Impacts of Surviving and Dead Shrubs and Grasses on Floral Diversity and Community Structure of Sandy Dunes of the UAE

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ABSTRACT

Desertification of sandy areas driven by wind erosion in the Arabian Gulf region often results in the dominance of few shrubs and grasses, while most of the land are devoid of vegetation. The impact of surviving and dead shrubs and grasses on floral diversity and plant community structure was assessed on stabilized sand dunes in Dubai Desert Conservation Reserve. Shrubs have greater role in facilitating plant recruitment and survivorship and hence enhancing floral diversity, compared to grasses. Both dead shrubs and grasses attained significantly greater species richness, abundance and diversity indices compared to comparable surviving shrubs and grasses, so the effect of dead grasses was more pronounced than that of dead shrubs. Grasses have a greater role in enhancing floral diversity after their death. For restoring the productivity and species diversity of degraded sandy desert habitats, the study recommends the maintenance and growing shrubby plants as an early successional stage that facilitate the environment of other annuals and perennial plant. This would help in stability of the fragile desert ecosystems.

Key wards**:** competition, deserts, facilitation, floral diversity, shrubs, grasses

1. INTRODUCTION

In most desert ecosystems, vegetation is spatially heterogeneous and consists of vegetation patches alternating with areas of bare soil [1]. Typically, desertification of sandy areas driven by wind erosion often results in the dominance of few shrubs and grasses, while most of the land are devoid of vegetation [2]. Several studies in arid and semiarid ecosystems have demonstrated that seedling establishment and survival were greater underneath and around the canopies of shrubs than in the open spaces between them [3] & [4].

Plants could influence their neighbors in many ways, resulting in a broad range of detrimental or beneficial outcomes. The abundance, performance and spatial distribution of plant species are highly linked to the strength and sign of the interactions involving them in their communities [5] & [6]. Seedlings can experience both facilitative and competitive effects of neighboring adult ‘nurse’ plants. Seedlings can benefit from reduced thermal stress or evapotranspiration [7], [8]. Improved soil texture, nutrient content and water availability [9], [10], [11], [12] & [13] and protection from herbivory provided by nurse plants [14] & [15]. Conversely, nurse plants can also have negative effects on seedling survival and establishment in their understory community. These competitive interactions may be through light deprivation, competition for water and nutrients, or leaching of allelopathic compounds [9], [11], [16], [17] & [10]. Generally, the net direction and strength of these interactions are thought to depend on site productivity [18]. Facilitative interactions have been described mainly for harsh conditions, such as those occurring in arid and semiarid environments [19]; [20] & [21].

Grasses possess most of their roots in the upper layer of the soil. In their global analysis of root distribution [22] indicated that grasses had 44% of their roots in the top 10 cm of soil, whereas shrubs had only 21% in the same depth. In addition, in the arid the Patagonian steppe, [23] indicated that 54% of the grasses root biomass is located in the top 10 cm of the soil. However, most of the shrubs roots are present in the lower layers of the soil [23]. Grasses of the arid and semiarid ecosystems take up most of the water from the upper layers of the soil and utilize frequent and short-duration pulses of water availability, whereas shrubs take up most of the water from the lower layers of the soil and utilize infrequent and long-duration pulses of water availability [24]. The difference in soil water use between shrubs and grasses might affect their interference or facilitative interactions with the understory vegetation.

It has been reported that shading by the shrub canopy reduces the solar radiation intensity and temperature at the soil surface and, consequently, water losses by evaporation [10], [25], [26] & [27]. However, the canopy effect depends on the intensity of the crown. Open canopies, such as that of grasses and dead shrubs should have lower effects on shading and water losses by evaporation, compared to surviving shrubs that have denser canopies. In addition, soil fertility under dead shrubs should be similar, if not more than, compared to surviving shrubs. Conversely, the surviving plants would compete with understory community, but dead plants shouldn't do that. The assessment of the impacts of dead and surviving shrubs and grasses on the understory vegetation would help in determining the important factors responsible for plant-plant interactions in a hyper arid desert conditions.

Despite several studies assessed the impact of shrubby plants on the associated plants, few did that on the grasses. Usually, grasses have shallow advantageous root systems. In the loose sand dunes, grasses rely mainly on the atmospheric moisture and on any little showers of rains. Consequently, intense competition is expected between grasses and the associated plants, especially annuals, on the limited water in the sandy soils. However, shrubs usually have deeper root systems that enable them to secure some of their water requirement from the deeper layer of the ground. Consequently, the competition between grasses and the associated species is expected to be less intense, compared to that of shrubs with their associated species. The aim of the present study was to assess the impact of surviving and dead shrubs and grasses on floral diversity and plant community structure on stabilized sand dunes in Dubai Desert Conservation Reserve (DDCR), Dubai.

2. MATERIALS AND METHODS

2.1 The research site

The Dubai Desert Conservation Reserve (DDCR - 24^o to 25^o latitude and 55^o to 56^o longitude) is a designated area set aside for conserving the natural flora, fauna and landscape of the desert ecosystem in Dubai, UAE (Fig. 1). It is an arid area, characterized by two distinctive seasons: a long dry season (April-November) with very high temperatures, and a short season (December - March) with mild to warm temperatures and light rainfall, the climatic data of Sharjah Airport, which is one of the nearest meteorological stations to the study area, shows that the mean daily temperature ranges between 12.1^{o}C in January to about 42^{o}C in June-August. The long-term records (1934-2004) of this metrological station showed an average rainfall of 102.8 mm. However, variations in annual rainfall are considerable. A maximum of 345 mm was recorded in 1957 while a minimum of 3.0 mm was recorded in 1985 [28].

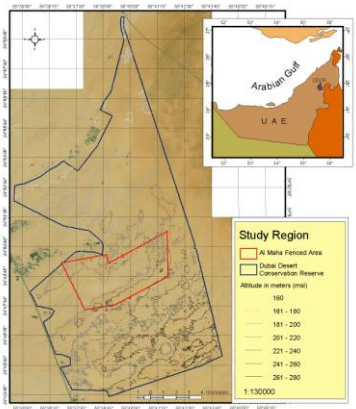

Fig. 1: Location map of the Dubai Desert Conservation Reserve (DDCR), core fenced area of Al Maha Resort (AMR) and the topography as 20m slope increment contour lines.

The DDCR encompasses about 225km^2 of sand dune desert and spans about 5% of the total area of Dubai. The DDCR is a fenced area with a perimeter of about 85km. The reserve was declared in 2002 and the perimeter was completed in late 2003. The DDCR is mainly a sand dune-desert ecosystem. The topography is simple with the landscape dominated by low to medium-high sand dunes.

2.2 Methodology

Both surviving and dead shrubs and grasses were represented by 30 individuals, except surviving grasses were represented by twelve individuals. The lower sample size of surviving grasses was due to rarity of this life form in the study area. The individuals were randomly selected on the stabilized dunes of the DDCR. Number of individuals of the associated plant species was counted in 1m x 1m quadrate laid around each dead or surviving individual and in open places next to it (about 2 m away from the individuals). The studied nurse shrubs were *Limeum arabicum*, *Rhanterium epapposum*, *Dipterygium glaucum* and *Crotalaria aegyptiaca* and the studied nurse grasses were *Pennisetum divisum* and *Panicum turgidum*. However, it was hard to define the identity of the dead shrubs or grasses. The average diameter of surviving nurse shrubs and grasses ranged between 0.8 m and 1.2 m and the average height was about 0.5-0.8 m. All the studied shrubs and grasses were characterized by open canopies; the soil underneath them receives sunlight and rainfalls. Frequency of occurrence, density, abundance and importance value index (IVI) was calculated for every plant of the associated species. Species richness and three diversity indices (Shannon-Wiener, Simpson, and Brillouin) were calculated for each targeted dead and surviving shrub and grass individual.

3. RESULTS

3.1 Impacts on abundance and species diversity

Species diversity and abundance were significantly greater under surviving shrubs, compared to under surviving grasses. Species richness, abundance, Simpson, and Brillouin indices were greater under surviving shrubs than under surviving grasses by 140%, 29%, 20.2% and 26.3%, respectively. This indicates that shrubs have greater role in facilitating plant recruitment and survivorship and hence enhancing floral diversity, compared to grasses, which might have inhibition role. However, there was no significant difference between diversity and abundance of species under dead shrubs and dead grasses; both attained significantly greater species richness, abundance and diversity indices compared to comparable surviving shrubs and grasses, so the effect of dead grasses was more pronounced than that of dead shrubs. Species richness, abundance, Shannon-Wiener, Simpson, and Brillouin indices were greater by 25%, 35%, 1.27%, 5.42% and 6.6%, respectively under dead, compared to surviving shrubs, but by 220%, 87.1%, 9.4%, 40.5% and 47.7% under dead grasses, compared to surviving grasses. This indicates that grasses have a greater role in enhancing floral diversity after their death (Table 1).

There was no significant difference between abundance of associated plants both under and in the open places next to dead and surviving shrubs and grasses; the exception was the surviving grasses as the abundance under them was significantly lower, compared to the open places. However, species richness and diversity indices were greater under surviving and dead shrubs and grasses compared to open places. The exception, again, is the surviving grasses, which attained lower values, compared to open places. This supports the hypothesis that surviving grasses inhibit the recruitment and growth of associated flora.

3.2 Impacts on community structure

Eremobium aegyptiacum is one of the most common annual herbs in the study area that was not significantly affected by the presence of surviving or dead shrubs and grasses; so, its abundance was greater in the open spaces between crowns, compared to underneath them. Surviving and dead shrubs facilitated the recruitment of four and five species, respectively; the IVI of these species were significantly greater under, compared to the open places between surviving and dead shrubs. *Aristida adscensionis*, *Bassia muricata* and *Tribulus pentandrus* were facilitated by both surviving and dead shrubs. In addition, *Crotalaria aegyptiaca* was facilitated by surviving shrubs and both *Chrozophora oblongifolia* and *Tragus racemosus* were facilitated by dead shrubs. On the other hand, both *Arnebia hispidissima* and *Centropodia forsskalii* were inhibited under both surviving and dead shrubs. For example, IVI of *Arnebia hispidissima* was 0.0 and 13.9 under surviving and dead shrubs, respectively; compared to 57.1 and 48.4 in open places next to surviving and dead shrubs, respectively.

Surviving grasses facilitated the recruitment of three species (*Plantago boissieri*, *Tribulus pentandrus* and *Arnebia hispidissima*) and inhibited the recruitment of other three species (*Gisekia pharnaceoides, Monsonia nivea* and *Neurada procumbens*). However, the dead grasses facilitated the recruitment of six perennial shrubby species (*Cyperus conglomeratus, Heliotropium digynum, Bassia muricata, Chrozophora oblongifolia, Farsetia linearis*, and *Morettia parviflora*) and inhibited the survival of only three herbaceous species (*Centropodia forsskaolii, Plantago boissieri* and *Arnebia hispidissima*). For restoring the productivity and species diversity of degraded sandy desert habitats, the study recommends the maintenance and growing shrubby plants as an early successional stage that facilitate the environment of other annuals and perennial plant. This would help in stability of the fragile desert ecosystems.

4. DISCUSSION

In the deserts, the presence or absence of neighboring plants is reported to influence plant growth and survival and has long been associated with plant–plant interactions that range from extreme competition to facilitation. Competition among desert plants tends to exclude neighbors, but facilitation of small by large plants that can promote clumped spatial patterns [19], [29]. In the present study, the species richness and different diversity indices were significantly greater under the surviving shrubs, compared to barren areas next to them. The greater diversity under the shrub canopy could be attributed to greater spatial heterogeneity that could be present under the canopies. It is expected to find greater variation shade intensity and amount of water received by stem flow and soil fertility resulted from letter decomposition. For example, stem flow spatially concentrate the water in certain spots under the canopy [30]. Such heterogeneity creates more save sites for emergence of more species, compared to the more homogeneous barren areas between shrubs. Conversely, the present study showed that there was no significant difference between abundance of associated plants under and in the open places next to surviving shrubs. This indicates that greater intraspecific competition for the limited resources, especially water, might reduce the density of the different species under the shrub canopies. Raindrops intercepted by the shrub canopy reduce water availability because of direct losses through evaporation [31]; [32]. In the arid and semiarid environments, competition for water is more important than competition for light or nutrients [33].

The overall effect of nurse plants on their herbaceous understory is determined by the balance of both facilitation and competition. The manifestation of nutrient facilitation depended on the root architecture of individual nurse plants. Nurse plant with low fine-root biomass in the upper soil horizons had strong positive effects on understory biomass. In contrast, nurse plants with high fine-root biomass in the upper soil horizons and that probably did not reach at the water table had strong negative effects on understory biomass [34]. In our study, species diversity and abundance were significantly greater under surviving shrubs, compared to surviving grasses. This indicates that competition between nurse grasses and the associated species might be the main factor for their lower diversity and abundance, compared to both open sites. In arid and semiarid ecosystems, it has been documented that grasses take up most of the water from the upper layers of the soil and utilize frequent and short-duration pulses of water availability, whereas shrubs take up most of the water from the lower layers of the soil and utilize infrequent and long-duration pulses of water availability [24]. The insignificant difference, in the present study, between richness and abundance of species under dead shrubs and dead grasses further support the hypothesis that surviving grasses exclude some of the associated species.

Livestock grazing affects over 90% of the land on the Arabian Peninsula, of which 44% is severely or very severely degraded [35]. Continuous grazing has resulted in loss of vegetation, erosion and desertification of these lands [36]. In particular, desertification of sandy areas driven by wind erosion often results in coarse, poor soil and low land productivity, which can degrade the human living environment and impede socioeconomic development [2]. For restoring the productivity and species diversity of the degraded sandy desert habitats, the present study recommends the maintenance and growing shrubby plants as an early successional stage that facilitate the growth of other annuals and perennial plants. This would help in stability of the fragile desert ecosystems.

Table 1: Effects of surviving and dead shrubs and grasses on species abundance and diversity indices

Life form	Survival status	Position to crown	Richness	Abundance	Simpson	Shannon-Wiener	Brillouin
Shrubs	**Surviving**	Under	**24**	**40**	**0.864**	**3.5**	**3.31**
		Next	**24**	**38**	**0.803**	**2.94**	**2.79**
	Dead	Under	**30**	**54**	**0.875**	**3.69**	**3.53**
		Next	**28**	**58**	**0.801**	**3.05**	**2.9**
Grasses	**Surviving**	Under	**10**	**31**	**0.842**	**2.91**	**2.62**
		Next	**16**	**59**	**0.854**	**3.1**	**2.87**
	Dead	Under	**32**	**58**	**0.921**	**4.09**	**3.87**
		Next	**20**	**69**	**0.828**	**3.02**	**2.85**

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