Diversity and spatial distribution patterns of the benthic macrofauna communities in the southeast of the Caspian Sea (Golestan Province– Iran) in relation to environmental conditions

Aliakbarian A.1; Ghorbani R.1*; Fazli H.2; Salman Mahini A.1; Yelghi A.3; Naddafi R.4

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Abstract
Biodiversity and structure of the benthic macrofauna communities were studied in the southeast the Caspian Sea (Golestan Province – Iran) during one year from October 2014 to September 2015. Seasonal samplings were done at 6 stations in 3 transects. Depth, temperature, salinity, pH, E.C., total organic matter and grain size were measured. More than 4,037 individuals belonging to five orders, Polychaeta, Oligochaeta, Bivalvia, Diptera and Amphipoda, and eight families including Nereididae, Spionidae, Amphartidae, Tubificidae, Smelidae, Cardiidae, Chironomidae and Gammaridae were identified. In terms of total individuals, Streblospio gynobranchiata, Hypania invalida and Cerastoderma lamarcki, were the most abundant species, and Polychaeta were dominant in the research region. The highest density of all species was observed in autumn (1515 ind m⁻²) and the lowest was observed in summer (698 ind m⁻²). The maximum diversity, richness, and evenness were 1.36, 0.6 and 0.98, respectively. The results of distance-based redundancy analysis (db-RDA) showed that environmental factors such as salinity, depth and substrate type were all important in detecting the distribution pattern of macrobenthic species in the research region. The dominant species, S. gynobranchiata, was distributed in the areas with smaller grain size and higher TOM and muddy sediments and had the most correlation with salinity, temperature, pH and E.C. Species such as T. fraseri. H. invalida and P. robustoides showed more dependency on TOM and mud factors in the spring and summer, while their dependency became lower in autumn and winter. Abra ovate was less influenced by all factors except the substrate.

Keywords: Community, Biodiversity, Macrofauna, Caspian Sea, Environmental factors, RDA

1-Department of Fisheries and Environment, Gorgan University of Agricultural Science and Natural Resources, P. O. Box: 386, Gorgan, Iran.
2- Caspian Sea Ecological Research Center, Iranian Fisheries Science Research Institute, Agricultural Research Education and Extension Organization, P.O.Box, 961, Sari, Iran
3-Inland Waters Aquatics Resources Research Center, Iranian Fisheries Science Research Institute, Agricultural Research Education and Extension Organization, Gorgan, Iran
4-Department of Aquatic Resources, Institute of Coastal Research, Swedish University of Agricultural Sciences, 74242 Öregrund, Sweden

*Corresponding author’s email: rasulghorbani@gmail.com
**Introduction**

The Caspian Sea is the world’s largest landlocked body of water on Earth, containing approximately 40% of the global continental water mass (Dumont, 1998). Structurally, it is divided into three different parts. The central and southern parts are deep, 788 and 1,025 m in depth, respectively, with a marine type of water circulation and a salinity of 12-13 ppt which is usual of a number of continental seas. Various ecosystems as a result of different patterns of salinities and depth were created in this sea so that many different animals in accordance with their osmoregulation capacities can live in different parts (Taheri et al., 2012). Although a great part of the Caspian Sea fauna is endemic, because of its long-term geographical isolation and independent evolution (Dumont, 2000), non-native immigrants from the Arctic basin, Black-Azov Seas (Atlantic-Mediterranean fauna), and fresh water habitats are inevitable among the native species (Zenkevitch, 1963). The Golestan Province is located to the east of the southern coast of the Caspian Sea along the Iranian border. The gradient and structure of the seabed in this area somewhat alter from mud and sludge on the Gomishan coast to gravel and sand on the Miankaleh coast. There is almost no tidal current. The major rivers existing in the vicinity of the sampling sites are Gorganrud and Atrak Rivers and the Atrak River joins the Caspian Sea in the Torkmanestan coast.

Macro-fauna as consumers in intermediate trophic levels, are essential agents of both bottom-up and top-down forces in the water system; they themselves represent resources and consumers for other levels of the food chain and resource restriction and predation are the factors that regulate their populations (Gogina et al., 2010). Benthic macro fauna and macro algae are easy sampling organisms that many papers published on their distribution in specific environmental stresses (Ghorbanzadeh Zaferani et al., 2017). Nutrient cycles, primary productivity, decomposition, and translocation of materials are the most important factors which are affected by benthic macrofauna (Wallace and Webster, 1996). In aquatic ecosystems, the presence or activities of macrofauna species often alter the flow of resources and physical ambience, thereby constructing or modifying habitats, which then effect all other organisms in the community (Gogina and Zettler, 2010). Moreover, benthic invertebrates play an important role on benthic feeding fish and even indirectly on feeding a group of pelagic fish. Macrofauna are the main food items for sturgeon fish, the very valuable and ancient species of Caspian Sea that caviar is derived from (Karpinsky, 1992; Haddadi Moghadam et al., 2005). The most important factor in controlling the biomass and diversity of macrofauna in this Sea, is grazing pressure especially caused by young sturgeon (Karpinsky, 2010).

Over the past decade, the structure of benthic communities is influenced by stressful conditions in the southern coasts of this sea. The invasion of *Mnemiopsis leidyi* in this area, changed...
Macrofauna diversity from domination by Crustacea to Bivalvia (Roohi et al., 2010) and demersal feeder fish stocks (Fazli et al., 2012, 2013). In addition, Streblospio gynobranchiata became the dominant species of macrofauna (Taheri and Yazdani, 2011). On the other hand, heavy metals (Karbassi and Amirnezhad, 2004), waste water (Shahryari et al., 2009), microbial pollution (Fereidouni et al., 2006) and oil extraction (Taheri and Yazdani, 2011) are the main problems for living animals in this sea. The southeast coast of the Caspian Sea is the location of fishing cooperatives that carry out fishing activities seven months of the year. Fishing activities often cause disturbances on the bottom, besides affecting biomass and diversity of benthic organisms. Therefore, although analysis of community structures is useful for the management and conservation of the environment, only a few studies have described benthic animals of the south Caspian Sea (Kasymov, 1989; Tait et al., 2004; Parr et al., 2007) especially on the Iranian border (Taheri et al., 2007; Bandany et al., 2008) and the macrofauna community of this area remains largely unknown. The purpose of this paper was to study macrobenthic community structure and biodiversity in the southeast Caspian Sea. These results can help us to evaluate environmental and man-made changes on fauna, and monitor the effect of invasive species and improve management of this area in the future.

Materials and methods

Study area

Sampling was conducted between the Gomishan and Miankaleh coasts within 36° 54´ 450´´ to 37° 13´ 355´´N and 53° 55´ 974´´ to 53° 47´ 080´´ E (Fig. 1)

Figure 1: The map of stations in this study.
Sampling
Seasonal sampling was carried out at 6 stations in 3 transects (Fig. 1), ranging in depths from 0.5 to 8 meters, during October 2014–September 2015. At each station, three replicate samples of 25 cm² were collected using a Van Veen grab. In the field, the contents of each grab were gently sieved using a 0.5 mm mesh and the retained material was fixed in 4% buffered formalin and stained with Rose Bengal (Abrantes et al., 1999). Then, the macrofauna were separated in the laboratory, identified and counted under a stereomicroscope. Another separate sediment samples was taken from the surface (≈4 cm) at each station using a Van Veen grab and stored in a clean plastic container to measure the percentage of the total organic matter (TOM) and the sediment grain size (MacLeod et al., 2004). Total organic matter was determined by determining weight loss on ignition (4 hours at 550 °C) after drying (24 hours at 90°C) to a constant weight (Abrantes et al., 1999). Grain size analysis was performed using a particle size analyzer. Nearly 150 g of each grab sample was submitted to standard dry-sieve through a series of mesh sizes (from 63 m to 2 mm) and mechanically shaken for 10 minutes. The sediments retained on each sieve were weighed and the percentage of each grain size category was determined (Diaz-Castaneda and Harris, 2004). Sediment fractions (gravel, sand, and silt–clay) were reported as percentages and defined pursuant to the Wentworth scale. Physicochemical data (depth, temperature, salinity and pH) of the water column were obtained using a CTD at each sampling station.

Analysis
The macrobenthic communities spatial distribution and diversity were described by univariate analysis based on the following parameters: abundance, species number (S), diversity (as Shannon–Wiener’s, H’), species richness (as Margalef’s, D), and evenness (as Pielou’s, J). At all stations, the mentioned parameter values per square meter were calculated. Collected data were tested for normality (using Shapiro–Wilk) and homogeneity of variance (using Levene’s test). Significance of all tests was accepted at p≤0.05. Whenever data were normal and homogeneous, one-way analysis of variance (ANOVA) was used to test the differences among the biological parameters (density, mean species number, diversity, richness and evenness). Distance-based redundancy analysis (db-RDA) was performed to identify the relationships among environmental variables and macrofauna assemblage structures using CANOCO software (ter Braak, 1986; ter Braak and Smilauer, 1998) with the software options set for forward selection to test the significance of environmental variables. All environmental and frequency data were natural log (X+1) transformed and normalized, and then plotted in two dimensional space. All figures dependent on analysis were made by Excel and Primer programs.
Results

Environmental conditions

Environmental factors are shown in Table 1. The total organic matter (TOM) values varied between 2.6 at station 6 in autumn and 6.36 at station 1 in summer. The maximum salinity was recorded at station 1 in autumn and the minimum was recorded at station 3 in winter. According to the grain size, the stations situated in the Gomishan region had the finest sediments while the stations in the Miankaleh region showed the coarsest sediments.

Community structure

Totally 4,093 individuals belonging to eight families were identified in the macrofauna samples from 18 stations (Table 2). Polychaeta, comprising 73.92% of the total individuals was the numerically dominant group and Streblespio gynobranchiata and Hypania invalida accounting for 40 and 25.9 %, respectively were the dominant species that were observed at all of the stations. Bivalvia (12.77%), Oligochaeta (6.54%) and Diptera (5.65%) were the next abundant groups. Amphipoda and the species Pontogamarus robustoides showed the lowest frequency. Polychaeta, with three species, had the highest diversity and density among other groups. In the present study, Amphartidae was nearly always found at the all stations. It seems it could live in different water and sediment conditions. Also, one species of Amphipoda and Diptera were observed (Table 2).

The mean frequency and occurrence percentage of different macrofauna species in different seasons are shown in Table 3. This table showed that, the highest average density of macrofauna species was observed in spring (S. gynobranchiata) and the least was related to Tubificoides fraseri in winter. Oligochaeta (T. fraseri) were not seen in spring and summer and their frequency was confined to winter. S. gynobranchiata was the dominant species in all seasons except in autumn when H. invalida along with S. gynobranchiata were the common species, while the species like A. ovata, C. albidus and P. robustoides reached the lowest levels. Seasonal changes in mean values of density (+standard deviation) in all stations are shown in Table 4. The maximum density among stations belonged to station 1 which was slightly different from station 3 in autumn. Also, the minimum frequency of all species was observed in station 6 in summer (Table 4). One-way ANOVA analyses showed significant differences in mean species number, diversity, richness and evenness among stations. All frequency data were natural log (X+1) transformed and normalized. The highest mean number of species (0.74) was obtained at station 4 and the lowest (0.64) was at station 1. The highest diversity index (1.36) was obtained at station 4 while the lowest (1.2) was observed at station 1. The maximum and minimum of evenness index were obtained at stations 4 and 1, respectively, while the maximum richness index was recorded in station 5, but stations 1 and 3 showed the minimum value of richness (Table 5).
The results of distance-based redundancy analysis (db-RDA) revealed that, environmental variables had significant effects on the spatial distribution of macrobenthic animals, (Fig. 2). The lines of Shanon index showed that Gomishan zone was more variable than Miankaleh in all seasons except spring. The RDA demonstrated that in all seasons, sand was the only influential factor in Miankaleh region while the others were less effective. TOM, mud and depth were the factors that were more related to the Gomishan region. The RDA also revealed relationships among 8 species and environmental variables (Fig. 2). S. gynobranchiata was distributed in regions with smaller grain size and higher TOM and mud. This species showed the most dependency on salinity, temperature, pH and E.C. T. fraseri also was dependent on these factors in autumn and winter (the seasons in which this species was found). H. invalida and P. robustoides were found in regions with more TOM and smaller grain size. A. ovate was less influenced by all factors except sand, and thus, this species was found mainly in sandy regions. All factors were equally affected C. albidus and N. diversicolor, and C. lamarckii was mainly found in the regions in which the grain size was larger.

Table 1: Average values of environmental factors measured in this study.

<table>
<thead>
<tr>
<th>Season</th>
<th>Station</th>
<th>Temp.(°C)</th>
<th>Salinity</th>
<th>E.C.</th>
<th>pH</th>
<th>Sand</th>
<th>Mud</th>
<th>TOM</th>
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<td>2</td>
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<td>10.2</td>
<td>1.71</td>
<td>8.04</td>
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<td>73.7</td>
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</tr>
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<td>3</td>
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<td>10.2</td>
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<td>36.22</td>
<td>63.7</td>
<td>5.51</td>
</tr>
<tr>
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<td>4</td>
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<td>8.02</td>
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<td>67.29</td>
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<td>77.12</td>
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<td>80.8</td>
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</tr>
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<td>10.46</td>
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<td>25.5</td>
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<td>31.6</td>
<td>68.3</td>
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<td>24.8</td>
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<td>1.73</td>
<td>8.4</td>
<td>31.42</td>
<td>68.5</td>
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<td>10.9</td>
<td>1.75</td>
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<td>1.77</td>
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<td>68.9</td>
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<td>10.73</td>
<td>1.73</td>
<td>8.3</td>
<td>61.52</td>
<td>38.4</td>
<td>3.21</td>
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<td>1.71</td>
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<td>69.36</td>
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<td>10.23</td>
<td>1.75</td>
<td>8.16</td>
<td>72.06</td>
<td>27.9</td>
<td>2.6</td>
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<td>1</td>
<td>9.2</td>
<td>9.2</td>
<td>1.33</td>
<td>8.6</td>
<td>33.09</td>
<td>66.91</td>
<td>5.02</td>
</tr>
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<td>9.1</td>
<td>1.41</td>
<td>8.5</td>
<td>32.77</td>
<td>67.2</td>
<td>4.90</td>
</tr>
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<td>3</td>
<td>8.76</td>
<td>8.5</td>
<td>1.58</td>
<td>8.6</td>
<td>32.63</td>
<td>67.36</td>
<td>4.5</td>
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<td>9.5</td>
<td>1.62</td>
<td>8.4</td>
<td>56.67</td>
<td>43.32</td>
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<td>9.23</td>
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<td>9.8</td>
<td>9.43</td>
<td>1.67</td>
<td>8.3</td>
<td>59.98</td>
<td>40.02</td>
<td>2.86</td>
</tr>
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</table>
### Table 2: List of macrobenthic invertebrate species identified in the south-east Caspian Sea.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polychaeta</td>
<td>Nereididae</td>
<td>Nereis</td>
<td>Nereis diversicolor</td>
<td>6.99</td>
</tr>
<tr>
<td>Spionidae</td>
<td></td>
<td>Streblospio</td>
<td>Streblospio gynobranchiata</td>
<td>40</td>
</tr>
<tr>
<td>Ampharetidae</td>
<td></td>
<td>Hypania</td>
<td>Hypania invalida</td>
<td>25.9</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td>Tubificidae</td>
<td>Tubificoides</td>
<td>Tubificoides fraseri</td>
<td>6.54</td>
</tr>
<tr>
<td>Smelidae</td>
<td></td>
<td>Abra</td>
<td>Abra ovata</td>
<td>1.62</td>
</tr>
<tr>
<td>Bivalvia</td>
<td>Cardiidae</td>
<td>Cerastoderma</td>
<td>Cerastoderma lamarcki</td>
<td>11.15</td>
</tr>
<tr>
<td>Diptera</td>
<td>Chironomidae</td>
<td>Chironomus</td>
<td>Chironomus albidus</td>
<td>5.65</td>
</tr>
<tr>
<td>Amphipoda</td>
<td>Gammaridae</td>
<td>Pontogammarus</td>
<td>Pontogammarus robustoides</td>
<td>2.06</td>
</tr>
</tbody>
</table>

### Table 3: Density and occurrence percentage of each family in each season in m².

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Spring per%</th>
<th>Summer per%</th>
<th>Autumn per%</th>
<th>Winter per%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polychaeta</td>
<td>Nereididae</td>
<td>24</td>
<td>36</td>
<td>156</td>
<td>41</td>
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<tr>
<td>Spionidae</td>
<td></td>
<td>565</td>
<td>324</td>
<td>377</td>
<td>461</td>
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<tr>
<td>Ampharetidae</td>
<td></td>
<td>206</td>
<td>144</td>
<td>437</td>
<td>317</td>
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<tr>
<td>Oligochaeta</td>
<td>Tubificidae</td>
<td>0</td>
<td>0</td>
<td>243</td>
<td>7</td>
</tr>
<tr>
<td>Smelidae</td>
<td></td>
<td>11</td>
<td>19</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Bivalvia</td>
<td>Cardiidae</td>
<td>51</td>
<td>77</td>
<td>269</td>
<td>25</td>
</tr>
<tr>
<td>Diptera</td>
<td>Chironomidae</td>
<td>46</td>
<td>59</td>
<td>10</td>
<td>90</td>
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<tr>
<td>Amphipoda</td>
<td>Gammaridae</td>
<td>19</td>
<td>39</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>922</td>
<td>698</td>
<td>1515</td>
<td>958</td>
</tr>
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</table>

### Table 4: Mean±SD of Species number (S), diversity (H'), richness (D) and evenness (J) in all stations of the south east Caspian Sea.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Station</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
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<tbody>
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<td>Gomishan</td>
<td>1</td>
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<td>1.26±0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.1±0.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.8±0.35&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>1.78±0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.44±0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.91±0.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.75±0.9&lt;sup&gt;abc&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.75±0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.31±0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.05±0.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.96±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.65±0.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.24±0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.58±0.16&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.48±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Miyancaleh</td>
<td>5</td>
<td>1.56±0.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.27±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.68±0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.34±0.35&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>1.67±0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.07±0.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.81±0.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.51±0.12&lt;sup&gt;bc&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5: Mean species number (S), diversity (H'), richness (D) and evenness (J) during this study.

<table>
<thead>
<tr>
<th>Station</th>
<th>species number (S)</th>
<th>Pielou’s(J)</th>
<th>Shannon–Wiener’s H’</th>
<th>Margalef’s(D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.64±0.06&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.86±0.07&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.24±0.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.52±0.04&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>0.73±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.97±0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.35±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.54±0.007&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>0.70±0.03&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.93±0.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.29±0.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.52±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>0.74±0.005&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.98±0.006&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.36±0.009&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.59±0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>0.72±0.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.95±0.06&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.32±0.09&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.6±0.03&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>0.71±0.04&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.94±0.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.31±0.08&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.57±0.02&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Discussion

Although a lot of species of macrofauna were reported in the Caspian Sea (Birshtein et al., 1968; Kasymov, 1994), in comparison, the biodiversity of Caspian Sea is lower than the other seas like the Black Sea and the Barents Sea (Zenkevitch, 1963). Low salinity, i.e., (maximum 13 ppt) probably is one of the main reasons, because for true freshwater species it is too high, but for marine origin species it is too low. Therefore, these conditions are just favorable for brackish water species (Mordukhai-Boltovskoi, 1979; Karpinsky, 2005). The second reason may be the long geographical isolation of the Caspian Sea from the Black Sea (open seas), which began about 5-6 million years ago, which is adequate time for the evolution of unique fauna (Zenkevitch, 1963), meaning that great parts of the Caspian fauna are endemic (Dumont, 2000). The south Caspian Sea, with 13 ppt salinity and the highest depth, is a unique ecosystem (Taheri et al., 2012). In the shallow Iranian waters, less than 22 species of macrofauna have been reported (Roohi, et al., 2010; Taheri and Yazdani, 2011; Ghasemi, 2014). In the present study, eight species of macrofauna were identified. In Gorgan Bay, Saghali et al. (2012) found 13 families while Taheri et al. (2012) obtained 8 families of macrofauna in the south of the Caspian Sea. In the Baku Bay, Kasymov (1989) found 9 species of macrobenthos while Tait et al. (2004) obtained 62 and Parr et al. (2007) identified 71 species of macrofauna in the south of Baku, Azerbaijan. It should be mentioned that
The present study was carried out in shallow waters. Although, in the Caspian Sea some different orders of macrofauna were reported, we did not find communities of small forms such as Cumacea and Mysidacea that had been reported by Kasymov (1994) for the south Caspian Sea. A similar result was obtained in Gorgan Bay (Saghali et al., 2012; Taheri et al., 2012) and Noor Coast (Taheri and Yazdani, 2011). It is necessary to note that different parts of the Caspian Sea have variable structures in terms of macrofauna communities, because of different environmental conditions (Kasymov, 1994). High species diversity among the macrofauna in marine ecosystems belongs to polychaetes while fewer than ten species have been known in the Caspian Sea up to now (Birshtein et al., 1968; Kasymov, 1989, 1994; Grigorovich et al., 2003; Tait et al., 2004). In this study, only three species of polychaetes were found. Similar results were observed in the Gorgan Bay and the south-west of the Caspian Sea (Taheri et al., 2007; Bandany et al., 2008), the Gorgan Bay and the south-east of the Caspian Sea (Taheri et al., 2012) and the south of Baku, Azerbaijan (Parr et al., 2007). The community structure of southern Caspian polychaetes before 2005, was primarily dominated by members of the Ampharetidae and Nereididae, particularly H. invalida that was the endemic polychaete (Kasymov, 1994; Soleimani, 1994; Hashemiyan, 1998; Karpinsky, 2002; Parr et al., 2007; Roohi et al., 2010). However, after the arrival of S. gynobranchiata, the dominance has been replaced by this species (non-indigenous) (Parr et al., 2007). This disappearance may be related to the invasion of S. gynobranchiatac and T. fraseri into this area, because ampharetids and S. gynobranchiata inhabit similar habitats and are both considered surface deposit feeders (Zenkevitch, 1963; Fauchald and Jumars, 1979; Taheri et al., 2011, 2012), it appears that S. gynobranchiata is able to outcompete native ampharetids in shallow waters and displace them at greater depths in the southern Caspian Sea (Ghasemi, 2014). In addition, high salinity in brackish waters and low biodiversity in the southern parts of the Caspian Sea may be the reason that species with a marine origin such as S. gynobranchiata can live easily at high densities in this part (Kasymov, 1994; Taheri and Yazdani, 2011). During the past century, a lot of exotic species entered the Caspian Sea (Grigorovich et al., 2003). Originally Tubificoides fraseri had been reported in North America (Brinkhurst, 1986) but there was not any report from the Caspian Sea before 2005 (Birshtein et al., 1968; Kasymov, 1989, 1994; Grigorovich et al., 2003; Tait et al., 2004). Taheri and Yazdani (2011) first reported the existence of this species in the Caspian Sea. They had guessed it was transported into the Caspian Sea by ballast water via the Volga–Don canal. In this study, we observed one species of oligochaeta which is similar to results reported by Taheri and Yazdani (2011) on the Noor coast, Taheri et al. (2012) and Saghali et al. (2012) in Gorgan Bay, while six species were
reported in the south Caspian Sea (Parr et al., 2007). One of the most important
groups of macrofauna in the Caspian
Sea is mollusca that have been
observed in all parts of it (Malinovskaja et al., 1998; Parr et al., 2007; Roohi et al.,
2010). In our study, bivalvia, with
two species, in terms of diversity and
density were in second place and they
were observed in most stations. In other
studies, one species (Cerastoderma
lamarckii) of bivalvia was reported in
Mazandaran Province (Ghasemi, 2014;
Taheri and Yazdani, 2011) and two
species were reported in Gorgan Bay
(Taheri et al., 2012). Also, we did not
find any Gastropoda. Similar results
were reported in the Noor coast (Taheri and Yazdani, 2011) and Gorgan Bay
(Taheri et al., 2012). Also, Ghasemi
and Kamali (2014) reported one species
of Pyrgula sp. in Mazandaran Province
and Saghali et al. (2012) reported three
species in Gorgan Bay, while 16
species were observed in Azerbaijan
(Parr et al., 2007). Identification of
Amphipoda, an important component of
aquatic ecosystems that was reported in
Caspian Sea, is really difficult
(Karpinsky, 2005). One species of
Amphipoda (P. robustoides) was found
in the present study. It is one of the
most common Ponto-Caspian
Amphipods. Its native range includes
coastal zones of the Caspian
(Grabowski, 2011). Dedju (1980)
describes this species as strictly
phytophilous. However, the species is
often found also on stony or sand-
muddy bottom (Carasu et al., 1955,
own data). Similar results were
obtained by Ghasemi (2014), Taheri et
al. (2012), Taheri and Yazdani (2011)
and Saghali et al. (2012), but in the
Mazandaran Province, 11 species of
Amphipods were observed (Ghasemi
and kamali, 2014). Also, four species
were reported by Roohi et al. (2010) in
the south Caspian Sea. But in different
parts of this sea different numbers of
Amphipoda were reported
(Malinovskaja et al., 1998; Tait et al.,
2004; Parr et al., 2007). Unfortunatelly,
the invasion of the Mnemiopsis leidyi
into this sea, caused a decrease in the
abundance of benthic crustacean. It
could be related to the predation of their
larvae by M. leidyi (Roohi et al., 2010).
Chironomus albidus is just one species
of insects that was reported in the
southern part of the Caspian Sea (Parr
et al., 2007) and we observed it in the
western and eastern parts, but it was not
found in the Noor coast (Taheri and
Yazdani, 2011). Furthermore, three
species (Malinovskaja et al., 1998) of
Hirudinea in the northern part of this
sea and one species in the southern part
(Parr et al., 2007; Roohi et al., 2010)
were reported but no species was found
in the present study. Similar results
were reported by Saghali et al. (2012),
Taheri and Yazdani (2011), Ghasemi
(2014) and Taheri et al. (2012). Due to
the number of species and their
abundance and biomass, our results and
those of other researchers suggest a
high degree of variability in the macro-
benthic fauna in the southern Caspian
Sea (Kasymov, 1989; Soleimani, 1994;
Hashemiyan, 1998; Karpinsky, 2002;
Parr et al., 2007; Taheri et al., 2007;
Bandany et al., 2008; Roohi et al.,
2010; Taheri and Yazdani, 2011;
In this study, S. gynobranchiata accounting for 40% of the total individuals was the numerically dominant species that were observed at all of the stations, and A. ovate representing 1.62% of the total individuals was the lowest species in terms of number. In this study, maximum diversity (1.36) and richness (0.98) were very low. Similar results were obtained in the south Caspian Sea (Taheri et al., 2007; Bandany et al., 2008; Taheri and Yazdani, 2011). The value of these indices could be related to the small number of macrofauna in the sampling and the existence of the dominant species (S. gynobranchiata) with very high density in each season.

Results obtained from CANACO software indicated clear spatial differences in macrobenthic assemblage structures in relation to environmental variables such as grain size, TOM, depth and other factors in the southeast of the Caspian Sea. Numerous research have shown that the spatial distribution of macrobenthic invertebrates along shallow waters is related to environmental variables (Gogina and Zettler, 2010; Taheri and Yazdani, 2011; Saghali et al., 2012; Ghasemi et al., 2014). Also, the results of Mehdipour et al. (2018) indicated that temperature, nitrate, silicate, phosphate and nitrite were the most important factors in the composition and abundance fluctuation of hard substratum macro invertebrates communities, in Caspian Sea. Thus, the results of the present study are consistent with those of past studies. While Taheri et al. (2012) reported that they did not find any significant correlations between the density of macrofauna and all the environmental conditions, they suggested that macrofauna assemblages were controlled by other factors such as different kinds of pollution like heavy metals and rural and agricultural waste water. Based on the results of RDA analyses, the type of sediment (sand vs. mud) is one of the factors responsible for the spatial distribution of macrobenthic species in terms of feeding types (Gray, 1974; Nanami et al., 2005; Taheri and Yazdani, 2011; Martins et al., 2013; Ghasemi et al., 2014). This means that, suspension-feeders (e.g., bivalves) are more abundant in a sandy flat in which water speed prevents accumulation of detritus on the bottom and current activity brings more potential food to the suspension-feeders than would weaker currents. In contrast, deposit-feeders (e.g., polychaetes) are more abundant in a muddy flat in which the weak currents allow organic matter to settle down and provide an adequate source of nutrition for a large number of deposit-feeders. In this study, A. ovate showed the most relevance with sand factor in comparison to others, while C. lamarcki displayed the lower dependency on the type of sediment. In contrast, three species of polychaete (S. gynobranchiata, N. diversicolor, H. invalida) were deposit-feeders and were more abundant in regions with small grain size. In addition, in deeper areas TOM and mud increased, and since S. gynobranchiata was numerically the dominant macrobenthic and the fact
that it is a deposit feeder (Cinar et al., 2005; Ghasemi et al., 2014) a higher density of macrobenthos found in deeper water may be related to TOM percentage increase (as a food) and sand percentage decrease. These results obtained from the present study are consistent with the results of other researchers about macrobenthic invertebrates (Nanami et al., 2005; Taheri and Yazdani, 2011; Martins et al., 2013; Ghasemi et al., 2014).

Seasonal density variation of the macrofauna may depend on many factors such as breeding activity of macrofauna and predator pressure (Kevrekidis, 2005; Taheri and Yazdani, 2011). The highest density of macrofauna was observed in autumn. This may be related to density of T. fraseri and C. lamarcki that were maximal in this season. The lowest density of macrofauna was recorded in summer; it may be related to the higher predation rate as the reproduction season for many benthivorous fish in the Caspian Sea starts from late winter to late spring. Higher metabolic rate, because of an increase in temperature, associated with higher feeding intensity of predators can be the other reason for the lowest density in summer.

In conclusion, the present results demonstrated very low biodiversity in terms of macrofauna in the southeast Caspian Sea, and indicated significant correlations between the density of macrofauna and various environment conditions.

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References


