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Plant assemblage and diversity variation with human disturbances in coastal habitats of the western Arabian Gulf

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Abstract: Knowledge about plant diversity along disturbance gradients is essential for conservation and management of fragmented coastal habitats. This study examined the effects of human disturbance intensity in coastal habitats of Kuwait on diversity, composition, identity and assemblage of vascular plant species. Plant survey data from 113 plots (5 m×5 m each) were randomly selected in 51 sites at coastal fragmented habitats at three levels of disturbance intensities (high, moderate and low) and were statistically analyzed. The results revealed that about 76% of the recorded species are considered threatened species in Kuwait, most of which are being lost in high disturbed habitats. Disturbance led to the dominance of *Zygophyllum qatarense*, *Cornulaca aucheri* and *Salsola imbricata*, which are species of disturbance indicators. Richness, total plant cover and species diversity were higher in moderate and low disturbed habitats than in high disturbed habitats. Beta diversity between high and low disturbed habitats was higher than either between high and moderate, or between moderate and low disturbed habitats. Cluster analyses showed statistically significant differences in composition of plant assemblages, which indicate high beta diversity between the habitat types. Intensive urbanization and industrialization are among the most serious threats that contribute to declines in biological diversity and rapid fragmentation of coastal habitats in Kuwait. Establishing protective enclosures in the disturbed habitats, planting endangered and vulnerable species, and establishing a natural reserve at Nuwaiseeb are recommended conservation actions to avoid loss of the fragmented coastal habitats and to facilitate restoration of native plants.

Keywords: plant diversity; disturbance gradient; threatened species; habitat fragmentation; coastal habitat; salt marsh restoration

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Coastal habitats along the western coast of the Arabian Gulf are among the most productive ecosystems in Arabian Desert, providing diverse habitats (salt marsh, mudflat, sand plain, limestone ridge and gravel plain) for a wide variety of vascular plants. In particular, salt marsh is one of the prominent landforms that extend along the western coast of the Arabian Gulf, especially in Kuwait, Saudi Arabia, Qatar and United Arab Emirates (Richer, 2009; Kleo and

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Al-Qtaibi, 2011; Loughland et al., 2012). Salt marshes also occupy narrow fringes to large expanses of shorelines in many other areas of the world including Egypt (Shaltout et al., 2003), North America, United Kingdom, Australia and South Africa (Boorman, 2003).

Coastal habitats are being rapidly fragmented and destroyed mainly due to intensive urbanization and industrialization (Loughland, 2012). Biological conservation studies stated that habitat fragmentation is among the most serious threats that contribute to declines in biodiversity (Lake, 2000; Laegdsgaard, 2006; Zedler and West, 2008). Over the last 50 years, human activities have had severe consequences on plant diversity and species composition in the coastal habitats of Kuwait (Brown 2003; Abd El-Wahab et al., 2014). The human disturbances include urbanization, industrialization, overgrazing, camping and off-road vehicles (Omar, 1991; Zaman, 1997; Khalaf et al., 2014). Baby et al. (2014) stated that industrial and urban developments in Kuwait have decreased the carrying capacity of coastal habitats. Omar et al. (2007) observed significant reduction in coastal plant distribution in Kuwait, particularly for *Nitraria retusa*, a salt-tolerant shrub, due to human-induced land degradation.

Understanding disturbance effects on species diversity is fundamental to conservation planning (Biswas and Mallik, 2010). Assessments of plant diversity and vegetation composition of fragmented habitats are necessary for understanding the impacts of human disturbance and the vulnerability of coastal habitats to habitat fragmentation. Studies described vegetation ecology (Halwagy and Halwagy, 1977; El-Ghareeb et al., 2006; El-Sheikh et al., 2010), dune vegetation (Al-Dousari et al., 2008; Abd El-Wahab and Al-Rashed, 2010; Al-Awadhi and Al-Dousari, 2013), and effects of human disturbance on the structure and community composition of *Haloxylon salicornicum* (Abd El-Wahab et al., 2014) and *N. retusa* (Khalaf et al., 2014; Abd El-Wahab, 2015) along the northern coast of Kuwait but not much on the assessment of the human disturbance effects upon the productivity, diversity and floral composition particularly along the southern coast (Al-Ateeqi and Al-Hurban, 2006). This study aims to examine the effects of human disturbance intensity in coastal habitats on plant diversity, composition and assemblages along the southern coastal habitats of Kuwait, specifically to test whether fragmented habitats with high human disturbances have lower richness and diversities and are different in species composition of vascular plants than in habitats with low disturbance intensity.

1 Materials and methods

1.1 Study area

The study area is in the southern coastal area of Kuwait along the west shore of the Arabian Gulf (Fig. 1). The topography of the coastal area is characterized by coastal limestone ridges (as high as 5–15 m parallel to the coastline), coastal dunes, sand plains and tidal lagoons. The coastal flat terrain is bounded landward by salt marshes known as sabkhas (Al-Hurban and Al-Sulaimi, 2009) that occupies about 4% of the total area of the country. Due to the presence in the most important locations near the coastline, coastal sabkhas host intense urban activities like resorts, vacation homes, major ports, power and desalination plants, and oil refineries (Kleo and Al-Otaibi, 2011). One of the mega projects on the southern coast of Kuwait is Al-Khiran Pearl City Project that incorporates many kilometers of waterways connecting with the Al-Khiran estuary. Broad canals were excavated into lowlands, and the soil was used to build up the land for residential development (Jones et al., 2012). With rapid developmental activities along the coastline, in addition to harsh weather, the extent of all natural coastal habitats in Kuwait is changing and their conditions are deteriorating (Baby et al., 2014).

Kuwait has a typical arid to hyper-arid climate characterized by long, hot and dry summer, short winter, a wide range of temperature and low amount of precipitation with a great irregularity in time and space. Average day time temperature in summer reaches 44°C and 23°C for the nighttime. The highest ever recorded temperature was 53.3°C in August 2011. In winter, the temperature reaches 15°C during the day and 3°C during the night. The lowest temperature recorded was –4°C in January 1964. The annual precipitation varies between 30 and 250 mm, most of which falls in the winter and spring months (Halwagy et al., 1982). The mean annual precipitation for the period 1985–2002 was 128 mm. Relative humidity reaches 60% in winter and 20% in summer. The evaporation rate ranges from 4.6 mm/d in January to 22.9 mm/d in June. Wind is mostly northwest with an annual average speed of 13.6 km/h and a maximum speed of 40 km/h in winter and 60 km/h in summer. Dust and sand storms prevail over the area, which can occur in any time of a year but are common in March to August. About 50% of dust storms occur in May, June and July (El-Baz and Al Sarawi, 2000; Almedeij, 2012).

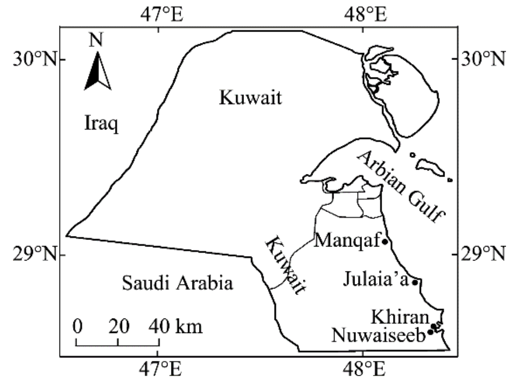

Fig. 1 The location of the study area

The coastal environment in Kuwait is dominated by sparse salt-tolerant small shrubs and perennial herbs. In rainy seasons, the area is covered by a large number of annuals. The type and density of vegetation is primarily controlled by the amount of precipitation and soil characteristics (Halwagy et al., 1982). Along the coast of the Gulf, low vegetative dunes or nabkas are developed within or around shrubs and subshrubs such as *N. retusa*, *Tamarix aucheriana* and *Halocnemum strobilaceum* (Halwagy and Halwagy, 1977; Gunatilaka, 1986; Al-Dousari et al., 2008). The salt marshes show a distinct zonation but in general *H. strobilaceum* dominates on the supratidal zone and *N. retusa* on the middle marsh beyond the reach of highest tides. *T. aucheriana*, *Zygophyllum qatarense*, *Suaeda aegyptiaca* and *Salsola imbricata* also form distinct zones on elevated landward edge of the marsh (Halwagy and Halwagy, 1977; El-Ghareeb et al., 2006). The coastal sand dunes and sand plains are mainly dominated by *H. salicornicum* and *Cyperus conglomeratus*. The associated species include *Fagonia bruguieri*, *Launaea mucronata*, *Moltkiopsis ciliata* and *Stipagrostis plumosa*. In winters and springs, *Haloxylon* community is accompanied by many ephemerals such as *Schismus barbatus, Plantago boissieri*, *Ifloga spicata*, *Stipa capensis*, *Filago pyramidata*, *Erodium laciniatum* and *Lotus halophilus* (Abd El-Wahab et al., 2014).

The carbonate-dominant is better known in southern coast of Kuwait than in the northern coast (Gunatilaka, 1986). Diagenetic anhydrite occurs exclusively in the salt marshes of Khiran in association with a wide zone of the halophyte, *H. strobilaceum* (Gunatilaka et al., 1980). Soils of salt marshes are rich in calcite and gypsum and mainly covered by aeolian deposits forming sand sheets (Al-Ateeqi and Al-Hurban, 2006). Soil profile of the southern coastal area is characterized by a thin surface layer (up to 10 cm depth) of loose fine and medium sandy soil rich in carbonate content in whitish yellow color. The sub-surface soil (about 10–30 cm in depth) shows hard carbonated layer. The following soil layers (from 30–100 cm in depth) are fine sand punctuated with compact hard carbonated thin layers (about 1 cm in thickness each) with remnants of small Mollusca shells. Yellowish brown soil layer rich in sulfate mineral is recognized at the depth of 45–75 cm.

1.2 Vegetation survey

Plant survey and field observation were conducted in October to November 2013 and April to June 2014 in salt marshes and sand dunes in the southern coastal habitats of Kuwait. A total of 113 plots (5 m×5 m each) were randomly selected in 51 habitat fragments (study sites) with varied human disturbance intensities (high, moderate, and low) and biogeographic characteristics. High disturbed sites (25 sites, 47 plots) were mainly in Khiran area, particularly at the new phases of Al-Khiran Pearl City Project where intensive construction, excavations and earthmoving occurred. Moderate disturbed sites (13 sites, 27 plots) were at the borders of the previous project and close to the main roads and populated areas of Khiran and Manqaf areas. Low disturbed sites (13 sites, 39 plots) were mainly at more or less neglected patches in salt marshes about 3 km away from the nearest populated area of Julaia'a (Fig. 1).

The geographical location of each site was measured with a global positioning system device (model GPS 315 Magellan, Garmin, USA). At each plot, species richness (number of plant species), abundance (number of individuals of each species) were counted. Canopy height, maximum and minimum canopy diameters of each species were recorded. Average canopy diameter (D) was calculated. Canopy cover of each plant species was calculated by π times the square semi-canopy-diameter. Identification, nomenclature and growth form of plant species were according to Täckholm (1974), Daoud and Al-Rawi (1985), Boulos (1988) and Omar et al. (2007).

Evaluations of the local conservation status of plant species were carried out following the criteria and categories of the IUCN Red List of Threatened Species (IUCN, 2012). These criteria may be summarized as follows: A, declining populations; B, geographic range size, fragmentation, decline or fluctuations; C, small population size and fragmentation; D, very small population or very restricted distribution; E, Quantitative analysis of extinction risk. The main threatened categories considered in this study are endangered (EN), vulnerable (VU) and near threatened (NT). The current field survey data and the available literatures about floristic composition (Daoud and Al-Rawi, 1985; Boulos, 1988; Al-Ateeqi and Al-Hurban, 2006; Omar et al., 2007), population size (Abd El-Wahab and Al-Rashed, 2010; Abd El-Wahab et al., 2014; Khalaf et al., 2014), plant distribution (Halwagy and Halwagy, 1977; El-Ghareeb et al., 2006; El-Sheikh et al., 2010), habitat fragmentation and anthropogenic activities along the coast of Kuwait (Al-Dousari et al., 2008; Al-Awadhi et al., 2014; Baby et al., 2014) were considered to apply the IUCN criteria.

1.3 Statistical analyses

According to the presence percentage of species in the surveyed sites, species were classified into five categories: very common (>50%), common (50%–30%), associated (30%–10%), rare (10%–5%), and very rare (<5%), which were applied to the study areas with high, moderate and low disturbance levels separately. Shannon index and Dominance index were calculated using EcoSim Professional (Entsminger, 2014). Shannon diversity index (H') takes into account both the species richness and abundance.

$$H' = -\sum_{i=1}^{S} P_i \ln P_i \ . \tag{1}$$

Where P_i is the proportion of individuals found in the i^{th} species; S is the number of species. Dominance index (Simpson index) gives more weight to common or dominant species.

$$\text{Dominance index} = \frac{1}{\sum_{i=1}^{S} P_i^2} \ . \tag{2}$$

Beta diversity was measured among high, moderate and low disturbed habitats using the Wilson-Shmida index (β_T) (Wilson and Shmida, 1984; Koleff et al., 2003). This measure of beta diversity (β_T) combines the idea of species turnover reflected by the gain (g) and loss (l) of species along a habitat (H) gradient, standardized by the average sample richness (α). Thus

$$\beta_T=(g(\mathrm{H})+l(\mathrm{H}))/2\alpha. \tag{3}$$

Cluster analysis of vegetation structure was tested statistically using average linkage of Bray-Curtis distance which was calculated from differences in abundance and cover of each species (Cophenetic correlation=0.752). Differences in species richness, total plant cover, Shannon index, and Dominance index were tested using one-way ANOVA test and Duncan's multiple range test. Pearson correlations were used to determine how species richness, total plant cover and diversity indices in high, moderate and low disturbed sites are related. Statistical analyses were carried out using SPSS software (IBM Corp., 2012) and FDiversity software (Casanoves et al., 2010).

2 Results

2.1 Vegetation description and floristic composition

The vegetation of the coastal fragmented habitats could be divided into three types based on disturbance intensity levels. Heavily disturbed habitats are characterized by very sparse vegetation mainly at small refuges (e.g. furrows, depressions and neglected areas), reduced plant cover, absence of palatable species, large patches of bare ground, abundant evidences of earthmoving, soil excavation, soil compaction and recent heavy machinery tracks (trucks and tractors, etc.). Moderately disturbed habitats have sparse recolonized vegetation, numerous signs of cutting and grazing, and medium signs of soil erosion. There is also much less evidence of vehicle use than in high disturbed habitats. Lightly disturbed habitats have minimal disturbance to soils, which are characterized by large patches of diffuse vegetation (especially with perennial herbs and subshrubs), high density and cover of subshrubs, and few signs of recent erosion and off-road vehicle.

The total inventory of vascular plants recorded in this survey is 38 plant species that belong to 34 genera and17 taxonomic families. Chenopodiaceae is the most represented family (10 species), followed by Asteraceae (5 species) and Zygophyllaceae (3 species). Most of the recorded species are salt-tolerant species. Annuals represent 40% of the floral composition of the study area. Perennial herbs and sub-shrubs dominate the vegetation of the study area (Fig. 2).

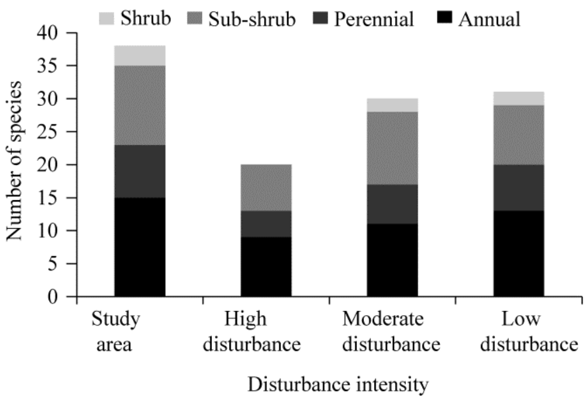

Fig. 2 The species distribution along the disturbance gradient in the southern coast of Kuwait

The most abundant recorded species at different habitats are *Z. qatarense*, *Cornulaca aucheri*, and *S. imbricata*. Within disturbed habitats, *C. aucheri* is the most representative species in high disturbed habitats, whereas *Z. qatarense* is the most representative species in moderate and low disturbed habitats. *N. retusa*, *Lycium shawii* and *T. aucheriana* were recognized only in habitats with moderate and low disturbances (Table 1). Camel feces and signs of browsing of palatable species, *C. conglomeratus*, *T. aucheriana* and *M. ciliata*, were recorded in the moderate and low disturbed sites.

The associated species constitutes about 16% of the recorded species in the study area, whereas common and very common species constitute only 8%. No difference was found in the number of species between habitats with moderate and low disturbances. However, they are significantly different in species composition. In addition, the average abundance, crown cover, diameter and height were higher in low disturbed habitats than in moderate disturbed habitats (Table 1). The majority of the recorded species (76%, 29 species) are either rare or very rare with presence

Table 1 Plant species composition of high, moderate and low disturbed habitats

Species	High (47 plots)				Moderate (27 plots)				Low (39 plots)			
	P (%)	D (m)	H (m)	C (m^2)	P (%)	D (m)	H (m)	C (m^2)	P (%)	D (m)	H (m)	C (m^2)
Aeluropus lagopoides (L.) Trin. Ex Thwaites[VU]	0.00	0.00	0.00	0.00	3.70	0.35	0.08	0.10	17.95	0.32	0.08	0.21
Aizoon hispanicum L.[NT]	4.26	0.30	0.22	0.10	3.70	0.50	0.30	0.20	0.00	–	–	–
Anabasis setifera Moq.[VU]	0.00	–	–	–	3.70	0.25	0.20	0.05	5.13	0.30	0.28	0.07
Astragalus spinosus (Forssk.) Muschl.[VU]	0.00	–	–	–	0.00	–	–	–	2.56	0.23	0.15	0.04
Atractylis carduus (Forssk.) C. Chr.[VU]	0.00	–	–	–	3.70	0.18	0.20	0.02	2.56	0.18	0.30	0.07
Bienertia cycloptera Bge. ex Boiss.[NT]	0.00	–	–	–	3.70	0.12	0.04	0.81	2.56	0.35	0.30	0.10
Brassica tournefortii Gouan	0.00	–	–	–	0.00	–	–	–	2.56	0.14	0.20	0.07
Cistanche tubulosa (Schrenk) Wight[NT]	0.00	–	–	–	7.41	0.05	0.20	0.003	0.00	–	–	–
Convolvulus oxyphyllus Boiss.[VU]	4.26	0.12	0.10	0.03	3.70	0.25	0.18	0.15	0.00	–	–	–
Cornulaca aucheri Moq.	65.90	0.21	0.20	0.50	55.500	0.22	0.17	0.70	23.08	0.26	0.24	0.21
Cressa cretica L.[VU]	2.13	0.20	0.08	0.06	0.00	–	–	–	5.13	0.41	0.07	0.18
Cyperus conglomeratus Rottb.[VU]	25.53	0.25	0.18	0.22	22.22	0.47	0.31	1.48	10.26	0.16	0.16	0.12
Fagonia bruguieri DC.[NT]	2.13	0.28	0.05	0.06	3.70	0.23	0.70	0.16	7.69	0.24	0.05	0.22
Filago pyramidata L.	0.00	–	–	–	0.00	–	–	–	2.56	0.08	0.08	0.13
Frankenia pulverulenta L.	6.38	0.08	0.05	0.01	3.70	0.07	0.05	0.05	5.13	0.10	0.05	0.03
Gypsophila capillaris (Forssk.) C. chr[NT]	2.13	0.33	0.40	0.25	3.70	0.15	0.25	0.04	2.56	0.42	0.50	0.55
Halocnemum strobilaceum (Pall.) M. Beib.[VU]	4.26	0.20	0.19	0.04	14.81	0.79	0.38	1.88	0.00	–	–	–
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	0.00	–	–	–	3.70	1.40	0.31	4.62	15.38	1.34	0.40	4.90
Haplophyllum tuberculatum (Forssk.) A. Juss.	2.13	0.18	0.25	0.02	3.70	0.28	0.35	0.24	0.00	–	–	–
Heliotropium bacciferum Forssk.[NT]	2.13	0.47	0.30	1.73	3.70	0.23	0.20	0.12	2.56	0.31	0.32	0.23
Ifloga spicata (Forssk.) Sch.Bip.	0.00	–	–	–	0.00	–	–	–	2.56	0.03	0.08	0.01
Launaea capitata (Spreng.) Dandy[NT]	2.13	0.13	0.08	0.01	7.41	0.15	0.06	0.05	5.13	0.16	0.06	0.04
Launaea mucronata (Forssk.) Muschl.[NT]	2.13	0.28	0.30	1.19	3.70	0.19	0.30	0.06	20.51	0.22	0.28	0.35
Lotus halophilus Boiss. & Sprun.	0.00	–	–	–	3.70	0.08	0.03	0.02	0.00	–	–	–
Lycium shawii Roem. & Schult[EN]	0.00	–	–	–	0.00	–	–	–	5.13	1.16	0.80	1.90
Malcolmia grandiflora (Bunge) O. Kuntze	0.00	–	–	–	0.00	–	–	–	2.56	0.23	0.20	0.28
Moltkiopsis ciliata (Forssk.) I.M.Johnst.[VU]	0.00	–	–	–	0.00	–	–	–	5.13	0.11	0.07	0.04
Nitraria retusa (Forssk.) Asch.[EN]	0.00	–	–	–	3.70	1.58	1.15	3.90	0.00	–	–	–
Plantago ciliata Desf.	8.51	0.08	0.07	0.03	25.93	0.08	0.05	0.04	5.13	0.10	0.07	0.28
Plantago psammophila Angew & chal.-Kabi.	21.28	0.12	0.08	0.62	37.04	0.13	0.09	0.15	10.26	0.14	0.09	1.18
Salsola imbricata Forssk. (=*S. baryosoma*)	29.79	0.30	0.25	0.23	51.85	0.38	0.25	1.56	28.21	0.59	0.37	2.70
Salsola jordanicola Eig. [VU]	0.00	–	–	–	3.70	0.23	0.20	0.04	2.56	0.35	0.20	0.10
Schismus barbatus (L.) Thell.	21.28	0.06	0.07	0.04	25.93	0.06	0.06	0.06	15.38	0.06	0.08	0.11
Seidlitzia rosmarinus Ehrenb ex. Bunge[VU]	0.00	–	–	–	3.70	0.70	0.50	0.39	5.13	0.72	0.42	2.26
Suaeda aegyptiaca (Hasselq.) Zohary	12.77	0.33	0.29	0.41	18.52	0.25	0.19	0.07	17.95	0.20	0.19	0.75
Suaeda vermiculata Forssk.ex J.F. Gmel.	4.26	0.16	0.12	0.10	14.81	0.23	0.20	0.18	28.21	0.28	0.23	0.81
Tamarix aucheriana Decne.[EN]	0.00	–	–	–	3.70	5.00	4.00	19.60	17.95	0.84	0.71	1.72
Zygophyllum qatarense Hadidi.	57.45	0.23	0.16	0.58	59.26	0.28	0.19	0.47	69.23	0.23	0.19	0.46

Note: P, presence percentage; D, average values of crown diameter; H, height; C, coverage. Threatened categories: [EN], endangered; [VU], vulnerable; [NT], near threatened; –, data not available.

percentage less than 10%. About 62% of these species (18 species) are not recorded in high disturbed habitats, which appeared in habitats with moderate (28%, 8 species) and low (24%, 7 species) disturbances.

Based on IUCN categories, *N. retusa*, *T. aucheriana* and *H. strobilaceum* are considered as endangered species. Most of the recorded sub-shrubs are considered as vulnerable species (34.2%) including *H. strobilaceum*, *Seidlitzia rosmarinus* and *C. conglomeratus*. The near threatened species constitute 21.1% of the recorded species (Table 1).

2.2 Plant species diversity

Total plant cover, species richness, Shannon and dominance indices were higher in low and moderate disturbed habitats than in high disturbed habitats. Based on one-way ANOVA, differences in species richness, Shannon index and total plant cover among the three disturbed habitats were statistically significant. However variations in dominance index were not significant. Duncan's multiple range test showed significant variations between high disturbed habitats and moderately disturbed habitats in terms of species richness, total plant cover and Shannon index. However, variations between habitats with moderate and low disturbances were not significant (Table 2).

Table 2 Total plant cover and alpha diversity indices in the high, moderate and low disturbed habitats

	High disturbance (*n*=47)	Moderate disturbance (*n*=27)	Low disturbance (*n*=39)	*F*	*P*
Species richness (number/25 m^2)	2.809^{a}	4.074^{b}	3.487^{ab}	3.973	0.022
Shannon index	0.645^{a}	1.026^{b}	0.828^{ab}	4.750	0.011
Dominance index	0.570	0.529	0.628	1.060	0.350
Total plant cover (%)	4.246^{a}	11.681^{b}	12.465^{b}	8.393	<0.001

Note: *n*, number of plots; *F*, one-way ANOVA; *P*, significance of *F* test; similar letters for each variable indicate no significant variation according to Duncan's multiple range test.

In the high disturbed habitats, Pearson correlations showed highly and significantly positive relationships among species richness, Shannon index and total plant cover. Dominance index showed highly and significantly negative relationships with species richness and Shannon index in moderate and low disturbed habitats (Table 3). Beta diversity (β_T) between high and low

Table 3 Pearson correlations between total plant cover and alpha diversity indices in the high, moderate and low disturbed habitats

	Species richness	Shannon index	Dominance index	Total plant cover
High disturbance (*n*=47)				
Species richness	1.000	0.903^{**}	0.096	0.514^{**}
Shannon index	0.903^{**}	1.000	−0.047	0.278
Dominance index	0.096	−0.047	1.000	0.196
Total plant cover	0.514^{**}	0.278	0.196	1.000
Moderate disturbance (*n*=27)				
Species richness	1.000	0.891^{**}	-0.554^{**}	−0.159
Shannon index	0.891^{**}	1.000	-0.629^{**}	-0.407^{*}
Dominance index	-0.554^{**}	-0.629^{**}	1.000	0.089
Total plant cover	−0.159	-0.407^{*}	0.089	1.000
Low disturbance (*n*=39)				
Species richness	1.000	0.892^{**}	-0.554^{**}	0.155
Shannon index	0.892^{**}	1.000	-0.644^{**}	−0.046
Dominance index	-0.554^{**}	-0.644^{**}	1.000	−0.170
Total plant cover	0.155	−0.046	−0.170	1.000

Note: *n*, number of plots; *, correlation at significance level P<0.05 (2-tailed); **, correlation at significance level P<0.01 (2-tailed).

disturbed habitats (0.29) was higher than either between high and moderate (0.22) or between moderate and low disturbed habitats (0.25).

2.3 Plant assemblages

Based on cluster analyses, the study area harbors 10 plant assemblages (Fig. 3). Although there is no clear clustering relative to the disturbance level, four assemblages were exclusively restricted to a certain type of disturbed habitat (Table 4). Disturbance levels (high, moderate and low) are mixed among most of the tree branches (Fig. 3). Most of the assemblages in high and moderate disturbed habitats are dominated by *Z. qatarense*, *C. aucheri*, *S. imbricate* and *C. conglomeratus* (Table 4). The subshrubs and perennial herbs are the predominant in different assemblages. Shrubs such as *T. aucheriana*, *H. salicornicum*, *L. shawii* and *N. retusa* are recorded only in habitats with low and moderate disturbances either as dominant or associated species (Table 4).

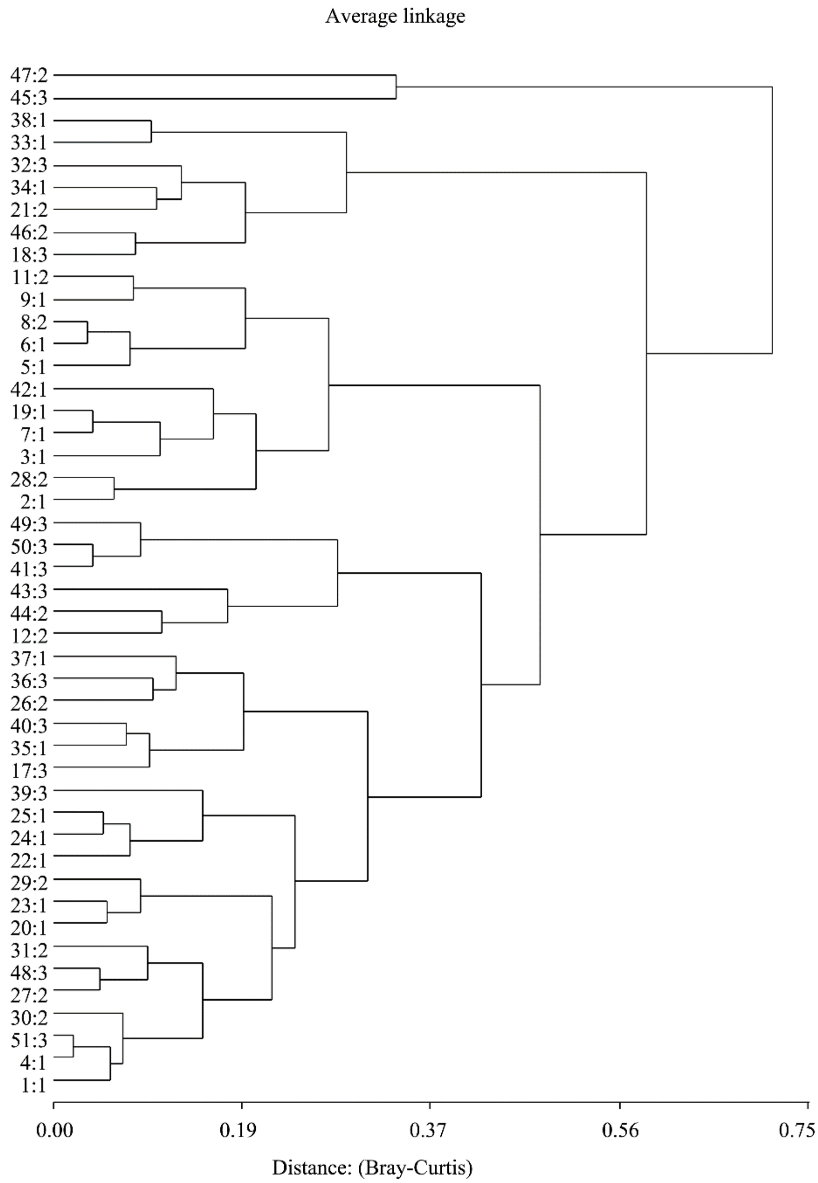

Fig. 3 Cluster dendrogram of the disturbed 51 sites (1, high; 2, moderate; 3, low disturbance) based on abundance and the coverage of 38 plant species recorded in this study. Sites grouped using average linkage of Bray-Curtis dissimilarities (Cophenetic correlation, 0.752).

Table 4 Dominant and associated species of the plant assemblages at the disturbed habitats

Assemblage	Disturbance level	Dominant species	Associated species	Number of species
1 (*n*=1)	M	*Tamarix aucheriana*, *Salsola imbricata*	*Suaeda aegyptiaca*	3
2 (*n*=1)	L	*Haloxylon salicornicum*	*Cornulaca aucheri*, *Fagonia bruguieri*	4
3 (*n*=2)	H	*Cornulaca aucheri*, *Zygophyllum qatarense*, *Plantago psammophila*	*Salsola imbricata*, *Cyperus conglomeratus*, *Schismus barbatus*	6
4 (*n*=5)	H, M, L	*Salsola imbricata*, *Cornulaca aucheri*, *Zygophyllum qatarense*	*Plantago psammophila*, *Cyperus conglomeratus*, *Schismus barbatus*	16
5 (*n*=5)	H, M	*Salsola imbricata*, *Cornulaca aucheri*, *Zygophyllum qatarense*	*Suaeda aegyptiaca*, *Suaeda vermiculata*, *Aizoon hispanicum*, *Halocnemum strobilaceum*	13
6 (*n*=6)	H, M	*Cornulaca aucheri*, *Salsola imbricata*, *Zygophyllum qatarense*	*Heliotropium bacciferum*, *Suaeda aegyptiaca*, *Cyperus conglomeratus*	14
7 (*n*=3)	L	*Tamarix aucheriana*, *Haloxylon salicornicum*, *Seidlitzia rosmarinus*, *Zygophyllum qatarense*	*Lycium shawii*, *Suaeda vermiculata*, *Aeluropus lagopoides*, *Fagonia bruguieri*	13
8 (*n*=3)	M, L	*Salsola imbricata*, *Haloxylon salicornicum*	*Nitraria retusa*, *Halocnemum strobilaceum*, *Lycium shawii*, *Launaea mucronata*, *Zygophyllum qatarense*	15
9 (*n*=6)	H, M, L	*Cornulaca aucheri*, *Cyperus conglomeratus*, *Zygophyllum qatarense*	*Salsola imbricata*, *Suaeda aegyptiaca*, *Suaeda vermiculata*, *Launaea mucronata*	16
10 (*n*=14)	H, M, L	*Zygophyllum qatarense*, *Cornulaca aucheri*, *Cyperus conglomeratus*, *Salsola imbricata*	*Plantago psammophila*, *Suaeda vermiculata*, *Suaeda aegyptiaca*, *Launaea mucronata*, *Schismus barbatus*	18

Note: *n*, number of sites; H, high; M, moderate; L, low.

3 Discussion

Although coastal salt marshes of the Arabian Gulf are heavily impacted by urbanization activities, there is a paucity of data on vegetation changes and threatened status of plant species. This study found that habitat fragmentation in coastal ecosystems caused by the intensive urbanization directly impact the arid and hyper-arid coastal ecosystems through the loss of trees and shrubs, where rarity of precipitation exacerbates the impacts of urbanization and decreases the chance of recovery (Batanouny, 1983; Richer, 2009; Baby et al., 2014; Khalaf et al., 2014). In addition, the deterioration of salt marsh communities may be due to the groundwater level fluctuation or an increase in groundwater salinity (Khalaf et al., 1995). McKinney (2006) stated that urbanization is one of the main human activities that causes drastic and irreversible habitat alterations. Brown (2003) also detected that species richness, relative abundance and productivity of coastal habitats showed a clear reduction at high levels of human disturbances. It was estimated that about 90% of the native coastal salt marshes along the Arabian Gulf have been lost as a result of urban development activities (Loughland et al., 2012).

Floristic composition of the costal habitats with the dominance of succulent sub-shrubs and perennial herbs is particularly common in salt marshes (El-Ghareeb and Rezk, 1989; Laegdsgaard, 2006; Zedler and West, 2008). Biswas and Mallik (2010) found that disturbance-habitat-stability coupling may have significant effect on particular plant life forms. In 1970s, annuals represented up to 65% of the coastal habitats flora (Halwagy and Halwagy, 1977). In this study, the percentage of the annuals decreased to about 40%. However, low and medium disturbances encourage incidence of annuals rather than high disturbances. These findings, in consistence with several studies of terrestrial and aquatic communities, support the intermediate disturbance hypothesis (Lake, 2000). Most of the recorded species (76%) are considered threatened species including *N. retusa*, *L. shawii*, *T. aucheriana* and *H. strobilaceum.* In 1970s and 1980s, these species were considered as dominant and landmark species in the coastal salt marsh habitats

(Halwagy and Halwagy, 1977; Gunatilaka et al., 1980; Gunatilaka and Mwango, 1987), which indicate that the study area had suffered high intensity and frequency of disturbances and aridity conditions.

This study showed that disturbance led to the dominance of productive and succulent sub-shrubs, such as *Z. qatarense*, *C. aucheri*, and *S. imbricate*, which are disturbance indicators, specifically for urbanization type of disturbance. Their broad tolerance to environmental conditions is evidenced by their occurrence in virtually disturbed coastal salt marshes (Zedler and West, 2008). The total plant cover of the disturbed habitats reached about 4% in high disturbed habitats and about 12% in moderate and low disturbed habitats. The reduction in vegetation coverage due to human disturbance was estimated to about 80%. In 1970s, the total plant cover of the coastal salt marsh habitats reached up to 65% for *H. strobilaceum* community, 85% for *Z. qatarense*, 33% for *N. retusa*, and 45% for *T. aucheriana*. The coastal dunes habitats are dominated by the communities of *Rhanterium epapposum*, *Convolvulus oxyphyllus*, and *H. salicornicum* with coverage up to 32%.

Species richness has attracted particular attention from the international conservation communities (Caldecott et al., 1996; Wulff et al., 2013). Species richness, Shannon index, abundance and total plant cover varied significantly with disturbance intensities that support the hypotheses of this study. These results confirm the importance of species richness and Shannon index for ecosystem assessment along disturbance gradient (Biswas and Mallik, 2011). Pakeman (2011) found that high level of anthropogenic disturbances, mainly due to urbanization and overgrazing, reduced functional richness of plant assemblages. Although statistical analyses showed no significant difference between moderate and low disturbed habitats in terms of diversity and total plant cover, these habitats were different in floristic and assemblage compositions. These findings indicate that low and moderate levels of disturbance may play a central role in regulating species diversity (Lake, 2000). The high value of β_T may reflect rapid ecologically significant changes in the high disturbed habitats (Wilson and Shmida, 1984). Community differences indicate high beta diversity between the habitat types.

4 Conclusions

Salt marsh habitats are being lost along the coastal area of Kuwait due to severe removal of vegetation and restructuring of the area for urban development. Habitat fragmentation due to intensive urbanization is among the most serious threats that contribute to declines in biological diversities. The results disclosed the absence of trees and severe decline in abundance of shrubs and sub-shrubs that were reported in 1970s and 1980s as dominant landmark species in the coastal salt marsh habitats. Based on the IUCN categories of threatened species, this study recommends that remnants of the shrub populations; *N. retusa*, *L. shawii* and *T. aucheriana* should be recognized as local endangered species; sub-shrub populations of *H. strobilaceum*, *S. rosmarinus* and *C. conglomeratus* should be recognized as local vulnerable species in Kuwait. Establishing small protective enclosures, natural reserves, refuges, planting endangered and vulnerable species in the disturbed habitats at Nuwaiseeb are recommended conservation actions to avoid loss of the fragmented coastal habitats and to facilitate restoration of native plants. Raising public awareness and participation are very important for the implementation of the local restoration plans.

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