Discriminating mesozooplankton communities in Bushehr marine coastal ecosystems- Persian Gulf

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Abstract

Coastal ecosystems of Bushehr are shallow environments subject to human impacts, including shrimp aquaculture and urban expansion activities. A spatial-temporal study was conducted in order to assess the actual ecological status of the creeks, estuary and marine sites on the basis of their taxonomic composition and density of mesozooplankton. Zooplankton species distribution and abundance data at 6 sampling sites during June 2015 - March 2016 revealed 24 taxa represented by 5 divergent groups. During the study period, high salinities (around 35-47 PSU) were recorded, characterizing all systems as a coastal-marine ecosystem, rather than true estuarine.

The mesozooplankton assemblage was characterized by the dominant marine Copepod, *Labidocera* sp., *zoeas* of coastal/marine crab, *Ilyoplax frater*, marine copepod *Acartia fossae* and a marine pelagic tunicate, *Oikopleura dioica*. Copepods were the main dominant group and *Labidocera* sp. the most abundant species, with high abundances in winter, whereas high abundances of the *Ilyoplax frater* were noticed in summer. Based on SIMPER analyses, highest dissimilarity was observed between Ramleh and Lashkary and discriminating taxa for all sites were *Labidocera* sp followed by *Ilyoplax frater* contributing to more than 68% of the total average dissimilarities for all locations. The multivariate BIO–ENV procedure indicated that *Labidocera* sp. followed by *Acartia fossae* strongly correlated to the variability of depth, transparency and salinity. Finally the results showed that temporal and spatial variation in the mesozooplankton community is consistent with the dynamic character of the habitat characterized as a typical coastal marine system (with low average depths, transparency and high salinity).

Keywords: Mesozooplankton, Creek, Estuary, Bushehr, Persian Gulf

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Introduction

Marine zooplankton communities are usually structured by the spatio-temporal variation of physical forces and primary production in environments they occupy. Coastal and estuarine ecosystems are variable environments for rapid fluctuations in two main variables, salinity and temperature (Bouman *et al*., 2003; Kibirige and Perissinotto, 2003). High levels of temperature, salinity and fluctuations of these physical factors cause increase in metabolism and thermal stress, reduction in adaptation and this is likely to be reflected in changes in community structure (Porri *et al*., 2007). In tropical coastal, creeks and estuarine environments, salinity appears to be an important key abiotic factor regulating zooplankton composition but in creeks with no freshwater input, unlike estuaries which are directly influenced by fluvial discharge–physical forces such as evaporation have a direct influence on salinity levels (Stemberger and Lazorchak, 1994; Edwards and Richardson, 2004). Wind forcing, current patterns and ebbing of the tides are other important factors controlling the structure of plankton communities and patterns of abundance through space and time (Taylor *et al*., 2002).

Zooplankton are the most abundant constituents that function as major food stuff for larvae of planktivorous fish, shrimp, crabs, chaetognaths and even jellyfishes, in natural waters and in aquaculture ponds. Most fishes and shrimp / prawns during their critical life stage receive their nourishment feeding on copepods. It has been reported that in many countries the failure of fishing is attributed to reduced zooplankton, especially copepod populations (Ramfos *et al*., 2006), Moreover, many zooplankton taxa are known to be sensitive or tolerant indicator species whose presence or absence may represent the relative influence of different water types on ecosystem structure and may be important in assessing the health of coastal ecosystems (Soetaert and Rijswijk, 1993). So zooplankton species composition, temporal abundance and spatial distribution should be considered as great significance in finding detrimental changes in environment, fishery potential and cultural management strategies (Isari *et al.*, 2007).

In recent ecological studies, multivariate methods have been used for distinguishing changes in biological communities in their environmental conditions (Clarke and Warwick, 1994). Also a number of studies focused on relating species composition and abundance patterns to ambient sea conditions (Iguchi, 2004).

During this investigation, an attempt was made to distinguish zooplankton assemblages from relatively unknown situations within the creeks, estuaries and coastal waters of the Persian Gulf. Bushehr coastal area has occupied 905 km of the northern coastline of the Persian Gulf with different ecosystems including creeks, estuaries and different types of coastal habitats. This region has a hot and humid climate (Azarmsa, 2008). The evaporation rate in the Bushehr coastal area is pretty high. It is next to desert and is subjected to dry winds that intensify evaporation from the water. The mean air temperature in summer is 50°C and in winter 6°C. During hot seasons the sea surface temperatures of the Persian Gulf are high and a huge thermal through system is usually dominant over the region. The summer sea surface temperatures of the Persian Gulf are known to be highest in the world (Azarmsa, 2008).

Bushehr coastal ecosystems are nursery grounds and fishery landing places (Niamaimandi, 2007). The Ramleh, Dubbeh, Shif and Lashkary are creeks with no entrance of water supply, but strongly influenced by human activity and characterized by a high load of organic matter as well as toxic substances (Mirza *et al.*, 2012). The Farakeh is a river-estuary receiving freshwater with no distinct load of organic and toxic pollution, and marine coastal site is located where between Dubbeh and Shif.

Materials and methods

Study area and sampling procedure

This study was carried out in coastal waters adjacent and north east of Bushehr (Fig. 1). Six sampling sites were set up 4 in Creek-Estuaries, Ramleh, Dubbeh, Shif and Lashkary, 1 in Farakeh River -Estuary and 1 in coastal waters of sea.

Site Number	Site Name	Longitude	Latitude	Ecosystem type
1	Ramleh	N 29° 10.702´	E 050°38.792´	Creek-Estuary
2	Farakeh	N 29° 08.865´	E 050° 38.838´	River-Estuary
3	Dubbeh	N 29° 06.613´	E 050° 40.294´	Creek-Estuary
4	Sea site	N 29° 16. 371´	E 050° 42.501 ´	Coastal
5	Shif	N 29° 04.117´	E 050° 51.130´	Creek-Estuary
6	Lashkary	N 28° 58.948´	E 050° 51.947´	Creek-Estuary

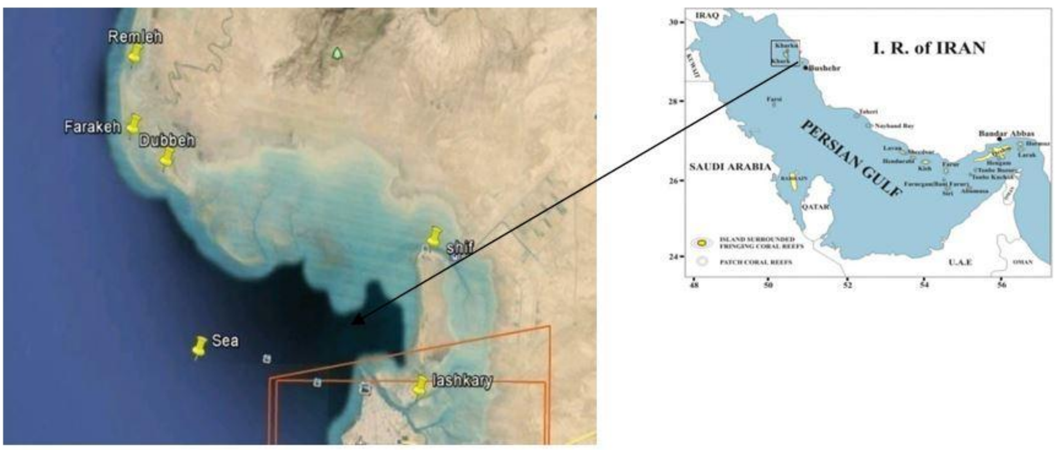


Figure 1: Sites of sampling: Ramle (site 1), Farakeh (Site 2), Dubbeh (Site 3), Sea (Site 4), Shif (site 5), Lashkary (Site 6).

A series of 7 bimonthly samples were collected from Jun. 2015 to March. 2016. Depth, Sea surface temperature (SST°C), dissolved Oxygen (mL L^{-1}), salinity (PSU); pH and chla were measured at each site, using onboard CTD (Times of sampling 1: Jun-15, 2: Jul-15, 3: Sep-15, 4: Nov-15, 5: Jan-16, 6: Feb-16, 7: Mar-16).

Zooplankton samples were collected by hauling a Bongo net, (330 μm mesh size, 30 cm mouth diameter, and 180 cm length), with a flow meter (Hydro-Bios).

Hauls were towed for 5 min at a speed of approximately 1 knot. Because all site were located in shallow waters (over 5 meter depth contour), zooplankton samples were collected by a horizontal tow, 1 m below the surface. Replicate samples were immediately fixed in 5% formalin. Species identification to the lowest possible taxonomic level (genus or species) and enumeration of preserved samples were carried out in the laboratory (Newell and Newell, 1977; Barnes, 1978; Omori and Jked, 1984; Al-Yamani *et al*., 2011).

The abundance of zooplankton was expressed in number of individuals per ind. m^{-3} of water.

Statistical analyses

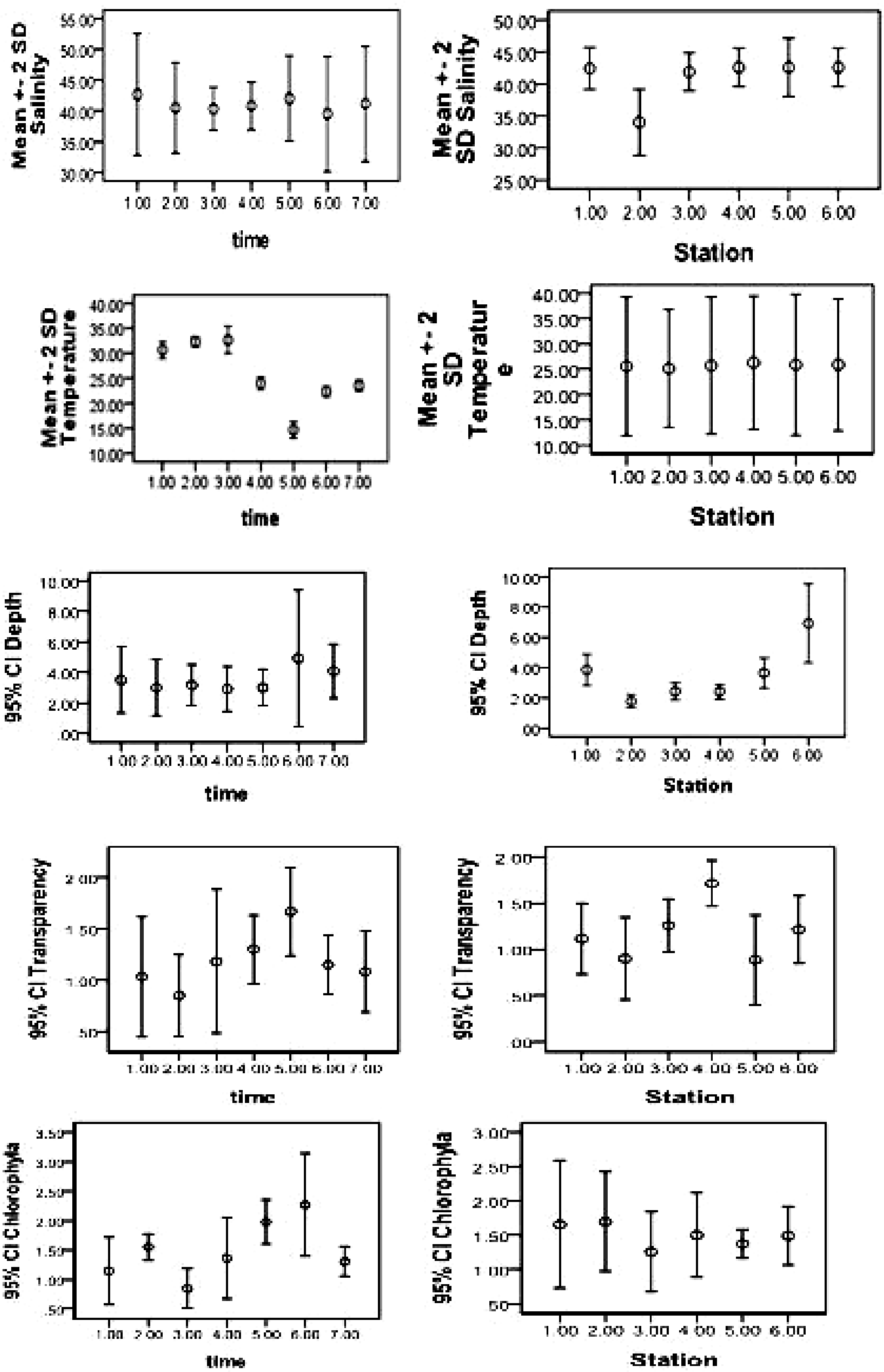
Univariate and descriptive analysis were performed using the SPSS software version 19. Statistical analysis of abundance data employed a variety of multivariate techniques, using the PRIMER 5 software package (Clarke and Warwick, 1994).

MDS ordinations were judged to separate spatial and temporal groups with similar zooplankton community structure and environmental variables (trough ordination of Bray–Curtis similarity) To identify discriminating species contributing mostly to the dissimilarity among sampling sites, Similarity percentages (SIMPER) analysis implemented in PRIMER v5,This analysis was used to determine taxa most responsible for assemblage groupings (Sites). Finally, environmental variables best correlated with the multivariate patterns of zooplankton community were identified using the BIO–ENV procedure (Clarke and Ainsworth, 1993).

Results

Sea surface temperature at Bushehr coastal ecosystems varied between 14 and 34°C (mean=25.7°C). Salinity recorded was more than 40‰ in most sites throughout most of the year, only Lower salinities were recorded at Farakeh Estuary, ranging 34-39 PSU, and the highest in Shif Creek, ranging 41-47 PSU (Fig. 2).

Altogether the mesozooplankton community was typically composed of 24 taxa of which copepods formed the dominant group especially the genus *Labidocera.* Calanoids consisted of 4, and cyclopoids, 3 species. Other taxa were brachyuran zoea, Chaetognatha, Tunicata and Cumaceans (Table 1).



Mean +- 2 SD Salinity
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Mean +- 2 SD Salinity
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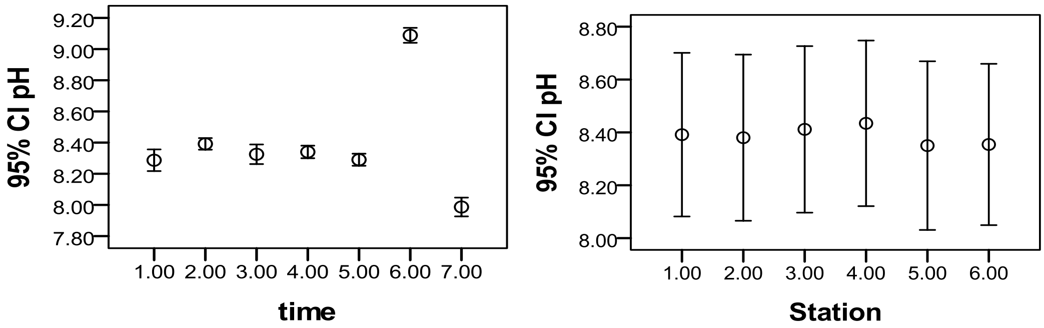

Figure 2: Temporal and spatial variations in average (mean±SD) of salinity, temperature, depth, transparency, chl a and pH in coastal ecosystems of Bushehr, 2015 -2016.

Table 1: Zooplankton species and their relative abundance- Coastal ecosystems of Bushehr (2015 - 2016).

Taxa	Relative abundance (%)
Copepoda, Calanoida	
Temora turbinata	<1
Labidocera sp.	50.9
Acartia fossae	<10
Tortanus barbatus	<1
Copepoda, Cyclopoida	
Oithona brevicornis	<0.1
Oithona plumifera	<1
Corycaeus lubbocki	<0.1
Mysid shrimp	
Rhopalophthalmus sp.	<1
Malacostracea	
Penaeus semisulcatus protozoea	<1
Lucifer hansenimysis I.	<1
Lysmata sp. zoea IV	<1
Callianassa sp. zoea I	<0.1
Upogebia sp. zoea I&III	<10
Pachycheles sp. zoea I	<1
Dardanus sp. zoea I	<1
Paguristes sp. zoea I	<1
Pagurus sp. zoea III	<0.1
Ebalia sp.	<0.1
Parthenope sp.	<1
Ilyoplax frater zoea VI	28.4
Chaetognatha	
Sagitta enflata	<10
Sagitta neglecta	<10
Tunicata	
Oikopleura dioica	<10
Appendicularia sicula	<0.1

Labidocera sp. and *Oikopleura dioica* were both highest in February 2016.They also displayed the same spatial pattern with higher values at 6 sites. *Ilyoplax frater* and *Acartia fossae* were highest in September 2015; both displayed the same spatial pattern with higher values at site 1 (Fig. 3).

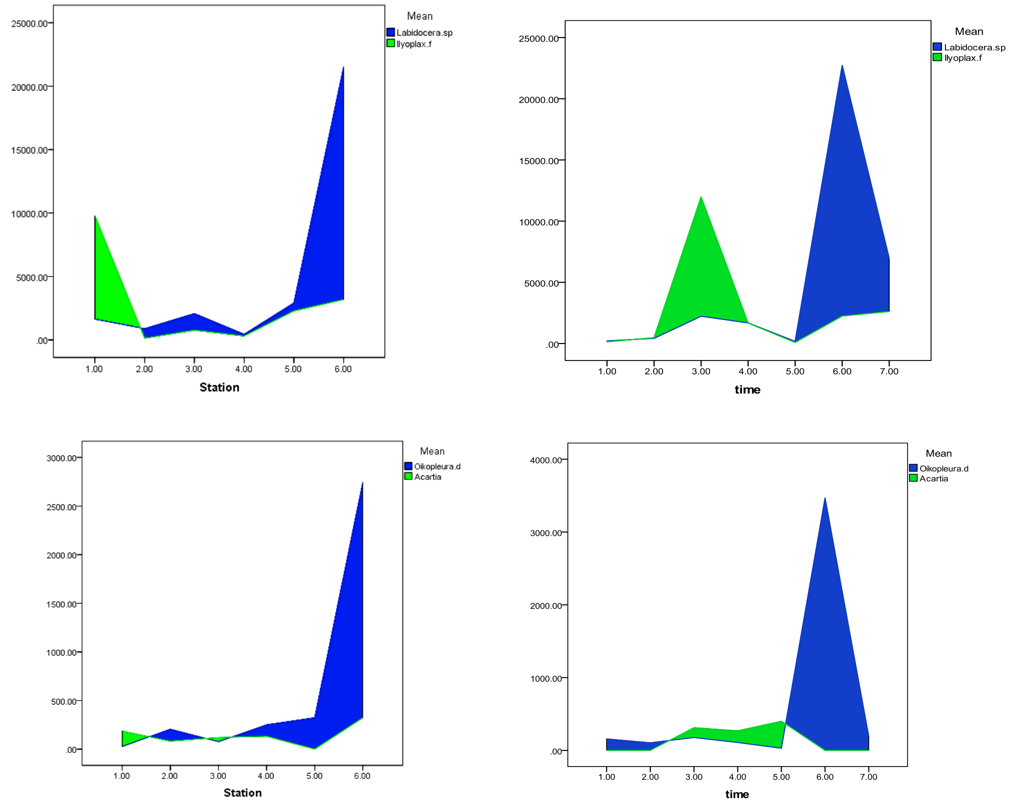

Figure 3: Annual cycles and spatial patterns of abundance for differenced pair first 2 dominant taxa, *Labidocera* sp. and *Ilyoplax frater* followed by differenced pair *Oikopleura dioica* and *Acartia fossae.*

Bray–Curtis similarities were calculated based on physical parameters, water temperature, pH, salinity, secchi depth and Chla data for sites during the sampling period. A temporal pattern was seen in MDS ordination for sites, and a distinct spatial difference was observed (Fig. 4).

SIMPER analysis performed on Bray-Curtis resemblance matrixes of abundance data revealed that about 7-9 species contributed to more than 90% of the total average dissimilarities per sampling environments and the most important discriminating species were *Labidocera* sp., *Ilyoplax frater* (zoea VI), *Acartia fossae* and *Oikopleura dioica* and the highest dissimilarity was observed between Ramleh and Lashkary (Table 2). Among the taxa with the highest contributions, just *Labidocera sp.*, *Ilyoplax frater* accounted for more than 10% of average dissimilarities.

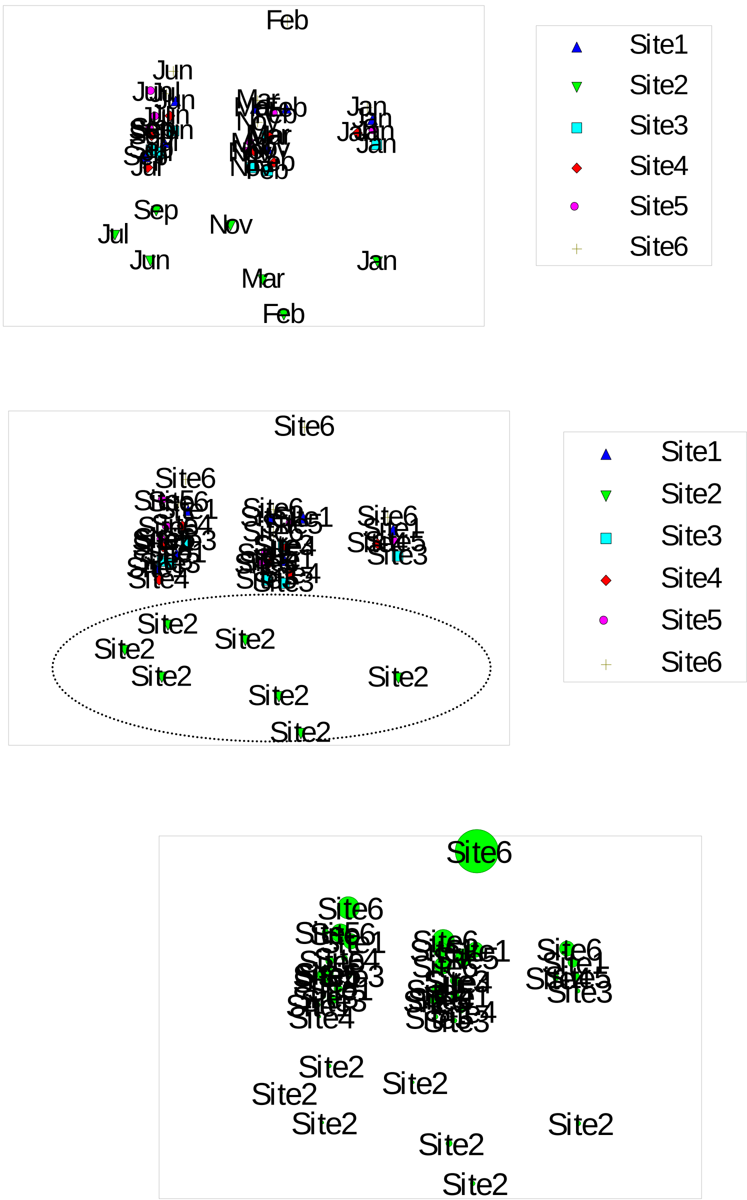

Figure 4: Temporal and spatial MDS ordination plots according to the physical parameters. The last one is MDS plot with the values of physical parameters (bubbles) superimposed on the sites.

The BIO–ENV procedure indicated that the zooplankton discriminating species including *Labidocera* sp., *Acartia fossae, and Ilyoplax frater*, *Sagitta enflata*, *Oikopleura dioica* was strongly correlated to the variability of the environmental parameters for coastal ecosystems of Bushehr. The greatest correlation between the similarity rankings of 5 mentioned species abundance and combinations of environmental variables was 0.983, using the matrix based on trends in depth, transparency, salinity, followed by temperature, pH and chla, respectively.

Table 2: SIMPER for 24 species of zooplankton for coastal ecosystems of Bushehr. Abundance and the percentage contribution of the top 7 to 9 discriminating taxa that contributed the greatest dissimilarity until 91.02% of the accumulated total dissimilarity (Cum. Dis%). The highest discrimination was observed between Ramleh and Lashkary sites as groups with total average dissimilarity of 87.5 % and the least discrimination was observed between Frakeh and Sea sites with total average dissimilarity of 71.5% (Diss.: dissimilarity, Contrib.: Contribution, Cum.: Cumulative).

Species	Abundance				
	Ramleh	**Lashkary**	**Diss.%**	**Contrib.%**	**Cum. Con%**
Labidocera sp.	1632.5	21521	32.9	37.69	37.69
Ilyoplax frater	9796.2	3181.1	26.7	30.54	68.23
Acartia fossae	185.9	323.39	8.86	10.13	78.36
Oikopleura dioica	27.01	2743.2	4.43	5.06	83.42
Sagitta enflata	48.16	2155.1	4.41	5.05	88.47
Upogebia sp.	4.78	73.28	1.13	1.29	89.76
Parthenope sp.	15.98	146.6	1.1	1.26	91.02
	Farakeh	**Sea**			
Labidocera sp.	887.4	445.76	21.8	30.51	30.51
Oikopleura dioica	206.22	251.43	9.64	13.49	44.00
Ilyoplax frater	128.71	305.33	7.36	10.31	54.30
Sagitta enflata	155.09	273.94	7.18	10.05	64.36
Sagitta neglecta	46.85	295.15	6.78	9.49	73.85
Acartia fossae	82.21	131.75	6.31	8.83	82.68
Rhopalophthalmus sp.	48.71	117.92	2.67	3.74	86.42
Parthenope sp.	14.4	112.18	2.53	3.55	89.97
Temora turbinata	4.75	29.99	1.17	1.64	91.61

Discussion

Climatic conditions over the Persian Gulf are harmonious with aridity and hotness of the surrounding landmasses. Maximum air temperature in coastal ecosystems of Bushehr increases abruptly to reach over of 50°C in summer (Azarmsa, 2008). The present study recorded maximum water temperature of 33-34°C during July and September and minimum of 14°C during January, for coastal waters of Bushehr.

According to MDS ordination of similarity in the physical parameters sampled within coastal ecosystems of Bushehr, Farakeh, with similar temporal pattern was distinctly separated from the other sampling sites (Fig. 4) Also Site 6 (Lashkary) with highest values for the combination of environmental parameters in February was separated from others (Fig. 4).

Salinity recorded was more than 40‰ in most sites (except for Farakeh) throughout most of the year; and site 6 recorded readings up to 47‰, the consequence of this high salinity, is marked drop in some oligo and mesohaline taxonomic groups of zooplankton even in Farakeh as a river-estuary (Fig. 2). In fact some species are of either marine or freshwater origin and many live at the edge of their salinity tolerance (Wong *et al*., 2000; Alcaraz *et al*., 2007). However the salinity acts as a major ecological factor in the distribution of living organisms and its variation caused by dilution and evaporation, is most likely to influence the faunal distribution of the coastal ecosystems (Teseng *et al*., 2004),

The present study reveals that mesozooplankton composed of 24 taxa, including 7 copepod species, dominated by holoplanktonic organism such as Copepoda, Brachyura, and Appendicularia.

Contrary to expectations of high diversity for different ecosystems of Bushehr, the semi-isolated nature of the Persian Gulf restricts various zooplankton species resulting in an impoverished pelagic faunal assemblage dominated by a few species. Among all planktons, calanoid copepods were the most dominant group, in terms of abundance throughout the investigation period. First dominant species, *Labidocera* sp. (with a relative abundance of 51%) flourished in February in Lashkary and the second one, *Ilyoplax frater* (28%) flourished in September in Ramleh (Fig. 2). In general, total plankton abundance reflected high similarity in succession pattern during the study time with *Labidocera* sp. but this investigation showed a discrete assemblage of predominant species, *Ilyoplax frater* in relation to the prevailing time in September (Fig. 3).The third dominant taxa was *Oikopleura dioica* with a relative abundance of <10% (its abundance peaked in February in Lashkary) and the forth *Acartia fossae* with less than 10% (highest abundance in September in Lashkary) (Fig. 3). The dominance and abundance of copepods, in particular the calanoids in the marine ecosystem is not surprising since they were known for many years (Deevey and Brooks, 1977; Webber and Roff, 1995; Hwang *et al*., 2010). Based on a research on “Discriminating zooplankton assemblages for Bay of Bengal” *Labidocera* sp. was recorded as oceanic species for its tendency to higher salinity (~35‰) in comparison with coastal waters with lower salinity(~24‰) (Rakhesh *et al*., 2006). *Ilyoplax frater* is a typical inhabitant of inter and sub tidal mudflats, and its larvae are transported into the marine waters f coastal area and of nearby estuaries (Duggan *et al*., 2008).

Clarke and Warwick (1994) proposed Similarity Percentage (SIMPER) to find out discriminating species (those which characterize a particular biotic assemblage or community). Results of breaking down the dissimilarities between samples/groups/sites would show species contributions and species would be ordered by their average contribution to the average dissimilarity. For coastal locations of Bushehr, according to results of SIMPER analysis, the maximum dissimilarity was determined as 87.5% between Ramleh and Lashkary with an average contribution of 7 species and the minimum was 71.5% between Farakeh and Sea with an average contribution of 9 species (Table 2). The first taxon and the best discriminator accounting for the greatest percentage dissimilarity for assemblage groupings between all sites was *Labidocera* sp.

The contribution of *Labidocera* sp. to the average dissimilarity was 37.7% for Ramleh and Lashkary and the highest contribution for this discriminating calanoid was observed as 42% between Dubbeh and Lashkary. The second species, *Ilyoplax frater* (zoeaVI) contributing great dissimilarity to all pairings (except for pairing Farakeh and Sea as third species) separated Ramleh and Lashkary with 31%, contribution for dissimilarity. This contribution for *Ilyoplax frater* reached its highest, 38.6%, between Remleh and Shif. *Acartia fossae* accounted for the greatest percentage dissimilarity with 10% contribution separating Ramleh and Lashkary and it was the third discriminator species (for 7 pairings of 15) (Table 2).

On the basis of 24 mesozooplankton abundance data and species association through MDS Bray–Curtis similarities no clear pattern could be distinguished for 5 coastal locations of Bushehr (not presented) because through results of SIMPER analysis a group of just two taxa were contributing great dissimilarity to all pairings. In fact, little or no significant spatial and temporal differences were observed and a single zooplankton community was apparent throughout all sites, dominated by a few marine (4 dominant) species resistant to high salinity.

Changes in zooplankton community structure across water bodies noticed during this study could not be matched with any single environmental parameter even differing salinity as a fundamental factor. Since biological considerations suggest that a simple linear coding is not appropriate, application of a multivariate and a combination of variables is more precise (Clarke and Warwick, 1994).The BIO–ENV procedure indicated that the zooplankton community structure was strongly correlated to the variability of all environmental variables. This analysis gave greatest correlation between changes in rankings of species abundance for *Labidocera* sp., *Acartia fossae*, and similarity with combinations of depth, transparency, salinity, temperature, and pH, chla, respectively (Table 3). This correlation drops slightly from 0.98, to 0.96 when, the two mentioned species were changed to *Ilyoplax frater* (zoea VI) and the less dominant taxa, *Sagitta enflata, Oikopleura dioica* (Table 3). It seems in February when the water temperature was relatively low (22°C), the zooplankton community consisted of mainly *Labidocera* sp., but in September (32°C) another prevalent species Brachyuran crab, *Ilyoplax rater* was responsible for population discriminating.

Table 3: Relationships between multivariate biological structure and the combination of environmental variables (depth, transparency, salinity, temperature, pH, chla) according to BIO-ENV analysis-coastal ecosystems of Bushehr (2015-2016). (The first 2 higher correlations are based on changing in community composition from 3th species*, and the rest are based on changing from second species).**

Correlation	Species – environmental variables
0.983	*Labidocera* sp., *Acartia fossae, IIyoplax frater, *Sagitta enflata, Oikopleura dioica*, depth, transparency, salinity, temperature, pH, chla
0.975	*Labidocera* sp., *Acartia fossae, IIyoplax frater, *Sagitta neglecta, Oikopleura dioica* depth, transparency, salinity, temperature, pH, chla
0.969	*Labidocera* sp., *Acartia fossae, **Callianassa. zoea, IIyoplax frater, Oikopleura dioica* depth, transparency, salinity, temperature, pH, chla
0.968	*Labidocera* sp., *Acartia fossae,**Upogebia* sp. *zoea, IIyoplax frater, Oikopleura dioica* depth, transparency, salinity, temperature, pH, chla

Also this structure, a narrow range of BIO-ENV correlation for all sites in our study, inconsistent with the dynamic character of the habitat, characterized as a typical coastal marine system (salinity around 35-40) with low average depth and transparency.

In conclusion, we contend that spatial variability in community structure of zooplankton could be largely a result of differences in the hydrographical conditions. At least on the basis of the observations, the coastal waters of all Bushehr environments are characterized by persistent physical stress, heterogeneity of environmental conditions, prevailing temporal variations and high salinity. Finally our data provided basic information for biological monitoring of the Persian Gulf, using first report on mero and holo-mesozooplankton community composition, indicator species and multivariate procedures regarding environmental variables.

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