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ORIGINAL ARTICLE

Assemblages of macro-fauna associated with two seagrass beds in Kingdom of Bahrain: Implications for conservation

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KEYWORDS

Seagrass conservation;
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Abstract Seagrass ecosystems in Bahrain contribute significantly to the productivity of local fisheries and provide food sources and nursery grounds for vulnerable species. However, these ecosystems are under continuous threats from anthropogenic pressures, including reclamation and dredging, industrial effluents, domestic discharges, and brine water from desalination plants. Surveying seagrass beds and associated macro-fauna is required to contribute to management and conservation effort of these sensitive ecosystems. Macrobenthic assemblages were sampled from two seagrass beds off the western and eastern coasts of Bahrain that are subjected to different environmental conditions. Differences in structure and composition among the assemblages between the two sampling sites were detected. The western site was numerically dominated by crustaceans, while molluscs were the dominant group in the eastern site. Salinity and sediments were the main environmental factors responsible for explaining 44% of the community patterns in the study areas. Seagrass cover was 95 ± 3.6% and 78 ± 7.4% for the western and eastern sites, respectively. Implications of this study may allow better decisions to be made concerning the conservation of seagrass ecosystems in Bahrain.

1. Introduction

Seagrass meadows are highly productive ecosystems that provide important ecological functions and economic services (Sheppard et al., 1992; Duarte, 2002; Duffy, 2006). Ecologically, seagrass ecosystems provide food sources and function as nursery grounds for threatened species such as turtles and dugongs (Price et al., 1993; Preen, 2004). They can also improve water quality by stabilizing loose sediment and by filtering some pollutants out of the water (Duffy, 2006). Economically, they contribute significantly to the productivity of local fisheries (Vousden, 1995; Abdulqader, 1999).

Despite the important of these habitats, seagrass ecosystems are presently experiencing global decline primarily because of

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human disturbances, such as direct destruction of physical habitat, interference with the biological functions associated with seagrass beds, overexploitation, eutrophication and pollution (Erftemeijer and Lewis, 2006; Airoldi and Beck, 2007; Burkholder et al., 2007; Cabaco et al., 2008). In some parts of the world such as Bahrain, coastal and marine environments are the prime target for most of the major housing, recreational, economic and industrial developments (Naser et al., 2008). Reclamation and dredging activities may contribute directly or indirectly to the loss of seagrass beds, due to direct physical removal and burial, and the increase in turbidity levels (Zainal et al., 1993). Additionally, several land-based activities in the region affect the quality of coastal and marine environments, including industrial effluents, domestic discharges and brine water discharged by desalination plants. These activities are continuing threats for seagrass ecosystems in Bahrain. Therefore, there is a concern that the productivity of Bahraini coastal and marine environments could be affected by reduced functioning of seagrass ecosystems due to human-induced pressures (Abdulqader, 2001).

While efforts are being made to conserve seagrass ecosystems in Bahrain by establishing marine protected areas (Al-Zayani, 2003), there is still relatively little understanding of the role of seagrass habitat for associated plant, invertebrate, and fish communities. Therefore, baseline surveys of seagrass beds and associated macro-faunal assemblages are necessary to manage and conserve these fragile ecosystems (Naser, 2010). This study aims to characterize the community structure of macrobenthic assemblages associated with two seagrass beds located off the western and eastern coasts of Bahrain, and to explore the implications of conserving such beds in the light of the increased human pressure on the coastal and marine environments.

2. Materials and methods

2.1. Study area and sites selection

Seagrass beds are distributed along the southeast coast, and along the west coast of Bahrain (Vousden, 1995). Seagrasses in Bahrain are represented by three species, *Halodule uninervis*, *Halophila stipulacea* and *Halophila ovalis* (Phillips, 2003). Two subtidal seagrass beds were selected off the west (N 26°05.564, E 50°26.528) and east (N 26°00.840, E 50°43.124) coastlines of Bahrain (Fig. 1). The selected sites were of relatively comparable depths with approximate averages of 5 and 4 m for the western and eastern sites, respectively. At each site, a 1 km^2 sampling area was established and divided into nine stations at the intercepts points with a distance of 500 m between each one. This grid sampling design was adopted in order to investigate the spatial distribution of macrobenthic assemblages. The sampling was conducted in August 2006.

2.2. Measurement of environmental parameters

Environmental parameters including depth (*m*), water temperature (°C), salinity (psu), pH, dissolved oxygen (mg l^{-1}) and water transparency (*m*) were measured at each station using GARMIN FishFinder 240, glass thermometer, refractometer (Atago F/mill8901), Radiometer model pH 82, dissolve oxygen meter (Eil 7130) and Secchi disc, respectively. Measurements were taken at a depth of approximately 1 m below water surface.

2.3. Percentage cover of seagrass

Quadrats were photographed to estimate percentage cover seagrass non-destructively (Montefalcone, 2009). A quadrat (1 m^2) was deployed in each station by SCUBA diving and still photographs were taken. Percentage cover of seagrass at each station was calculated from five photo-quadrats using Image J 1.41 software. The mean percentage cover for the two sites was subsequently determined.

2.4. Sampling and treatment of macrobenthic invertebrates

Sediment samples were collected using hand-operated Van Veen grab (0.0675 m^2). In each station, four grabs were collected; three replicates for macroinvertebrates and one grab for organic content and grain size analysis of sediment. Macroinvertebrate samples were sieved in situ through a 1 mm sieve using seawater, transferred into labelled polyethylene bags, and stored under ice. At the laboratory, faunal samples were fixed using buffered formalin (4%) stained with Rose Bengal, and subsequently preserved using 70% ethanol. Organisms were sorted according to their taxonomic groups, counted and identified to the lowest possible taxonomic level using relevant identification guides (Jones, 1986; Green, 1994; Bosch et al., 1995; Richmond, 2002; Wehe and Fiege, 2002).

2.5. Sediment grain size analysis

The analysis of sediment particle size was carried out following Holme and McIntyre (1984), and involved sieving 50 g of homogenized sediment through a series of sieves on a mechanical sieve shaker (KARL KOLB). The weight of sediment fraction retained in each sieve was obtained and median particle size was determined. Another subsample of the homogenized sediment was used to determine the organic content by incinerating a known weight at a temperature of 550 °C for 12 h.

2.6. Statistical analysis

Univariate and multivariate analyses were employed to test for differences between the two sites. Ecological indices such as diversity index of Shannon–Wiener, Margalef's index of richness and Pielou's index of evenness were calculated. The spatial variation of macrobenthic assemblages was analysed by multidimensional scaling (MDS) based on Bray–Curtis dissimilarity index using square root transformed data. Environmental variables were analyzed based on Euclidean distance similarity measure. Environmental variables best correlated with patterns of macrobenthic assemblages were identified using Spearman coefficient (BIO-ENV analysis). Tests were performed using PRIMER® v 6 (Clarke and Gorley, 2006), and differences between the two sites were tested by one-way ANOVA using MINTAB v 12 statistical packages.

3. Results

3.1. Environmental parameters

There was a significant difference in salinity levels between western and eastern sites (55.1 ± 0.2 and 45.0 ± 0.0 psu for western and eastern sites, respectively ($P \leqslant 0.001$). Relatively

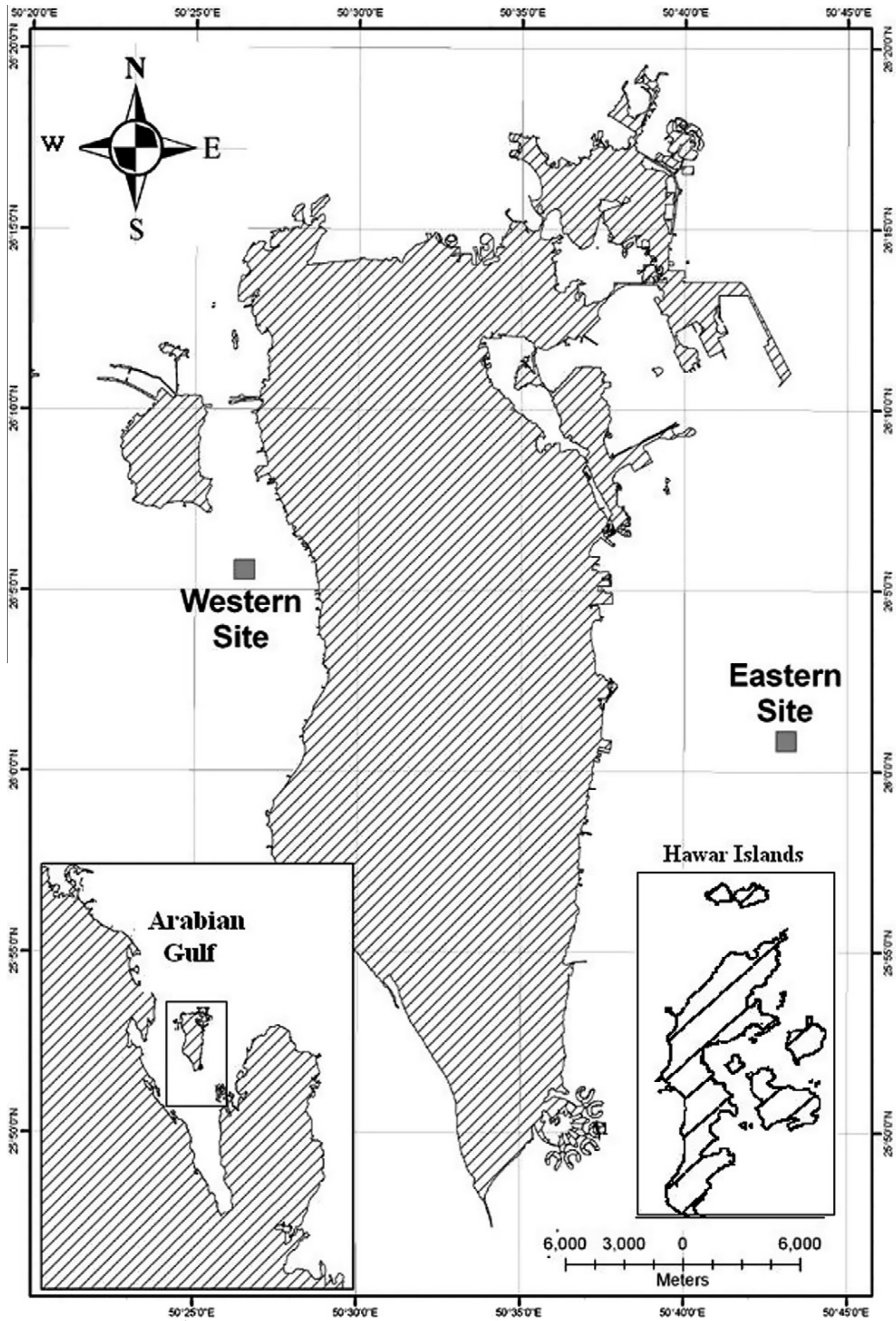

Figure 1 Map of Bahrain showing the locations of sampling sites.

comparable depths were detected in both selected seagrass beds (5.3 ± 1.9 and 3.9 ± 1.0 m for western and eastern sites, respectively). Sediments on both sites were categorized as medium sand. Although no significant difference was detected, sediment of western site was relatively finer ($Ø = 1.47 \pm 0.7$) than the eastern one ($Ø = 1.13 \pm 0.4$) (Table 1).

Non-parametric multi-dimensional scaling (MDS) (Fig. 2) for the environmental parameters revealed that eastern stations were clustering together indicating a higher level of similarity between these stations. Conversely, western stations were relatively scattered on the MDS. In particular, stations W1 and W2 showed higher levels of dissimilarity with the rest of stations, which could be attributed to the high percentage of clay (25%), and the depth (7.2 m), respectively.

3.2. Percentage cover of seagrass

Percentage cover of seagrass was higher in the western site (95 ± 3.6%) than the eastern one (78 ± 7.4%). The three species of seagrass were recorded in all stations of both sites with

Table 1 Environmental factors of the sampled station in the western and eastern sites.

Environmental variables	Depth (*m*)	Transparency (*m*)	Dissolved oxygen ($mg\ l^{-1}$)	pH	Salinity (psu)	Organic content (%)	Mean sediment particle (*Ø*)
Western site	5.3 ± 1.9	4.5 ± 1.2	5.0 ± 0.2	7.9 ± 0.3	55.1 ± 0.6	9.1 ± 3.8	1.47 ± 0.7
Eastern site	3.9 ± 1.0	3.4 ± 0.9	4.9 ± 0.3	7.9 ± 0.2	45.3 ± 0.0	2.9 ± 1.2	1.13 ± 0.4

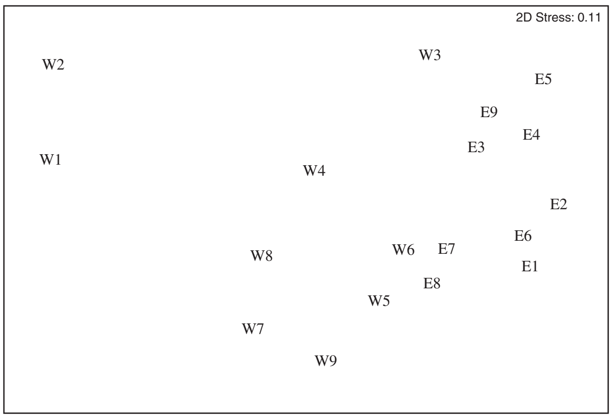

Figure 2 MDS plot for square-root normalized environmental parameters using Euclidean distance. ANOSIM: R = 0.514, P = 0.001. E = eastern site, W = western site, and numbers correspond with number of stations.

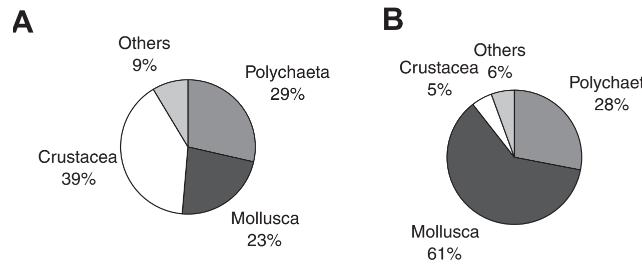

Figure 3 Numerical dominance among major taxonomic groups recorded in the (A) western and (B) eastern sites.

H. stipulacea being the most abundant followed by *H. uninervis* and *H. ovalis*. Generally, seagrasses in the western site were taller and denser with more limited sand patches between them than those found in the eastern site.

3.3. Faunal community structure

Differences in community structure were detected between the western and eastern sites. A total of 519 individual organisms belonging to 42 species were recorded in the western site compared with 887 individuals belonging to 40 species in the eastern site. In the western site, crustaceans were the most abundant among the major taxonomic groups followed by polychaetes, molluscs, and the remaining groups (ascidians, sponges and cnidarians), respectively. Conversely, crustaceans were the least dominant group in the eastern site, which was dominated by molluscs followed by polychaetes and the remaining taxonomic groups (Fig. 3).

Ecological indices namely, Shannon-Wiener diversity (H′), species richness (Margalef's R), and evenness (Pielou's J) were relatively higher in the western site than the eastern one (Fig. 4). However, only the evenness index was statistically significantly different (P = 0.045).

The MDS of faunal abundance revealed a clear separation between samples collected from the western and eastern sites (Fig. 5) suggesting pronounced differences in their community structure (ANOSIM: R = 0.541, P = 0.001). A similarity of 35% separated the eastern from the western stations. However, stations W3 and W9 exhibited distinctive dissimilarities with the rest of stations. Station W3, the shallowest (2 m), was devoid of echinoderms while station W9 was distinguished by the highest and lowest numbers of crustaceans and molluscs, respectively.

Correlations (Spearman) between environmental parameters and biotic assemblages indicated that 44% of the biota patterns were explained by a combination of salinity and the percentage of medium sand.

4. Discussion

Seagrass habitats support greater macro-fauna species diversity, abundance and biomass than adjacent unvegetated habitats (Coles and McCain, 1990; Ansari et al., 1991; Al-Khayat, 2007). But, there is often considerable variability in the macro-faunal assemblages associated with these seagrass beds (Worthington et al., 1992; Hemminga and Duarte, 2000), suggesting that various physical and chemical factors influence macro-faunal abundance and distribution within these seagrass meadows (Borum et al., 2004; Marba et al., 2006).

Salinity has a profound effect on seagrass distribution as well as abundance and composition of invertebrate fauna (Joyce et al., 2005). Despite the limited marine area of Bahrain, there are variations in salinity regimes around these islands. Salinities on the west coast of Bahrain are usually higher than those on the east coast (means of 50–57 and 43–45 psu for the west and east coasts, respectively) (Price et al., 1985). In this study, despite the high salinity in the western coast of Bahrain, seagrass cover was relatively high in the selected site. Seagrass cover is controlled by several interactive factors, including light, substratum type and water movements (Jones et al., 2002). The western site was characterized by high water visibility, fine sediment and moderate water movements in comparison with the eastern site. Price and Coles (1992) indicated that seagrass cover in the western Arabian Gulf coast shows significant positive correlation with latitude, but not with salinity, temperature or depth.

Sediment characteristics are major factors in governing the spatial distribution of marine benthos (Levinton, 2008). In the Arabian Gulf, grain size and sediment stability are main factors controlling subtidal sand communities (Basson et al., 1977). In the present study, the effects of salinity and sediments

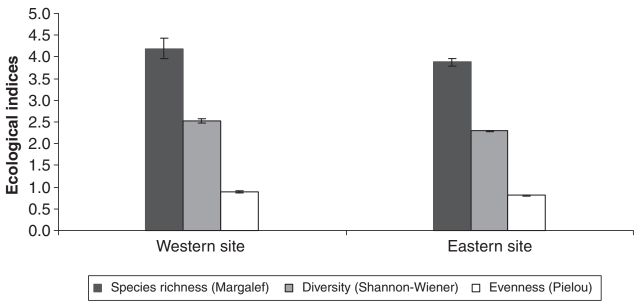

Figure 4 Ecological indices of faunal assemblages in the western and eastern sites.

in governing macrobenthos community patterns in the sampling areas were evidently reflected in the statistical analyses.

Species richness in the Arabian Gulf has been shown to be low in areas where high salinity dominates (Sheppard et al., 1992; Price et al, 2002). High numbers of individual organisms were associated with the eastern site, where the seagrass cover was relatively lower than the western site indicating that additional environmental factors such as salinity are affecting the abundance of macrobenthic assemblages off the western coast of Bahrain.

Conversely, the higher salinity on the western site did not restrict significantly the diversity of macrobenthic assemblages, which could be attributed to the higher densities of seagrasses and finer sediments. This is consistent with the general trend of increasing faunal diversity with decreasing sediment particle in the Arabian Gulf (Coles and McCain, 1990). Higher seagrass cover was reflected in the evenness of the community structure of the western site. Crustaceans only accounted for 5% of the total community population in the eastern site compared with 39% in the western site. Despite the extreme natural environmental conditions including high levels of salinity that may restrict richness of macrobenthos in the Arabian Gulf (Sheppard et al., 1992), seagrass beds maintain high levels of biodiversity and evenness. Therefore, conserving and managing these beds are deemed to be priorities due to the increased human-induced pressures on the coastal and marine environments.

Several implications could be derived from this study to conserve seagrass beds in Bahrain. Human-induced alterations of salinity and sediment characteristics due to hypersaline discharges and the massive reclamation and dredging activities in the marine environment of Bahrain could affect directly or indirectly seagrass beds and their associated biota. Recently, several major economic, housing and recreational projects based on or related to the coastal and marine environment have been undertaken at a rapid rate in Bahrain. Such mega-projects could interfere with water circulation and subsequently alter the salinity (Al-Jamali et al., 2005), which in turn may affect seagrass ecosystems.

Salinity has been shown to increase during the construction phase of major causeways in the Arabian Gulf (Price et al., 1985). Such implications should be incorporated into environmental studies for the proposed new causeway (ca. 40 km) linking between Bahrain and Qatar. This new causeway could alter the current velocities and salinity around Hawar islands. These islands host the most extensive seagrass beds in Bahrain (Phillips, 2003).

Fluctuations in salinity due to brine discharge from desalination plants may affect the marine biota (Miri and Chouikhi, 2005; Abdul-Wahab, 2007). For instance, Gacia et al. (2007) reported that the seagrass *Posidonia oceanica* showed some evidence of salinity stress such as lower rate of leaf growth and increased leaf necrosis as a result of brine discharge off the Spanish coast. In Bahrain, most of the major power and desalination plants are located on the east coast, which may result in cumulative impacts from the brine discharges.

Turbidity and sedimentation are commonly associated with dredging and reclamation activities, which may result in disappearance of seagrass beds from coastal areas mainly due to physical removal and/or burial (Erftemeijer and Lewis, 2006). Although sensitivity to burial varies among species, *H. uninervis* and *H. ovalis* showed 50% shoot mortality at a burial level of 2 cm (Cabaco et al., 2008). Within the last three decades, reclamation activities in Bahrain resulted in adding around 55.5 km^2 to the total land area (CIO, 2003), which could have impacted the surrounding seagrass beds. For instance, Zainal et al. (1993) reported a loss of 10.2 km^2 of seagrass beds on the east coast of Bahrain that were detected from remote sensing imagery

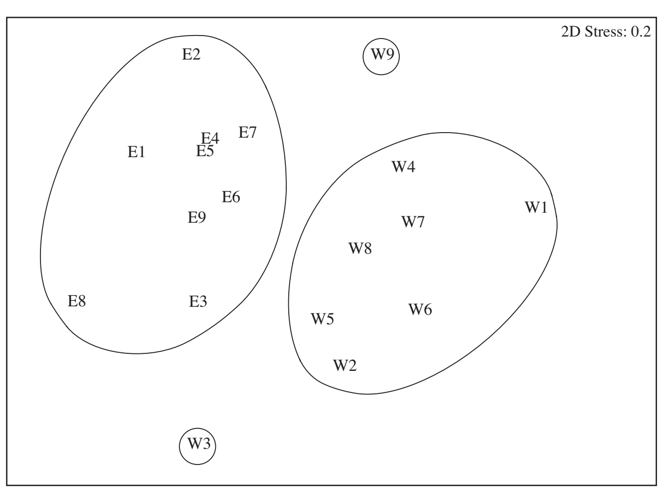

Figure 5 MDS plot for square-root transformed faunal abundance using Bray–Curtis similarity coefficient. Resemblance matrices were clustered to generate similarity of 35% on the MDS. ANOSIM: $R = 0.541$, $P = 0.001$.

between the period of 1985 and 1992, which was mainly attributed to dredging and reclamation activities.

5. Conclusions

Bahraini coastal and marine environments will continue to be a major focus for developmental projects. Therefore, it is important to maintain a balance between such legitimate developments and conserving coastal and marine environments. Seagrass ecosystems should be given a priority in the conservation and management efforts in Bahrain. Introducing effective mitigation measures that associated with environmental impact studies of major coastal and marine projects and enforcing existing regulations related to dredging and reclamation may contribute into conserving these ecosystems.

Additionally, conducting ecological baseline studies, and monitoring programs are essential parts of any effort to conserve seagrass ecosystems in Bahrain. These studies should not be limited to seagrasses, but also extended to investigate other primary producers such as algae and secondary consumers including macrobenthic and fish assemblages, and their interactions (Walker et al., 2001), which could increase the national and international conservational benefits of these habitats.

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