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# Effect of Seasonal Monsoons on Calanoid Copepod in Chabahar Bay-Gulf of Oman

Neda Fazeli*, Rasool Zare

*Khorramshahr University of Marine Science. Department of Biology, Khorramshahr, Iran*

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Abstract

Seasonal abundance and diversity of calanoid copepod was studied from zooplankton samples collected between August 2007 and May 2008 in Chabahar Bay (one of the Iranian coasts of Gulf of Oman located on the southeastern Iran (25° 17' 45"N- 60° 37' 45" E). This area is influenced by seasonal monsoons. Five stations were investigated along the Bay. Zooplankton was collected with vertical plankton tows using 100-µm mesh net. The net was towed obliquely from a depth near the bottom to the surface. The main peak of calanoid density was recorded in SW-monsoon with an average of (445.19 ± 126.16 individual. $m^{-3}$) and formed 62.40% of the total copepod while pre-monsoon was characterized by the lowest calanoid density (153.75 ± 54.20 ind.$m^{-3}$) and formed 26.73% of the total copepod. The results suggested calanoid abundance regulated by variations in chlorophyll (*a*) concentrations and temperature. Overall, 45 calanoid species representing 11 families and 15 genera were identified during four surveys. SW-monsoon was characterized by highest diversity index (H'=1.95) and species richness (D= 1.66). Pre-monsoon showed lowest numerous of calanoid species (mean 13), diversity index (H'=1.42), and species richness (D=1.39)



Keywords: calanoid, abundance, diversity, monsoon, Chabahar Bay, Gulf of Oman.

## 1. Introduction

Chabahar Bay is a small semi-enclosed and sub-tropical bay on the south-eastern coasts of Iran (25° 17' 45"N- 60° 37' 45" E). The Bay surface area is 290 km2 with 14 km wide, located between of Chabahar and Konarak (Figure 1). The average depth of the bay is 12 m (ranges from 8-22m). This Bay is connected to the Indian Ocean by the Gulf of Oman. Therefore, the effect of Indian monsoonal winds on this area is remarkable. The year is divided into periods of northeast (NE) monsoon, southwest (SW) monsoon, and its following inter-monsoon periods (post-south west monsoon(post-monsoon), and pre-southwest monsoon (pre-monsoon) (Wyrtki, 1973; Wilson, 2000). This bay is one of the five major ports in the Arabian Sea and Gulf of Oman, located in naturally suitable fish sites. Nonetheless, very scant published information is available on the Bay (Wilson, 2000). Calanoid copepods are the representative taxa of the pelagic mesozooplankton and are both highly diverse and abundant (Angel, 1994). In spite of the abundant evidence about the importance of zooplankton in marine pelagic food webs and the importance of calanoids as food for larval fish (Runge, 1988; Motta *et al.*, 1995), there is limited information about the zooplankton and calanoid density, abundance, diversity and composition in Chabahar Bay. However, there is some information based on copepoda in Mussa creeks by Savari *et al.*, 2003; Savari *et al.*,2004, and on total zooplankton in ROPME Sea (AL-Khabbaz & Fahmi, 1994), in Arabian Sea (Smith, 1995; Baars,1999), in waters of Pakistan (Kazmi, 2004; Saravankumar, 2007), and in Arabian Sea and Indian Ocean (Pillai *et al.*, 1973; Madhupratap, 1987; Tiwari & Nair 1993; Mwaluma *et al.*,2003; madhu *et al.*,2007). The above researchers observed calanoid as the major component of copepod.

The present study is the first in this region to examine the abundance and diversity of calanoid copepod (with temporal-spatial variation) and the impact of environmental factors on their abundance.

## 2. Materials and methods

Zooplankton sampling conducted during four oceanography cruises: 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, other 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-µm mesh nets equipped with Hydrobios flow meter. Plankton samples fixed immediately in 4-5% formalin, buffered to a حأ of 8 with sodium tetraborate (borax). The species diversity was calculated using Shannon–Weaver diversity index

* Corresponding author. n_fazeli200@yahoo.com.

(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 Braye Curtis similarity index using PRIMER (Clarke & Warwick, 1994).

## 3. Results

The values of different parameters are shown in Figure 2. The mean of water temperature varied from (20.52 ± 0.20°C) in NE-monsoon to (29.92 ± 0.05° C) in SW-monsoon. The mean of salinity ranged from (36.7 ± 0.06) in SW-monsoon to (36.91) in pre-monsoon. The minimum and maximum values of chlorophyll (*a*) concentrations were noticed (0.77 ± 0.08 mg. $m^{-3}$) to (1.84 ± 0.92 mg. $m^{-3}$) in SW-monsoon and NE-monsoon, respectively (Figure 2c). The average of dissolved oxygen (DO) ranged from 5.66 ± 0.05 $ml.l^{-1}$ in SW-monsoon to 8.80 ± 0.03 $ml.l^{-1}$ in NE-monsoon. Pre-monsoon season showed the maximum Silicate ($SiO_4$) concentration (av. 0.031 ± 0.006 mg. $m^{-3}$) whereas the minimum was during the NE monsoon (av.0.017 ± 0.05 mg. $m^{-3}$). The variation of nitrate ($NO_3$) concentration was (av. 0.026 ± 0.004 mg. $m^{-3}$) in pre-monsoon to (av. 0.002 ± 0.0002 mg. $m^{-3}$) in post-monsoon. Minimum and maximum values of phosphate ($PO_4$) concentration were from (av. 0.015 ± 0.006 mg. $m^{-3}$) during the NE-monsoon season to (av.0.008 ± 0.002 mg. $m^{-3}$) during the SW-monsoon season.

Calanoid was the major component of copepod during SW-monsoon comprising 62.40% of total copepod and NE-monsoon (comprising 44.96%). The lowest abundance of calanoid was observed in pre-monsoon (26.73%). In post–monsoon calanoid copepods represented 33.72% of total copepod numbers. Among calanoids, the species belong to following families: Acartidae, Paracalanidae, Centropagidae, Clausocalanidae, Pontellidae, Eucalanidae, Euchaetidae, Lucicutiidae, Pseudodiaptomidae, Temoridae, and Candaciidae. A significant increase was noticed in calanoid abundance in SW-monsoon (445.19 ± 176.13 $ind.m^{-3}$) as compared to NE-monsoon (219.19 ± 37.09 $ind.m^{-3}$), post-monsoon (160.61 ± 43.15 $ind.m^{-3}$), and pre-monsoon seasons (153.56 ± 54.20) ($p<0.05$) (Figure 3a). ). Spatial variation based on calanoid abundance during four study periods was significant (Figure 3b).

Overall, 45 calanoid species representing 11 families and 15 genera were identified during four periods in the Chabahar Bay. Some species appeared only in one season and showed lowest abundance. *Lucicutia flavicormis* and *Lucicutia gaussae* were observed during post-monsoon at stations 1 and 3 (comprising 0.01%). *Paracanadica truncate* , *Euchatea marina* was noticed at station 1 during NE-monsoon (comprising 0.01%) as rare calanoid species. *Bestiolina similis*, *Delius nudus* appeared at station 2 in pre-monsoon (comprising 0.04 %). Dominant species in Chabahar Bay are presented in table 1**.** *Temora turbinata* and *Centropages tenuremis* flourished in NE- monsoon as major species (~12%).

SW-monsoon was characterized by highest diversity index (H'=1.95) and species richness (D= 1.66). Pre-monsoon showed the lowest abundance of calanoid species (mean 13), diversity index (H'=1.42) and species richness (D=1.39) (Table 2).

Pearson correlation showed that physico-chemical parameters such as salinity, chlorophyll(*a*) concentration, and pH do not provide any significant correlation with calanoid abundance, whereas calanoid showed a significant positive correlation with temperature ($P < 0.05$, Table 3). Chlorophyll (*a*) concentration showed a significant correlation with phosphate.

Results of cluster analyses based on calanoid density revealed the presence of 2 main groups (*I* and *II*). Station 5 separated from others and group *II* comprised stations 1, 2, 3, and 4 (Figure 4).

## 4. Discussion

The seasonal variations in abundance of calanoid copepod in Chabahar Bay appear to be regulated by environmental parameters (Fazeli, 2008). In this study, the water temperature was from 20.53 ± 0.20 °C during NE-monsoon to 29.92 ± 0.05 °C during SW-monsoon. The positive association between temperature and total calanoid abundance ($p<0.05$) reveals that temperature is the major factor controlling the abundance of calanoid in Chabahar Bay. This result is in agreement with the findings of Rezai *et al.*, 2004 and Li *et al.*, 2008 about Malacca strait and Taiwan Strait.

Boucher *et al.* (1987) and Williams *et al.* (1994) believe that copepod abundance and distributions are influenced by hydrographic conditions in tropical waters. Nonetheless, salinity, pH and DO appear to play a minor role in influencing abundance and distribution patterns of calanoida in Chabahar Bay. No significant relationship was noticed between those parameters and total calanoid abundance. An opposite trend was observed in some studies in Arabian Sea and Indian Ocean (Pillai *et al.*, 1973; Madhupratap, 1987, 1984; Tiwari & Nair 1993). Those studies showed that salinity plays a key role in copepod abundance.

The results of this investigation support the hypothesis that food importance (e.g. phytoplankton) regulates the abundance of calanoid. The positive association between chlorophyll (*a*) and phosphate concentration implies the increase of chlorophyll(*a*) in high phosphate concentrations. Eduardo (1998) suggests that copepod abundance was, at least in part, regulated by food availability (e.g. phytoplankton); Tranter (1973) said that zooplankton increased after a higher lag time of higher phytoplankton. Therefore, we conclude that calanoid copepod increases after a lag time of higher phytoplankton (chlorophyll (*a*) concentration) and phytoplankton increases after the periods of higher phosphate concentration in the Bay. A similar trend was observed in some studies in some parts of the Indian Ocean by Baars (1999), Madhu *et al.* (2007), and Saravankumar (2007).

Species diversity was generally high in stations far from the shore (St 1 and 2) than those near the shore (St 3 and 5). Also, species richness was increasingly enhanced in stations that are far from the shore and in those in the middle of the Bay. Because of the organisms living in near shore waters seem to be adapted to high food

Table1. Major calanoid copepod species in the Chabahar Bay during monsoonal seasons (Sw.m=SWmonsoon, post.m=postmonsoon, NEmonsoon=NEmonsoon and pre.m=premonsoon) (+++: highly abundant (>1000 $m^{-3}$), moderately abundant (++:100-1000 $m^{-3}$), Presence (+:1-100.$m^{-3}$) and (-: absence)

| Species | SW.m | post.m | NE.m | pre.m |
|---|---|---|---|---|
| *Paracalanus elegans* | +++ | +++ | +++ | ++ |
| *P.*sp | ++ | +++ | - | ++ |
| *Acrocalanus longicornis* | +++ | ++ | ++ | - |
| *A.gracilis* | +++ | + | +++ | - |
| *A.*sp. | +++ | +++ | +++ | ++ |
| *Temora turbinata* | ++ | +++ | +++ | +++ |
| *Pseuodiaptomus* sp. | ++ | - | +++ | ++ |
| *Centropages tenuiremis* | ++ | +++ | +++ | ++ |
| *Labidocera.* sp. | +++ | + | ++ | - |
| *Pseuodiaptomus marinus* | - | - | ++ | - |
| *Lucicutieae flavicornis* | - | + | - | - |

Table 2. Diversity indices (H) and species richness (D) of calanoida.

| Stations | SW-monsoon | post- monsoon | NE- monsoon | pre-monsoon |
|---|---|---|---|---|
| 1 | 2.36 (2.46) | 2.15 (2.20) | 2.62 (2.82) | 1.59 (1.06) |
| 2 | 2.82 (2.50) | 2.59 (2.27) | 1.60 (0.97) | 1.49 (0.57) |
| 3 | 1.61 (0.65) | 1.92 (1.15) | 1.56 (0.56) | 1.33 (0.48) |
| 4 | 2.39 (1.84) | 1.67 (1.36) | 1.72 (1.15) | 1.63 (0.96) |
| 5 | 0.59 (0.86) | 1.55 (0.78) | 1.71 (1.23) | 1.10 (0.41) |
| Mean | 1.95 (1.66) | 1.97 (1.55) | 1.84 (1.34) | 1.42 (1.39) |
| N.species | 30 | 29 | 31 | 13 |

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

| Variables | Temperature | Salinity | Chl(*a*) | pH | DO | $SiO_4$ | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|---|---|
| Calanoid density | 0.48* | 0.20 | -0.23 | -0.32 | -0.21 | - | - | - |
| Chl(*a*) | -0.38 | 0.06 | 1 | 0.27 | 0.33 | 0.05 | 0.05 | 0.93** |

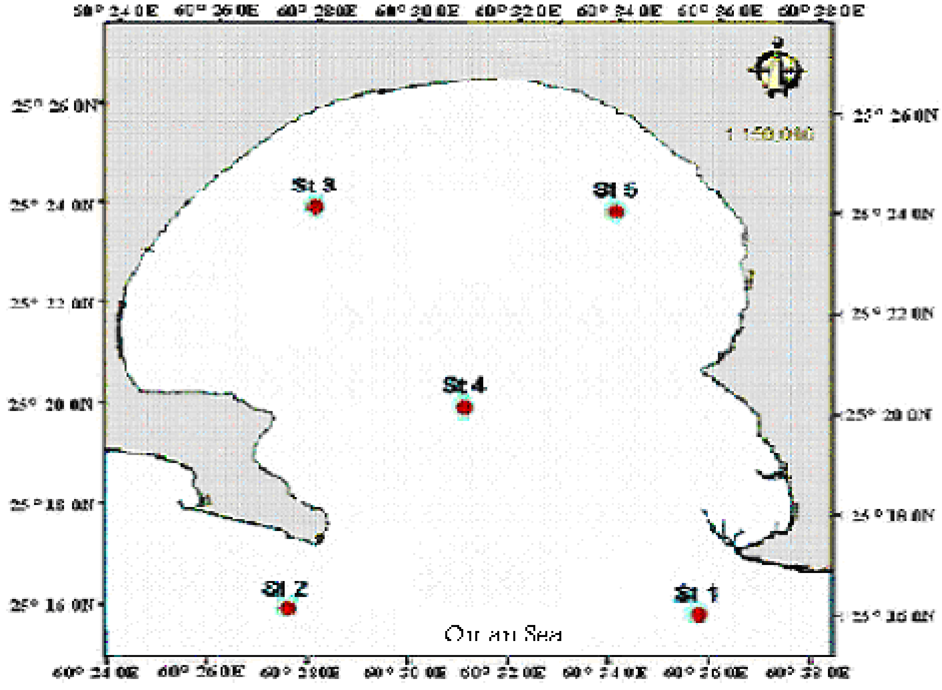



Figure 1.Sampling stations (the numbers show stations)

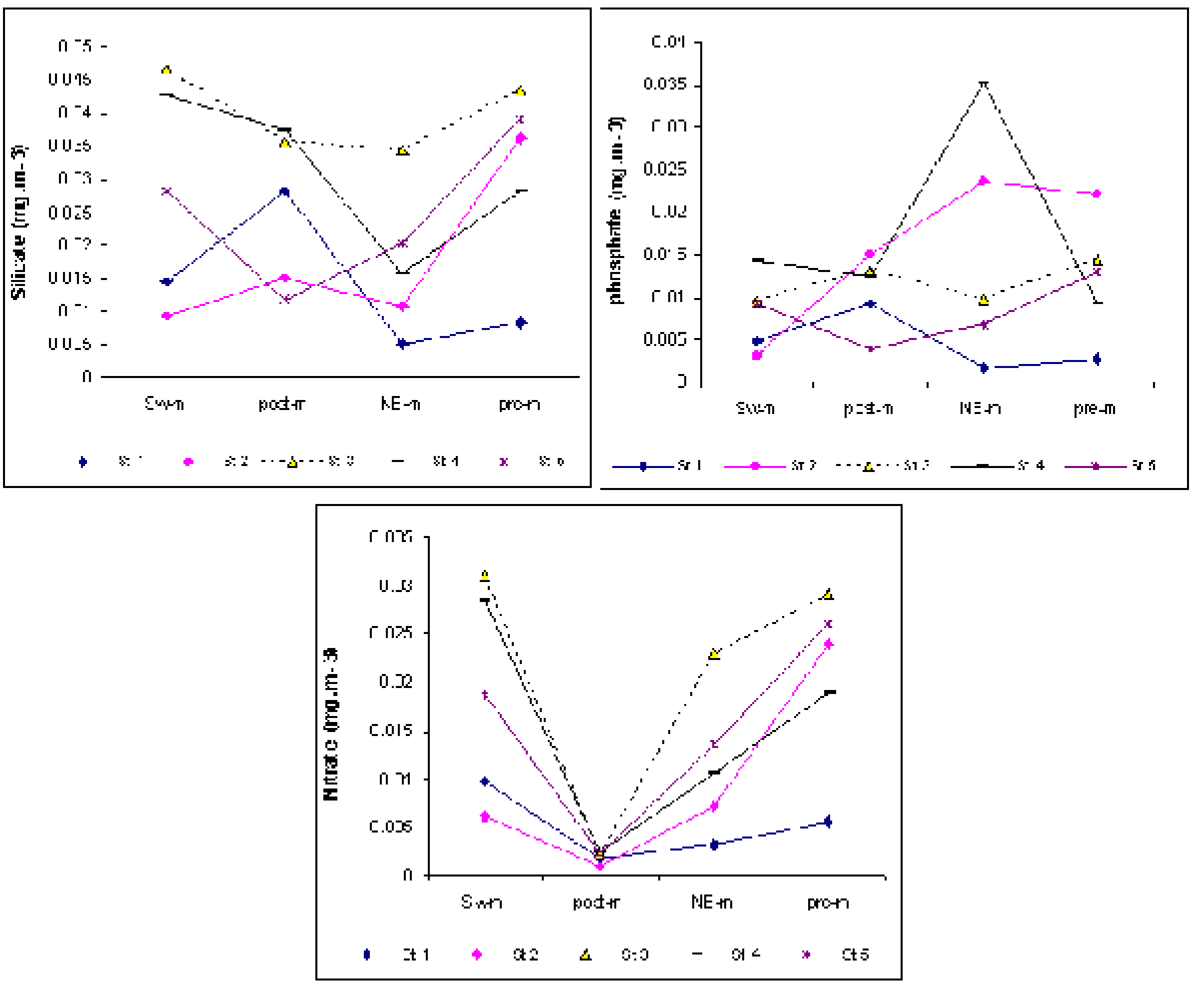
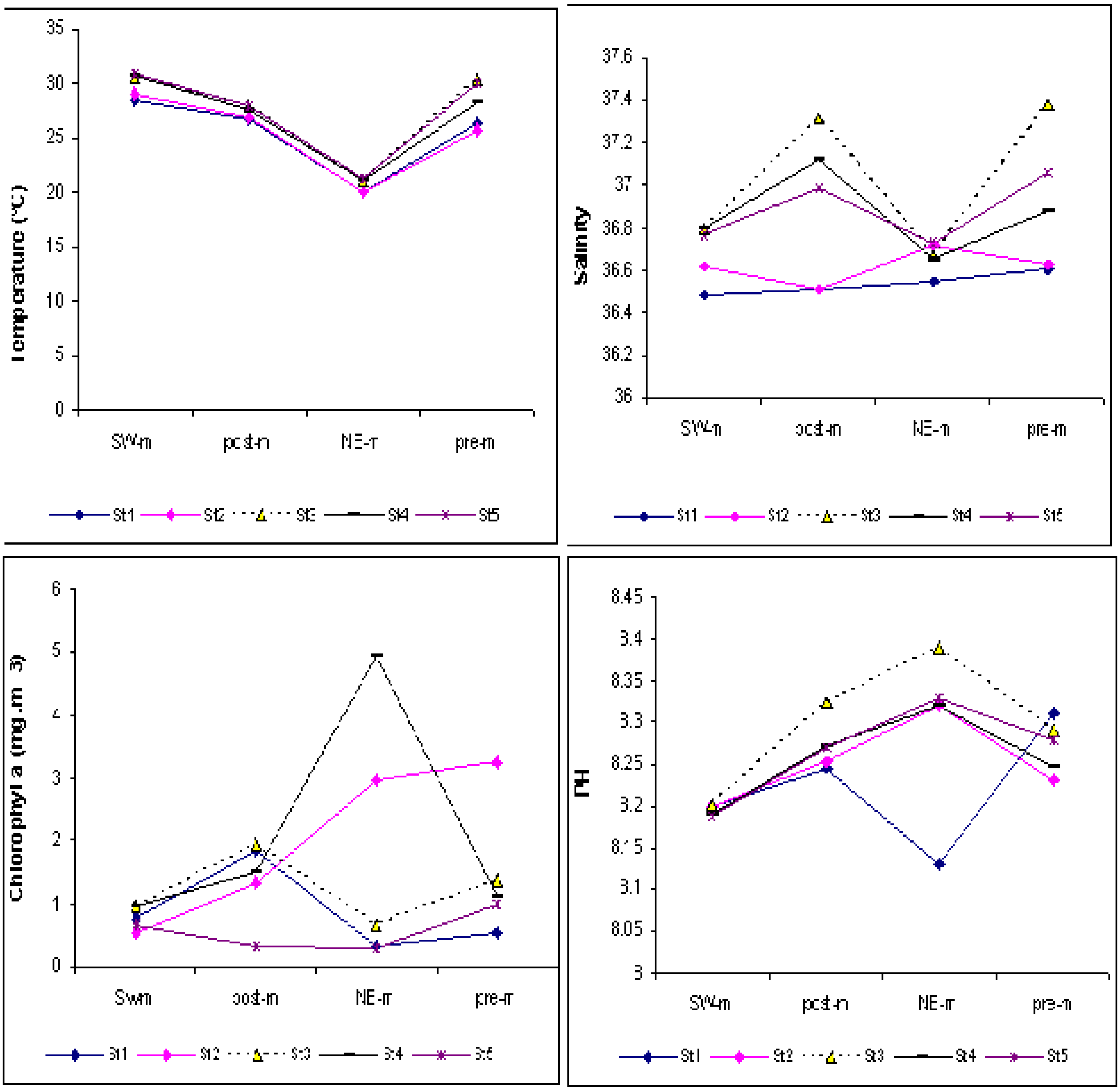



Figure 2. Distribution of major physico-chemical variables during monsoonal seasons (x axis as seasons and Y axis as physico-chemical variables) continues next page…………

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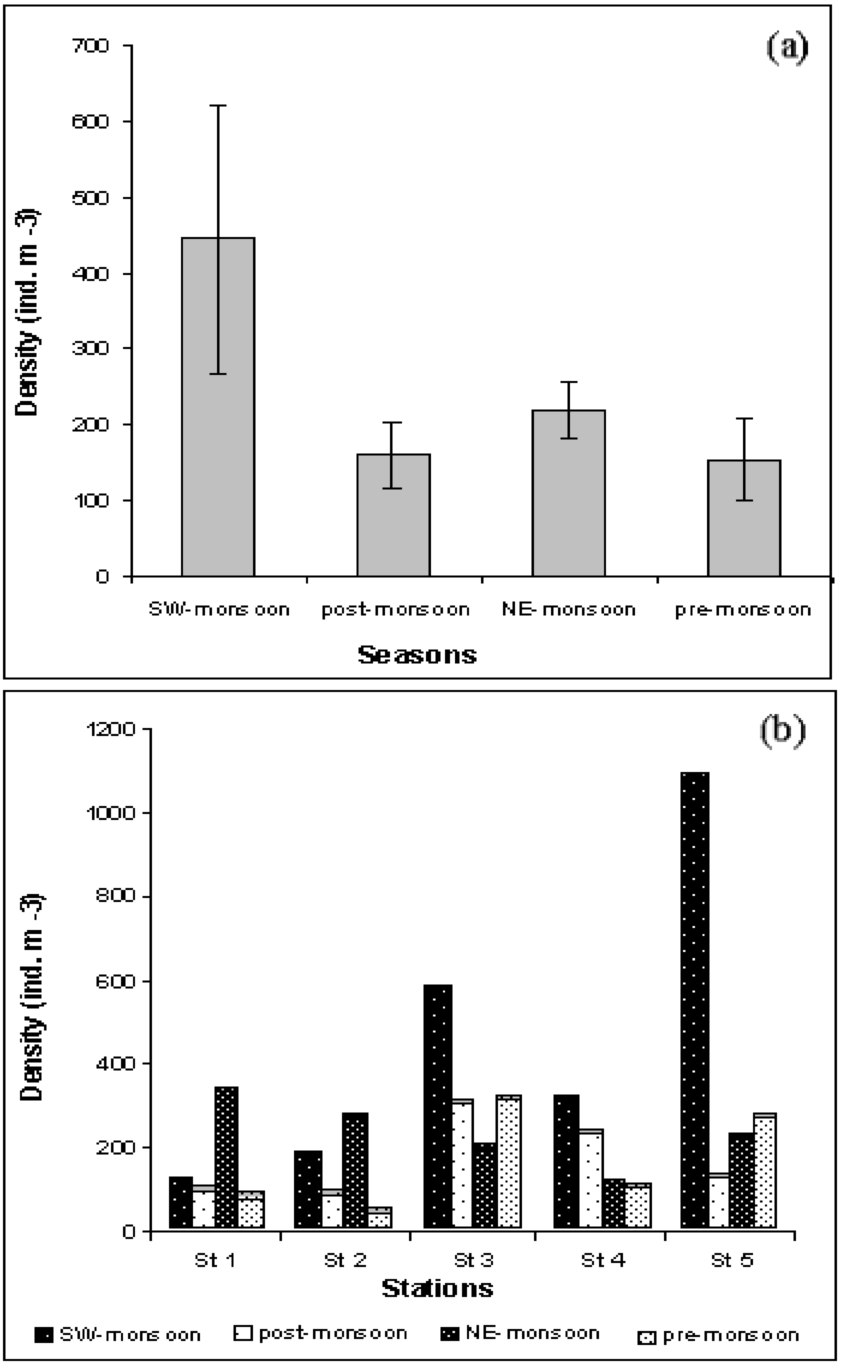


Figure 3. Abundance of calanoid density in Chabahar Bay in stations (a) and seasons (b).

 

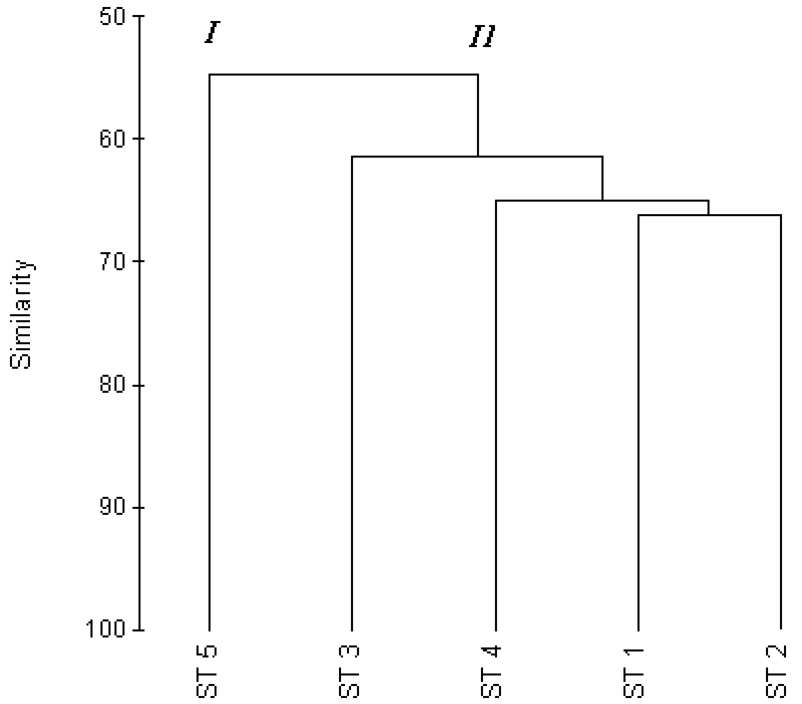


Figure 4. Cluster analyses showing similarity of stations based on calanoid density in Chabahar Bay.

concentration they are unable to thrive in offshore area where food levels are low (Somoue *et al.*, 2005).

Spatial and temporal variations in zooplankton have been associated with changes in phytoplankton standing stocks (Al-Najjar, 2000) and with combined effects of regional climatology and local hydrographic variables (Aoki *et al.*, 1990; Tomosada & Odate, 1995) as observed in other marine habitats including Indian Ocean (Haury, 1988; Piontkovski *et al.*, 1995).

According to the studies, spatial and temporal variations in calanoid copepod throughout the Chabahar Bay can be related to variations in the environmental variability. The temperature and chlorophyll (*a*) concentration play a major role in determining the spatial and temporal patterns of calanoid distribution and abundance.

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