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Seasonal Availability And Abundance Of Zooplankton In The South Bengal Coast Of West Bengal, India

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Abstract

An intra-seasonal study on zooplankton abundance was carried on in the Bay of Bengal to elucidate the fertility of the area as a new fishery ground. The purpose of this study was to determine the composition, abundance, and distribution of zooplankton in 3 separate points of the Bay of Bengal. Point 'A' is Petuaghat, point B is Junput, and point C is Sankarpur. All samples were collected by oblique towing with a hand-net of 20 µm mesh size from these three separate areas. The zooplankton community consists of 22 species. Copepoda was the most dominant group both in terms of species number and abundance. Moreover, widely distributed groups in these areas were: copepods, protozoan zooplankton, arrow worms, larvaceans, cnidarians, ostracods, and the liaceans. According to the distribution pattern of major constituents of the zooplankton community indicated that the most productive site of these three areas is Petuaghat (Point A). Salinity regimes & the accessibility of phytoplankton prey prejudiced the distribution and composition of the zooplankton species assemblage.

Keywords: Zooplankton, Bay of Bengal, Species composition, Abundance, Distribution.

Introduction:

The coastal ecosystem is the most productive in the world contributing significantly to the coastal economy (Panda et. al., 2012). Coastal phytoplankton contributes about 15% to global oceanic production (Biswas et. al. 2009) and marine primary production yields more than 90 billion kg/yr. of food worldwide (Carter et. al., 2005). Phytoplankton controls the primary production phenomenon of the ocean. Zooplanktons are key components in the aquatic food chain and play an important role in the planktonic food web acting as a link between primary producers and higher trophic levels (Liu et al., 2013; Sahu et. al., 2013; Abdullah Al et. al., 2018). Zooplankton dramas a vital role in food web dynamics of marine ecosystem & biogeochemical cycling (Castonguay et al., 2008). Zooplankton habitually feeds on the phytoplankton and in turn produce food for animals of higher trophic levels (D'Alelio et al., 2016). Among zooplankton components, several copepod species have been employed as indicators of pollution (i.e., *Acartia clause*) and increasing temperature identified species are *Acartia tonsa* and *Acartia hudsonica* (Hirst et. al., 1999; Bianchi et. al., 2003; Mulyadi, 2004; Hooff, 2006) and copepod distribution pattern was used as an indicator of salinity variation (Thompson et. al., 2012; Vineetha et. al., 2015; Abu Hena et. al., 2016; Fontana et. al., 2016). The abundance and composition of zooplankton depend on a range of environmental conditions including water temperature, transparency, food availability, and nutrient supplies (Arashkevich et. al., 2002; Lo et. al., 2004; Sul-livan et. al., 2007; Abu Hena et. al., 2016; Abdullah Al et. al.,2018) The physical parameters are of special interest as it controls the mixing of water. Mixing of water makes nutrients available in various layers of the ocean and their availability for the pelagic organisms. There is a direct correlation between hydrology and plankton.

The present study area is highly influenced by seasonal changes in saline water. Aquaculture and anthropogenic activities also significantly contribute to changes in the coastal ecosystem of the Bay of Bengal. Therefore, comprehending the dynamic environmental parameters and their influence on zooplankton productivity is extremely important as it plays a vital role in the food web and coastal productivity. This will also aid in assessing the water quality in the future. Hence, the present study aims to find out the seasonal variation in zooplankton diversity, composition, and abundance in response to various environmental parameters.

Materials & Methods:

The present investigation was carried out from April 2019 to March 2021 on the South Bengal coast of the Bay of Bengal, India. Sampling was carried out at 3 transect points (point A; Petuaghat , point B; Junput and point C; Sankarpur) by using GPS (Garmin) fixed locations, starting from the coast to 2 km into the sea. Surface water samples were collected at these points during winter, summer, and monsoon season in the year 2019-21. The surface water samples from 0.5 m water depth were collected with the help of a Niskin water sampler for various physicochemical and biological parameter analyses. Physicochemical (Temperature, pH, Salinity, DO, Free CO_2) and biological (zoo-plankton) parameters were analysed using standard methods. Temperature, pH was measured on the site using a precision thermometer (0.01°) and systronics pH meter respectively. For estimation of dissolved oxygen, water samples were fixed on the site by Modified Winkler's method, and the remaining water samples were stored in Tarson nutrient containers and transferred to ice-cold condition (4°C) for laboratory analysis. Salinity, dissolved oxygen, free CO_2 were analysed following the standard method (Strickland et. al. 1972).

Plankton (zoo) samples were collected from the coast to 3 km into the sea, i.e., from all the 3 stations, using a plankton net (pore size 20 µm, mouth area 0.3 m^2). One portion of the water sample collected was filtered for species identification and the other part was used for physicochemical parameter analysis. For taxonomic identification, the samples were fixed in 3% Lugol's solution followed by the addition of 4% buffered formaldehyde. Microscopic observations were done and captured in the form of an image with the help of a light microscope (Magnus MLX with a camera at 40x magnification). Zoo-plankton group identification was carried out by following the standard identification procedure (Balkis et. al. 2004., Dolan et. al., 2003, Kasturirangan et. al., 1963, Tanaka et. al., 1956).

Statistical analysis:

To study the biological diversity (H) and species richness (S) Shannon and Wiener's (1949) equations were used in word excel (2010). For Shannon diversity index analysis community ecology package R (Oksanen et al., 2016) was used.

Results:

The Physico-chemical parameters of the environment that drive the succession of zooplankton diversity were depicted seasonally in Table 1. a, 1. b, and 1. c. The Physico-chemical parameters showed a significant difference between seasons.

Table1. a. Seasonal variation in water quality parameters along with the study 'point A' during 2019-21.

Water Quality Parameters	Summer Season Average Value	SD	Monsoon Season Average Value	SD	Winter Season Average Value	SD
Temperature(°C)	27.7	± 0.2	27.8	± 0.5	22.4	± 0.1
pH	7.6	± 0.1	8.9	±0.05	7.9	± 0.03
Salinity (ppt)	30	± 5.0	12.8	± 1.0	28	± 0.6
DO(mg/L)	4.7	± 0.5	7.5	± 0.4	8.7	± 0.2
Free CO_2(mg/lit)	3.0	± 0.2	2.0	± 0.2	2.5	± 0.2

Table1. b. Seasonal variation in water quality parameters along the study 'point B' during 2019-21.

Water Quality Parameters	Summer Season Average Value	SD	Monsoon Season Average Value	SD	Winter Season Average Value	SD
Temperature(°C)	28.7	± 0.3	26.8	± 0.4	22.4	± 0.1
pH	7.5	± 0.1	8.5	± 0.05	7.9	± 0.4
Salinity (ppt)	31	± 3.0	13.7	± 1.0	28	± 0.4
DO(mg/L)	4.7	± 0.5	6.5	± 0.5	8.7	± 0.2
Free CO_2(mg/lit)	3.1	± 0.3	2.1	± 0.2	2.6	± 0.2

Table1. c. Seasonal variation in water quality parameters along with the study 'point C' during 2019-21.

Water Quality Parameters	Summer Season Average Value	SD	Monsoon Season Average Value	SD	Winter Season Average Value	SD
Temperature(°C)	28.7	± 0.2	27.7	± 0.5	23.4	± 0.2
pH	7.3	± 0.1	8.9	± 0.2	7.9	± 0.2
Salinity (ppt)	32	± 2.0	13.7	± 1.0	29	± 0.6
DO(mg/L)	4.5	± 0.5	7.5	± 0.4	8.6	± 0.2
Free CO_2(mg/lit)	3.1	± 0.2	2.1	± 0.2	2.6	± 0.2

The abundance of zooplankton in three different seasons has been tabulated in Table 2. From the tabulated data it was observed that in the summer season Copepod nauplii showed maximum abundance followed by *Euterpina acutifrons* and *Microsetella rosea* (Fig. 1). In the monsoon season, *Amphorellopsis acuta* showed the highest percentage of abundance followed by *Acrocalanus longicornis* and *Clausocalanus parapergens* (Fig. 2). In the winter season, Copepod nauplii showed utmost abundance followed by *Metacylis tropica* and

Microsetella rosea (Fig. 3). The Copepod nauplii showed high abundance in both the summer and winter seasons.

Table 2. Zooplankton abundance in coastal waters of South Bengal coast in 2019-2021.

Sl. No.	Observed Species	Summer Season Abundance		Monsoon Season Abundance		Winter Season Abundance	
		d./m^3%	%	d./m^3	%	d./m^3	%
1	*Acrocalanus longicornis*	0	0	700	10.32	0	0
2	*Amphorellopsis acuta*	0	0	800	11.79	0	0
3	*Bivalve veliger*	0	0	0	0	40	1.71
4	*Candacia truncata*	0	0	600	8.84	0	0
5	*Clausocalanus parapergens*	0	0	630	9.28	0	0
6	*Copepod nauplii*	150	27.78	950	14	500	20.94
7	*Euterpina acutifrons*	95	17.59	0	0	0	0
8	*Eutintinnus conicus*	0	0	0	0	80	3.42
9	*Favella campanula*	20	3.70	285	4.21	130	5.56
10	*Globigerina rubescense*	0	0	300	4.42	0	0
11	*Leprotintinnus nordqvisti*	0	0	0	0	90	3.85
12	*Leprotintinnus simplex*	0	0	0	0	85	3.63
13	*Metacylis jorgensenii*	10	1.85	0	0	75	3.21
14	*Metacylis tropica*	0	0	0	0	300	12.82
15	*Microsetella rosea*	80	14.81	0	0	280	11.97
16	*Oncaea scottodicarloi*	70	12.96	0	0	0	0
17	*Tintinnopsis acuminata*	60	11.11	400	5.89	220	9.40
18	*Tintinnopsis acuminata*	0	0	0	0	80	3.42
19	*Tintinnopsis cylindrica*	0	0	0	0	140	5.98
20	*Tintinnopsis dadayi*	0	0	0	0	60	2.56
21	*Tintinnopsis gracilis*	36	6.48	0	0	70	2.99
22	*Tintinnopsis tocantensis*	20	3.70	500	7.37	35	1.50

Figure 1. Zooplankton abundance (Percentage) in the summer season.

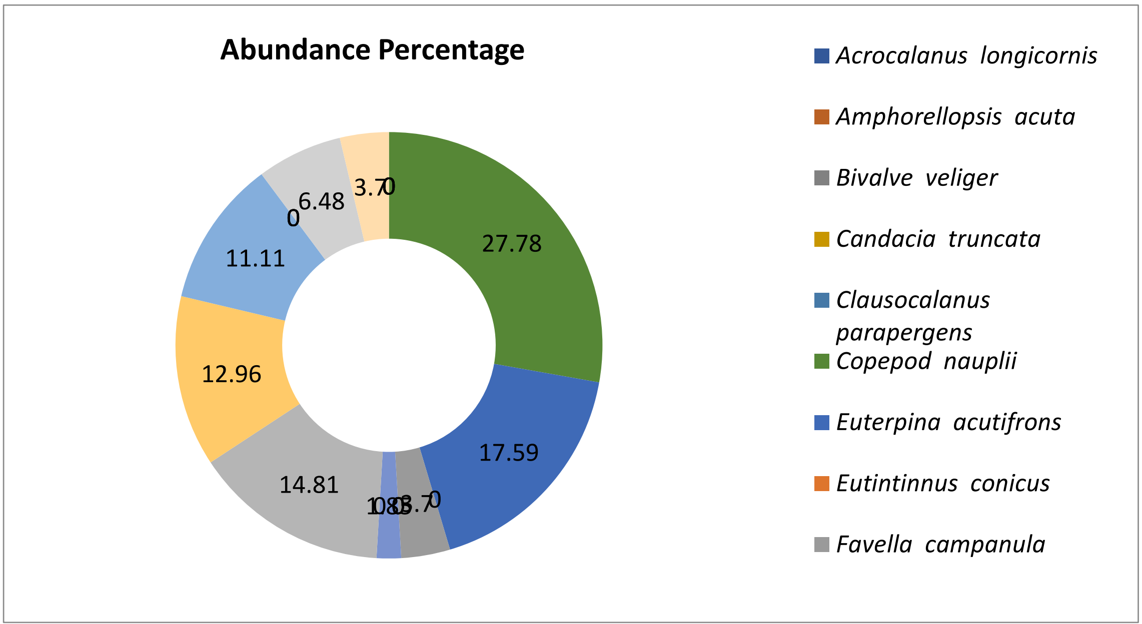

Figure 2. Zooplankton abundance (Percentage) in monsoon season.

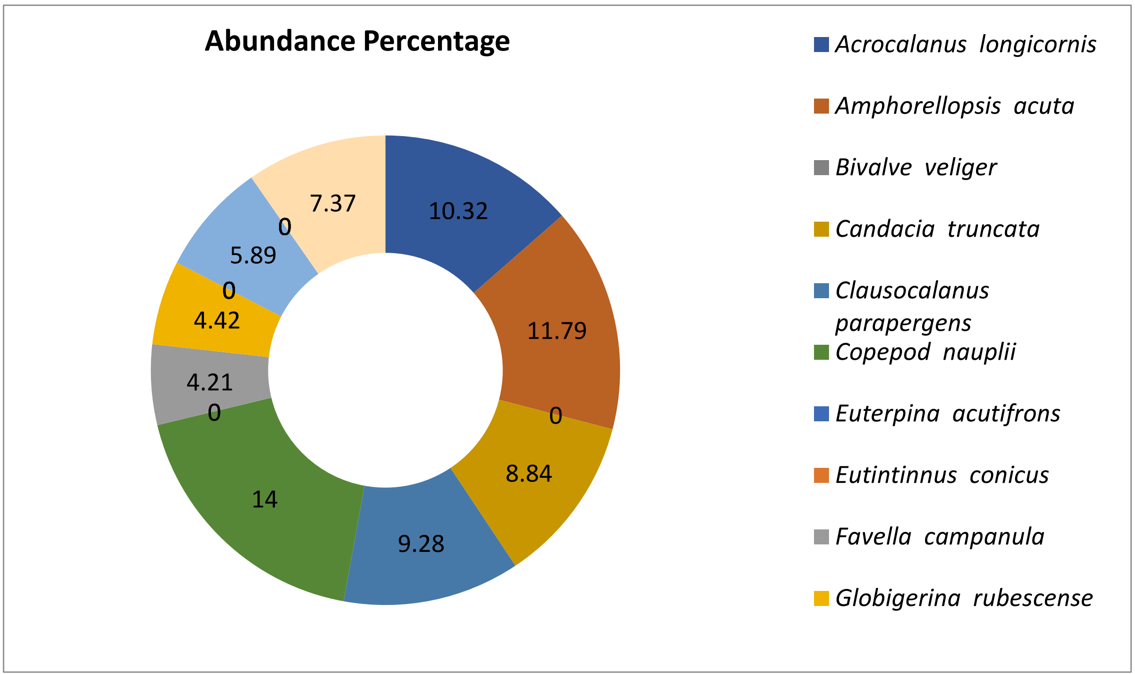

Figure 3. Zooplankton abundance (Percentage) in the winter season.

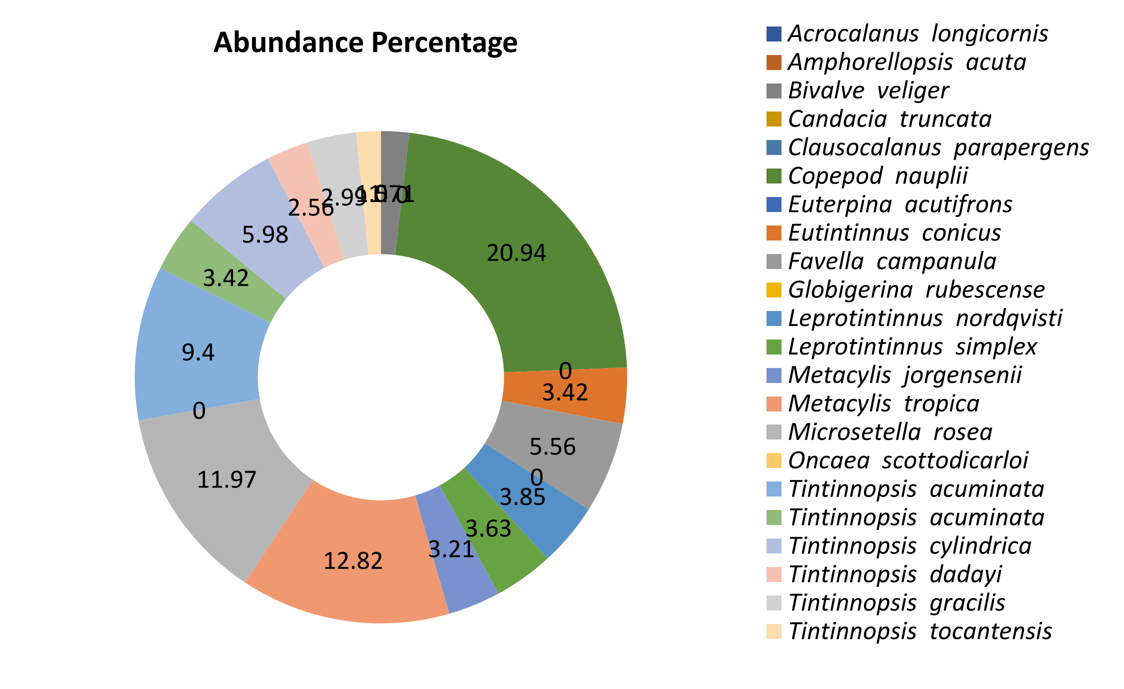

Table 3. Shannons-Weiner and Simpson Index in different seasons.

Serial No.	Seasons	Shannons-weiner Index (H)	(E)	Simpson Index (D)
1.	**Summer Season**	1.95018	0.630913	0.835421
2.	**Monsoon Season**	2.1272	0.688182	0.873821
3.	**Winter Season**	2.41249	0.780478	0.885544

*H = Shannon-weiner index, E = Evenness, D = Simpson Index.

Based on the observation it was seen that in the winter season the Shannon-Weiner index (H) was higher than the other two seasons and also shows greater evenness (E), so it can be concluded that in the winter season the plankton shows higher diversity and evenness. And the summer season shows a lower H value and E value (Table 3). Simpson diversity index shows higher value in the winter season and lower in the summer season, so the winter season shows higher diversity of the zooplankton species (Table 3).

Discussion:

The average water temperature value varied from 22.4 ± 0.1˚C to 28.7 ± 0.3˚C. Temperature is one of the important parameters for the ocean environment as it stimulates the organism's life & physicochemical parameters of marine (Sukumaran et al., 2013). In the winter season from the northeastern region, strong wind velocity decreases the water temperature (Dasha S. et. al 2019**)**. the pH of the water was alkaline throughout the year, but more alkalinity was observed 8.9 ± 0.2 during monsoon season. South Bengal coastal water was found to be more transparent during the winter season in comparison to summer and monsoon seasons. Due to moderate salinity, high transparency of water, nitrate availability, and comparatively higher N: Si : P ratio bring about the high density of phytoplankton and diversity of species (Dasha S. et. al 2019**)**. The salinity was maximum in summer value 32 ± 2 ppt and minimum in monsoon season value 12.8 ± 1 ppt. Low salinity throughout the monsoon period could be due to greater freshwater influx from the rivers (Dasha S. et. al 2019). The salinity of water plays a foremost role as a preventive factor subsequently it panels the floral and faunal diversity of coastal water ecosystems (Govindasamy et al., 2000; Sridhar et al., 2006; Subramanian and Mahadevan, 1999). During the winter season, the water was more oxygen concentration of 8.7 ± 0.2 mg/L, and a minimum dissolved oxygen concentration of 4.7± 0.3 was reported in the summer season.

During the study, 22 micro-zooplankton and meso-zooplankton species were observed (Table 2). The zooplankton diversity was higher in the winter season (15 species) followed by monsoon (12 species) and summer (9 species) season. The values of the Shannons-Weiner and Simpson Index also support the observations statistically**.** In the monsoon season higher abundance of zooplankton could be due to a higher organic nutrients load. Nutrients play a significant role in phytoplankton distribution and growth (Dasha S. et. al 2019). The observed average zooplankton number was 2340 ± 324 ind./m^3, 540 ± 40 ind./m^3, and 6786 ± 625 ind./m^3 in winter, summer, and monsoon season, respectively. Similarly in the winter season, zooplankton biomass also showed significant negative relation with temperature and salinity. In a study, it was detected that turbidity of water and the worn-out phytoplankton community is measured as the regulating factors for zooplankton community in western [Jyothibabu et. al. 2008] and central [Fernandes, V. 2008] Bay of Bengal. There are several factors like SST, water salinity, nitrate, silicate, etc. that are found to show a good correlation with zooplankton abundance **(**Dasha S. et. al 2019**)**. The Bay of Bengal (BoB) is an exceedingly dynamic ecosystem, obtains voluminous freshwater emancipation from rivers and over excessive precipitation. The coast is susceptible to cyclonic storms and provisions rich biodiversity. Hence, the current study will make available a reference line information on photosynthetic efficiency, hydrology, and zooplankton community dispersal along the south coast, along with it will provide a plankton model.

Conclusion:

The present investigation summarizes the seasonal fluctuation in physicochemical parameters and zooplankton diversity at South Bengal coastal waters seasonally. South Bengal coastal waters are highly subjective to saline water. Low salinity during the monsoon season could be due to a high influx of freshwater from the river, and any change in salinity due to precipitation and evaporation can induce changes in the distribution pattern of flora and fauna of the coastal ecosystem. Higher zooplankton abundance could be due to the high organic nutrient load in the monsoon season. Oxygen concentration was also observed to be below in summer due to the poor solubility of oxygen.

However, the seasonal nutrient and other physicochemical parameters were found to vary concerning freshwater inflow. This can in far that along the Odisha coast monsoon freshwater inflow contributes nutrient load. Whereas the coast received these nutrients through freshwater inflow, bottom sediment ejection. From the observations, it was concluded that on the South Bengal coast a total of 22 zooplankton indicated that the coastal water has rich plankton diversity. River discharge makes the bay water turbid, limited light, and less productive during a certain period.

References:

Abrantes, F. and Sancetta, C., Diatom assemblages in surface sediments reflect coastal upwelling off Southern Portugal, Oceanol. Acta, 1985, vol. 8, no. 1, pp. 7– 12. DOI 0399-1784/85/0176

Achary, M.S., Panigrahi, S., Satpathy, K.K., Sahu, G., Mohanty, A.K., Selvanayagam, M., and Panigrahy, R.C., Nutrient dynamics and seasonal variation of phytoplankton assemblages in the coastal waters of southwest Bay of Bengal, Environ. Monit. Assess., 2014, vol. 186, no. 9, pp. 5681–5695.https://doi.org/10.1007/s10661-014-3812-8

Balkis, N., Tintinnids (Protozoa: Ciliophora) of the Buyukcekmece Bay in the Sea of Marmara, Sci. Mar., 2004, vol. 68, no. 1, pp. 33–44. https://doi.org/10.3989/scimar.2004.68n133

Bashar, M.A., Waidbacher, and Ullah, S.M., Environ- mental assessment of industrial effluents, sewage sludges and harbour activities on river quality, Bangladesh,J. Asian Soc. Bangladesh Sci., 2005, vol. 31, pp. 1–14.

Berdalet, E., Marrase, C., Estrada, M., Arin, L., and Maclean, M., Microbial community responses to nitrogen and phosphorus deficient nutrient inputs: Micro- plankton dynamics and biochemical characterization, J. Plankton Res., 1996, vol. 18, no. 9, pp. 1627–1641. https://doi.org/10.1093/plankt/18.9.1627

Biswas, H., Dey, M., Ganguly, D., De, T.K., Ghosh, S., and Jana, T.K., Erratum to: Comparative analysis of phytoplankton composition and abundance over a two- decade period at the land–ocean boundary of a tropical mangrove ecosystem, Estuaries Coasts, 2009, vol. 33, pp. 395–398.https://doi.org/10.1007/s12237-009-9245-x

Carter, C.M., Ross, A.H., Schiel, D.R., Howard-Wil- liams, C., and Hayden, B., In situ microcosm experiment on the influence of nitrate and light on phyto- plankton community composition, J. Exp. Mar. Biol. Ecol., 2005, vol. 326, pp. 1–13.https://doi.org/10.1016/j.jembe.2005.05.006

Castonguay, M., Plourde, S., Robert, D., Runge, J. A., and Fortier, L., 2008. Copepod production drives recruitment in a marine fish. Canadian Journal of Fisheries and Aquatic Science, 65 (8): 1528-1531.

Chandramohan, P. and Sreenivas, S., Diel variation in zooplankton populations in mangrove ecosystem at Gadesu Canal south east cost of India, Indian J. Mar. Sci., 1998, vol. 27, pp.486–488.

Choudhury, A.K. and Pal, R., Phytoplankton and nutrient dynamics of shallow coastal stations at Bay of Bengal, Eastern Indian coast, Aquat. Ecol., 2009, vol. 44, pp. 57–71.https://doi.org/10.1007/s10452-009-9259

D'Alelio, D., Libralato, S., Wyatt, T., and d'Alcalà, M. R., 2016. Ecological-network models link diversity, structure and function in the plankton food-web. Sci Rep 6

De Pauw, N. and Naessens-Foucquaert, E., Nutrient- induced competition between two species of marine diatoms, Hydrobiol. Bull., 1991, vol. 25, no. 1, pp. 23–27. https://doi.org/10.1007/BF02259585

De, T.K., De, M., Das, S., Chowdhury, C., Ray, R., and Jana, T.K., Phytoplankton abundance in relation to cultural eutrophication at the land-ocean boundary of Sunderbans, NE Coast of Bay of Bengal, India, J. Environ. Stud. Sci., 2011, vol. 1, pp. 169–180. https://doi.org/10.1007/s13412-011-0022-3

Desikachary, T.V. and Prema, P., Diatoms from the Bay of Bengal, in Atlas of Diatoms, Desikachary, T.V., Ed., Madras: Madras Science Foundation, 1987, vol. 3, pp. 1–10.

Desikachary, T.V. and Ranjithadevi, K.A., Marine fos- sil diatom from India and Indian Ocean Region, in Atlas of Diatoms, Desikachary, T.V., Ed., Madras: Madras Science Foundation, 1986, vol. 1, pp. 1–77.

Dolan, J.R., Landry, M.R., and Ritchie, M.E., The species-rich assemblages of tintinnids (marine plank- tonic protists) are structured by mouth size, ISME J., 2013, vol. 7, no. 6, pp. 1237–1243. https://doi.org/10.1038/ISMEJ.2013.23

Dortch, Q. and Whitledge, T.E., Does nitrogen or sili- con limit phytoplankton production in the Mississippi River plume and nearby regions?, Cont. Shelf Res., 1992, vol. 12, no. 4, pp. 1293–1309. https://doi.org/10.1016/0278-4343(92)90065-R

Dwivedi, S.N. and Chaubey, A.K., Indian Ocean large marine ecosystems: need for national and regional framework for conservation and sustainable develop- ment, in Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability, and Management, Sherman, K., Okemwa, E., and Ntiba, M., Eds., Cambridge: Black- well, pp. 327–333.

FAO Yearbook, vol. 72: Fishery Statistics: Catches and Landings, 1991, Rome: FAO, 1993.

Fernandes, V., Ramaiah, N., Paul, J.T., Sardessai, S., Jyoti Babu, R., and Gauns, M., Strong variability in bacterioplankton abundance and production in central and western Bay of Bengal, Mar. Biol., 2007, vol. 153, pp. 975–985.

Fernandes, V., The effect of semi-permanent eddies on the distribution of mesozooplankton in the central Bay of Bengal, J. Mar. Res., 2008, vol. 66, no. 4, pp. 465–488.

Fernandes, V., The effect of semi-permanent eddies on the distribution of mesozooplankton in the central Bay of Bengal, J. Mar. Res., 2008, vol. 66, no. 4, pp. 465–488.

Gomes, H.R., Goes, J.I., and Saino, T., Influence of physical processes and freshwater discharge on the sea- sonality of phytoplankton regime in the Bay of Bengal, Cont. Shelf Res., 2000, vol. 20, pp. 313–330.

Goswami, S.C., Zooplankton Methodology, Collection and Identification: A field manual, Dhargalkar, V.K. and Ingole, B.S., Eds., New Delhi: National Institute of Oceanography, 2004.

Govindasamy, C., Kannan, L., Jayapaul, A., 2000. Seasonal variation in physico-chemical properties and primary production in the coastal water biotopes of Coramandal coast, India. J. Environ. Biol. 21 (1), 17.

Hecky, R.E., and Kilham, P., Nutrient limitation of phytoplankton in freshwater and marine environments: a review of recent evidence on the effects of enrich- ment, Limnol. Oceanogr., 1988, vol. 33, pp. 796–822.

Jyothibabu, R., Madhu, N.V., Maheswaran, P.A., Jay- alakshmy, K.V., Nair, K.K.C., and Achuthankutty, C.T., Seasonal variation of microzooplankton (20–200 m) and its possible implications on the vertical carbon flux in the western Bay of Bengal, Cont. Shelf Res., 2008, vol. 28, no. 6, pp.737–755.

Jyothibabu, R., Madhu, N.V., Maheswaran, P.A., Jayalakshmy, K.V., Nair, K.K.C., and Achuthankutty, C.T., Seasonal variation of microzooplankton (20–200 μm) and its possible implications on the vertical carbon flux in the western Bay of Bengal, Cont. Shelf Res., 2008, vol. 28, no. 6, pp.737–755. 45.

Jyothibabu, R., Vinayachandran, P.N., Madhu, N.V., Robin, R.S., Karnan, C., Jagadeesan, L., and Anjusha, A., Phytoplankton size structure in the Southern Bay of Bengal modified by the summer monsoon current and associated eddies: Implications on the vertical biogenic flux, J. Mar. Syst., 2014, vol. 143, pp. 98–119. https://doi.org/10.1016/j.jmarsys.2014.10.018

Kasturirangan, L.R., A Key for the Identification of the More Common Planktonic Copepod of Indian Coastal Waters, Indian National Committee on Oceanic Research Publication, no. 2, Panikkar, N.K., Ed., New Delhi: Council of Scientific and Industrial Research, 1963, pp. 1–87.

Kobayashi, F. and Takahashi, K., Distribution of dia- toms along equatorial transect in the western and central Pacific during La Niña conditions, Deep Sea Res., Part II, 2002, vol. 49, pp. 2801–2821. https://doi.org/10.1016/S0967-0645(02)00059-0

Li, K., Yin, J., Huang, L., Tan, Y., and Lin, Q., A com- parison of the zooplankton community in the Bay of Bengal and South China Sea during April-May, 2010, J. Ocean Univ. China, 2017, vol. 16, no. 6, pp.1206– 1212.

Mackenzie, F.T., Ver, L.M., Sabine, C., Lane, M., and Lerman, A., C, N, P, S global biogeochemical cycles and modeling of global change, in Interactions of C, N, P and S, Biogeochemical Cycles and Global Change, Wollast, R., Mackenzie, F.T., and Chou, L., Eds., Ber- lin: Springer-Verlag, 1993, pp. 1–61. https://doi.org/10.1007/978-3-642-76064-8_1

Madhav, V.G. and Kondalarao, B., Distribution of phytoplankton in the coastal waters of east coast of India, Indian J. Mar. Sci., 2004, vol. 33, no. 3, pp. 262– 268.

Madhu, N.V., Jyothibabu, R., Maheswaran, P.A., Ger- son, V.J., Gopalakrishnan, T.C., and Nair, K.K., Lack of seasonality in phytoplankton standing stock (Chlo- rophyll a) and production in the western Bay of Bengal, Cont. Shelf Res., 2006, vol. 26, pp. 1868–1883. https://doi.org/10.1016/j.csr.2006.06.004

Panda, S.S., Dhal, N.K., and Panda, C.R., Phyto- plankton diversity in response to abiotic factors along Orissa coast, Bay of Bengal, Int. J. Environ. Sci., 2012, vol. 2, no. 3, pp. 1818–1832.

Pandiyarajan, R.S., Shenai-Tirodkar, P.S., Ayajuddin, M., and Ansari, Z.A., Distribution, abundance and diver- sity of phytoplankton in the inshore waters of Nizam- patnam, South East coast of India, Indian J. Geo-Mar. Sci., 2014, vol. 43, no. 3, pp. 348–356.

Panigrahi, S., Wikner, J., Panigrahy, R.C., Satapathy, K.K., and Acharya, B.C., Variability of nutrients and phyto- plankton biomass in a shallow brackish water ecosystem (Chilika Lagoon, India), Limnology, 2009, vol. 10, no. 2, pp. 73–85. https://doi.org/10.1007/s10201-009-0262-z

Paul, J.T., Ramaiah, N., and Sardessai, S., Nutrient regimes and their effect on distribution of phytoplankton in the Bay of Bengal, Mar. Environ. Res., 2008, vol. 66, no. 3, pp. 337–344. https://doi.org/10.1016/j.marenvres.2008.05.007

Paul, J.T., Ramaiah, N., Gauns, M., and Fernandes, V., Preponderance of a few diatom species among the highly diverse microphytoplankton assemblages in the Bay of Bengal, Mar. Biol., 2007, vol. 152, no. 1, pp. 63–73.

Porra, R.J., Thompson, W.A., and Kriedemann, P.E., Determination of accurate coefficients and simultane- ous equations for assaying chlorophylls a and b extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absorption spectroscopy, Biochim. Biophys. Acta, 1989, vol. 975, no. 3, pp. 384–394. https://doi.org/10.1016/S0005-2728(89)80347-0

Pramanik, D.S. and Mohanty, S.S., Seasonal variation of primary productivity of Bay of Bengal at Chandipur on Sea, Odisha, Int. J. Fish. Aquat. Stud., 2016, vol. 4, no. 2, pp. 331–336.

Quasim, S.Z., Biological productivity of Indian Ocean, Indian J. Mar. Sci., 1977, vol. 6, pp. 122–137.

Saumya Dasha , Safet Padhanb , Geetanjali Rajhansb , Pradipta Kumar Mohapatrab , Ranjit Kumar Sarangic , Dipti Rauta , Biswaprajna Mohantya , Susri Nayaka , and Lipika Patnaik, Abundance and Diversity of Plankton in the Coastal Waters of Chandipur, Bay of Bengal.Russian Journal of Marine Biology, 2019, Vol. 45, No. 3, pp. 252–261.

Srichandan, S., Kim, J.Y., Bhadury, P., Barik, S.K., Muduli, P.R., Samal, R.N., Pattnaik, A.K., and Ras- togi, G., Spatiotemporal distribution and composition of phytoplankton assemblages in a coastal tropical lagoon: Chilika, India, Environ. Monit. Assess., 2015, vol. 187, p. 47.

Sridhar, R.T., Thangaradjou, S., Senthil Kumar, Kannan, L., 2006. Water quality and phytoplankton characteristics in the Palk Bay, Southeast coast of India. J. Environ. Biol. 27 (3), 561—566.

Strickland, J.D. and Parsons, T.R., A Practical Hand- book of Seawater Analysis, Bulletin 167, Ottawa: Fisher- ies Research Board of Canada, 1972.

Subramanian, B., Mahadevan, V., 1999. Seasonal and diurnal variations of hydro biological characters of coastal waters of Chennai (Madras) Bay of Bengal. Indian J. Mar. Sci. 28 (4), 429—433.

Subramanyan, R., The Dinophyceae of the Indian Sea, J. Mar. Biol. Assoc. India, 1968, vol. 3, pp. 118–133.

Sukumaran, M., Muthukumaravel, K., Sivakami, R., 2013. Seasonal variation in physico-chemical characteristics of Agniar Estuary, Southeast Coast of India. Asia Pac. J. Res. 2 (8), 108—120, http:// apjor.com/files/1376844720.pdf.

Tanaka, O., The pelagic copepods of the Izu region, middle Japan systematic account I. Families Calanidae and Eucalanidae, Publ. Seto Mar. Biol. Lab., 1956, vol. 5, no. 2, pp. 251–272.

Thangaradjou, T., Sarangi, R.K., Shanthi, R., Poorn- ima, D., Raja, K., Saravanakumar, A., and Balasubra- manian, S.T., Changes in nutrients ratio along the central Bay of Bengal coast and its influence on chlorophyll dis- tribution, J. Environ. Biol., 2014, vol. 35, pp. 467–477.

Tomas, C.R., Identifying Marine Phytoplankton, Lon- don: Academic, 1997.

Vinayachandran, P.N. and Mathew, S., Phytoplankton bloom in the Bay of Bengal during the northeast mon- soon and its intensification by cyclones, Geophys. Res. Lett., 2003, vol. 30, no. 11, p. 1572. https://doi.org/10.1029/2002GL016717