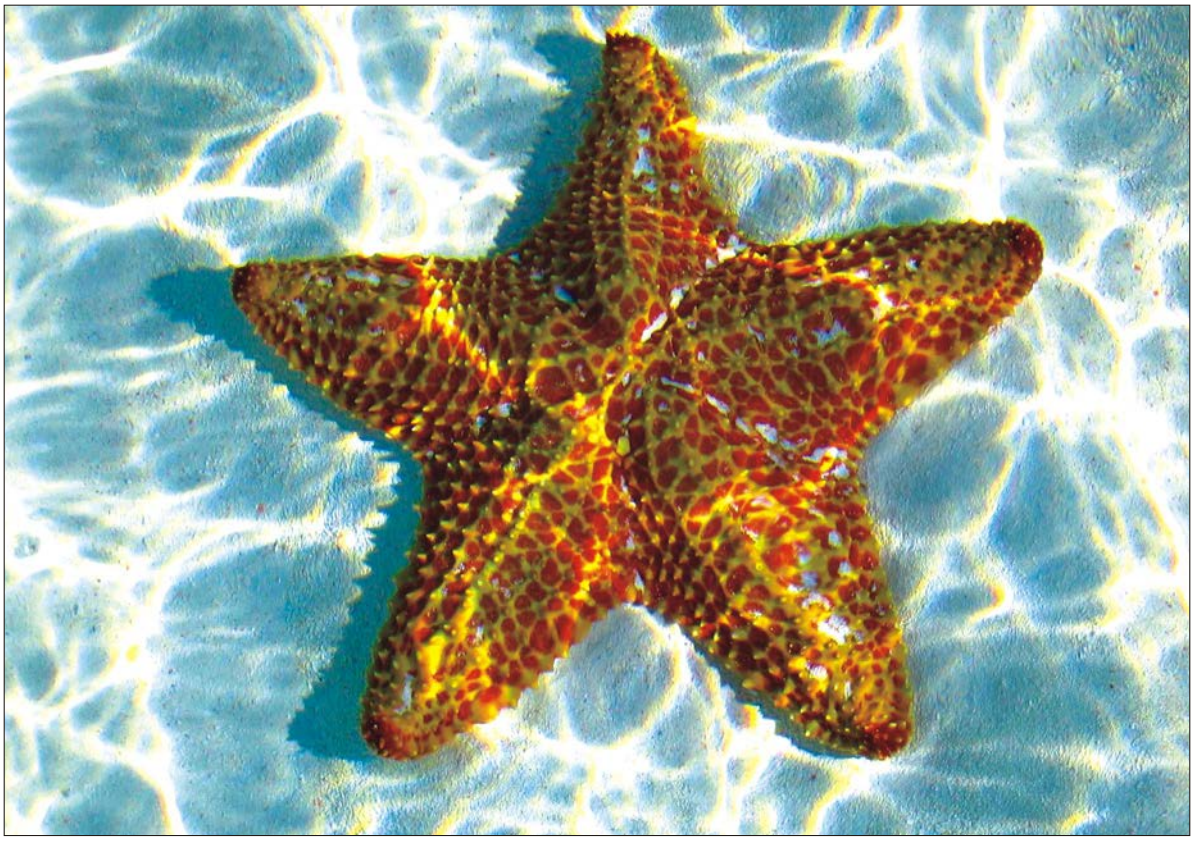

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Summer Distribution of Zooplankton in Coastal Waters of Odisha, East Coast of India

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ABSTRACT

Zooplankton production and composition with water chemistry characteristics and phytoplankton standing stock in coastal waters of Odisha coast was investigated during summer season (March/April) of 2010. The ranges of air and surface water temperature (°C) were 26.40-35.70 and 27.10-30.20, respectively. pH, salinity (PSU), DO (mg L^{-1}) and BOD (mg L^{-1}) values varied from 8.13-8.45, 24.32-28.96, 6.55-7.90 and 0.36-3.26, respectively. The inorganic nutrients (μmol L^{-1}) viz. nitrate, nitrite, ammonia, phosphate and silicate varied from 1.15-20.11, 0.12-1.15, 0.27-4.02, 0.13-2.81 and 3.96-17.06, respectively. Zooplankton density and biomass were ranges from 481-5685 Org. m^{-3} and 0.04-9.60 mL m^{-3}, respectively. The density of zooplankton was maximum at Mahanadi and minimum at Gopalpur. Totally, 40 groups of zooplankton were recorded. Out of the 40 zooplankton forms, 22 groups belonging to holoplankton and 18 different types of meroplankton were encountered. Among the holoplankton, copepod formed the dominant group at all the sampling sites. The total recorded meroplankton were dominated by crustacean forms.

Key words: Zooplankton, copepoda, nutrients, Odisha, Bay of Bengal

INTRODUCTION

The coastal water bodies are in greater risks of pollution because of their close proximity to land. The increasing human population, unplanned urbanization, deforestation, technological advancement, rapid industrialization, beach development, construction of Harbours and Fishing Jetties and over fishing in marine environments have affected the marine organisms in many ways. The slow rate of dispersion of pollutants in coastal waters than those in the open ocean, makes things more complicated. The secondary production contributed by zooplankton is a vital linkage in the food chain. Many species of zooplankton are used as bioindicators of water quality. Rao (1958) used chaetognaths to locate the current pattern in the Indian seas. Zooplankton provides an important food source for larval fish and shrimp in natural waters and in aquaculture ponds. The larvae of fishes feed mostly on zooplankton because zooplankton provide the necessary amount of protein requires for the rapid growth and development of different organs specially the gonad of fishes. The zooplankton contribute substantial biogenic material to ooze formation which has wide application in instrument related industry where the ooze is used as thermal insulators, chromatographic column filters, etc.

Studies pertaining to the zooplankton community in coastal water anywhere along Odisha coast are meagre and mostly limited to Chilika lake (Patnaik, 1973; Sewell, 1913; Devasundaram and Roy, 1954; Srichandan *et al*., 2012), Rushikulya estuary (Gouda and Panigrahy, 1995), Bahuda estuary (Mishra and Panigrahy, 1996, 1999), Burhabalanga estuary (Ramaiah *et al*.,

1996), Mahanadi estuary (Srichandan *et al*., 2013), Gopalpur port (Sahu *et al*., 2012), Gopalpur creek (Sahu *et al*., 2013) and coastal waters of Bay of Bengal of Rushikulya estuary (Sahu *et al*., 2010; Baliarsingh *et al*., 2013). The main objective of the study is to observe zooplankton abundance, its composition and to determine physico-chemical parameters in the coastal water and also to know the relationship between physicochemical parameters and zooplankton abundance.

MATERIALS AND METHODS

Odisha is one of the four maritime states situated on the East coast and lies between 17.49'N-22.34'N Lat. and 81.27'E-87.29'E Long. The 480 km long coast line of Odisha which extends from Bahuda estuary mouth on its South to Digha on its North. One of the extravagant features of Odisha coast is that it is predominated by sandy beaches. The present study was carried out in nine coastal areas such as Gopalpur (port and industrial area) [19.30N, 84.97E], Rushikulya (ecologically sensitive area) [19.37N, 84.08E], Chilika (Ramsar Site) [19.66N, 85.51E], Puri (a moderately urbanized area) [19.79N, 85.82E], Konark (pollution due to township sewage) [19.87N, 86.11E], Paradip (port and industrial area) [20.26N, 86.68E], Mahanadi (effluents from fertiliser and phosphate industries brings attention) [20.29N, 86.72E], Dhamra (highly influenced by agricultural run-off) [20.80N, 86.96E] and Chandipur (municipal sewage affected) [21.45N, 87.05E]. These stations were so selected that they can cover the southern, central and northern regions of entire Odisha coast.

Collection of water and plankton samples: Sampling was carried out during summer 2010 at nine shore stations along Odisha coast (Fig. 1). At each station, surface water samples were

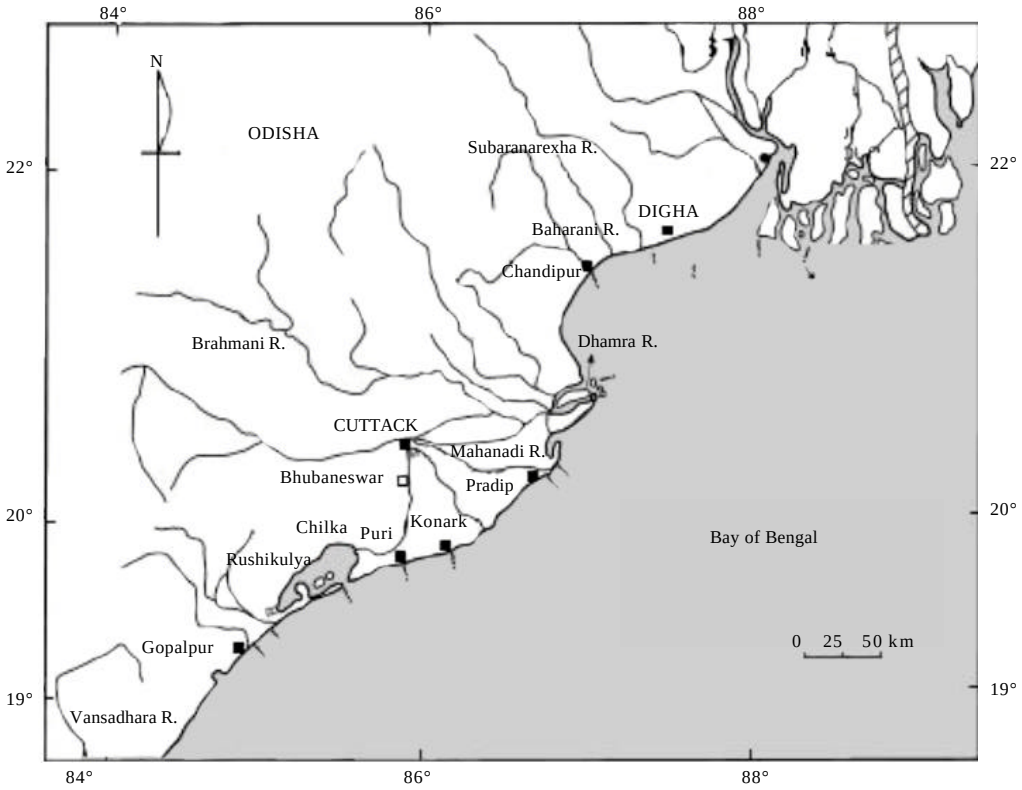

Fig. 1: Geographical location of sampling sites

collected using a plastic bucket for hydrographical parameters. pH, air and water temperature were measured using a Field Water Quality Ananlysis Kit (Make: WTW). Determination of salinity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) and analysis of different nutrients like nitrate (NO_3), nitrite (NO_2), ammonia (NH_4), phosphate (PO_4) and silicate (SiO_4) were measured by following various standard procedures prescribed by APHA (1998).

The zooplankton samples were taken from all shore stations by filtering 3000 L of water through conical plankton net made of bolting silk having a mesh size of 300 μm and preserved using 5% formaldehyde. In the laboratory, the zooplankton samples were divided into two sub-samples with the help of a Folsom Plankton Splitter for quantitative and qualitative analysis. From one sub-sample, the biomass was determined following the volume-displacement method. Estimation of qualitative composition of the zooplankton were done with other sub-sample. The numerical abundance values were represented in Org. m^{-3}. The relative abundance was computed from total density and the density of each group. Different group of zooplankton were identified using many publications by various authors, especially Newell and Newell (1977), Smith (1977), Wimpenny (1966) and Conway *et al.* (2003).

RESULTS AND DISCUSSION

Water quality parameters: The variation in water quality indices along Odisha coast during summer 2010 is shown in Table 1. Air and surface water temperature values varied from 26.40-35.70°C and from 27.10-30.20°C, respectively. The trend of variation of water temperature in different stations almost followed the air temperature. The variation of temperature was insignificant, an indication of similar temperature along the Odisha coast which was a characteristic of the tropical environment. The salinity variation always plays a key role in the distribution of living organisms in coastal ecosystem. The salinity value during the present study ranged from 24.32-28.96 PSU. Thus, the salinity variation during the surveys depicted near homogenous situation.

Table 1: Variation of water quality indices at Odisha coast

Parameters	GPL	RSK	CHK	PURI	KNK	PRP	MAH	DHA	CHP
Air temp. (°C)	32.90	31.50	35.70	31.35	32.20	30.30	30.60	27.6	26.40
Surface water Temp. (°C)	30.00	29.40	29.70	29.65	29.60	27.70	30.20	28.3	27.10
pH	8.15	8.15	8.41	8.35	8.45	8.21	8.33	8.13	8.16
Salinity (PSU)	28.96	28.79	26.31	25.96	27.55	27.77	24.32	27.42	25.98
DO (mg L^{-1})	6.58	6.55	6.90	7.29	7.32	7.32	7.35	6.77	7.90
BOD (mg L^{-1})	1.27	0.36	1.36	2.91	0.91	3.26	2.55	2.03	2.78
NO_2 (μmol L^{-1})	0.35	0.20	0.12	0.21	0.17	0.22	0.32	0.43	1.15
NO_3 (μmol L^{-1})	2.43	1.15	7.17	9.44	5.12	6.28	4.91	20.11	4.91
NH_4 (μmol L^{-1})	0.53	0.35	0.51	4.02	0.27	0.64	1.05	0.91	1.33
PO_4 (μmol L^{-1})	0.23	0.13	0.62	0.46	0.19	0.72	2.81	1.24	0.22
SiO_4 (μmol L^{-1})	4.23	5.53	7.11	8.70	4.14	3.96	17.06	12.27	13.32
Phyt pop (Cells L^{-1})	15660	8460	15000	50720	15840	49800	13860	19000	16800
Chl-a (mg m^{-3})	0.53	1.08	0.45	5.39	1.4	1.87	0.56	0.52	3.02
ZooBio (mL m^{-3})	0.2	0.08	0.32	0.32	0.8	0.16	0.8	0.04	9.6
ZooPop (org. m^{-3})	481	3392	1253	909	2093	2885	5685	1336	4099

GPL: Gopalpur, RSK: Rushikulya, CHK: Chilika, KNK: Konark, PRP: Paradip, MAH: Mahanadi, DHA: Dhamra, CHP: Chandipur, Phytopop: Phytoplankton population, ZooPop: Zooplankton population, ZooBio: Zooplankton biomass

pH is an index of hydrogen ion concentration. During the study period, pH remained alkaline with maximum (8.45) and minimum (8.13) along coastal waters of Odisha. The narrow pH range recorded, favours many chemical reactions inside aquatic organisms (cellular metabolism) that are necessary for their survival and growth.

The variation in DO and BOD were from 6.55-7.90 mg L^{-1} and 0.36-3.26 mg L^{-1}, respectively. The observed dissolved oxygen concentration and BOD levels were within the acceptable range i.e., less than 10 mg L^{-1} for dissolved oxygen and less than 4 mg L^{-1} for BOD.

Nutrients play a key role in growth, reproduction and metabolic activities of plankton. The recorded highest NO_3 value i.e., 20.11 µmol L^{-1} (Dhamra) and 9.44 µmol L^{-1} (Puri) may be due to the effect of direct discharges of pollutants and other biodegradable wastes but the nitrate concentration were within the acceptable range. The recorded low values i.e., 1.15 µmol L^{-1} in Rushikulya may be due to the waters of Rushikulya are least influenced by land runoff and due to the neretic water dominance which contained only negligible amount of NO_3 (Gouda and Panigrahy, 1996; Das *et al.*, 1997; Govindasamy *et al.*, 2000). NO_2 concentration during our study ranged from 0.12 µmol L^{-1} (Chilika) to 1.15 µmol L^{-1} (Chandipur). The observed higher NO_2 values in Chandipur could be due to the oxidation of ammonia and reduction of nitrate, increased planktonic organisms excretion. NH_4 values ranges between 0.27 and 4.02 µmol L^{-1}. The higher concentration of NH_4 in Puri could be partially due to the death and decomposition of phytoplankton. The concentration of PO_4 in Mahanadi was higher (2.81 µmol L^{-1}) as compared to other stations which may be due to the effect of fertilizer based industries. The SiO_4 are generally introduced into the coastal water bodies primarily from the weathering of land. The silicate content during the present study varied from 3.96-17.06 µmol L^{-1}. The recorded highest values in Mahanadi may be due to highly influence of land runoff.

A correlation coefficient matrix was performed between different environmental variables and zooplankton parameters i.e., zooplankton biomass, zooplankton population and dominant group copepod (Table 2). A significant positive relationship was observed between zooplankton biomass and DO ($r = 0.715$, $p<0.05$) and zooplankton biomass and NO_2 ($r = 0.941$, $p<0.01$). The dominant group copepod performed significant negative relationship with salinity ($r = -0.708$, $p<0.05$) and positive with PO_4 ($r = 0.824$, $p<0.01$), SiO_4 ($r = 0.716$, $p<0.05$) and zooplankton population density ($r = 0.906$, $p<0.01$) (Table 3). Salinity has already been proved as an influencing parameter for zooplankton population (Padmavati and Goswami, 1996) but in the present study, however, no definite correlation was discernible between salinity and zooplankton. The dominancy of copepoda in zooplankton population is clearly understood from the strong positive correlation between them. No significant correlation was observed between zooplankton population density and other environmental variables. Distribution of nutrients is mainly based on season, tidal flow and freshwater flow from land source and moreover utilisation of available nutrients due to increased photosynthetic activity by phytoplankton during summer (Kumar and Perumal, 2011).

Biological characteristics: The zooplankton community throughout the sampling period were represented by thirteen phyla namely sarcomastigophora, ciliophora, cnidaria, ctenophora, platyhelminthes, mollusca, annelida, arthropoda, phoronida, brachiopoda, echinodermata, chaetognatha and urochordata. A total of twenty two diverse groups belonging to holoplankton and eighteen different types of meroplankters were recorded (Table 3). Among the arthropoda, the crustaceans constitute the major constituents in zooplankton community of any marine environment. They have been described under two categories, the copepods and other non-copepod crustaceans.

Table 2: Pearson correlation matrix among different environmental variables of Odisha coastal waters during study period

	AT	WT	pH	Salinity	DO	BOD	NO_2	NO_3	NH_4	PO_4	SiO_4	Phytopop	Chl-*a*	ZooBio	ZooPop	Copepoda
AT	1															
WT	0.741*	1														
pH	0.583	0.504	1													
Salinity	0.166	-0.056	-0.457	1												
DO	-0.481	-0.492	0.263	-0.644	1											
BOD	-0.496	-0.491	-0.066	-0.561	0.669*	1										
NO2	-0.759*	-0.676*	-0.479	-0.230	0.576	0.359	1									
NO_3	-0.376	-0.268	-0.103	-0.157	-0.054	0.307	0.027	1								
NH_4	-0.168	0.037	0.158	-0.438	0.326	0.550	0.075	0.253	1							
PO_4	-0.144	0.240	0.127	-0.670*	0.127	0.366	-0.083	0.252	0.019	1						
SiO_4	-0.541	-0.109	-0.078	-0.796*	0.417	0.437	0.505	0.334	0.267	0.732*	1					
Phytopop	-0.088	-0.260	0.095	-0.094	0.306	0.714*	-0.177	0.226	0.641	-0.079	-0.204	1				
Chl-a	-0.255	-0.230	0.133	-0.265	0.525	0.523	0.217	0.031	0.881**	-0.303	0.032	0.692*	1			
ZooBio	-0.601	-0.635	-0.232	-0.309	0.715*	0.314	0.941**	-0.155	0.083	-0.188	0.407	-0.158	0.312	1		
ZooPop	-0.413	-0.161	-0.020	-0.562	0.529	0.289	0.338	-0.319	-0.067	0.560	0.611	-0.173	-0.007	0.396	1	
Copepoda	-0.312	-0.017	0.053	-0.708*	0.472	0.466	0.210	-0.151	0.009	0.824**	0.716*	-0.054	-0.091	0.209	0.906**	1

*Significant at 0.05 level, **Significant at 0.01 level, Phytopop: Phytoplankton population, ZooPop: Zooplankton population, ZooBio: Zooplankton Biomass

Table 3: Distribution of zooplankton groups (abundance and percentage composition) in different sampling locations

Group	GPL	RSK	CHK	PURI	KNK	PRP	MAH	DHA	CHP
Acantharians	***	***	***	***	***	16(0.55)	3(0.05)	***	***
Amphipoda	***	3(0.08)	37(2.98)	27(1.74)	***	***	***	27(2.00)	16(0.39)
Appendicularians	17(3.46)	83(2.44)	16(1.28)	5(0.35)	67(3.18)	43(1.48)	27(0.47)	1(0.10)	16(0.39)
Chaetognaths	***	***	***	5(0.35)	***	5(0.18)	5(0.09)	151(11.28)	29(0.72)
Cladocerans	6(1.25)	5(0.16)	5(0.43)	21(1.39)	37(1.78)	272(9.43)	3(0.05)	***	***
Copepods	301(62.47)	1235(36.40)	832(66.38)	933(60.98)	704(33.63)	2112(73.20)	5027(88.41)	933(69.88)	2221(54.20)
Ctenophores	***	***	***	***	***	5(0.18)	3(0.05)	1(0.07)	***
Cumaceans	1(0.28)	***	***	***	***	***	***	***	***
Euphausiids	***	***	16(1.28)	11(0.70)	***	***	***	32(2.40)	***
Foraminifera	7(1.39)	3(0.08)	***	11(0.70)	32(1.53)	5(0.18)	21(0.38)	***	77(1.89)
Gastropods	10(1.94)	11(0.31)	***	43(2.79)	288(13.76)	16(0.55)	5(0.09)	***	37(0.91)
Hydroidomedusae	***	***	5(0.43)	5(0.35)	416(19.87)	48(1.66)	13(0.23)	1(0.07)	***
Insecta	3(0.55)	3(0.08)	***	***	***	***	3(0.05)	***	11(0.26)
Isopoda	3(0.69)	11(0.31)	11(0.85)	5(0.35)	13(0.64)	***	***	***	19(0.46)
Lamellibranch	17(3.60)	***	***	43(2.79)	219(10.45)	***	40(0.70)	***	91(2.21)
Lucifers	***	99(2.91)	***	11(0.70)	53(2.55)	***	8(0.14)	23(1.70)	***
Ostracods	***	***	80(6.38)	***	***	***	***	67(4.99)	195(4.75)
Penaeid Prawn	1(0.28)	***	***	***	***	***	3(0.05)	4(0.32)	1085(26.48)
Platyhelminthes	***	3(0.08)	***	***	***	***	***	***	***
Polychaeta	7(1.39)	3(0.08)	11(0.85)	***	3(0.13)	43(1.48)	51(0.89)	***	19(0.46)
Siphonophores	1(0.28)	8(0.24)	27(2.13)	64(4.18)	5(0.25)	21(0.74)	***	4(0.30)	***
Tintinnids	31(6.37)	3(0.08)	***	***	***	37(1.29)	40(0.70)	1(0.10)	64(1.56)
Actinotrocha larvae	***	***	***	***	***	***	***	***	***
Actinula Larvae of Anthomedusae	***	***	***	***	5(0.25)	***	11(0.19)	***	***
Alima Larva of Squilla	***	***	***	***	***	***	***	1(0.10)	***
Brachiopod Larvae	***	***	5(0.43)	***	***	***	***	***	***
Caridean Larvae	26(5.40)	19(0.55)	***	***	51(2.42)	***	11(0.19)	21(1.60)	***
Crustacean cypris larvae	2(0.42)	21(0.63)	***	16(1.05)	13(0.64)	***	40(0.70)	***	32(0.78)
Crustacean nauplii	9(1.80)	19(0.55)	***	5(0.35)	123(5.86)	37(1.29)	69(1.22)	***	29(0.72)
Echinoderm Larvae	***	***	***	***	***	***	***	***	***
Euphuasiids Larvae	***	***	5(0.43)	59(3.83)	***	53(1.85)	***	***	***
Fish egg	8(1.66)	19(0.55)	107(8.51)	128(8.36)	29(1.40)	85(2.96)	53(0.94)	5(0.40)	3(0.07)
Fish Larvae	8(1.66)	3(0.08)	***	***	***	27(0.92)	29(0.52)	***	19(0.46)
Gastropod Larvae	9(1.80)	1024(30.19)	27(2.13)	27(1.74)	8(0.38)	27(0.92)	59(1.03)	27(2.00)	***
Larvae of Bivalves	7(1.39)	787(23.19)	59(4.68)	107(6.97)	16(0.76)	***	21(0.38)	***	40(0.98)
Post Larvae of penaeid prawn	***	***	***	***	***	***	***	***	21(0.52)
Megalopa Larvae	1(0.14)	***	***	***	***	***	***	3(0.20)	16(0.39)
Mysis	1(0.28)	***	***	***	5(0.25)	***	45(0.80)	4(0.30)	***
Polychaete Larvae	1(0.28)	***	***	5(0.35)	3(0.13)	21(0.74)	64(1.13)	1(0.10)	***
Zoea Larvae	4(0.83)	***	11(0.85)	***	3(0.13)	11(0.37)	32(0.56)	28(2.10)	59(1.43)

GPL: Gopalpur, RSK: Rushikulya, CHK: Chilika, KNK: Konark, PRP: Paradip, MAH: Mahanadi, DHA: Dhamra, CHP: Chandipur

Copepods: Among all the groups/taxa, copepod was not only the dominant one but also well distributed all along the Odisha coast. The population density of copepod showed well marked spatial variation and it ranged from 301 Org. m^{-3} (Gopalpur) to 5027 Org. m^{-3} (Mahanadi) (Table 3). The occurrence of higher values of copepod among the other zooplankton in Odisha coast corroborates many earlier findings (Wellershaus, 1974; Sarkar *et al.*, 1984; Nagarajaiah and Gupta, 1985; Nair *et al.*, 1984; Padmavati and Goswami, 1996; Mishra and Panigrahy, 1999; Karuppasamy and Perumal, 2000; Qasim, 2005; Madhu *et al.*, 2007; Koppelmann and Weikert, 2000). In the entire study, copepoda were found to represent by fifty eight species, belonging to twenty two families and four orders, out of which thirty eight species were from calanoida. The order cyclopoida, harpacticoida and poicilostomatoida were represented only by 4, 5 and 11 species, respectively (Table 4). Calanoida copepods contributed upto 95.61%, cyclopoida copepod upto 11.78%, harpacticoida upto 20.89% and poicilostomatoida upto 48.33% of total copepods. The calanoida copepod dominated over other groups in the entire shore of Odisha coast except in Rushikulya where Poecilostomatatoida was remained as the dominant group. The dominance of calanoid group may be due to their continuous breeding behavior, quick larval development and their well adaptation to the widely changing environmental conditions (Ramaiah and Nair, 1997; Santhanam and Perumal, 2003). Copepoda, being the dominant component of the zooplankton community, species diversity is used as an index in all biological monitoring studies to characterize the water quality (Gajbhiye *et al.*, 1981). Copepoda are known to select preferred habitats and hence their distribution may vary with species (Lalli and Parsons, 1997). Further among the calanoida, the species *Acrocalanus longicornis* remained dominated the other species in both Gopalpur and Puri, *Pseudodiaptomus aurivilli* in Rushikulya, Chilika and Chandipur, *Pseudodiaptomus serricaudatus* in Konark, Temora turbinata in Paradip and Dhamra, *Paracalanus parvus* in Mahanadi (Table 4). Along the Odisha coast, most common species of copepod was *Acrocalanus longicornis* in all sites except in Dhamra. Rakhesh *et al.* (2006) have reported that *Acrocalanus* sp. were characterizing the coastal locations off North Coastal Andhra Pradesh and the findings of the present study corroborate the same. The single family Oithonidae belongs to the order cyclopoida was occurred in all the shores except in Puri, Mahanadi and Dhamra. Among the oithonidae, *Oithona similis* were present at both Gopalpur and Rushikulya, *Oithona* sp. was found from three transects i.e., Gopalpur, Chilika and Konark, *Oithona spinirostris* was encountered at Paradip and Rushikulya and *Oithona breviconis* only at Chandipur. Abundance of the genus *Oithona* was mainly due to its high reproductive capacity (Santhanam and Perumal, 2003; Kumar and Perumal, 2011). The species such as *Euterpina acutifrons* (Gopalpur, Rushikulya, Chilika, Konark, Paradip and Chandipur), *Miracia efferata* (Rushikulya), *Microsetella rosea* (Rushikulya), *Microsetella norvegica* (Gopalpur, Rushikulya), *Clytemnestra scutellata* (Rushikulya, Chilika, Dhamra) of the Harpacticoid were observed (Table 4). During the present study, the harpacticoid group was completely absent in two region i.e., Puri and Mahanadi. Three families such as Oncaeidae, Sapphirinidae and Corycaeidae were represented by poiecilostomatoida. Among these 3 families, the Corycaeidae was the most dominant one as compared to the others in all the shores except at Chilika and were represented by the species such as *Corycaeus agilis, C. catus, C. speciosus*, *Corycaeus* sp., *Farranula carinata* and *F. gibbula*. Out of these 6 species, *Corycaeus catus* even emerged as dominant copepod at Rushikulya. At Chilika, *Oncaea conifera* was remained as the dominant species.

Table 4: Distribution of copepod species in different sampling locations of Odisha coast

	Taxon	GPL	RSK	CHK	PURI	KNK	PRP	MAH	DHA	CHP
Phylum	Arthropoda	-	-	-	-	-	-	-	-	-
Class	Maxillipoda	-	-	-	-	-	-	-	-	-
S.Class:	Copepoda	-	-	-	-	-	-	-	-	-
Order	Calanoida	-	-	-	-	-	-	-	-	-
Family	**Metridinidae**									
	Pleuromamma sp.	-	-	-	-	-	-	-	-	-
Family	**Acartiidae**									
	Acartia erythraea	-	-	-	-	-	-	158(3.14)	34(3.64)	-
	(Giesbrecht 1889)									
	A. spinicauda	-	-	-	-	-	-	-	25(2.68)	-
	(Giesbrecht 1889)									
Family	**Candaciidae**									
	Candacia discaudata	-	-	-	-	-	-	-	13(1.39)	-
	(A. Scott 1909)									
	Candacia sp.	-	-	-	-	-	-	-	15(1.61)	-
	Paracandacia truncate	-	12(0.97)	-	-	-	-	-	-	-
	(Dana 1849)									
Family	**Centropagidae**									
	Centropages furcatus	18(5.98)	8(0.65)	56(6.73)	-	-	-	-	-	-
	(Dana 1849)									
	C. orsinii	-	-	-	68(7.29)	-	-	53(1.05)	-	-
	(Giesbrecht 1889)									
Family	**Pontellidae**									
	Calanopia minor	-	24(1.94)	-	-	-	-	-	-	-
	(A. Scott 1902)									
	Labidocera acuta	-	3(0.24)	-	-	-	-	25(0.50)	-	-
	(Dana 1849)									
	L. pectinata	-	-	-	-	-	-	18(0.36)	-	-
	Pontella securifer	-	-	-	-	-	-	21(0.42)	-	-
	(Brady 1883)									
Family	**Temoridae**									
	Temora discaudata	-	-	-	-	-	-	97(1.93)	81(8.68)	-
	(Giesbrecht 1889)									
	T. stylifera	-	-	-	-	-	-	-	-	-
	T. turbinata	-	-	-	-	-	460(21.78)	991(19.71)	225(24.12)	-
	(Dana 1849)									
Family	**Tortanidae**									
	Tortanus barbatus	-	-	-	-	25(3.55)	-	-	158(16.93)	-
	(Brady, 1883)									
	T. forcipatus	-	-	-	15(1.61)	21(2.98)	-	-	25(2.68)	-
	(Giesbrecht, 1889)									
	T. gracilis	-	-	-	12(1.29)	-	-	-	-	-
	(Brady, 1883)									
Family	**Calanidae**									
	Canthocalanus pauper	23(7.64)	18(1.46)	-	-	-	320(15.15)	687(13.67)	-	65(2.93)
	(Giesbrecht, 1888)									
	Mesocalanus tenuicornis	-	-	-	-	-	-	-	37(3.97)	-
	(Dana 1849)									
	Nannocalanus minor	-	-	-	41(4.39)	-	-	99(1.97)	31(3.32)	-
	(Claus 1863)									

Table 4: Continue

	Taxon	GPL	RSK	CHK	PURI	KNK	PRP	MAH	DHA	CHP
Family	**Paracalanidae**									
	Acrocalanus gracilis (Giesbrecht 1888)	-	-	-	-	-	-	-	19(2.04)	-
	A. gibber (Giesbrecht 1888)	-	27(2.19)	-	-	22(3.13)	298(14.11)	510(10.15)	-	-
	A. longicornis (Giesbrecht 1888)	98(32.56)	28(2.27)	126(15.14)	372(39.87)	180(25.57)	58(2.75)	101(2.01)		51(2.30)
	Calocalanus pavo (Dana 1849)	-	32(2.59)	-	-	-	-	-	-	-
	Paracalanus aculeatus (Giesbrecht 1888)	-	-	45(5.41)	-	93(13.21)	-	62(1.23)	58(6.22)	71(3.20)
	P.parvus (Claus 1863)	-	19(1.54)	38(4.57)	-	-	375(17.76)	1890(37.60)	33(3.54)	79(3.56)
Family	**Eucalanidae**									
	Eucalanus monachus	-	-	-	-	-	-	59(1.17)	-	-
	Eucalanus sp.	15(4.98)	19(1.54)	-	-	-	52(2.46)	-	9(0.96)	-
	Subeucalanus subcrassus (Giesbrecht 1888)	-	-	-	-	-	-	35(0.70)	46(4.93)	-
Family	**Arietellidae**									
	Metacalanus aurivilli (Cleve,1901)	-	28(2.27)	-	-	-	-	-	-	-
Family	**Clausocalanidae**									
	Clausocalanus arcuicornis (Dana 1849)	-	11(0.89)	-	-	-	-	-	-	-
Family	**Euchaetidae**									
	Euchaeta concinna	-	-	-	-	-	-	-	-	32(1.44)
	E. marina	-	-	-	-	-	-	-	18(1.93)	29(1.31)
	Euchaeta sp.	-	-	-	-	-	-	-	12(1.29)	-
Family	**Pseudodiaptomidae**									
	Pseudodiaptomus aurivilli (Cleve 1901)	29(9.63)	65(5.26)	298(35.82)	-	-	-	-	-	1590(71.59)
	P. serricaudatus (T.Scott 1894)	-	39(3.16)	-	212(22.72)	263(37.36)	43(2.04)	-	-	-
	Pseudodiaptomus sp.	-	-	-	26(2.79)	-	-	-	-	-
Order	Cyclopoida	-	-	-	-	-	-	-	-	-
Family	**Oithonidae**									
	Oithona brevicornis (Giesbrecht 1891)	-	-	-	-	-	-	-	-	89(4.01)
	O. spinirostris (Claus 1863)	-	11(0.89)	-	-	-	97(4.59)	-	-	-
	O. similis (Claus 1866)	9(2.99)	36(2.91)	-	-	-	-	-	-	-
	Oithona sp.	8(2.66)	-	98(11.78)	-	53(7.53)	-	-	-	-
Order	Harpacticoida	-	-	-	-	-	-	-	-	-
Familly	**Miraciidae**									
	Miracia efferata (Dana 1849)	-	5(0.40)	-	-	-	-	-	-	-
Family	**Ectinosomatidae**									
	Microsetella rosea (Dana 1848)	-	211(17.09)		-	-	-	-	-	-
	M. norvegica (Boeck 1864)	11(3.65)	12(0.97)	-	-	-	-	-	-	-

Table 4: Continue

	Taxon	GPL	RSK	CHK	PURI	KNK	PRP	MAH	DHA	CHP
Family	**Clytemnestridae**									
	Clytemnestra scutellata (Dana, 1848)	-	6(0.49)	18(2.16)	-	-	-	-	21(2.25)	-
Family	**Euterpinidae**									
	Euterpina acutifrons (Dana 1848)	12(3.99)	24(1.94)	19(2.28)	-	12(1.70)	48(2.27)	-	-	35(1.58)
Order	Poecilostomatatoida	-	-	-	-	-	-	-	-	-
Family	**Oncaeidae**									
	Oncaea conifer (Giesbrecht 1891)	-	-	68(8.17)	-	-	82(3.88)	-	-	-
	O. mediterranea (Claus 1863)	-	21(1.70)	-	-	-	-	-	-	-
	O. venusta (Philippi 1843)	-	15(1.21)	53(6.37)	50(5.36)	-	79(3.74)	-	-	-
Family	**Sapphirinidae**									
	Sapphirina ovatolanceolata (Dana 1849)	-	-	-	-	-	-	-	-	19(0.86)
	Sapphirina sp.	-	-	-	3(0.32)	-	-	-	-	-
Family	**Corycaeidae**									
	Corycaeus agilis (Dana 1849)	-	-	-	-	-	-	-	-	22(0.99)
	C. catus (F. Dahl 1894)	-	405(32.79)	13(1.56)	32(3.43)	-	-	221(4.40)	-	31(1.40)
	C. speciosus (Dana 1849)	-	-	-	-	-	89(4.21)	-	-	-
	Corycaeus sp.	38(12.62)	90(7.29)	-	-	35(4.97)	111(5.26)	-	73(7.82)	-
	Farranula carinata (Giesbrecht 1891)	-	12(0.97)	-	-	-	-	-	-	-
	F. gibbula (Giesbrecht 1891)	40(13.29)	54(4.37)	-	102(10.93)	-	-	-	-	108(4.86)

Other crustaceans: Other holoplanktonic crustaceans recorded during the study include amphipods, cladocerans, cumaceans, euphausiids, insecta, isopods, lucifers, ostracods and penaeid prawns (Table 3). The cladocerans were observed at all most all the shores of Odisha with densities varied between 3.00 (Mahanadi) to 272 org. m^{-3} (Paradip) except in Chandipur and Dhamra. The higher abundance of cladocerans in the waters of Paradip was also reported by Naomi *et al.* (1990). The lucifers and penaeid prawns were registered with high values at Rushikulya and Chandipur, respectively. The numerical abundance of lucifers varied from 8-99 and 1-1085 org. m^{-3}. Cumaceans found only at Gopalpur. Amphipods and isopods were observed in almost all shores. Other holoplankton crustaceans groups were also represented in zooplankton samples, whose occurrence and abundance was sporadic, even though they collectively dominated zooplankton at times.

Non crustaceans: During the period of investigation, the abundance of hydroidomedusae fluctuated from 1-416 org. m^{-3} (Table 3). In Konark, it occupied the second order of dominancy with 416 org. m^{-3} and this group were completely absent at Gopalpur, Rushikulya and Chandipur. Higher density of hydroidomedusae in the East coast of India (Santhakumari and Nair, 1999) and in the inshore waters during summer season was reported by Zakaria (2004). In the present investigation, occurrence of siphonophores observed in all most all sites except in Mahanadi and

Chandipur and they varied from 1-64 org. m^{-3}. Ctenophores were observed only at Paradip, Mahanadi and Dhamra with very low numerical abundance. Many workers showed that low ctenophore abundance in summer may be due to the some species of polychaetes and fish prey on ctenophores (Cargo and Schultz, 1967; Fraser, 1970; Greve, 1972, 1977). Another reason for low abundance of ctenophore may be due to the limitation of food in summer or destruction of young ctenophore by adult copepods (Greve, 1977).

Several other groups that contributed to the holoplankton population were appendicularians, foraminifera, chaetognaths, insecta, bivalves, acantharians, gastropods, lamellibranch, platyhelminthes, polychaetes and tintinnids etc. Among these groups, appendicularians were noticed in all the sites. Occurrence of appendicularians in summer season was also similar to the report of Santhanam and Perumal (2003) and in the coastal waters of Tamil Nadu was noticed by Iyyapparajanarasimapallavan *et al.* (2013). Among all the shore of Odisha, the higher population density of foraminifera was observed in Chandipur (77 org. m^{-3}). During our study, we observed some benthic foraminifera in Chandipur which might be due to the reason that foraminifera may have been swept off the bottom upward into the water column (Murray, 1965). Lower percentage of composition of tintinnids was due to use of large mesh size (200 µm) of plankton net (Sieburth *et al.*, 1978).

Meroplankton: Meroplankton constitutes a major fraction of zooplankton community in tropical seas. They are mostly represented by different larvae of benthic invertebrates, fish eggs and fish larvae. The meroplankton components of the present study were represented mainly by eight larval groups (Table 3). They were the larvae of crustaceans, molluscs, polychaetes, brachiopods, echinoderms, phoronida, anthomedusae and chordates. Crustacean larval population mostly comprised of cirripede cypris, crustaceans nauplii, zoea larvae, megalopa larvae, alima larva of squilla, euphausiid larvae, caridean larvae, mysis and post larvae of penaeid prawns etc. The brachyuran zoea larvae were quite abundant in some collections during summer season (George, 1958). Molluscan veligers and larvae of polychaetes were also encountered in almost all shore during the entire period of observation. Brachiopod larvae, echinoderm larvae, actinotrocha larvae of phoronida, actinula larvae of anthomedusae were less in number compared to others. Fish egg and larvae were encountered in all sampling shores during the entire period of observation. It indicates that the coastal ecosystem serves as a breeding and nursery grounds for a variety of shell fish and fin fish. These observations are consistent with the reports of Chandrasekaran and Natrajan (1993). The meroplankton encounterd in the study were ecologically important. For this study, a total of 18 meroplankton were recorded.

Population density and relative abundance: The population density of zooplankton exhibited wide range of spatial variations. The density varied between 481 org. m^{-3} (Gopalpur) and 5685 org. m^{-3} (Mahanadi) (Table 1). During the present study, for the purpose of computing relative abundance, the zooplankton population were divided into two major groups; holoplankton and meroplankton. The holoplankton were represented mainly by copepods, other crustaceans (cumaceans, amphipods, isopods, ostracods, lucifers, penaeid prawn, cladocerans, euphausiids, etc.) and non crustaceans which included the appendicularians from tunicates, cnidarians (hydroidomedusae, siphonophores and ctenophores), protozoans (acantharia, foraminifera) gastropods, lamellibranch, insecta, platyhelminthes, polychaetes and chaetognaths etc. The whole bulk of meroplankton were represented by the larvae of crustaceans, molluscs, polychaetes, brachiopods, echinoderms, phoronida, anthomedusae and chordates. The percentage composition of different groups was given in Fig. 2. During the present study, among the other major groups,

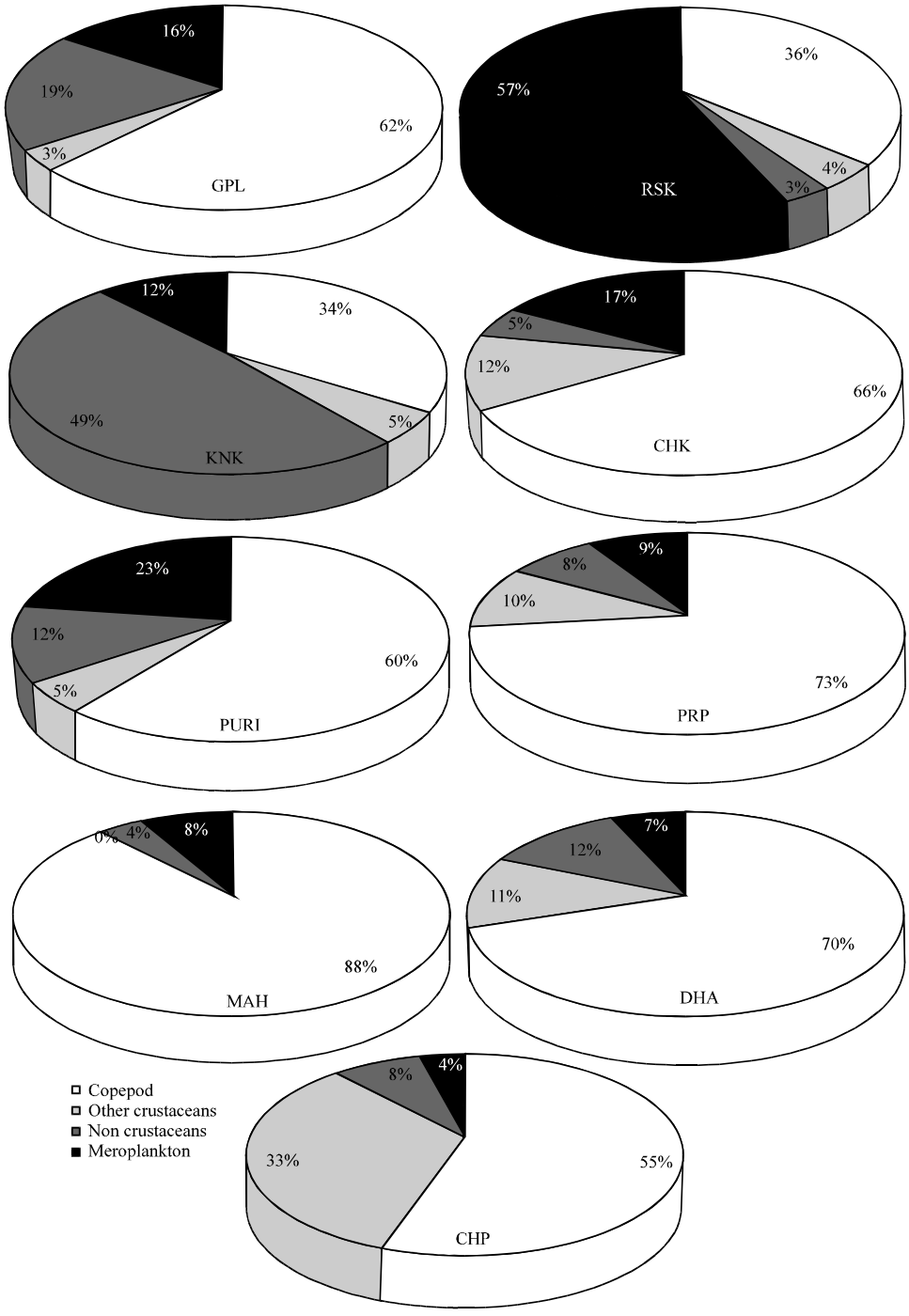

Fig. 2: Relative abundance of zooplankton community along Odisha coast. GPL: Gopalpur, RSK: Rushikulya, CHK: Chilika, KNK: Konark, PRP: Paradip, MAH: Mahanadi, DHA: Dhamra, CHP: Chandipur

contribution of copepod to the total zooplankton population were more at most of the sites except Rushikulya and Konark where meroplankton and non-crustaceans domianated over others.

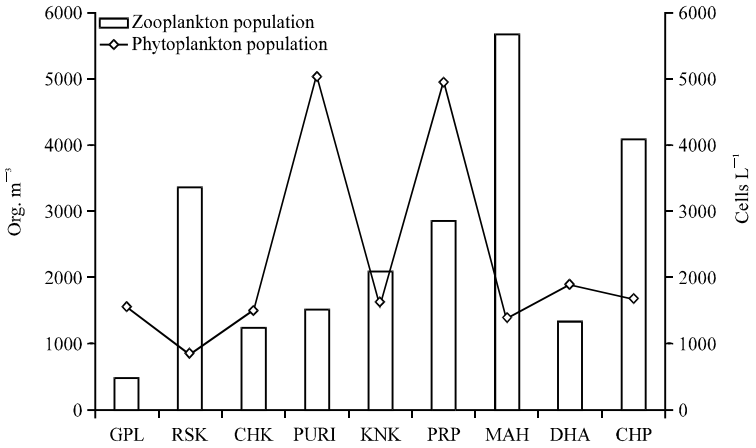

Fig. 3: Distribution of zooplankton with phytoplankton along Odisha coast during summer-2010. GPL: Gopalpur, RSK: Rushikulya, CHK: Chilika, KNK: Konark, PRP: Paradip, MAH: Mahanadi, DHA: Dhamra, CHP: Chandipur)

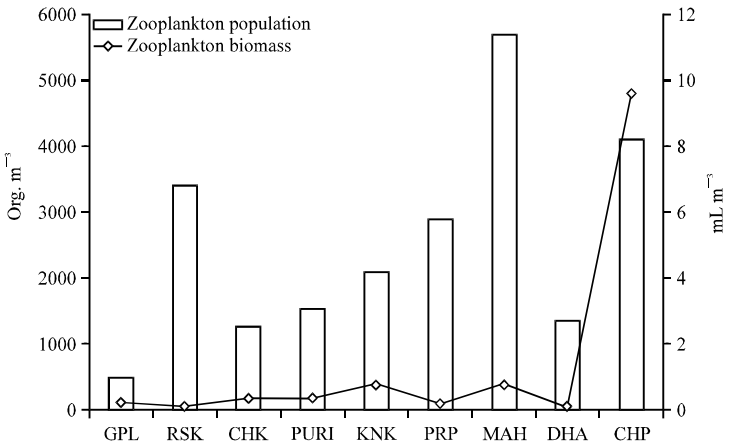

Fig. 4: Distribution of zooplankton with biomass along Odisha coast during summer-2010. GPL: Gopalpur, RSK: Rushikulya, CHK: Chilika, KNK: Konark, PRP: Paradip, MAH: Mahanadi, DHA: Dhamra, CHP: Chandipur

During the present study, zooplankton population density is negatively related (Fig. 3) with phytoplankton population density which might be attributed due to variation in composition of flora and fauna (Haridas *et al.*, 1973; Tiwari and Nair, 1993). During the period of observation, at some stations, the zooplankton density has often shown lack of agreement with corresponding value of zooplankton biomass (Fig. 4). This may be account for the presence or absence or restricted distribution of certain large organisms such as cnidarians, ctenophores, lucifers and penaeid prawns etc, reported to be responsible for the depletion of phytoplankton and copepods (Goswami, 1973; Desai *et al.*, 1983; Fransz *et al.*, 1984).

CONCLUSION

In the present study, holoplanktonic copepod formed the dominant group at most of the sampling sites. Crustacean forms dominated the meroplankton group. Observation of fish egg and

larvae at almost all the sampling stations along the coast indicated that the coastal ecosystem serves as a breeding and nursery grounds for a variety of shell fish and fin fish. The results of present study showed that spatial distribution of zooplankton was governed by salinity and dissolved oxygen. A long term study in seasonal aspect is needed to understand the effect of other ambient water quality parameters on zooplankton species composition and distribution of coastal waters of Odisha coast. The present study on zooplankton will act as baseline information for future environmental assessment purpose as this kind of studies are meagre in this coast.

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