

Seasonal Variation of Copepoda in Chabahar Bay-Gulf of Oman

Neda Fazeli ^a, Hamid Rezai Marnani ^b, Saeed Sanjani ^b, Rasool Zare ^a, Simin Dehghan ^a and Najme Jahani ^a

^a Khorramshahr University of Marine Science, Department of Biology, Khorramshahr, Iran

^b Iranian National Center of Oceanography (INCO)

Abstract

Zooplankton was collected with vertical plankton tows using 100 µm mesh nets during August to November 2007 and February to May 2008 from five stations through the Chabahar Bay. Totally, 75 copepods species were identified. Post-monsoon was characterized by the highest numerous of copepod species and diversity. Pre-monsoon showed the lowest number of copepod species and diversity index. The results showed that seasonal variation of chlorophyll-a concentration associated phosphate concentration is a major factor controlling abundance of copepod after a time lag. Abundance of copepod was significantly higher during the pre-monsoon as compared to other seasons.

الملخص

جمعت الهوام الحويانية خلال الفترة (أب إلى تشرين الثاني 2007 و شباط إلى ايار 2008) من خمسة مواقع في خليج شهبهار. تم تحديد 75 نوعا من المجذافيات. اظهرت النتائج تميزا لظهور المجذافيات بعد هطول الامطار الموسمية و كذلك اقل ظهورا قبل هبوب الرياح الموسمية. الاختلاف الجوهرى للمجدافيات كان واضحا خلال فترة ما قبل هبوب الرياح الموسمية مقارنة بالمواسم الاخرى. اظهرت النتائج ان التغيرات الفصلية لظهور المجذافيات ارتبط ارتباطا وثيقا بتراكم اليخضور و الفوسفات.

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Keywords: Copepoda, Abundance, Diversity, Monsoon, Chabahar Bay, Species richness.

1. Introduction

Chabahar Bay is a sub-tropical and semi-enclosed bay with high biological production, providing an ideal breeding ground for many economically important fishes and shell fishes (Fazeli, 2008). Information on the marine zooplankton of the Chabahar Bay is scanty, except for the projects of Sanjarani, 2007 and Zareei, 1994, who worked in the Goater Bay. Further, many projects existed at Oman Sea such as Seraji, 2007.

The ecological importance of zooplankton, especially its main component such as copepods, in the pelagic food webs of the world's oceans has long been recognized. These organisms often constitute a significant component of the plankton community in many marine environments (Relevante *et al.*, 1985; Burkill *et al.*, 1987; Al-Najjar, 2002); and play a central role in the transfer of nutrients and energy through the marine food webs (Poulet and Williams, 1991; Williams *et al.*, 1994; Kiorboe, 1997) and have an important role in the trophy food web (Thiriot, 1978). Copepods support energy transfer between primary

producers (phytoplankton) and the final consumer of highly valuable fish and crustacean species (Faure, 1951). Despite abundant evidence of the importance of zooplankton in marine pelagic food webs, little is known about their density, composition, stratification and distribution in Chabahar Bay. The main objective of the present study is to examine the composition of the main planktonic taxa, temporal and spatial variation of the abundance and distribution of copepods and the impact of environmental factors on copepod's abundance.

2. Materials and Methods

2.1. Study Area

Chabahar Bay is a small semi-enclosed bay on the southeastern coasts of Iran (from 25° 17' 45"N- 60° 37' 45" E). This Bay is connected to the Indian Ocean by the Oman Sea. The Bay surface area is 290 km² with 14 km wide located between of Chabahar and Konarak (Fig.1). The average depth of this Bay is 12 m (ranges from 8-22m).

* Corresponding author. n_fazeli200@yahoo.com.

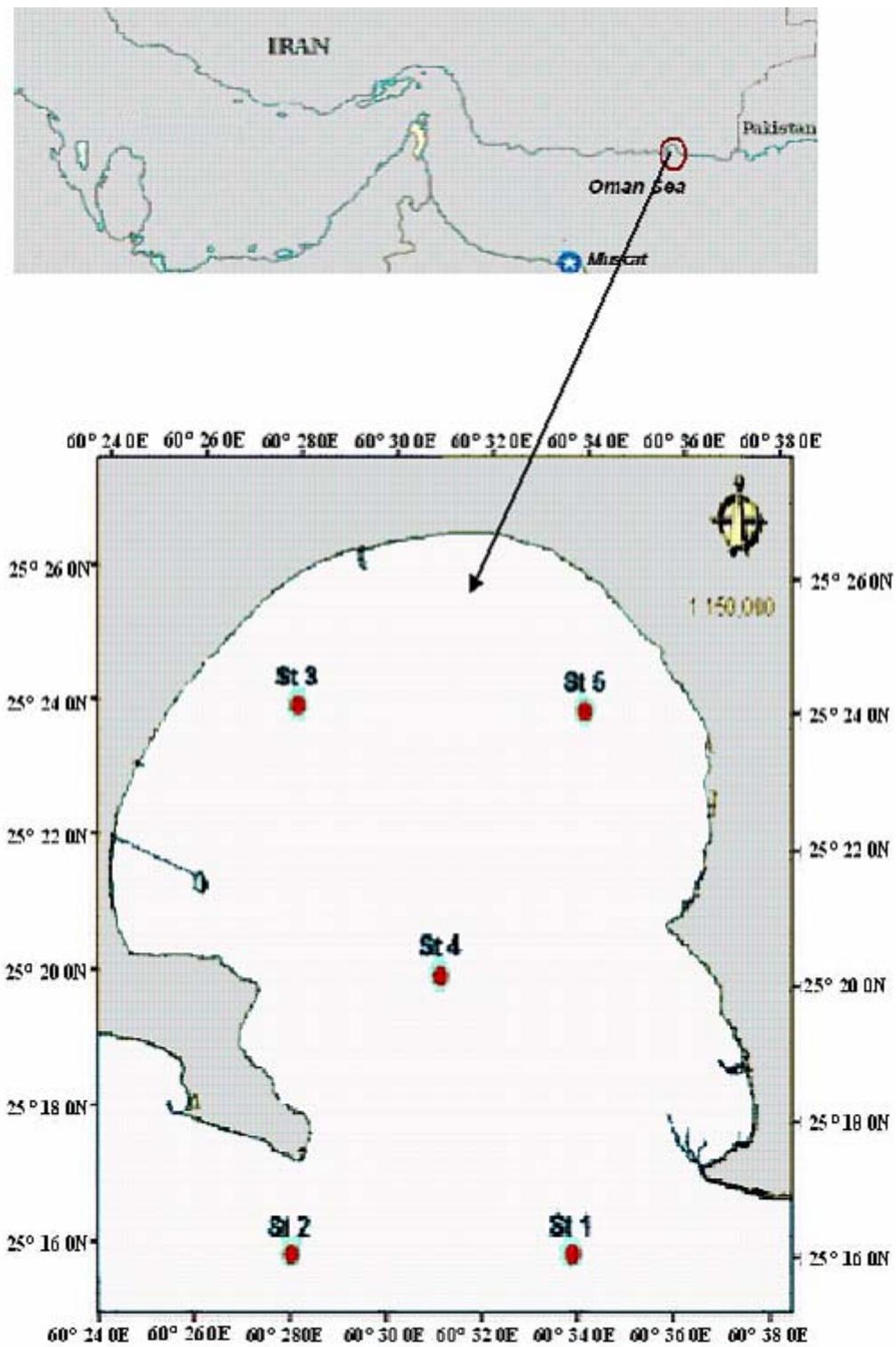


Figure 1. Sampling stations in the Chabahar Bay-Oman Sea

2.2. Sampling

Four sampling cruises were carried out in August 2007 (SW-monsoon), November 2007 (post-monsoon), February 2008 (NE-monsoon), and May 2008 (pre-monsoon). Five stations were investigated throughout the Chabahar Bay. Two stations (St. 1 and 2) were located far from shore waters with 22 m depth, another two stations were near the shore with 6m depth (St. 3 and 5) and the final station (St. 4) was located in the middle of the bay with 12m depth. Zooplankton was collected by using 100- μ m mesh nets equipped with Hydrobios flow meter, from near the bottom to the surface at each station where physico-chemical variables were determined. The samples were preserved immediately in 4-5% formalin, buffered to a pH of 8 with sodim tetraborate (borax). Organisms were identified to groups and copepods to species level (whenever possible) and counted. Density was expressed as individuals per m^{-3} (individual. m^{-3}). Only adult copepods were counted (Somoue *et al.*, 2005).

2.3. Data Analysis

Species diversity was calculated using Shannon–Weaver diversity index (Shannon–Weaver, 1963) and Species richness (Margalef, 1968). The data were further subjected to hierarchical cluster and multidimensional scaling (MDS) analyses to identify the similarity between stations based on composition of copepod species that were calculated as Bray Curtis similarity index using PRIMER (Clarke and Warwick, 1994).

3. Results

3.1. Environmental variables

The mean of water temperature varied from $(20.53 \pm 0.20^{\circ}\text{C})$ in NE-monsoon to $(29.92 \pm 0.05^{\circ}\text{C})$ in SW-monsoon. The mean of salinity ranged from $(36.7 \pm 0.06 \text{ Psu})$ in SW-monsoon to (36.91 Psu) in pre-monsoon (Fig.2b). The minimum and maximum values of chlorophyll-*a* concentrations were noticed $(0.77 \pm 0.08 \text{ mg. } m^{-3})$ in SW-monsoon to $(1.84 \pm 0.92 \text{ mg. } m^{-3})$ in NE-monsoon (Fig.2c). The average of dissolved oxygen (DO) ranged from $5.66 \pm 0.05 \text{ ml.l}^{-1}$ in SW-monsoon to $8.80 \pm 0.03 \text{ ml.l}^{-1}$ in NE-monsoon (Fig.2d).

Pre-monsoon season showed the maximum Silicate (SiO_4) concentration (av. $0.031 \pm 0.006 \text{ mg. } m^{-3}$) whereas it was minimum during the NE-monsoon (av. $0.017 \pm 0.05 \text{ mg. } m^{-3}$) (Fig. 2e). The variation of nitrate (NO_3) was (av. $0.026 \pm 0.004 \text{ mg. } m^{-3}$) in pre-monsoon (av; $0.002 \pm 0.0002 \text{ mg. } m^{-3}$) in post-monsoon (Fig. 2f). Minimum and maximum values of phosphate (PO_4) were from $0.015 \pm 0.006 \text{ mg. } m^{-3}$ during the NE-monsoon season to $0.008 \pm 0.002 \text{ mg. } m^{-3}$ during the SW-monsoon season (Fig. 2g).

3.2. Copepoda abundance and composition

Copepods were the dominant group during four seasons, reaching 69.73% ($1253.57 \pm 302.65 \text{ ind. } m^{-3}$) during pre-monsoon, 67.02% ($613.30 \pm 326.35 \text{ ind. } m^{-3}$) during SW-monsoon, 62.58% ($594.12 \pm 54.11 \text{ ind. } m^{-3}$) during post-monsoon and 47.38% ($904.17 \pm 161.7 \text{ ind. } m^{-3}$) in NE-monsoon (Fig 3; Fig 4). Copepod abundance

increased significantly ($p < 0.05$) during pre-monsoon than other seasons. There were significant spatial differences during SW-monsoon, post-monsoon and NE-monsoon ($p < 0.05$).

3.3. Community structure

Totally, 75 copepod species including 5 orders, 19 families, and 21 genera were identified during four cruises in Chabahar Bay. Some species were observed only in one season with lowest abundance (less than 25 ind. m^{-3}) (Table1) such as '*Saphirina gastric apherina nigromoculata* (at station 2) *Lucicutia flavicornis*, *Lucicutia gaussae* (at stations 1 and 3) and one species from Monstrilloida (at station 1) that only occurred during post-monsoon. *Oithona fallax*, *Paracanadica truncate*, *Euchatea marina* were observed at station 1 (only during NE-monsoon). *Bestiolina similis*, *Delius nudus* just appeared during pre-monsoon (at station 2). *Euterpina acotifrons*, *Macrosetella gracilis* and *Microsetella rosea* were observed highest (44.87% from total copepoda) in pre-monsoon. *Temora turbinata* were greater during pre-monsoon (7.94%) and NE-monsoon (12.06%). Moreover, Psododiptomidae species increased remarkably during NE-monsoon (7.57%) and were rare in other seasons. Results of cluster analyses based on copepod abundance revealed the presence of 2 main groups (groups I and II) during each season (Fig 5).

4. Discussion:

Zooplankton abundance in Chabahar Bay follows a cycle related to the monsoonal winds. In Chabahar bay, climatic changes and other environmental variables due to monsoonal winds play a key role in zooplankton community (Fazeli, 2008).

Nutrient enrichment is a key factor regulating temporal variations in zooplankton (mostly copepods) in coastal environments (Garcia and Lopez, 1989). Further, phytoplankton is a source of nourishment of herbivorous copepods (Tan *et al.*, 2004), but in present study there was not positive correlation between chlorophyll-*a* concentration and copepods abundance. According to (Tranter, 1973) there was a time lag between phytoplankton bloom and the increase of zooplankton. Our results showed chlorophyll-*a* concentration increased with phosphate concentration ($p < 0.01$) (Table 2). Domestic sewage and industrial effluents noticed around the bay may also be responsible for increase of nutrients (mostly phosphate) and chlorophyll-*a* concentration consequently. This fact suggests that an earlier increase of phytoplankton must have favored such an increase in copepod and that the early bloom of phytoplankton may have used up the phosphate in this area.

Baars (1998) noticed during the SW- monsoon, that upwelling occurs in almost the entire western Arabian Sea, giving high primary productivity and vast diatom blooms, especially off Oman. This contrast with our result is because these areas are greatly affected by monsoonal winds and zooplankton densities were highest in the upwelling seasons, but upwelling was not reported in Chabahar Bay (Wilson, 2000).

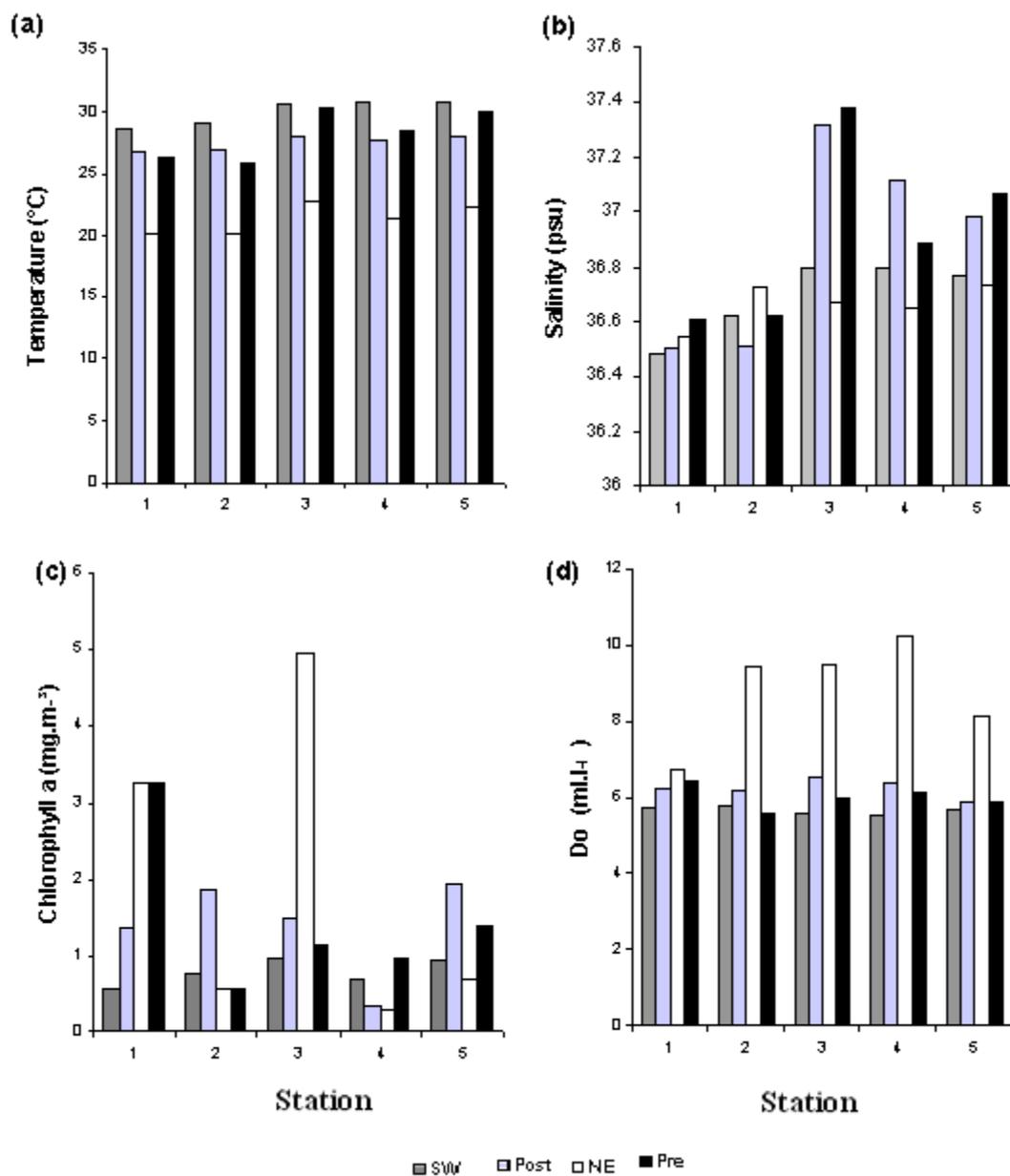


Figure 2. a, b, c, d, Distribution of major physico-chemical variables during monsoonal seasons (x axis as stations and Y axis as physico-chemical variables).

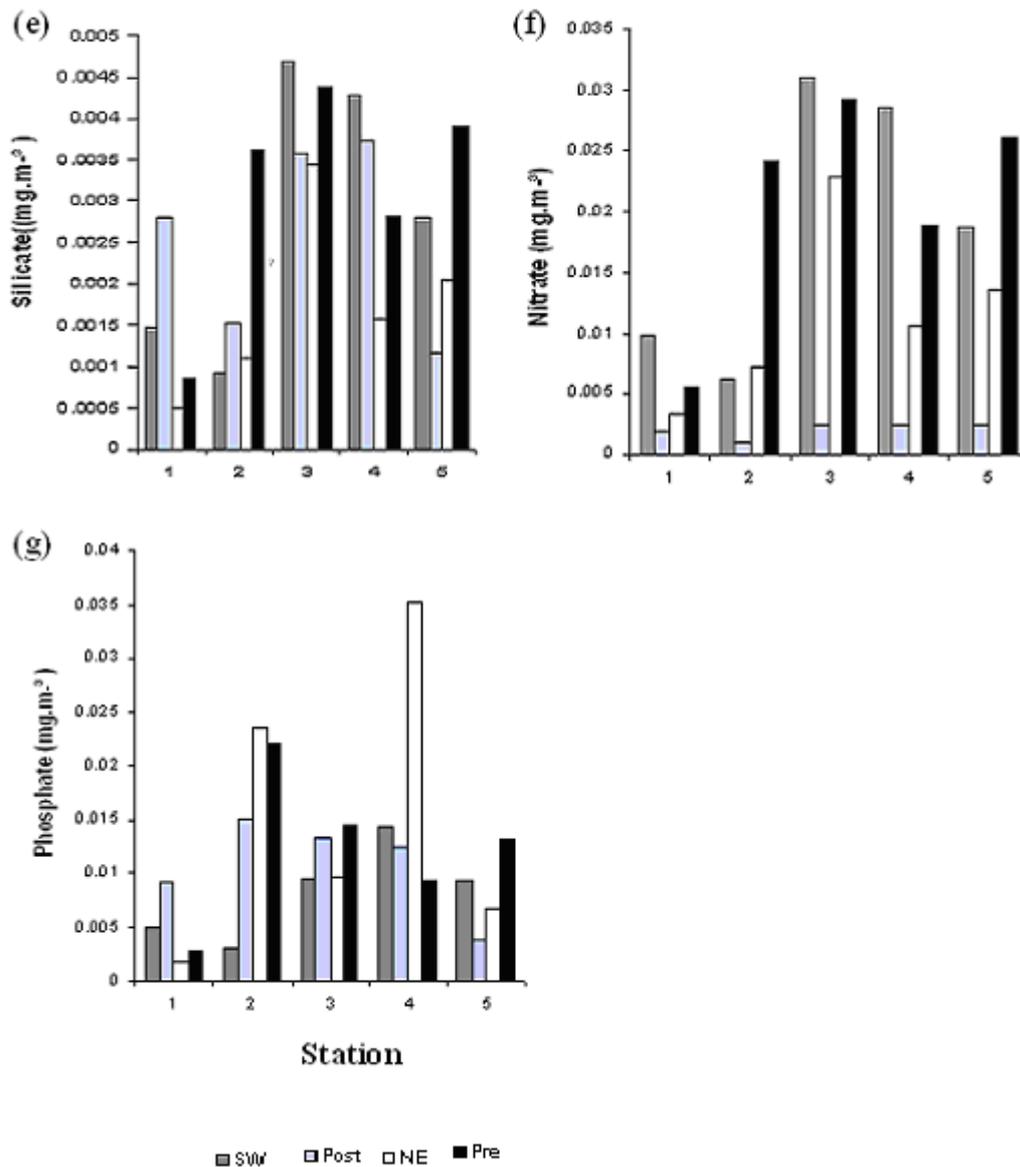


Figure 2. e, f, g. Distribution of major physico-chemical variables during monsoonal seasons (x axis as stations and Y axis as physico-chemical variables).

Since, there was no correlation between copepoda abundance and temperature-salinity, we conclude that the abundance of copepoda does not have any relationship with these parameters in Chabahar bay, while in some tropical embayments and estuaries in India, accelerate of zooplankton production during the periods of high salinity was documented by (Baidya and Choudhury, 1984; Tiwari and Nair 1993) and high temperature by (Li *et al.*, 2008).

Copepod diversity and richness were related to copepod abundance inversely. Species richness was enhanced towards the far from the shore and middle stations of the bay (Table 3). This is because organisms living in near shore waters seem to be adapted to the qualification and unable to thrive in offshore area (Faure, 1951). Increase of diversity and richness indices in far from shore communities is common in Indian Ocean

(Madhupratap, 1986). This trend was observed in waters of Africa by (Okemwa, 1990) in Tudor Bay, (Mwaluma, 1997) in Kenya, (Osore, 1992; Osore, 1994) in Gazi Bay and (James *et al.*, 2003) in Media creek. In India, in the Bay of Bengal and Cochin backwaters, the similar trend were reported by (Pillai *et al.*, 1973; Nair *et al.* 1981; Tiwari and Vijayalakshmi, 1993), who attributed this high diversity to the calmer, more stable oceanic waters.

In this study *Oithona nana* had much abundance through the year. This species is a euryhaline and euryterm species in tropical water (Nishida, 1985). Most abundance of copepod species during the pre-monsoon belongs to Harpacticoida in particular *Macrosetella gracilis*, *Microsetella rosea*, *Euterpina acutifrons* and *Corycaeus andrewsi*.

In conclusion, chlorophyll-*a* concentration appear to be the important factor leading to increase of copepod

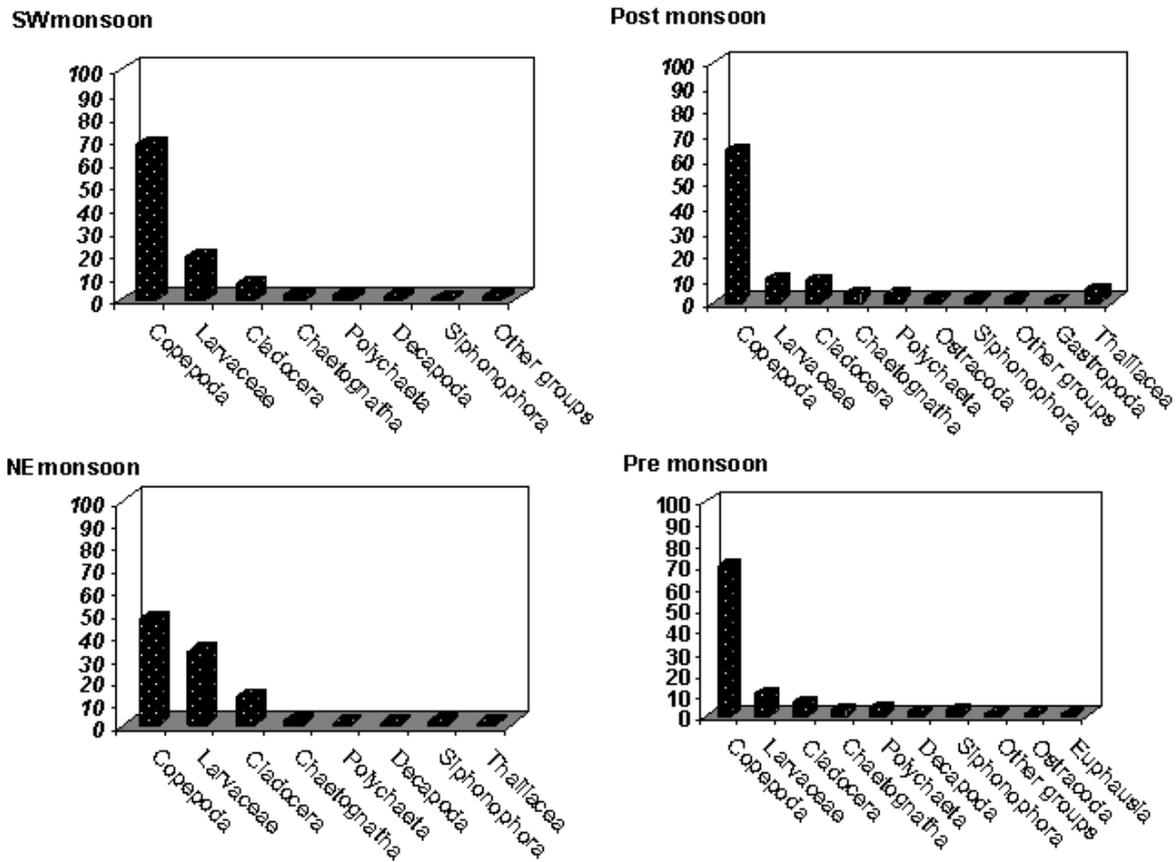


Figure 3. Percentage of zooplankton groups (%) during monsoonal seasons in Chabahar Bay.

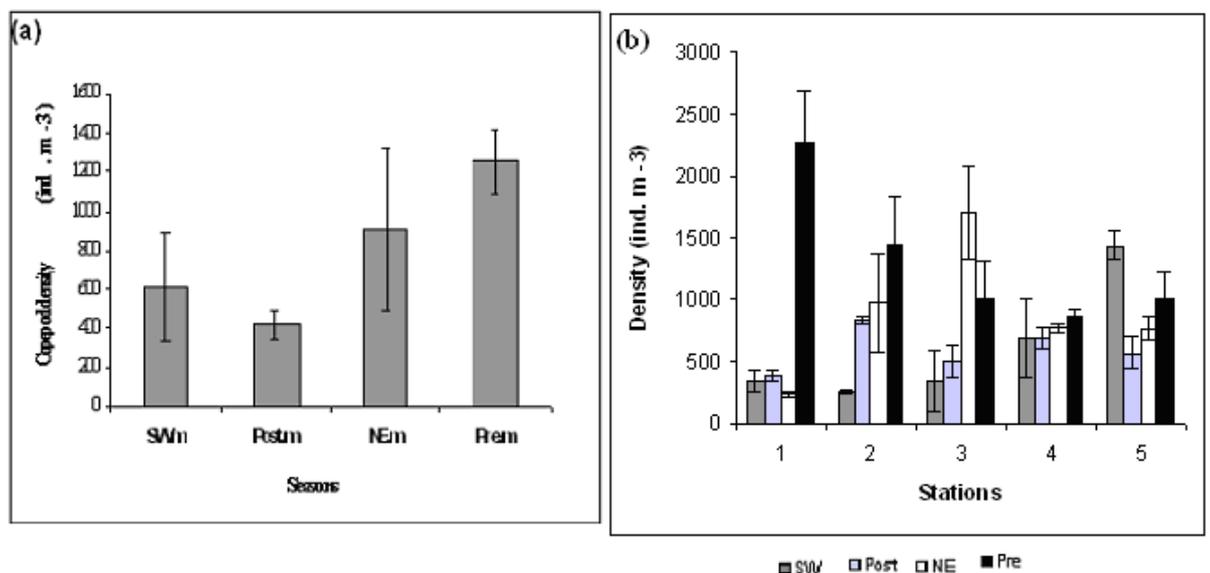


Figure 4. Seasonal (a) and spatial (b) distribution of copepoda during monsoonal seasons in Chabahar Bay.

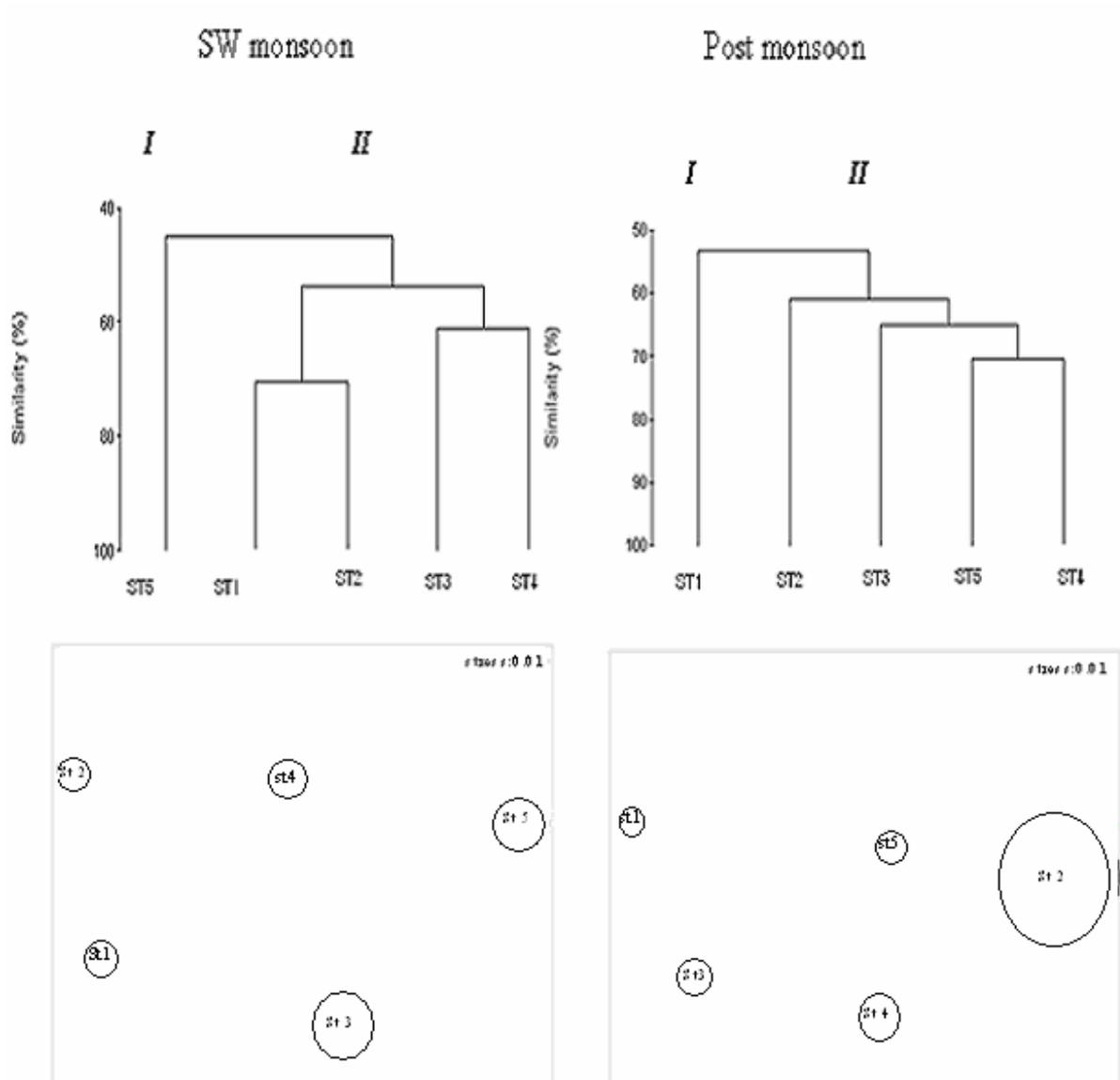


Figure 5. Cluster and MDS analyses showing similarity of stations during monsoonal seasons based on copepod composition in Chabahar Bay.

*Figure 5 continues in the next page.

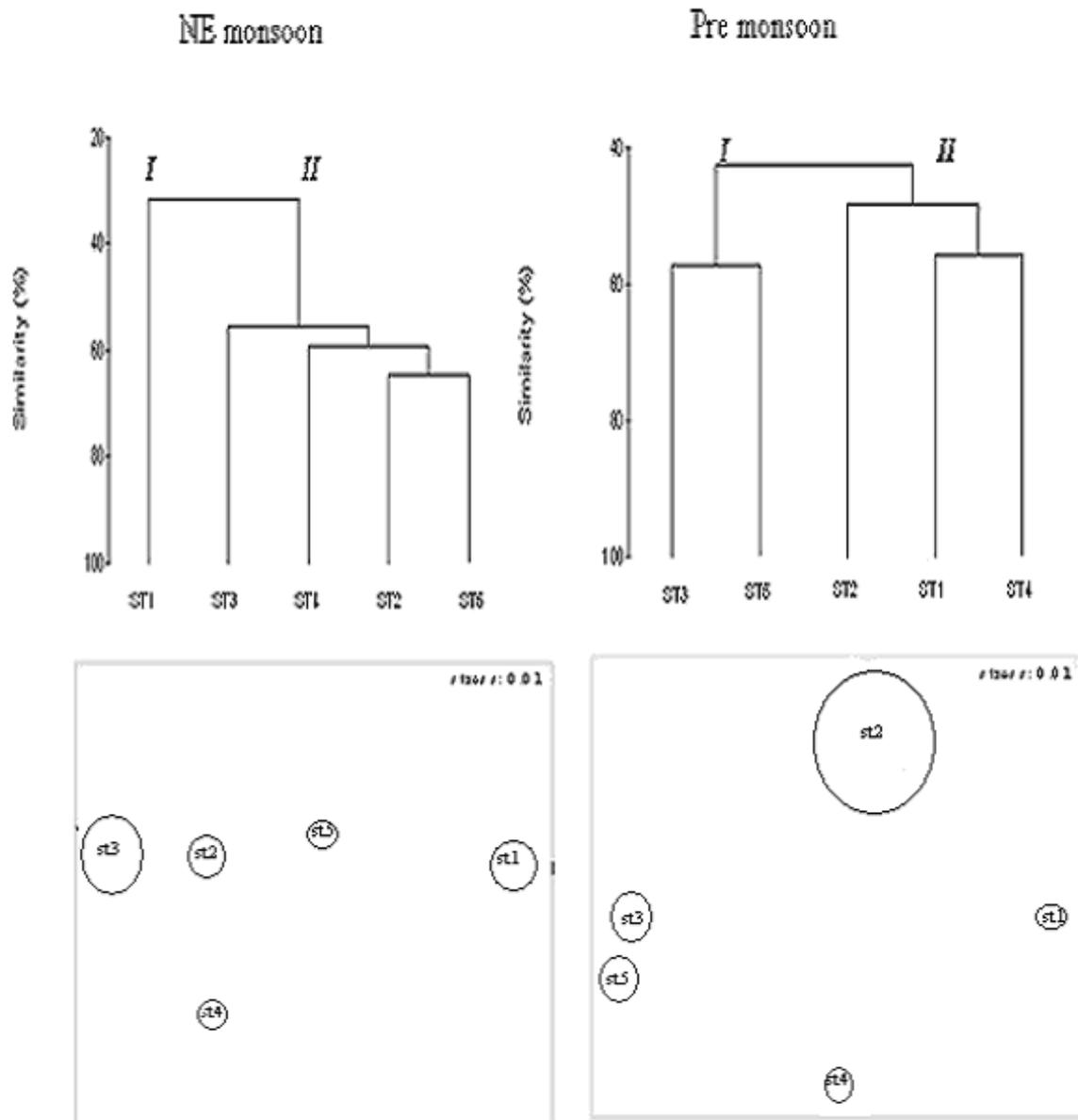


Figure 5. Cluster and MDS analyses showing similarity of stations during monsoonal seasons based on copepod composition in Chabahar Bay.

Table 1. Abundance of copepod species (ind. m⁻³) in monsoonal seasons in Chabahar Bay.

Species	SW .m	post. m	NE. m	pre.m
<i>Paracalanus crassirostris</i>	1125.62	2830.62	255.24	548.34
<i>P.elegans</i>	2782.11	4162.53	1558.07	516.59
<i>P. aculatus</i>	56.1676	1701.56	160	47.418
<i>P.denudatus</i>	579.69	540.17	165	-
<i>P.parvus</i>	189.02	140.55	125	87.129
<i>P.sp</i>	600.52	1350.36	-	288.60
<i>Acrocalanus longicornis</i>	1230.81	339.7	222.22	-
<i>A.gracilis</i>	2152.94	61.54	630.48	-
<i>A.gibber</i>	2479.67	187.59	246.96	-
<i>A.monochus</i>	1374.52	87.90	316.75	259.74
<i>A.sp</i>	1219.27	541.49	525.71	412.67
<i>T. desicaudata</i>	89.43	1584.75	40	-
<i>T.turbinata</i>	677.3	5698.92	9291.32	5717.78
<i>T.stylifera</i>	-	299.07	-	-
<i>Eucalanus subcrassus</i>	221.32	626.23	1004.45	-
<i>E. morcantus</i>	-	210.12	-	-
<i>E.sp</i>	87	-	31.75	-
<i>E. crassus</i>	231.25	133.25	31.75	-
<i>E. attenuatus</i>	41.03	-	40	-
<i>E.monochus</i>	85.10	49.84	-	-
<i>E. pileatus</i>	44.07	-	-	-
<i>E. halinus</i>	44.07	-	-	-
<i>Acartia pasifica</i>	644.97	-	-	-
<i>A.erythraea</i>	47.60	-	-	-
<i>A.sp</i>	187.56	277.50	111.11	225.11
<i>A. longirenis</i>	205.66	389.75	236.11	-
<i>Clausocalanus furcatus</i>	-	-	430.58	-
<i>C. gracilis</i>	-	110.42	-	-
<i>C. minor</i>	-	-	766.96	-
<i>C.sp</i>	600.52	-	285	-
<i>Calocalanus styliremis</i>	45.30	42.60	-	-
<i>C. plumulosus</i>	-	63.06	31.75	-
<i>C.pavo</i>	47.60	55	-	-
<i>Pseudodiptomus sp</i>	136.03	-	4994.04	299.32
<i>P.marinus</i>	-	-	589.21	-
<i>Centropages furcatus</i>	-	-	713.22	-
<i>C. tenuremis</i>	690.54	384.41	9441.95	839
<i>Labidocera sp</i>	27518.82	84.49	375.24	-
<i>Pontellina</i>	-	90.115	-	-
<i>Paracanadica truncata</i>	-	-	191/11	-
<i>Lucicutia sp</i>	-	-	31/75	-
<i>L. flavicornis</i>	-	20.51	-	-
<i>L. gaussae</i>	-	22.04	-	-
<i>Bestiulina similis</i>	-	-	-	130
<i>Delius nudus</i>	-	-	-	127
<i>Euchata marina</i>	-	-	31.75	-

<i>Oithona oculata</i>	1952.91	1742.31	1558.78	1619.05
<i>O. attenuata</i>	3600.99	2762.99	1891.85	965.99
<i>O.nana</i>	3551.84	5254.90	10203.44	6323.23
<i>O. brevicornis</i>	336.41	2496.91	3761.27	1238.10
<i>O.simplex</i>	1343.38	5624.04	750.95	761.90
<i>O. rigida</i>	3883.92	1913.12	1284.20	1111.11
<i>O.plumifera</i>	45.35	1058.42	591.11	894.66
<i>O. sp</i>	5270.54	5911.14	5735.79	7163.06
<i>O.fallax</i>	-	-	31.75	-
<i>Corycaeus pacificus</i>	194.72	311.33	166.98	-
<i>C. andrewsi</i>	1005.18	659.05	1528.07	5125.54
<i>C. asiaticus</i>	321.52	279.52	236.11	1910.13
<i>C. erythraeus</i>	90.52	2013	267.86	-
<i>C. sp</i>	725.13	390.30	166.96	285.71
<i>C. affinis</i>	-	243.68	125	331.07
<i>C. dahli</i>	-	384.77	361.11	-
<i>C. speciosus</i>	-	65.86	220.24	-
<i>Oncea media</i>	608.28	3626.43	2907.78	-
<i>O. venusta</i>	703	1860.83	634.20	259.74
<i>O. clevei</i>	417.74	1174.20	160	-
<i>O. minuta</i>	44.07	670.01	-	387.72
<i>Sapphirina sp</i>	-	-	331.35	-
<i>S. gastrica</i>	-	44.35	-	-
<i>S. nigromaculata</i>	-	45.35	-	-
<i>Clytemnestra scutellata</i>	-	123.08	1227.88	704.81
<i>Macrosetella gracilis</i>	302.14	2375.38	753.49	14286.96
<i>Microsetella rosea</i>	172.92	280.86	366.96	8116.86
<i>Euterpina acutifrons</i>	4058.41	8791.82	4831.53	10440.73
<i>Monstrilloida</i>	-	105.17	-	-

Table 2. Pearson correlation of major environmental parameters and copepoda density

Variables	Chl-a	Temperature	Salinity	DO	SiO3	NO3	PO4
Copepod density	0.05	-0.26	-0.08	0.20	-	-	-
Chl- a	1.00	-0.38	0.06	0.33	0.05	0.05	0.93**

(* significant at 0.05 level; ** significant at 0.01 level).

Table 3. Diversity index (H') and species richness (D) of Copepoda in monsoonal seasons.

Stations	SW .m	post .m	NE .m	pre .m
1	3.09 (4.10)	3.03 (4.59)	2.89 (4.39)	2.52 (1.65)
2	3.41 (4.11)	3.34 (4.23)	2.67 (2.40)	2.47 (1.90)
3	2.40 (1.35)	2.62 (2.99)	2.19 (1.44)	1.96 (1.57)
4	2.73 (3.13)	2.85 (3.58)	2.88 (2.97)	2.14 (1.84)
5	1.15 (1.71)	2.33 (1.79)	2.54 (2.55)	1.93 (1.04)
Mean	2.55 (2.88)	2.83 (3.43)	2.63 (2.75)	2.20 (1.60)
Number species	50	58	57	33

abundance (after a time lag) and associated phosphate concentrations during pre-monsoon.

Acknowledgements

We wish to thank Dr. Irina Prusova for guide and Iranian National Center of Oceanography for the encouragement and support. The study was supported by Khorramshahr University of Marine Science.

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