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Seasonal variations in abundance and diversity of copepods in Mond River estuary, Bushehr, Persian Gulf

ALIAKBAR HEDAYATI[1,♥], MOJTABA POULADI[1], AMIR VAZIRIZADEH[2], AMIR QADERMARZI[1], NEDA MEHDIPOUR[3]
[1]Faculty of Fisheries and Environmental Sciences, Gorgan University of Agricultural Sciences and Natural Resources. Gorgan, Golestan, Iran. Tel.: +98-913 152 8572, ♥email: hedayati@gau.ac.ir
[2]Department of Marine Biology and Fisheries, Persian Gulf Research Institute, Persian Gulf University. Bushehr, Iran
[3]Iranian National Institute for Oceanography and Atmospheric Science. Tehran, Iran

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Abstract. *Hedayati A, Pouladi M, Vazirizadeh A, Qadermarzi A, Mehdipour N. 2017. Seasonal variations in abundance and diversity of copepods in Mond River estuary, Bushehr, Persian Gulf. Biodiversitas 18: 447-452.* The present study was carried out to investigate the abundance and biodiversity of copepods from Mond River (MR) estuary, Bushehr, the Persian Gulf during 4 seasons and their relationships with environmental factors. The water samples were collected in mid-season from spring 2012 to winter 2013 for one year period. Copepod samples were collected by using of 140 µm plankton net with 25 cm mouth diameter and vertical towing in all stations. Copepod assemblages were comprised of 4 orders, 13 families, and 10 genera. Orders were included; Calanoida, Cyclopoida, Poecilostomatoida, Harpacticoida and Genera were included: *Cathocalanus*, *Acrocalanus*, *Paracalanus*, *Subeucalanus*, *Centropages*, *Temora*, *Calanopia*, *Labidocera*, *Pontella*, *Acartia*, *Oithona*, *Oncaea*, *Corycaeus*, *Microsetella*, *Microsetella* and *Euterpina*. The order Calanoida with 10 genera was the most diverse and dominant order between Identified orders. The means (±SE) of copepods abundance were recorded in spring (5853.4±1826.19 Individual m^{-3}), in summer (6707.6±1930.15 Ind. m^{-3}), in fall (4393.6±1263.37 Ind. m^{-3}) and in winter (3400±763.98 Ind. m^{-3}), respectively. Simpson and Shannon-Wiener biodiversity indices were obtained in spring (0.87±0.11 and 2.86±0.19), in summer (0.89±0.006 and 3.11±0.15), in fall (0.86±0.13 and 2.66±0.2) and in winter (0.83±0.12 and 2.39±0.15), respectively. The copepod assemblages had most amounts of diversity and abundance at station 5 in all seasons. Pearson correlation showed a significant correlation between copepod diversity and abundance with salinity, pH and temperature. Results showed that salinity factor was more effective environmental factor on Simpson (0.01> P and r=0.783) and Shannon-Weiner indices (0.01> P and r=0.727), and copepods abundance (0.01> P and r=0.664) in MR estuary.

Keywords: Abundance, copepod, diversity, environmental factor, Mond Estuary

INTRODUCTION

Estuaries form a transfer region between marine environments and rivers and are subject to both marine influences such as waves, tides, and the invasion of saline water and riverine influences, such as currents of fresh water and sediment. The currents of both fresh water and sea water prepare high levels of nutrients in the water column and sediment, making estuaries among the most productive natural habitats (McLusky and Elliott 2004; Lam-Hoai et al. 2006). Zooplankton communities are ideal candidates for the study of the ecosystem reaction to climate variations because their life cycles are short, then assemblages have the potential to respond and reflect event-scale and seasonal variations in environmental situations. Moreover, many zooplankton taxa are known to be indicator species whose presence or absence may illustrate the relative influence of different water types on ecosystem structure. Thus zooplankton may serve as sentinel taxa that reflect changes in marine environments by preparing early indications of a biological response to climate changes (Mackas et al. 2001; Hays et al. 2005; Hooff and Peterson 2006).

Copepods are playing a key role in the food webs in the oceans and are known as secondary producers. They make the link between phytoplankton and microzooplankton and higher levels of food chains, such as macrozooplankton and planktivorous fishes (Ohman and Hirch 2001; Kimmel 2011; Calbet et al. 2001; Frangouils et al. 2004). So far, many types of research on zooplankton including copepods have been done in the Persian Gulf waters (Michel and Herring 1984; Al-Khabbaz and Fahmi 1994; Savari et al. 2004; Farhadian and Pouladi 2014, Reazi et al. 2014). Due to the importance of copepods in marine ecosystems and the lack of sufficient information in relation to these planktonic assemblages in Mond estuary, the aim of this study was to identify copepod species and calculation of their diversity and density in different seasons in relation to environmental factors in MR estuary.

MATERIALS AND METHODS

Study area

The study area was located in the MR estuary, the southeastern part of Bushehr province, and north of Persian Gulf, Iran. Along MR estuary, five sampling stations were determined based on environmental gradients of flow dynamics and mixing of fresh and coastal waters, depth, tides, river flow and geo-morphological features (Figure 1).

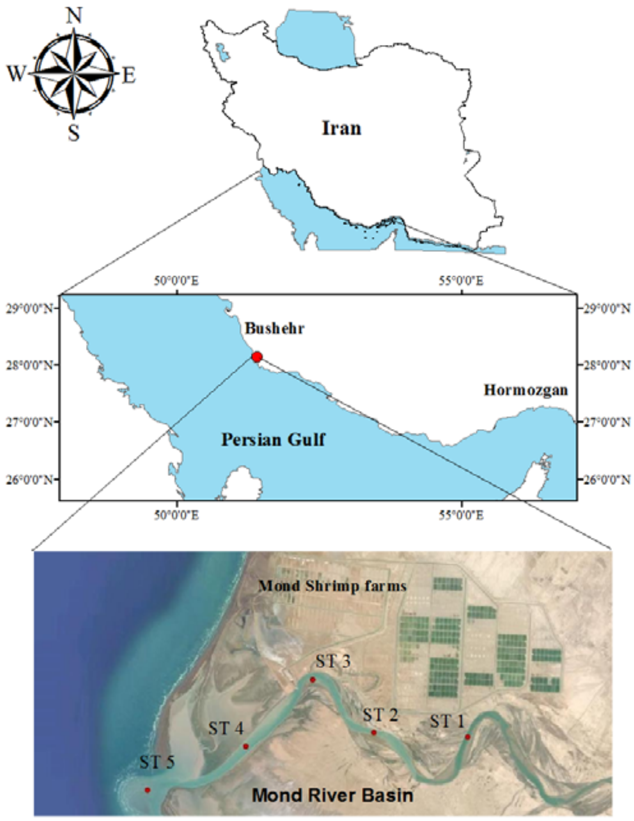

Figure 1. Sampling stations in Mond River estuary, Persian Gulf, Bushehr, Iran

Procedures

Seasonal samplings were carried out in the middle of each season for one year period from May 2012 to February 2013. Water temperature and pH were recorded by Mercury thermometer and pH meter model WTW. Salinity was recorded by using Atago S/Mill refractometer. Dissolved oxygen was measured by YSI 51 Oxygen meter (Model OH, USA) and transparency was obtained by Secchi depth plate. Copepod samples were collected by using of 140 µm plankton net with 25 cm mouth diameter and vertical towing in all stations with three subsamples of each station for measurement of abundance and diversity.

All sampling activities were accomplished in high tide times. For determination of copepod abundance, three sub-samples from each sample with a volume of 10 mL were prepared and were poured in Bagarov's chamber. Counting and identification of copepod communities were done by using of laboratory loop (Olympus, SZ6045, Japan) with magnification of 6 and invert microscope (model CETI, making Belgium) with magnification of 40 and seawater and brackish water zooplankton keys (Fernando 2002; Conway et al. 2006; Ali et al. 2009). The following formula was used to calculate the abundance of copepod (Omori and Ikeda 1984):

$$D = (N / V1) \times V2 / V \qquad (1)$$

D: Copepod abundance, N: Number of individuals in the sample, $V_{1:}$ Volume of the sample used for counting (mL), $V_{2\,:}$The exact size of the original sample (mL), V: Volume of water filtered by plankton net (m^3)

The Shannon-Wiener diversity index (H′) (Shannon and Weaver 1948) and Simpson diversity index (D) (Simpson 1949) were used for species diversity as following:

$$H = -\sum_{i=1}^{s}(Pi)(\ln Pi) \qquad (2)$$

$$D = 1 - \sum_{i=1}^{s}(Pi)^2 \qquad (3)$$

Pi: the relative abundance of the i^{th} taxon, S: total number of taxa

One-way ANOVA was performed to test significant seasonal differences in copepod abundance, diversity and water quality factors. Data were presented as means ± standard error of means. All data met the parametric test assumptions (normal distribution, homogeneity of variance, independence and randomness of the data). Data was transformed by Arcsin-square root to ensure a normal distribution (Zar 1984). All statistical analysis was carried out by using SPSS version 18.0 and diversity indices were calculated by using Ecological Methodology, version 6.0 (Krebs 1999).

RESULTS AND DISCUSSION

The copepod communities in Mond River estuary were comprised of 4 orders, 13 families and 10 genera (Table 1). Genera were including, i.e. *Cathocalanus*, *Acrocalanus*, *Paracalanus*, *Subeucalanus*, *Centropages*, *Temora*, *Calanopia*, *Labidocera*, *Pontella*, *Acartia*, *Oithona*, *Oncaea*, *Corycaeus*, *Microsetella*, *Microsetella* and *Euterpina*. Among the identified copepods, *Acartia fossae* (587±295 Individual m^{-3}), *Acartia* sp. (467±266 Ind. m^{-3}) and copepod nauplii (1000±303 Ind. m^{-3}) in spring, *Acartia* sp. (547±289 Ind. m^{-3}) and *Acartia ohtsukai* (426±182 Ind. m^{-3}) and copepodite (453±148 Ind. m^{-3}) in summer, *Acartia fossae* (400±193 Ind. m^{-3}), *Acartia* sp. (307±185 Ind. m^{-3}) and copepod nauplii (626±185 Ind. m^{-3}) in fall, *Labidocera* sp. (346±154 Ind. m^{-3}), *Acartia fossae* (333±216 Ind. m^{-3}) and copepod nauplii (426±116 Ind. m^{-3}) in winter had the highest abundance, respectively. During sampling period; *Temora discaudata, Calanopia elliptica, Acartia fossae, Acartia* sp. and *Oithona brevicornis* had the most presence and *Centropages orsinii* and *Pontella* sp. showed the least presence in the estuary environment (Table 1).

Most population abundance of copepods were observed in station 5 in the mouth of estuary in all seasons that were (12733±1930 Ind. m^{-3}) in spring, (14067±3154 Ind. m^{-3}) in summer, (9467±1268 Ind. m^{-3}) in fall and (6267±1314 Ind. m^{-3}) in winter, respectively (Figures 2). Among Copepods, calanoids were the dominant assemblages in MR estuary. Cyclopoid and calanoid copepods are dominant holoplanktonic zooplankton in some estuaries. They are main grazers of microzooplankton and phytoplankton and they play the role of prey for zooplanktivorous fishes and invertebrates (Benfield 2013). A similar situation has been reported in other estuaries (Primo et al. 2009; Hwang et al. 2010; Xuelu et al. 2011; Farhadian and Pouladi 2014). Also, copepods nauplii as a wide variety of species were observed in Mond River estuary, which occurred in appreciable amounts. Copepods nauplii, copepodites and adult stages of smaller copepods are important grazers and essential food sources for critical fish larval stages and are considered to be an important component of the marine trophic web (Webber and Roff 1995).

Change of species composition and community structure can be explained numerically with species diversity (Kulshreshta et al. 1989). The diversity of zooplankton species in aquatic ecosystems is linked to its abundance. High diversity might indicate larger food chain, inter-specific interaction and stability among the estuarine zooplankton community (Varadharajan and Soundarapandian 2013). Highest amounts of copepods Simpson and Shannon-Weiner diversity were obtained in station 5 that were (0.91±0.003) and (3.52±0.092) in spring, (0.91±0.02) and (3.63±0.28) in summer, (0.9±0.01) and (3.36±0.14) in fall, (0.88±0.009) and (2.96±0.14) in winter, respectively (Figures 3 and 4). In comparison the seasons were studied, summer with the average abundance (6707±1930) an average Simpson (0.89±0.006) and Shannon-Weiner (3.11±0.15) had highest amounts and winter with average abundance (3400±763) an average Simpson (0.83±0.12) and Shannon-Weiner (2.39±0.15) had lowest amounts, respectively (Table 2).

Table 1. Comparison of copepods presence (*) during different seasons in Mond River estuary

Order	Identified copepod	Spring	Summer	Fall	Winter
Calanoida	*Cathocalanus pauper*	*	*		
	Acrocalanus longicornis	*	*	*	
	Paracalanus sp.		*		*
	Paracalanus indicus	*		*	
	Subeucalanus flemingeri	*	*	*	*
	Centropages orsinii		*		
	Temora discaudata	*	*	*	*
	Temora Turbinata	*	*	*	
	Calanopia elliptica	*	*	*	*
	Labidocera sp.	*			*
	Labidocera minuta		*	*	
	Pontella sp.		*		
	Acartia fossae	*	*	*	*
	Acartia sp.	*	*	*	*
	Acartia ohtsukai		*	*	
Cyclopoida	*Oithona attenuata*	*	*	*	
	Oithona brevicornis	*	*	*	*
	Oithona sp.	*	*		
Poecilostomatoida	*Oncaea* sp.	*			*
	Corycaeus sp.	*	*	*	
	Corycaeus agilis			*	*
Harpacticoida	*Microsetella* sp.	*	*		
	Macrosetella sp.	*	*	*	
	Euterpina sp.		*		*
Others	Copepodite larvae	*	*	*	*
	Nauplii larvae	*	*	*	*

The seasonal average of temperature and dissolved oxygen were 23.92 °C and 8.28 mg L^{-1} in spring; 33.4 °C and 6.87 mg L^{-1} in summer; 19.54 °C and 7.39 mg L^{-1} in fall, and 14.8 °C and 9.46 mg L^{-1} in winter, respectively. The seasonal average of water transparency, salinity and pH were 43.6 cm, 28.2 ppt and 8.2 in spring; 44.8 cm, 38.8 ppt and 8.1 in summer; 46 cm, 35.8 ppt and 8.1 in fall and 49.8 cm, 25.2 ppt and 8.15 in winter, respectively (Table 3).

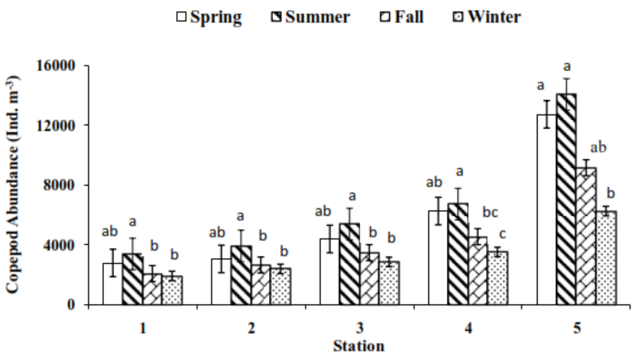

Figure 2. Seasonal abundance (Mean ±SE) of copepods at different stations in Mond River estuary (0.05> P)

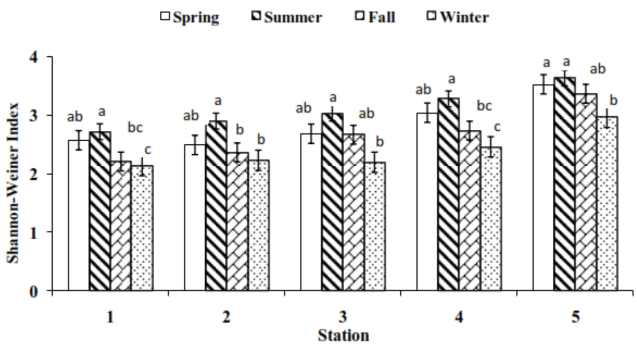

Figure 3. Shannon-Weiner diversity (Mean ±SE) of copepods at different stations in Mond River estuary (0.05> P)

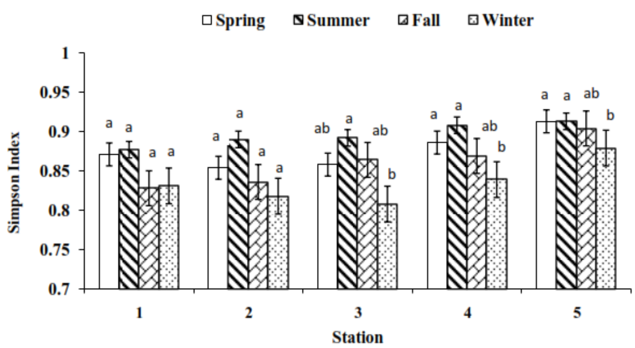

Figure 4. Simpson diversity (Mean ±SE) of copepods at different stations in Mond River estuary (0.05> P)

Table 2. Mean (±SE) of copepods abundance and diversity indices in different seasons in Mond River estuary (0.05> P)

Index	Spring	Summer	Fall	Winter
Abundance	5853.4±1826.19 [a]	6707.6±1930.15 [a]	4393.6±1263.37 [a]	3400±763.98 [a]
Simpson	0.87±0.11 [ab]	0.89±0.006 [a]	0.86±0.13 [bc]	0.83±0.12 [c]
Shannon-Weiner	2.86±0.19 [ab]	3.11±0.15 [a]	2.66±0.2 [ab]	2.39±0.15 [b]

Table 3. Mean (±SE) of water quality factors in different seasons in Mond River estuary (0.05> P)

Parameters	Spring	Summer	Fall	Winter
Salinity (ppt)	28.2±4.21[bc]	38.8±1.68[a]	35.8±1.53[ab]	25.2±4.19[c]
Dissolved Oxygen (mg L^{-1})	8.28±0.15[b]	6.87±0.22[c]	7.39±0.11[c]	9.46±0.38[a]
pH	8.2±0.025[a]	8.1±0.013[b]	8.1±0.06[b]	8.15±0.045[ab]
Temperature (^{O}C)	23.92±0.16[b]	33.4±0.5[a]	19.54±0.2[c]	14.8±0.33[d]
Transparency (cm)	43.6±0.68[b]	44.8±1.16[b]	46±1.05[b]	49.8±1.5[a]

Note: Values with different letters indicate significant mean differences

Table 4. Pearson correlation between some of water properties with abundance and biodiversity indices in Mond River estuary, Persian Gulf, Iran

Correlation		Abundance	Simpson Index	Shannon-Weiner Index
Salinity	Pearson Correlation	0.664**	0.783**	0.727**
	Sig. (2-Tailed)	0.001	0.001	0.001
Dissolved Oxygen	Pearson Correlation	-0.056	-0.243	-0.370
	Sig. (2-Tailed)	0.816	0.302	0.108
pH	Pearson Correlation	0.541*	0.453*	0.322
	Sig. (2-Tailed)	0.014	0.045	0.166
Temperature	Pearson Correlation	0.452*	0.652**	0.734**
	Sig. (2-Tailed)	0.045	0.002	0.001
Transparency	Pearson Correlation	0.182	0.019	-0.156
	Sig. (2-Tailed)	0.441	0.936	0.512

Note: * Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level. Data in parentheses are significant level

Correlation between water parameters with copepods abundance and diversity indices are presented in (Table 4). The results showed that there were positive correlation between copepods abundance and salinity (0.01> P and r=0.664); Simpson diversity and salinity (0.01> P and r=0.783); Shannon-Wiener diversity and salinity (0.01> P and r=0.727); copepods abundance and pH (0.05> P and r=0.541); Simpson diversity and pH (0.05> P and r=0.453); copepod abundance and Temperature (0.05> P and r=0.452); Simpson diversity and Temperature (0.01> P and r=0.652); Shannon-Wiener diversity and Temperature (0.01> P and r=0.734) (Table 4).

Generally, Copepods productions are related to range of biological parameters such as egg productions, successful egg blossoming, survival and growth of nauplii, the copepodite stages, the median age, adult sex ratio and access to food and non-biological factors such as temperature, salinity, dissolved oxygen, the acidity and other parameters Their reproductive cycles, growth, reproduction and survival rates are all important factors that affecting fish resources (Harris et al. 2000; Roman et al. 2005; Knuckey et al. 2005; Prabhahar et al. 2011).

Salinity was positively correlated with the copepods abundance, Shannon-Weiner and Simpson diversity indices (0.01> P). The salinity in Bushehr coastal waters is affected by the general trend of salinity variation in the Persian Gulf which is depended on the current entering from the Indian Ocean and Oman Sea into the Persian Gulf, and mixing of low saline-freshwater of Mond and Helleh Rivers with high saline seawater (Kamp and Sadrinasab 2006; Aein Jamshid et al. 2014). Salinity is the most important factor influencing the community structure of zooplankton assemblages in tropical estuaries. Development of a salinity gradient from the upstream areas to the sea in estuaries is mainly due to strength of diurnal tidal current and the volume of freshwater flow from the upstream (Nasser et al. 1998; Mishara and Panigrahy 1999; Lee et al. 2006; Hwang et al. 2010). 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 (Mann 2000).

The pH was in alkaline range and showed a positive correlation with copepods abundance and diversity (0.05> P). MR basin has formed of alluvial and alkaline soils, therefore, it is expected to have alkaline water. Alkaline pH makes soluble carbon compounds such as calcium carbonate and bicarbonate usable for photosynthesis production and increasing the amount of chlorophyll *a* (Day et al. 1989). Natural plankton biomass increases within the pH range from 8 to 9 (Pedersen and Hansen 2003). The pH varies with aquatic acid-base balance. High pH may enhance the toxicity of some chemical compounds in the aquatic environment, thereby negatively affecting the health, feeding, and survival of marine copepods. However, little is known about the effects of pH on the physical ecology of marine plankton (Pedersen and Hansen 2003; Liu 2004; Li et al. 2008).

Many studies have reported that temperature is an important physical factor affecting plankton distribution. It can directly or indirectly impact the distribution of zooplankton, including copepod (Nakata et al. 2004; Bigler et al. 2006; Pipan et al. 2006). The results showed that there was a positive correlation between diversity (0.01> P) and density (0.05> P) of copepods with temperature which is corresponded with increasing the density of copepods in summer and decreasing of them in winter. In many ecosystems, the abundance of copepods is greatly affected by factors such as temperature and the amount of food in the water that it has a significant impact on the regulation of egg production and its growth (Niehoff 2007). The cold season results showed a decline in copepod population. Yahia et al. (2004) study showed that with decreasing temperature in cold months and subsequently lower food reserves, the abundance of copepods nauplii were reduced, which represent a reduction in egg productions and the number of adults in the cold season. Typically, with increasing of sunlight intensity in summer, the rate of photosynthesis and subsequently phytoplankton production rises that could lead to an increase in the diversity and density of herbivorous creatures (Madhu et al. 2007). Other studies in other parts of the Persian Gulf and the Indian Ocean have reported similar results (Michel and Herring 1984; Abdel-Aziz et al. 2007; Pouladi et al. 2014).

To conclude, this study revealed that the most diversity and abundance of copepod assemblages were at 5 stations in the mouth area of the estuary during all seasons and showed a positive correlation with salinity, pH, and temperature. Since few studies have been done in the estuaries of Persian Gulf, therefore, it is recommended to consider other planktonic assemblages for better perception of plankton roles in food webs in estuaries.

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REFERENCES

Abdel-aziz NE, Ghobashi AE, Dorgham MM, Eltohami WS. 2007. Qualitative and Quantitative study of copepods in DamitiaHorbor, Egypt. Egypt J Aquat Res 33 (1): 144-162.

Aein Jamshid K, Mohsenizadeh F, Omidi S. 2014. The Effects of Environmental Parameters and Nutrients on Microalgae Communities around the Shrimp Farm Complexes in Bushehr Province, in Persian Gulf . Intl J Adv Technol Eng Res 4 (3): 27-32.

Ali M, Al-yamani F, Khalaf TA. 2009. Observathion of Acartia (Acartiella) faoensis (Copepoda, Calanoida, Acartidae) near Bubiyan Island in the north of Kuwait. Crustaceana 82 (8): 1073-1077.

AL-Khabbaz M, Fahmi AM. 1998. Distribution of Copepoda in the ROPME Sea Area 1994. In: Terra. Scientific Publishing Company, Tokyo.

Benfield MC. 2013. Estuarine zooplankton. In: Day JW, Crump BC, Kemp WM, Yanez-Arancibia A (eds.). Estuarine Ecology. 2nd ed. Wiley-Blackwell, New York.

Bigler C, Heiri O, Krskova R, Lotter, AF, Sturm M. 2006. Distribution of diatoms, chironomids and cladocera in surface sediments of thirty mountain lakes in south-eastern Switzerland. Aquat Sci 68: 154-171.

Calbet A, Garrido S, Saiz E, Alcaraz M, Duarte CM. 2001. Annual zooplankton succession in coastal NW Mediterranean waters: the importance of the smaller size fractions. J Plankton Res 23: 319-331.

Conway VPD, White RG, Hoguest-Dt-Ciles J, Gallienne CP, Robine DB. 2006. Guide to the coastal and surface zooplankton of the south-western Indian Ocean. Occasional Publication of the Biological Association of the United Kingdom, No. 15, Plymouth, UK.

Farhadian O, Pouladi M. 2014. Seasonal changes in the abundance and biomass of zooplankton from shallow mudflat river-estuarine system in Persian Gulf. Braz J Aquat Sci Tech 18 (2): 19-29.

Fernando CH. 2002. A Guide to tropical freshwater zooplankton. Bacchus Publishers, Leiden, The Netherlands.

Frangoulis C, Christou ED, Hecq JH. 2004. Comparison of marine copepod outfluxes: nature, rate, fate and role in the carbon and nitrogen cycles. Adv Mar Biol 47: 253-309.

Harris R, Wiebe PH, Lenz J, Skjoldal HR, Huntley M. 2000. Introduction in ICES Zooplankton Methodology Manual. Academic Press, New York.

Hays GC, Richardson AJ, Robinson C. 2005. Climate change and marine plankton. Trends Ecol Evol 20: 337-344.

Hooff RC, Peterson WT. 2006. Copepod biodiversity as an indicator of changes in ocean and climate conditions of the northern California current ecosystem. Limnol Oceanogr 51 (6): 2607-2620.

Kamp FJ, Sadrinasab M. 2006. The circulation of the Persian Gulf: A numerical study .Ocean Sci 2: 27-41.

Knuckey RM, Semmens GL, Mayer RJ, Rimmer MA. 2005. Development of an optimal microalgal diet for the culture of the calanoid copepod Acartia sinjiensis: effect of algal species and feed concentration on copepod development. Aquaculture 249 (1): 339-351.

Krebs CJ. 1999. Ecological Methodology, 2nd ed. Addison-Welsey Educational Publishers, Inc., Menlo Park, CA.

Kulshrestha SK, Adholia UN, BhatnagarA, Khan AA, Saxenam M, Baghali M. 1989. Studies on pollution in River Kshipra: a in relation to water quality. Intl J Ecol Environ Sci 15: 27-36.

Lam-Hoai T, Guiral D, Rougier C. 2006. Seasonal change of community structure and size spectra of zooplankton in the Kaw River estuary (French Guiana). Estuar Coast Shelf S 68: 47-61.

Li C, Luo X, Huang X, Gu B. 2008. Effects of temperature, salinity, pH, and light on filtering and grazing rates of a calanoid copepod (Schmackeria dubia). Sci World J 8: 1219-1227.

Liu T. 2004. Effect of acidity-alkalinity on the growth of Acartia spinicauda. China Fish 12: 74-75.

Madhu NV, Jyothibabu RB, Balachandran KK, Honey UK, Martin GD, Vijay JC, Shiyas CA, Gupta GVM, Achuthankutty CT. 2007. Monsonal impact on planktonic standing stok and abundance in a tropical estuary (Chochin backwater- India). Estuar Coast Shelf S 73: 54-64.

Mann K H. 2000. Ecology of coastal waters: with implications and management. 2nd ed. Blackwell Science Publishers, USA.

Mackas DL, Thomson RR, Galbraith M. 2001. Changes in the zooplankton community of the British Columbia continental margin, 1985-1999, and their covariation with oceanographic conditions. Can J Fish Aquat Sci 58: 685-702.

McLusky DS, Elliott M. 2004. The Estuarine Ecosystem: Ecology, Threats and Management. University Press, New York.

Michel HB, Herring DC. 1984. Diversity and abundance of Copepoda in the northwestern Persian Gulf. Crustaceana, Supplement 7 (2): 326-335.

Mishra S, Panigrahy RC. 1999. Zooplankton ecology of the Bahuda estuary (Orissa), East coast of India. Indian J Mar Sci 28: 297-301.

Nakata K, Itoh H, Ichikawa T, Sasaki K. 2004. Seasonal changes in the reproduction of three oncaeid copepods in the surface layer of the Kuroshio Extension. Fisheries Oceanogr 13 (1): 21-33.

Nasser AKV, Siraimeetan P, Aboobakr PM. 1998. Zooplankton abundance and distribution at Minicoy lagoon, Lakshadweep. Indian J Mar Sci 27: 346-360.

Niehoff B. 2007. Life history strategies in zooplankton communities: The significance of female gonad morphology and maturation types for the reproductive biology of marine calanoid Copepods. Prog Oceanogr 74: 1-47.

Ohman MD, Hirche HJ. 2001. Density-dependent mortality in an oceanic copepod population. Nature 412 (6847): 638-641.

Omori M, Ikeda T. 1984. Methods in zooplankton ecology. John Wiley & Sons, New York.

Pedersen MF, Hansen PJ. 2003. Effects of high pH on a natural marine planktonic community. Mar Ecol Prog Ser 260: 19-31.

Pipan T, Christman MC, Culver, DC. 2006. Dynamics of epikarst communities: microgeographic pattern and environmental determinants of epikarst copepods in Organ Cave, West Virginia. Am Midl Nat 156 (1): 75-87.

Pouladi M, Farhadian O, Vazirizadeh A. 2014. Spatial and Temporal Variation in Copepod Community in the Helleh River Estuary-South Coast of Iran, Persian Gulf. Environ Stud Persian Gulf 1 (1): 37-50.

Prabhahar C, Saleshrani K, Enbarasan R. 2011. Studies on the ecology and distribution off zooplankton biomass in kadalur coastal zone, Tamil nadu, India. Curr Biol 2 (3): 1-4.

Primo AL, Azeiteiro UM, Marques SC, Martinho F, Pardal MA. 2009. Changes in zooplankton diversity and distribution pattern under varying precipitation regimes in a southern temperate estuary. Estuar Coast Shelf S 82: 341-347.

Rezai H, Amini N, Kabiri K. 2014. Spatial and Temporal Distribution of Zooplankton Biomass in the Northeast Persian Gulf. J Persian Gulf 5 (16): 79-84.

Roman MR, Zhang X, McGilliard C, Boicourt W. 2005. Seasonal and annual variability in the spatial patterns of plankton abundance in Chesapeake Bay. Limnol Oceanogr 50: 394-406.

Savari A, Nabavi SMB, Doustshenas B. 2004. Study of planktonic copepods distribution in Mussa creeks with PCA method. Sci J Persian Gulf 1: 771-785.

Shannon CE, Weaver W. 1948. A mathematical theory of communication. Bell Sys Tech J 27: 379-423, 623-656.

Simpson EH. 1949. Measurement of diversity. Nature 163: 688.

Varadharajan D, Soundarapandian P. 2013. Zooplankton abundance and diversity from Pointcalimere to Manamelkudi, South East Coast of Indian J Earth Sci Clim Change 4 (5): 151-161.

Webber MK, Roff JC. 1995. Annual biomass and production of the oceanic copepod community off Discovery Bay, Jamaica. Mar Biol 123 (3): 481-495.

Xuelu GAO, Jinming S, Xuegang L. 2011. Zooplankton spatial and diurnal variations in the Changjiang River estuary before operation of the Three Gorges Dam. Chin J Oceanol Limnol 29 (3): 591-602.

Yahia MND, Souissi S, Yahia-Kefi OD. 2004. Spatial and temporal structure of planktonic copepods in the bay of Tunis (Southwestern Mediterranean Sea). Zool Stud 43 (2): 366 375.

Zar JH. 1984. Biostatistical analysis, 2nd edition. Prentice Hall Inc., Englewood Cliffs, New York, USA.