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Abundance and Seasonal Variations of Zooplankton in the Arid Zone Mangroves of Gulf of Kachchh-Gujarat, Westcoast of India

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Abstract: The zooplankton was assessed quantitatively and qualitatively in regard to their abundance in creek waters at three sites along the western mangrove of Kachchh, west coast of India, for a period of two years (1999-2000). Totally 69 forms of zooplankton were recorded currently from 3 stations. Of these, the copepods formed the dominant group. The population density in all the three sites varied from 30,000 to 210,000 organisms m^{-3}. Surface water temperature varied from 17 to 37°C. Salinity varied from 34.0 to 44.0‰ and the pH ranged between 7.0 and 8.9. Variation in dissolved oxygen content was from 3.42 to 5.85 mg L^{-1}. These semi arid zone mangrove creek area having high densities were recorded during winter season.

Key words: Gulf of Kachchh, mangroves, zooplankton

INTRODUCTION

Tropical estuaries and lagoons are among the most productive and zooplankton rich ecosystems in the world (Robertson and Blabber, 1992). High zooplankton biomass and productivity may be related to the input of energy and organic matter from mangrove forests, which on of the most frequent coastal vegetation in the tropics (Lugo and Snedaker, 1974). Mangrove forests are periodically inundated by the tides and form a virtually inseparable part of the aquatic biome. However, zooplankton is an important intermediate component in estuarine food webs, acting as a trophic link between small particles (e.g., detritus and microalgae) and planktivorous fishes. These ecosystems have an outstanding direct socio economic importance for many tropical coastal regions (Aksornkoae *et al*., 1993; Uthoff, 1996).

Many workers have studied the composition and structure of zooplankton in the mangrove waters and estuaries both east and west coast of India which include those of (Goswami and Usha Goswami, 1990; Paulinose *et al*., 1998; Chandra Mohan and Sreenivas, 1998; Karuppasamy and Perumal, 2000). But such studies are not available for west coast of mangroves particularly in Gujarat and hence the present study was undertaken to explore the community structure and composition of zooplankton.

MATERIALS AND METHODS

The surface water temperature was measured *in-situ* with Merck mercury thermometer of 0.1°C accuracy. pH was measured with pH meter with reference to a standard buffer solution. Rainfall data was obtained from meteorological Department at Bhuj, Kachchh Gujarat. The salinity was estimated by hand refractometer (Atago, Japan) and DO was estimated by Winklers method on the spot. The site selection was based on their proximity to open coast and the level of anthropogenic pressure. The three selected sites, namely, Jakhau-Babber Creek (site 1), Sangi-Kharo Creek (site 2) and Medi-Sinthodi Creek (site 3) were with 5 km distances between each other (Fig. 1). Site 1 is located at latitude north 23°13 59'2 and longitude east 68°36 38'1, site 2 at latitude north 23°17' 36.4 and longitude east 68°31' 21 and site 3 at latitude north 23° 27 54.8 and longitude east 68°29 15.1.

Sampling of zooplankton at each of the three sites was carried out every month from the surface creek waters. The plankton net (mouth diameter 0.35 µm) made of bolting silk (No 10, Mesh size-158 µm) was towed for half an hour at each station. These samples were preserved in 5% neutralized formalin and used for qualitative analysis. For the quantitative analysis of zooplankton, known quantity of water (100 L) was filtered through a bag net (158 µm mesh size) and filtrate was made up to 1 L in a wide mouthed polyethylene

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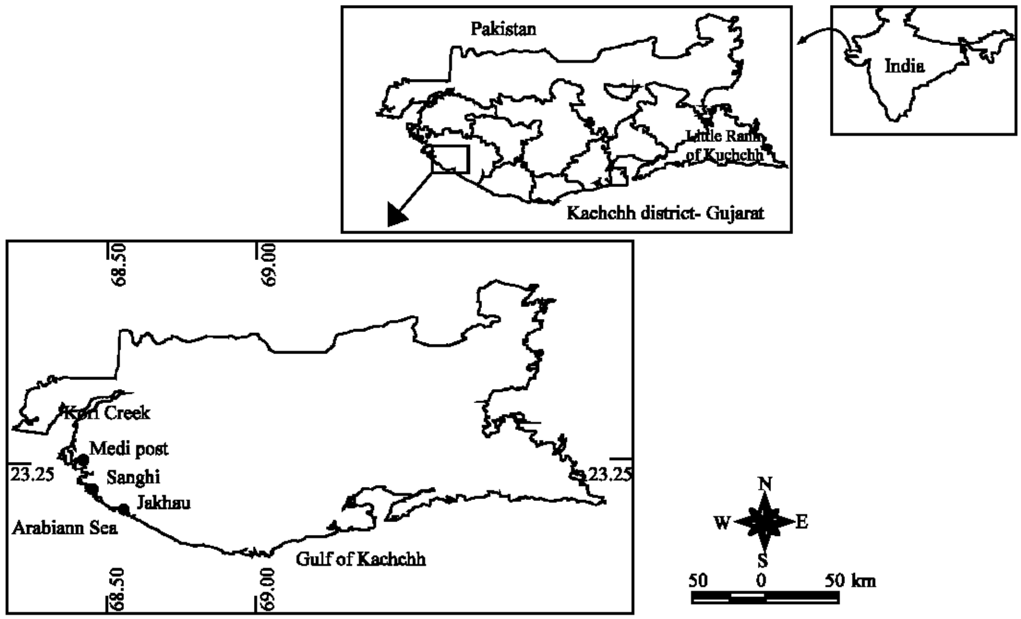

Fig. 1: Map showing the study area

container. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope. The zooplankton density was been expressed in organisms m^{-3}. Biodiversity were calculated following the standard formulae diversity: H' = -∑pi log pi; I = 1; richness: D = 1-C; C = $\sum Pi_2$, Pi = ni/N and evenness: J' = H'/log S, (Shannon and Weaver, 1949; Gleason, 1922 and Pielou, 1966). The data thus collected was grouped into different seasons and a calendar year was divided into 3 main seasons namely winter-(November-February), summer-(March-June) and Monsoon-(July-October). Correlation coefficient (r) analysis was performed between zooplankton density and physico-chemical parameters and two-way analysis (ANOVA) was employed to find out variations in all hydrographic parameters between stations and seasons.

RESULTS

The total rainfall received during the first year (1999) was 607 mm and 272 mm during second year (2000). Comparatively, rainfall rate was higher during first year then the second year. Most of the rainfall occurred as downpour, confined to 4-9 days of the year during the months of July and August.

Salinity (‰) varied from 34 to 44 during monsoon and summer seasons (Fig. 2). The surface water temperature (°C) ranged from 17 to 37 during winter and summer seasons (Fig. 3). The dissolved oxygen values were high (5.85 mg L^{-1}) during the monsoon (August) and low (3.42 mg L^{-1})) during the summer (May) season (Fig. 4). The monthly fluctuations in the pH followed a trend varied from 7.0 to 8.9 during monsoon and summer season (Fig. 5).

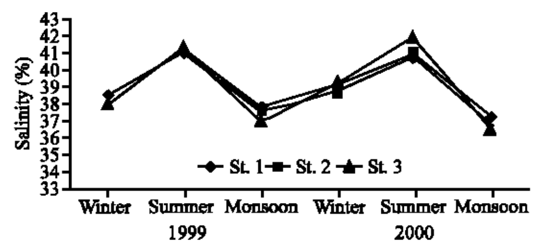

Fig. 2: Seasonal variation of salinity recorded from stations 1, 2 and 3

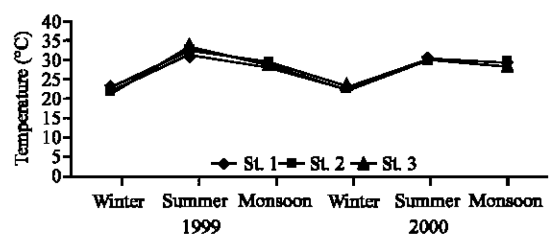

Fig. 3: Seasonal variation of surface water temperature recorded from stations 1, 2 and 3

Monthly variation in zooplankton species composition, percentage composition, population density, species diversity, richness and evenness were documented for a period of two years from January 1999 to December 2000 at all the three sites. Totally 69 forms of zooplankton were recorded currently from 3 stations. Of these, the copepods formed the dominant group. Among various species, *Acartia danae*, *Eucalanus crassus*, *Paracalanus parvus*, *Centropages furcatus*, *Euterpina acutifrons* and *Macrosetella gracilis* were present throughout the study period at all the three stations.

Zooplankton recorded during the present study constituted the following groups members of tentaculata, foramanifera, ciliata, polychaete larvae, chaetognatha, rotifers, cladocera, copepoda, cumaceae, decapoda larvae and ichthyoplankton. Species composition of zooplankton was recorded at stations 1, 2 and 3. During the present investigation, a total number of 69 species of zooplankton were identified from all the three stations (Table 1). At station 1, 58 species of zooplankton were recorded

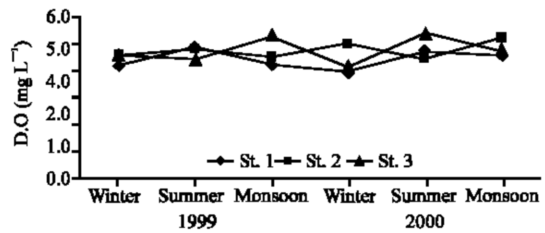

Fig. 4: Seasonal variation of dissolved oxygen recorded from stations 1, 2 and 3

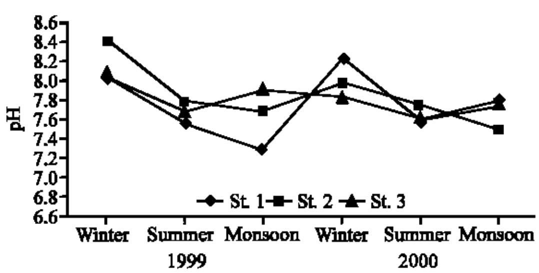

Fig. 5: Seasonal variation of pH recorded from stations 1, 2 and 3

Table 1: Checklist of zooplankton recorded at station 1, 2 and 3

	Station 1	Station 2	Station 3
Tentaculata			
Pleurobrachia globosa	+	+	+
Foraminifera			
Globigerina sp.	+	+	+
Ciliata			
Eutiutinnus tenuis	+	+	+
Favella brevis	-	+	+
F. phlippineusis	+	+	+
Tiutinnopsis butscheli	+	+	+
T. beroidea	+	-	+
T. directa	-	+	+
T. minuta	+	+	+
T. tubulosa	+	+	+

Table 1: Continued

Polycheate larvae			
Chaetopterus sp.	+	+	+
Ophiodromus sp.	+	+	+
Chaetognatha			
Sagitta serratodentata	+	+	+
Sagitta enflata	-	+	+
Sagitta sp.	+	+	+
Rotifers			
Brachionus calyciflorus	+	-	+
B. rubeus	+	+	+
Keratella tropica	+	+	+
Cladocera			
Evadne tergestina	-	+	+
Copepoda-Calanoida			
Acartia danae	-	+	+
A. erythraea	+	+	+
A. spinicauda	+	+	+
Acartia sp.	+	+	+
Acrocalanus gibber	+	+	+
Centropages furcatus	+	+	+
C. orsinii	+	+	+
Eucalanus crassus	+	-	+
E. elongatus	+	+	+
E. monachus	+	+	+
Eucalanus sp.	+	+	+
Labidocera acuta	-	+	+
Euchaeta marina	+	+	+
Euchaeta sp.	-	+	+
Paracalanus parvus	+	+	+
Pontella brevicornis	+	+	+
P. danae	+	+	+
Pontellopsis scotti	+	+	+
Pseudodiaptomus			
Serricaudatus	+	-	+
P. elongatus	+	+	+
P. strigilipes	-	+	+
Temora discaudata	+	+	+
Undinula vulgaris	+	+	+
Harpacticoida			
Euterpina acutifrous	+	+	+
Macrosetella gracilis	-	+	+
Microsetella rosea	+	+	+
Cyclopoida			
Oithona brevicornis	+	+	+
O. plumifera	+	-	+
O. rigida	+	+	+
Oncaea sp.	+	+	+
Cumaceae			
Paradiastylis sp.	+	+	+
Decapoda			
Lucifer hansenii	+	+	+
Larvae			
Bipinnaria larvae	+	+	+
Bivalve veliger	+	+	+
Brachiuran larvae	+	+	+
Cerripede nauplius	+	-	+
Cumaceans larvae	-	+	+
Euphausid larvae	+	+	+
Gastropod veliger	+	+	+
Glycerid larvae	+	+	+
Hermit crab larvae	+	+	+
Mysid larvae	+	+	+
Nemotode larvae	+	+	+
Oikopleura larvae	+	+	+
Penaeid nauplius	+	+	+
Ichthyoplankton			
Ambassis commersonii	+	+	+
Leiognathus sp.	+	+	+
Mugil sp.	+	+	+
Therapon sp.	-	+	+
Thryssa sp.	+	+	+

+ : Present, - : Absent

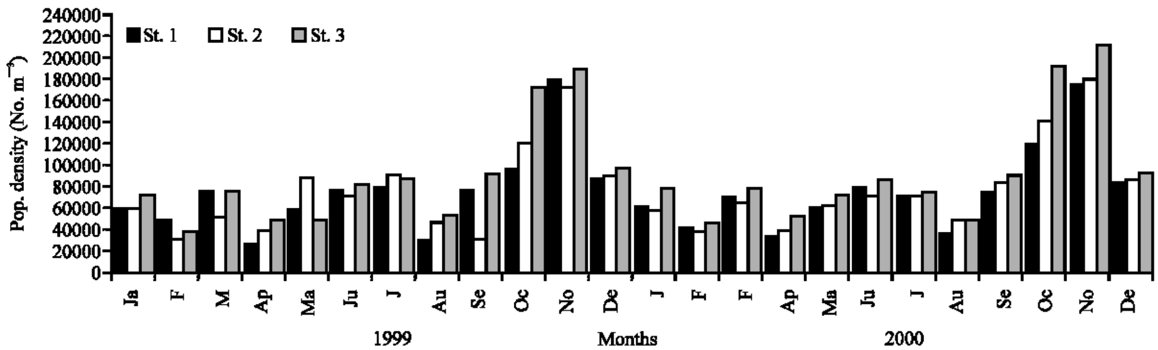

Fig. 6: Seasonal variation of population density recorded from stations 1, 2 and 3

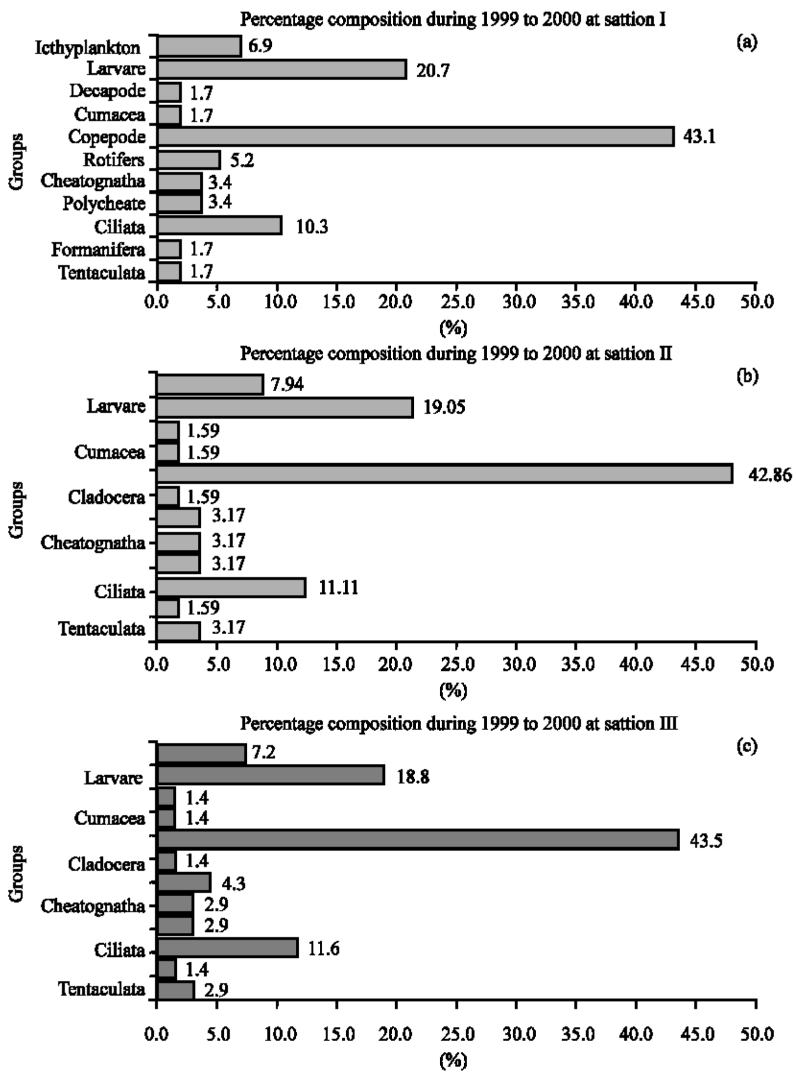

Fig. 7: a, b and zooplankton recorded during 1999 to 2000 at stations 1, 2 and 3

Table 2: Zooplankton species diversity, richness and evenness at station 1, 2 and 3 during 1999 to 2000

	Station 1			Station 2			Station 3		
	Diversity								
Years	Winter	Summer	Monsoon	Winter	Summer	Monsoon	Winter	Summer	Monsoon
1999	3.181	3.146	3.035	3.118	2.630	2.788	3.220	3.057	3.105
2000	3.072	3.163	2.956	3.102	3.114	3.069	3.108	3.089	3.158
Richness									
1999	0.952	0.901	0.890	0.982	0.921	0.862	0.984	0.952	0.896
2000	0.987	0.892	0.865	0.945	0.978	0.895	0.983	0.972	0.901
Evenness									
1999	0.965	0.980	0.985	0.985	0.843	0.903	0.983	0.978	0.978
2000	0.980	0.978	0.980	0.983	0.980	0.983	0.990	0.978	0.983

which include Tentaculata-(1), Formaniferans-(1), Ciliata-(6), Polycheate larvae-(2), Chaetognatha-(2), Rotifers-(3), Copepoda-(25), Cumaceae-(1), Decapoda-(1), Larvae-(12), Ichthyoplankton-(4). At station 2, 63 species were recorded which include Tentaculata-(1), Formanifera-(1), Ciliata-(7), polycheate larvae-(2), Chaetognatha-(3), Rotifers-(2), Cladocera-(1), Copepoda-(27), Cumaceae-(1), Decapoda-(1), Larvae-(12) and Ichthyoplankton-(5) forms. At station 3, a total of 69 species were found which comprise Tentaculata-(1), Formanifera-(1), Cilata-(8), Polycheate larvae-(2), Chaetognatha-(3), Rotifers-(3), Cladocera-(1), Copepoda-(30), Cumaceae-(1), Decapoda-(1), Larvae-(13) and Ichthyoplankton-(5).

The percentage composition was at station 1, copepoda group were represented highest 43.1% and minimum 1.7% was recorded Decapoda, cumacea, formanifera and tentaculata groups (Fig. 7a). In station 2, the copepoda group were dominant 42.86% was recorded and minimum 1.59% was recorded decapoda, cumacea, cladocera and formanifera (Fig. 7b). At station 3, the highest 43.5% was recorded copepoda group and lowest percentage was 1.4% the following groups decapoda, cumacea, cladocera and foraminifera (Fig. 7c).

The population density in all the 3 stations varied between 30,000 to 210,000 organisms m^{-3} (Fig. 6). When compared site wise, abundance the highest value was recorded in site 3 which was more in winter and less in the station 1 during summer. The two-way analysis of variance results showed significant value between stations ($p<0.005$) and seasons ($p<0.005$). The diversity values varied from 2.63 to 3.22 bits/individual (Table 2). The maximum species diversity recorded during the winter and the minimum diversity during the monsoon and summer seasons. The overall richness values of the study area ranged from 0.86 to 0.98. Generally richness was higher during winter and lower during monsoon season. The species evenness index varied from 0.96 to 0.99, which was the maximum during monsoon and winter and the minimum during winter and summer seasons. Two-way analysis of variance results showed no significant between stations and seasons.

DISCUSSION

Rainfall is the most important cyclic phenomenon in tropical countries as it brings important changes in the hydrographical characteristics of the marine and estuarine environments. In present study, peak values of rainfall were recorded during the monsoon months of July and August. The rainfall in India is largely influenced by two monsoons viz., southwest monsoon on the west coast, northern and northeast India and by the northeast monsoon on the southeast coast (Perumal, 1993). In Gujarat, particularly in Kachchh district, the monsoon is predicted by the hot dry weather prevailing in the months of March-June. The rain sets in over most of the Gujarat between late June to September, while October and November constitute the early winter (Gujarat Institute of Desert Ecology (GUIDE), 1999). The months of December, January and February are practically without rain. Kachchh district experiences typical 'Monsoon climate' with rainy season confined to four months from mid June to September when 93 to 98 percent of the annual rainfall occurs (Gujarat Institute of Desert Ecology (GUIDE), 2000).

The surface water temperature in the present study ranged between 17 and 37°C. There was a steady increase in temperature from March to June, which was peak during May and very low temperature of 17°C recorded during winter. All the stations showed a similar trend in terms of seasonal changes. Generally, surface water temperature is influenced by the intensity of solar radiation, evaporation, insolation, freshwater influx and cooling and mix up with ebb and flow from adjoining neritic waters (Govindasamy *et al*., 2000). In the present study, summer peaks and monsoonal troughs in water temperature has been found to be similar to that reported for west coast of India (Desai, 1992; Arthur, 2000).

The salinity acts as a limiting factor in the distribution of living organisms and its variation caused by dilution and evaporation and influences the fauna of the intertidal zone (Gibson, 1982). Generally, changes in salinity in the brackish-water habitats such as estuaries, backwaters and mangrove are due to the influx of freshwater from land run off caused by monsoon or by tidal variations. This is further evidenced by the negative correlation (r = -0.350 at station 1, r = -0.513 at station 2 and r = -0.500 at station 3) obtained between salinity and rainfall. Salinity showed a significant positive correlation (r = 0.212 at station 1, r = 0.114 at station 2 and r = 0.260 at station 3) with temperature. In the present study, salinity at all the sites was high during summer and low during the monsoon season. Higher values during summer could be attributed to the high degree of evaporation and also due to neritic water dominance from sea (Senthilkumar *et al*., 2002). Though perennial rivers are absent, the run off due to rains during the monsoon season could influence the reduction in salinity. Thus the variations of salinity in the study sites could probably be due to mainly freshwater run off entering the creek systems as reported by Vijayalaksmi *et al.* (1993) for the Gulf of Kachchh and Saisastry and Chandramohan (1990) for the Godavari estuary.

It is well known that the temperature and salinity also affect the dissolution of oxygen (Vijayakumar *et al*., 2000). In the present investigation, dissolved oxygen was high during monsoon in all the sites which might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing or it may be also due to photosynthesis. Relatively low values recorded during winter may be due to reduced agitation and turbulence of the coastal and creek waters. Das *et al.* (1997) have attributed seasonal variation of dissolved oxygen mainly to the freshwater influx and ferruginous impact of sediments. Further, significant inverse relationship between rainfall and nutrients indicated that freshwater input constituted the main source of the nutrients in the mangroves. The 2 way analysis of variance results showed that there was no significant variation between stations and seasons.

Hydrogen ion concentration (pH) in surface waters remained alkaline at all the sites throughout the study period with maximum value during the summer and winter seasons and minimum values during monsoon. Generally, fluctuations in pH values during different seasons of the year are attributed to factors like removal of CO_2 by photosynthesis through bi-carbonate degradation, dilution of seawater by freshwater influx, reduction of salinity and temperature and decomposition of organic matter (Upadhyay, 1988; Ragothaman and Patil, 1995 and Rajasegar, 2003). The statistical analysis also revealed that salinity had highly significant negative correlation with rainfall.

Zooplankton recorded in the present study consisted of 69 species from all the three stations during 1999 to 2000. Copepods were the dominant group followed by larvae and other forms such as ciliata, cladocera, tentaculata, formanifera, polycheate larvae, chaetognatha, ichthyoplankton, rotifers, cumacea and decapoda. Among them copepods were the predominant group with a total number of 30 species, calanoids and harpecticoida followed by cyclopoida were represented with more number of species. Among various species, *Acartia danae*, *Eucalanus crassus*, *Paracalanus parvus*, *Centropages furcatus*, *Euterpina acutifrons* and *Macrosetella gracilis* were present throughout the study period at all the three stations. Among the Ciliata, Tintinnioida was the most abundant genus with 4 species, *Tintinnopsis butscheli*, *T. beroidea*, *T. directa*, *T. minuta* were recorded in all the stations. Similarly, *Favella brevis* and *F. phlippinensis* were recorded throughout the study period, as tintinnids are highly tolerant to greater fluctuations in salinity (Srinivasan *et al*., 1988).

Similar order of dominance was reported earlier Gajbhiye *et al.* (1981) in polluted and unpolluted regions of Bombay, Padmavati and Goswami (1996) in Mandovi-Zuari estuary system of Goa, Vijayalakshmi *et al.* (1998) in Vashishti estuary, Maharashtra in the west coast. Among the larvae, bivalve and gastropod veliger, larvae of bipinnaria, brachyura, cumacea, euphausids, glycerids, hermit crabs, mysids and oikopleura were dominant in all the three stations.

Zooplankton population density during the present study ranged from 30,000 org. m^{-3} to 210,000 org. m^{-3}. Lowest density values (30,000 org.m^{-3}; summer, 2000) were recorded in stations 1. The highest value recorded during winter (210,000 org. m^{-3}) in station III, which might be due to blooms and swarms, which are mainly suggested as the main cause for sudden outburst in plankton biomass in the sea. Further, higher population density with more number of copepods species were observed by Rajagopalan *et al.* (1992) and Paulinose *et al.* (1998) in Gulf of Kachchh. In East coast, Chandrasekaran (2000) highest density value 22,13,094 org. L^{-1} was recorded in Pichavaram mangrove creek. Generally, blooms and swarms are of common occurrence during the post monsoon months (Rajagopalan *et al*., 1992; Madhupratap *et al*., 2001). In the present study area, zooplankton maximum density was recorded during winter. Nair *et al.* (1968) suggested that normally northern region of the Arabian Sea experiences high biological productivity in winter, which results from convective, overturning and associated with winter cooling. Low density values observed in monsoon months at all the stations might be because of sudden shift in salinity and other environmental parameters, which in turn decrease the zooplankton population density (Nair *et al*., 1968).

Zooplankton diversity, richness and evenness maximum values were in winter and summer and minimum during monsoon. Peak values recorded in winter and summer seasons could be due to stable environment and high population density of zooplankton during these periods. During monsoon months, low values in this attribute were recorded. Zooplankton density showed significant positive correlation with phytoplankton diversity and richness values and negative significance with phytoplankton density. In general among the three stations, station 3 evinced the high population density, richness, diversity and evenness than the stations 2 and 1. High density of primary producers in this station might be the reason for this high secondary producer's density. The hitherto study revealed that the distribution of zooplankton abundance and diversity reflects the status of mangrove creek systems diversity and productivity as a whole.

CONCLUSION

The present baseline information of the zooplankton distribution and abundance would form an useful tool for further ecological assessment and monitoring of these coastal ecosystems of western mangroves of Kachchh.

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