Available online at: www.mbai.org.in doi: 10.6024/jmbai.2013.55.1.01715-10

Seasonal variation of zooplankton abundance and composition in Gopalpur creek: a tropical tidal backwater, east coast of India

Biraja Kumar Sahu[1], S. K. Baliarsingh, S. Srichandan and K.C. Sahu*
Dept. of Marine Sciences, Berhampur University, Berhampur-760007, Odisha, India
[1]ANCOST, National Institute of Ocean Technology, Port Blair, A & N Islands, India.

*Correspondence e-mail: kalicsahu@rediffmail.com

Received: 23 Jan 2012, Accepted: 25 May 2013, Published: 30 May 2013

Original Article

Abstract
Zooplankton abundance and composition was studied in Gopalpur creek in premonsoon, monsoon and post monsoon season with some hydrographic parameters. Water temperature, salinity and chlorophyll a has shown significant variation ($p<0.01$) among seasons while pH has shown significant variation ($p<0.01$) among stations. A total of 45 zooplankton groups/taxa were observed in which the copepods formed the dominant group in all seasons. The average biomass was higher in premonsoon but no significant variation of biomass was observed among seasons and stations. Zooplankton biomass correlated positively with water temperature and salinity. No correlation was found between chlorophyll a and zooplankton biomass. Zooplankton composition was found dissimilar in the three seasons. Cumaceans, a hyperbenthic fauna were found only in post monsoon season.

Keywords: *Zooplankton, seasonal, Gopalpur creek, east coast of India.*

Introduction

Zooplankton plays a major role in the functioning and the productivity of aquatic ecosystems through its impact on the nutrient dynamics and its key position in the food web (Keister *et al.*, 2012). Many species of zooplankton can be used as biological indicators for water pollution, water quality and eutrophication (Bonnet and Frid, 2004). Zooplankton communities are highly influenced by spatio-temporal variations in hydrochemical parameters and physical forces (Bianchi *et al.*, 2003). Species composition and seasonal variation in plankton densities are important in determining the trophic level of lakes and lagoons. In some monitoring models, the relationship between phytoplankton and zooplankton is employed (Tallberg *et al.*, 1999). The evaluation of phytoplankton and zooplankton together allows one to establish connections between fish fauna and their development in the habitat (Baykal *et al.*, 2006).

Information with respect to the plankton of the coastal waters along Odisha coast are meager and mostly limited to Chilika lake (Devasundaram and Roy, 1954; Sewell, 1913; Patnaik, 1973), Rushikulya estuary (Gouda and Panigrahy, 1995), Bahuda estuary (Mishra and Panigrahy, 1999), Burhabalanga estuary (Ramaiah *et al.*, 1996) and coastal waters off Rushikulya estuary (Sahu *et al.*, 2010). The present study focuses on seasonal abundance and composition of zooplankton of Gopalpur creek. The study area is receiving pollutants from Gopalpur township and nearby hatcheries. The output of this study will act as a reference for researchers and coastal developers involved in environmental impact assessment studies.

Material and methods

Study area

Gopalpur creek is a backwater biotope present in the Gopalpur-on-Sea coastal area of southern coast of Odisha. It is situated between latitude 19º 16′ 22″ N - 19º 15′ 39″ N and longitude 84º 54′ 0.6″ E - 84º 55′ 15″ E. It joins Bay of Bengal through an inlet. The locations of five sampling sites (1 to 5) are indicated in Fig .1. Rainfall in this area though confined to monsoon seasons with peak in August and September, rain due to tropical cyclones is common. The average annual rainfall is 1,210 mm (Mishra *et al*., 2001). Semidiurnal tidal pattern is witnessed in the study area (Gouda and Panigrahy, 1993). In summer, the inlet intermittently closes due to formation of sand bar. However seawater enters into the creek by means of seepage through porous sandbar which was reported earlier (Choudhury and Panigrahy, 1991). In addition to this, seawater entering into the creek during high tide was observed. The study area receives freshwater runoff in monsoon and onset of postmonsoon by means of a small tributary *"Nandia Nala"*. This area is having immense importance due to its capture (marine fishes) and culture (shrimp) fishing activities (Choudhury and Panigrahy, 1991). The creek environment is influenced by many anthropogenic activities such as sewage discharge, agricultural runoff, oil spills due to regular mechanized fishing boat movements and tourism.

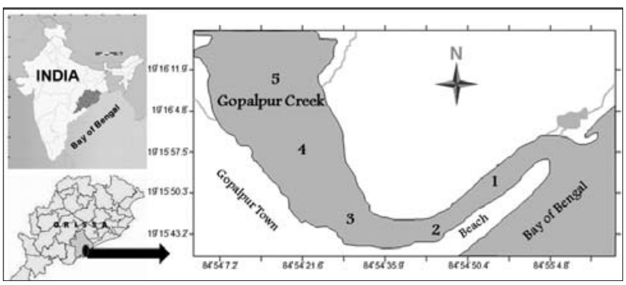

Fig.1 Map showing sampling stations in the study area

Sampling description

Three sampling surveys, each were carried out during premonsoon (PRM), monsoon (MON) and post-monsoon (POM) of 2010. The above seasons [PRM (Mar-Jun), MON (July-Oct), POM (Nov-Feb)] were classified according to the onset and termination of southwest monsoon which is the climatic factor of the study area. At each station, surface water samples were collected using a clean plastic bucket. Air and water temperature were measured using a centigrade thermometer of ±0.1º C accuracy. The pH of the water sample was recorded by a digital field pH meter (Model Eutech pH scan 2) with ±0.1 accuracy. Water samples for estimation of salinity, dissolved oxygen (DO) and chlorophyll a (Chl-a), were collected in separate containers and were transported to the laboratory for analysis. Transparency was measured during sampling with a secchi disc and expressed in meters. Zooplankton samples were collected at each station by horizontal hauling of a conical plankton net (mesh size of 120μm), fitted with a flowmeter (HydroBios) by towing from a mechanized fishing boat for 5 minutes. Plankton samples were preserved in 5% neutralized formaldehyde.

Laboratory analysis

Salinity was estimated following the Knudsen's titrimetric method (APHA, 2005). DO was determined following Winkler's titration method. Chl-a was estimated by adopting spectrophotometric method (Strickland & Parson, 1972). Zooplankton biomass was determined by volume displacement method. The sample was filtered by using a net cloth. The residue was soaked by blotting paper for extra water. Then the residue was transferred to a measuring cylinder with known volume of water. The increase in volume of water gives the volume of zooplankton. It is expressed in ml/m^3. For zooplankton diversity and abundance, samples were sub-sampled by using Folsom plankton splitter and the sub-sample volume was made up to 100ml. An aliquot of 5ml was taken by using stempel pipette and observed under stereo microscope for identification and counting. The volume of water filtered through the net is calculated from the flowmeter readings. The population density is expressed in Nos./100m^3 The relative abundance was computed from total density and the density of each group/taxa. For identification, standard literature such as Newell and Newell (1977) and Conway *et al*. (2003) were referred.

Data analysis

To evaluate seasonal differences, the observation period was classified into three seasons: Pre-Monsoon (PRM), Monsoon (MON) and Post monsoon (POM). Hydrographic and biological parameters were subjected to analysis of variance (ANOVA) to see any significant variation among seasons and stations. Correlation analysis was applied to understand the parameters that covary with each other.

Results and discussion

Hydrographic parameters

The basic hydrographic parameters such as air temperature, water temperature, salinity and pH showed visible temporal variation (Fig. 2). The mean values of these parameters are given in Table 1 for PRM, MON and POM. Air and water temperature were less in monsoon season due to southwest monsoon (Fig. 2.a & b) and followed the trend PRM>POM>MON and similar trend was also observed by

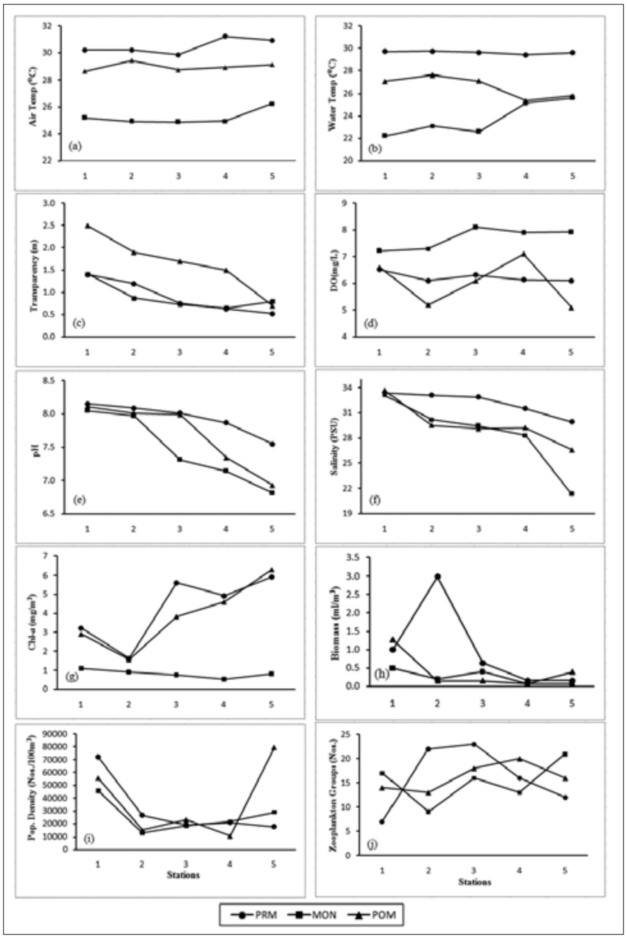

Fig.2 Stationwise and seasonwise variation of hydrographic and biological parameters (PRM: Premonsoon, MON: Monsoon, POM: Post monsoon)

Mitra *et al*., 1990. Spatial variation in water temperature at the stations might be influenced by viable intensity of prevailing streams and the resulting mixing of seawater (Reddi *et al*., 1993). Transparency of the creek ranged from 0.52 to 2.5 m (Avg. 1.1 m) with higher transparency in post monsoon (Fig. 2.c). The average salinity was found maximum in premonsoon period (32.19 PSU) and minimum in monsoon season (28.48 PSU). Similar trend was also observed by other authors (Achary *et al*., 2010; Mitra *et al*., 1990) (Table 1). Station wise, salinity values decreased towards inner creek in all the three seasons (Fig. 2.f). The salinity values found to be in conformity with the observations of Choudhury and Panigrahy (1991). Monsoon season showed lower pH due to southwest monsoon rain water inflow and it was less towards inner creek that receives land runoff water first (Fig 2.e). DO values ranged from 5.10 to 8.10 mg/L (Avg 6.65 mg/L) with high concentration in monsoon period (Fig. 2.d).

Chlorophyll a concentration was found to be higher in both PRM and POM than MON (Fig 2.g). Similar trend in Chl-a is also reported by several authors (Sarupria *et al*., 1998; Sridhar *et al*., 2010). Chl-a concentration ranged from 1.63 to 5.93 mg/m^3 (Avg 4.27 mg/m^3), 0.54 to 1.11 mg/m^3 (Avg 0.83 mg/m^3), 1.56 to 6.32 (Avg 3.85 mg/m^3) in PRM, MON and POM respectively (Table. 1). Station wise chlorophyll a concentration increased from outer creek to inner creek.

Zooplankton biomass and density

Zooplankton biomass ranged from 0.16 to 3.00 ml/m^3 (Avg 0.99 ml/m^3) in premonsoon, 0.08 to 0.50 ml/m^3 (Avg. 0.25 ml/m^3) in monsoon and 0.08 to 1.28 ml/m^3 (Avg 0.42ml/m^3) in post monsoon season (Table 1 and Fig. 2.h). The average biomass was higher in premonsoon but no significant variation of biomass was observed among seasons as well as among stations (Table 2). Zooplankton biomass correlated positively with water temperature and salinity (Table 4). Water temperature and salinity exhibited significant seasonal variation ($p<0.01$). Zooplankton density ranged

Table 1. Range and average (Avg) of hydrographic and biological parameters

	PRM				MON				POM			
Parameters	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
Air Temp (°C)	29.8	31.2	30.5	0.57	24.9	26.3	25.2	0.58	28.6	29.4	29.0	0.32
Water Temp (°C)	29.4	29.7	29.6	0.13	22.2	25.6	23.8	1.53	25.4	27.6	26.6	0.96
Transparency (m)	0.5	1.4	0.9	0.4	0.65	1.41	0.9	0.3	0.7	2.5	1.7	0.6
Salinity (PSU)	29.95	33.41	32.19	1.44	21.33	33.1	28.48	4.37	26.61	33.67	29.63	2.54
pH	7.55	8.15	7.93	0.24	6.81	8.05	7.46	0.54	6.93	8.11	7.68	0.52
DO (mg/L)	6.10	6.52	6.24	0.18	7.22	8.10	7.69	0.40	5.10	7.10	6.02	0.87
Chlorophyll-a (mg/m3)	1.63	5.93	4.27	1.8	0.54	1.11	0.83	0.21	1.56	6.32	3.85	1.79
Biomass (ml/m3)	0.16	3.00	0.99	1.18	0.08	0.50	0.25	0.19	0.08	1.28	0.42	0.50
Density (Nos./100m3)	17603	72100	31287	23081	12700	45899	25519	12825	10345	79533	36692	29780
Groups/Taxa (Nos.)	7	23	16	7	9	21	15	4	13	20	16	3

Min: Minimum, Max: Maximum, Avg. Average, SD: Standard Deviation from 17603 to 72100 Nos./100m^3 (Avg 31287 Nos./100m^3) in premonsoon, 12700 to 45899 Nos./100m^3 (Avg 25519 Nos./100m^3) in monsoon and 10345 to 79533 Nos./100m^3 (Avg 36692 Nos./100m^3) in post monsoon (Table 1 and Fig. 2.i). Higher density was observed in post monsoon season. There was significant variation in density among stations (p$<$0.05) rather than seasons (Table 2). Chlorophyll a has not shown any correlation with biomass or density (Table 4).

Table 2. One way ANOVA results of hydrographic and biological parameters.

	Among seasons		Among Stations	
Parameters	F	Sig.	F	Sig.
Water Temp	31.171	.000	.400	.805
Transparency	4.399	.037	2.098	.156
Salinity	9.190	.004	1.461	.285
pH	1.441	.275	6.364	.008
DO	12.993	.001	.348	.840
Chlorophyll a	8.106	.006	.842	.529
Biomass	1.357	.294	1.035	.436
Density	.296	.749	3.583	.046

Significant values ($p < 0.05$) are given in bold.

Table 4. Correlation matrix of hydrographic and biological parameters

	Trans parency-	AT	WT	Salinity	pH	DO	Chl-a	Biomass	Density
Trans-parency	1								
AT	.113	1							
WT	.376	.865**	1						
Salinity	.641**	.686**	.932**	1					
pH	.572*	.343	.693**	.808**	1				
DO	-.219	-.772**	-.753**	-.610**	-.339	1			
Chl-a	-.152	.745**	.500*	.317	-.018	-.628**	1		
Biomass	.257	.286	.544*	.597**	.434	-.193	-.119	1	
Density	.205	.134	.262	.318	.057	-.285	.210	.252	1

*p$<$0.05, **p$<$0.01

Zooplankton composition

A total of 45 zooplankton groups/taxa were identified (Table 3). Zooplankton population density (Nos./100m^3) and relative abundance (%) during premonsoon, monsoon and post monsoon are presented in Table 3. In premonsoon, it ranged from 7 to 23 Nos. (Avg 16 Nos.) (Table 1 and Fig. 2.j). Copepods were 27622 Nos./100m^3 (80.65%) followed by prawn larvae (2.78%), zoea larvae (2.63%), isopods (1.54%). Fish eggs and larvae were found 321 and 15 Nos./100m^3 respectively. In monsoon, the zooplankton group ranged from 9 to 21 Nos. (Avg. 15 Nos.). Copepods were 20368 Nos./100m^3 (69.04%) followed by caridean larvae (4.05%) and mysis larvae (2.47%). Fish eggs and fish larvae were found to be 79 and 56 Nos./100m^3 respectively. In post monsoon, the zooplankton group ranged from 13 to 20 Nos. (Avg 16 Nos.). Copepods were 31292 Nos./100m^3 (76.42%) followed by isopods (3.11%) and veliger larvae of bivalve (2.60%). Cumaceans, a hyperbenthic fauna were found only in post monsoon season. Tintinnids, medusae, siphonophores, chaetognaths, polychaetes, copepods, isopods, cladocera, ostracods, euphausiids, mysis larvae, *Lucifer* spp., prawn larvae, gastropods, bivalve larvae, appendicularia, fish eggs and fish larvae were observed in all seasons while foraminifera, ctenophore, amphipod, calyptosis (euphausiid larvae), brachiopod etc. were found in premonsoon season only. Abundance of copepod was found to be higher in PRM followed by POM and MON.

Copepods were the dominant taxa similar to the earlier reports from west coast (Padmavati and Goswami, 1996) and east coast of India (Mishra and Panigrahy, 1999; Sahu *et al*., 2010). The high zooplankton density during premonsoon and post monsoon season could be related to the stable hydrographical condition while low density during the monsoon season was attributed to heavy flood and freshwater inflow (Damotharan *et al*., 2010). The zooplankton density showed significant variation among stations. This might be due to change in salinity profile from inner part to outer part of the backwater. Chaetognaths, an active plankton predator (Feigenbaum and Maris, 1984) were observed in high abundance during post monsoon than other seasons. This high abundance coincided with high abundance of copepods indicating active predation in post monsoon season. Copepods form an important food item for chaetognaths (Saito and Kiørboe, 2001) and they play an important role in energy transfer to higher trophic levels

Table 3. Zooplankton population density (Nos./100m3) and relative abundance (%) during Premonsoon (PRM), Monsoon (MON), Post monsoon (POM)

	PRM	%	MON	%	POM	%
Foraminifera	122	0.36	-	-	-	-
Tintinnids	18	0.05	31	0.10	19	0.05
Medusae	163	0.47	207	0.70	480	1.17
Siphonophores	399	1.16	71	0.24	40	0.10
Ctenophores	7	0.02	-	-	-	-
Chaetognaths	36	0.11	142	0.48	741	1.81
Polychaetes	19	0.06	250	0.85	190	0.46
Polychaete larvae	-	-	22	0.07	111	0.27
Copepods	27622	80.65	20368	69.04	31292	76.42
Copepod nauplii	286	0.84	683	2.32	74	0.18
Amphipods	30	0.09	-	-	-	-
Isopods	529	1.54	279	0.94	1273	3.11
Cladocerans	127	0.37	552	1.87	419	1.02
Ostracods	91	0.27	670	2.27	63	0.15
Euphausiids	155	0.45	14	0.05	227	0.55
Euphausiid larvae	119	0.35	-	-	-	-
Mysids	-	-	200	0.68	-	-
Mysis larvae	59	0.17	729	2.47	148	0.36
Lucifer spp.	55	0.16	700	2.37	198	0.48
Protozoea of Lucifer	-	-	693	2.35	305	0.74
Sergestids	-	-	-	-	118	0.29
Cumaceans	-	-	-	-	667	1.63
Caridean larvae	205	0.60	1194	4.05	612	1.49
Brachyuran zoea larvae	281	0.82	371	1.26	215	0.52
Zoea larvae	901	2.63	-	-	-	-
Megalopa larvae	10	0.03	14	0.05	10	0.02
Anomuran larvae	-	-	-	-	933	2.28
Zoea larvae of Elamena sp. (spider crab)	-	-	32	0.11	-	-
Alima larva of Squilla	-	-	-	-	20	0.05
Penaeid prawn	954	2.78	142	0.48	533	1.30
Barnacle nauplii	-	-	369	1.25	46	0.11
Cirripede larvae	36	0.11	78	0.26	27	0.07
Brachiopod larvae	466	1.36	-	-	-	-
Gastropods	21	0.06	39	0.13	147	0.36
Gastropod larvae	79	0.23	258	0.87	773	1.89
Bivalve larvae	21	0.06	23	0.08	1064	2.60
Lamellibranch	62	0.18	-	-	-	-
Lamellibranch larvae	20	0.06	488	1.65	-	-
Thecosomata	496	1.45	337	1.14	-	-
Pteropods	18	0.05	-	-	-	-
Ascidian larvae	15	0.04	50	0.17	-	-
Appendicularians	490	1.43	330	1.12	14	0.03
Salpa	-	-	28	0.10	10	0.02
Fish eggs	321	0.94	79	0.27	44	0.11
Fish larvae	15	0.04	56	0.19	133	0.33
Total	34248	100	29500	100	40948	100

(Bone *et al*., 1991). It has been found that approximately 10-30% of the copepod biomass is transferred by this pathway through chaetognath biomass (Pierrot-Bults, 1996).

The population dynamics of zooplankton with its environmental parameters is focused in this study. The study reveals that the water temperature and salinity varied significantly ($p<0.01$) among seasons while pH varied significantly ($p<0.01$) among stations. Since pH is an important mortality factor for zooplankton community (Lukaszewski, 1999), such a significant alteration in pH is to be studied further to know any anthropogenic influence. The study further reveals a temporal significant chlorophyll a variation ($p<0.01$) rather than a spatial. Zooplankton composition was found to be dissimilar in the three seasons. Out of the 45 zooplankton groups/taxa recorded, the copepods were found to be the dominant group in all the seasons. Although average biomass was higher in premonsoon, there was no significant variation among seasons and stations. Cumaceans, a hyperbenthic fauna were found only in post-monsoon season. As the present study is a seasonal quantitative approach of zooplankton dynamics, the causes of their spatio-temporal variations can be the future line investigation. But what controls the season wise and station wise fluctuation in zooplankton abundance and species composition should be further studied in relation to environmental and anthropogenic factors.

References

Achary, M. S., G. Sahu, A. K. Mohanty, M. K. Samatara, S. N. Panigrahy, M. Selvanayagam, K. K. Satpathy, M. V. R. Prasad and R. C. Panigrahy. 2010. Phytoplankton abundance and diversity in the coastal waters of Kalpakkam, East Coast of India in relation to the environmental variables. *The Bioscan* Special Issue, 2: 553-568.

APHA. 2005. Standard methods for the examination of water and waste water.21st Edition. American Public Health Association, Water Work Association, Water Pollution Control Federation, Washington DC, 1368 pp.

Baykal, T., S. Salman and I. Acikgoz. 2006. The Relationship between Seasonal Variation in Phytoplankton and Zooplankton Densities in HirfanlÝ Dam Lake *Turk. J. Biol.*, 30: 217-226

Bianchi, F., F. Acri, A. Bernardi, A Berton, A. Boldrin, E. Camatti, D. Cassin and A. Comaschi. 2003. Can plankton communities be considered as bioindicators of water quality in the lagoon of Venice? *Mar. Pollut. Bull.*, 46: 964-971.

Bone, Q., H. Kapp, and A.C. Pierrot-Bults. 1991. Introduction and relationships of the group. In: Q. Bone, H. Kapp, and A.C. Pierrot-Bults (Eds.) *The biology of Chaetognaths*. Oxford, Oxford University Press, p.1-4.

Bonnet, D and C.S. Frid. 2004. Copepod species considered as indicators of water mass influence and changes: results from a Northumberland coastal station. *ICES. J. Mar. Sc.*, 61: 485-491.

Choudhury, S.B. and R.C. Panigrahy. 1991. Seasonal distribution and behavior of nutrients in the creek and coastal waters of Gopalpur, east coast of India. *Mahasagar*. 24 (2): 81-88.

Conway, D.V.P., R.G. White, J. Hugues-Dit-Ciles, , C.P. Gallienne and D.B. Robins. 2003. Guide to the coastal and surface zooplankton of the south-western Indian Ocean. Occasional Publications. Marine Biological Association of the United Kingdom (15) 354pp.

Damotharan, P., N.V. Perumal and M. Arumugam. 2010. Seasonal variation of physicochemical characteristics in point Callimore Coastal waters (South East Coast of India). *Middle. East. J. Sci. Res.*, 6(4): 333-339.

Devasundaram, M.P. and J.C. Roy. 1954. A preliminary study of the plankton of Chilka lake for the years 1950-51. In: Proceeding of symposium on Marine and Freshwater Plankton in the Indo-Pacific, Bangkok, 1-7 Jan. 1954. FAO Indo-Pacific Fisheries Council, Bangkok, and UNESCO, Jakarta. p. 48-54.

Feigenbaum, D., and R. C. Maris. 1984. Feeding in the Chaetognatha. In : Harold Barnes, AD Ansell and RN Gibson (Eds.) *Oceanography and Marine Biology Annual Review*, Vol.22 University College London Press. P.343–392.

Gouda, R. and R.C. Panigrahy. 1993. Monthly variation of some hydrographic parameters in the Rushikulya Estuary. *Mahasagar,* 26(2): 73-85.

Gouda, R. and R. C. Panigrahy. 1995. Zooplankton ecology of the Rushikulya estuary, East coast of India. *J. Aqua. Cult. Trop.*, 10(3): 201-211.

Keister, J.E., Bonnet, D., Chiba, S., Johnson, C.L., Mackas, D.L., and Escribano, R. 2012. Zooplankton population connections, community dynamics, and climate variability. *ICES J. Mar. Sci.*, 69: 347-350.

Lukaszewski, Y., Arnott, S.H., and Frost, T.M. 1999. Regional versus local processes in determining zooplankton community composition of Little Rock Lake, Wisconsin, USA. *J. Plankton. Res.*, 21: 991-1003.

Mishra, P, P.K. Mohanty, A.S.N. Murty and T. Sugimoto. 2001. Beach profile studies near an artificial open-coast port along south Orissa, east coast of India. *J. Coast. Res.* Special Issue 34:164–171.

Mishra, S. and R. C. Panigrahy. 1999. Zooplankton ecology of the Bahuda estuary (Orissa), east coast of India. Indian. *J. Mar. Sci.*, 28(3): 297-301.

Mitra, A., K.C. Patra and R.C. Panigrahy. 1990 .Seasonal variations of some hydrographical parameters in a tidal creek opening into the Bay of Bengal. *Mahasagar.*, 23: 55-62.

Newell, G.E. and R. C. Newell. 1977. Marine Plankton- A Practical Guide. Hutchinson Educational Ltd., London, 244 pp.

Padmavati, G. and S. C. Goswami. 1996. Zooplankton ecology in the Mandovi-Zuari estuarine system of Goa, West coast of India. Indian. *J. Mar. Sci.*, 25(3): 268-273.

Patnaik, S. 1973. Observations on the seasonal fluctuation of plankton in the Chilka Lake. *Indian J. Fish.*, 20(1): 43-55.

Pierrot-Bults, A. C. 1996. Chaetognatha. In: Gasca, R. & Suárez, E., (Eds.) *Introducción al estudio del zooplancton marino*. México, ECOSUR/CONACYT. p.529-596.

Ramaiah, N., A. Chatterji and M. Madhupratap. 1996. A study on the zooplankton of the Burhabalanga estuary, Orissa coast. *Proc.Indian Natnl. Sci. Acad.*, B62, 1:1-4.

Reddi, K. R., N. Jayaraju, I . Suriyakumar and K. Sreenivas. 1993. Tidal fluctuation in relation to certain physico-chemical parameters in Swarnamukhi River estuary, East coast of India. *Indian. J. Mar. Sci.* 22: 232-234.

Sahu, G., A. K. Mohanty, B. Singhasamanta, D. Mahapatra, R.C. Panigrahy, K.K. Satpathy and B.K. Sahu. 2010. Zooplankton Diversity in the Nearshore waters of Bay of Bengal, Off Rushikulya Estuary. *IUP J. Environ. Sci.*, 4 (2): 61-85.

Saito, H., and T. Kiørboe. 2001. Feeding rates in the chaetognath Sagitta elegans: effects of prey size, prey swimming behavior and small- scale turbulence. *J. Plankton.* Res., 23(12): 1385–1398.

Sarupria J.S. and R. M. S. Bharagava. 1998. Seasonal distribution of chlorophyll-a in the exclusive economic zone (EEZ) of India. *Indian. J. Mar. Sci.*, 27: 292-297.

Sewell, R. B. S. 1913. Notes on plankton from the Chilka Lake. *Rec. Indian. Mus.*, 9(5): 338-340.

Sridhar, R., T. Thangaradjou, and L. Kannan. 2010. Spatial and temporal variations in phytoplankton in coral reef and seagrass ecosystems of the Palk Bay, southeast coast of India. *J. Environ. Biol.*, 31(5) 765-771.

Strickland, J. D. H. and T.R. Parson. 1972. A practical handbook for seawater analysis. *Bull. Fish. Res. Board. Can.*, 167: 1-311.

Tallberg, P, J. Horppila, A. Vaisane and L. Nurminen. 1999. Seasonal succession of phytoplankton and zooplankton along a trophic gradient in eutrophic lake-implications for food web management. *Hydrobiologia.*, 412: 81-94.