

The Effect of Habitat Structural Complexity on Gastropods in Anarid Mangrove Wetland

Haniyeh Ebadzadeh

Tarbiat Modares University

Mehdi Ghodrati Shojaei (✉ mshojaei@modares.ac.ir)

Tarbiat Modares University <https://orcid.org/0000-0002-5594-3730>

Jafar Seyfabadi

Tarbiat Modares University

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Abstract

Structural complexity of mangrove forests are thought to provide critical habitats for a variety of invertebrates. We studied the influence of mangrove structure and seasonality on the gastropod diversity in the extreme mangrove ecosystem of the Persian Gulf. Sampling was conducted in two successive years (February and June 2018, February and June 2019) at two mangrove habitats i.e., pneumatophore zone and mudflats. The communities were characterized by the dominance of specific taxa and the comparably low species richness. In total, 18 taxa were identified, including 14 species occurring in the mangrove forest and 16 species in the mudflats. Assimineidae dominated the community in both mangrove habitats. Mean density of gastropods was 1.5-fold higher in the pneumatophore zone ($86.12 \pm 135.21 \text{ ind.m}^{-2}$) than in the mudflats ($54.33 \pm 108.69 \text{ ind.m}^{-2}$). Species such as *Haminoea vitrea*, *Peronia verruculata*, *Assimineia mesopotamica* and *Platevindex tigrinus* were found to benefit from the presence of pneumatophores, which highlights the importance of local habitat complexity. Gastropod communities varied significantly between the habitats, but there was little difference in the community structure between seasons. Distance-based linear models revealed that total organic carbon and total organic nitrogen best explained the variation in gastropods community structure.

1. Introduction

Mangroves are valuable ecosystems in the intertidal zones of tropical and subtropical coastlines (Adame et al., 2020; Schwamborn et al., 2002). Being among the most productive ecosystems (Alongi, 2002; Bouillon et al., 2008), mangroves are important feeding and nursery grounds for a wide variety of marine species (Nagelkerken et al., 2008). Besides acting as natural barrier by reducing the energy of waves and storm surges (Saenger, 2002), mangroves mitigate climate changes by sequestering and storing atmosphere carbon dioxide in sediments (Taillardat et al., 2018). In the context of environmental health, mangrove play a crucial role in nutrient recycling and heavy metal remobilization and, therefore, improved water quality (Alongi, 2008; Hussain and Badola, 2010). Out of the total estimated 176 km² of mangrove habitats in the Persian Gulf and Gulf of Oman, Iran possesses the highest natural coverage of about 90 km² along the southern coasts (Delfan et al., 2021). This represents the northernmost boundary of mangrove distribution in the Indian Ocean. In Iran, the largest mangrove habitat is located in the Hara Biosphere Reserve enclosed between the northern coast of Qeshm Island and the coast of Khamir Port with an area of about 56 km². Only two mangrove species, namely *Avicenna marina* and *Rhizophora mucronata*, are present in this region, where the *A. marina* is the most common species

accounting for > 97% of the total tree cover.

Benthic invertebrates shape the structure and functioning of mangrove systems and play significant role linking mangrove-derived detritus and higher trophic levels (Lee, 2008; Delfan et al., 2020). Due to their limited mobility, benthic organisms cannot avoid environmental disturbances, which makes them important biotic indicators of coastal system health (Nordhaus et al., 2017). Gastropods are among the predominant groups of macrofauna in mangrove ecosystems (Delfan et al., 2021). They entrap primary production by grazing on fallen leaves and microphytobenthos in mangrove ecosystems (Hajializadeh et al., 2020; Nordhaus et al., 2009). Gastropods can reach a high biomass in mangroves and occupy different levels in the food web and, therefore, have significant impacts on energy flow and export of materials to the other ecosystems. In addition, gastropods play critical role

in maintaining the productivity of mangroves by cleaning their root systems from encrusting organisms (Koch and Wolff, 1996).

The complexity of mangrove habitats has been shown to have a positive relationship with species diversity (Kamal et al., 2017; Kiruba-Sankar et al., 2018). There is a general consensus that structurally heterogeneous habitats provide a wider range of niches, and different ways of exploiting environmental resources and thus increase species diversity (Kathiresan and Bingham, 2001). Several studies compared macrofauna communities in vegetated and unvegetated habitats and revealed that different microhabitats may contribute differentially to the density, biomass, and diversity (Boström et al., 2010; Macintosh and Ashton, 2002; Sheridan, 1997). However, the majority of reports are based on results of surveys conducted only in tropical systems where productivity is presumably high. To our knowledge, little is known about the effects of vegetation on the macrofauna community composition in arid mangrove systems. The knowledge of macrofauna diversity patterns across different habitat is important for better conservation practices in mangrove habitats (Nordhaus et al., 2006). Here, we examine differences in gastropods community and diversity patterns in mangrove vegetated and unvegetated microhabitats. We hypothesized that vegetated microhabitats would harbor higher diversity of gastropods than unvegetated microhabitats in the Persian Gulf.

2. Materials And Methods

2.1. Study area and sampling

The study was conducted in Khuran mangrove forest (Fig. 1), where only one tree species exist, i.e. *Avicennia marina* (Delfan et al., 2021; Shojaei et al., 2019). Tides are semidiurnal with an average height of 2–3 m during spring tides (Sheppard et al., 2010) that usually inundated the mangrove trees to the depth of more than two meters. The mean annual rainfall is about 185 mm (Hajjalizadeh et al., 2020). Air temperature range from a minimum of 6.4 °C to 46.6 °C (Mafi-Gholami et al., 2017). Gastropods were collected in two successive years during February and June 2018 and 2019 from six transects subdivided into two distinct habitats representing the pneumatophore zone and bare mudflats. Three quadrats (25×25 cm) were placed on the substrates from which organisms were hand-picked. Only live-collected specimens were taken into account, since empty shells can obscure the real diversity of gastropods. Gastropods were preserved in 70% ethanol for later identification. In the laboratory, species were identified to the lowest possible taxonomic level and the number of individuals were counted. Four environmental parameters were measured at each site including pH, salinity, temperature, and electric conductivity (EC) using portable device. Sediment samples were also taken for determination of sediment geochemistry, using sampling corer of 5 cm diameter and 5 cm depth. Samples were placed in plastic bags, labeled, and were kept at 4 °C until they were oven-dried at 60 °C. Total organic carbon (TOC) and total organic nitrogen (TON) were determined using Walkley-Black (Allison, 1975) and Kjeldahl methods (Bremner, 1960), respectively. In addition, the percentage of silt, sand and clay were determined using hydrometry methods (Bouyoucos, 1962). An environmental data matrix transformed ($\log x + 1$) and normalized prior to analyses (Clarke and Gorley, 2006).

2.2. Statistical analysis

For species diversity indices, i.e., Margalef's richness, Shannon-Wiener index (H'), Simpson, and Pielou's evenness index (J'), were calculated using DIVERSE analysis (Clarke and Gorley, 2015). Two-way ANOVA was

used to analyze the effect of habitats and seasons on species diversity indices. Taxonomic similarity between samples was calculated based on Bray-Curtis distance, whereas the similarity matrix of environmental variables were calculated using normalized Euclidean distance. Non-metric multidimensional scaling (nMDS) was used to visualize the possible similarity of gastropods composition between habitats and seasons. Similarity percentage analysis (SIMPER) analysis was used to identify the species that contributed most to differences between fixed factors. Two-way PERMANOVA design with season and habitat as fixed factors was used to determine the main effects of habitats and seasons on species composition. Spearman correlation was used to determine a collinearity among environmental variables. As none was collinear, all variables were tested. The univariate analysis was performed using SPSS (Version 16.0, SPSS Inc., Chicago, IL) and multivariate analysis was performed using Primer + PERMANOVA software package (PRIMER-E Ltd).

3. Results

3.1. Environmental variables

The recorded environmental variables are specified in Table 1. The PCA ordination of the environmental variables revealed clear habitat and seasons clustering (Fig. 2). The first two principal components explained 59.8% (PCA1 = 42.6%, PCA2 = 17.2%) of the variability in environmental data over the seasons and microhabitats. TOC, pH and EC were the major determinants of differences between seasons along the first axis, while temperature was influential along axis 2 (Table 2).

Table 1
Mean (\pm SD) of environmental variables in Khuran mangrove, Persian Gulf

	Season		Microhabitats	
	Winter	Summer	Pneumatophore zone	Muddy bank
PH	7.66 \pm 0.11	7.64 \pm 0.10	7.60 \pm 0.11	7.70 \pm 0.09
EC	6.38 \pm 2.76	6.29 \pm 2.35	7.2 \pm 2.51	5.42 \pm 2.24
TON	0.04 \pm 0.02	0.03 \pm 0.02	0.04 \pm 0.02	0.03 \pm 0.02
TOC	0.59 \pm 0.36	0.58 \pm 0.30	0.74 \pm 0.31	0.41 \pm 0.26
Temperature	24.28 \pm 1.18	32.17 \pm 1.17	28.40 \pm 4.27	28.49 \pm 4.02
Salinity	31.20 \pm 1.03	31.32 \pm 1.14	31.30 \pm 1.20	31.17 \pm 0.96

Table 2
PCA of environmental variables in Khuran mangrove, Persian Gulf

Environmental variables	PC1	PC2	PC3	PC4	PC5
PH	0.506	0.148	0.176	0.361	-0.565
EC	-0.502	0.262	-0.013	-0.167	-0.751
TON	-0.316	-0.275	-0.013	0.88	0.008
TOC	-0.565	-0.167	-0.204	-0.06	0.028
Temperature	-0.193	0.868	0.181	0.226	0.34
Salinity	-0.19	-0.229	0.946	-0.113	0.036

3.2. Gastropods

Results from the gastropod fauna collected within each of the four sampling events (February and June 2018, February and June 2019) indicated a generally consistent pattern among the sampling events. In total, 18 species were found, including 14 species in vegetated habitats and 16 species in un-vegetated habitats. Both habitats had 13 species in common (Table 3). The overall mean of gastropod density was higher at vegetated habitat ($86.12 \pm 135.21 \text{ ind.m}^{-2}$) than un-vegetated mudflats ($54.33 \pm 108.69 \text{ ind.m}^{-2}$). Only four species (*Mitrella blanda*, *M. cartwrighti*, *Pellamora densilabrum*, *Pseudominolia* sp.) were found in mudflat microhabitats, while two species (*Haminoea vitrea*, *Peronia verruculata*) were only found in vegetated microhabitats. The results of two-way ANOVA for the effects of season and habitat on species diversity showed that all diversity indices were significantly higher in summer relative to winter, whereas only Pielou's evenness index differed significantly between habitats (Table 4 and Fig. 3). In addition, there was no significant interaction between season and habitat. The mean density of gastropods in summer ($101.52 \pm 144.06 \text{ ind.m}^{-2}$) was higher than in winter ($44.69 \pm 88.48 \text{ ind.m}^{-2}$).

Table 3

Taxonomic list and mean density of each taxa in two habitats and seasons in Khuran mangrove, Persian Gulf

species	Genus	Family	Microhabitats		Season	
			Pneumatophore zone	Muddy bank	Summer	Winter
<i>Assimineea mesopotamica</i> (Glöer, Naser & Yasser, 2007)	Assimineea	Assimineidae	80	34.96	60.80	60.57
<i>Assimineea</i> sp.	Assimineea	Assimineidae	4.89	7.70	5.48	6.86
<i>Assimineea zubairensis</i> (Glöer & Naser, 2013)	Assimineea	Assimineidae	17.33	8.29	21.03	4
<i>Barleeia</i> sp.	Barleeia	Barleeiidae	2.22	0.59	2.74	0
<i>Cerithidium cerithinum</i> (Philippi, 1849)	Cerithidium	Cerithiidae	0.44	1.18	1.37	0
<i>Cyclostrema ocrinium</i> (Melvill & Standen, 1901)	Cyclostrema	Liotiidae	2.22	1.18	3.20	0
<i>Cyclostrema supremum</i> (Melvill & Standen, 1903)	Cyclostrema	Liotiidae	0.89	2.96	3.20	0
<i>Haminoea vitrea</i> (A. Adams, 1850)	Haminoea	Haminoeidae	6.22	0	6.40	0
<i>Iravadia quadrasi</i> (O. Boettger, 1893)	Iravadia	Iravadiidae	11	12.44	20	1.14
<i>Littoraria intermedia</i> (Philippi, 1846)	Littoraria	Littorinidae	0.44	2.96	2.74	0
<i>Mitrella blanda</i> (G. B. Sowerby I, 1844)	Mitrella	Columbellidae	0	3.55	2.74	0
<i>Mitrella cartwrighti</i> (Melvill, 1897)	Mitrella	Columbellidae	0	1.18	0.91	0
<i>Neverita didyma</i> (Röding, 1798)	Neverita	Naticidae	0.89	2.37	1.82	1.14
<i>Pellamora densilabrum</i> (Melvill, 1912)	Pellamora	Iravadiidae	0	2.37	1.83	0
<i>Peronia verruculata</i> (Cuvier, 1830)	Peronia	Onchidiidae	2.22	0	1.83	0.57

			Microhabitats		Season	
<i>Pirenella cingulata</i> (Gmelin, 1791)	Pirenella	Potamididae	1.08	16.22	6.60	8.78
<i>Platevindex tigrinus</i> (Stoliczka, 1869)	Platevindex	Onchidiidae	15.94	1.77	7.31	13.07
<i>Pseudominolia</i> sp.	Pseudominolia	Trochidae	0	0.59	0.46	0

Table 4
Results of two-way ANOVA of the effects of habitat and season on species diversity indices at Khuran mangrove, Persian Gulf. Statistical significances are indicated in bold.

Margalef richness index					Pielou's evenness			
Source	df	Mean Square	F	Sig.	df	Mean Square	F	Sig.
Habitat	1	0.001	0.009	0.927	1	0.119	7.524	0.009
Season	1	0.574	8.035	0.007	1	0.145	9.175	0.004
Habitat * Season	1	0.004	0.054	0.817	1	0.022	1.378	0.247
Error	41	0.071			41	0.016		
Shannon-Winer's index					Simpson's diversity index			
Source	df	Mean Square	F	Sig.	df	Mean Square	F	Sig.
Habitat	1	0.075	0.523	0.474	1	0.049	2.216	0.144
Season	1	1.509	10.534	0.002	1	0.326	14.593	0.00
Habitat * Season	1	0.041	0.284	0.597	1	0.019	0.851	0.362
Error	41	0.143			41	0.022		

The MDS plots for gastropod communities revealed a clear separation between habitats (Fig. 4a), whereas no clear separation was found between summers and winter (Fig. 4b). The ANOSIM tests confirmed the differences on the structure of gastropods communities between habitats (Global $R=0.17$, $p=0.001$, number of permutations = 999).

A SIMPER analysis was used to identify the role of individual species in contribution to the dissimilarity between microhabitats and seasons (Table 5). The average dissimilarity was 71.60% between seasons, mainly due to the presence of *Assimineia mesopotamica*, *Pirenelia cingulate* and *Platevindex tigrinus* accounting for 51.51% of the dissimilarity between seasons (Table 5). The average dissimilarities between habitats was 75.52% which was mostly explained by *A. mesopotamica*, *P. tigrinus* and *P. cingulate* accounting for 54.05% of dissimilarity between microhabitats (Table 5). Two-way PERMANOVA analysis for effects of habitat and season showed that only habitat significantly affected the species composition ($F=7.06$, $P=0.001$), whereas the effects of season as well as the interaction between habitat and season were not significant (Table 6). According to DISTLM analysis, the best model was achieved by a combination all environmental variables which accounted for

21.49% of the variability of the data (Table 7). For species composition only TON, TOC were significant as identified by the marginal test ($P < 0.05$, Table 7).

Table 5

Results of SIMPER analyses indicating the species contribution to the observed differences in gastropods community structure between seasons and habitats in Khuran mangrove, Persian Gulf

Season (Average dissimilarity = 71.60)						
	Winter	Summer				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Assiminea mesopotamica</i>	2.56	2.68	15.57	1.05	21.74	21.74
<i>Pirenella cingulata</i>	1.11	1.6	11.41	0.88	15.94	37.68
<i>Platevindex tigrinus</i>	1.26	1.04	9.91	0.82	13.84	51.51
<i>Assiminea</i> sp.	0.67	0.64	8.15	0.64	11.38	62.89
<i>Assiminea zubairensis</i>	0.55	1.46	8.09	0.82	11.3	74.19
<i>Iravadia quadrasi</i>	0.2	1.12	4.94	0.65	6.9	81.09
Habitats (Average dissimilarity = 75.52)						
	Pneumatophore zone	Mudflat				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
<i>Assiminea mesopotamica</i>	2.92	2.23	15.57	1.08	20.61	20.61
<i>Platevindex tigrinus</i>	0.64	2.37	14.18	1.03	18.78	39.39
<i>Pirenella cingulata</i>	1.82	0.23	11.07	0.88	14.66	54.05
<i>Assiminea</i> sp.	0.75	0.54	8.14	0.63	10.78	64.82
<i>Assiminea zubairensis</i>	1.2	0.87	7.7	0.8	10.19	75.02
<i>Iravadia quadrasi</i>	0.74	0.68	4.74	0.65	6.28	81.3

Table 6
 Results of PERMANOVA for comparing species composition of gastropods in Khuran mangrove, Persian Gulf. Bold values indicate significant level.

Source	df	SS	MS	Pseudo-F	P (perm)
Season	1	3043.6	3043.6	1.132	0.32
Habitat	1	18997	18997	7.0651	0.001
Season × Habitat	1	8.3536	8.3536	0.003	0.983
Res	59	159000	2688.8		
Total	62	181000			

Table 7

DISTLM marginal tests and the overall best solutions used to identify environmental variables affecting the species composition of gastropods in Khuran mangrove, Persian Gulf. SS (trace) = portion of sum of squares related to the analyzed environmental variable; Pseudo-F = F value by permutation; No. Vars = number of variables; RSS = Residual Sum of Squares. Bold values indicate significant level.

Marginal tests				
Variable	SS(trace)	Pseudo-F	P	Prop.
pH	5115.8	1.7711	0.139	2.82E-02
EC	6876.5	2.4046	0.056	3.79E-02
TON	22279	8.5452	0.001	0.12287
TOC	13617	4.953	0.003	7.51E-02
Temperature	3280	1.1238	0.343	1.81E-02
Salinity	2190.3	0.7459	0.589	1.21E-02
Overall best solutions				
R²	RSS	No. Vars	Selections	
0.21488	1.42E + 05	6	All variables	
0.2118	1.43E + 05	5	EC, TON, TOC, Temperature, Salinity	
0.20779	1.44E + 05	5	pH, TON, TOC, Temperature, Salinity	
0.2064	1.44E + 05	5	pH, EC, TON, TOC, Temperature	
0.20458	1.44E + 05	4	TON, TOC, Temperature, Salinity	
0.20265	1.45E + 05	4	EC, TON, TOC, Temperature	
0.19758	1.45E + 05	4	pH, TON, TOC, Temperature	
0.19355	1.46E + 05	3	TON, TOC, Temperature	
0.19165	1.47E + 05	5	pH, EC, TON, TOC, Salinity	
0.19026	1.47E + 05	5	pH, EC, TON, Temperature, Salinity	

4. Discussion

The results of the current study revealed a distinct community composition of gastropods in different habitats of Khuran mangrove ecosystem in the Persian Gulf. *A. mesopotamica* and *P. tigrinus* were the dominant species in pneumatophore zone which highlighted their importance in shaping the gastropod community structure in mangrove ecosystem. In contrast, *Pirenella cingulate* and *Littoraria intermedia* were the dominant species in mudflats. *P. tigrinus* is very common sea slug in mangrove ecosystem of the Persian Gulf, mostly confined within the *A. marina* fringe (Hajjalizadeh et al., 2020). As a dominant grazer and representing important component in the food web dynamics of this mangroves, *P. tigrinus* actively forages for microbial mats and

mangrove leaf litter at low tide (Akbari et al., 2021). It avoids being covered by water at high tide by climbing various parts of mangrove trees (personal obs.). Adult snails are preyed upon by gray heron *Ardea cinerea* and western reef heron *Egretta gularis* and the juveniles may be preyed on by crabs (personal obs.).

Overall, species richness of gastropods in Khuran mangrove system was low despite being a relatively undisturbed habitat. For example, around 50 species were found in Malay peninsula (Macintosh and Ashton, 2002), 30 species in the west coast of Thailand (Macintosh et al., 2002), and 41 species in the Segara Anakan lagoon, Indonesia (Nordhaus et al., 2009). In general, species richness of mangrove gastropods parallel to that of mangrove trees, as higher mangrove species richness provide different habitat types and food source for associated fauna (Ashton et al., 2003; Nordhaus et al., 2009). The Khuran mangrove system harbors only one mangrove tree species which provide a homogenous habitat type for different species (Delfan et al., 2021). A low richness of gastropods corresponded with a low diversity of mangrove trees in mangrove system of Qatar (Al-Khayat et al., 2019). Similarity, (Chen et al., (2007) reported that gastropods were low in a rehabilitated mangrove system in [Jiulongjiang Estuary, China](#). Whereas, a high species richness of gastropods was observed in forests with high tree diversity in Indonesia (Nordhaus et al., 2009)

The results of two-way ANOVA for the effects of season and habitat on species diversity showed that all diversity indices significantly differed between seasons, whereas, only Pielou's evenness index differed significantly between habitats. In addition, there was no significant interaction between season and habitat. Despite this, we observed higher species diversity in pneumatophore zone compared to bare mudflats. The species richness and density of benthic macrofoula has been traditionally attributed to the structural complexity of habitats. The structural complexity of *Avicenna* aerial roots provides habitat and refuge for resident fauna and the only hard substrates for benthic animal in mangrove habitats (Kamal et al., 2017; Kawaida et al., 2017; Norris et al., 2019). Hard substrates have indirect benefits for primary consumers by providing a settlement for benthic microalgae (Miller et al., 1996; Shahraki et al., 2014). Aerial roots also provides shelter from predators for many invertebrate species and protects resident fauna from wave action and storm surge (Kristensen and Alongi, 2006; Kristensen et al., 2012; Nordhaus et al., 2017). The above-ground structure of mangroves may function as a trap for suspended materials in the ecosystem and thus increasing organic matter input in mangrove habitats (Furukawa et al., 1997; Kamal et al., 2017). The trapping of suspended matters combined with decaying of plant detritus contributes to an abundant food source for gastropods (Nordhaus et al., 2011). In general, the gastropods are detritus feeders and their abundance is subject to the availability of food such as detritus and algae (Akbari et al., 2021; Rahmawati et al., 2015). They prefer habitats protected from currents, waves and direct sunlight (Rahmawati et al., 2015; Zvonareva et al., 2015). The mangrove canopy may also play a significant role in shaping the gastropod community in the pneumatophore zone (Ellis and Bell, 2004). In arid mangrove ecosystem of the Persian Gulf, shade provides refuge from desiccation and heat stress as these areas have lower temperatures than bare mudflats. Shade reduces the visibility of gastropods, making them less vulnerable to some predators. In line with the results of the current study, Sheridan (1997) reported a higher density of macrofoula in mangrove habitats compared to bare habitats. In contrast, Alfaro (2006) found that mangrove habitat had the lowest diversity among the six marine habitats in New Zealand. The observed contradiction is probably due to different sampling periods and methodologies (Nordhaus et al., 2009; Sheridan, 1997).

Conclusion

The results of the current research were in line with results of previous studies which showed that the complexity of aquatic habitats influences the density of gastropods. The characterization of gastropods communities within mangrove stands and adjacent mudflats at Khuran strait, northern Persian Gulf, indicated that while mangroves yield a higher density and diversity of gastropods, adjacent mudflats also harbor high value of biodiversity. This lead us to the conclusion that, while conservation efforts have been focused on mangrove forests, adjacent bare mudflats should also be taken into consideration as provides habitat for various mangrove fauna.

Declarations

Authorship contribution

HE and MGS designed the study, collected the data. HE, MGS, and JS, analyzed the data and wrote a draft of the manuscript. All authors contributed to the revision of the work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical approval

No animal testing was performed during this study.

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Figures

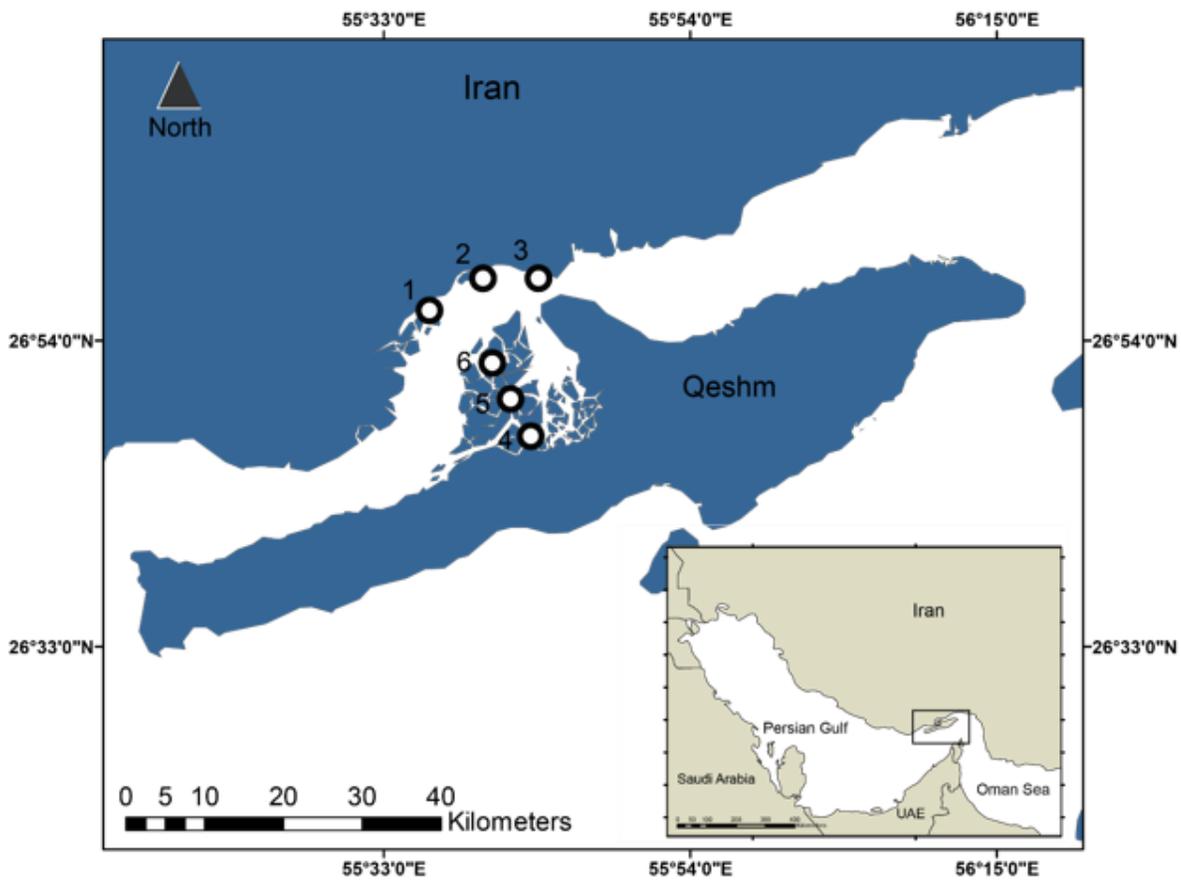


Figure 1

Map showing the positions of the sampling sites in Khuran mangrove habitat

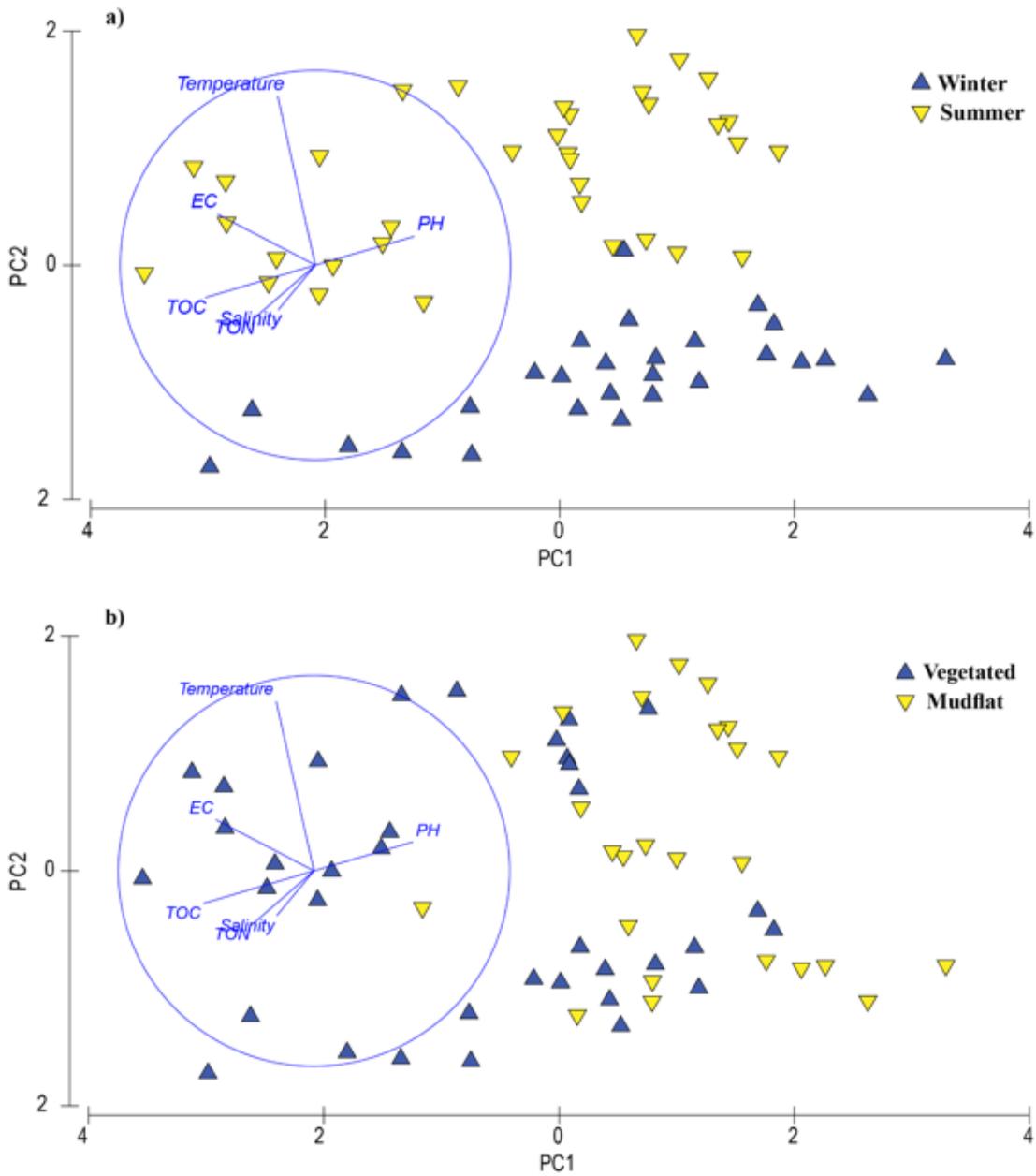


Figure 2

PCA plot of environmental variables (EC, pH, salinity, temperature, TOC, TON) for the gastropods in Khuran mangrove, Persian Gulf, in two (a) seasons (W = winter and S = summer) and two (b) habitats (P = pneumatophore zone and M = mudflats)

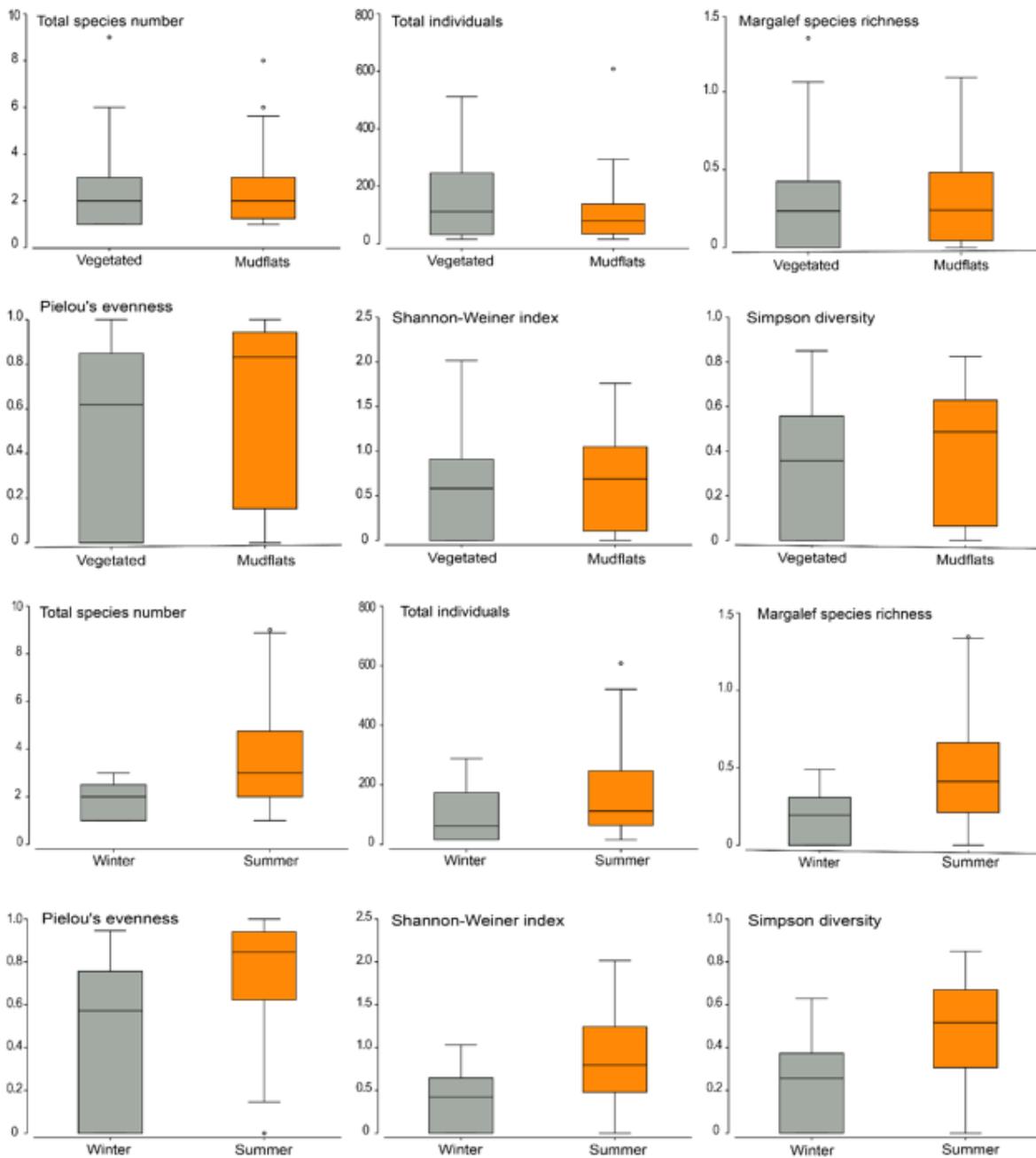


Figure 3

Comparison of diversity indices between seasons (winter and summer) and habitats in Khuran mangrove, Persian Gulf, between (a) habitats (P = pneumatophore zone and M = mudflats) and (b) seasons (W = winter and S = summer)

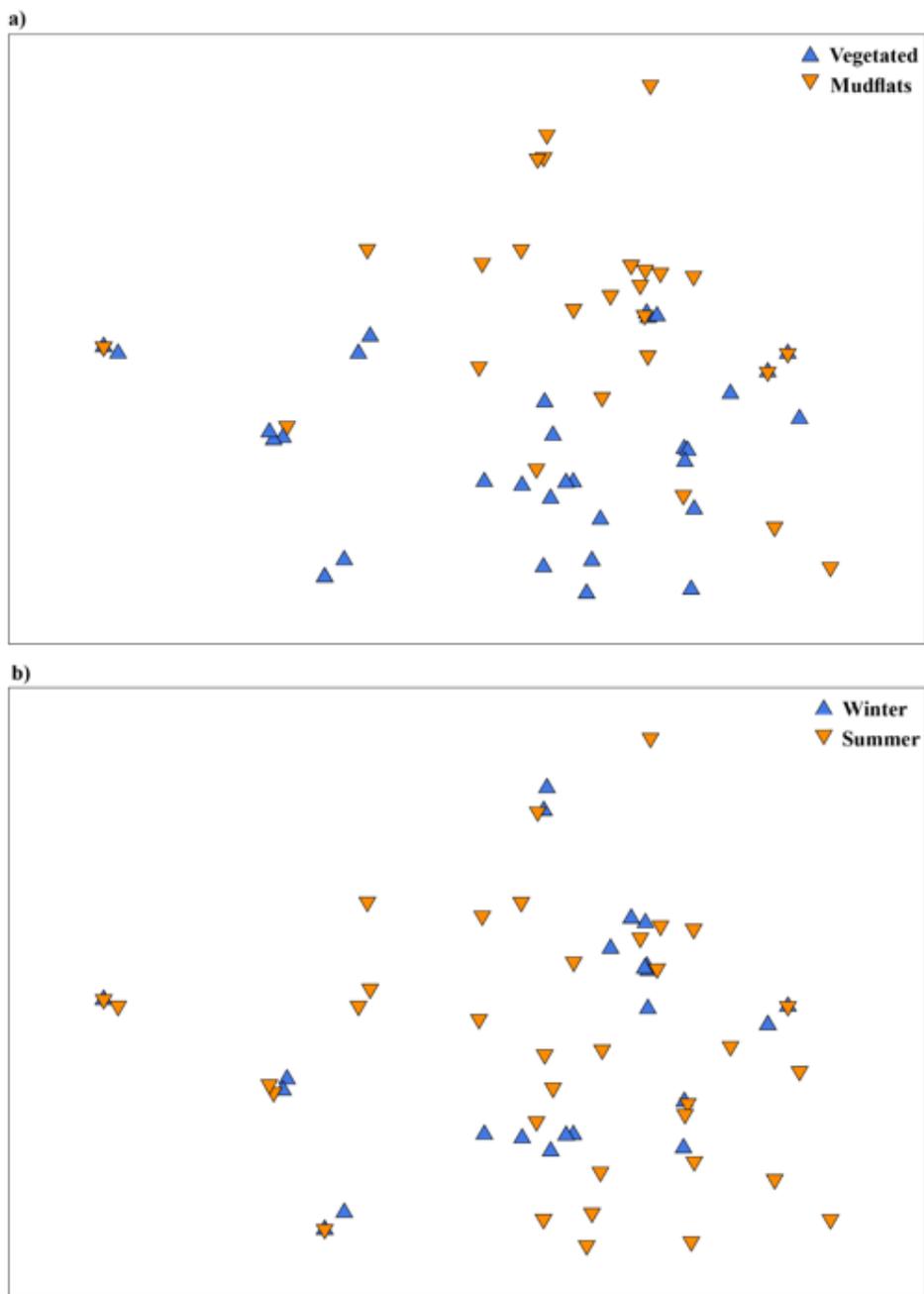


Figure 4

Multidimensional scaling ordination (MDS) of gastropods community composition in Khuran mangrove, Persian Gulf, between (a) habitats (P = pneumatophore zone and M = mudflats) and (b) seasons (W = winter and S = summer)