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Intertidal seagrass *Halodule uninervis*: Factors controlling its density, biomass and shoot length

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ABSTRACT

The seagrass *Halodule uninervis* is distributed in separate patches along the coast of Kuwait but its distribution in the meadows in Kuwait bay appear to be declining. Physical, chemical and biotic factors were investigated in three contrasting locations to determine how these affect the biomass, shoot density and length of this seagrass. There are significantly longer leaves, higher biomass and shoot density in *H. uninervis* beds in south compared to that of Doha in Kuwait bay. At the same time, there are significantly longer leaves in lower intertidal zone compared to upper intertidal zone. The characteristics of tidal pools formed during low tide seem to determine the extent of exposure these seagrass endure during low tide. Most of the meadows in the intertidal zone were in tidal pools of loamy sand to sandy sediments. Tidal pools at the southern sites have a constant influx of seawater that significantly reduce the temperature and salinity of these tidal pools during summer. Shoot density and biomass at all three sites increased during the year, reaching maximum during July, after which these plants shed their leaves by an escape mechanism that is evident especially in Doha seagrass population. Doha meadows exist in isolated tidal pools and experience temperatures above 45^{o}C. Turbidity at Doha is also significantly higher, hence reducing the availability of light to these seagrass. But at all sites, the concentration of heavy metals in the sediment and plant tissues were below toxic levels. The diversity and density of epiphytes on the leaves were also high from late spring to mid-summer, the period of rapid growth of the species.

Keywords: Seagrass; biomass; *Halodule uninervis*; salinity; epiphytes.

INTRODUCTION

Seagrasses are marine flowering plants found in bays, estuaries and coastal waters from the mid-intertidal zones down to depths of 50 or 60 meters (Green & Short, 2003). There are about 50-60 species of 12 genera and 4 families (Larkum *et al.*, 2006; Green & Short, 2003). They thrive on types of substrates but most seagrass beds occur on sand and mud substrates (Dawes, 1998).

In many places seagrasses cover extensive areas, often referred to as seagrass beds or seagrass meadows. Although there are relatively few seagrass species, the complex physical structure and high productivity of these ecosystems enable them to support a considerable biomass and diversity of associated species. Seagrasses play an important role in binding sediment sand providing some protection for coastal erosion.

The growth, development and reproduction of seagrasses are affected by various chemical factors, such as salinity (Short & Neckles, 1999; Walker & McComb, 1990), oxygen concentration (Holmer & Bondaard, 2001; Dawes, 1998), nutrient availability, and pH level (Larkum *et al.*, 2006).The prevalence of heavy metals can also affect the photosynthetic apparatus and inhibit enzyme activity (Macinnis & Ralph, 2002). Other factors influencing the growth and distribution of seagrass species include turbidity, light availability (Short *et al.,* 2001; Dennison, 1987; Dennison & Alberte, 1985), tidal exposure, waves (Erftemeijer & Herman, 1994; Fosenca & Kenworthy, 1987), and various biotic factors,such as epiphytes, epifauna, and grazing (Lanyon *et al.*, 1989).

Halodule uninervis is the most dominant species in the Arabian Gulf and it occurs in scattered patches or meadows along the shoreline (Green & Short, 2003).

Only two species have been reported in Kuwait, *Halodule uninervis* and *Halophila ovalis* both of which are found on beaches of Khiran, and Nuwaiseeb which are on the south open shores, whereas the former is also found on Dbaiyah, located along the mid-southern coast and sheltered beaches of Doha on the north coast. Comparing Doha site to Nuwaiseeb, Khiran, and Dbaiyah it can be seen that northern location is different having a carbonate rocky platform shore with gentle slope and unequal, semidiurnal tidal cycle with 3.5 - 4 m tidal range (Jones, 1986) and salinity reaching up to 42 psu. On the other hand, the southern locations are characterized by clear waters, slopping sandy shores and a predominantly diurnal tidal cycle with less than 2 m tidal range.

The local distribution of seagrasses has not been fully documented, and only few seagrass beds have been identified to date (Al-Hasan & Jones, 1989; Al-Sarawi *et al.*, 1985). Scattered seagrass meadows appear to be declining particularly along the northern shore line probably because of urbanization, a phenomenon also observed in other areas around the world (Waycott *et al.*, 2004; Duarte, 2002). Survival and abundance of these seagrasses are dependent on the degree of fluctuation of environmental conditions in the intertidal zone. Currently there is no experimental data to substantiate the factors that may be contributing to this phenomenon.

This study aims to determine the effect of environmental conditions in

Kuwait bay compared to those at south open waters on morphology and density of this seagrass.

MATERIALS AND METHODS

Sampling Sites.

Seagrass meadows were studied in three intertidal areas in Kuwait. These are located in Doha, Dbaiyyah and Nuwaiseeb areas (Figure 1). Doha site is located along south of Kuwait bay and it consists of a large intertidal flat, composed of exposed rocky platform. The intertidal area is approximately 1 km long seaward. In the intertidal area and in close proximity to the selected sampling site there are few metal-ship wrecks. *Halodule uninervis* was the only species at this site and meadows were small patches in a shallow tidal pools.

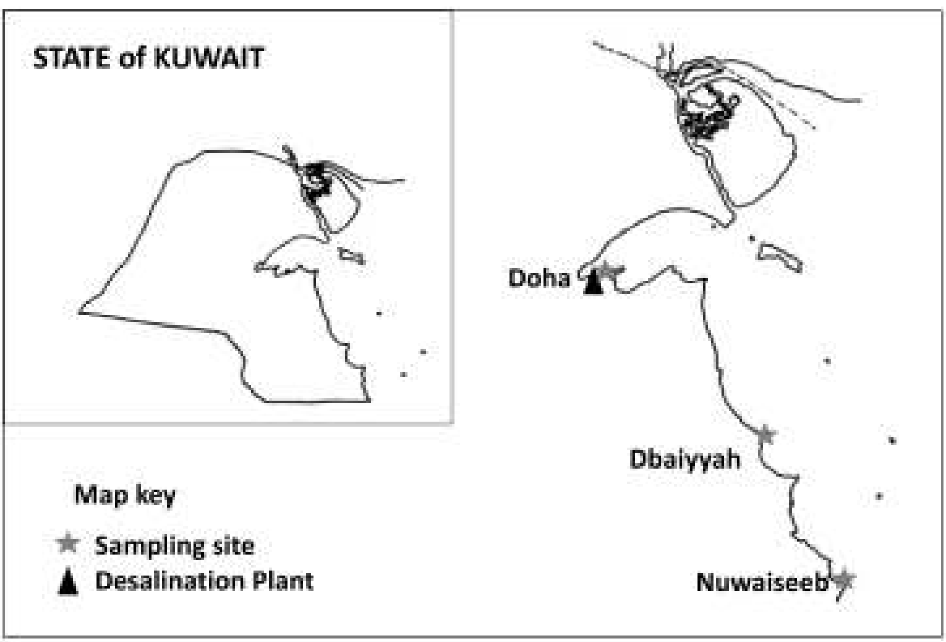


Fig. 1. Map of the State of Kuwait (inset) showing the coastal outline with the selected study sites. In Kuwait Bay Doha site is in close proximity to a desalination plant. Southern sites (Dbaiyyah and Nuwaiseeb) are located on the open waters of the Arabian Gulf.

Dbaiyyah site is located along the mid-southern Kuwait coastal area. The intertidal area is also approximately 1 km long with *Halodule uninervis* as the only seagrass species, distributed in larger meadows extending to the subtidal zone.

Nuwaiseeb site is located along southern coastal area near the border of Saudi Arabia. The intertidal area is nearly 3 km long. The first 50 m from the coast shows a sharp slope reaching to 5 m depth. It contains a mixture of *Halodule uninervis* and *Halophila ovalis* in very large meadows. These meadows extend to the subtidal zone. Study of seagrass was restricted to the intertidal area in all selected sites.

Physical and chemical properties of seawater and sediment

Temperature, salinity, turbidity, pH and dissolved oxygen were measured *in situ* on a monthly bases using a water quality checker (U-10 Horiba Ltd, Japan) in meadow and bare areas.

Sediment thickness was calculated as an average of 20 random measurements using a metal scale. Core sediment samples were collected using metal tins measuring 13 cm in diameter and 3 cm deep. Sediments where then dried in an oven at 45°C for a period of two days, and the average of three dry weights were recorded for each site. Bulk density (B. D.) was calculated as sample dry weight divided by volume. Particle density (P.D.) was calculated as the weight of the sediment particles divided by volume. Sediment texture and percent pore space were also calculated according to Brady (1990).

The Nitorgen and Phosphorous concentrations in sediment samples were determined using the Palintest system soil testing kit (ELE International. Palintest Photometer 5000, England). Total carbon, nitrogen, hydrogen and sulfur in sediment samples were determined using the Elemental Analyzer (LECO Corporation, U.S.A). Measurements were recorded as an average of three different readings.

Heavy metals in seagrass tissues and sediment.

Because of the presence of several metal ship wrecks at Doha site, it is expected that levels of heavy metals may vary among sites and therefore, heavy metals in seagrass and sediments were measured.

Every two months, five samples of seagrass tissues and sediment samples were collected at low tide from different sites and stored at 4°C for further analysis. The tissues were rinsed with filtered seawater followed by deionized water and then divided into above-ground tissues (leaves) and below-ground tissues (rhizomes). Each tissue type was oven dried at 45°C for 48 hours, and the dried samples were ground using a mortar and pestle. Ground leaf and rhizome tissues (0.5 g) were placed in 50 ml centrifuge tubes and 3.0 ml concentrated nitric acid and 1 ml hydrochloric acid was added to each sample. After 48 hours at room temperature, the resultant solution was diluted with deionized water to 50 ml. The samples were digested for organic constituents in a fully automatic microwave digester (Spectroprep, CEM). A graphite furnace (Varian SpecrtAA 220Z) was used to determine copper (Cu), lead (Pb) and nickel (Ni) in plant and sediment samples and iron (Fe) in plant tissues. Flame Atomic Absorption (Perkin Elmer model 500) was used to determine iron (Fe) in sediment samples. Quality assurance including the recovery of metals to that of the standards and blanks was carried out as described by Arnold *et al*. (1992).

Biomass, shoot density, leaf length, width, internode length and number of roots

Halodule uninervis shoot density and biomass (dry weight) were determined by taking random samples using 30.5 cm^2 quadrate at low tide. In each study site, 5 random samples were taken from meadow areas every two months. The area of the quadrate was dug out approximately 15 cm deep and sediment containing seagrass was taken to the laboratory in labeled plastic bags. These samples were rinsed carefully in tap water to remove the sediment. The length and width of leaves, internode length, number of roots per shoot, and shoot density were determined for each sample.

Epiphyte density

Epiphyte density and diversity on leaves were determined for the three sites. Twenty ramets were randomly selected and leaves examined using a light microscope and scanning electron microscope (SEM). Epiphytes were counted in three 1 cm length segments; leaf tip, middle, and base of each leaf and epiphytes and epifauna were photographed for identification. Biovolume of the prevailing epiphyte was calculated according to Brierley *et al*. (2007).

Statistical analysis

Data were statistically analyzed by one-way analysis of variance (ANOVA) test to examine the significance of the difference in heavy metal content between different plant parts, between sediments from meadow and bare areas, between different study sites, winter months and summer months. Also, ANOVA test was applied to difference between locations and meadow and bare areas with regard to sediment bulk density, particle density, percentage of pore space, biomass, and shoot density. Pearson correlation analysis was used to test biomass, and shoot density, against different environmental conditions including heavy metals concentration in leaves and in rhizomes. All statistical analyses were performed using SPSS statistical software v 14 (SPSS Inc., an IBM company, Chicago). Error bars used in graphic representations of different data represent standard deviations.

RESULTS

At all study sites, the distribution of *Halodule uninervis* beds was mainly restricted to tidal pools formed during low tide. Doha intertidal area is a flat platform, and tidal pools are generally shallow. In Dbaiyyah and Nuwaiseeb, where intertidal areas are relatively steep, large tidal pools with constant in flux of seawater are observed.

Physical and chemical characters of seawater

Turbidity of seawater is significantly different between the selected sites. The seawater was most turbid at Doha particularly during the summer (Table 1). There was no significant difference between the water turbidity at Dbaiyyah and Nuwaiseeb sites regardless of season. The lowest water temperature was 14.5°C and the highest was 34.2°C in summer when ambient temperature exceeded 45°C at all sites. Temperature of 38°C was recorded in shallow tidal pools with some seagrass in Doha when ambient temperature exceeded 50 °C. The range of dissolved oxygen in the intertidal water at all three sites was 5.0-9.6 mg l^{-1}. There was no significant difference in the dissolved oxygen measurements at all three sites (Table 1). Also during winter the amount of dissolved oxygen was slightly higher. Meadows also had a slightly higher mean of dissolved oxygen value (6.5 mg l^{-1}) compared to bare areas (6.0 mg l^{-1}). Salinity was significantly different among the sites. The highest recorded salinity was at Doha with 45.2 ppt during the summer, followed by Nuwaiseeb with 42.0 ppt and Dbaiyyah with 38.6 ppt (Table 1). pH values at all three sites were between 7.6 and 8.5. Statistically, there was no significant difference in pH of seawater during the winter or summer.

Table 1. Physical and chemical characteristics of coastal seawater at Doha, Dbaiyyah, and Nuwaiseeb. Parameters measured were temperature (Temp.); turbidity (Turb.); dissolved oxygen (D. O.); salinity (Sal.); and pH. Values represent the means of data collected monthly for 2 years during winter and summer seasons. Numbers between brackets are standard deviation. Parameters showing significant difference ($P < 0.05$) between sites when tested using One-way ANOVA are indicated with an asterisk.

Location	Parameters	Winter	Summer
Doha	Temp (°C)	19.8 (±3.5)	26.9 (±4.8)
	Turb (NTU) *	4.2 (±3.2)	5.4 (±3.6)
	D. O. (mg/l)	7.6 (±0.9)	5.7 (±0.4)
	Sal (ppt) *	38.7 (±2.8)	38.3 (±3.0)
	pH	8.2 (±0.1)	8.1 (±0.1)
Dbaiyyah	Temp (°C)	16.0 (±0.4)	25.2 (±2.2)
	Turb (NTU) *	2.0 (±1.9)	2.7 (±1.9)
	D. O. (mg/l)	8.0 (±0.6)	7.0 (±1.0)
	Sal (ppt) *	34.7 (±0.4)	35.8 (±1.4)
	pH	7.8 (±0.1)	7.9 (±0.2)

Cont. Table 1.

Location	Parameters	Winter	Summer
Nuwaiseeb	Temp (°C)	17.5 (±2.6)	27.9 (±4.9)
	Turb (NTU) *	3.0 (±1.8)	1.3 (±0.4)
	D. O. (mg/l)	7.4 (±0.7)	5.9 (±0.6)
	Sal (ppt) *	36.3 (±1.5)	37.5 (±2.7)
	pH	7.9 (±0.1)	8.1 (±0.1)

Sediment pore space, thickness, bulk density and particle density.

The percentage of pore space was significantly different ranging between 47.5 - 54.7% for meadow areas and between 36.5-51.1% in bare areas, with Doha recording lowest meadow area pore space (47.5%), and Dbaiyyah being the highest (54.7%). Sediment thickness in Nuwaiseeb was significantly greater than that recorded for Doha and Dbaiyyah, and at all sites sediment thickness at meadow areas is greater than bare areas (Fig. 2). There was no significant difference in particle density and bulk density between meadow and bare areas and among sites (P 0.05). The highest particle density was 6.6 g ml^{-1} in the meadow areas of Doha; the lowest (5.5 g ml^{-1}) was in the bare areas of Dbaiyyah site. The average bulk density for meadow and bare areas at all sites was 2.97 g ml^{-1} and 3.17 g ml^{-1}, respectively.

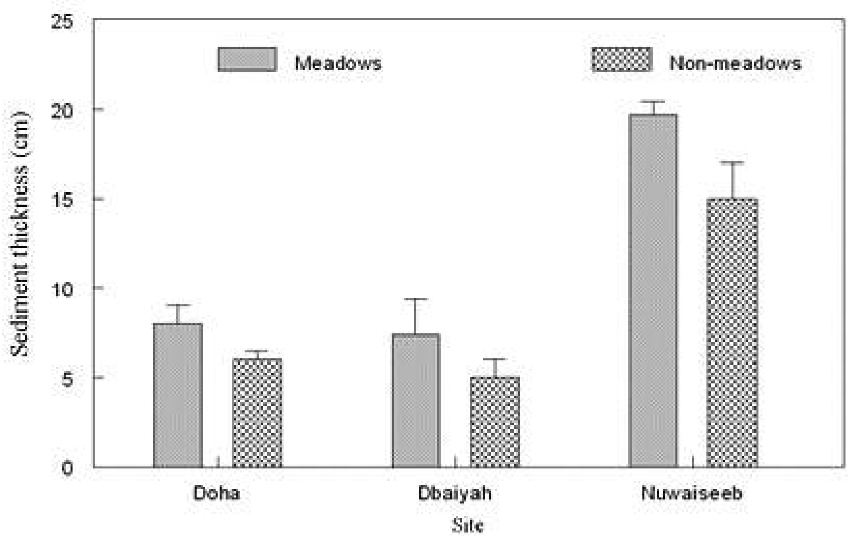


Fig. 2. Sediment thickness in *Halodule uninervis* meadow and bare (non-meadow) areas in Doha, Dbaiyyah, and Nuwaiseeb. Each value represents an average of 20 random measurements.

Sediment texture, nutrient concentration and pH

The percentage of clay in all three sites was between 7 and 14% with the highest clay content in the bare areas of Nuwaiseeb. Dbaiyyah had the lowest clay content. Silt content appeared to be approximately the same in all three sites (average of 2.3%). sediment type was determined to be sand to loamy sand in both the meadow and bare areas in all sites. The meadow sediment in Dbaiyyah and Nuwaiseeb was sandy soils, and in Doha the sediment of meadows was loamy sand.

There was no significant difference in nitrogen content in meadow and bare sediments in all sites (Table 2). The mean nitrogen content in the sediments of all three sites was 1.15 mg l^{-1}. Phosphorus content was significantly different among the sites but not between meadow and bare areas (Table 2). Phosphorus content in all three sites was between 13.2-74.0 mg l^{-1} with the highest P content in Doha. The bare area of the Dbaiyyah site had the lowest P content.

Table 2. Concentrations of nitrogen and phosphorus in the sediment samples collected from the *Halodule uninervis* meadows (M) and the bare areas (N. M.) at Doha, Dbaiyyah, and Nuwaiseeb.

Site	Meadow/Non-Meadow	N mg l^{-1}	P mg l^{-1}
Doha	M	1.0	70.0
	N. M.	1.2	74.0
Dbaiyyah	M	1.1	14.4
	N. M.	1.2	11.2
Nuwaiseeb	M	1.2	12.5
	N. M.	1.2	13.2

Leaf length, width, internode length and number of roots

There are three leaves per each shoot of *Halodule uninervis*, with the longest leaf being oldest, which is referred to as mature leaf and the shortest leaf, the youngest. The maximum length of mature leaves of *Halodule uninervis* at all three sites was approximately 7.41 cm. Maximum mature leaf lengths were recorded in Dbaiyyah (7.8 cm) during July and the shortest (1.4 cm) in Doha during August (Figure 3a). Generally, leaves of *Halodule uninervis* were observed to be longest during July and much shorter during August, especially at Doha, where leaves were mostly brown with leaf tips scorched and deteriorated and seagrass leaf debris is evident at shoreline. Lengths of young leaves (Figure 3b) at three sites mostly followed similar trend as mature leaves, with the maximum leaf lengths were recorded in Dbaiyyah (2.88 cm) during

July, and the shortest (0.68 cm) in Doha during September. At all three sites seagrass in the lower intertidal zone had longer mature leaves compared to leaves from the backshore. Leaf width at all study sites and during all times was 1 mm.

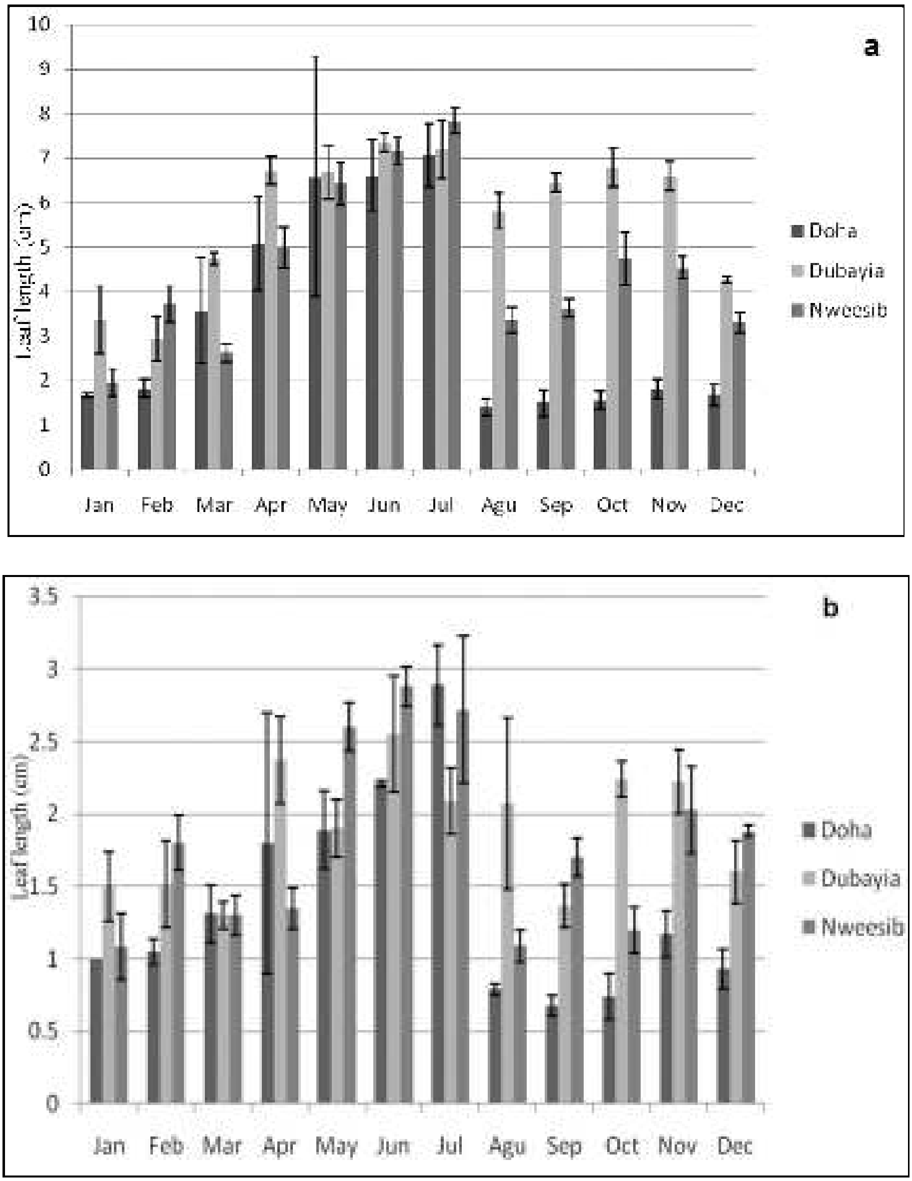


Fig. 3. Monthly average lengths of mature (a) and young (b) leaves of *Halodule uninervis* in Doha, Dbaiyyah, and Nuwaiseeb.

The length of internodes at all three sites ranged from 0.4 to 4.0 cm with the longest internodes observed at Dbaiyyah (0.5-4.0 cm) and the shortest at Doha (0.4-3.2 cm). Internode lengths observed at Nuwaiseeb ranged between 0.4-3.5 cm. The number of roots per shoots at all three sites ranged from 1 to 8. Generally, the average number of roots per shoot was four.

Concentration of heavy metals in seagrass tissues and sediments

Samples from the three different study sites were examined for the level of Cu, Pb, Ni and Fe. The concentrations of these heavy metals were determined in leaves, rhizomes and sediments at each site (Table 3). Copper, lead and Ferrous, but not Nickel content of all samples studied (sediment, rhizomes, and leaves) in different locations significantly varied between seasons ($P = .012$, .024, .362, .002 respectively). There is a significant difference between different locations with regard to sediment content of Copper, lead, Ferrous and Nickel ($P = .011$, 000, .000, .000 respectively). The highest concentration of Cu was found in the leaf tissues at Dbaiyyah and Nuwaiseeb (Table 3). Sediments from Doha site contained higher copper concentration than sediments in other sites. Rhizome tissues at Nuwaiseeb accumulated significantly higher copper content than those of Doha and Dbaiyyah. In general *H. uninervis* tissues had significantly higher copper compared to the sediment samples. The lead concentration in the sediments was significantly higher than in seagrass tissues in Doha and Nuwaiseeb. Lead concentration was the highest in the meadow sediments at Doha site. In general, the lowest amount of lead was observed in the rhizome tissues.

The nickel content in *Halodule uninervis* tissues was significantly higher than the content in sediment (Table 3). Leaf tissue in general appeared to accumulate significantly higher nickel content at all sites.

Generally, iron content in tissues and sediments was highest in Doha compared to Dbaiyyah and Nuwaiseeb.

Table 3. Concentrations of copper, lead, nickel and iron in *Halodule uninervis* above ground tissues (leaves), and underground tissues (rhizomes). In addition to heavy metals concentration in sediment collected from *H. uninervis* meadows at Doha, Dbaiyyah, and Nuwaiseeb. Each value represents average of five samples collected every two months for one year. Numbers between brackets are standard deviation.

Element	Leaves (μg / g dry weight tissue)			Rhizomes (μg / g dry weight tissue)			Sediment (μg / g dry weight sediment)		
	Doha	Dbaiyyah.	Nuwaiseeb	Doha	Dbaiyyah.	Nuwaiseeb	Doha	Dbaiyyah.	Nuwaiseeb
Cu	50.6 (±20.3)	79.3 (±55.6)	89.8 (±45.)	52.3 (±26.0)	54.3 (±35.0)	86.7 (±13.3)	44.1 (±3.0)	25.9 (±6.3)	15.3 (±2.1)
Pb	20.5 (±5.3)	32.6 (±19.0)	21.7 (±4.5)	18.0 (±9.3)	29.9 (±7.2)	17.4 (±4.1)	30.0 (±5.9)	29.6 (±1.7)	24.2 (±6.4)
Ni	87.2 (±16.1)	55.6 (±20.5)	74.5 (±13.4)	72.1 (±27.1)	58.0 (±20.4)	55.7 (±12.1)	72.1 (±5.3)	48.2 (±11.5)	50.6 (±13.1)
Fe	8.4 (±1.4)	5.0 (±2.0)	5.1 (±0.7)	7.0 (±2.2)	6.1 (±2.2)	6.5 (±1.7)	11.8 (±1.4)	7.6 (±1.1)	8.8 (±2.4)

Biomass and shoot density

Shoot density and biomass (Figure 4) were significantly different among the study sites In summer the maximum numbers of shoots were 498, 552 and 638 per square foot for Doha, Dbaiyyah and Nuwaiseeb, respectively. Shoot density and biomass at all three sites were at a maximum during July and greatly declined during August (Figure 4). Shoot density in different locations negatively correlate with increase in turbidity, salinity and pH (Table 4). On the other hand, no correlation was observed between biomass and different physical conditions.

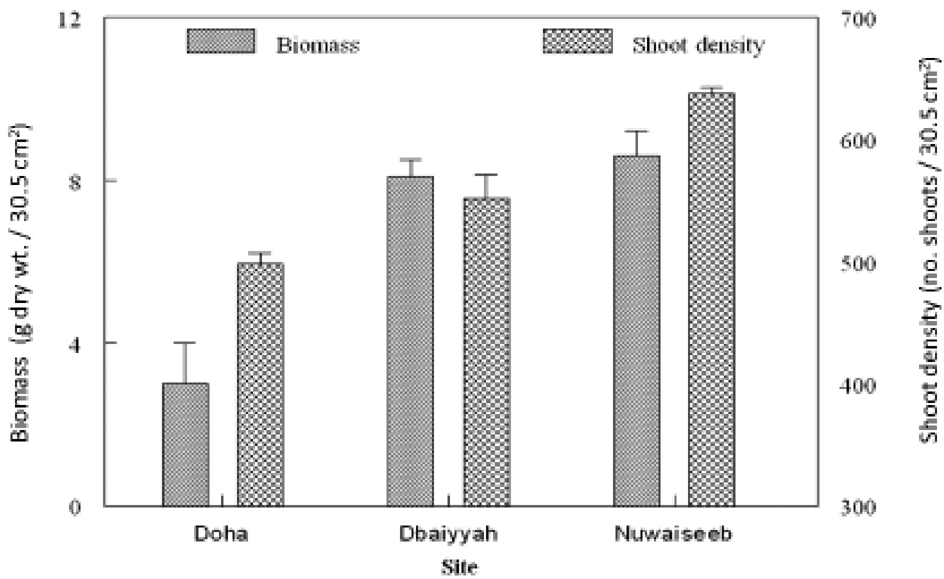


Fig. 4. Shoot density (number of shoots / 30.5 cm2) and biomass (dry weight / 30 cm2) of *Halodule uninervis* at Doha, Dbaiyyah, and Nuwaiseeb.

Shoot density and biomass negatively correlated with the concentrations of Ni in leaves and in rhizomes, Fe in leaves, and Cu in rhizome (Table. 4).

Table 4. Pearson correlation analysis of shoot density, and biomass of intertidal *Halodule uninervis* in Doha, Dbaiyyah, and Nuwaiseeb against dissolved oxygen concentration (D. O.); turbidity (Turb.); salinity (Sal.); pH of seawater (pH Wtr); pH of sediment (pH Sed.); seawater temperature (Temp.) and heavey elements (Cu, Pb, Ni, and Fe) concentrations in rhizomes, leaves and sediment. For all tests n = 90.

Correlation		D. O.	Turb.	Sal.	pH Wtr	pH Sed.	Temp.	Rhizome				Leaf				Sediment			
								Cu	Pb	Ni	Fe	Cu	Pb	Ni	Fe	Cu	Pb	Ni	Fe
Shoot density/12 inch^2	Pearson Correlation	0.137	-.215*	-.212*	-.210*	0.071	0.057	.304**	0.199	-.325**	-0.201	0.038	0.189	-.246*	-.538**	-.544**	-.303**	-.552**	-.459**
	Sig. (2-tailed)	0.197	0.042	0.045	0.047	0.504	0.597	0.004	0.059	0.002	0.057	0.72	0.075	0.02	0	0	0.004	0	0
Biomass/12 inch^2	Pearson Correlation	0.105	-0.2	-0.15	-0.163	0.117	0.038	.312**	0.182	-.318**	-0.178	0.045	0.195	-.243*	-.517**	-.543**	-.313**	-.534**	-.466**
	Sig. (2-tailed)	0.324	0.053	0.167	0.126	0.273	0.724	0.003	0.087	0.002	0.092	0.672	0.065	0.021	0	0	0.003	0	0

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

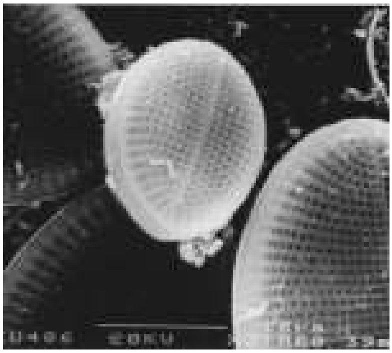
*. Correlation is significant at the 0.05 level (2-tailed).

Epiphytic Density on *Halodule uninervis*

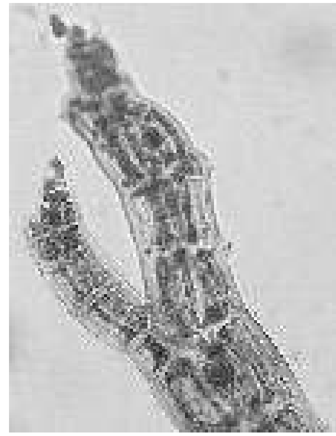
A total of fifteen epiphytes and two epifauna were found on *Halodule uninervis* leaves in all three sites. These species were separated into five groups (Table 5), diatoms (Figure 5a); a red alga *Polysiphonia* sp (Figure 5b); epifauna *Ventroma* sp. and *Clytia* ap. (Figure 5c); a cyanobacterium *Calothrix* sp. (Figure 5d); and an unknown prostate algae (Figure 5e).

Table 5. Epiphytes and epizoa diversity and average number on *Halodule uninervis* leaves collected from Doha, Dbaiyyah and Nuwaiseeb. Values represent average of organism's number on leaves of twenty randomly selected ramets collected during August and May.

	Average no. of organisms/shoot					
Location	**Doha**		**Nuwaiseeb**		**Dbaiyyah**	
Sampling date	**May**	**Aug**	**May**	**Aug**	**May**	**Aug**
Diatoms	2550.1	161.7	1735.0	107	89.6	150.5
Unknown prostrate alga	228.5	20.6	111.4	0	0	0
Red algae	0	0	3.6	7.2	17.8	6.2
Epifauna	0	2.1	2.6	1.1	12.2	1.7
cyanobacteria	0.2	4.8	9.8	0	0	4.9

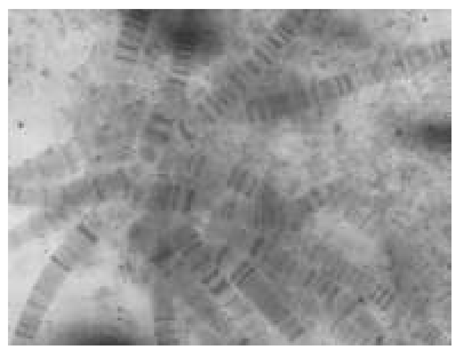


(a)



(b)

(c)



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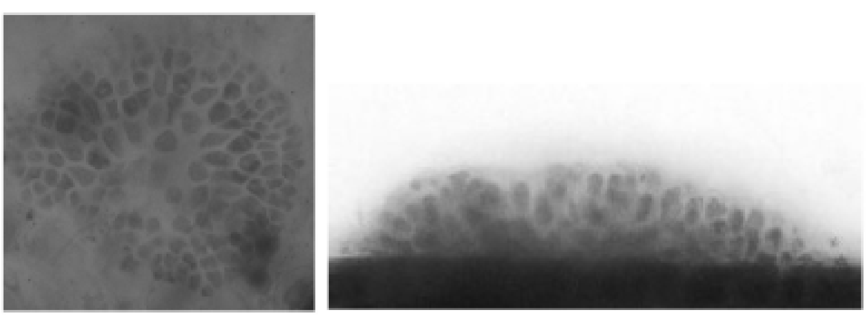

(e)

Fig. 5. Images taken under scanning electron microscope (a, c), and light microscope (b, d, e) of different epiphytes and epizoa attached to *Halodule uninervis* leaves collected from Doha, Dbaiyyah, and Nuwaiseeb. (a) *Cocconies sp*., a diatom ;(b) *Polysiphonia sp*., a red alga; (c) *Clytia ap*., an epifauna ; (d) *Calothrix sp*., a cyanobacterium; and (e) an unknown prostate alga.

The diatom *Cocconies* sp. were by far the most abundant epiphyte on seagrass shoot and the biovolume (Figure 6) of this species was highest in August at the three sites.

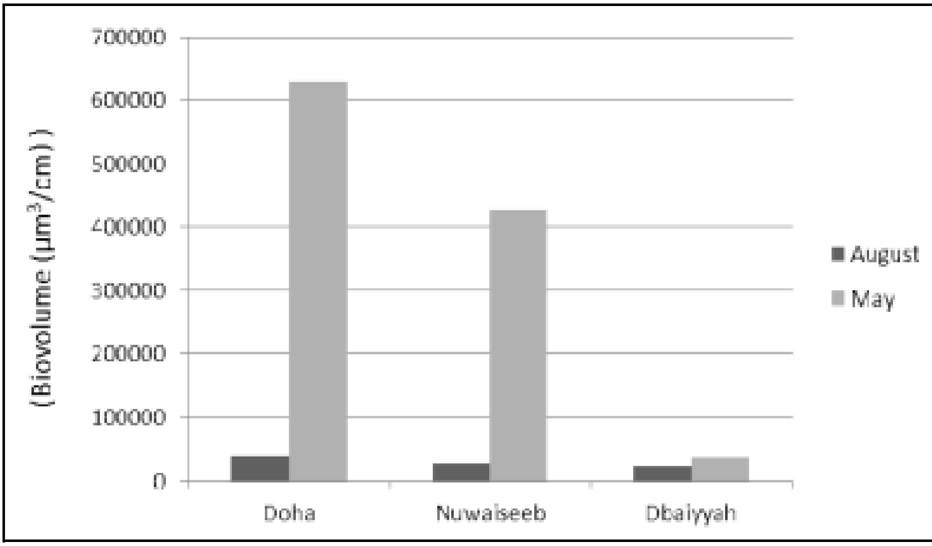

Fig. 6. Biovolume of epiphytic of *Cocconies* sp. attached to *Halodule uninervis* leaves collected from intertidal meadows of Doha, Dbaiyyah, and Nuwaiseeb during August and May.

Polysiphonia was observed in both Dbaiyyah and Nuwaiseeb, but not in Doha. Epifauna were found mostly on the upper segments of the mature seagrass leaves in all sites.

DISCUSSION

Analysis of the texture of the sediments of all three sites showed the sediments to be almost the same, Doha was composed of loamy sand and Dbaiyyah and Nuwaiseeb were of sandy sediment. It was found that although some seagrasses are able to colonize rocks and soft substrates (Larkum *et al*., 2006). *Halodule uninervis* at all study sites was confined to the sandy sediment, even if shallow, and not in muddy sediments or rocky platforms.

Seagrass rhizomes and roots penetrate the sediments creating more pore spaces, whereas in the bare areas the percentage of pore space is less due to the absence of seagrass roots and rhizomes. At the same time, seagrass act as sediment trap (Larkum *et al*., 2006) and hence sediment thickness of meadow areas at all study sites was higher than bare areas.

At all study sites, the distribution of *H. uninervis* beds were mainly restricted to tidal pools formed during low tide, obviously to avoid direct exposure to high air temperature (up to 50°C). Doha tidal pools are generally shallow due to its rocky platform topography. Therefore, evaporation plays an important role in increasing salinity, which affects the survival of *H. uninervis* beds. The daily exposure of seagrass beds is less at Dbaiyyah and Nuwaiseeb, where intertidal areas are relatively steep in slope and therefore low tide does not expose large areas.

At the same time, the large tidal pools in Dbaiyyah and Nuwaiseeb are in close contact with seawater from subtidal zone which provides constant influx of seawater, there by reducing the elevated salinity and temperature compared to Doha. Topography influence exposure level at flat platform intertidal areas of Doha result in vastly exposed areas whereas, intertidal areas with steep topography at Dbaiyyah and Nuwaiseeb are characterized by narrower exposed areas.

The daily exposure of seagrass beds, particularly at the Doha site, appeared to reduce seagrass cover and increase fragmentation of the beds (i.e. lower shoot density and biomass) and decrease shoot length. This is because exposure intensified the effects of various factors such as temperature, salinity and desiccation, especially during summer months (Fonseca & Bell, 1998). The biomass and shoot density of *Halodule uninervis* increased to a maximum at mid-summer and a reduction is observed thereafter through either leaf shedding or destruction by temperature, salinity and/or evapotranspiration, particularly at Doha site.

The presence of a rocky platform at Doha site appeared to be unfavorable for *Halodule uninervis* growth and development, confining them to the sandy areas.

Halodule uninervis has the broadest temperature and salinity tolerance among all seagrasses (Masini *et al.,* 2001) and can even survive brief exposure during low tide (Sheppard *et al*., 1992). At Doha, low tide could last for a few of hours (2-4 h), during which *H. uninervis* is exposed to ambient temperatures above 45°C affecting the growth and development of the species directly or indirectly through evapotranspiration or increased salinity

The data on salinity indicated that *Halodule uninervis* is not restricted to narrow limits of salinity, particularly in Kuwait bay. The species may be considered euryhaline because it appears to thrive well in oceanic to hypersaline waters **(**den Hartog, 1970**)**. The shedding of leaves during August could be an adaptation to combat high salinity and temperature.

Turbidity was inversely related to shoot length at all three study sites. At Doha, where *Halodule uninervis* shoot length was the shortest, turbidity was higher during the summer months. Turbidity at Doha site is caused by suspended particulates that flowed from Shatt Al-Arab and Iranian rivers into Kuwait Bay. On the other hand, Dbaiyyah and Nuwaiseeb, which are situated at the south have much lower turbidity.

Morphologically *Halodule uninervis* could be of narrow leaf (0.5- 1 mm in width) or wide leaf (up to 1 cm) type (Waycott *et al*., 2004). Examining the morphology of local *Halodule uninervis,* it can be seen that it is of the narrow leaf type (1 mm width) which is usually associated with intertidal zone (Waycott *et al*., 2004) and the type having generally shorter leaves than other regions, for example, it ranges between 5 and 15 cm in Australia and Indonesia (Green & Short, 2003) whereas in Kuwait it ranges between 1.4 and 7.8 cm. This reduction in height seems to be in connection with exposure and high temperatures as explained earlier. In addition, there are always 3 leaves per shoot in the local species, whereas it range between 2-4 leaves in those regions (Green & Short, 2003). The longest leaf is in lateral position, whereas the shortest leaf is in either mid or lateral position. Internodes of local *H. uninervis* are long compared to those of other regions, where it can be as short as 1 mm only (Vermaat *et al*., 1995). The faster the plant is growing the shorter these internodes are (Hedge *et al*., 2009; Schwartzchild & Zieman, 2008). The long internodes of local *Halodule uninervis* reflect its slow growth resulting from harsh conditions it is exposed to.

In the present study, concentrations of all tested heavy metals in sediment and in *Halodule uninervis* tissues (leaves and rhizomes) were below toxic levels. The upper limit of nontoxic levels of copper, lead, nickel and iron in seawater sediments were 250, 80, 225 $\mu g\ g^{-1}$ and 20.80 $\mu g\ g^{-1}$, respectively (Pendias, 2001; Prasad, 1999). The slightly elevated concentration of heavy metals at the Doha site may be attributed to the presence of shipwrecks that leaches iron into surrounding water and sediments, in addition to industrial wastes from the Shuwaikh area and along the Doha coastal area, other than chemical effluent discharge from the nearby desalination plants.

There is five times more P in Doha sediments than in southern locations probably due to same reasons as mentioned above. It is well documented that higher nutrition level and pollution in seawater can result in higher periphytic diatoms load (see for example Bothwell, 1988).

Diatoms constitute an important part of the epiphytic flora. These are usually pinnate and are largely dominated by species of *Cocconies* (family cocconiedaceae, order Achnanthales) (Fourtanier & Kociolek, 1999), which grow all the year round with a maximum occurrence in May. During May and especially in Doha, *Cocconies* sp. formed a continuous monospecific layer on the colonized leaves. It grows firmly attached to the substratum by a gelatinous pad which can resists any strong water currents.

The diversity and density of epiphytes and epifauna assemblages peaked from late spring to mid-summer, i.e the period of rapid growth of the seagrass. During this period the epiphytes were concentrated on the upper segments of mature leaves. However, during late-summer more epiphytes were found on the lower segments of leaves. This was probably due the discoloration and damage of leaf tips.

CONCLUSION

Halodule uninervis is a dominant seagrass along the shallow coastal waters of Kuwait. Further survey is necessary to determine the distribution of this species as well as other species of seagrass. The significantly higher turbidity in Doha compared to the two southern locations and the nature of the tidal pools are most likely the reason for the difference in growth of *Halodule uninervis* in this location compared to others. Most of the meadows in the intertidal zone were in tidal pools of loamy sand and sandy sediment. Due to topography at south, tidal pools have a continuous influx of seawater, which significantly reduced the temperature and salinity of these tidal pools in summer. On the other hand, the flat topography at Doha creates discrete tidal pools during low tide. Meadows in these isolated tidal pools experienced temperatures above 45 ^{o}C, which appear to affect the growth and development of *Halodule uninervis*. Leaf shedding observed in late summer may be an important survival mechanism for the plant to escape exceedingly high temperatures and salinity in late summer. This shedding can also help to discard the dense epiphytes on leaves that increased from late spring to midsummer.

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عشب البحر المد جزري *Halodule uninervis* : عوامل تتحكم في الكثافة، الكتلة الحيوية، وطول السيقان النباتية

ضياء البدر و داود شعيل و رضا الحسن و باتريس سليمان
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خلاصة

ينتشر عشب البحر من نوع *Halodule uninervise* على شكل رقع متفرقة في المناطق الساحلية الكويتية، ولكن توزيع هذه المروج في جون الكويت يبدو في تراجع. وقد تم التحقق من العوامل الفيزيائية والكيميائية والحيوية لتحديد تأثير هذه العومل على الكتلة الحيوية، كثافة السيقان النباتية، وطول هذه الأعشاب البحرية في ثلاث مواقع متباينة. وظهرت زيادة متميزة في الكتلة الحيوية، الكثافة النباتية، وطول هذه الأعشاب البحرية في المروج الجنوبية مقارنة بتلك التي في الدوحة في جون الكويت. وحيث تميزت الأعشاب في المناطق المد جزرية الدنيا عن تلك العليا بطول أوراقها. إن طبيعة البرك المائية أثناء الجزر هي العامل الرئيسي المحدد لمدى تعرض هذه الأعشاب للانكشاف للهواء أثناء الجزر. حيث أن معظم هذه المروج الموجودة في المنطقة المد جزرية تكون في برك مائية من تربة الطفال الرملي إلى التربة الرملية. والبرك المائية في الحقول الجنوبية في المنطقة المد جزرية تكون متصلة مع مياه البحر وبالتالي يتوفر لها تجدد مستمر من مياه البحر مما يخفض درجة الحرارة والملوحة في هذه البرك أثناء الصيف. وتتزايد كثافة السيقان النباتية والكتلة الحيوية في جميع المناطق الثلاث أثناء السنة، لتصل إلى الحد الأعلى أثناء شهر يوليو، وبعد ذلك تبدأ أوراق هذه النباتات بالتساقط في آلية هروب واضحة وبالأخص الأعشاب البحرية بالدوحة. إن المروج في هذه المنطقة توجد في برك مائية منعزلة أثناء الجزر وتتعرض لدرجات حرارة تتعدى 45 درجة سيليزية أثناء الصيف. وعكارة المياه في الدوحة مرتفعة بدرجة متميزة عن باقي المواقع وبالتالي تقلل تلك العكارة من الضوء المتوفر لهذه الأعشاب البحرية. وبالنسبة لتركيز المعادن الثقيلة في التربة وفي الأنسجة النباتية فهي أقل من النسب السامة لتلك المعادن في جميع المناطق المدروسة. وأظهرت الدراسة أن تنوع وكثافة النباتات الدقيقة الملتصقة على أسطح أوراق الأعشاب البحرية كانت أيضاً عالية من فترة آخر الربيع إلى منتصف الصيف، والتي هي فترة النمو السريع لهذا النوع من الأعشاب البحرية.

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سلسلة علمية محكمة

تُعنى موضوعاتها بمنطقة الخليج والجزيرة العربية، وتهدف إلى إبراز خصوصيتها، ورصد قضايا التنمية بأبعادها الحضارية الشاملة في ضوء المتغيرات الجارية.

قواعد النشر

أولاً : أن يكون البحث أو (الدراسة) معنية بشؤون منطقة الخليج والجزيرة العربية في المجالات الآتية: السياسة، الاقتصاد، الجغرافيا، التاريخ، علم النفس، الاجتماع، الأنثروبولوجيا التربية، اللغة العربية وآدابها، الثقافة، البيئة، القانون، الإعلام ، التراث (الآثار والحضارة والفنون) .

ثانيــــاً: أن تمثل الدراسة إضافة جديدة إلى حقل التخصص.

ثالثـــاً: لم يسبق تقديمها أو جزء منها للنشر إلى جهة أُخرى.

رابعـــاً: ألا يقل عدد صفحات البحث أو (الدراسة) عن ١٠٠ صفحة.

خامساً: يقدم المركز مكافأة مالية رمزية عن كل دراسة.

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