analysis, used to determine whether a population has the potential for growth or stability in the near future, and factor resolution, used to determine the kinds of intervention necessary that would result in a growing or stabilized population can be applied (Pavlik 1994). Survivorship, seed production, and frequency of establishment are important elements in a trend analysis that will identify unstable or declining populations. Guided by the results of trend analysis, factor resolution can be used to indicate the specific manipulation needed for the recovery of that population (Pavlik 1994).

Conclusions

Conservation of biological diversity through restoration is possible with timely human intervention. Restoration of degraded landscapes is a long-term process and it can take up to ten years (or more) before changes are seen in the landscape. A good knowledge of species, composition of plant communities and populations and their phenology, geomorphology of the area, substrate, climate and water flows are all necessary before any restoration work can take place. Seed collection of key species from native populations, planting and irrigation are necessary steps for restoration programmes. All restoration projects require careful and objective monitoring to measure their success and the resulting data contributes to our understanding of restoration ecology.

Appendix 1.

Species list:

Acacia tortilis (Forssk.) Hayne
Aeluropus lagopoides (L.) Trin.
Aerva javanica (Burm.f.) Juss. ex Schult.
Anastatica hierochuntica L.
Anvillea garcinii (Burm.f.) DC.
Aristida adscensionis L.
Blepharis ciliaris (L.) B.L.Burtt
Calotropis procera (Aiton) W.T.Aiton
Cenchrus ciliaris L.
Chrozophora oblongifolia A.Juss.
Citrullus colocynthis (L.) Schrad.
Cleome brachycarpa DC.
Cometes surattensis L.
Convolvulus virgatus Boiss.
Corchorus depressus (L.) Stocks
Crotalaria aegyptiaca Benth.
Cymbopogon sp.

Ducrosia anethifolia (DC.) Boiss.
Euphorbia granulata Forssk.
Euphorbia larica Boiss.
Fagonia bruguieri DC.
Fagonia indica Burm.f.
Fagonia ovalifolia Hadidi
Farsetia linearis Decne. ex Boiss.
Forsskaolea tenacissima L.
Haloxylon salicornicum (Moq.) Bunge ex Boiss.
Haplophyllum tuberculatum (Forssk.) A.Juss.
Heliotropium calcareum Stocks.
Heliotropium bacciferum Forssk.
Halothamnus bottae Jaub. & Spach
Indigofera argentea Burm.f.
Indigofera intricata Boiss.
Iphiona scabra Decne.
Kohautia caespitosa Schinzl.
Lasiurus scindicus Henrard
Launaea sp.
Lindenbergia indica (L.) Vatke
Lycium shawii Roem. & Schult.
Monsonia nivea (Decne) Webb
Morettia parviflora Boiss.
Ochradenus arabicus Chaudhary, Hillc. & A.G.Mill.
Physorrhynchus chamaerapistrum (Boiss.) Boiss.
Plantago ovata Forssk.
Plantago ciliata Desf.
Plocama aucheri (Guill.) M.Backlund & Thulin
Polycarpaea repens (Forskk.) Asch. & Schweinf.
Polygala erioptera DC.
Polygala irregularis Boiss.
Prosopis cineraria (L.) Druce
Pseudogaillonia hymenostephana (Jaub. & Spach) Lincz.
Pulicaria glutinosa Jaub. & Spach
Reseda aucheri Boiss.
Rhazya stricta Decne.
Salsola imbricata Forssk.
Schweinfurthia imbricata A.G.Mill., M.Short & D.A.Sutton
Schweinfurthia papilionacea (Burm.f.) Boiss.
Scrophularia deserti Delile
Seetzenia lanata (Willd.) Bullock
Solanum nigrum L.
Sphaerocoma aucheri Boiss.
Stipagrostis plumosa (L.) Munro ex T.Anderson
Tephrosia apollinea (Delile) DC.
Tribulus pentandrus Forssk.
Vernonia arabica F.G.Davies
Viola cinerea Boiss.

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