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Mapping the distribution and occurrence of four newly recorded species of seagrasses in the North-West Arabian Gulf

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Abstract - For a long time the Iraqi regional waters of north-west Arabian Gulf were classified as free of seagrasses due to the absence of the information concerning these important angiosperms. During the survey carried out by scientist of the Marine Science Center and German divers in 2013-2014 to study the Coral reefs distribution and occurrence in this area, the divers with the help of underwater camera caught photos indicates the existence of seagrass meadows in different places of the north-west Arabian Gulf, so the efforts were made to examine this issue and a work were carried out in April 2017 to study the existence, species composition, occurrences and distribution of seagrass species in the Iraqi marine waters of the north-west Arabian Gulf for the first time. Six sites were chosen distributed along the north-west of Arabian Gulf where the depth was ranging from 0.5 to 15.0 m. Six meadows of seagrass were identified, classified, mapped and seagrass diversity and abundance were investigated. Four species of seagrass namely *Halophila stipulacea* (Forsskal) Ascherson, *Halophila ovalis* (R. Brown) Hooker f., *Halophila decipiens* Ostenfeld and *Halodule uninervis* (Forsskal) were recorded for the first time in Iraq. *Halophila decipiens* Ostenfeld was recorded as a new to the whole area of the Arabian Gulf and the Iraqi marine waters and found at a depth of 12-15 m. *Halodule uninervis* was found to be the most dominant species at all the studied sites followed by *Halophila stipulacea*. The total seagrass area estimated at all the stations was about 678 hectare fluctuated at different stations. Higher Seagrass total coverage area (240 ha) was found at shallower waters (0.5-3.0 m) compared with 60 ha at deeper waters (12-15 m). The exposed locations showed low seagrass coverage of 35 % comparing with sheltered sites (65 %). The relationship between depth and total coverage of seagrass was significant, while it was not significant with sites. Highest richness value was found in the Alkheran area (Khor Al-Zubair) at a depth of 0.5 m. The relative evenness of the seagrasses species, with different depths showed that the depth 0-3 m has the highest value. The distribution of seagrasses in Khor Al-Zubair and Khor Abdullah down to the open area of Khor Al-Omaya was mapped by using the GIS and Arc Map version 10.5 applications.

Key words: Mapping, Seagrass, Arabian Gulf.

Introduction

Over 10,000 years Seagrasses have been used by humans to fertilize fields, build houses, make furniture, thatch roofs, make bandages and so on (Vassollo, 2013). Seagrasses support commercial fisheries and biodiversity, clean the surrounding water and get rid of carbon dioxide (Orth, 1984; Coles *et al.*, 1993). For those reasons seagrasses are believed to be the third most valuable ecosystem in the world, it consists 0.2 % of global ocean (Duarte, 2002). Seagrasses sometimes called the "lungs of the sea" because one square meter of seagrass can produce 10 liters of oxygen every day and help to distribute the dissolve oxygen (Komatsu, 1989;

Komatsu *et al.*, 1990; Short, 2011). The leaves of Seagrass can absorb nutrients and slow the flow of water, capturing sand, dirt and silt particles. Their roots trap and stabilize the sediment, which helps improve water clarity and quality and reduces erosion and protect coastlines against storms (Ward *et al.*, 1984; de crissac and Boudouresque, 1985; Komatsu and Nakaoka, 2000; Komatsu and Yamano, 2000). Seagrasses are often regarded as a nursery habitats because they provides shelter for small invertebrates, small fish and juveniles of larger fish species (Boudouresque and Herbiers, 2006; Diaz-Almela and Duarte, 2008; Buchet, 2015). Many microalgaal species, bacteria and invertebrates grow as "epiphytes" directly on living seagrass leaves. Seagrasses regarded as home to many fishes (Jackson *et al.*, 2001), sharks, turtles, marine mammals, mollusks, sponges, crustaceans, polychaete worms, and so on (Arasaki and Arasaki, 1978).

The seagrasses of the Arabian region have been studied by several workers (Price, 1992). Most work has been done in the Red Sea (e.g. den Hartog, 1970; Aleem, 1979; Jacobs and Dicks, 1985, Price *et al.,* 1988, Eslam *et al.*, 2010; El Shaffi, 2011; El Shaffi *et al.*, 2014) and in the Arabian Gulf area (Basson *et al.*, 1977; Price and Coles, 1992; Durako *et al.*, 1993; Kenworthy *et al.*, 1993). Only four species are known to occur in the Gulf, with most communities dominated by smaller-bodied species, *Halodule uninervis* (Forssk.) Aschers., *Halophila ovalis* (R. Brown) Hook. f., and *Halophila stipulacea* (Forssk.) Aschers. (Basson *et al.*, 1977; Coles and McCain, 1990; Price, 1992; Price and Coles, 1992; Kenworthy *et al.*, 1993). A large species, *Syringodium isoetifolium* (Aschers.) Dandy, occurs in the Arabian Gulf, but it is very rare (Jupp *et al.*, 1996). Al-Bader *et al.* (2014) studied the factors controlling the density, biomass and shoot length in *Halodule uninervis* in the coast of Kuwait, while Al-Arbash *et al.* (2016) studied the biochemical response of the seagrass *H. uninervis* to changing in salinity in Kuwait bay. In Iraq there was no any record of seagrass species existence so far. This is the first study on the species composition, occurrence and distribution of seagrasses in the Iraqi regional waters of the north west of the Arabian Gulf.

Materials and Methods

The distribution, density and species composition of seagrass meadows were studied on April 2017, in north-west Arabian Gulf. Sampling along six stations represented different ecological habitats from in-shore and offshore, shallow and deep waters (0.5 m to 15.0 m depths) were selected (Fig. 1). St.1 in Alkheran area at Khor Al-Zubair (30° 11' 17.44″ N & 47 ° 53 ' 31.76″ E), St. 2 in Khor Al-Zubair port (30.4 °4 ' 26″ N & 42 °47 ' 57.21″ E), St.3 in Al-Samta Island (30° 00' 23″ N & 47 ° 58 ' 52.48″ E), St.4 near Khor Abdullah port (30.1 °36 ' 72″ N & 48 °8 ' 15.88″ E), St.5 opposite to Al-Fao port (29 °51 ' 36.63″ N & 48 °23 ' 29.72″ E), St.6 in Khor Al-Omaya (29° 38' 28.82″ N & 48 ° 51 ' 42.83″). Stations 1 and 4 regarded as shelter stations, while stations 2, 3 & 6 were exposed ones. Marking of seagrass meadows were carried out when the seagrass beds were exposed in the intertidal area with a GPS. While in the shallow subtidal area (<10m depth) the marking of the meadows were made by using a boat going around each seagrass meadow and recorded them by using GPS attach to track every 5 seconds from single fixed position. Underwater camera were used to identify the continuous or scattered meadows and to determine the deep meadows. In the deep waters (>10 m depth), the seagrass meadows were mapped, using mixed of transects and spots, in the same way of mapping the shallow subtidal beds. Seagrass meadows were mapped using the GIS with Arc Map vers.10.5 applications. To estimate the diversity and abundance of seagrasses, 6 transects ranges between 15 m and 150 m length each perpendicular to the shore. In each transect seagrass diversity and abundance was estimated. Five quadrates of 1m x 1m ($1m^2$) each were chosen randomly per each transect. Richness index and Evenness index were calculated according to Majurran (1988). Identification of seagrass species followed: Phillips and Menez, (1988); Kuo and Den Hartog (2001); Green and Short, (2003) and Waycott *et al.* (2004).

Figure 1. Sampling stations in the studied area.

Results

Four species of seagrasses were recorded for the first time from the north-west Arabian Gulf waters of Iraq (Fig. 1), namely *Halodule uninervis* (Forsskal), *Halophila decipiens* Ostenfeld, *Halophila ovalis* (R. Brown) Hooker f. and *Halophila stipulacea* (Forsskal) Ascherson (Fig. 2). The species *Halophila decipiens* is recorded for the first time in all the Arabian Gulf region including the Iraqi marine waters (Fig. 2; Plates 1, 2, 3 and 4).

The descriptions of these species are given below:

Order: Alismatales
Family: Cymodoceaceae
Genus: Halodule
Species: *Halodule uninervis* (Fig. 2, Plate 1)

Morphology: Dimensions of the leaf of this species are different with leaf blade it is up to 12 cm long. The leaf width ranges from 0.01-0.4 cm, with a linear shape. The sheath of the leaf is well developed and stays long after the blade is shed. The leaf has three longitudinal veins, the mid vein being the most obvious and easiest to identify. The margin of the leaf is smooth and the leaf tip has three distinct points (called “teeth”), one in the middle and one on each side. The stems are short, erect and vertical at each node and can hold 1-4 leaves. The rhizome is typically smooth.
Habitat: shallow and deep intertidal.

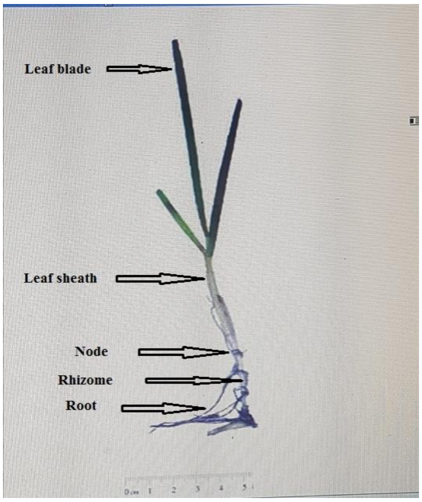
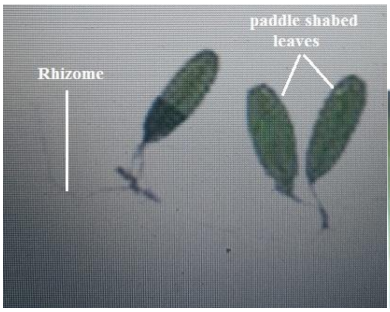


Figure 2. Plate 1. *Halodule uninervis*.

Order: Alismatales
Family Hydrocharitaceae
Genus: Halophila
Species: *Halophila decipience* (Fig. 2, Plate 2)

Morphology: The leaf blade is 2.3 cm long, 0.5 cm wide and paddle-shaped with hairs on both sides of the leaf blade. There are 6-9 unbranched cross leaf veins. The leaf margin is finely serrated and the leaf tip is rounded. The petioles are 3-15 mm long, each bearing pairs of leaves and they develop directly from the rhizome. The rhizome is smooth, thin and elongated.
Habitat: Deep coastal waters.



(A) (B)

Figure 2. Plate 2. *Halophila decipience*, (A) leaves (B) hairs on the leaves (10x)

Order: Alismatales
Family Hydrocharitaceae
Genus: Halophila
Species: *Halophila ovalis* (Fig. 2, Plate 3)

Morphology: The leaf blade is oval shaped up to 3 cm long and 1.0-2.0 cm wide. The leaf without sheets, there are two scales cover the base of the petiole. 10-28 branched cross veins are found in the mid vein. The leaf margin is smooth without hairs on the leaf surface. Petioles are 0.5-8.0 cm in length and arise directly from the rhizome. Each petiole supports leaf pairs. Rhizome is light in colour, smooth and thin.
Habitat: Shallow and deep coastal waters.

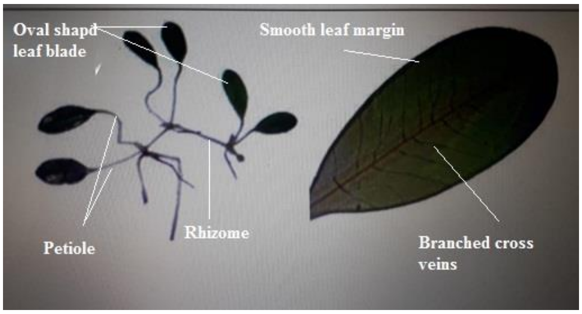


Figure 2. Plate 3. *Halophila ovalis* showing the oval shape leaves and smooth leaf margin.

Order: Alismatales
Family Hydrocharitaceae
Genus: Halophila
Species: *Halophila stipulacea* (Fig. 2, Plate 4)

Morphology: The leaf blade is linear to oblong in shape up to 5 cm long and 1.0 cm wide. The leaf sheath is large and transparent covering a short petiole. The veins of the leafs have 10-40 branched cross veins with a clear mid vein. The leaf margin is serrated and tiny hairs sometimes found on one side of the leaf surface. The leaf tip is rounded, and serrated. Two short stems, each carrying two leaves. The rhizome is smooth with long internodes and always covered by leaf scars at the stem base.
Habitat: Shallow and deep coastal waters.

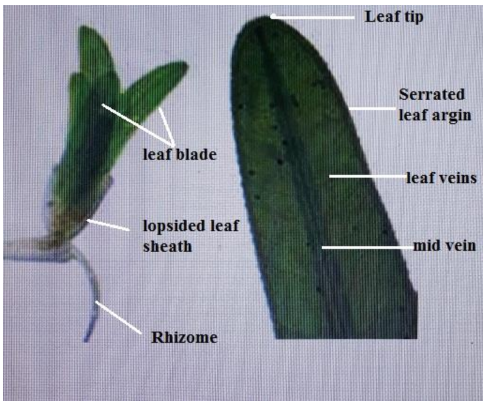


Figure 2. Plate 4. *Halophila stipulacea* showing leaf blade with lopsided leaf sheath, serrated leaf margin and veins.

The seagrass *Halodule uninervis* was the most common species recorded at 6 sampling stations followed by *Halophila stipulacea*, recorded at 5 stations (Fig. 3).

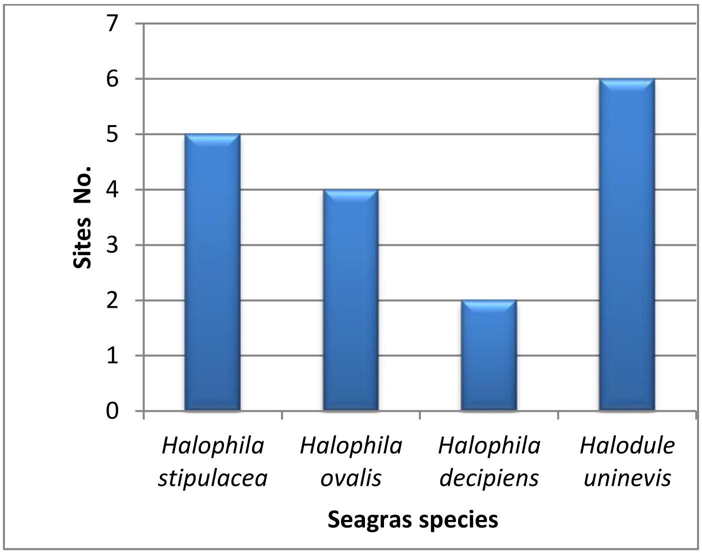


Figure 3. The occurrence of seagrass species in the different sampling sites

Six seagrass meadows were recorded along the coasts of the study area .The depth range was between zero and 15m. Seagrass meadows were estimated and the total area was 678 hectare. The largest meadow of 240 ha was recorded at station 1, while the smallest one (60 ha) was recorded at station 2 (Fig. 4). *Halophila uninervis* showed the highest total seagrass coverage area of 35.40%, recorded at site 1, while the lowest total coverage of 8.85% was showed by *Halophila decipiens* and found at site 2. Other seagrass sites coverage were lies between these values (Fig. 5).

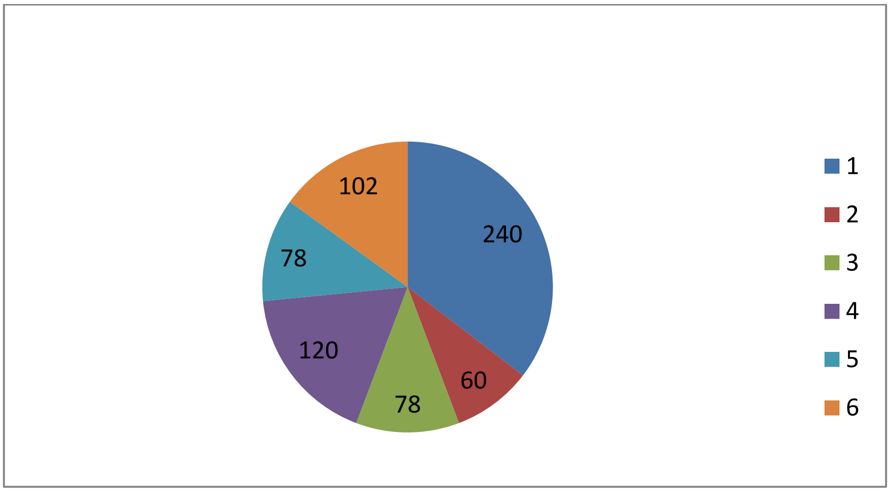


Figure 4. Estimated total seagrass area coverage in hectare at different stations.

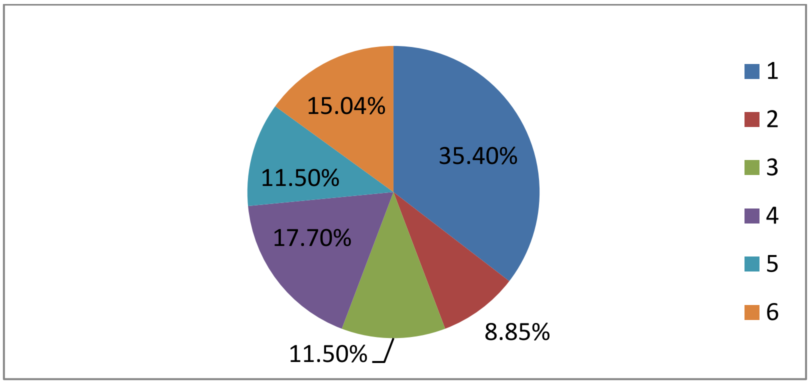


Figure 5. The total means coverage area of seagrass species at different sites

The exposed locations showed low seagrass total coverage area of 35.34% at stations 2, 5 & 6, compared with sheltered sites 64.60% at stations 1, 3 & 4 (Fig. 5). The shallow waters (less than 10m deep) indicated that they have more seagrass coverage (≅60%) than the deep waters (10-15m) which had ≅ 40% sea grass coverage (Fig. 6). The seagrass coverage area showed a reverse relationship with depth, i.e. when the depth increased, the total seagrass coverage decreased. The highest seagrass coverage were recorded at depth 0.5m at site 1, in contrast, the lowest seagrass coverage recorded at depth 15m at site 2 (Fig. 6).

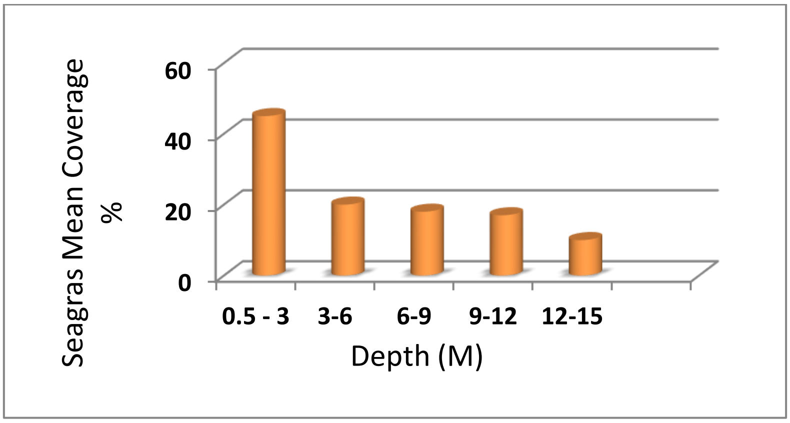


Figure 6. The relation between seagrass mean coverage area and depth.

The relationship between the depth and total coverage of seagrass was found significant ($p \leq 0.01$), while the relationship between the total coverage and sites were not significant ($p \geq 0.01$). Diversity index at different sites indicated that Al-Kheran area (station 1) showed the highest value of richness index (1.003), while station 2 (Khor Al-Zubair Port) showed the lowest richness value (0.332). Concerning the depth the highest richness value was recorded at depth 0-3m (1.211), while the lowest richness value of 0.345 was recorded at depth 15m. The evenness of the seagrasses species, with different depths showed that the depth 0-3m has the highest value of evenness (0.886), while the depth 15m has the lowest value of 0.679.

The final maps of the real and predicted seagrass species distribution in the studied area are given in Figure (7). The distribution and density of seagrass species in Khor Al-Zubair were shown at the top of the map, while the seagrass distribution and density in Khor Abdullah and the open area of Khor Al-Omaya are shown at the bottom of the map.

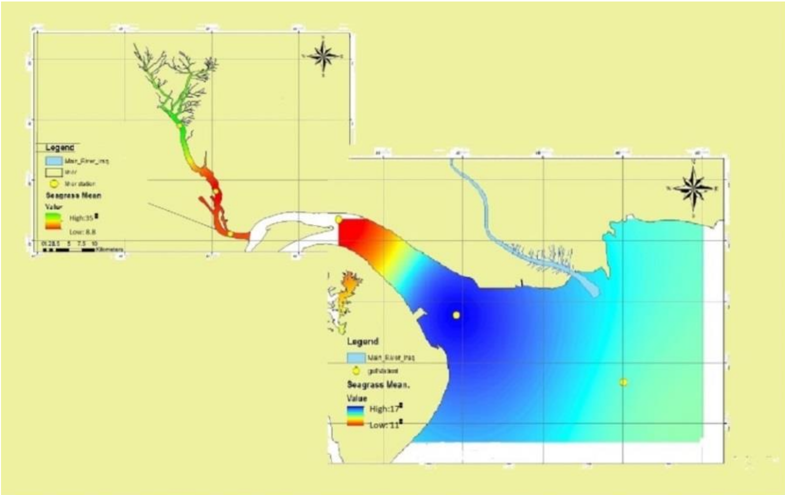


Figure 7. Seagrass occurrence and distribution map of Khor Al-Zubair (top) and Khor Abdullah and Khor Al-Omaya (bottom) using GIS and Arc Map Ver. 10.5.

Discussion

Fifty species of seagrasses were belonging to 12 genera were recorded all over the world. Eleven species were reported from the Arabian region (Sheppard *et al*., 1992). While Seven species were listed from the Gulf of Aqaba and five from the Gulf of Suez (Green & Short, 2003). Four species namely (*Halodule uninervis, Halophila decipiens, Halophila ovalis* and *Halophila stipulacea*) are known from the western Arabian Gulf, *H. uniniveris* is the most common species (Price *et al*., 1987; Price and Coles,1992; Philips, 2003).The fourth species *Syringodium isoetifol* was reported from Abu Ali in the Arabian Gulf. This is in agreement with the results obtained in this study. The three species *H. stipulacea, H. ovalis* and *H. uninervis* recorded in this study are new records for the Iraqi marine waters after along lack of interest in these angiosperm (Erflemeijer and Shuail, 2012). *Halophila decipience* is a new records for Iraq and the Arabian Gulf region, it was recorded at depths between 12-15m in two sites only St. 2 & 6. This species was recorded in the Red sea from two locations by Jacobs and Dicks (1985) in the Gulf of Suez at 30 m deep and by El-Shafii (2014) at 7 m and 42 m in waters off the southern Egyptian coast. The distribution of this species in the Red Sea and the Arabic region is unknown, but it is likely to be found throughout these suitable habitat (Al-Shafii, 2014). This species seems to enter these stations as alien species through ships stopped for a long time during the war and adapts itself to the habitats of these two ports (Khor Al-Zubair port and Khor Al-Omaya port) which explain why it is restricted for only these two locations (Ibrahim, In press).

The abundance of seagrasses in different depths is generally limited by light, however, other factors such as temperature, sediment composition, water motion, salinity and sheltering condition are limiting factors for the distribution and abundance of seagrasses (Backman and Barilotti, 1976; Larkum, 2006). Light regarded as the most important factor affecting depth zonation, moreover, the water in the Arabian Gulf is not transparent, a depth limitation of about 6-10m is common (Sheppard and Borowitzka). Only in one event when seagrasses been found in adepth of 17m far offshore (Basson *et al.*, 1977). In the Arabian Gulf, the development of seagrasses beds is affected hardly by changes in seasonal weather and temperature.

Some areas of sea beds may change their cover from 90% in summer season to third of this density in winter (Vousden, 1988). Price *et al.* (1988) found that Seagrasses species occurrence were control by the interaction of environmental conditions. Al-Bader *et al.* (2014) concluded that shoot density and biomass of *H. uninervis* were increased during the year reaching a maximum density in July, after which these plants shed their leaves by an escape mechanism. Price *et al.* (1988) concluded that the interactions of environmental factors probably control the occurrence of individual seagrass.

The estimated area of 600 ha of seagrass in the studied area is extended inshore and offshore from depths of 0-15m. The largest meadow of 240 ha was recorded in Al-Kheran site (St.1) at the mouth of Khur Al-Zubair, while the smallest meadow of 60 ha was recorded at the middle of Khur Al-Zubair port. A number of branches like tree branched were distributed around station 1 (Fig. 1) which regarded as the main sources of organic matter, essential minerals and sediment characteristics for the seagrass meadows in the area (Fig. 1). Garcia and Duarte (2001) indicated that the input of organic matter and the accumulation of seagrass detritus in the sediments increase the amount of microbial substrates in the sediments while Larkum *et al.* (2006) and Eslam Osama *et al.* (2010) recorded that the deposition of finer sediments is an important factor limiting seagrass distribution. All species recorded during this study were found in waters at depth ≤10m except *H. decipience* which was found in waters at depth 12-15m deep. The total coverage of seagrasses showed a general trend of decreasing with depth (Fig. 6). Sheltering conditions exhibit significant effect on seagrass abundance and distribution. Backman and Barilotti (1976) suggested that wave action is considered as limiting factor for seagrass abundance and distribution.

References

Al-Arbash, A., Al-Bader, D. 2016. Structural and biochemical responses of the seagrass *Halodule uninervis* to changes in salinity in Kuwait Bay, Doha area. Kuwait J. Sci., 43(4): 131-142.

Al-Bader, D.A., Shuail, D.A., Al-Hassan, R. and Suleman, P. 2014. Intertidal seagrass Halodule uninervis: Factors controlling its density, biomass and shoot length. Kuwait J. Sci., 41(1): 171-192.

Aleem, A.A. 1979. A contribution to the study of seagrasses along the Red Sea coast of Saudi Arabia. Aquat. Bot., 7: 71-78.

Arasaki, M. and Arasaki, T. 1978. Compilation of stories on algae. Tokai University Press, Tokyo, 228 pp.

Backman, T.W., Barilotti, D.C. 1976. Irradiance reduction: effects on standing crops of the eelgrass Zostera marina in a coastal lagoon. Mar. Biol., 34: 33-40.

Basson, P.W., Burchard, J.E., Hardy, J.T. and Price, A.R.G. 1977. Biotopes of the western Arabian Gulf. Aramco, Dhahran, 284 pp.

Boudouresque, C.F. Les Herbiers à Posidonia oceanica. In Préservation et Conservation des Herbiers à Posidonia Oceanica; Boudouresque, C.-F., Bernard, G., Bonhomme, P., Charbonnel, E., Diviacco, G., Meinesz, A.,Pergent, G., Pergent-Martini, C., Ruitton, S., Tunesi, L.L., Eds.; Ramoge Publication: Monaco, 2006; pp. 10–24.

Buchet, V. 2015. Impact assessment of invasive flora species in *Posidonia oceanica* Meadows on fish assemblage: An Influence on Local Fisheries?: The Case Study of Lipsi Island, Greece. Master's Thesis, University of Akureyri, Akureyri, Island, 31 March 2015.

Coles, S.L. and McCain, J.C. 1990. Environmental factors affecting benthic in faunal communities of the western Arabian Gulf. Mar. Environ. Res., 29: 289-315.

Coles, R.G., Lee Long, W.J., Watson, R.A. and Derbyshire, K.J. 1993. Distribution of seagrasses and their fish prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. Aust. Mar. Freshwater. Res., 44: 193-210.

Den Hartog, C. 1970. Seagrasses of the World. North Holland, Amesterdam.

Díaz-Almela, E. and Duarte, C.M. 2008. Management of Natura 2000 habitats. 1120 Posidonia beds (*Posidonion oceanica*); European Commission: Brussels, Belgium.

Duarte, C.M. 2002. The future of seagrass meadows. Environ. Conserv., 29: 192-206.

Durako, M.J., Kenworthy, W.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W. 1993. Assessment of the toxicity of Kuwait crude oil on the photosynthesis and respiration of seagrasses of the northern Gulf. Mar. Poll. Bull., 27: 223-227.

El-Shaffai, A. 2011. Field Guide to Seagrasses of the Red Sea. Gland, Switzerland: IUCN and Courbevoie, France: Total Foundation, 58 pp.

El-Shaffai, A.A., Hanafy, M.H. and Gab-Alla, A.A. 2014. Distribution, Abundance and Species composition of Seagrasses in Wadi El-Gemal National Park, Red Sea, Egypt. Indian Journal of Applied Science, 4(3): 1-8.

Erftemeijer, P. and Shuail, D.A. 2012. Seagrass habitats in the Arabian Gulf: distribution, tolerance thresholds and threats. Aquatic Ecosystem Health and Management, 15: 73-83.

Eslam, O., Hassan, A.M. and Abou Zaid, M.M. 2010. Distribution and status of seagrass beds around Hurghada area, Red sea, Egypt. Egypt. J. Aqua. Res., 36(2): 293-304

Gacia, E. and Duarte, C.M. 2001. Sediment retention by a Mediterranean *Posidonia oceanica* meadow: The balance between deposition and resuspension. Estuarine, Coastal and Self Science, 52: 505-514.

Green, E.P. and Short, F.I. 2003. World Atlas of Seagrasses. Prepared by UNEP World conservation Monitering Center, University of California press, Berkeley, USA.

Ibrahim, F.H. (In press). Study on Ballast water of ships from North-West of Arabian Gulf.

Jackson, E.L., Rowden, A.A., Attrill, M.J., Bossey, S. and Jones, M. 2001. The importance of seagrass beds as a habitat for fishery species. Oceanogr. Mar. Biol., 39: 269-304.

Jacobs, R.P.W.N. and Dicks, B. 1985. Seagrasses in the Zeit Bay area and at Ras Gharib (Egyptian Red Sea Coast). Aquat. Bot., 23: 137-147.

Jupp, B.P., Durakom, M.J., Kenworthy, W.J., Thayer, G.W. and Schillak, L. 1996. Distribution, abundance, and species composition of seagrasses at several sites in Oman. Aquatic Botany, 53(3-4): 199-213.

Kenworthy, W.J., Durako, M.J., Fatemy, S.M.R., Valavi, H. and Thayer, G.W. 1993. Ecology of seagrasses in northeastern Saudi Arabia one year after the Gulf War oil spill. Mar. Pollut. Bull., 27: 213-222.

Komatsu, T. 1989. Day-night revision in the horizontal distribution of dissolved oxygen contain and PH in a Sargassum forest. J. Oceanogr. Soc. Japan, 45: 106-115.

Komatsu, T. and Nakaoka, M. 2000. Water flow and sedimentation rate in seagrass beds off Khao Bae Na in Trang province, Thailand. Biological Marine Mediterranea, 7: 240-242.

Komatsu, T. and Yamano, H. 2000. Influence of seagrass vegetation on bottom topography and sediment distribution on a small spatial scale in the Dravuni Island Lagoon, Fiji. Biol. Mar. Mediterr, 7: 243-246.

Kuo, J. and den Hartog, C. 2001. Seagrass taxonomy and identification key. Pages 31-58 in F.T. Short and R.G. Coles, eds. Global seagrass research methods. El Sevier Science, Amsterdam.

Larkum, A.W.D., Orth, R.J. and Duarte, C. (Ed). 2006. Seagrasses: biology, ecology and conservation. Springer: Dordrecht, Netherlands, 691 pp.

Majurran, A.E. 1988. Ecological Diversity and its measurement. Chapman and Hall. London, 179 pp.

Orth, R.J., Heck, K.L.J. and Van Monfrans, J. 1984. Faunal communities in seagrass beds: A review of the influence of plant structure and prey characteristics on predatory-prey relationships. Estuaries, 7: 339-350.

Phillips, R.C. and Menez, E.G. 1988. Seagrasses: Washington, D.C., Simthsonian Institution Press, Smithsonian Contributions to the Marine Science Series, No. 34, 104 pp.

Price, A.R.G. 1992. Seagrasses and other dynamic substrates. In: C.R.C Sheppard, A.R.G. Price and C.M. Roberts (Eds.), Marine Ecology of the Arabian Region: Patterns and Processes in Extreme Tropical Environments. Academic Press, London, PP: 141-160.

Price, A.R.G. and Coles, S.L. 1992. Aspects of seagrass ecology along the western Arabian Gulf coast. Hydrobiologia, 234: 129-141.

Price, A.R.G., Crossland, C.J., Dawson Shepherd, A.R., McDowall, R.J., Medley, P.A.H., Stafford Smith, M.G., Ormond, R.F.G. and Wrathall, T.J. 1988. Aspects of seagrass ecology along the eastern coast of the Red Sea. Bot. Mar., 31: 83-92.

Sheppard, C.R.C., Price, A.R.G. and Roberts, C.M. 1992. Marine ecology of the Arabian region: Patterns and Processes in Extreme Tropical Environments. Academic Press, London, 359 pp.

Short, F.T., Polidoro, B., Livingstone, S.R., Carpenter, K.E., Bandeira, S., Bujang, J.S., Calumpong, H.P., Carruthers, T.J.B., Coles, R.G., Dennison, W.C., Erftemeijer, P.L.A., Fortes, M.D., Freeman, A.S., Jagtap, T.G., Kamal, A.H.M., Kendrick, G.A., Kenworthy, W.J., LaNafie, Y.A., Nasution, I.M., Orth, R.J., Prathep, A., Sanciangco, J.C., Tussenbroek, B.V., Vergara, S.G., Waycott, M. and Zieman, J.C. (2011) Extinction risk assessment of the world's seagrass species. Biol. Conserv., 144(7): 1961-1971.

Vassallo, P., Paoli, C., Rovere, A., Montefalcone, M., Morri, C. and Bianchi, C.N.

2013. The value of the seagrass *Posidonia oceanica*: A natural capital assessment. Mar. Pollut. Bull., 75: 157-167.

Vousden, D.H.P. 1986. The Bahrain marine habitat survey. Project Report. Vols. 1&2., Environmental Protection Committee, State of Bahrain.

Ward, L.G., Kemp, W.M. and Boyton, W.R. 1984. The influence of waves and seagrass communities on suspended particulates in an estuarine embayment. Mar. Geol., 59: 85-103.

Waycott, M., McMahon, K., Mellors, J., Calladine, A. and Kleine, D. 2004. A Guide to tropical seagrasses of the indo-west Pacific. James Cook University, Townsville.