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Spatio-temporal variation of zooplankton diversity in mangroves around Mumbai coast, Maharashtra

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Abstract
Zooplankton diversity was assessed in the mangrove areas of three stations comprised of two estuaries, viz. Bhayandar and Patalganga and one enclosed mangroves at Lokhandwala, Mumbai. Zooplankton were identified under 11 groups. Overall, tintinnids was most dominant group (ranging from 160 to 2360 cell/l) followed by copepods group of zooplankton from all three stations. Polychaetes larvae were present at Lokhandwala, where found as decapods, gastropods larvae and bivalve larvae were found in Bhayandar and Dharamtar. Relationship based on different environment parameters at Bhayandar show positive correlation of zooplankton with pH. At Lokhandwala and Dharamtar show negative correlation of zooplankton with all environment parameters (except water temperature). Dominance index (*D*) is maximum with 0.56 in January, 0.69 in March and 0.53 in November at Bhayandar, Lokhandwala and Dharamtar, respectively. High species evenness (*J'*) was recorded at Bhayandar and ranged between 0.43 and 0.79 as compared to Lokhandwala (0.31 and 0.84) and at Dharamtar (0.47 and 0.82). The Shannon-Weiner index (*H'*) ranged from 1.3788 to 2.5219 at Bhayandar, 0.7219 to 1.9688 at Lokhandwala and 1.5538 to 2.7232 at Bhayandar. Simpson Diversity Index (1-λ') is maximum with 0.82 in February, 0.70 in January and 0.83 in December at Bhayandar, Lokhandwala and Dharamtar respectively.

Keywords: Mangrove, zooplankton, tintinnids, correlation

Introduction

Mangrove ecosystems are the predominant type of vegetation still covering about 25 % of tropical and subtropical coastlines throughout the world (World Resource Institute, 1996) [1] and they provide nursery grounds for fish and shellfish (Robertson and Duke 1987 [2]. Mangroves support various trophic organisms in an estuarine condition (Robertson and Blaber 1992 [3], Sasekumar *et al*. 1992) [4]. Zooplankton, which are the secondary consumers in an ecosystem, are of importance as many juvenile fish/larval stages feed upon them (Turner, 1984) [5]. In mangrove ecosystems, zooplankton forms a fundamental trophic link in aquatic food webs as well (Godhantaraman, 2001) [6]. The mangrove ecosystem in and around Mumbai is under various stress due to anthropogenic pressure, affecting the zooplankton diversity. Thus, any change in the composition and functioning of the zooplankton community affects the state of the whole ecosystem. In the present study, an attempt is made towards documenting and analysing the spatio-temporal variation of zooplankton which is important prerequisite for ecosystem modelling and rational management.

Materials and Methods

Sampling sites

Study area was divided in to three sites viz. Bhayandar (19°18'37.70"N to 72°51'14.55"E), Lokhandwala (19° 5'26.43"N to 72°50'53.54"E), and Dharamtar (18°49'48.61"N to 72°55'21.97"E) around Mumbai coast. Samples were collected monthly based on the tide from October 2016 to April 2017 (seven months) during low tide water from three selected stations.

Water quality parameters

Water temperature (Caliberated mercury thermometer), salinity (refractometer ATAGO S/Mill-E) and pH (OAKTON eco tester pH) were measured at the time of sampling. Water collected for DO was fixed at the site, while for BOD, sample was brought to laboratory for further processing.

Sampling for zooplankton analysis

Samples were collected by filtering water through 200 µm standard zooplankton net with 30 cm mouth size. Filtered samples were collected in 100 ml bottle and preserved it with 5% formalin.

Qualitative analysis of Zooplankton

Zooplankton samples were placed on glass slides with help of calibrated dropper. Identification was done under different magnification using HUND inverted microscope. For taking the photographs of same, olypus FX 100 microscope was used. Zooplankton were identified under different major group (Al-Yamani *et al.* 2011[7] and Conway, 2012) [8].

Quantitative analysis of zooplankton

For the quantitative study of zooplankton, five replicated of sub samples were counted in Sedgwick rafter cell. The result was estimated in terms of individuals. 100 m^{-3} (individual /100 m^3) of water sample (Goswami, 2004) [9].

Diversity indices

Number of diversity indices was used for assessing the diversity abundance and richness. Shannon's diversity index (H'), Simpson's diversity index (D), Pielou's evenness index (J'), and Species richness index (d) these all indices have been calculated by using basic programme PAST to know the phytoplankton diversity.

Results

Physico-chemical parameters

Water temperature

The water temperature during investigation ranged between 26.5 ± 3.5 ºC, 26.0 ± 4.0 ºC and 26.5 ± 3.5 ºC at Bhayandar, Lokhandwala and Dharamtar, respectively. At Bhayandar the maximum temperature was recorded in the month of April 30.0 ºC, at Lokhandwala in November 30.0 ºC and at Dharamtar in October & April 30.0 ºC. The minimum temperature was recorded during month of January & February 23.0 ºC (Bhayandar), January 22.0 ºC (Lokhandwala) and January 23.0 ºC (Dharamtar) (Figure 1).

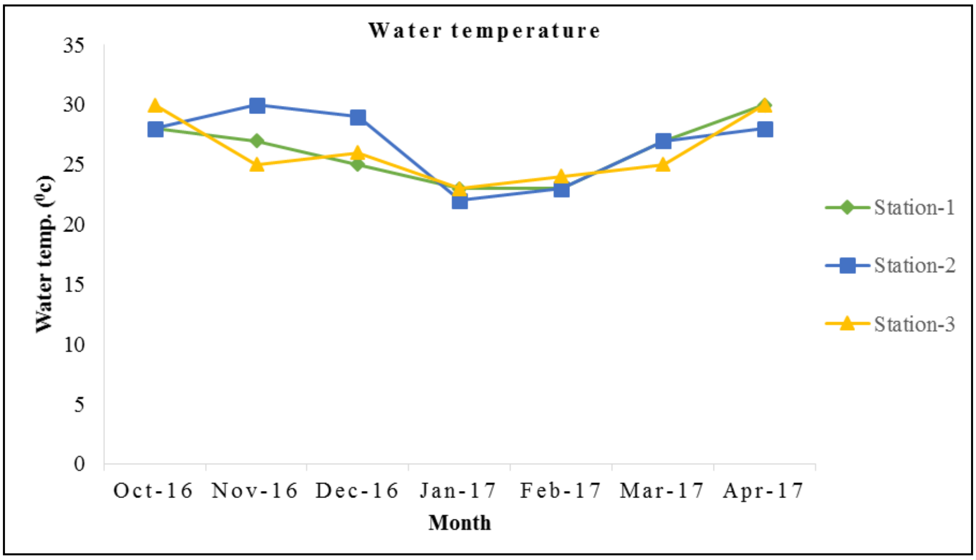

Fig 1: Monthly variation in water temperature (ºC) among three stations

Salinity

The salinity during investigation ranged between 31.0‰ ± 3.0‰, 16.5 ± 13.5 ‰ and 18.5‰ ± 14‰ at Bhayandar, Lokhandwala and Dharamtar, respectively. At Bhayandar, maximum salinity was recorded in the month of January 34‰, at Lokhandwala in April 30‰ and at Dharamtar in November 33‰. The minimum salinity was recorded during month of March 28‰ (Bhayandar), October 3‰ (Lokhandwala) and 4‰ (Dharamtar) (Figure 2).

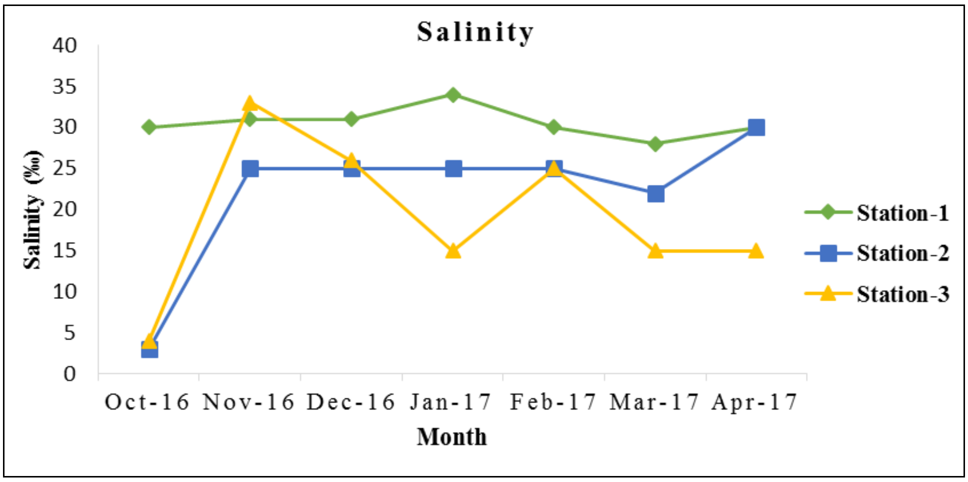

Fig 2: Monthly variation in salinity (‰) among three stations

Ph

The pH during investigation ranged between 8.2 ± 1.0, 8.3 ± 1.1 and 7.95 ± 0.95 at Bhayandar, Lokhandwala and Dharamtar respectively. At Bhayandar maximum pH was recorded in the month of March 9.2, at Lokhandwala in March 9.4 and at Dharamtar in March 8.9. The minimum pH was recorded during month of April 7.2 (Bhayandar), October 7.2 (Lokhandwala) and October 7.0 (Dharamtar) (Figure 3).

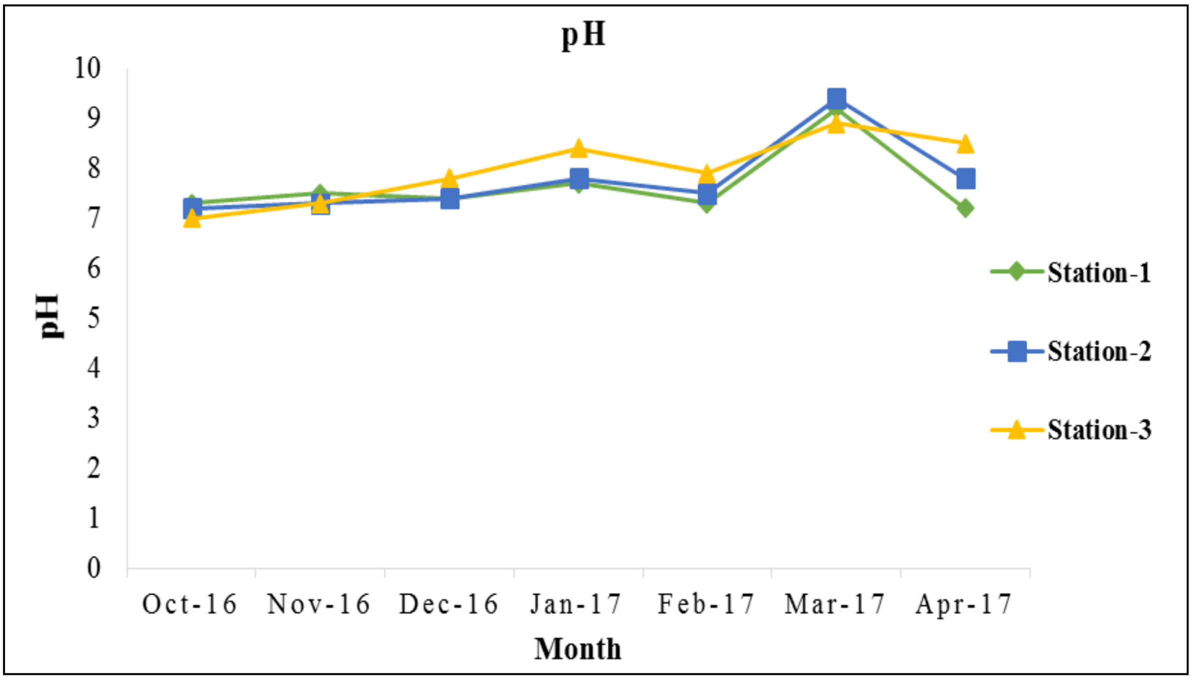

Fig 3: Monthly variation in pH among three stations

Dissolved oxygen

The Dissolved oxygen during investigation ranged between 2.8 ± 1.2 mg/l, 2.4 ± 1.6 mg/l and 6.6 ± 1.8 mg/l. at Bhayandar, Lokhandwala and Dharamtar, respectively. At Bhayandar the maximum Dissolved oxygen was recorded in the month of November 4.0 mg/l, at Lokhandwala in March 4.0 mg/l and at Dharamtar in Feburary 8.4 mg/l. The minimum Dissolved oxygen was recorded during month of January 1.6 mg/l (Bhayandar), December & January 0.8 mg/l (Lokhandwala) and October and November 2.8 mg/l (Dharamtar) (Figure 4).

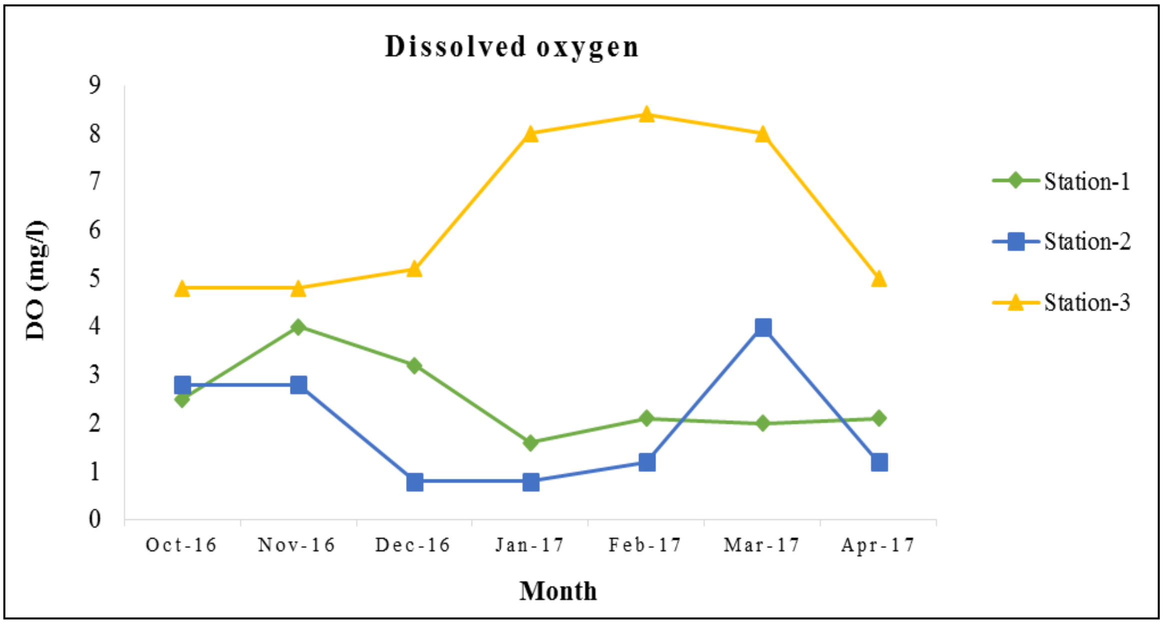

Fig 4: Monthly variation in Dissolved Oxygen (mg/l) among three stations

Biological Oxygen Demand

The Biological Oxygen Demand during investigation ranged between 2.85 ± 1.15 mg/l, 2.6 ± 1.4 mg/l and 2.1 ± 1.7 mg/l. at Bhayandar, Lokhandwala and Dharamtar, respectively. At Bhayandar the maximum Biological Oxygen Demand was recorded in the month of March 4.0 mg/l, at Lokhandwala in January & February 4.0 mg/l and at Dharamtar in March 3.8 mg/l. The minimum Biological Oxygen Demand was recorded during month of November 1.7 mg/l (Bhayandar), March 1.2mg/l (Lokhandwala) and December 0.4 mg/l (Dharamtar) (Figure 5).

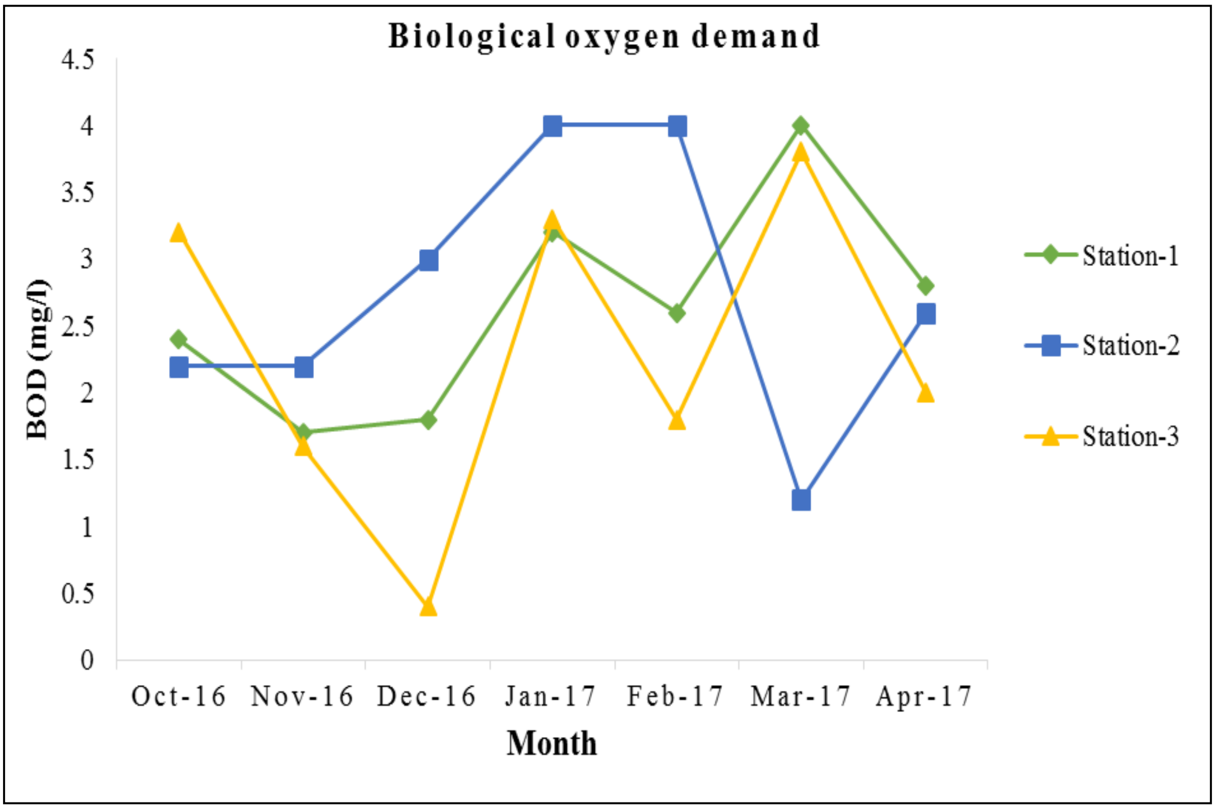

Fig 5: Monthly variation in Biological Oxygen Demand (mg/l) among three stations

Temporal zooplankton abundance at Bhayandar

Copepods were most dominant group followed by foraminifera. Another groups were present in few months (Figure 6). Highest abundance of zooplankton was found in March followed by April and February.

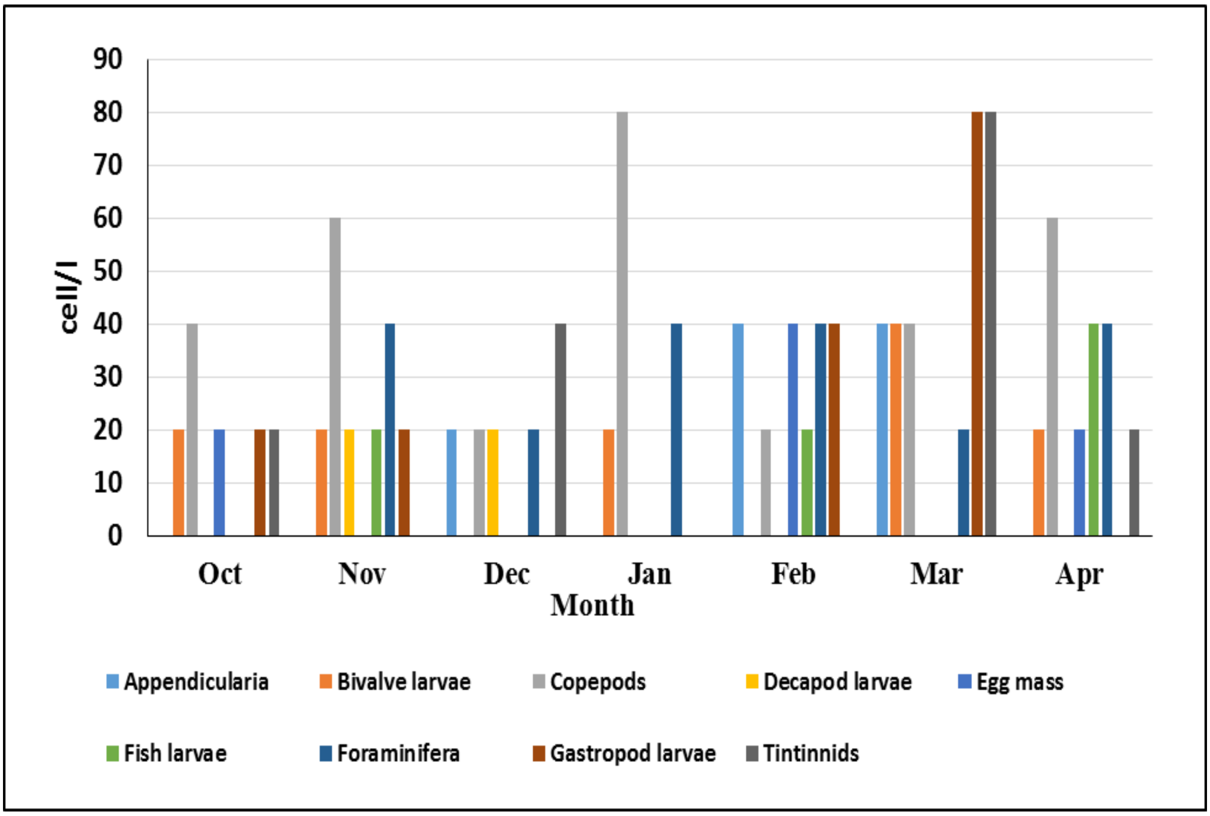

Fig 6: Temporal variation in average zooplankton (group wise) abundance at Bhayandar

Temporal zooplankton abundance at Lokhandwala

Tintinnids were most dominant group followed by decapods larvae group. The other groups were present in few months (Figure 7). Highest abundance of zooplankton was found in December followed by October and November

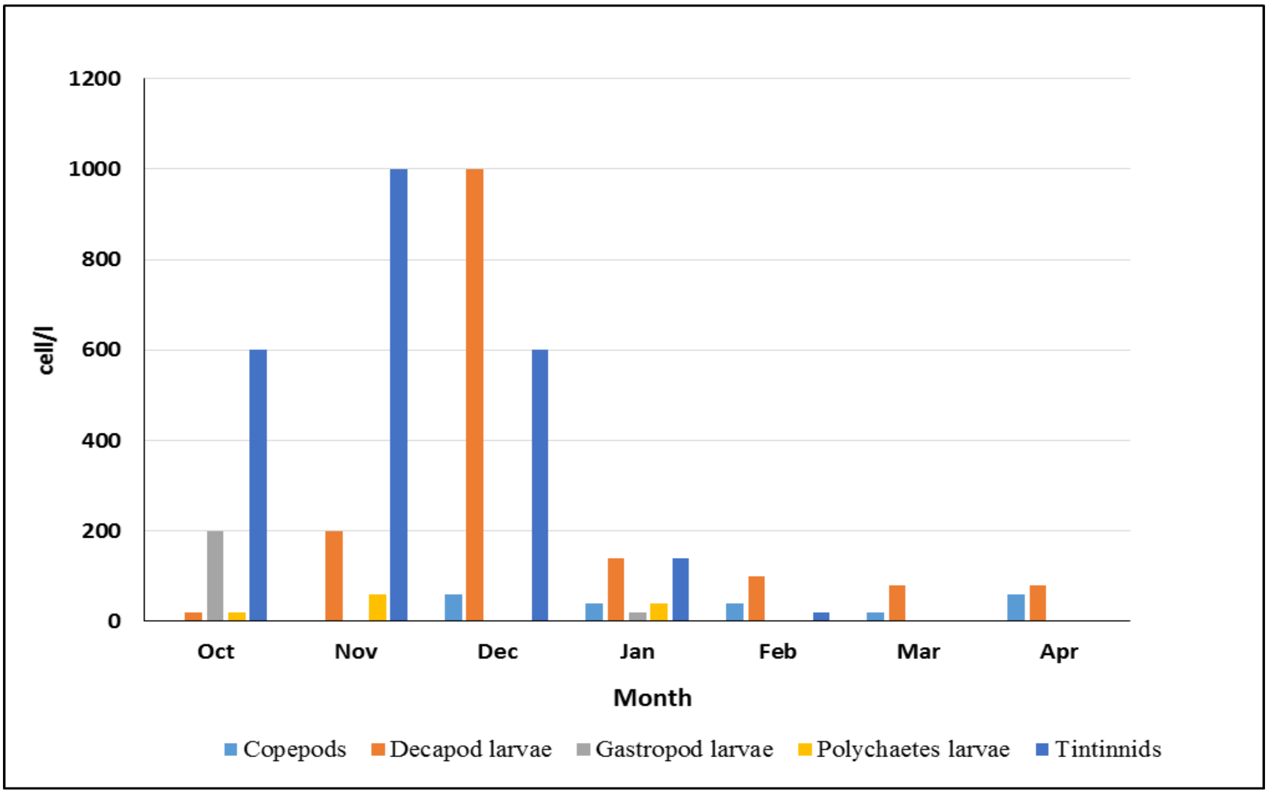

Fig 7: Temporal variation in zooplankton (group wise) abundance at Lokhandwala

Temporal zooplankton abundance at Dharamtar
Tintinnids were most dominant group followed by copepods. The other groups were present in few months (Figure 8). Highest abundance of zooplankton was found in November followed by December.

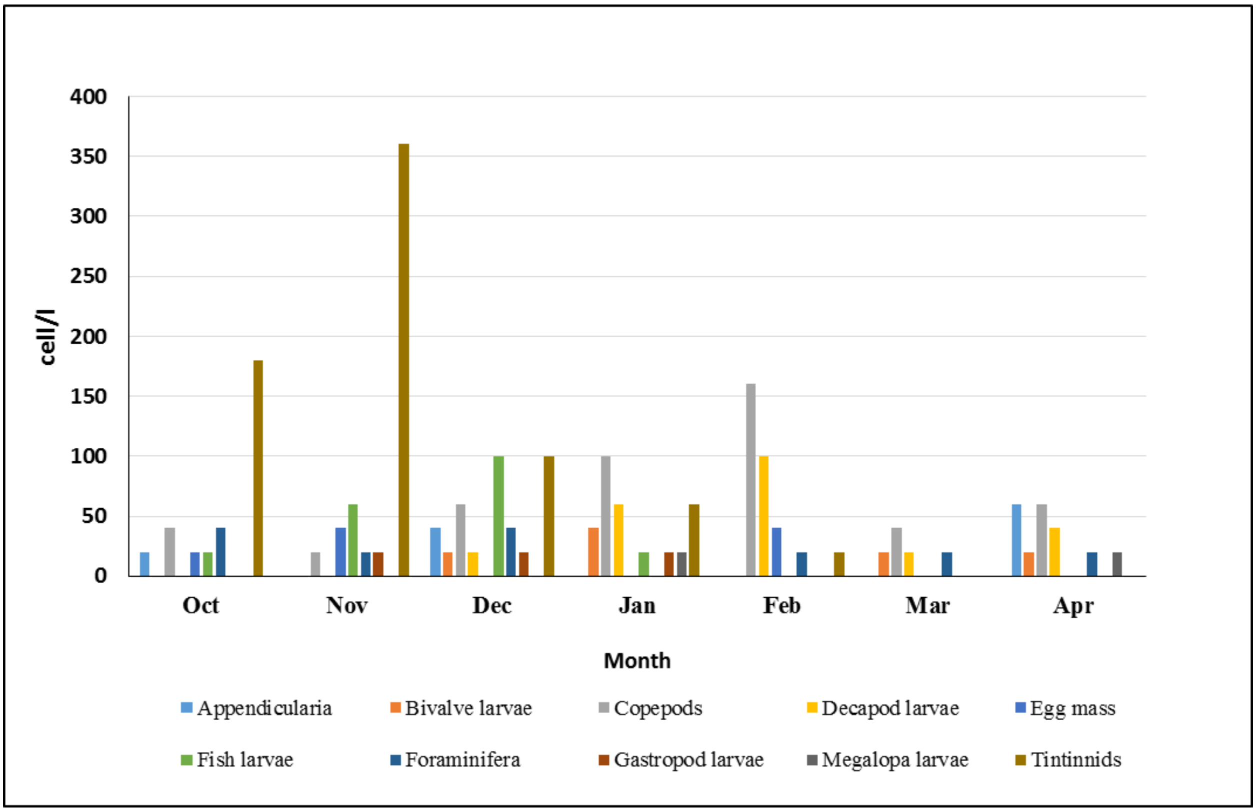

Fig 8: Temporal variation in average zooplankton (group wise) abundance at Dharamtar

Spatial variation in zooplankton among three stations
Spatial variations of the zooplankton showed that tintinnids are the most dominant group (ranging from 160-2360 cell/l) followed by decapods larvae and copepods in all the stations. Highest abundance of zooplankton from station 2 followed by station 3 (Figure 9). The dominant zooplankton groups from three stations (Plate 1).

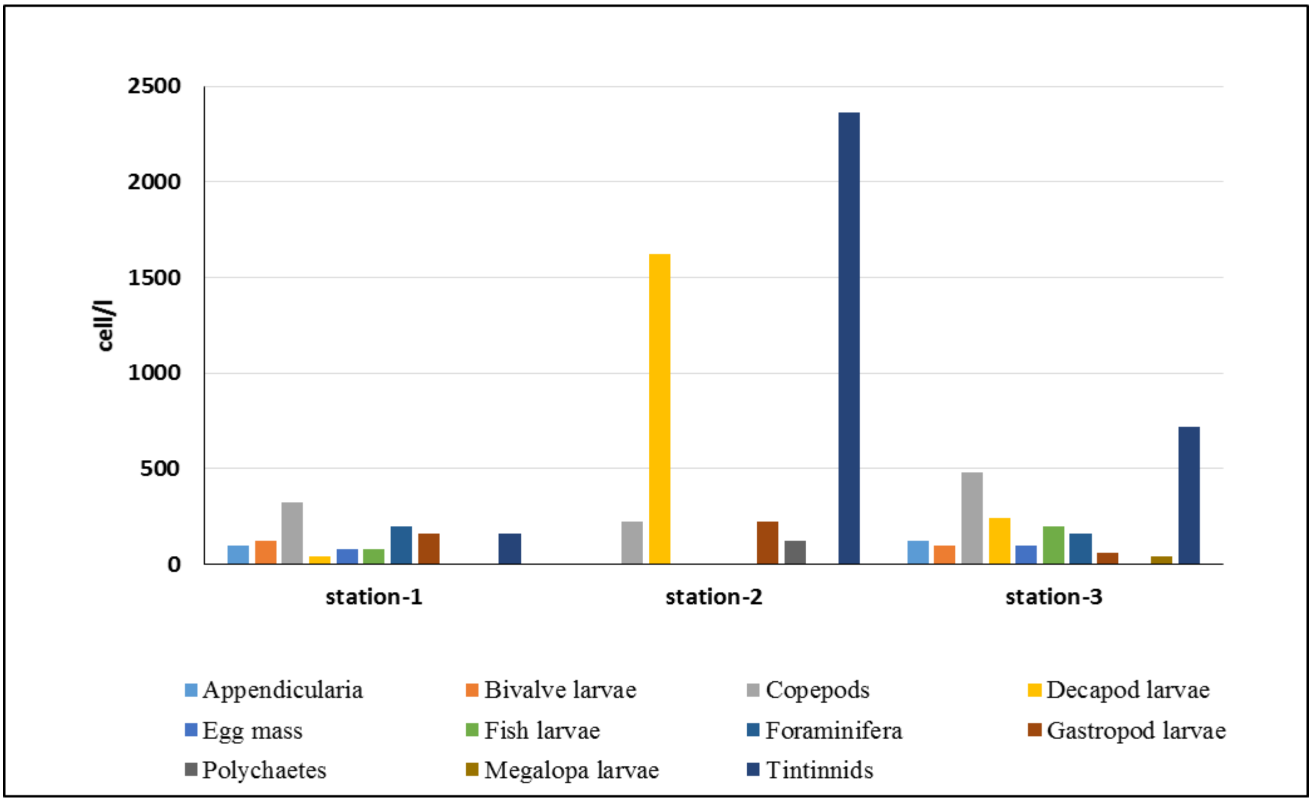

Fig 9: Spatial variation in average zooplankton abundance among three stations

Spatio-temporal occurrence in zooplankton

The spatio-temporal distribution of zooplankton showed that copepods, were most common group followed by tintinnids. Polychaetes larvae were present at Lokhandwala, where found as gastropods larvae and bivalve larvae were found in Bhayandar and Dharamtar (Table 1)

Table 1: Spatio-temporal occurrence of zooplankton among three stations

Group	Oct-16			Nov-16			Dec-16			Jan-17			Feb-17			Mar-17			Apr-17		
	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3	S1	S2	S3
Appendicularia	-	-	+	-	-	-	+	-	+	-	-	-	+	-	-	+	-	-	-	-	+
Bivalve larvae	+	-	-	+	-	-	-	-	+	+	-	+	-	-	-	+	-	+	+	-	+
Copepods	+	-	+	+	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
Copepod larvae	-	+	-	+	+	-	-	+	-	+	+	-	-	+	-	-	+		-	+	-
Decapod larvae	-	-	-	-	-	-	+	-	+	-	-	+	-	-	+	-	-	+	-	-	+
Egg mass	+	-	+	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Fish larvae	-	-	+	+	-	+	-	-	+	-	-	+	+	-	-	-	-	-	+	-	-
Foraminifera	-	-	+	+	-	+	+	-	+	+	-	-	+	-	+	+	-	+	+	-	+
Gastropod larvae	+	+	-	+	-	+	-	-	+	-	+	+	+	-	-	+	-	-	+	-	-
Megalopa larvae	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+
Polychaetes larvae	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Tintinnids	+	+	+	-	+	+	+	+	+	-	+	+	-	+	+	+	-	-	+	-	-

Correlation Analysis

Correlation between different environment factors at Bhayandar has been represented in the table. Two tailed ANOVA analysis shows positive correlation of zooplankton with pH at p< 0.05 (Table 2).

Table 2: Correlation between different environment parameters at Bhayandar

Parameters	Water temp.	Salinity	pH	DO	BOD	ZP
Water temp.	1					
Salinity	-0.513	1				
pH	0.004	-0.437	1			
DO	0.200	-0.044	-0.259	1		
BOD	-0.011	-0.261	0.749	-0.812*	1	
ZP	0.202	-0.669	0.768*	-0.261	0.685	1

*Correlation is significant at the 0.05 level (2-tailed).

Correlation between different environment factors at Lokhandwala have been represented in the table. Two tailed ANOVA analysis shows negative correlation of zooplankton with all environmental factors, except water temperature (Table 3).

Table 3: Correlation between different environment parameters at Lokhandwala

Parameters	Water temp.	Salinity	pH	DO	BOD	ZP
Water temp.	1					
Salinity	-0.142	1				
pH	-0.128	0.197	1			
DO	0.513	-0.422	0.484	1		
BOD	-0.706	0.296	-0.510	-0.928**	1	
ZP	0.605	-0.157	-0.555	-0.090	-0.055	1

**Correlation is significant at the 0.01 level (2-tailed).

Correlation between different environment factors at Dharamtar have been represented in the table. Two tailed ANOVA analysis shows negative correlation of zooplankton with pH at $p < 0.05$ (Table 4).

Table 4: Correlation between different environment parameters at Dharamtar

Parameters	Water temp.	Salinity	pH	DO	BOD	ZP
Water temp.	1					
Salinity	-0.534	1				
pH	-0.279	-0.102	1			
DO	-0.722	-0.020	0.592	1		
BOD	-0.183	-0.626	0.450	0.539	1	
ZP	-0.188	0.624	-0.756*	-0.434	-0.627	1

*Correlation is significant at the 0.05 level (2-tailed).

Correlation of pooled data of all the parameters across the stations among the different environment factors and zooplankton abundance is given in table 5. Two tailed ANOVA analysis shows no correlation among the stations.

Table 5: Correlation between different environments parameters among three stations

Parameters	Water temp.	Salinity	pH	DO	BOD	ZP
Water temp.	1					
Salinity	-0.277	1				
pH	-0.135	-0.097	1			
DO	-0.123	-0.377	0.339	1		
BOD	-0.296	-0.212	0.189	-0.073	1	
ZP	0.104	-0.145	-0.031	-0.507*	0.058	1

*Correlation is significant at the 0.05 level (2-tailed).

Diversity indices
Temporal variation in diversity indices

Tables 6-8 give an account of temporal variations in diversity. Dominance index (*D*) is maximum with 0.56 in January, 0.69 in March and 0.53 in November at Bhayandar, Lokhandwala and Dharamtar, respectively. At Bhayandar minimum with 0.20 in February, at Lokhandwala with 0.15 in January and at Dharamtar with 0.18 in December. High species evenness (*J'*) was recorded at Bhayandar and ranged between 0.43 and 0.79, with minimum value in the month of January and maximum in the month of February as compared to Lokhandwala (0.31 and 0.84), with minimum value in the month of January and maximum in the month of March and at Dharamtar (0.47 and 0.82), with minimum value in the month of November and maximum in the month of December. Shannon's Diversity Index (*H*') is maximum with 2.52 in February, 1.96 in January and 2.72 in December at Bhayandar, Lokhandwala and Dharamtar respectively. Simpson Diversity Index (*1-λ'*) is maximum with 0.82 in February, 0.70 in January and 0.83 in December at Bhayandar, Lokhandwala and Dharamtar respectively**.**

Table 6: Temporal variation in diversity indices at Bhayandar

Month	Dominance Index (*D*)	Pielou Eveness Index (*J'*)	Shannon's Diversity Index (*H*')	Simpson Diversity Index (*1-λ'*)
October	0.2897	0.7103	2.2516	0.7843
November	0.3144	0.6856	2.1732	0.7945
December	0.2897	0.7103	2.2516	0.7843
January	0.5650	0.4350	1.3788	0.5755
February	0.2044	0.7956	2.5219	0.8241
March	0.2302	0.7698	2.4402	0.8027
April	0.2282	0.7718	2.4464	0.8040

Table 7: Temporal variation in diversity indices at Lokhandwala

Month	Dominance Index (*D*)	Pielou Eveness Index (*J'*)	Shannon's Diversity Index (*H*')	Simpson Diversity Index (*1-λ'*)
October	0.5278	0.4722	1.0965	0.4325
November	0.6144	0.3856	0.8953	0.3429
December	0.5072	0.4928	1.1443	0.5055
January	0.1521	0.8479	1.9688	0.7055
February	0.4406	0.5594	1.2988	0.5346
March	0.6891	0.3109	0.7219	0.3232
April	0.5757	0.4243	0.9852	0.4243

Table 8: Temporal variation in diversity indices at Dharamtar

Month	Dominance Index (*D*)	Pielou Eveness Index (*J'*)	Shannon's Diversity Index (*H'*)	Simpson Diversity Index (*1-λ'*)
October	0.4079	0.5921	1.9669	0.6426
November	0.5323	0.4677	1.5538	0.4980
December	0.1802	0.8198	2.7232	0.8271
January	0.2309	0.7691	2.5550	0.8072
February	0.4355	0.5645	1.8751	0.6733
March	0.4214	0.5786	1.9219	0.7273
April	0.2736	0.7264	2.4131	0.7970

Discussion

Water quality parameters

According to Gopinathan (1975) [10], in tropical countries the temperature does not act as limiting factor for primary production. The optimum water temperature is important for biological and chemical reactions in the organisms present in water. 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 water (Saravanakumar *et al.* 2008) [11]. In present study, higher water temperature was found in summer season than winter season at all the stations. Similar result was found by Karthik *et al.* (2012) [12].

The pH scale measure the acidity and alkalinity of a solution. If a body of water is too basic or too acidic, aquatic life may get affected. Most fluctuation in pH during different months can be attributed to factors like removal of CO_2 by photosynthesis, dilution of seawater by freshwater discharge, reduction of salinity, temperature and decomposition of organic matter (Upadhyay, 1988 [13] and Rajasegar, 2003) [14]. In the present study, pH all the three stations its showing almost near to neutral pH except during month of March.

The salinity is another major factor which limits the distribution of aquatic organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone (Gibson, 1982) [15]. In the present study, salinity was shows much variations. Bhayandar was did not show much fluctuations because this sites was near to estuary mouth. Lokhandwala and Dharamtar showed more fluctuations because more freshwater influx as well as tidal influx. Lowest value for salinity in the month of October combined effected that was less than 5‰ due to precipitation received in monsoon months and low tide.

Dissolved oxygen is one of the most significant parameter for aquatic organisms. The maximum DO was observed at Dharamtar than Bhayandar and Lokhandwala because Dharamtar is unpolluted with pristine environment supporting maximum biodiversity. Lokhandwala have a huge discharge of untreated domestic sewage, municipal solid wastes and chemical effluents. Yadava *et al.* (1987)[16] reported wide fluctuation in dissolved oxygen content of water in the lakes might be due to dense aquatic vegetation, shallow water depth and intense anthropogenic activities. Das *et al.* (1997) [17]and Saravanakumar *et al.* (2007) [18] reported variations of DO due to freshwater influx, which was during the monsoon season and more DO concentration might be due to the cumulative effect of higher wind velocity in the mangroves.

Lokhandwala has high BOD as compared to Bhayandar and Dharamtar. This might be due to the influx of organic sewage and dumping other anthropogenic wastes from the near city area. This affects the water and soil quality, wellbeing of aquatic, benthic organisms and mangrove vegetations.

Zooplankton variation and abundance

The zooplankton constitute an important component of secondary production in aquatic systems and play a key role in energy transfer in the ecosystem. The zooplankton community, which is a vital link in the food chain exhibits relatively lesser diversity in tropical water than temperate water because diversity is influenced by a number of physico-chemical and biological factors. In present study, at Bhayandar where copepods were most dominant group followed by foraminifera due to higher salinity and water temperature during month of March. Padmawati and Goswami (1996) [19] reported bulk of the copepods was maximum when temperature and salinity was highest in environment. Copepods exhibit a variety of reproductive strategies to compensate for losses to population due to predation. Copepods have colonised many different subterranean habitats.

The copepods are good indicators of habitat heterogeneity. Copepods originated in the marine environment and apparently entered fresh water through multiple colonisation waves (Boxshall and Jaume, 2000) [20]. At Lokhandwala, highest abundance of zooplankton was found in December followed by October and November, where most dominant group was tintinnids followed by decapods larvae due to heavily polluted site. Similar result was found by Feng *et al*. (2015) [21] reported tintinnids have potential bioindicator capacity for discriminating water quality status in marine ecosystems. Tintinnids represent a group of ciliates belonging to the subclass choreotrichida. Tintinnids play an important role in the transfer of matter and energy between the microbial food web and food chain in the marine planktonic ecosystem (Pierce, 1992) [22].

Vertical migration of decapod larvae in the water column are common both in estuarine and coastal environments. The vast majority of the decapoda was found in sea water almost 90% (Kaestner, 1980) [23]. At Dharamtar, highest abundance of zooplankton was found in November followed by December, where tintinnids and copepods were most dominant groups and other groups also present almost all the months due to pristine environment. In present study, based on spatial patterns in zooplankton group abundances of tintinnids was the most dominant group followed by decapods larvae and copepods in all the stations.

Correlation analysis

Relationship based on different environment parameters at Bhayandar show positive correlation of zooplankton with pH. At Lokhandwala and Dharamtar show negative correlation of zooplankton with all factors (except water temperature). While zooplankton indicated positive correlation with water temperature at all station. Temperature showed significant positive relationships with abundance of marine rotifers. The positive influence of temperature on zooplankton in temperate conditions is well documented in Sweden water bodies (Bērzinš and Pejler 1989) [24].

Diversity indices

Dominance index (*D*) is maximum with 0.56 in January, 0.69 in March and 0.53 in November at Bhayandar, Lokhandwala and Dharamtar, respectively. Biological Evenness for determining and calculating frequency (rampancy or numbers) of species types and also their distribution method as to how the frequency (numbers) are spread in a given one sample both before and after the seasonal monsoon (Ludwing and Reynolds, 1988) [25]. According to Bakus (2007) [26] the Evenness index varied from 0 (no evenness) to 1 (greatest evenness). High species evenness (*J'*) was recorded at Bhayandar and ranged between 0.43 and 0.79 as compared to Lokhandwala (0.31 and 0.84) and at Dharamtar (0.47 and 0.82). Shannon's Diversity Index (*H'*) is the most common measure of species diversity in ecology. It "quantifies the uncertainty in the species identity of an individual that is picked at random" from a dataset (Tuomisto, 2010) [27]. According to Margalef (1978) [28] the index can take values between 0 and 5. Molvaer *et al.* (1997) [29] established the following relation between the indices and the different ecological levels according to what is recommended by the Water Framework Directive as High status: >4 bits/indv, Good status: 4–3 bits/indv, Moderate status: 3–2 bits/indv, Poor status: 2–1 bits/indv and Bad status: 1–0 bits/indv. In the present study, the Shannon-Weiner index (*H'*) ranged from 1.3788 to 2.5219, 0.7219 to 1.9688 and 1.5538 to 2.7232 at Bhayandar, Lokhandwala and Dharamtar respectively. According to Bakus (2007) [26], the Simpson index varied from 0 (no diversity) to 1 (maximum diversity). Simpson Diversity Index (1-λ') is maximum with 0.82 in February, 0.70 in January and 0.83 in December at Bhayandar, Lokhandwala and Dharamtar respectively.

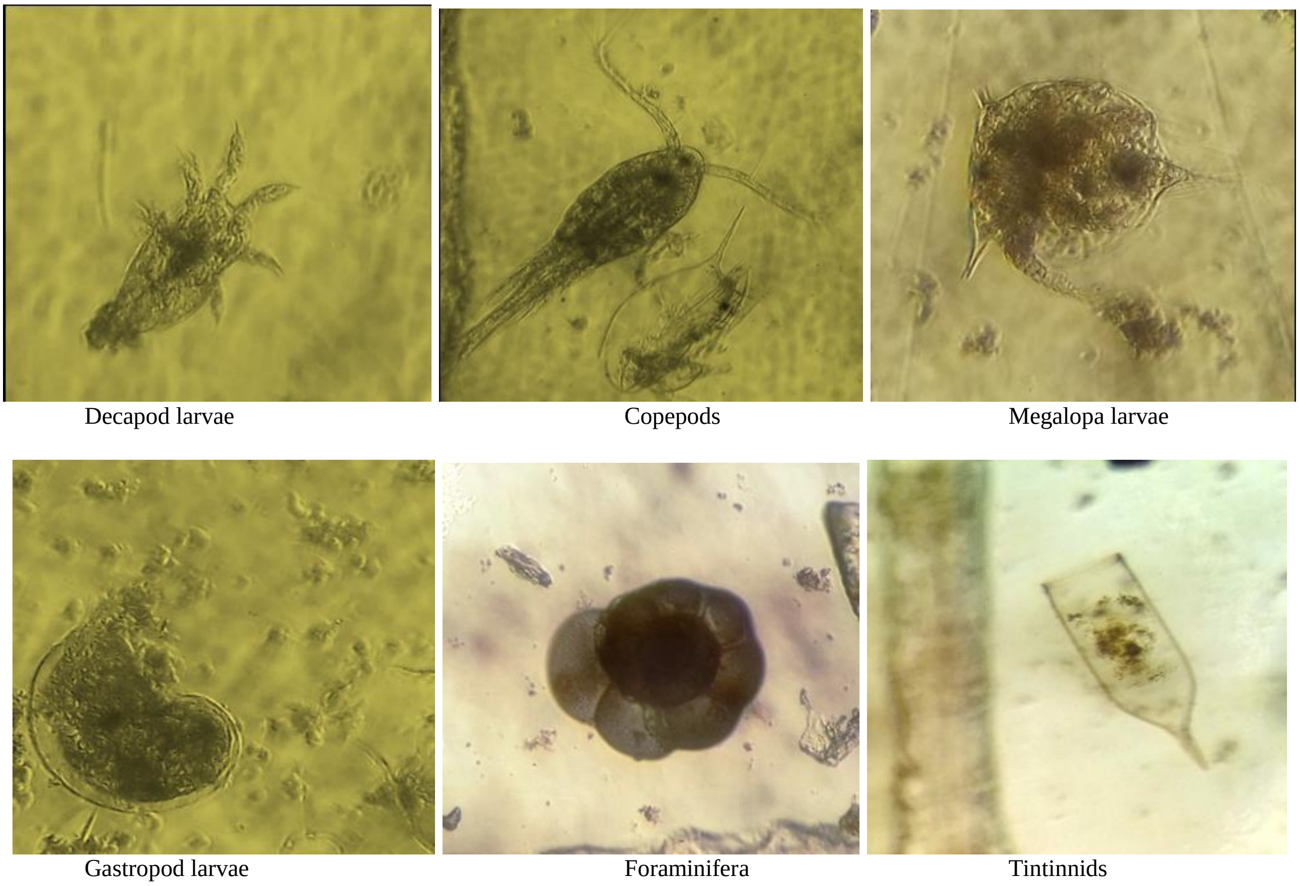

Plate 1: Dominant zooplankton groups among three stations

References

1. The World Resources Institute, UNEP, UNDP, World Bank. Oxford Univ. Press, Oxford, 1996, 365.
2. Robertson AI, Duke NC. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other near shore habitats in tropical Australia. Mar. Biol. 1987; 96:193-205.
3. Robertson AI, Blaber SJM. Plankton, epibenthos and fish communities. In AI Robertson, DM Alongi, eds. Coastal and estuarine studies 41, tropical mangrove ecosystems. Washington DC: American Geophysical Union, 1992, 173-224.
4. Sasekumar A, Chong VC, Leh MU, Cruz RRD. Mangroves as a habitat for fish and prawns. Hydrobiologia. 1992; 247:195-207.
5. Turner JT. The feeding ecology of some zooplankters that are important prey items of larval fish. NOAA Tech. Rept. NMFS. 1984; 7:1-28.
6. Godhantaraman N. Seasonal variations in taxonomic composition, abundance and food web relationship of microzooplankton in estuarine and mangrove waters, Parangipettai region, southeast coast of India. Indian J. Mar. Sci. 2001; 30:151-160.
7. Al-Yamani FY, Skryabin V, Gubanova A, Khvorov S, Prusova I. Marine zooplankton practical guide. Kuwait Institute for Scientific Research, Kuwait, 2011, 399.
8. Conway DV. Marine Zooplankton of Southern Britain-

Part 2: Arachnida, Pycnogonida, Cladocera, Facetotecta, Cirripedia and Copepoda. Occasional Publication. The Journal of the Marine Biological Association of United Kingdom. 2012; 25:1-138.
9. Goswami SC. Zooplankton methodology, collection and identification. National institute of oceanography. New Delhi: Dona Paula, 2004.
10. Gopinathan CP. Studies on the estuarine diatoms of India. Bulletin of the Department of Marine Sciences. 1975; 7(4):995-1004.
11. Saravanakumar A, Rajkumar M, Thivakaran GA, Serebiah JS. Abundance and seasonal variations of phytoplankton in the creek waters of western mangrove of Kachchh-Gujarat. Journal of environmental biology. 2008; 29(2):271.
12. Karthik R, Kumar Arun M, Sai Elangovan S, Siva Sankar R, Padmavati G. Phytoplankton abundance and diversity in the coastal waters of Port Blair, South Andaman Island in relation to environmental variables. J Mar. Biol. Oceanogr. 2012; 1(2):2.
13. Upadhyay S. Physico-chemical characteristics of the Mahanadi estuarine ecosystem, east coast of India. Ind. J Mar. Sci. 1988; 17(1):19-23.
14. Rajasegar M. Physico-chemical characteristics of the Vellar estuary in relation to shrimp farming. Journal of Environmental Biology. 2003; 24(1):95-101.
15. Gibson RN. Recent studies on the biology of intertidal fishes. Oceanography and Marine Biology. 1982; 20:363-414.
16. Yadava YS, Singh RK, Choudhury M, Kolekar V. Limnology and productivity of Dighali beel (Assam). Tropical Ecology. 1987; 28(2):137-146.
17. Das J, Das SN, Sahoo RK. Semidiurnal variation of some physicochemical parameters in the Mahanadi estuary, east coast of India. Indian, J Mar. Sci. 1997; 26:323-326.
18. Saravanakumar A, Sesh Serebiah J, Thivakaran GA, Rajkumar M. Benthic macro faunal assemblage in the arid zone mangroves of gulf of Kachchh - aGujarat. J. Ocean Univ. China. 2007; 6:33-39.
19. Padmavati G, Goswami SC. Zooplankton ecology in the Mandovi-Zuari estuarine system of Goa, west coast of India. IJMS. 1996; 25(3):268-273.
20. Boxshall GA, Jaume D. Making waves: the repeated colonization of fresh water by copepod crustaceans. Advances in Ecological Research. 2000; 31:61-79.
21. Feng M, Zhang W, Wang W, Zhang G, Xiao T, Xu H. Can tintinnids be used for discriminating water quality status in marine ecosystems? Marine pollution bulletin. 2015; 101(2):549-555.
22. Pierce RW, Turner JT. Ecology of planktonic ciliates in marine food webs. Reviews in Aquatic Sciences. 1992; 6(2):139-181.
23. Kaestner A. Invertebrate Zoology. Crustacea. Huntington, N.Y.: Krieger. PLOS ONE. 1980, III.
24. Bērzinš B, Pejler B. Rotifer occurrence in relation to pH. Hydrobiologia. 1987; 147(1):107-116.
25. Ludwing JA, Reynolds JF. Statistical ecology, A primer methods & computing, John Wiley & sons pub, 1988, 337.
26. Bakus GJ. Quantitative analysis of marine biological communities. 2007, 143-148.
27. Tuomisto H. A consistent terminology for quantifying species diversity? Yes, it does exist. Oecologia. 2010; 164(4):853-860.
28. Margalef R. Life-forms of phytoplankton as survival alternatives in an unstable environment, Oceanol. Acta. 1978; 1:493-509.
29. Molvaer J, Knutzen JF, Magnusson J, Rygg B, Skei J, Sorensen J. Classification of the environmental quality of fjords and coastal waters. SFT Veiledning 97:03. Norwegian Pollution Control Authority, Oslo, Norway, 1997, 36.