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Spatial and Temporal Variation in Copepod Community in the Helleh River Estuary – South Coast of Iran, Persian Gulf

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ABSTRACT

Copepods are the main zooplankton assemblages in most tropical and semi-tropical estuaries. In this research, copepod population dynamics were investigated in Helleh River estuary, Persian Gulf during four seasons beginning from summer 2011 to spring 2012. Samples were taken using plankton net with mesh size of 140 µm and vertical towing from 5 fixed-stations in mid-season. Results showed that copepod comprised 10 families viz. Acartiidae, Paracalanidae, Pontellidae, Temoridae, Oithonidae, Oncaeidae, Corycaeidae, Euterpinidae, Ectinosomatidae, and Miraciidae and 10 genera viz., Acartia, Paracalanus, Labidocera, Temora, Oithona, Oncaea, Corycaeus, Euterpina, Microsetella, and Macrosetella. The most dominant copepod was Acartia sp., with the highest abundance in the fall (36068.3 ind./m^3) and the lowest in the winter (1857.3 ind./m^3). Diversity was the highest in the summer and the lowest in the winter. There were significant correlations (P<0.01) between copepod abundance as well as biodiversity with salinity and dissolved oxygen. Based on this study, the most important factors in mudflat shallow river–estuarine system that can describe most changes of copepod assemblages were salinity, dissolved oxygen, chlorophyll a, temperature and Secchi depth, respectively. The cluster analysis aggregated the community into two groups, one associated with nauplii copepod and the other with copepodids and adults.

1 INTRODUCTION

Estuaries are places for human activities such as navigation, shipping, urban, industrial wastes (Carlberg, 1980; Chau, 1999; Kress et al., 2002), and human settlements around them (Chi-Fang et al., 2004), fishing, aquaculture (Jennerjahn et al., 2004) and the resorts activities (Baird et al., 1986; Costanza et al., 1989). Furthermore, other activities such as deforestation, intensive farming, raising livestock, sand mining, river diversion, and conversion of mangrove forests into shrimp/fish ponds may change estuaries and the marine environments (Morton and Blackmore, 2001; Jennerjahn et al., 2004). Estuaries are one of the most productive aquatic ecosystems that constitute physical, chemical and biological parameters between

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freshwater and coastal ecosystems. Most of this variability is reflected in the dynamics of the biological populations, particularly planktonic community (Calbet et al., 2001; Valde's et al., 2007; Marques et al., 2007). In addition, zooplankton assemblages were used to monitor certain aspects of the environment including hydrographic events, eutrophication, pollution, global warming and environmental problems in terms of long-term changes (Omori and Ikeda, 1984). A number of studies have shown how plankton might be an important indicator of change in marine systems (Molinero et al., 2005) and several features refer to planktons as special indicators of climate change (Taylor et al., 2002).

Copepods are the most important component of the zooplankton in terms of abundance, biomass and diversity in aquatic ecosystems. They have an important role in transferring energy and organic materials from primary producers to higher trophic levels such as fish and shrimp stocks (Ara, 2004; Shimode et al., 2006). Spatial and temporal studies on copepod abundance and diversity provide a basis for the assessment of their contribution in secondary production as well as their role in estuary trophy (Magalhaes et al., 2006).

One of the riverian-estuary systems in south coast of Iran is Helleh River estuary in Persian Gulf. The Helleh River basin has an ecological importance for migratory birds, wildlife and aquatic organisms especially fish. The freshwater of this estuary comes from Helleh River. It is a permanent river with 170 km length that discharges to the Persian Gulf at 54 km far from Bushehr. The Helleh River originates from south part of Zagros Mountains, Iran. This river receives the Dalaki and Shapur rivers at west of Shiraz, Fars province. The highest concentration of nutrients (NO3, PO4 and SiO4) reaches to Persian Gulf from Iranian coastal waters (ROPME, 2003), such as Helleh River estuary. Therefore, proper management of nutrients loaded to Persian Gulf which determines the composition of planktonic assemblages at different parts of estuarine rivers, especially at mudflat shallow estuary such as Helleh River estuary is essential to assess the environmental conditions.

Therefore, research on zooplankton, especially copepod is important for the management of Helleh River estuary. This study aimed to investigate the pattern of distribution, abundance and diversity of copepods in different seasons and stations in the Helleh River estuary of Persian Gulf.

2 MATERIALS AND METHODS

The study area was located in the Helleh estuary (latitude=28º 20' N; longitude=51º 30' E), in southwest of Bushehr province placed at north of Persian Gulf, Iran (Fig. 1). Along Helleh River estuary (Fig. 1) five sampling stations were determined based on environmental gradients of flow dynamics and mixing of fresh and costal water, depth, tides, river flow and geomorphological features. Seasonal samplings were carried out in the middle of each season for a one-year period from August 2011 to April 2012. Measurements were made of water temperature, Secchi depth, dissolved oxygen (YSI 51 Oxygenmeter, OH, USA), pH (WTW 330 pHmeter, Weilheium, Germany) and salinity *in situ*. Three water samples of 3-L were collected from the surface at sampling site for measuring of measuring chlorophyll a (Fig. 1) by a Van Dorn water sampler. Amount of chlorophyll *a* was determined according to Parsons et al. (1984) in the laboratory.

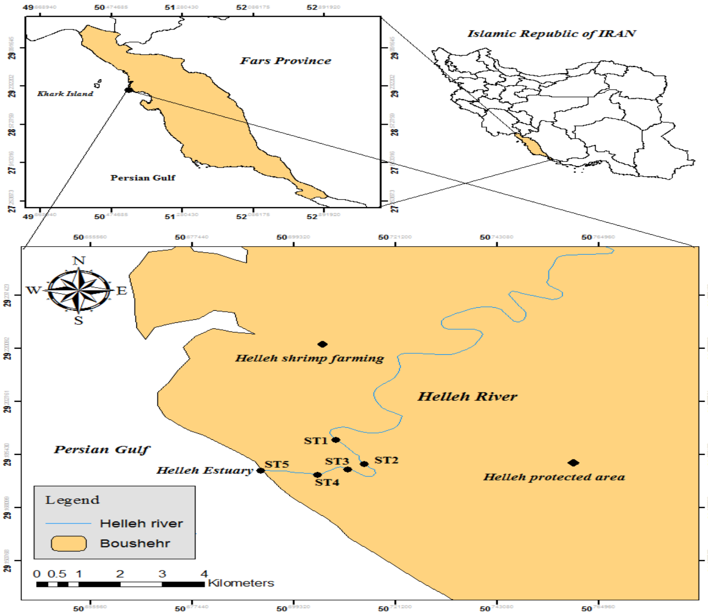

Fig. 1. Stations (ST) and geographic location in the Helleh River estuary

Counting of copepods was carried out by 3 sub-samples of 10 ml using a Bagarov's plate chamber. Copepods were identified using zooplankton keys (Monchenko, 1974; Grindley, 1981; Maguire et al., 1984; Nishida, 1985; Todd and Laverack, 1991; Chihara and Murano, 1997) under laboratory loop (Olympus, SZ6045, Japan) with magnification of ×6 and also inverted microscope (model CETI, Belgium) with magnification of ×100. The formula of D= (N/V1) ×V2/V was used to calculate the abundance of zooplankton (Omori and Ikeda, 1984), where, D= zooplankton abundance, N= number of individuals in the sub-sample, V1= volume of the sub-sample (ml), V2= volume of original sub-sample (ml), V= volume of water filtered by plankton net (m^3). The biodiversity indices of Shannon-Wiener (H) and Simpson (D) were determined based on Omori and Ikeda (1984) and Ecological Methodology (version 6) (Krebs, 2001) as follows:

$$D = 1 - \sum_{i=1}^{s} (P_i)^2$$

$$H = -\sum_{i=1}^{s} (P_i)(\ln P_i)$$

Where Pi is the relative abundance of the i th taxon and S is total number of taxa.

Statistical analysis of data was performed using one-way ANOVA to investigate any significant differences between the different parameters. Comparison of means was conducted by using Duncan's test at significance level of 5% (Zar, 1984; Pallat, 2004). Pearson correlation, between the abundance, diversity and water quality parameters were carried out. Clusters were depicted in SPSS software (version18).

3 RESULTS

3.1 Water quality parameters

Seasonal average of water temperature and dissolved oxygen were 32.4 °C and 6.8 mg/L in summer; 19.2 °C and 7.1 mg/L in fall; 13.6 °C and 11.3 mg/L in winter; 23 °C and 8.4 mg/L in spring; respectively (Fig. 2).

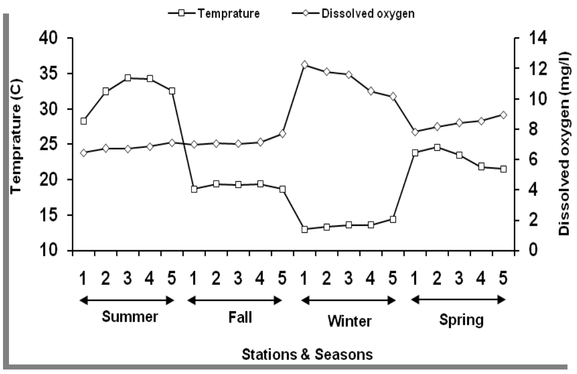

Fig. 2. Average temperature and dissolved oxygen in the Helleh River estuary.

Seasonal average of water salinity and pH were 39.6 ppt and 8.1 in summer; 37.6 ppt and 8.1 in fall; 17.2 ppt and 8.1 in winter; 27.8 ppt and 8.2 in spring; respectively (Fig. 3). Seasonal average of Secchi depth and chlorophyll *a* were 44.4 cm and 0.11 mg/m^3 in summer; 48 cm and 0.38 mg/m^3 in fall; 50 cm and 0.05 mg/m^3 in winter; and 45.2 cm and 0.24 mg/m^3 in spring, respectively (Fig. 4).

3.2 Copepod composition

The copepod in Helleh estuary comprised of 10 genera including: Acartia, Euterpina, Oithona, Oncaea, Paracalanus, Corycaeus, Labidocera, Macrosetella, Microsetella and Temora had the maximum presence (Table 1). Among the identified copepods, Acartia sp. and copepod nauplii had the highest abundance, respectively.

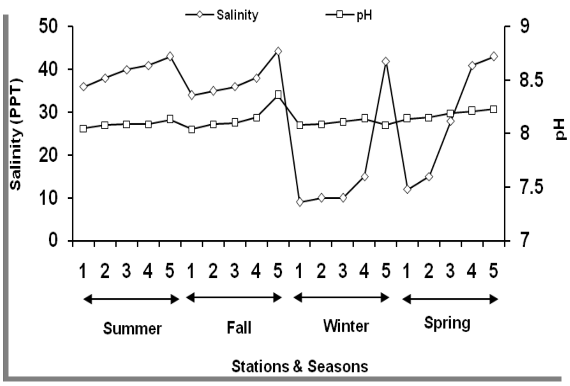

Fig. 3. Average of salinity and pH in Helleh River estuary.

The maximum density (abundance) of copepod was estimated in fall at all sampling stations (Fig. 5). The abundance (%) of copepod genera for each season is presented in Figs 6-9 separately.

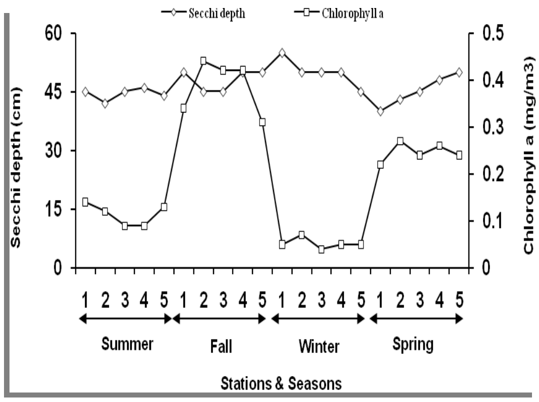

Fig. 4. Average Secchi depth and chlorophyll a in the Helleh River estuary

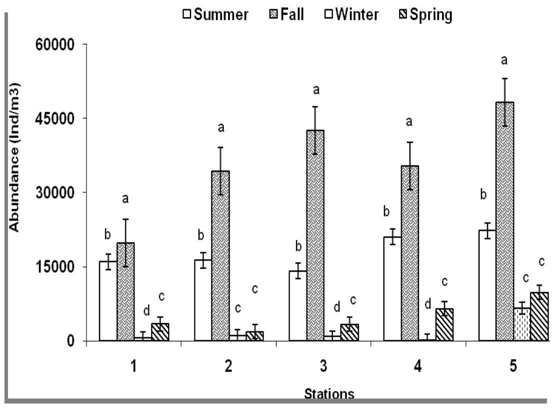

Fig. 5. Average (± standard error) abundance of copepod from the Helleh River estuary.

Table 1
Identified copepods in Helleh River estuary during the study period.

Phylum	Sub-phylum	Order	Family	Genus
Artheropoda	Crustaceae	Calanoida	Acartiidae	*Acartia* sp.
			Paracalanidae	*Paracalanus* sp.
			Pontellidae	*Labidocera* sp.
			Temoridae	*Temora* sp.
		Cyclopoida	Oithonidae	*Oithona* spp.
			Oncaeidae	*Oncaea* sp.
			Corycaeidae	*Corycaeus* sp.
		Harpacticoida	Euterpinidae	*Euterpina* sp.
			Ectinosomatidae	*Microsetella* sp.
			Miraciidae	*Macrosetella* sp.

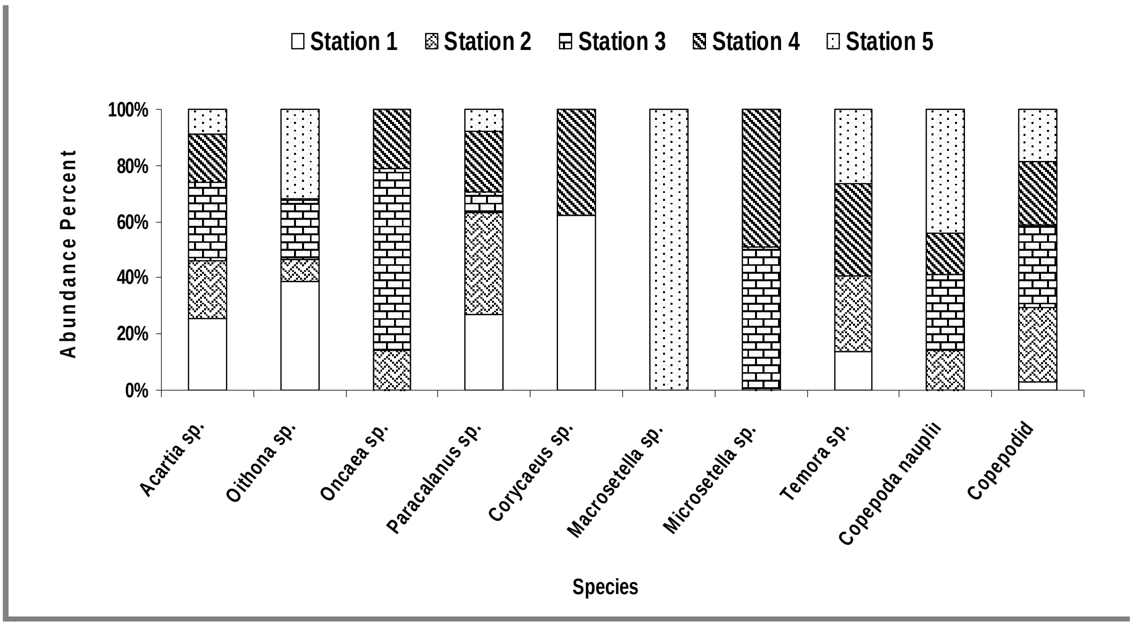

Fig. 6. Copepod abundance (%) from the Helleh River estuary in summer 2011

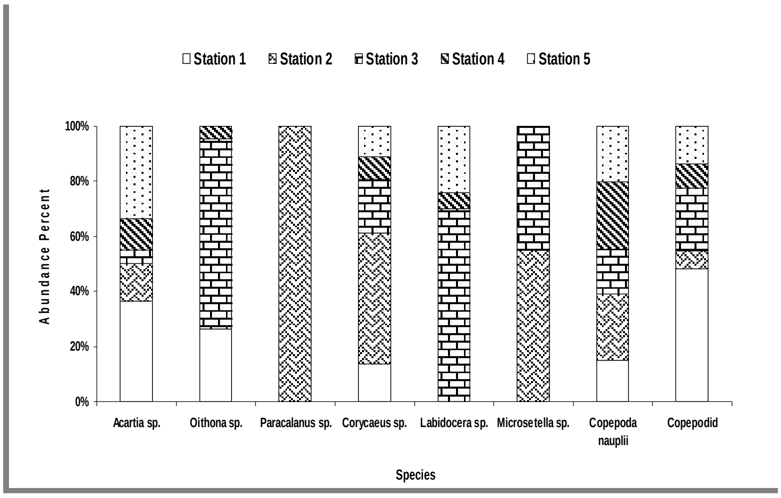

Fig. 7. Copepod abundance (%) from the Helleh River estuary in fall 2011.

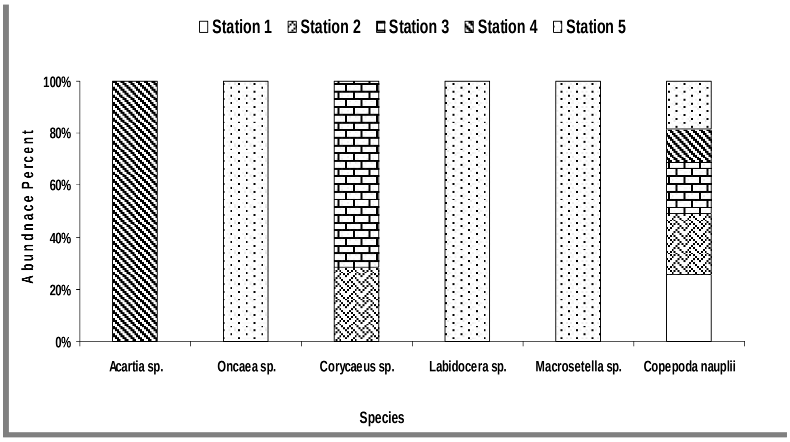

Fig. 8. Copepod abundance (%) from the Helleh River estuary in winter 2012.

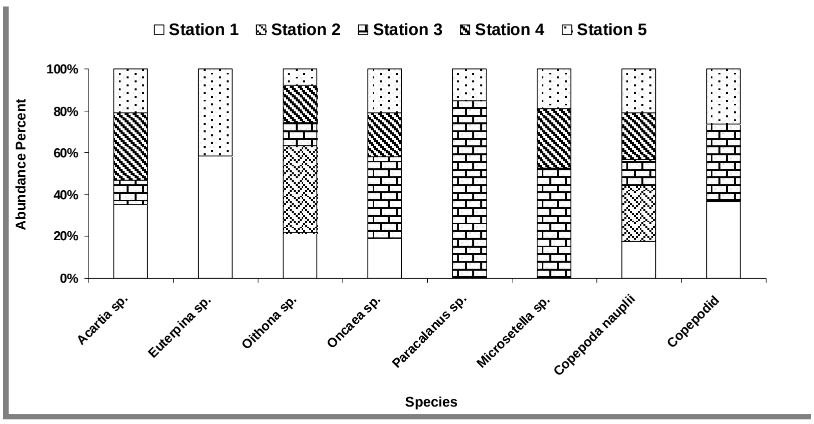

Fig. 9. Copepod abundance (%) from the Helleh River estuary in spring 2012.

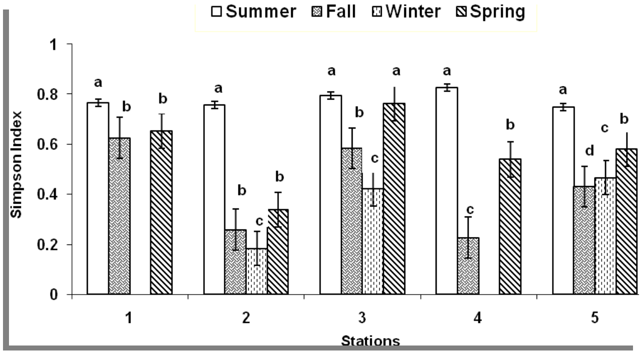

Fig.10. Average (± standard error) Simpson diversity of copepods in the Helleh River estuary.

3.3 Copepod biodiversity

The mean seasonal Simpson and Shannon-Weiner biodiversity indices are presented in Figs 10 and 11. According to Simpson and Shannon-Weiner biodiversity indices, there were significant differences among seasons, highest in summer and lowest in winter (Fig. 12). In other words, mean copepod diversity of Simpson and Shannon-Weiner were 0.78 and 2.41 in summer; 0.42 and 1.23 in fall; 0.35 and 0.83 in winter; and 0.58 and 1.75 in spring, respectively (Fig. 12).

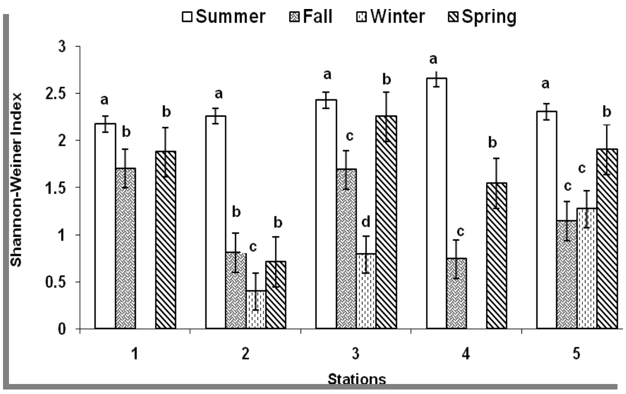

Fig. 11. Average (± standard error) Shannon-Weiner diversity of copepods in the Helleh River estuary

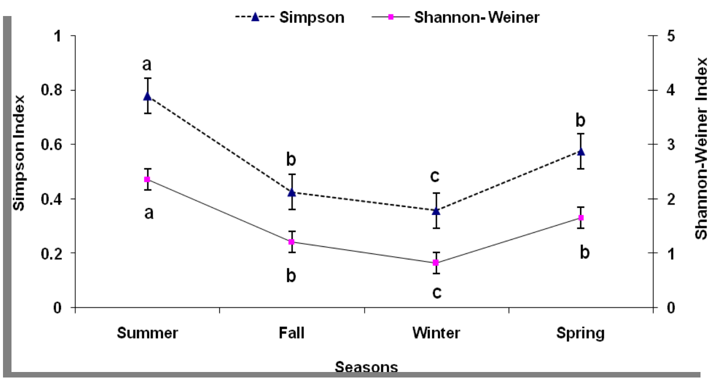

Fig. 12. Average (± standard error) Simpson and Shannon-Weiner diversity of copepods in the seasons in the Helleh River estuary

Table 2
Pearson correlation coefficients among some of water quality parameters with abundance, Simpson and Shannon-Weiner indices in the Helleh River estuary

Parameter	Abundance	Simpson	Shannon-Weiner
Salinity	0.634 [b]	0.555 [a]	0.618 [b]
Dissolved oxygen	-0.626 [b]	-0.668 [b]	-0.700 [b]
pH	-0.003	-0.044	-0.016
Temperature	0.173	0.797 [a]	0.835 [a]
Secchi depth	-0.46	-0.616 [b]	-0.592 [b]
Chlorophyll *a*	0.671 [b]	0.007	0.025

[a] significant correlation in 0.05 level
[b] significant correlation in 0.01 level

3.4 Pearson correlation

Correlation among water parameters, copepod abundance and diversity indices are presented in Table 2. The results showed that there were correlations between salinity and dissolved oxygen with copepod abundance, Simpson, Shannon-Weiner indices. In addition, temperature and Secchi depth were correlated with Simpson and Shannon-Weiner diversity. The chlorophyll a was correlated with copepod abundance.

3.5 Cluster analysis

Cluster analysis of zooplankton abundance and diversity showed that two main categories (A and B) are available in Helleh river estuary. Dendrogram of copepod composition also showed the existence of copepod nauplii in group A and other genera in group B (Fig. 13). Comparison of abundance in all stations showed stations 2, 3, 4 and 5 in fall in group A and other stations in group B (Fig. 14). Based on diversity cluster (Fig. 15, Fig. 16), Simpson and Shannon-Weiner diversity generally had two groups, first in fall and winter (B) and second in summer and spring (A).

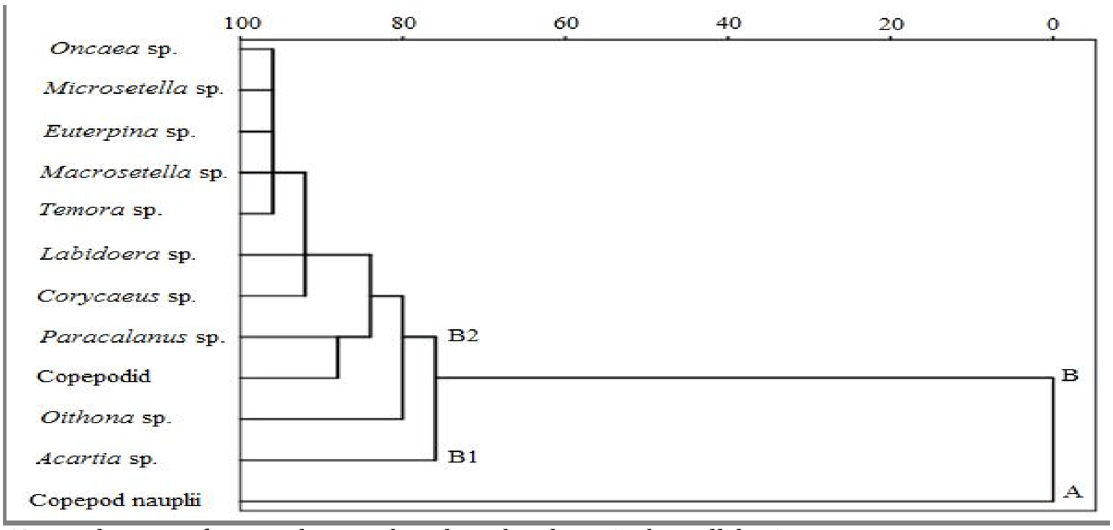

Fig. 13. Dendrogram of copepod genera based on abundance in the Helleh River estuary

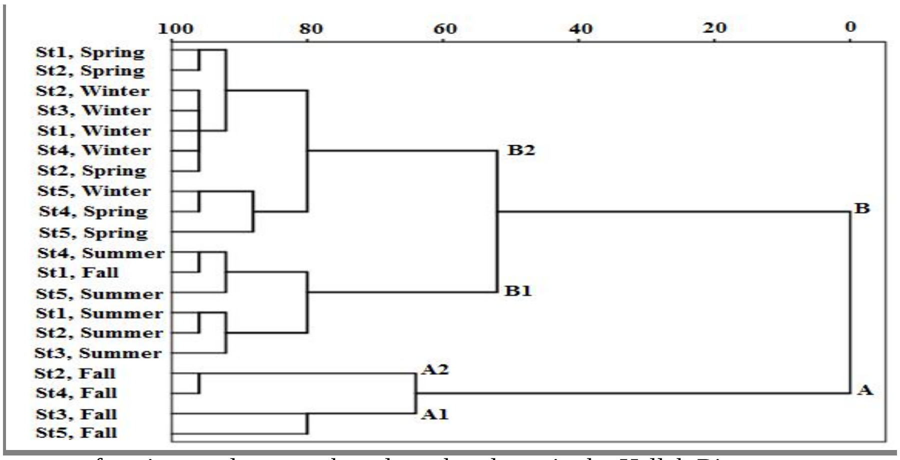

Fig. 14. Dendrogram of stations and seasons based on abundance in the Helleh River estuary

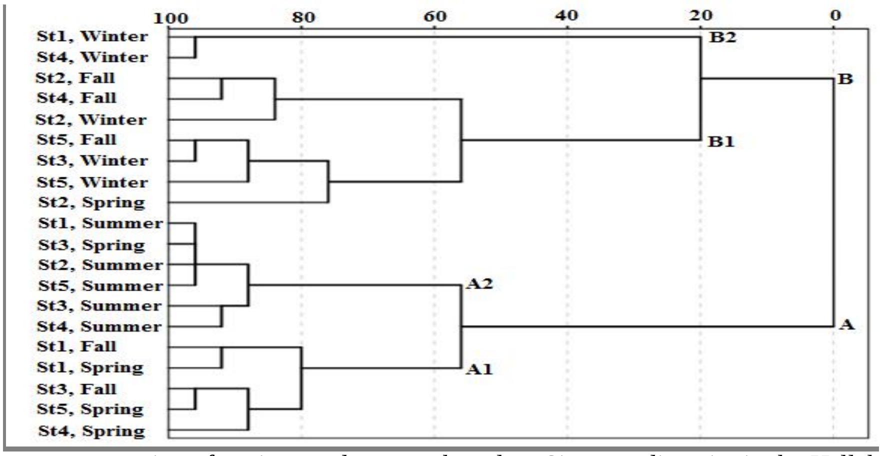

Fig. 15. Dendrogram comparing of stations and seasons based on Simpson diversity in the Helleh River estuary

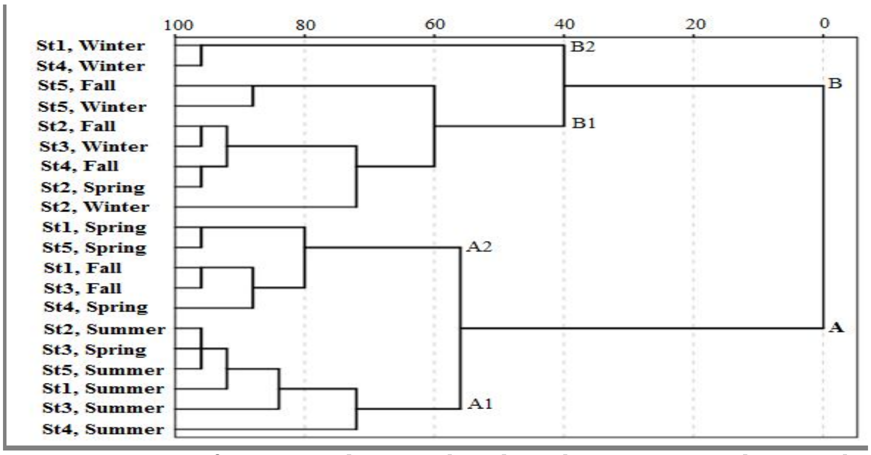

Fig. 16. Dendrogram comparison of stations and seasons based on Shannon-Weiner diversity the Helleh River estuary

4 DISCUSSION

It is widely recognized that copepods abundance in estuaries significantly fluctuates with time in relation to physical and chemical parameters due to tidal cycles and environment parameters (Ara, 2004; Sterza and Fernandes, 2006). During seasonal sampling in the Helleh River estuary, 10 genera of copepods were observed. Copepod nauplii were the most abundant among them. Among calanoid copepod, Acartia sp. was present in all seasons, with the most abundance at the mouth of the estuary (station 5). Similar situation was common in other estuaries (Tiwari and Nair, 1993; Wooldridge and Callahan, 2000; Primo et al., 2009; Hwang et al., 2010; Xuelu et al., 2011).

Generally, copepods make the bulk of zooplankton and they are the dominant zooplankton group in most tropical estuaries (Osore, 1992; Zabella and Gaudy, 1996; Mishara and Panigrahy, 1999; Marcolin et al., 2003; Lee et al., 2006; Hwang et al., 2010). Copepod nauplii play an important role in aquatic ecosystems as the main food item of larger zooplankton (Hopcroft et al., 1998). Compared to total zooplankton density, copepods nauplii had the highest percentage of abundance in fall, winter and spring. In general, cluster analysis showed that copepod nauplii had the highest abundance between adults and copepodids during the time of study. Similarly, Park and Marshall (2000) reported that copepod nauplii are the major component of the zooplankton density.

In the estuaries, there are distinct patterns of seasonal variation in abundance of zooplankton, and it is difficult to make generalizations (Day et al., 1989). The zooplankton of estuarine system varies significantly according to changing tides and other factors. Dominance of copepods in fall was due to the high thermal tolerance, environmental and reproductive conditions that plankton was living in. In contrary, the lowest copepod population in winter could be related to poor living conditions such as a decrease in water temperature and reduction of photosynthetic primary production (Omori and Ikeda, 1984).

The change of species composition and community structure can be explained numerically with species diversity (Kulshreshta et al., 1989). In this study, the highest diversity of copepod was in the summer and the lowest in winter based on Simpson and Shannon-Wiener diversity indices. Mann (2000) reported that the greatest numbers of species occur in more saline waters, and species diversity tends to decrease with decreasing salinity. Distribution of major groups of zooplankton populations is governed by various behavioral and physiological adaptations of the plankton population to ever changing hydrographical conditions. It depends on the regime of individual estuaries which varies according to climate and the catchments area of its feeder river (Mohan et al., 1999). In general, in estuaries, the majority of the diversity is near the mouth of them, where coastal and neritic species live. Usually peak of diversity is in salinity of 36 ppt and diversity amount will be reduced by decreasing the salinity range (Sirinivasan et al., 1998). In the present study, there were no such conditions that could be due to fluctuations of copepods abundance in different stations which can be caused by environmental, reproductive and nutritional conditions (Omori and Ikeda, 1984).

Salinity is the most important factor influencing the community structure of zooplankton populations in tropical estuaries (Nasser et al., 1998; Lee et al., 2006; Hwang et al., 2010). In addition, other physicochemical parameters also regulate the copepod community structure. Development of a salinity gradient from the upstream areas to the sea in estuaries is mainly due to the strength of diurnal tidal current and the volume of freshwater flow from the upstream. In this study, salinity showed positive correlation with the copepods abundance, Simpson diversity and Shannon-Weiner diversity. Salinity affects the overall composition of the zooplankton community and may affect the individual species at different stages of their life cycle (Day et al., 1989). Mishara and Panigrahy (1999) noted salinity as the most important factor in the distribution of zooplankton (Specifically copepods) in the estuaries. They reported that freshwater flows into estuaries decreased the zooplankton densities.

Other physicochemical parameters such as turbidity and chlorophyll *a* have effects on zooplankton distribution. During the present study, compared with affecting factors on zooplankton, chlorophyll *a* had positive correlation with copepods that perhaps indicates to the importance of food to zooplankton. In other studies, similar results are observed (Zaballa and Gaudy., 1996; Lee et al., 2006). The availability of food items is one of the major factors determining the zooplankton distribution (Mitra et al., 1990; Park and Marshall, 2000).

In the present study, temperature had positive correlation with copepods diversity. Several authors (Madhupratap, 1987; Mishra and Panigrahy, 1999) believe that temperature has no significant effect on tropical zooplankton populations and diversity. However, Osore (1992), Lopes (1994) and Nasser et al., (1998) considered temperature as an important factor affecting the abundance and distribution of zooplankton populations..

Estuaries are an ecotone region for aquatic organisms, especially for feeding and development of aquatic larvae. The crustacean plankton, especially copepod, is ecologically, economically and biologically significant in sustainable management. These organisms as consumers of primary production in aquatic ecosystems and secondary producers in food chains are considered as an indicator in environmental studies. Further studies are recommended for environment monitoring in the Helleh River estuary.

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