International Journal of Aquatic Biology (2015) 3(4): 245-257
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.NPAJournals.com

Original Article

Monsoon effects on the copepod community structure in the Chabahar Bay, Oman Sea

Neda Fazeli*[1], Rasool Zare[2], Seyed Mohammad Bagher Nabavi[3], Saeed Sanjani[3]

[1]Guilan University, Department of Marine Biology, Rasht, Iran.
[2]Department of Fisheries, Faculty of Natural Resources University of Tarbiat Modarres, Noor, Iran.
[3]Khorramshahr University of Marine Science and Technology, Department of Biology, Khorramshahr, Iran.

Abstract: Calanoid, cyclopoid, harpacticoid and poecilostomatoid copepods were investigated over the year at five stations in the Chabahar Bay, Oman Sea. This area is under the influence of the Indian Ocean seasonal monsoons. The samples were collected using vertical plankton tows with 100 µm mesh nets. Copepods were identified into 20 genera and 59 species. Calanoid formed about 15% to 62% and cyclopoid 26% to 39% of total copepod abundance. Harpacticoid constituted about 6% in South West (SW)-monsoon and flourished well in pre (SW)-monsoon, formed 46% of copepod abundance. Poecilostomatoid accounted for approximately 5% to 13% of the total copepods. The most dominant species were *Temora turbinata*, *Paracalanus elegans*, *Oithona nana* and *Euterpina acutifrons*. The results showed that the species composition and distribution of copepods differed between the monsoon seasons, due to changes in hydrographic conditions. Furthermore, high abundance of small-sized copepods observed in offshore stations.

Article history:
Received 6 July 2014
Accepted 24 January 2015
Available online 25 August 2015

Keywords:
Abundance
Copepods
Diversity
Monsoon
Oman Sea

Introduction

The Chabahar Bay is a small semi-enclosed bay on the southeastern coasts of Iran (25°17'45"N, 60°37'45"E). This Bay is connected to the Indian Ocean via Oman Sea being influenced by Indian monsoonal winds (Fazeli and Zare, 2011). The Asian monsoon in the Oman Sea is characterized by two distinct seasons separated by two transitional (inter-monsoon) periods: the Southwest (SW) Monsoon from June through September, the Northeast Monsoon (NE) from December through March, the spring transition (pre-monsoon) in April and May and the fall transition (post-monsoon) in October and November (Caulfield, 1990). The Chabahar Bay is one of the five major regions of the Oman Sea providing an ideal breeding ground for many fishes and shell fishes (Wilson, 2000). The bay is located between Chabahar and Konarak. It has 14 km wide and a surface area of 290 km^2. The average depth of the bay is 12 m (ranging from 8 to 22 m) (Fazeli and Zare, 2011; Fazeli et al., 2013).

The monsoon has remarkable effects in the region. A peak in chlorophyll-α biomass dominates in the Indian Ocean at SW Monsoon (Yoder et al., 1993). Lower salinity water reaches the sea surface in coastal upwelling that occurs during SW Monsoon along the coast of Oman (Morrison et al., 1998). Water temperatures decrease from 27-29°C at Oman Sea (Caulfield, 1990). During the fall transition, water temperatures cool slowly. Average sea temperatures cool from 28-29°C in October to 27°C in November and oligotrophic conditions slowly return (Caulfield, 1990). The cool, dry northeaster winds that characterize NE Monsoon result in a typical winter time convection/nutrient enrichment scenario in the northern Arabian Sea (Banse and McClain, 1986; Madhupratap et al., 1996). In this season, the monsoon results in a surface water mass with salinity between 35.5-36.5 and temperatures greater than 22°C as Arabian Sea. Water

* Corresponding author: Neda Fazeli
E-mail address: neda_fazeli200@yahoo.com

temperatures range from 25°C in April to 29°C in May (Caulfield, 1990).

The responses of the zooplankton community structure to seasonal changes in the physical environment have not been analyzed fully yet during 1990s. There is one trend, however, which has been noted in every seasonal study so far: the NE Monsoon is characterized by increased abundance of cyclopoid copepods, such as the genera *Oithona* and *Oncaea*, compared with the SW Monsoon. Small calanoid copepods predominate during the SW Monsoon (Madhupratap et al., 1996). In coastal waters of the region, *Undinula vulgaris* and *Paracalanus aculeatus* were reproductive in both the NE and SW Monsoons, along with *Cosmocalanus darwini* and *C. plumulosus* in the SW Monsoon (Smith et al., 1998).

Many studies have described copepod community structure in many parts of Indian Ocean, Arabian Sea and the Persian Gulf (Madhupratap, 1987; Smith, 1995; Savari et al., 2004) but little is known about the copepods of the Chabahar Bay (Fazeli et al., 2010; Fazeli and Zare, 2011; Fazeli et al., 2012; Fazeli and Zare, 2012; Fazeli et al., 2013). Therefore, the main objective of this study is to investigate the spatial and temporal variability in abundance and diversity of copepods and effect of monsoon on species composition of the Chabahar Bay.

Materials and Methods

Sampling was conducted during four oceanography cruises, including August 2007 (SW Monsoon), November 2007 (post-monsoon), February 2008 (NE Monsoon) and May 2008 (pre-monsoon). Five stations were investigated through the Bay that have been provided in detailed by Fazeli et al. (2013). Four plankton samples were collected vertically at each station twice for counting, using a simple net with a mouth diameter of 30 cm and a mesh size of 100 μm and with a Hydrobios flow meter mounted in the center of the net opening.

Samples were preserved immediately in 4-5% formalin, buffered to a pH of 8 with sodium tetra borate (borax), and identified to the lowest taxa.

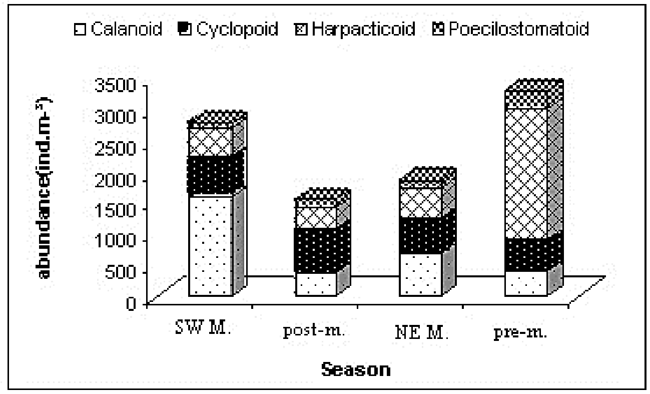

Figure 1. Total abundance of calanoid, cyclopoid, harpacticoid and poecilostomatoid by season in the Chabahar Bay.

Zooplankton abundance was expressed as ind. m^{-3} (Somoue et al., 2005). At each station, prior to sampling, the environmental parameters were recorded using a CTD profiler lowered from the sea surface to near the bottom. Seasonal changes of the environmental parameters *viz.* temperature, salinity and chlorophyll-α during studied period have been provided in detailed by Fazeli et al. (2013). Zooplankton was identified to species level using Chen and Zhang (1974), Nishida (1985) and Conway et al. (2003).

A two-Way ANOVA was used to examine a significant of difference in abundance of zooplanktons amongst periods and locations. The Pearson correlation were performed to determine the significance between environmental parameters and copepod genera abundance. Species diversity was calculated using Shannon-Weaver diversity index (Shannon and Weaver, 1963) and species richness (Margalef, 1968). The data were further subjected to hierarchical clustering analyze to identify the similarity between the stations based on the composition. This was calculated as a Bray-Curtis similarity index with log10 (x+1) data using PRIMER version 5.2.8 (Clarke and Warwick, 1994).

Results

Abundance and composition: Sixty six copepod species belonged to calanoid, cyclopoid, harpacticoid and poecilostomatoid were identified. Copepod density was significantly higher during pre-monsoon (with a total abundance of 3276.81 ind.

Table 1. Copepod relative abundance (%) in the Chabahar Bay.

	SW M.	Post-m.	NE M.	Pre-m.
CALANOID				
Acartiidae				
Acartia sp.	0.24	0.37	0.15	0.30
A. longiremis	0.27	0.54	0.32	-
Centropagidae				
Centropages tenuremis	0.91	0.52	12.81	1.14
Clausocalanidae				
Clausocalanus sp.	0.06	-	0.38	-
Eucalanidae				
Eucalanus subcrassus	0.29	0.57	1.36	-
E. sp.	0.11	0.00	0.04	-
E. crassus	0.30	0.18	0.04	-
E. attenuates	0.05	-	0.05	-
E. monachus	0.11	0.07	-	-
Paracalanidae				
Acrocalanus longicornis	1.63	0.31	0.30	-
A. gracilis	2.86	0.08	0.85	-
A. gibber	3.29	0.25	0.33	-
A. monachus	1.82	0.12	0.42	0.35
A. sp	1.62	0.73	0.71	0.56
Calocalanus plumulosus	-	0.08	0.04	-
Paracalanus crassirostris	1.49	2.81	0.34	0.79
P. elegans	4.70	5.60	2.11	0.85
P. aculeatus	2.23	2.29	0.21	0.57
P. denudatus	0.77	0.73	0.22	-
P. parvus	0.25	0.19	0.16	0.67
P. sp	0.40	4.95	-	1.45
Pontellidae				
Labidocera sp.	36.60	0.07	0.50	-
Pseudodiaptomidae				
Pseudodiptomus sp.	0.18	-	6.77	0.90
Temoridae				
Temora desicaudata	0.11	2.13	0.05	-
T. turbinate	1.02	7.66	12.35	7.94
T. stylifera	-	0.40	0.23	-
CYCLOPOID				
Oithonidae				
Oithona aculata	2.59	3.34	2.11	2.21
O. attenuate	4.78	3.71	2.56	1.31
O. brevicornis	0.44	3.36	5.60	1.69
O. plumifera	0.06	1.42	1.80	1.22
O. rigida	4.63	2.65	1.74	1.51
O. simplex	1.61	7.56	1.42	1.04
O. nana	4.72	8.66	13.84	8.63
O. ssp.	7.01	8.95	7.78	9.78
POECILOSTOMATOID				
Corycaeidae				
Corycaeus andrewsi	1.33	0.89	2.07	7.01
C. asiaticus	0.42	0.38	0.32	2.61
C. erythraeus	0.11	0.42	0.36	-
C. pacificus	0.96	0.52	-	0.39
C. affinis	-	0.33	0.16	0.45
C. dalhi	-	0.52	0.49	-
C. speciosus	-	0.09	0.29	-

Table 1. Continued.

	SW M.	Post-m.	NE M.	Pre-m.
Oncaeidae				
Oncaea media	0.80	4.88	3.94	-
O. venusta	0.93	2.50	0.86	0.35
O. clevei	0.55	1.58	0.21	-
O. minuta	0.05	0.90	-	0.52
Sapphirinidae				
Sapphirina sp.	-	0.06	0.44	-
HARPACTICOID				
Clytemnestridae				
Clytemnestra scutellata	-	0.17	1.66	0.96
Ectinostomatidae				
Microsetella rosea	0.23	0.38	0.49	11.08
Miraciidae				
Macrosetella gracilis	0.40	3.19	1.02	19.51
Euterpinidae				
Euterpina acutifrons	5.39	11.82	6.55	14.26

m^{-3}) and SW Monsoon (with a mean of 2790.55 ind. m^{-3}) than other seasons (Fig. 1).

Among calanoids, the species belonged to the genera of *Acartia*, *Acrocalanus*, *Calocalanus*, *Centropages*, *Clausocalanus*, *Eucalanus*, *Labidocera*, *Pseudodiaptomus*, *Paracalanus* and *Temora* were the major components of copepod community during SW Monsoon with an average of 1604.13 ± 1318.53 ind. m^{-3}. In post–monsoon, calanoid copepods represented 354.30 ± 43.15 ind. m^{-3} showing the lowest abundance. Thirty-four calanoid species representing 8 families and 12 genera were identified during four periods in the Chabahar Bay. Some species were observed only in one season in very low abundance (Table 1). *Acartia pacifica*, *A. erythraea*, *Eucalanus pileatus* and *E. hyalinus* were present only in SW Monsoon. *Clausocalanus gracilis*, *E. miscanthus*, *Sapphirina gastrica*, *S. nigromaculata*, *Calocalanus styliremis*, *Lucicutia flavicormis* and *L. gaussae* were observed during post-monsoon and disappeared in other seasons. *Centropages furcatus*, *C. furcatus*, *Pseudodiptomus marinus* and *C. minor* were observed only in NE Monsoon. The dominant calanoid throughout the year were *Temora turbinate* and *Paracalanus elegans*.

Cyclopoids were presented all year in large numbers with a density of 701.30 ± 75.05 ind. m^{-3} during post-monsoon. All identified species of cyclopoid belonged to the genus *Oithona*. The lowest abundance was found during pre-monsoon with an average of 503.30 ± 293.95 ind. m^{-3}. *Oithona fallax* appeared only in NE Monsoon. The dominant cyclopoid throughout the year was *O. nana*.

Harpacticoids had four genera, including *Clytemnestra*, *Microsetella*, *Macrosetella* and *Euterpina*. The maximum abundance was observed in pre-monsoon (with an average of 2122.76 ± 994.42 ind. m^{-3}) which comprised 45.81% of total copepod abundance. Harpacticoids had the lowest abundance in post-monsoon with an average of 352.80 ± 22.21 ind. m^{-3}. *Clytemnestra scutellata* showed the lowest abundance through the year and disappeared in SW Monsoon. The dominant harpacticoids throughout the year were represented by *E. acutifrons* and *Macrosetella gracilis*.

The species of Poecilostomatoid belonged to the genera *Corycaeus*, *Oncaea* and *Sapphirina*. The highest abundance was found in pre-monsoon with a density of 276.64 ± 75.87 ind. m^{-3}. *Corycaeus* was present throughout the year but in large numbers in pre-monsoon. The next common poecilostomatoid was *Oncaea* which it showed maximum abundance during post-monsoon. A small abundance of *Sapphirina* was found during post-monsoon and NE Monsoon and disappeared entirely during SW Monsoon and pre-monsoon. The dominant

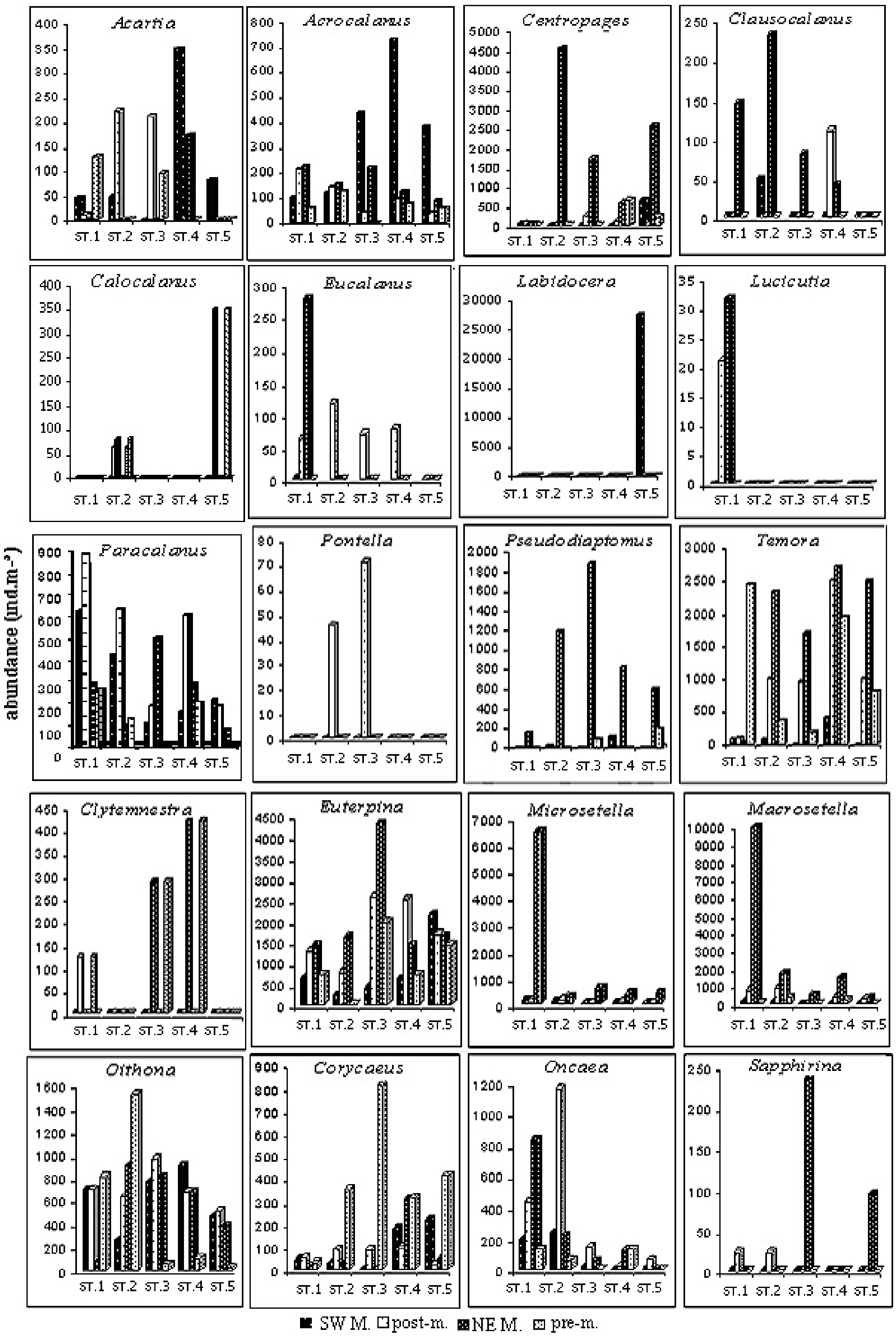

Figure 2. Average copepod genera abundance in the Chabahar Bay during each sampling station.

poecilostomatoid throughout the year were *Corycaeus andrewsi* and *Oncaea media.*

Temporal and spatial variation of copepods: The variation of copepod genera showed a fluctuation

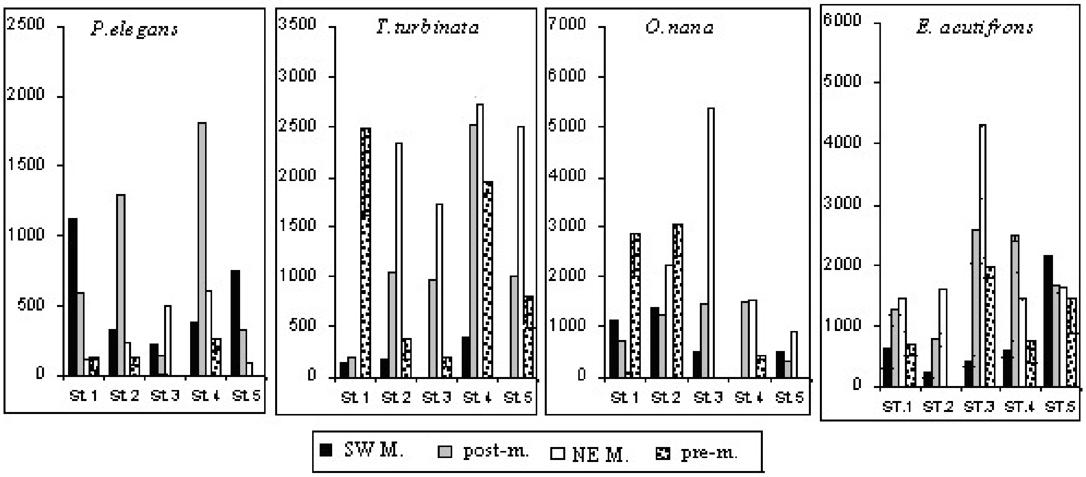

Figure 3. Average density of dominate copepod species in the Chabahar Bay.

seasonally and spatially (Fig. 2). A significant increase in *Acartia* was found during SW Monsoon (with an average of 104.73 ± 62.83 ind. m^{-3}) and post-monsoon (88.78 ± 52.33 ind. m^{-3}) compared to other seasons. *Acrocalanus* (with an average of 355.83 ± 116.06 ind. m-³) and *Labidocera* (with an average of 5503.76 ± 5492.75 ind. m-³) also showed highest abundance during SW Monsoon.

In post-monsoon, *Paracalanus* (499.01 ± 88.73 ind. m^{-3}), *Oncaea* (366.55 ± 211.09 ind. m^{-3}) and *Eucalanus* (65.64 ± 18.84 ind. m^{-3}) showed the highest abundance. A significant increase of *Euterpina* was found during post-monsoon and NE Monsoon.

NE Monsoon showed the maximum abundance of *Temora* (1866.26 ± 485.84 ind. m^{-3}), *Pseudodiaptomus* (933.15 ± 292.28 ind. m^{-3}), *Clausocalanus* (98.83 ± 40.20 ind. m^{-3}) *Calocalanus* (86.09 ± 151.79 ind. m^{-3}), *Centropages* (1888.40 ± 795.48 ind. m^{-3}) and *Sapphirina* (66.27 ± 46.29 ind. m^{-3}). *Macrosetella gracilis* and *M. rosea* showed a high abundance during NE Monsoon compared to other periods. In pre-monsoon, the maximum abundance of *Corycaeus* (382.64 ± 124.77 ind. m^{-3}) was found. *Clytemnestra scutellata* showed a higher abundance during pre-monsoon and NE Monsoon.

Spatial variations in abundance of copepod are shown in Figure 2. Among calanoids, we observed the maximum average abundance of *Eucalanus* and *Paracalanus* at station 1, *Centropages* and *Clausocalanus* at station 2, *Pseudodiaptomus* at station 3, *Temora*, *Acartia* and *Acrocalanus* at station 4. In Pontellidae, *Labidocera* showed a higher abundance in station 5. *Calocalanus* was observed only at stations 2 and 5. Among cyclopoids, the maximum abundance of *Oithona* was found at station 2. Among poecilostomatoids, *Oncaea* showed a higher abundance at stations 1 and 2, whereas *Sapphira* showed the maximum abundance at station 3. *Corycaeus* showed the highest abundance at stations 3 and 4. Among harpacticoids, a low abundance of *E. acutifrons* was found at station 2, while *M. gracilis* and *M. rosea* showed a higher average abundance at station 1. A higher abundance of *C. scutellata* was found in stations 3 and 4 (Fig. 3).

Figure 4 shows cluster analysis for calanoid, cyclopoid, harpacticoid and poecilostomatoid to investigate similarities between stations based on density data. The results indicated the presence of two groups; station(s) in group I separated from other stations in group II. In calanoids, the highest similarity of stations was observed in stations 2 and 3. Stations 1 and 4 showed the maximum similarity of cyclopoids density. In harpacticoids, the highest similarity of stations was observed in stations 2 and 4. In poecilostomatoids, the highest similarity of stations was presented in stations 1 and 2.

Species diversity and richness: In SW Monsoon, calanoid formed by the relatively high diversity

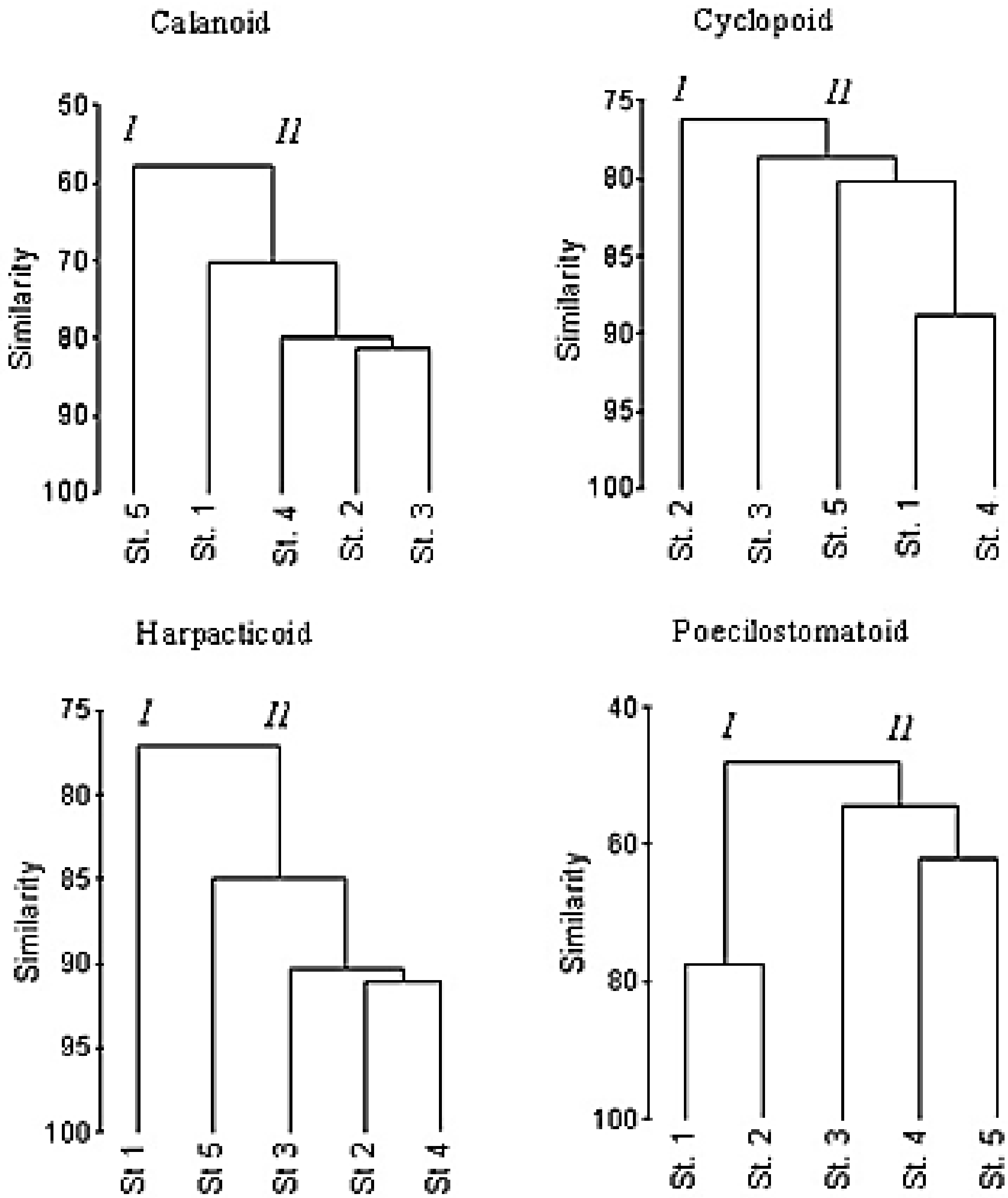

Figure 4. Cluster analyses showing similarity of stations during monsoonal seasons based on calanoid, cyclopoid, harpacticoid and poecilostomatoid density in the Chabahar Bay.

index and species richness (2.28/2.60), while a low value was observed in pre-monsoon (1.01/0.44) (Table 2). The highest and lowest cyclopoid species diversity and richness were observed in NE Monsoon and pre-monsoon, respectively. In poecilostomatoids, the highest and lowest species diversity and richness were observed during post-monsoon and pre-monsoon, respectively. Harpacticoid species diversity and richness were relatively low during four periods. The highest species diversity and richness of harpacticoid was recorded in pre-monsoon (0.97/0.28) and the lowest in SW Monsoon (0.36/0.15).

Environmental parameters and zooplankton: A Pearson product correlation was calculated to examine whether any relationship existed between copepod genera and environmental parameters in the Chabahar Bay. The results are presented in Table 3.

Discussion

NE Monsoon consists of the moderate wind-driven mixing, a net flux of heat from the ocean to the

Table 2. Diversity indices (H) and species richness (D) of calanoid, cyclopoid, harpacticoid and poecilostomatoid.

	SW M.(H/D)	post- m.(H/D)	NE M. (H/D)	Pre-m.(H/D)
CALANOID				
Station 1	2.73(3.83)	2.36(2.46)	2.51(2.61)	1.33(0.46)
Station 2	2.68(3.01)	2.82(2.50)	1.60(0.97)	1.85(0.92)
Station 3	2.22(1.89)	1.61(0.65)	1.56(0.56)	-
Station 4	2.66(2.66)	2.39(1.84)	1.66(1.04)	1.89(0.83)
Station 5	1.13(1.63)	0.59(0.86)	1.71(1.23)	-
Mean	2.28(2.60)	1.95(1.66)	1.80(1.28)	1.01(0.44)
CYCLOPOID				
Station 1	1.62(0.75)	1.70(0.83)	1.77(0.80)	0.83(0.22)
Station 2	1.89(0.93)	2.02(0.77)	1.78(0.77)	1.89(0.74)
Station 3	1.68(0.59)	1.59(0.69)	1.64(0.73)	1.38(0.50)
Station 4	1.58(0.70)	1.62(0.70)	0.91(0.44)	0.69(0.14)
Station 5	1.50(0.48)	1.26(0.49)	1.50(0.75)	-
Mean	1.64(0.69)	1.63(0.69)	1.52(0.69)	0.95(0.32)
HARPACTICOID				
Station 1	0.84(0.29)	0.97(0.38)	0.35(0.12)	0.89(0.20)
Station 2	0.86(0.34)	0.91(0.26)	1.20(0.37)	0.74(0.22)
Station 3	-	0.10(0.12)	-	1.18(0.37)
Station 4	0.11(0.12)	0.47(0.25)	0.54(0.14)	1.21(0.36)
Station 5	-	0.44(0.13)	1(0.37)	0.86(0.25)
Mean	0.36(0.15)	0.57(0.22)	0.61(0.20)	0.97(0.28)
POECILOSTOMATOID				
Station 1	1.67(0.85)	2.16(1.43)	1.80(0.99)	0.63(0.16)
Station 2	1.39(0.58)	1.66(1.27)	0.69(0.19)	0.98(0.40)
Station 3	-	2.07(1.15)	1.55(0.63)	0.91 (0.24)
Station 4	1.37(0.58)	2.01(1.39)	-	0.98(0.27)
Station 5	0.18(0.28)	0.63(0.18)	0.91(0.63)	0.37(0.13)
Mean	0.92(0.45)	1.70(1.08)	0.99(0.48)	0.77(0.24)

atmosphere, and elevated evaporation (Wiggert et al., 2000). Apparently, nutrients transported via this wintertime mixing fuel the subsequent spring phytoplankton bloom as defined by the appearance of the chlorophyll-α in the Chabahar Bay which confirmed the record of Kumar and Prasad (1999) in Arabian Sea. High temperature was observed in SW Monsoon result in high sunlight. In post-monsoon and NE Monsoon, temperature decreased throughout the Bay by decreasing sunlight. Salinity did not vary significantly during warm and cold season as evaporation is high during cold season (Wiggert et al., 2000). Water temperature, chlorophyll-α and salinity in the Chabahar Bay were similar to those of Caulfield (l990) in Oman Sea and Arabian Sea.

The variation of species among the four sampling seasons is apparently influenced by monsoon (Chen, 1992). In summer, by the prevailing SW Monsoon some species e.g., *A. gibber*, *A. gracilis*, *Labidocera sp.*, *O. rigida* and *O. attenuate* were dominant. *Labidocera* sp. was the most common species (36%) in this season but showed a low abundance during post-monsoon and NE Monsoon, and disappeared during pre-monsoon. *Acrocalanus gibber* and *A. gracilis* were abundant during SW Monsoon but decreased during other seasons which confirmed the record of Vengadesh et al. (2009). Trophic resources may play an important role in controlling of *Acrocalanus* in tropical environments (Gusma and Mckinnon, 2009). It seems that temperature play a major role in abundance of *O. rigida* and *O. attenuate* as they were positively related to temperature.

In autumn, the prevailing post-monsoon declined, the copepod abundance was observed that it can be explained due to decrease in chlorophyll-α concentrations. The Chabahar Bay seems to have an

Table 3. Pearson correlation of major environmental parameters and major species density ('*' significant at 0.05 level; '**' significant at 0.01 level)

	Chl(*a*)	Salinity	Temperatu	Depth
P. elegans	0.15	-0.42*	-0.14	0.49*
A. gibber	-0.27	-0.23	-0.46*	-0.01
T. turbinate	0.31	0.01	-0.62**	0.47*
Pseudodiaptomus sp.	0.23	-0.19	-0.61**	-0.22
Centropages tenuremis	0.19	-0.16	-0.46*	-0.10
Labidocera sp.	-0.13	-0.01	0.31	-0.21
O. nana	0.21	-0.31	-0.63**	0.65**
O. attenuate	0.23	0.23	0.67**	0.23
O. rigida	-0.28	0.23	0.53*	0.23
Corycaeus andrewsi	0.28	0.53*	0.29	-0.39
Oncaea media	0.05	-0.39	-0.32	0.55*
Euterpina acutifrons	-0.07	0.37	-0.28	-0.55*
Macrosetella gracilis	-0.05	-0.25	-0.52*	0.30
Microsetella rosea	-0.17	-0.21	-0.46*	0.24

oligotrophic condition during this season similar to Arabian Sea (Baars et al., 1998). *Temora turbinate*, *O. simplex*, *O. media and M. gracilis* were the most common species in this season.

Centropages tenuremis, *T. turbinate*, *O. media* and *Pseudodiptomus* sp. were dominant during winter by the prevailing NE Monsoon. Entrainment of nutrients into the upper layer by winter cooling was caused producing phytoplankton blooms in this season similar to those of the Gulf of Aden (Baars, 1998) and Arabian Sea (Kumar and Prasad, 1999). On the other hand, abundance of *C. tenuremis*, *T. turbinate* and *Pseudodiaptomus* sp. was negatively related to temperature. It was stated that there is a negative relationship between nutrients and temperatures below 22°C. High concentrations of the phosphates and low temperatures allow development of different plankton compartments (Roy, 1992). The joint effect of high nutrients and low temperature can result in high abundance of some opportunistic species such as *T. turbinate* (Madhupratap, 1987) which is the major species of *Temora* in the Chabahar Bay. They almost flourish in high chlorophyll-α concentration (Madhupratap, 1987). This observation confirmed those of Hsieh and Chiu (2002), Hwang and Wong (2005) and Shih and Chiu (1998) along coast of Taiwan.

In spring, by the prevailing pre-monsoon *C. andrewsi*, *Microsetella rosea* and *M. gracilis* were dominant, while they decreased significantly during other seasons. A high abundance of harpacticoid was remarkable during this season. It can be explained by their adaptive strategy to overcome the harsh mechanical disturbances which occur in pre-monsoon. These copepods are always reproductively active, and tolerant to harsh climatic regime (Mantha et al., 2012).

Paracalanus elegans, *T. turbinate*, *O. nana*, *E. acutifrons* were occurred in all sampling seasons. The high abundance of these species during a year might be due to high tolerance to temperature and salinity variation (e.g., *O. nana*, Nishida, 1985), reproductive adaptive natures (e.g. *E. acutifrons*, Mantha et al., 2012) and opportunistic behavior (e.g., *T. turbinate*, Madhupratap, 1987). Similar to the present result, *Paracalanus* spp. and *T. turbinate* were the most dominant copepods species in Mida Creek (Mwaluma et al., 2003). Also *Paracalanus*, *Oithona*, *Microsetella* and *Oncaea* were dominant in Malaysia (Nakajima et al., 2008).

In this study, the high abundance of small-sized copepod such as *O. media*, *P. elegans*, *T. turbinate* and *O. nana* were observed in offshore samples which confirmed those of Rezai et al. (2004) in the Strait of Malacca. These species showed positive relationship with depth. The results showed a negative correlation between *E. acutifrons* and depth. This species is a near-shore species (Jitchum and Wongrat, 2009; Russell et al., 1996; Somoue et al., 2005) which showed higher abundances in the Chabahar Bay when salinity was the highest similar to those of Moreira (1975).

From SW Monsoon to pre-monsoon, the calanoid and cyclopoid species diversity and richness tended to be lower, reflecting lower structured communities. The highest richness of harpacticoid was observed in pre-monsoon suggesting their high population density in this season. During post-monsoon, species richness of poecilostomatoid increased along with increasing population density. Spatially, copepods showed higher species diversity and richness in offshore stations. A higher diversity in offshore stations was due to stable environmental conditions prevailing which permitted plankton community to increase diversify which confirmed those of Sivasamy (1990) and Shanthi and Ramanibai (2011) in northern Arabian Sea.

In conclusion, the species composition and distribution of copepods differed between the monsoon seasons, resulted in changes of hydrographic conditions. Community structure of copepod changed by the prevailing monsoon in each season and caused some species flourished or disappeared. However, *P. elegans*, *T. turbinate*, *O. nana* and *E. acutifrons* were dominant through the year. The present information would form a useful tool for further ecological assessment in the Chabahar Bay.

Acknowledgments

We wish to thank Irina Prusova for guide and Iranian National Center of Oceanography (INCO) for the encouragement and support.

References

Baars M., Schalk P., Veldhuis M. (1998). Seasonal fluctuations in plankton biomass and productivity in the ecosystems of the Somali Current, Gulf of Aden, and Southern Red Sea. In: K. Sherman, E. Okemwa, M. Ntiba (Eds.). Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability, and Management (Cambridge, MA: Blackwell Science). pp. 143-174.

Banse K., McClain C.R. (1986). Winter blooms of phytoplankton in the Arabian Sea as observed by the Coastal Zone Colour Scanner. Journal of Marine Ecology Progress Series, 34: 201-211.

Caulfield M.P. (1990). The Persian Gulf Region, a Climatological Study. Department of the navy headquarters United States. Marine Corps Washington, DC 20380-0001.

Chen Q.C., Zhang S.Z. (1974). The planktonic Calanoid copepods of the Yellow Sea and the East China Sea. Journal of Studies Marine Sinica, 7: 20-133.

Chen Q.C. (1992). Zooplankton of China Seas (1). Science Press, Beijing. 87 p.

Clarke K.R., Warwick R.M. (1994). Changes in Marine Communities: An Approach to Statistical Analysis and Inter Predation. Plymouth Marine Laboratory, Plymouth. 144 p.

Conway D.V.P., Rowena G.W., Joanna H-D C., Christopher P.G., David B.R. (2003). Guide to the costal and surface zooplankton of the south-western Indian Ocean. Plymouth. Marine laboratory, 354 p.

Fazeli N., Rezai Marnani H., Sanjani S., Zare R., Dehghan S., Jahani N. (2010). Seasonal variation of Copepoda in Chabahar Bay-Oman Sea. Jordan Journal of Biological Sciences, 3(4): 153-164.

Fazeli N., Zare R. (2011). Effect of Seasonal Monsoons on Calanoid Copepod in Chabahar Bay-Oman Sea. Jordan Journal of Biological Science, 4(1): 1-170.

Fazeli N., Rezai Marnani H., Zare R. (2012). Spatial and temporal distribution of Oncaeidae in Chabahar Bay. Journal of Life Sciences, 6: 216-220.

Fazeli N., Zare R. (2012). The seasonal change of female and male Paracalanidae (Calanoid Copepod) in Chabahar Bay-Oman Sea. Journal of Ecologia, 2(4): 93-103.

Fazeli N., Savari A., Nabavi S.M.B., Zare R. (2013). Seasonal variation of zooplankton abundance, composition and biomass in the Chabahar Bay, Oman Sea. International Journal of Aquatic Biology, 1(6): 294-305.

Gusma L.F.M., Mckinnon A.D. (2009). *Acrocalanus gracilis* (Copepoda: Calanoid) development and production in the Timor Sea. Journal of Plankton Research, 31(9): 1089-1100.

Hsieh C.H., Chiu T.S. (2002). Summer spatial distribution of copepods and fish larvae in relation to hydrography in the northern Taiwan Strait. Journal of Zoological Studies, 41: 85-98.

Hwang J.S., Wong C.K. (2005). The China Coastal Current as a driving force for transporting *Calanus sinicus* (Copepoda: Calanoid) from its population centers to waters of Taiwan and Hong Kong during the NE Monsoon period in winter. Journal of Plankton Research, 27: 205-210.

Jitchum P., Wongrat L. (2009). Community structure and abundance of epipelagic copepods in a shallow protected bay, Gulf of Thailand. Kasetsart University Fisheries Research Bulletin, 33(1): 28-40.

Kumar S.P., Prasad T.G. (1999). Formation and spreading of Arabian Sea high-salinity water mass. Journal of Geophysical Research, 104:1455-1464.

Madhupratap M. (1987). Status and strategy zoolankton of tropical Indian estuaries: a review. Journal of Plankton Society of Japan, 34: 65-81.

Madhupratap M., Prasanna Kumar S., Bhattahiri P.M.A., Dileep Kumar M., Raghukumar S., Nair K.K.C., Ramaiah N. (1996). Mechanisms of the biological response to winter cooling in the northeastern Arabian Sea. Journal of Nature, 384: 549-552.

Mantha G., Muthaiyan S., Narayana M., Kareem A., Hans-Uwe D., Kandasamy S., Jiang-Shiou H. (2012). Community Structure of the Harpacticoida (Crustacea: Copepoda) on the Coast of Chennai, India. Zoological Studies, 51(4): 463-475.

Margalef D.R. (1968). Perspectives in Ecological Theory. The University of Chicago Press, Chicago. 111 p.

Moreira G.S. (1975). Studies on the salinity resistance of the copepod *Euterpina aeutifrons* (Dana). In: F.J. Vernberg (Ed.). Physiological ecology of estuarine organisms, Belle W. Baruch Library Maine Science Univ. S.C. Press, Columbia. pp: 73-79.

Morrison J.M., Codispoti L.A., Gaurin S., Jones B., Manghnani V., Zheng Z. (1998). Seasonal variation of hydrographic and nutrient fields during the US JGOFS Arabian Sea Process Study. Journal of Deep-Sea Research II, 45: 2053-2102.

Mwaluma J., Osore M., Kamau J., Wawiye P. (2003). Composition, Abundance and Seasonality of Zooplankton in Mida Creek, Kenya. Western Indian Ocean. Journal of Marine Science, 2(2): 147-155.

Nakajima R., Yoshidia T., Othman B.H.R., Toda T. (2008). Dial variation in abundance, biomass and size composition of zooplankton community over a coral-reef in Redang Island, Malaysia. Journal of Plankton Benthos Research, 3(4): 216-226.

Nishida S. (1985). Taxonomy and distribution of the family Oithonidae (Copepods, Cyclopoida) in the pacific and Indian Oceans. Ocean Research Institute. University of Tokyo, Japan, No. 20. 167 p.

Rezai H., Yusoff F.M.D., Arshad A., Ross O. (2004). Spatial and temporal variations in calanoid copepod distribution in the Straits of Malacca. Journal of Hydrobiologia, 537(1-3): 157-167.

Roy C. (1992). Reponses des stocks de poisons pelagiques a la dynamique des upwellings en Afrique de l'Ouest. ORSTOM. Analyse et Modelisation, Paris: Collection Etudes et Theses, 120 p.

Russell R., Hopcroft J., Roff C. (1996). Zooplankton growth rates: diel egg production in the copepods *Oithona*, *Euterpina* and *Corycaeus* from tropical waters. Journal of Plankton Research, 18 (5): 789-803.

Savari A., Nabavi S.M.B., Doustshenas B. (2004). Study of planktonic copepods distribution in Mussa creeks with PCA method. Science Journal of Persian Gulf, (1): 771-785.

Shannon C.E., Weaver W. (1963). The Mathematical Theory of Communication. University of Illinois Press, Urbana. 144 p.

Shanthi M., Ramanibai R. (2011). Studies on Copepods from Chennai Coast (Cooum and Adyar), Bay of Bengal - During the Cruise. Current Research Journal of Biological Science, 3(1): 132-136.

Shih C.T., Chiu T.S. (1998). Copepod diversity in the water masses of the southern East China Sea north of Taiwan. Journal of Marine System, 15: 533-542.

Sivasamy S.N. (1990) Plankton in relation to coastal pollution at Ennore Madras coast. Indian Journal of Marine Science, 19: 115-119.

Smith S., Roman M., Prusova I., Wishner K., Gowing M., Codispoti L., Barber R., Marra J., Flagg C. (1998) Seasonal response of zooplankton to monsoonal reversals in the Arabian Sea. Journal of Deep-Sea Research II, 45: 2369-2403.

Smith S.L (1995). The Arabian Sea: Mesozooplankton response to seasonal climate in a tropical Ocean. ICES Journal of Marine Science, 52: 427-43.

Somoue L., Elkhiati N., Ramdani M., Hoai T.L., Ettahiri O., Berraho A., Chi T.D. (2005). Abundance and structure of copepod communities along the Atlantic coast of southern Morocco. Journal of Acta Adriatica, 46: 63-76.

Vengadesh P.M., Rajkumar P., Thillai Rajasekar K. (2009). Seasonal variations of plankton diversity in the Kaduviyar estuary, Nagapattinam, southeast coast of India. Journal of Environmental Biology, 30(6): 1035-1046

Wiggert J.D., Jones B.H., Dickey T.D., Brink K.H., Weller R.A., Marra J., Codispoti L.A. (2000). The Northeast Monsoon's impact on mixing, phytoplankton biomass and nutrient cycling in the Arabian Sea. Deep-Sea Research, 47(2): 1353-1385.

Wilson S.C. (2000). The Arabian Sea and Gulf of Oman. In: C.R.C. Sheppard (Ed.). Seas at the Millenium. Pergamon Press, Amsterdam. pp: 17-33.

Yoder J.A., McClain C.R., Feldman G.C., Esaias W.E. (1993). Annual cycles of phytoplankton chlorophyll concentrations in the global ocean: a satellite view. Journal of Global Biogeochemical Cycles, 7: 181-194.

International Journal of Aquatic Biology (2015) 3(4): 245-257
ISSN: 2322-5270; P-ISSN: 2383-0956
Journal homepage: www.NPAJournals.com

چکیده فارسی

اثرات مونسون بر ساختار جوامع پاروپایان خلیج چابهار، دریای عمان

ندا فاضلی[۱]، رسول زارع[۲] ،سید محمد باقر نبوی[۳]، سعید سنجانی[۳]
[۱]گروه زیست‌شناسی دریا، دانشگاه گیلان، رشت، ایران.
[۲]گروه شیلات، دانشکده منابع طبیعی، دانشگاه تربیت مدرس، نور، ایران.
[۳]گروه زیست‌شناسی، دانشگاه علوم و فنون دریایی خرمشهر، خرمشهر، ایران.

چکیده:
در این مطالعه، پاروپایان شامل کالانوئید، سیکلوئید، هارپکتیکوئید و پوسیلوستوماتوئیدها در پنج ایستگاه خلیج چابهار، دریای عمان طی مدت یک سال مورد بررسی قرار گرفتند. این منطقه تحت تاثیر بادهای فصلی مونسون اقیانوس هند می‌باشد. نمونه‌ها با استفاده از تور پلانکتونی با چشمه ۱۰۰ میکرون و به طور عمودی جمع‌آوری شدند. پاروپایان از ۲۰ جنس و ۵۹ گونه شناسایی شدند. کالانوئیدها ۱۵ تا ۶۲ درصد و سیکلوئیدها ۲۶ تا ۳۹ درصد فراوانی کل پاروپایان را تشکیل می‌دادند. فراوانی هارپکتیکوئیدها در مونسون تابستانه حدود ۶ درصد بود. فروانی آنها در مونسون بهاره افزایش یافت و ۴۶ درصد فروانی کل پاروپایان را به خود اختصاص داد. فراوانی پوسیلوستوماتوئیدها تقریباً ۵ تا ۱۳ درصد کل پاروپایان بود. گونه‌های غالب شامل *Temora turbinata*، *Paracalanus elegans*، *Oithona nana* و *Euterpina acutifrons* بودند. نتایج نشان داد که ترکیب و پراکنش پاروپایان در فصول مختلف مونسون متفاوت می‌باشد که ناشی از تغییر شرایط هیدروگرافیک می‌باشد. علاوه بر این فراوانی گونه‌های پاروپای کوچک در ایستگاه‌های دور از ساحل بیشتر از ایستگاه های نزدیک ساحل بود.
کلمات کلیدی: فراوانی، پاروپایان، تنوع، مونسون، دریای عمان.