Dhaka Univ. J. Biol. Sci. **32**(2): 135-148, 2023 (July) DOI: https://doi.org/10.3329/dujbs.v32i2.67673

PLANKTON SEASONALITY AND ITS RELATIONSHIP WITH SOME PHYSICOCHEMICAL FACTORS IN SOUTH-EASTERN COASTS OF BAY OF BENGAL, BANGLADESH

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Key words: The Bay of Bengal, Plankton, Abundance, Diversity, Physicochemical factors.

Abstract

This study was conducted between January and December, 2014 in four sampling stations of the Bay of Bengal, namely Teknaf beach, Inani beach, St. Martin's Island and Sonadia Island. A total of 39 plankton species were recorded from 4 stations. Among those, 8, 3,2,14 and 2 species belonged to algae, protozoa, rotifera, copepods, and ostracods respectively. Copepoda was the most abundant zooplankton at all stations. The highest monthly density of plankton was 111.2 ind./l at Teknaf beach and the lowest was 5.6 ind./l at Sonadia Island of the Bay of Bengal. Some species such as, *Biddulphia* sp., *Coscinodiscus centralis,* copepod nauplii, *Canthocalanus pauper, Acrocalanus* spp., *Clausocalanus* spp., *Oithona spinirostris* were more abundant than other plankton. The plankton population showed positive correlation with physicochemical factors like water temperature and air temperature whereas negatively correlated with pH, DO, CO_2, salinity, acidity and alkalinity with a few exceptions.

Introduction

In Bangladesh, the recent evidences indicate that regional changes in climate, particularly temperature increase has already affected the ecosystems of the coastal Bay of Bengal (BoB)(1). The BoB connects a number of rivers along Cox's Bazar coast and during monsoon nutrients are added into the Bay of Bengal, which significantly affects the growth of phytoplankton primarily in the coastal regions. However, in the mid-pelagic the vertical distribution of phytoplankton effects primary productivity and balances energy flow in the tropic levels (Lampert *et al.*(2)). Thus up and down welling of nutrients play a significant and crucial role in the growth and population dynamics of phytoplankton upon which the grazing intensity and growth of zooplankton is dependent. So, as a whole the plankton composition can be used as bio-indicators for assessing the water quality particularly regarding the enrichment of nutrients. A functional top-down effects of energy thus helps the survival of other consumers and

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decomposers of the marine ecosystem. So far, relevant to the research works on plankton of the Bay of Bengal, only a few could be mentioned (Islam and Aziz, 1975a[3], Islam and Aziz, 1975b[4]; Sadia *et al.* 2022[5], Alam *et al*. 2021[6] and Alam *et al.* 2022[7]). The composition, abundance and diversity of plankton from the vast majority of the area of the BoB are still unknown. No significant research work has yet been carried out on the physicochemical parameters of water of BoB, Bangladesh. The present research has therefore been aimed to determine the composition, abundance, and diversity of plankton and their relationship with physicochemical factors of water covering the important coastal beaches of Inani, Teknaf, St. Martin's Island (East para), and Sonadia Island of BoB Cox's Bazar, Bangladesh.

Materials and Methods

Figure 1 represents the studied locations of the south eastern BoB namely, Inani and Teknaf beach and Sonadia and St. Martin's Island. The GPS values of the sampling stations have been presented in Table 1. The study stations are typical sandy beach and is visited daily by a number of tourists and affected by high and low tide sequences. In some protected area, characteristic dune vegetation may be seen. The collection of plankton samples for the present research was carried out from the vicinity of the beach as directed towards the sea. In-situ measurements of some physicochemical factors were also carried out at each study stations.

Table 1. Plankton sampling stations and their geographical locations.

Sl.	Study Stations	Upazila	Latitude	Longitude
1	Inani beach (Cox's Bazar)	Cox's Bazar Sadar	$21^0 14'137''$	$92^0 02'574''$
2	Teknaf beach	Teknaf	$20^0 50'784''$	$92^0 16'\ 296''$
3	St. Martin's Island (East Para)	Teknaf	$20^0 37'866''$	$92^0 19'648''$
4	Sonadia Island	Moheshkhali	$21^0 31'155''$	$91^0 53'864''$

Plankton and water samples were collected and analyzed bimonthly between January and December 2014 from Inani, Teknaf, Sonadia and St. Martin's Island. *In situ* measurements of sea water collected from the beach were carried out recording air and water temperature, pH, acidity, free-CO_2, dissolved oxygen (DO), alkalinity and salinity with help of Hach FF-3 kit (USA). At the same time 50 L of sea water was passed through a nylon plankton net (64 μm mesh size, Millipore corp., Bedford, MA) to collect the sample of phyto- and zooplankton. Triplicate samples were collected on each time of sampling at each station. The plankton concentrate volume collected in the sample bucket of the plankton net was 50 ml. The sample was immediately poured in a sample vial labeled and preserved with 4% buffered formaldehyde. All the samples were transported to the laboratory of the Department of Zoology, University of Dhaka for further analysis.

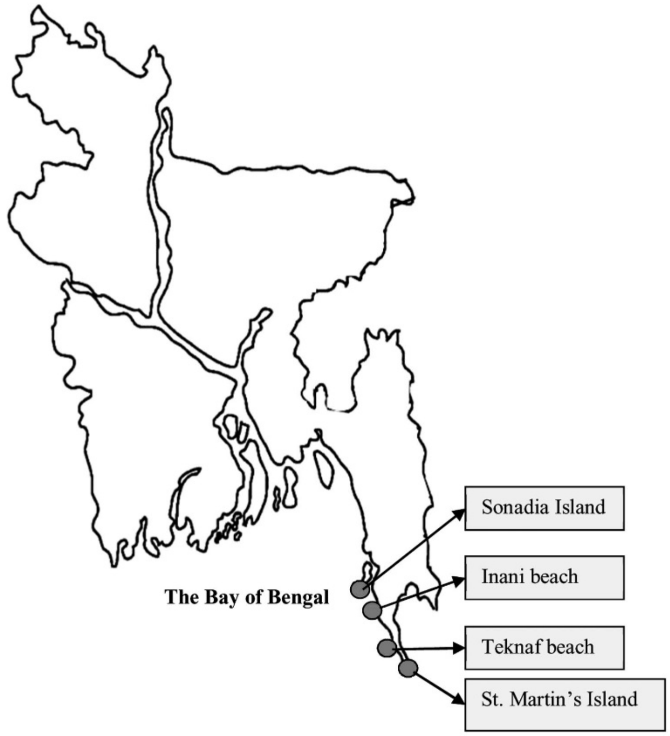


Fig.1. Study stations shown on a map of Bangladesh indicating the south eastern coast of the Bay of Bengal (BoB).

The qualitative and quantitative study of the plankton samples were carried out with the help of a compound microscope (Axioskop 40, Japan) and a standard Sedgeweak-Rafter Counting Chamber (SRCC) at 10 ×10. The specimen was identified up to genera or species level by consulting Ward and Whipple[8], Conway *et al.*[9], Sahu *et al.*[10]. Quantitative analysis of plankton was followed by the total count method. The number of plankton estimated per ml was calculated by adopting the following formula (Santhanam *et al.*[11]).

$$N = \frac{AxC}{L}$$

where,

N = the number of plankton/L

A = plankton concentrate volume (50 ml).

C = number of plankton counted in 1 ml sample with SRCC

L = amount of water (L) passed through plankton net (50 L).

The statistical analysis were done using Excel software package (version 10).

Results and Discussion

Physicochemical factors of water and its relationship with plankton: Air temperature was high (33^{0}C) in September in both Sonadia Island and Inani beach but lowest of this (22^{0}C) was recorded in Teknaf beach and St. Martin's Island in March (Figs 2-4). In the present study, among the four studied coastal aquatic ecosystems of the BoB, the populations of plankton were positively correlated with temperature (Table 2). So, the temperature ranges among the coastal waters are optimum for plankton growth and multiplication. It may be noted that an increases in air and water temperature included high microbial activity with faster nutrient regeneration which could also be well co-related with the both phyto- and zooplankton density. The result revealed that during study, air and water temperature were found to be responsible for total plankton increase at all four study sites. Mozumder *et al.*(12) observed inverse relationship between protozoan and water temperature.

High seawater pH (8.5) was recorded during March,May and September, in Inani and Teknaf beach and St. Martin's Island, respectively. Whereas the lowest record of pH (7.71) was obtained in March and July, respectively in Sonadia and St. Martin's Island (Figs 2-5). pH plays an important role on the suitability of water media for growth. Among the four marine aquatic environments of BoB, the plankton population were positively correlated with pH at Inani and Teknaf beach, whereas negatively corelated at St. Martin's Island and Sonadia Island (Table 2). Mozumder *et al*.(12) observed inverse relationship between protozoan population density and pH. Chowdhury *et al.*(13) found significant positive correlation among pH and with the zooplankton (the coefficient being 0.38).

In the present study high concentration of DO (11.6 mg/l) was recorded during March, at St. Martin's Island and but a lower value (3.7 mg/l) was recorded at Teknaf beach in November (Figs 3-4). This variation was due to winter cooling, which reduce microbial activity hence less production of organic matter prevailed in the community. Among the four marine environments, the populations of plankton were negatively correlated with DO except Sonadia Island (Table 2). Sahib(14) observed the direct correlation between highly saturated DO and zooplankton populations in Shendurni River, Kerela, India. But Chowdhury *et al.*(13) observed negative correlation between DO and zooplankton (coefficients being -0.26). Mozumder *et al*.(12) observed positive relationship between protozoan population and DO.

Free CO_2 was high (41.4 mg/L) in March, at Sonadia Island and a lowest CO_2 (7.6 mg/l) was recorded during May at St. Martin's Island (Figs 4-5). Among the four studied marine ecosystems, the population of zooplankton were negatively correlated with CO_2 except Teknaf beach (Table 2).

Salinity fluctuation in oceanic environment depends upon the concentration flux occurred in total solids (Boyd and Tucker,(15)). High salinity (41%) was recorded in January at Inani beach and St. Martin's Island. Whereas, it was low (16%) during

September at Sonadia Island (Figs 2-5). The increased value of salinity during the month of January was due to higher evaporation rate. Plankton density correleated negatively with salinity except Inani beach and St. Martin's Island where the relationships were positive (Table 2). Rajagopal *et al.*(16) observed negative correlation between zooplankton population and salinity. Kumar *et al.*(17) observed positive and high correlation between zooplankton population and salinity in aquatic environments of Karnataka, India.

High value of acidity (95 mg/l) was recorded during November at St. Martin's Island and low value (22 mg/l) during May at Sonadia Island (Figs 4-5). In the present study, zooplankton correlated negatively with acidity in all the stations except Sonadia Island (Table 2).

High value of alkalinity (119mg/l) was recorded during March at Teknaf beach but the alkalinity was low (28 mg/l) during July at Inani beach (Figs 2-3). Except Inani beach and St. Martin's Island, the populations of zooplankton correlated negatively with Alkalinity (Table 2).

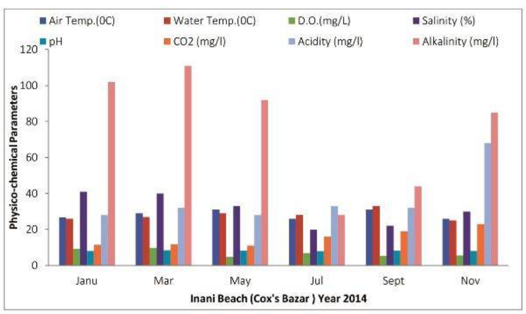


Fig. 2. Physicochemical factors of Inani Beach (Cox's Bazar).

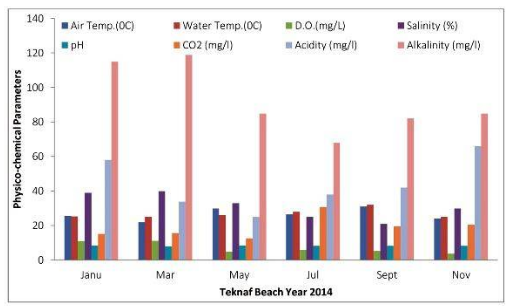


Fig. 3. Physicochemical factors of Teknaf Beach.

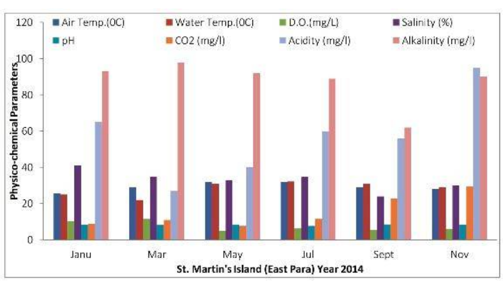


Fig. 4. Physicochemical factors of St. Martin's Island (East Para).

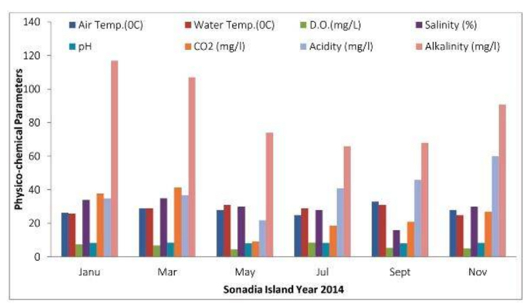


Fig. 5. Physicochemical factors of Teknaf Beach.

Biological analysis: The seasonal assemblage of plankton species was maximum at Inani beach in May consisting of population from algae, protozoa and ostracoda. While in September and November the population consisted of rotifera and copepoda respectively (Fig. 6). In contrast, the seasonal assemblages of plankton species were minimum in November for algae, July for protozoa, rotifera and copepoda and November for cladocera in the same study station. Furthermore, the sum of the assemblages of the plankton species was maximum (32 ind/l) in May and minimum (17.6 ind/l) in January.

Table 2. Showing correlation co-efficient computed between physicochemical factors of water and density of total plankton of four research stations.

Sl.	Relationship	Correlation co-efficient 'r'			
		Inani beach	Teknaf beach	St. Martin's Island	Sonadia Island
1	Air temp vs total plankton	0.542442	0.773184	0.794889	0.126965
2	Water temp vs total plankton	0.151759	0.530659	0.059471	0.260267
3	pH vs total plankton	0.349461	0.556044	-0.30712	-0.0316
4	DO vs total plankton	-0.5576	-0.46398	-0.06195	0.316882
5	CO_2vs total plankton	-0.28681	0.369403	-0.60173	-0.342
6	Salinity vs total plankton	0.021656	-0.59388	0.10199	-0.70794
7	Acidity vs total plankton	-0.10894	-0.5526	-0.75387	0.441201
8	Alkalinity vs total plankton	0.183545	-0.73929	0.382625	-0.71346

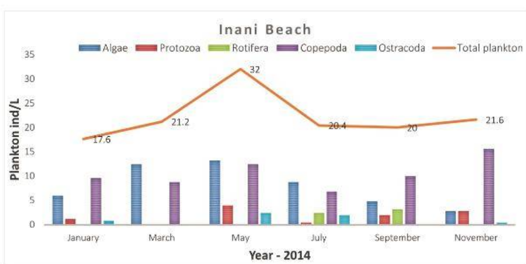


Fig. 6. Density variation of plankton groups and total plankton at Inani beach (Cox's Bazar).

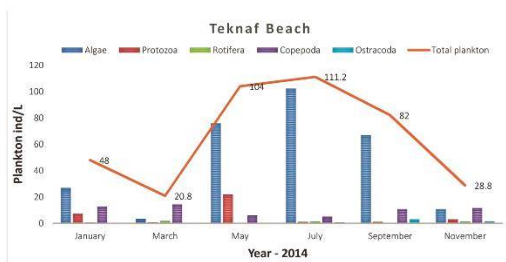


Fig. 7. Density variation of plankton groups and total plankton at Teknaf beach.

At Teknaf beach, the seasonality of different plankton group proportions showed maximum for phytoplankton, protozoa, rotifera, copepoda, and ostracoda in July, January, March and September respectively (Fig. 7). In contrast, the trend of seasonality for minimum population were for phytoplankton, and protozoa, rotifera, copepoda and ostracoda in March, January, July and January respectively. Furthermore, the sum of the assemblages of the plankton species was maximum (111.2 ind/l) in July and minimum (20.8 ind/l) in March.

At St. Martin's Island, the groupwise seasonality of plankton species were maximum for phytoplankton, protozoa, rotifera, copepoda and ostracoda in May, January, September, November and July respectively (Fig. 8). The minimum of the above mentioned trend was found for phytoplankton, protozoa, rotifera, copepoda, and ostracoda in November, May, March, July and January respectively. Furthermore, the sum of the assemblages of the plankton species was maximum (65.2 ind/l) in May and minimum (26 ind/l) in January.

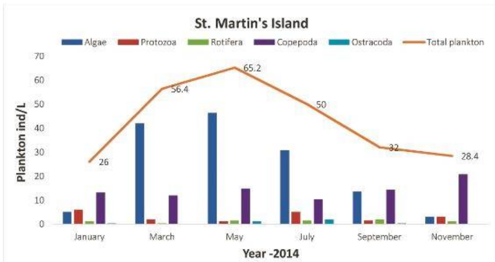


Fig. 8. Density variation of plankton groups and total plankton at St. Martin's Island.

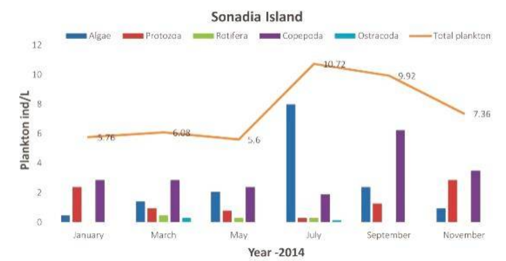


Fig. 9. Density variation of plankton groups and total plankton at Sonadia Island.

At Sonadia Island, the seasonality of different groups of plankton showed a trend in their maxima in July, November, March, September, and March for phytoplankton particularly diatom, protozoa, rotifer, and ostracoda respectively (Fig. 9). In contrast, their maxima followed a trend of phytoplankton, diatom, protozoa, rotifer, copepoda, ostracoda in January, November, July, May, and July respectively. Furthermore, the sum of the assemblages of the plankton species was maximum (10.72 ind/l) in July and minimum (5.6 ind/l) in May.

Results of the present investigation demonstrated that algae, protozoa, rotifera, copepoda, and ostracoda mainly constituted the plankton groups of studied coastal aquatic environments. The plankton species increased their abundance during summer (May - July), probably corresponding to the water quality, decaying vegetation, increased levels of nutrient in the sediment and higher abundance of bacteria in the aquatic environment during this time (Figs 6-9) In contrast, the abundance of plankton species decreased in winter (January, March and November), probably corresponding to low water temperature and high alkalinity (Figs 2-5). According to Platt *et al.* (18), during monsoon nutrients are injected to the mouth of the Bay of Bengal through river discharge, which significantly affects the growth of phytoplankton. In marine ecosystem physical process such as upwelling, down welling and terrestrial run off play significant role in nutrient composition in continental shelf, which affects the phytoplankton distribution and abundance.

Plankton collected from the four study stations of the Bay of Bengal across seasons could be identified to 39 species (Table 3). Among them, 16 species belonged to algae (Figs 10a-o), 4 species belonged to protozoa (Figs 11a-b), 2 species belonged to rotifera (Fig. 13a-b), 15 species were copepods (Figs 12a-f) and 2 from (Figs 14a-b, Table 3) ostracoda. Station wise, a total of 21 27, 26, and 19 species were recorded from Inani beach, Teknaf beach, St. Martin's Island and Sonadia Island respectively (Table 3). So, species diversity was higher at Teknaf beach than other sampling stations. Sahu *et al.*(19) recorded a total of 28 zooplankton taxa and Baliarsingh *et al*.(20) observed 94 species of phytoplankton of which diatom, dinoflagellate, green and blue-green algae constituted 71, 11,8, and 4 species respectively from coastal water of Gopalpur port, East coast of India. Alam *et al.*(21, 22) identified a total of 68 phytoplankton species under 22 genera and 34 species of zooplankton from different sampling stations in the adjacent marine area of St. Martin's Island of Bangladesh. Islam *et al*.(23) identified a total of 137 phytoplankton species from the south eastern coastal area of the BoB whereas, 115 species of diatoms from 44 genera, 15 species of dinoflagellates from 8 genera, 2 species of green algae from 2 genera, 4 species of cyanobacteria from 3 genera and 1 species of silicoflagellate.

Results show that, the copepods populations, however, were more abundant than other plankton groups in the all four studied coastal aquatic environments of the Bay of Bengal (BoB), and this was probably because of their ability to withstand and survive in varying physicochemical conditions prevailing at different seasons. Alam *et al.*(21) also found copepod as most abundant group. The ostracod populations were fewer in the studied coastal aquatic environment's surface water. Jitlang *et al.*(24) found both copepods and ostracods were abundant in the BoB. Fernandes and Ramaiah(25) also observed that copepods often dominate mesozooplankton communities in terms of abundance and biomass in the Bay of Bengal, as is the pattern in other parts of the world ocean. Temperature, chlorophyll-a, and seasonality are some factors believed to affect copepod diversity (Roy *et al.*(26), Rutherford *et al.*(27)). As suggested, copepods are ectotherms with short generation times, so warmer temperatures influence metabolic rates and indirectly affect diversity. The Bay of Bengal is a warm pool throughout the year with low chlorophyll-a that does not change markedly with seasons, and according to Woodd-Walker *et al.* (28), more species are evidenced to co-occur in such areas with lower seasonal changes in physical properties and primary productivity.

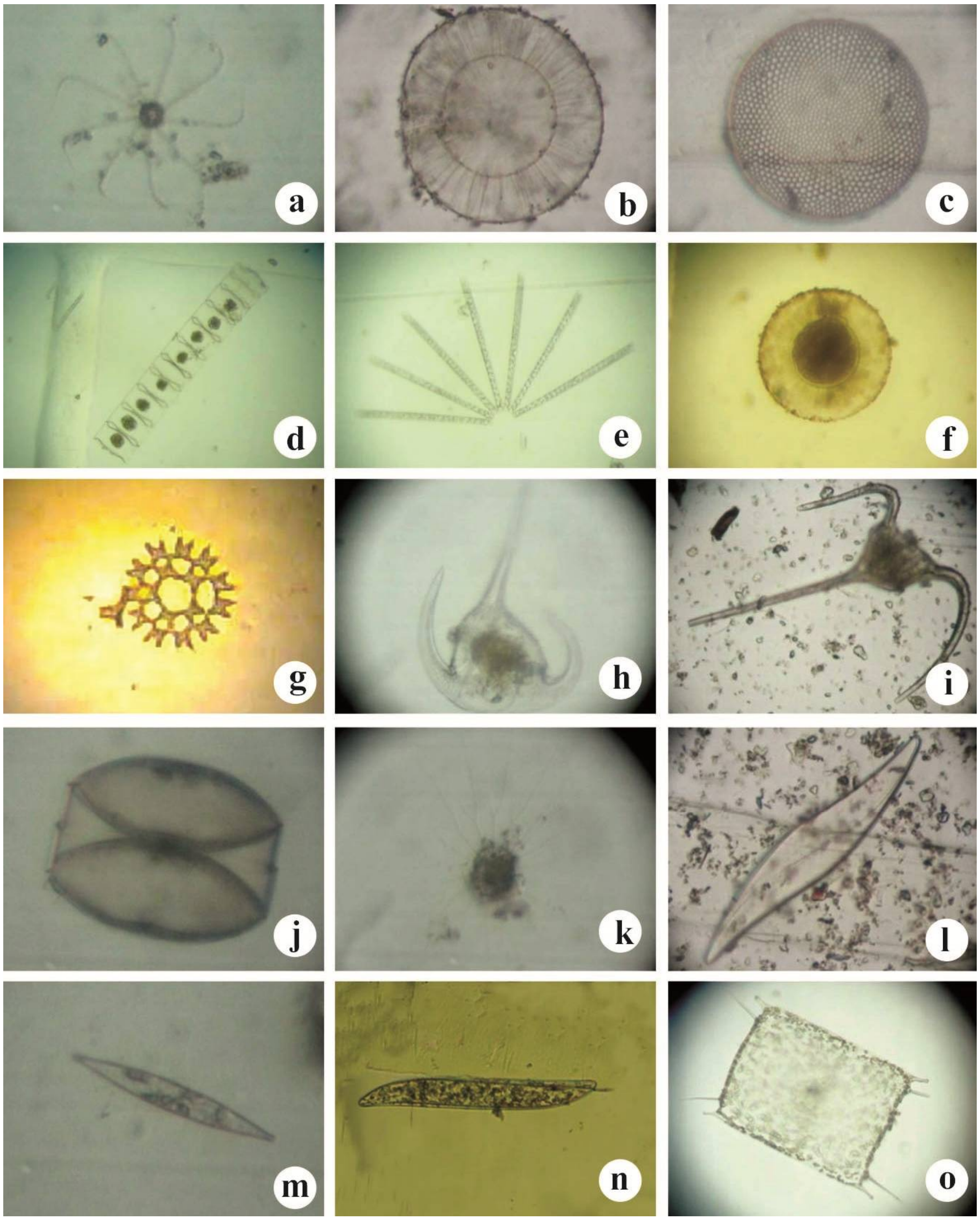
From the floristic and faunal standpoint of the four marine ecosystem, very little similarity has been observed. As a whole, six plankton taxa viz. *Coscinodiscus centralis,* Copepod nauplii, *Canthocalanus pauper, Acrocalanus* spp., *Clausocalanus* spp., *Oithona spinirostris* were found common in occurrence in all the four marine ecosystem. Some species such as, *Biddulphia* sp., *Coscinodiscus centralis,* Copepod Nauplii, *Canthocalanus pauper, Acrocalanus* spp., *Clausocalanus* spp., *Oithona spinirostris* were more abundant than other plankton species (Table 3). Alam *et al.*(21) found the species belonging to the genera *Oithona*, *Canthocalanus*, *Balanus*, *Euterpina* and *Microsetella* were most common in the plankton population of St. Martin's Island.

Results of the present study showed seasonal variation of plankton in the water of Inani beach, Teknaf beach, St. Martin's Island and Sonadia Island and correlation between plankton and physicochemical factors of water was also observed. Regular investigation of plankton density and physicochemical factors of water of The Bay of Bengal (BoB) should be analyze to determine its environmental and ecological status.

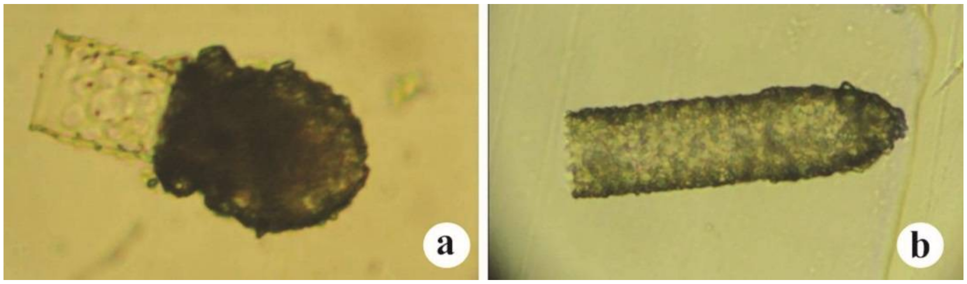
Table 3. Plankton and its distribution at different sampling stations of BoB.

	Group name	Genus/Species	Name of the study stations			
			Inani beach	Teknaf beach	St. Martin's Island	Sonadia Island
Phyto-plankton	Algae	*Bacteriastrum hyalinum*			+	
		Bacteriastrum delicatulum		+		
		Biddulphia sp.	+	+		+
		Bellerochea malleus			+	
		Ceratium declinatum		+		
		Ceratium trichoceros	+	+		
		Coscinodiscus centralis	+	+	+	+
		Cyclotella sp.	+			
		Pediastrum duplex	+			
		Planktoniella sol		+		
		Thalassiothrix fraunfeldii			+	
		Unidentified	+	+		
		Gyrosigma balticum	+	+		+
		Nitzschia sp.			+	
		Pleurosigma sp.	+	+		+
		Odontella sinensis	+			
		Hemidiscus hardmannianus			+	
Total Phytoplankton taxa (Algae)			**9**	**9**	**6**	**4**
Zoo-plankton	Protozoa	*Acanthochiasma* spp.		+	+	+
		Centrocubus spp.		+	+	+
		Codonellopsis ostenfeldi				+
		Tintinnopsis gracilis		+	+	
		Total Protozoan taxa	**0**	**3**	**3**	**3**
	Rotifera	*Hexarthra fennica*		+	+	
		Ploesoma hudsoni		+	+	+
		Unidentified	+			+
		Total Rotifers taxa	**1**	**2**	**2**	**2**
	Copepoda	Copepod nauplii	+	+	+	+
		Macrosetella gracilis	+		+	
		Lucicutia flavicornis		+	+	+
		Temora spp.		+	+	+
		Temoradis caudata	+			
		Canthocalanus pauper	+	+	+	+
		Acrocalanus spp.	+	+	+	+
		Paracalanus aculeatus		+	+	
		Pseudodiaptomus serricaudatus		+		+
		Calocalanus copepodid		+	+	
		Clausocalanus spp.	+	+	+	+
		Euchaeta spp.			+	+
		Scolecithricella spp.	+		+	+
		Oithona spp.			+	
		Oithona spinirostris	+	+	+	+
		Acrocalanus gracilis	+		+	
		Unidentified	+	+		
		Total Copepods taxa	**10**	**11**	**14**	**10**
	Ostracoda	*Macrochoecilla macrocheira*		+	+	
		Ishizakiella miurensis	+	+		
		Total Ostracods	**1**	**2**	**1**	**0**
Total Zooplankton taxa			**12**	**18**	**20**	**15**
Total plankton taxa			**21**	**27**	**26**	**19**

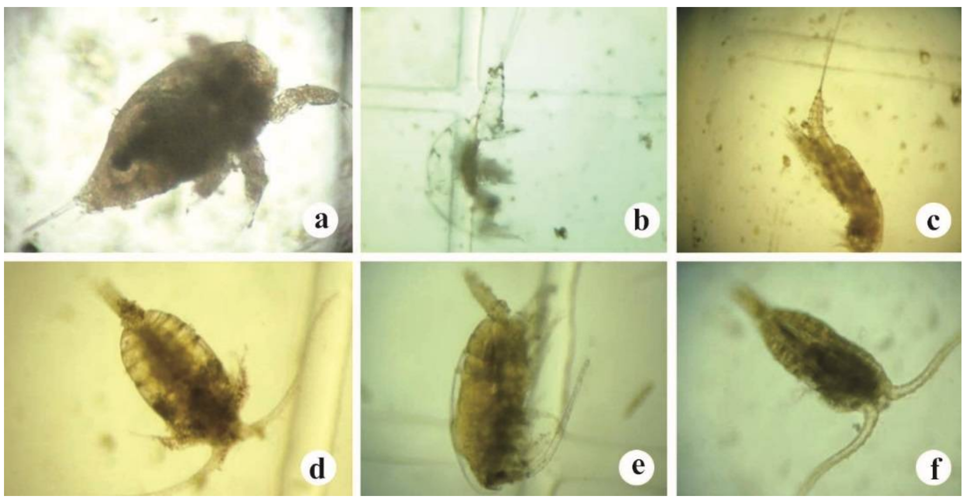
(+) Present in the study stations.



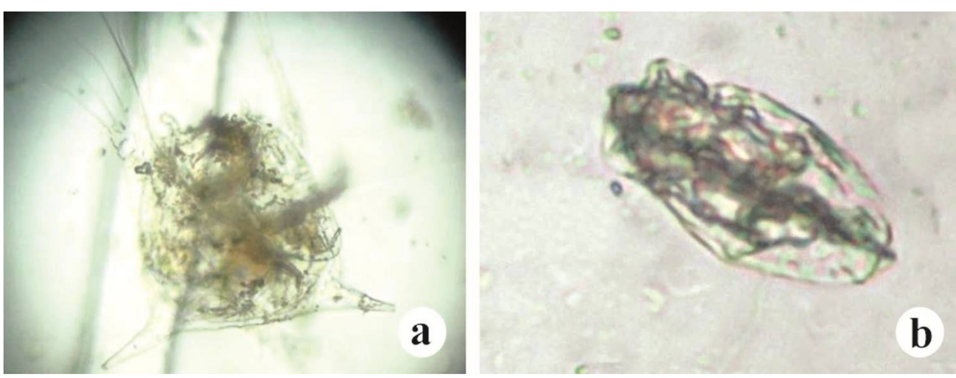
Figs 10a-o: Photomicrograph of Phytoplankton (Algae). a. *Bacteriastrum delicatulum* (Cleve), b. *Planktoniella sol* (Schutt), c. *Coscinodiscus centralis* Ehrenberg, d. *Bellerochea malleus* Van Heurck, e. *Thalassiothrix fraunfeldii* Hallegraeff, f. *Cyclotella* sp. F.T. Kutzing, g. *Pediastrum duplex* Meyen Lemm, h. *Ceratium declinatum* G. Karsten, i. *Ceratium trichoceros* Kofoid, j. *Hemidiscus hardmannianus* Mann, k. *Bacteriastrum hyalinum* Lauder, l. *Gyrosigma balticum* Rabenhorst, m. *Nitzschia* sp. Hassall, n. *Pleurosigma* sp. W. Smith, o. *Odontella sinensis* Grunow.



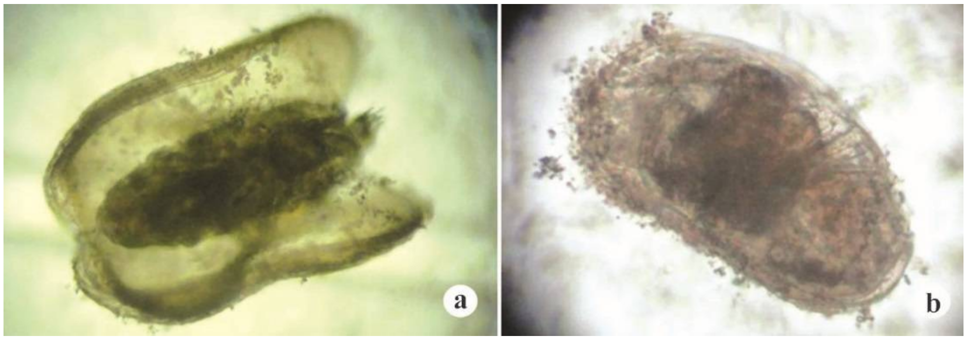
Figs 11a-b: Photomicrograph of Protozoa. a. *Condonellopsis ostenfeldi* Kofoid and Campbell, (b) *Tintinnopsis gracilis* Kofoid and Campbell.



Figs 12a-f: Photomicrograph of Copepoda. a. Copepod Nauplius larvae, b. *Macrosetella gracilis* Dana, c. *Macrosetella gracilis* Dana d. *Temora discaudata* Giesbrecht, e. *Acrocalanus gracilis* Giesbrecht, f. *Oithona spinirostris* Claus.



Figs 13a-b: Photomicrograph of Rotifera. a. *Hexarthra fennica* Levander, b. *Ploesoma hudsoni* Imhof.



Figs 14 a-b: Photomicrograph of Ostracoda. a. *Macrochoecilla macrocheira* Muller, b. *Ishizakiella miurensis* Hanai.

Acknowledgements

The first author expresses his deepest sense of gratefulness to Mr. Shyama Prosad Mozumder, a renowned mathematics teacher, for his moral support, statistical analysis, encouragement, and great patience during this research.

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(Manuscript received on 18 November, 2021; revised on 22 March, 2023)