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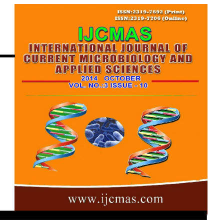


Original Research Article

Conservation condition of *Haloxylon salicornicum* (Moq.) Bunge ex Boiss. in degraded desert habitats of northern Kuwait

Raafat Hassan ABD El-WAHAB[1,2]*, Ahmad Rashed Al-RASHED[2], and Yousef Al-HAMAD[2]

[1]Botany Department, Faculty of Science, Suez Canal University, Ismailia 41522, Egypt
[2]Science Department, Faculty of Basic Education, Public Authority for Applied Education and Training, Adailiya 73251, Kuwait
**Corresponding author*

A B S T R A C T

The present study aims to analyse the effects of more than 10 years of in situ conservation on vegetation structure and soil conditions of desert habitats dominated by *Haloxylon salicornicum*. in northeast of Kuwait. Size measurements of *Haloxylon* shrubs and sediments of nabkas were carried out inside and outside Sabah Al-Ahmad Natural Reserve. Edaphic conditions of nabkas and interspaces were analysed. Analysis of variance and *t* test show significant variations of nabka vegetation structures and most of soil conditions between disturbed and non-disturbed sites. Differences of soil conditions between nabkas and interspaces are significant in non-disturbed sites. Species richness, total plant cover, and size features of *Haloxylon* shrubs and nabkas in non-disturbed sites are higher and more developed than in disturbed sites. Size structure analysis indicates that *Haloxylon salicornicum* is suffering population decline and should consider as vulnerable species in Kuwait. Human impacts are the main threats affecting the health and abundance of nabkas and causing land degradation and species loss. Management and conservation plan of degraded areas through establishing of permanent enclosures for a certain period of time and, where necessary, planting the natural dwarf shrub vegetation will speed up regeneration and restoration of the natural vegetation.

Keywords

Conservation, Human impacts, Land degradation, Plant diversity, Nabka vegetation

Introduction

Degradation of ecosystems and loss of biodiversity are considered global challenges with serious implications for sustainable use of the natural environment particularly in arid and semi-arid regions (UNDP, 2012). As a part of arid regions, Kuwait has suffered severe land degradation (Kassas, 1995). The main features of degradation in arid ecosystems include reduction in vegetation productivity, decrease in species diversity and increase in aeolian processes such as the erosion, transportation and deposition of sand (Dregne, 1986; Brown, 2003). In areas with degraded vegetation and human activities, these aeolian processes lead to formation of nabkas (Tengberg, 1995) around the base of perennial plants such as *Haloxylon salicornicum* (Abd El-Wahab and Al-Rashed, 2010).

Nabkas, which are also referred to as nebkhas, phytogenic mounds, phytogenic hillocks, coppices or vegetated dunes, are distributed extensively throughout Arabian desert (e.g., Batanouny and Batanouny, 1969; Khalaf *et al.*, 1995; El-Bana *et al.*, 2003; Abd El-Wahab and Al-Rashed, 2010), the Sahel zone (Nickling and Wolfe, 1994; Tengberg, 1995), South Africa (Dougill and Thomas, 2002), New Mexico (Langford, 2000), and China (Wang *et al.*, 2006). Assessment of vegetation and nabkas conditions have been considered as important indicators of wind erosion and land degradation in arid ecosystems (Khalaf *et al.*, 1995; Dougill and Thomas, 2002; El-Bana *et al.*, 2003).

Haloxylon salicornicum (Moq.) Bunge ex Boiss (local arabic name: 'rimth') is a diffuse dwarf shrub with much branched, almost leafless, woody stems. Its vegetative growth occurs mainly during late spring and early summer. Flowering takes place between September and October, and by January, abundant fruits have been produced and shed. *Haloxylon* is widely distributed in Egypt, Palestine, Jordan, Iraq, Kuwait, Arabian Peninsula, Iran, Afghanistan and Pakistan. In Kuwait, *H. salicornicum* is one of the main plant communities in northern and western areas (Halwagy *et al.*, 1982; Daoud and Al-Rawi, 1985; Omar *et al.*, 2007).

Variations in morphology and sediment characteristics of nabkas and their significance to plant diversity, wind erosion and land degradation in Kuwait have been studied by several authors (e.g., Khalaf *et al.*, 1995; Brown and Porembski, 1997, 1998, 2000; Brown, 2003; Al-Dousari *et al.*, 2008; Abd El-Wahab and Al-Rashed, 2010; El-Sheikh *et al.*, 2010). However, assessment of conservation condoition of nabkas in Kuwait are poorly known. Thus, the present study aims to determine the effects of about 10 years of conservation in Sabah Al-Ahmad Natural Reserve on size structure, species diversity, and soil conditions of *H. salicornicum* nabkas based on comparative statistical analysis between disturbed and non-disturbed sites in northeast of Kuwait.

Materials and Methods

Site description

Kuwait is a small country (about 17,800 km^2) located in the north-eastern part of the Arabian Peninsula. In general, Kuwait has gravelly and sandy desert topography of low to moderate relief (El-Baz and Al-Sarawi, 2000). Northern areas of Kuwait are characterized by active aeolian processes including transportation and deposition of sand. In these conditions, only plants like *Haloxylon* shrubs which have a deep and well-developed root system can thrive (Batanouny and Batanouny, 1969; Halwagy *et al.*, 1982; El-Sheikh *et al.*, 2010). Sabah Al-Ahmad Natural Reserve, about 330 km^2, is located in the north-eastern part of Kuwait (Figure 1). It was re-established and declared in 2004. The main geomorphologic feature in the area is Jal Al-Zor escarpment, which is 145 m above sea level. The main landforms characterizing Sabah Al-Ahmad Natural Reserve include gravel plains, slopes, wadis, shallow depressions, sand plains, coastal sand dunes, and coastal salt marshes. Nabkas are dominant in the last three landforms. The present work was carried out in sand plains and coastal sand dunes, which are dominated mainly by *Haloxylon salicornicum*. Around the individual shrubs, nabkas can be observed which are elongated towards the southeast, indicating that the prevailing wind direction is from the northwest (Brown and Porembski, 1997).

Kuwait has a typical desert climate characterized by long hot and dry summer, short winter, wide temperature variations, and low amount of rainfall with a great irregularity in time and space. Average temperature during summer reaches 44 °C during the day time and 23 °C during the night. In winter, it reaches 15 °C during the day and 3 °C during the night. The annual rainfall varies between 30 and 250 mm, most of which falls during the winter and spring, mainly between November and April (Halwagy *et al.*, 1982; Almedeij, 2012). The annual mean rainfall for the period of 1985 till 2002 was 128 mm. Precipitation amount decreases from north to south. Relative humidity reaches 60% in winter and 20% in summer. Wind is mostly northwest with speed that reaches 60 km per hour during cold weathers. Dust and sand storms prevailing over the area primarily originate from southwest of Iraq. Dust storm in Kuwait can occur during any month of the year, but are most common between March and August. About 50% of dust storms occur during May, June and July (El-Baz and Al-Sarawi, 2000).

Sampling and analysis of nabka vegetation

Vegetation survey and soil sampling were carried out at Sabah Al-Ahmad Natural Reserve, northeast of Kuwait. Fifty quadrates (10 × 10 m) were selected in stratified random technique (Barbour *et al.*, 1987) inside the natural reserve (non-disturbed sites) and outside the natural reserve (disturbed sites), 25 quadrates each. Geographical location of disturbed and non-disturbed sites was measured using GPS receiver "Trimble model". Plant species growing in each quadrate were recorded. Identification and life forms of plant species were following to Daoud and Al-Rawi (1985), Boulos (1988) and Omar *et al.* (2007). Species richness of disturbed and non-disturbed sites was calculated as the average number of species per quadrate (i.e., number of species in 100 m^2). Canopy cover, maximum and minimum diameters, and canopy height (H) of *Haloxylon salicornicum* shrubs were measured. Average diameter (D) and size index {(D + H) / 2} of *Haloxylon* shrubs were calculated. Nabkas height (H), width (W), and length (L), were measured. The average diameter of nabka (D) was estimated as average of width and length. Size index of the nabka was calculated as average of diameter and height. Nabka area was calculated using the area of the ellipse: $\{(\pi(l * w))/4\}$, where *l* was taken as the nabka length and *w* the nabka width (El-Bana *et al.*, 2003). Volume of nabka was calculated using half the volume of the cone: $\{\frac{1}{2}(0.33 * \pi r^2 h)\}$, where *r* was taken to be nabka height at the crest and *h* the nabka length (Dougill and Thomas, 2002).

Hundred surface soil samples (0-20 cm depth), two samples from each quadrate, were collected from nabkas and interspaces (i.e. the open areas between the nabkas). Soil samples were air-dried and sieved through 2 mm sieve to obtain representative sub-samples for chemical and physical analyses and to exclude gravels that are relatively less reactive. Soil fraction analysis using dry sieving (particle-size distribution) and hygroscopic moisture were measured (Klute, 1986). Soil pH was measured in 1 : 2.5 soil water extract. Soil electric conductivity was measured in 1 : 1 soil water extract. Soil organic matter was estimated by loss in ignition method. Total carbonate was measured using calcimeter. Soil chemical analyses were done according to Sparks *et al.* (1996).

Statistical analysis of the data including descriptive statistics, analysis of variance (ANOVA), *t* test, Pearson correlation, and regression analyses were carried out (Zar, 1984) using SPSS software (Statistical Package for Social Sciences, version 21).

Results and Discussion

General features of *Haloxylon salicornicum* nabkas

Haloxylon salicornicum is one of the major prominent communities in desert habitats, northeast of Kuwait. This community was recognized in different landfoms including gravel plains with sand sheets, slopes, gravel channels, coastal sand dunes and edges of coastal salt marshes. *Haloxylon* cover percentage varies between 2.01% and 17.37% in disturbed sites and between 9.08% and 32.07% in non-disturbed sites. In general, the average *Haloxylon* cover in non-disturbed sites (21.03%) is about three times of the disturbed sites (7.69%) (Table 1). The average percentages of nabkas area are 8.24% in disturbed sites and 39.17% in non-disturbed sites, which mean that sedimentation rate under *Haloxylon* shrub in non-disturbed sites is about four times that in disturbed sites.

Based on the presence percent of the recorded species (Table 2), the common associated perennial species include *Fagonia bruguieri*, *Launaea mucronata, Heliotropium bacciferum*, *Moltikiopsis ciliata, Helianthemum lippii*, *Haplophyllum tuberculatum*, *Stipagrostis plumosa* and *Citrullus colocynthis.* In winter and spring, *Haloxylon* community is accompanied by many ephemerals. The most frequent annual species include *Schismus barbatus, Plantago boissieri, Ifloga spicata, Stipa capensis*, *Filago pyramidata*, *Erodium laciniatum, Reichardia tingitana* and *Lotus halophilus* (Table 2). In this period of the year, the average of the total plant cover is about 15% in disturbed sites and 35% in non-disturbed sites (Table 1).

Plant diversity and human disturbance

Fifty plant species are recognized in the study area, with great proportion of annual species (31 species, about 62%). The recorded perennial species are 5 shrubs, 2 sub-shrubs, 8 perennial herbs, and 4 perennial grasses (Table 2). Based on independent sample *t* test, variations in species richness and plant cover between disturbed and non-disturbed sites were highly significant. On the other hand, variation in richness of annual species was low significant (Table 1). Non-disturbed sites were higher in species richness and plant cover than disturbed sites. The total recorded species was 32 species in disturbed sites and 42 species in non-disturbed sites. The average species richness is 7.64 species/100m^2 in disturbed sites and 10.52 species/100m^2 in non-disturbed sites (Table 1).

Human disturbance signs are very high in disturbed sites. The human disturbance activities include overgrazing, camping, off road driving, collecting and cutting of woody plants for cooking and heating. Camping areas are almost clear of vegetation, which indicate the high pressure of removal and collection of plants. The areas close to the camping sites (within 300 m from different sides) are considered also as high degraded sites. Many *Haloxylon* shrubs are almost dead due to severe cutting and off road driving. In these degraded sites, associated plant species is very sparse in occurrence and very low in species richness (1 to 3 species per quadrate). In the moderate degraded sites, the species richness varies between 4 to 6 species for each quadrate (Figure 2). Most of the associated plant species are often concentrated around the base of nabkas, particularly on their leeward side. Plant diversity in the interspaces is very poor. In the low degraded sites "very close to the natural reserve edges and particularly in spring", species richness increases from 10 to 12 species per quadrate (Figure 2) and interspaces also support many of the associated plant species.

In non-disturbed sites, human disturbance signs are almost absent. Moreover, restoration signs inside Sabah Al-Ahmad Natural Reserve are recognized, particularly within nabka and gravel plain landforms where grazing and quarry activities used to be done. Many perennial herbs and sub-shrubs grow in different parts of nabkas (i.e., top, edges, and leeward side) and interspaces. About 60% of the non-disturbed sites have high species richness that varies between 10 and 15 species per quadrate. In the low diversity sites, species richness varies between 7 and 9 species per quadrate (Figure 2). In addition, many holes of different size and shape are recognized on the surface of nabka sediments, which indicate that various kinds of animals use these sediments as safe living sites.

Variations in Soil Conditions

Soils of the study area are very dry, sandy in texture, with total sand varies between 96% and 99%, non-saline, low alkaline, low to moderate in organic matter, and moderate in total carbonate content (Table 3). One-way ANOVA, associated with Duncan's multiple range test show high significant differences in measured soil properties of nabkas and interspaces, collected from disturbed and non-disturbed sites dominated by *H. salicornicum*. Variations in soil electric conductivity and percentage of very fine sand are non-significant. Organic matter content is higher in non-disturbed soils than in disturbed soils. In addition, soils of interspaces are higher in organic matter than soils of nabkas. In disturbed sites, nabkas and interspaces soils have no significant variations in hygroscopic moisture, most of grain size fractions, pH, organic matter, and total carbonate. On the other hand, non-disturbed sites have clear variations in most of soil properties measured between soils of nabkas and interspaces (Table 3).

In disturbed sites, soils of nabkas have lower content of very coarse sand (8.48%) and higher content of fine sand (23.11%) than soils of interspaces (16.41%, and 18.83%, respectively). Variations in the other grain size fractions are not significant (Table 3). On the other hand, non-disturbed sites show obvious significant variations between nabkas and interspaces in percentages of different grain size fractions except coarse sand and very fine sand. Soils of nabkas in non-disturbed sites have lower content of very coarse sand (1.6%) and silt and clay content (0.68%), and higher content of medium sand (22.42%), fine sand (35.94%) than soils of the interspaces (19.50, 1.83, 14.01, and 25.76%, respectively) (Table 3).

Soils of nabka and interspace in disturbed sites have low content of hygroscopic moisture with non-significant variation (0.55% and 0.53%, respectively). In non-disturbed sites, interspace soils have higher content of hygroscopic moisture (1.50%) than nabka soils (0.58%). In non-disturbed sites, soils of nabka were lower in content of organic matter (1.24%) and total carbonate (4.39%) than soils of the interspace (2.21% and 8.19%, respectively) (Table 3).

Variations in Size Structure of *Haloxylon* Nabkas

Independent sample *t* test shows highly significant variations in morphometric measurements of *H. salicornicum* shrubs and sediments of nabkas between disturbed and non-disturbed sites. Differences in height of *Haloxylon* shrubs are not significant; however variations in size index are highly significant. In general, all morphological parameters of *Haloxylon* and nabkas are higher in non-disturbed sites than disturbed sites (Table 4). The average height of *Haloxylon salicornicum* shrubs is about 0.40 m above the nabka sediment. *Haloxylon* diameter varies between 0.29 and 2.75 m in disturbed sites and between 0.28 and 5.96 m in non-disturbed sites. The average canopy cover of *Haloxylon* shrubs in disturbed and non-disturbed sites are 0.80 m^2 and 1.66 m^2, respectively (p = 0.001, Table 4).

Most of the studied nabkas in disturbed sites are of small size and may consider as micro-nabkas. On the other hand, nabkas in non-disturbed sites are well developed and cover a considerable high basal area. The average nabka length is only 0.88 m in disturbed sites, while it reaches 2.00 m in non-disturbed sites. Height ranges from 0.04 to 0.62 m in disturbed sited and from 0.05 to 0.80 m in non-disturbed sites. The average area of nabkas is 0.79 m^2 in disturbed sites, and 3.76 m^2 in non-disturbed sites. The average nabka volume is 0.05 m^3 in disturbed sites, and 0.22 m^3 in non-disturbed sites ($p < 0.001$, Table 4).

Frequency distribution of size structure of *Haloxylon* shrubs and nabkas

Frequency distribution analysis of different morphological parameters of *Haloxylon* shrubs and nabkas showed that disturbed sites are characterized by skewed distribution towards small size categories, whereas non-disturbed sites are characterized by more or less continuous distribution of small, medium and large size categories (Figures 3 and 4). Frequency distribution of nabkas in disturbed sites tends to be L or inverse J shape which indicates that most of the measured nabkas individuals fall within small size categories. On the other hand, non-disturbed sites support more or less normal distribution shape (Figure 4).

Haloxylon canopy cover in disturbed sites varies between 0.07 m^2 and 5.94 m^2, whereas in non-disturbed sites it varies between 0.06 m^2 and 27.82 m^2. The first smallest three classes (between 0.01and 0.9 m^2) comprise 73.5% of *Haloxylon* shrubs in disturbed sites, and 41.5% in non-disturbed sites. On the other hand the largest three categories of canopy cover (between 2.1 and more than 2.7 m^2) comprise 6.4% of *Haloxylon* shrubs in disturbed area and 25.8% in non-disturbed sites (Figure 3).

This observation is also recognized with respect to nabka area. Range of nabka area in disturbed and non-disturbed sites are (0.02-9.59 m^2) and (0.09-50.9 m^2), respectively. The first smallest three classes (between 0.01and 2.0 m^2) comprise 92.8% of nabkas in disturbed sites, and 48.2% in non-disturbed sites. On the other hand, the largest three categories of canopy cover (between 6.1 and more than 8.0 m^2) comprise 1.6% of nabkas in disturbed sites and 14.1% in non-disturbed sites (Figure 4).

Size Structure relations between *Haloxylon* shrubs and nabkas

There are highly significant direct relations between size structure parameters of nabka sediments and *Haloxylon* shrubs in disturbed and non-disturbed sites (Table 5). In general, correlation coefficients between morphological parameters of *Haloxylon* shrubs and nabka sediments in non-disturbed sites are higher than in disturbed sites. For example, relations between *Haloxylon* canopy cover and nabka parameters in non-disturbed sites were as follows: nabka size index (r = 0.89), nabka area (r = 0.91) and nabka volume (r = 0.87). These coefficients decrease in disturbed sites to 0.87, 0.75 and 0.62, respectively. The height of *H. salicornicum* has low significant correlation with nabka parameters in disturbed sites, and has no significant correlation with nabka parameters in non-disturbed sites (Table 5).

Haloxylon salicornicum community is one of the land marks characterizing the Arabian deserts. It was recognized mainly in desert sandy habitats such as wadis, plains, and depressions (Brown and Porembski, 1997; Abd El-Wahab, 2008; Abd El-Wahab and Al-Rashed, 2010). In these habitats, aeolian processes such as transportation and deposition of sand become more pronounced (Nickling and Wolfe, 1994). The growth nature of *H. salicornicum* as multi-stems and close branching shrub renders the plant an effective ‘sand-trap’. Various categories of nabkas formed by *H. salicornicum* have been recognized in north of Kuwait (Halwagy and Halwagy, 1977; Brown, 2003; Al-Dousari *et al.*, 2008; Abd El-Wahab and Al-Rashed, 2010; El-Sheikh *et al.*, 2010). In addition to sandy habitats, *H. salicornicum* shrubs were recognized also in gravelly plains, rocky slopes, and edges of coastal salt marshes. El- Ghareeb *et al.* (2006) recognized *H. salicornicum* and *Zygophyllum qatarense* as one of the distinct plant communities in the coastal salt marshes of Kuwait. *Haloxylon salicornicum* is accompanied by a large number of winter ephemerals, which account for about 62% of the total recorded plant species. Halwagy *et al.* (1982) and (Brown and Porembski, 1998) stated that therophytes proportion may reach up to 90% of species particularly in years of plentiful rainfall.

Due to human impacts mainly grazing, collecting and uprooting of woody plants, and off road driving, many areas in north of Kuwait are severely degraded, and *Haloxylon* shrubs are usually scattered, small in size and sometimes dry or totally absent. The vegetation history showed that the geographic range of community of *H. salicornicum* in the northern and western areas of Kuwait has been reduced from 52.2% (Dickson, 1955) to 22.7% (Omar *et al.*, 2007). Brown (2003) stated that *H. salicornicum* community can attain up to about 25% cover in favourable locations. In the present study, we found that the cover of this community has been reduced to about 7.69 as average *Haloxylon* cover and 15% as total plant cover in disturbed sites, which indicate the continuity of the degradation in the geographic range of *H. salicornicum* community.

Comparison between *H. salicornicum* community in disturbed and non-disturbed sites shows positive effects of long term protection. The average canopy cover of *Haloxylon* shrubs and area of nabkas are about three to four times higher in non-disturbed sites than in disturbed sites. These results indicate that the main causes of land degradation in Kuwait are anthropogenic. Similar finding was reported by Brown and Porembski (1997) and Brown (2003). Ayyad (2003) stated that the most effective direct human impacts on biodiversity in arid ecosystems include habitat destruction and fragmentation, and overexploitation of biological resources. Anthropogenic impacts on population structures of woody perennials have been discussed in different arid regions such as Sinai desert (Abd El-Wahab *et al.*, 2013), Negev desert (Ward and Rohner, 1997), and Arabian Desert (Ayyad, 2003).

Nabkas play crucial roles in the ecology and evolutionary dynamics of many coastal and desert ecosystems. Soils of nabkas have higher content of medium and fine sand than soils of the interspaces. These variations are more obvious in non-disturbed sites. The accumulation of fine soil fractions in nabkas plays an important role as moisture reservoirs, which may interpret the high diversity of annuals on nabkas (Brown and Porembski, 1998) and encourage diversity in both plant and wild life (Abd El-Wahab and Al-Rashed, 2010). Many authors have indicated the importance of water availability for species diversity in desert ecosystems (e.g., Whittaker, 1972; Moustafa and Zayed, 1996; Abd El-Wahab, 2008). In disturbed sites, the present study shows non-significant variations between soils of nabkas and interspaces in most measured properties.

This is probably due to the human impacts which affect the development of nabkas and result in severe degradation. In non-disturbed soils, organic matter content is higher in soils of interspace than in soils of nabka. This is probably due to the increase of plant cover in the interspaces. Schlesinger *et al.* (1990) and Stock *et al.* (1999) have suggested that increased spatial heterogeneity of soil resources may be a useful indicator of desertification in semiarid shrub lands. More researches are still needed for better understanding and evaluating the micro-spatial heterogeneity of nabka sediments and interspace soils.

Based on statistical analysis, we found that canopy cover, average diameter, volume and size index are practically convenient measures for size structure of desert shrubs rather than height (Shaltout and Ayyad, 1994). The growth nature of desert shrubs tends to expand horizontally rather than vertically to combat harsh climatic conditions and to increase soil moisture (Shaltout *et al.*, 2009). Morphological parameters of *Haloxylon* and nabkas are higher in non-disturbed sites than in disturbed sites.

Frequency distribution behaviour of morphological parameters of *Haloxylon* shrubs and nabkas in disturbed sites towards small size categories (micro-nabkas) indicates the unstable situation due to human impacts. The lower proportion of medium and large *Haloxylon* nabkas may indicate also high juvenile mortality (Harper, 1977; Shaltout *et al.*, 2009). Based on these findings, which indicate that *Haloxylon salicornicum* is suffering population decline, and following to the criteria of International Union for Conservation of Nature (IUCN, 2013), *H. salicornicum* should consider as vulnerable species in Kuwait. On the other hand, distribution behaviour in non-disturbed sites indicates positive response of nabka vegetation to permanent conservation. The positive effect of conservation in Sabah Al-Ahmad Natural reserve on size structure of *H. salicornicum* and nabkas indicates that human impacts are the main threats affecting the health and abundance of nabka vegetation and causing land degradation and species loss.

In accordance with Omar *et al.* (1991), Shaltout *et al.* (1996), Zaman (1997) and Brown (2003), we indicate that exclusion of human impacts in such degraded habitats for a certain period of time may yield beneficial results on vegetation structure. Management and conservation plan of degraded areas in north of Kuwait should rely on (1) assessing the underlying causes of degradation, (2) removing or reducing the pressures that cause deterioration, (3) establishing enclosures in selected areas for at least 5 to 7 years, and (4) where necessary, re-establishing the natural dwarf shrub vegetation, as this is best adapted to the specific local environmental conditions.

Table.1 Floristic composition, plant cover and species richness in disturbed and non-disturbed sites. Independent sample *t* test values of plant cover and species richness along with their significance are also given

	Disturbed Sites	**Non-disturbed Sites**	***t***	**Sig. (2-tailed)**
Families	19	19		
Species	32	42		
Perennials	14	17		
Annuals	18	25		
Haloxylon cover%	7.69±3.87	21.03±7.13	8.225	<0.001
Total Plant Cover%	15.12±7.60	35.60±9.61	8.357	<0.001
Species richness / 100m^2	7.64±4.98	10.52±2.98	2.479	0.017
Perennials / 100m^2	2.36±1.15	3.52±1.78	2.734	0.009
Annuals / 100m^2	5.28±4.28	7.00±1.83	1.849	0.071

Figure.1 Location map of Kuwait showing Sabah Al-Ahmad Natural Reserve, non-disturbed sites (A) and disturbed sites (B)

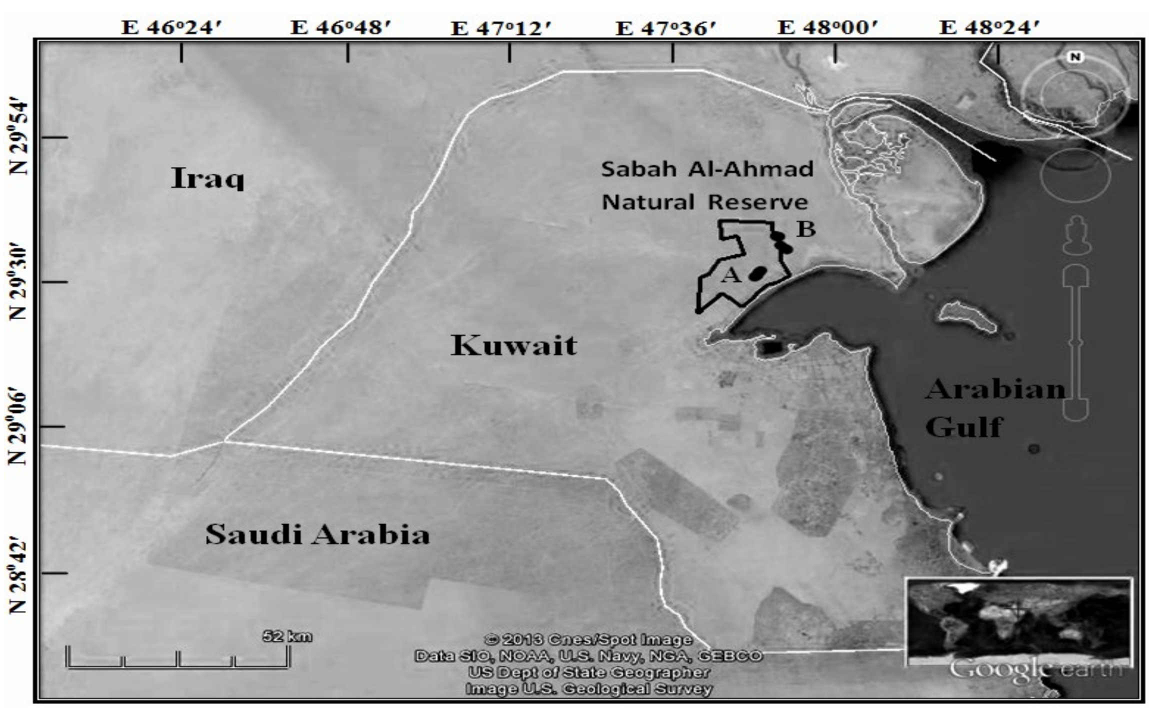


Table.2 Growth form and presence percent of the recorded plant species in disturbed and non-disturbed sites

Species List	Growth form	Presence %	
		Disturbed Sites	Non-disturbed Sites
Anisosciadium lanatum Boiss.	Annual herb	4	8
Anthemis deserti Boiss.	Annual herb	20	20
Astragalus annularis Forssk.	Annual herb	16	0
Astragalus hauarensis Boiss.	Annual herb	28	0
Astragalus spinosus (Forssk.) Muschl.	Shrub	0	4
Atractylis carduus (Forssk.) C. Chr.	Perennial herb	0	20
Bassia eriophora (Schrad.) Asch.	Annual herb	16	0
Cakile arabica Velen. and Bornm.	Annual herb	0	4
Calendula arvensis L.	Annual herb	0	8
Carduus pycnocephalus L	Annual herb	4	36
Cistanche tubulosa (Schrenk) Wight	Perennial herb	4	8
Citrullus colocynthis (L.) Schard.	Perennial herb	8	4
Convolvulus cephalopodus Boiss.	Perennial herb	0	4
Cornulaca monacantha Delile.	Shrub	16	16
Cyperus conglomeratus Rottb.	Perennial grass	4	0
Diplotaxis harra (Forssk.) Boiss.	Annual herb	0	36
Emex spinosa (L.) campd.	Annual herb	12	8
Erodium laciniatum (Cav.) Willd.	Annual herb	36	32
Fagonia bruguieri DC.	Sub-Shrub	32	32
Fagonia glutinosa Del.	Perennial herb	12	4
Filago pyramidata L.	Annual herb	40	32
Haloxylon salicornicum (Moq.)Bunge ex Boiss.	Shrub	100	100
Haplophyllum tuberculatum Forssk. A, Juss.	Sub-Shrub	16	4
Helianthemum lippii (L.) Dum. Cours	Perennial herb	8	20
Heliotropium bacciferum Forssk.	Shrub	20	20
Ifloga spicata (Forssk.) Sch.Bip.	Annual herb	60	60
Lasiurus scindicus Henrard	Perennial grass	0	20
Launaea capitata (Spreng.) Dandy	Annual herb	0	36
Launaea mucronata (Forssk.) Muschl.	Perennial herb	8	56
Lolium rigidum Gaudin	Annual grass	0	8
Lotus halophilus Boiss. and Sprun.	Annual herb	24	16
Lycium shawii Roem. and Schult	Shrub	0	4
Malcolmia grandiflora (Bunge) O. Kuntze	Annual herb	0	12
Matthiola longipetala (Vent.) DC.	Annual herb	0	0
Mesembryanthemum nodiflorum L.	Annual herb	4	0
Moltkiopsis ciliata (Forssk.).I.M.Johnst on.	Perennial herb	4	28
Neurada procumbens L.	Annual herb	20	20
Panicum turgidum Forssk.	Perennial grass	4	0
Plantago boissieri Hausskn. and Bornm.	Annual herb	32	84
Plantago ciliata Desf.	Annual herb	0	44
Plantago coronopus L.	Annual herb	0	32
Plantago ovata Forssk.	Annual herb	0	24
Reichardia tingitana (L.) Roth	Annual herb	48	8
Reseda arabica Boiss.	Annual herb	44	0
Savignya parviflora (Delile) Webb	Annual herb	0	20
Schimpera arabica Hochst and Steud.	Annual herb	0	4
Schismus barbatus (L.) Thell.	Annual grass	52	80
Senecio glaucus L.	Annual herb	0	16
Stipa capensis Thunb.	Annual grass	32	60
Stipagrostis plumosa (L.) Munro ex T. Anders.	Perennial grass	4	12

Table.3 Some soil properties variations (mean ± standard deviation) of *Haloxylon salicornicum* nabkas and interspaces, in disturbed and non-disturbed sites. *F* values along with their significance *p* values are also given. Mean values of each variable with similar letters indicate no significant variation according to Duncan's multiple range test

Soil variables	N	Disturbed Sites		Non-disturbed Sites		*F*	*p*
		Interspace	Nabka	Interspace	Nabka		
V.ery Coarse Sand %	25	16.41 ± 12.08^{c}	8.48 ± 6.42^{b}	19.50 ± 7.62^{c}	1.60 ± 1.86^{a}	26.18	< 0.001
Coarse Sand %	25	18.36 ± 5.60^{b}	20.70 ± 11.91^{b}	11.99 ± 3.42^{a}	10.41 ± 8.79^{a}	9.33	< 0.001
Medium Sand %	25	13.05 ± 6.73^{a}	14.69 ± 6.27^{a}	14.01 ± 5.67^{a}	22.42 ± 7.96^{b}	10.28	< 0.001
Fine Sand %	25	18.83 ± 4.15^{a}	23.11 ± 9.76^{b}	25.76 ± 2.86^{b}	35.94 ± 6.86^{c}	31.52	< 0.001
Very Fine Sand %	25	31.63 ± 7.41^{a}	31.62 ± 8.65^{a}	26.92 ± 6.54^{a}	28.94 ± 10.05^{a}	1.92	0.132
Silt + Clay %	25	1.72 ± 0.70^{bc}	1.39 ± 0.84^{b}	1.83 ± 0.79^{c}	0.68 ± 0.30^{a}	14.06	< 0.001
hygroscopic Moisture %	25	0.53 ± 0.30^{a}	0.55 ± 0.21^{a}	1.50 ± 1.18^{b}	0.58 ± 0.24^{a}	14.12	< 0.001
pH	25	7.60 ± 0.34^{b}	7.49 ± 0.36^{b}	7.54 ± 0.26^{b}	7.31 ± 0.19^{a}	4.41	0.006
Electric Conductivity mS cm^{-1}	25	1.98 ± 2.92^{a}	3.02 ± 8.45^{a}	1.48 ± 0.88^{a}	2.06 ± 0.87^{a}	0.507	0.679
Organic Matter %	25	1.07 ± 0.69^{a}	0.90 ± 0.35^{a}	2.21 ± 1.54^{b}	$1.24 \pm 0,43^{a}$	10.83	< 0.001
Total Carbonate %	25	5.11 ± 2.97^{a}	3.48 ± 2.15^{a}	8.19 ± 4.37^{b}	4.39 ± 1.30^{a}	8.23	< 0.001

Table.4 Size structure variations (mean ± standard deviation) of *Haloxylon salicornicum* and nabkas in disturbed and non-disturbed sites. Independent sample *t* test values of each variable along with their significance are also given

	Size variables	**Disturbed sites**	**Non-disturbed sites**	***t***	***Sig. (2-tailed)***
H. salicornicum	Height (H) m	0.41 ± 0.12	0.38 ± 0.11	1.63	0.104
	Diameter (D) m	0.93 ± 0.40	1.24 ± 0.77	4.05	< 0.001
	Size Index (D+H)/2	0.67 ± 0.24	0.81 ± 0.39	3.55	< 0.001
	Canopy Cover m^2	0.80 ± 0.79	1.66 ± 2.96	3.29	0.001
Nabka	Height (H) m	0.23 ± 0.20	0.32 ± 0.19	3.36	0.001
	Length (L) m	0.88 ± 0.55	2.00 ± 1.72	6.81	< 0.001
	Width (W) m	0.86 ± 0.61	1.59 ± 1.14	6.03	< 0.001
	Diameter (D) m	0.87 ± 0.54	1.72 ± 1.39	6.19	< 0.001
	Size Index (D+H)/2	0.56 ± 0.39	1.02 ± 0.76	6.23	< 0.001
	Area m^2	0.79 ± 1.23	3.76 ± 6.88	4.74	< 0.001
	Volume m^3	0.05 ± 0.08	0.22 ± 0.42	4.41	< 0.001

Table.5 Pearson correlation coefficient (*r*) between size structure parameters of *Haloxylon salicornicum* and nabkas in: disturbed sites, and non-disturbed sites. D: Average diameter

		Disturbed sites (N=120) *Haloxylon* "Canopy"				Non-disturbed sites (N=77) *Haloxylon* "Canopy"			
		Height	D	Size Index	cover	Height	D	Size Index	cover
Nabka	Height	0.36**	0.34**	0.39**	0.31**	-0.08	0.61**	0.58**	0.64**
	Length	0.27**	0.80**	0.76**	0.79**	-0.04	0.87**	0.85**	0.83**
	Width	0.32**	0.87**	0.83**	0.87**	-0.03	0.89**	0.87**	0.84**
	D	0.30**	0.87**	0.83**	0.87**	-0.04	0.93**	0.90**	0.88**
	Size Index	0.40**	0.89**	0.87**	0.87**	-0.05	0.93**	0.90**	0.89**
	Area	0.23*	0.79**	0.75**	0.88**	-0.09	0.91**	0.88**	0.91**
	Volume	0.36**	0.61**	0.62**	0.62**	-0.17	0.80**	0.77**	0.87**

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Figure.2 Frequency distribution of species richness in disturbed and non-disturbed sites**.** Species richness **c**lasses: 1 = 1-3, 2 = 4-6, 3 = 7-9, 4 = 10-12, 5 = 13-15, 6 = 16-18 species per quadrate

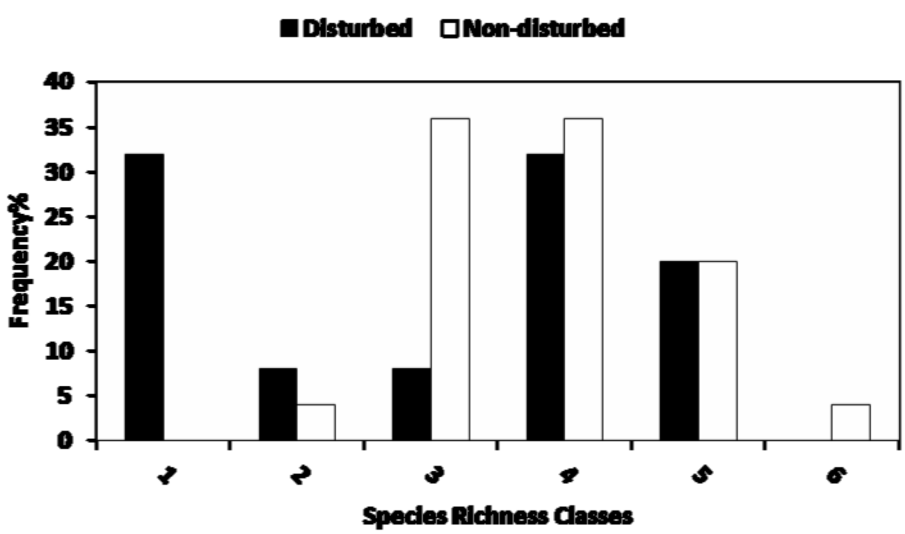


Figure.3 Frequency distribution of *Haloxylon salicornicum* canopy cover in disturbed and non-disturbed sites**.** Canopy cover **c**lasses: 1 = 0.01-0.30, 2 = 0.31-0.60, 3 = 0.61-0.90, 4 = 0.91-1.20, 5 = 1.21-1.50, 6 = 1.51-1.80, 7 = 1.81-2.10, 8 = 2.11-2.40, 9 = 2.41-2.70, 10 = >2.70 m^2.

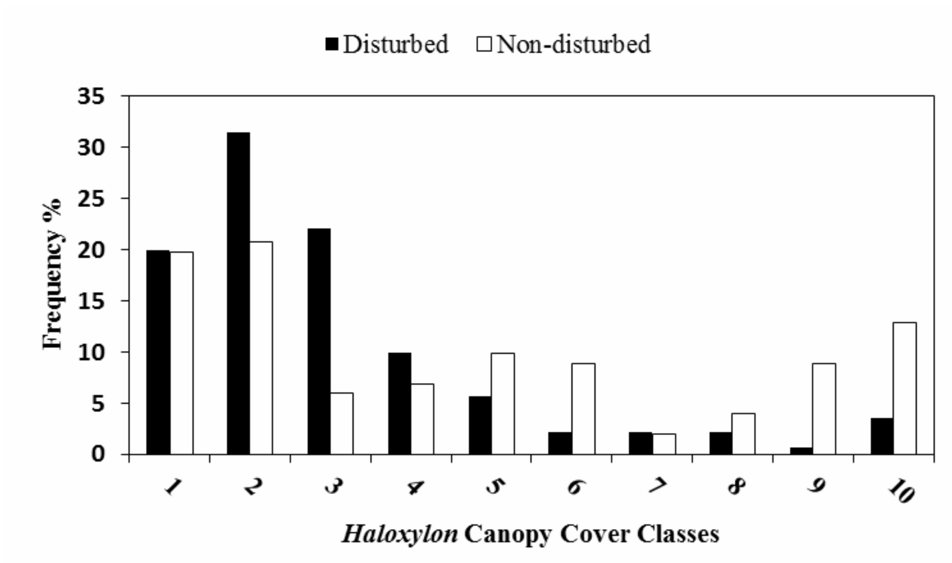
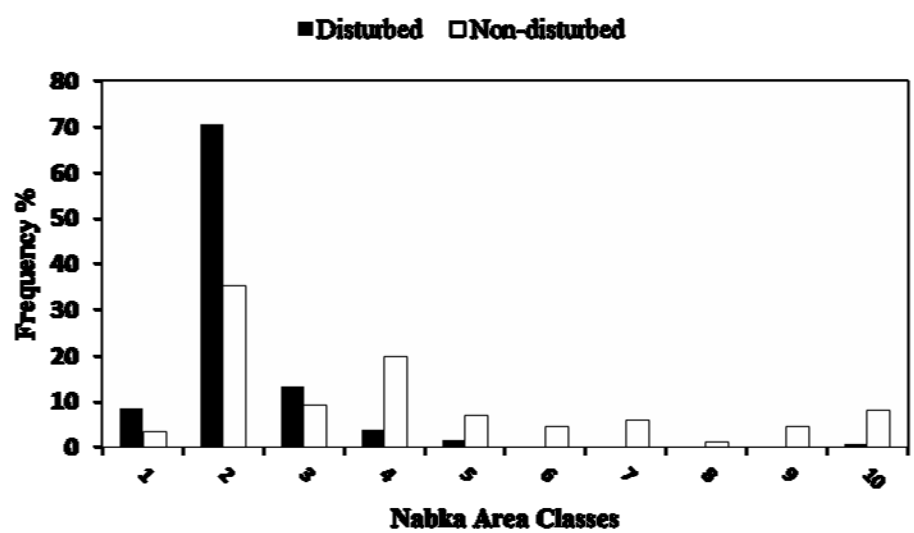


Figure.4 Frequency distribution of Nabka area in disturbed and non-disturbed sites. Nabka area classes: 1 = less than 0.1, 2 = 0.1-1.0, 3 = 1.1-2.0, 4 = 2.1-3.0, 5 = 3.1-4.0, 6 = 4.1–5.0, 7 = 5.1-6.0, 8 = 6.1-7.0, 9 = 7.1-8.0, 10 = more than 8 m^2.



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