Introduction

The ghaf tree (Prosopis cineraria) is an integral part of the cultural heritage of the United Arab Emirates (UAE) and to natural desert ecology. It occurs mainly in ‘open forests’ of sparsely distributed trees, but can also be found in clusters (Aspinall 2001) or in isolation. Land owners and scientists agree that numbers in the UAE have been reduced over the last few decades, due to overgrazing, copicing, urban expansion, and reduced access to ground water. It also appears that regeneration is limited, indicating that species survival could be threatened in localized areas.

The recently established Dubai Desert Conservation Reserve (DDCR) contains several isolated trees and four tree clusters that range in size from four to 455 trees. The tree clusters are of particular interest to the reserve since they provide a unique natural habitat (see Figure 1). The isolated trees, on the other hand, are all associated with human settlement in some way. Each cluster is located on a sand dune adjacent to a gravel plain. Even to the casual observer, clusters appear to contain trees of uniform size, and the boundaries of the two largest clusters appear to be distinct. These observations indicate that the population biology of clusters may be different to that of trees in open forests. A sound understanding of these clusters is essential to ensure their survival for future generations. The aim of this paper is to report initial observations in our studies of the DDCR ghaf tree clusters and at the same time identify gaps in our current knowledge.

Study site & data collection

The DDCR encloses 225 sq. km of sand sea, interspersed with several gravel plains. It has the dual role of preserving a part of the natural desert for future generations, and providing a resource for the tourism industry. Trees are subject to grazing pressure from a herd of approximately 1,200 camels, which remove all lower foliage from adult trees. Arabian oryx and several species of gazelle have been introduced to the reserve in stages over the last 40 years. Like the camels, oryx are regularly observed in or near a cluster, but the foliage of adult trees is out of their reach, due to the camels.

Data collection involved recording the circumference of all trees at chest height, and their location using GPS. This data was used to generate spatial maps of trees within clusters (Figure 2), and to assess the distribution of tree sizes within each cluster. Location information was also collected for Acacia tortilis and Calligonum comosum in the area of the forests, for comparison. Data collection and observations occurred during the winter of 2004 and 2005, and summer 2005. In a parallel study, a Zayed University graduate was employed to conduct telephone interviews of Emirati farmers in the DDCR. The survey included land management and ecology questions. Nine farmers were interviewed in Arabic, their comments then being transcribed into English.

The two largest clusters both have small groups of Acacia tortilis nearby on a gravel plain. An association between the two species has been reported previously (Sandison & Harris 1991; Ghazanfar 2004), but has not been investigated. Our data neither support nor refute the notion of a biological link between the species. The two species might simply prefer similar habitats.

Distribution and genetics

Prosopis cineraria or ghaf is centered on the Thar desert of India and Pakistan, but occurs in Afghanistan, Iran and the Arabian peninsula (Pasiecznik et al. 2004). The Arabian population consists of large, isolated populations that could be a relic from a former wetter period. Ghaf exists mostly in the UAE and Oman (Jongbloed et al. 2003), though it has also been reported as an infrequent species in the eastern and southern margins of the Rub’ al-Khali of Saudi Arabia (Mendaville 1980). Within the UAE, it is common in the inland sand plains and dunes of the Northern Emirates and eastern rim of Abu Dhabi emirate, and can also be found in wide wadi beds throughout the Hajar Mountains (Jongbloed et al. 2003).

There has been almost no molecular genetic work conducted intra-specifically on P. cineraria. People have considered the Arabian population to be highly genetically variable (e.g. Sandison & Harris 1991), based on vegetative morphological characteristics. However, morphological variation within all Prosopis species is typically high (Pasiecznik et al. 2004). In Oman, Brown (1988) attempted to relate observed morphological differences to enzyme isoenzyme expression, but results were inconclusive due to the small amount of the genome surveyed.

P. cineraria may hybridise with other Prosopis species. P. juliflora has been reported to hybridise with several other species in the genus, though not specifically with P. cineraria (Pasiecznik et al. 2004). Since P. juliflora is also present within the DDCR, there is a possible threat of genetic contamination to the present population.

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Figure 1: South Eastern Prosopis cineraria cluster in the Dubai Desert Conservation Reserve, showing the tight arrangement of trees without outliers.
Figure 2: Maps of three clusters of *Prosopis cineraria* (ghaf) trees in the Dubai Desert Conservation Reserve. (a) Western large group (b) North Eastern group (c) South Eastern group. Trees within clusters formed small groups not shown here, because they were too close together for the accuracy of the GPS to record. Circle sizes indicate the radius of trees at chest height.
Importance

*P. cineraria* is mainly valued for its highly nutritious livestock fodder (Pasiecznik et al. 2004) of leaves and immature seed pods. The species has been used for many other purposes, as is common in a region of limited, sparse resources. *Bedu* have been reported to eat both leaves and immature pods in the UAE (Jongbloed et al. 2003). Mature dry pods which are biscuit-like are sometimes eaten in Abu Dhabi too and in Oman (Brown 1968), while in Rajasthan, India the pods are boiled and dried, then eaten as a vegetable (Anonymous 1991). Gum within the bark can also be eaten if food is in short supply (National Academy of Sciences 1980).

Several medicinal uses are reported in Jongbloed et al. (2003), including an ingredient of eye drops for cataracts (pods), treatment of toothache and dyspepsia (leaves), pain relief (bark bark) and antiseptic (sap). A study by Rai et al. (1999) indicated that oil from the species had poorly developed antifungal properties. Wood, with a calorific value of around 5000 kcal per kg, is often the best local choice for firewood and making charcoal (Mahoney, 1990). DDCR farmers have reported using it for this purpose. The tree provides reasonably durable timber for construction, but is not a preferred species due to a twisted growth pattern (Sandison & Harris, 1991). Post-harvest decay of wood through pest and insect attack is also a limitation (Jain et al. 2005).

The tree is one of many species used for revegetation of the UAE desert (Kiriwa et al. 2002). An advantage of this species is that it can withstand partial burial (Gates & Brown 1988). Living trees whose trunks have been covered by two or three metres of sand are common in the UAE (Figure 3). Just as importantly, it is common to see trees that survive after losing up to two metres of sand from around their base.

Shade is important to the survival of *Oryx leucoryx* under natural conditions, since their daily foraging time is restricted by high body temperature (Seddon & Ismail 2002). In the DDCR, oryx and gazelles use trees of any species, and *Leptadenia pyrotechnica* shrubs, for shade. The Reserve also provides fresh water and supplementary feed at several locations, so shading may not be as important for survival within the Reserve.

**Figure 3:** A *Prosopis cineraria* tree that is surviving coppicing, grazing, and partial burial to approximately 3 m.

Morphological growth

Most of the existing *P. cineraria* trees in the UAE have a morphology that has been shaped by grazing pressures. In the DDCR, all the observed trees could be easily classified into three groups;

- Sprouts: Twenty four sprouts were observed during the winter of the study, growing from the rootstock of established trees. They typically grew laterally to about 30 cm, but some were aro (Figure 4). They were difficult to see among the sand and leaf trash, so many more sprouts were probably present. By the summer, they had mostly disappeared, presumably eaten by herbivores. No seedlings were observed, though if they existed away from the clusters they would not have been found.

- Shrub: Twenty five shrubs were observed, all of them within the same section of one cluster. This location had been fenced in past, but it is not known when the fence became ineffective at preventing camel grazing. Shrubs were around 2.5 m high and similarly wide, usually with two or more main trunks (Figure 5). The outer surfaces of shrubs were woody and thorny, and as winter moved to summer, foliage receded from the outer surface. Shrubs appeared to have emerged from sprouts rather than seeds. The similarity in size indicates that they all emerged during one or two seasons. The ratio of thorns to foliage was much higher in these shrubs than in the higher branches of adult trees.

  - Adult trees: Trees typically consist of a single trunk supporting a dome shaped canopy. Often, they appear in clumps of 2 to 4 trees with a linked root system. The rounded crown is a result of repeated coppicing (Pasiecznik et al. 2004). The practice of coppicing has been banned in the DDCR, so over time the canopy may change shape.

The species growth pattern under grazing appears to be as follows. The plant grows as a woody shrub, adding to its thorny exterior until its surface area is large and impenetrable enough to protect one of the central trunks from grazing. When this occurs, the bulk of the growth resources are put into the central trunk, so that the shrub transforms into a tree. Camels were observed to rip higher lateral branches of up to 10 cm diameter from the trunks of adult trees, thus maintaining the characteristic shape. A two-stage growth pattern (i.e. shrub to tree) has also been reported in *Acacia tortilis* in response to grazing (Jongbloed et al. 2003, Ghazanfar 2004).
Figure 4: *Prosopis cineraria* sprouts growing from the root of a nearby mature tree. Photo taken November 2004 under the South Eastern cluster.

Figure 5: *Prosopis cineraria* shrubs that arose in a previously fenced 'farm' area within the Dubai Desert Conservation Reserve. Note that shrubs are all the same size, indicating that they probably all emerged during the same season. Photo taken December 2004.
Cluster structure

The distribution of trunk radii within clusters followed a lognormal distribution in all three clusters when saplings and sprouts were excluded (Figure 6). The two eastern clusters were similar in average radius and distribution, while those of the western clusters were much larger (Table 1). This distribution is consistent with the hypothesis that most of the trees are of similar age, though other explanations are also possible. If radius is correlated with age, then the western cluster contains trees that are much older, and the cluster may have sparser trees because others in the cluster have died.

The cluster maps (Figure 2) show that the edge of a cluster is quite clearly defined. There are some thinly populated areas within clusters, possibly where the tree density has thinned through attrition or variable access to groundwater. In other places, there is a protrusion of trees from the edge of a cluster, indicating growth of the cluster. In all three clusters measured, the biggest trees were located on the edges of the cluster. These trees could be older than the others, or they might just be facing less competition for resources. If they are older, they may have provided the rootstock for the other trees to grow from vegetative sprouts.

Understory vegetation

In Pakistan and India, crops are grown right to the trunk of *Prosopis cineraria* (Mann & Shankamarayan 1980) and are said to benefit from the tree. In Oman, Brown (1998) described prolific growth of ephemeral species under the tree canopy following periods of rain, and the presence of perennial species throughout the rest of the year. He offered several hypotheses to explain the observation, but did not test them.

In the DDCR during the unusually wet 2005 winter, germination of ephemerals and perennial shrubs was conspicuously absent underneath the canopy of the trees, despite being present elsewhere. Hence, it appeared that the trees in the DDCR were having the exact opposite effect on understory vegetation.

The species produces allelopathic chemicals but they appear to be relatively weak (Gosel et al. 1989). In contrast, allelochemicals are relatively strong in the invasive alien species *P. juliflora*, inhibiting both germination and growth of *P. cineraria* (Al-Rawany et al. 2003). *Prosopis cineraria* is a phreatophytic (seeks ground water) legume, and could therefore obtain both nitrogen and water without competing directly with other plants. Root nodulation has been observed in the species (Sandison & Harris 1991), but has not been confirmed in the DDCR. In a Rajasthani study, soil under the canopy had a higher fungal biomass than the surrounding area, with maximum biomass during rainy months (Purohit et al. 2002). This observation suggests that the higher fungal biomass under the trees may be due to increased soil moisture. An extensive review of the ecological interactions between *ghaf* trees and other species is provided in Brown (1998), much of which is relevant to the UAE.

*P. cineraria* is unusual in that the greatest density of its fine roots is found well below the surface. In a study of 9-year old plantation trees, Singh (1994) observed the greatest density of roots at 30 to 60 cm below the surface. Whether this is consistent across soil types is not clear. Although deep lateral roots could be a response to shifting sands, there are other possible reasons for their evolution.

![Figure 6: Size distribution of *Prosopis cineraria* trees in the eastern clusters (North Eastern and South Eastern) of the Dubai Desert Conservation Reserve. There were probably more trees in the <1 cm category that were overlooked.](image)

**Table 1: Mean radius of trees in each cluster (excluding suckers and saplings)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Tree number</th>
<th>Average radius (cm)</th>
<th>Standard Error</th>
<th>Regeneration observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>North East</td>
<td>247</td>
<td>16.94</td>
<td>0.29</td>
<td>Sprouts (0.5 cm) and saplings (30 cm)</td>
</tr>
<tr>
<td>South East</td>
<td>456</td>
<td>16.84</td>
<td>0.20</td>
<td>Sprouts (0.5 cm) only</td>
</tr>
<tr>
<td>West Large</td>
<td>64</td>
<td>23.83</td>
<td>0.52</td>
<td>None</td>
</tr>
<tr>
<td>West Small</td>
<td>4</td>
<td>20.69</td>
<td>2.07</td>
<td>None</td>
</tr>
</tbody>
</table>

Tribulus 15.2 Autumn/Winter 2005
Water

Prospis cinerata leaves have a high transpiration rate compared to other desert perennials (Laurie, 1988). In the study by Laurie, transpiration continued throughout daylight hours but was greatest in late morning. The species is well known to be a phreatophyte, with tap root estimates ranging from 20 m (Manohary 1990) to 60 m below the surface (Jongbloed et al. 2003). The sudden death of large numbers of mature trees in India has been attributed to over exploitation of the underlying water table.

Groundwater supplies have been lowered by the increase in the number and size of farms using irrigation in the UAE (see Aspinall 2001). Reductions in quality have also been reported. Irrigation water is typically pumped from wells below the root zone, and thus may originate from different aquifers than those used by the trees. Anecdotal evidence suggests that the removal of groundwater has little effect on trees in some locations, but can be a concern elsewhere. Not enough is known about the structure of aquifers and the vertical movement of ground water to be able to predict the long-term effects of pumping in any location. In the DDCR, farmers reported that the water table has fallen, but they attribute this to a series of very dry years. Five of six farmers reported that the water has become saltier and have ceased using it for human consumption, despite perceived health benefits.

In Oman, an extensive study of dewfall found that it was greatest in the general vicinity of a P. cineraria forest, but that it was dramatically lower underneath the canopy of individual trees (Anderson 1988). Dewfall is the most frequently occurring form of freshwater for plants in the desert, so these microclimatic modifications could have a significant effect on plant communities near P. cineraria clusters.

Hydraulic lift, which has been convincingly reported in Acacia tortilis (Ludwig et al. 2003), has not been reported in P. cineraria. In this process, roots enable dry topsoil to be rehydrated with water from deeper in the soil profile, thus enabling nutrient uptake to continue during dry periods.

Grazing and coppicing

Fodder removal through both grazing and coppicing has a significant effect on the morphological structure of P. cineraria. The main herbivore is the camel, which exists in large numbers in the UAE. Before the creation of the Emirates in 1971 there were estimated to be 100,000 camels. This dropped to 39,500 by 1976 and then rose steadily to the current population of 250,000 (FAOSTAT 2004). Camels in the DDCR are housed in farms overnight, but allowed to forage throughout the desert during daylight. This form of land use is common throughout West Asia (Ferguson et al. 1990).

Coppicing (Figure 7) is commonly practised in the UAE, though it was recently banned in the DDCR. Farmers cut limbs from trees mainly from January to March when trees are most able to recover. It is believed that the practice is beneficial to the health and survival of trees. Indian studies have reported maximum fodder yields by complete coppicing every three years (National Academy of Sciences 1980), or by removing no more than two thirds of the crown (Kishan Kumar, VP 2000).

Reproduction

P. cineraria naturally reproduces either sexually through seeds, or vegetatively through root suckers to produce clones. The relative frequency of each method under natural conditions is not known, but could be determined through genetic analysis of a population. DDCR flower and seed production was very low during this study. Flowers appear in March and April (Khan 1980), and farmers reported that they typically feed al henbel (dried seed pods) to livestock in June. Seed dispersal is thought to occur mainly through grazing domestic & wild animals and possibly through birds (Al-Rawahi et al. 2003). No seedlings were observed during the study.

Most Prospis species are self-incompatible (Pascieznik et al. 2004), meaning they must be fertilised by a genetically different tree to produce fruit. If this is true of P. cineraria, and if a cluster were entirely clonal, then this would reduce the opportunity for pollination in a cluster.

Many of the individuals at shoot, shrub and tree stage were observed to be sharing roots with an adult tree, indicating vegetative reproduction. The distinct boundaries of the clusters are also indicative of vegetative reproduction, raising the possibility that each cluster represents one clonal unit. Commercial propagators have reported that the species suckers easily, but that cuttings do not readily root (Sandison & Harris 1991, Puri & Kumar 1995). This indicates that suckers rely on the parent plant for longer than other species. Optimised tissue culture conditions were reported in Shekhawat et al. (1993).

Conversely ‘open forests’ may result from sexual reproduction.

Figure 7: Coppiced Prospis cineraria, showing removal of most of the crown leaf
Conclusion

There is much that is not known about the biology of ghaf trees in the UAE. Detailed information is lacking for important management issues such as nodulation, disease prevalence, age distribution, population genetics, and capacity for hydraulic lift. In contrast, there is sufficient evidence that the current population is ageing and that replacement rates are too low. For clusters to be preserved, young trees must be protected from camels until they are large enough to withstand grazing. The hypothesis that trees within clusters reproduce vegetatively, whereas open forest trees reproduce sexually, should be tested. If true, it would have implications for management of the species.

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References


