Species composition, abundance and diversity of phytoplankton inhabiting around the swatch-of-no-ground, a sub-marine canyon of Northern Bay of Bengal

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Species Composition, Abundance and Diversity of Phytoplankton Inhabiting around the Swatch-of-No-Ground of Northern Bay of Bengal

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ABSTRACT: This study aimed to estimate the abundance and diversity of phytoplankton at different depth of water columns in Northern Bay of Bengal, Bangladesh. Samples were collected from 24 stations using Niskin water sampler from 0 to 250 m depths in four different cruises from January, 2017 to January, 2018 with the collaboration of Bangladesh Navy. Before sample identification, the samples were subjected to preservation using Lugol's solution. A total of 70 phytoplankton species were identified of which Bacillariophyceae, Dinophyceae and Chlorophyceae covered 74.28%, 21.42% and 4.28% of species, respectively. The average phytoplankton density was 12,238±7,281 cells/L. Results showed phytoplankton abundance and distribution was comparatively lower in higher water depth than surface water. The highest phytoplankton abundance (39,342 cells/L) was recorded at surface water and the lowest abundance (16 cells/L) was observed in 200 m depth. Phytoplankton abundances significantly reduced at higher water depths ($p < 0.05$) which might be associated with higher light and nutrients availability at surface water and mixed layer depth. However, there was weak negative correlation since r = - 0.33. Phytoplankton abundance was also varied from station to station at similar water depth. Species richness was the highest in surface water. In this study, estimated Shannon-Wiener index was 0.58 that represented phytoplankton was moderately distributed at surface water than higher depth. The findings of the present study might be used as a baseline study to understand the phytoplankton community of the Northern Bay of Bengal which directly and/or indirectly help to manage existing ecosystem and sustainable fisheries of the Bay of Bengal.

Keywords: Phytoplankton, Species composition and distribution, Diversity, Primary producer, Bay of Bengal.

INTRODUCTION

Phytoplankton is a vital element of marine ecosystems and widely considered as a potential bio-indicator of water quality changes that are occurred due to natural and anthropogenic causes such as indiscriminate dumping of domestic waste and industrial discharges, nutrient enrichment processes like coastal upwelling, etc. (Vitousek et al., 1997; Carter et al., 2005). Phytoplankton composition, distribution and diversity was influenced by several environmental factors such as nutrients variability, fluctuations in temperature or pH, changes of underwater light attenuation and alteration in mixed layer depth, etc. (Canale and Vogel 1974; Carter et al., 2005; Silkin et al., 2014). Temperature change is considered as the major determinants to influence phytoplankton growth rates, spatial and temporal distribution in marine water (Bouman et al., 2003; Marañón et al., 2014).

The vertical distribution of phytoplankton affects primary production as well as energy transfer to higher trophic levels (Williamson et al., 1996; Lampert et al., 2003; Hajdu et al., 2007). Light is the greatest supply at the top of the mixed layer and phytoplankton are hypothesized to exist there when there is adequate nutrient supply (Paerl, 1988). The light attenuation and nutrient gradients control the vertical distribution of phytoplankton (Klausmeier and Litchman, 2001).

The phytoplankton biomass and community composition are very important to understand ecosystem structure and dynamics of marine environment since their changes greatly affect pelagic system as well as the benthic community. The biomass of phytoplankton affects light climate and oxygen conditions for benthic macrophytes

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through their sedimentation (e.g., Sand-Jensen and Borum, 1991; Holmer and Bondgaard, 2001). Higher amount of phytoplankton production can lead to higher sedimentation rates, resulting in plenty of food for benthic communities, however, phytoplankton sedimentation and subsequent degradation by bacteria also lead to increased oxygen consumption and the risk of oxygen depletion for the benthos (Cederwall and Elmgren, 1990). Phytoplankton can also affect water quality, by giving water a bad odour when found in higher abundances or by producing toxins that can be released into the water when the phytoplankton be degraded or accumulated in other organisms feeding on them (e.g., mussels) (Zingone and Enevoldsen, 2000). Some phytoplankton species cause damage to fish gills, resulting in the mortality of wild fish and, for example, salmonids in fish farms (Albright et al., 1993). So, it is very important to understand and monitor the phytoplankton abundance, distribution and diversity in marine waters for ecosystem and sustainable fisheries management.

Globally, many studies have been conducted to determine phytoplankton compositions, abundances, distribution and diversity in different seas (e.g., Eker-Develi and Kideys, 2003; Guo et al., 2014; Ismael, 2015; Polikarpov et al., 2016; etc.). Some studies are also conducted in the vicinity of the Bay of Bengal, however, most of them are focused on Indian coastal waters (e.g., Sarojini and Sarma, 2001; Madhav and Kondalarao, 2004; Achary et al., 2014; Baliarsingh et al., 2016; etc.) Islam and Aziz (1975) and Aziz and Islam (1979) assessed the marine phytoplankton distribution in the north-eastern Bay of Bengal of Bangladesh, but it was very fragmented that needs to be updated. Another study assessed phytoplankton diversity, distribution and density from the estuarine areas of the Sunderbans of Bangladesh (Aziz et al., 2012) that might be different from the marine phytoplankton. However, there is no study on vertical distribution, abundance and diversity of marine phytoplankton in northern Bay of Bengal, Bangladesh. Thus, this study aimed to assess the abundance, distribution and diversity of marine phytoplankton during winter season from northern Bay of Bengal, Bangladesh.

MATERIALS AND METHODS

Study area

In this study, samples were collected from northern Bay of Bengal, Bangladesh from four cruises that were taken place in January (26.01.2017-28.01.2017) cruise of BNS Karotoa, February (12.02.2017-16.02.2017) cruise of BNS Turag, February (21.02.2017-27.02.2017) cruise of BNS Kapotakkho and December (30.12.2017-02.01.2018) cruise of BNS Turag with the collaboration of Bangladesh Navy. Samples were collected from 24 stations of the northern Bay of Bengal, Bangladesh (Fig. 1).

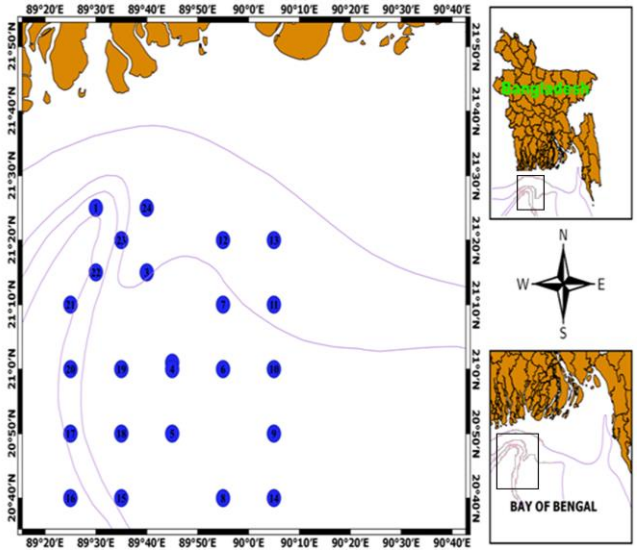


Figure 1. Phytoplankton sampling stations of the northern Bay of Bengal, Bangladesh

Phytoplankton sampling

Collection of surface sample at different stations: To estimate phytoplankton distribution at different stations, surface samples were collected by horizontal towing of plankton net (0.50 m mouth diameter) made up of bolting silk (No.10, mesh size 60 µm). The towing time was recorded exactly right after the plankton net was towed. Then, plankton net was pulled out after 3 minute. In this time 200 L water was passed through the net in every station.

Collection of samples at different depth: To estimate vertical distribution of phytoplankton, samples were collected by Niskin water sampler (8 L capacities). Water samples were collected at standard depths of 5, 10, 15, 20, 30, 40, 50, 70, 80, 90, 100, 150, 200 and 250 m depending on the depth of the water column.

Then plankton net of 18 µ mesh size having a filtering cone attached to a metal ring terminated 2.5 L was passed through in a collecting bottle of 250 ml to collect the phytoplankton sample.

Samples preservation

After sample collection, the samples were labeled with date, time of sampling, sampling station's geographical positions, and the horizontal and vertical distribution of sample type. The phytoplankton samples were preserved in Lugol's solution (10 g I_2, 20 g KI, 20 g glacial acetic acid and 200 ml water) following the methods of Tomas (1997) and Naz et al. (2012). Lugol's solution was added with the samples using a plastic dropper and mixed carefully with gentle saking. The color of the bottles became straw. Since sedimentation method was used for phytoplankton counting and species identification, the sample of phytoplankton was kept undisturbed in the dark at room temperature for 48 hours for sedimentation at Chemical Oceanography Laboratory, Department of Oceanography, University of Dhaka. After the sedimentation, water of the bottle was sucked out carefully by a suction pump and the final volume was adjusted in between 40 to 50 ml. Samples for phytoplankton analyses were fixed with lugol's iodine and stored in dark bottles.

Identification and counting of phytoplankton

Phytoplankton samples were identified with the help of biological microscope (Motic- TO.25 A) and counted in Sedgewick-Rafter (S-R) counting chamber taking 1 ml of concentrated sample on the grids of Sedgewick-Rafter cell (model-1801-G20, manufactured by Wild life Supply Company, USA. and model S50, manufactured by Graticules Ltd., Maryland Road, England) as per the phytoplankton identification protocol (Subramanyan, 1946; Subrahmanyan, 1946; Tomas, 1997; Naz et al., 2012).

The S-R cell was in rectangular chamber (50 mm long × 20 mm wide × 1 mm deep) having 1000 mm^2 area and 1000 mm^3 volume (1 mm^3 = 1 ml). The cover slip was placed diagonally across the cell which helped to prevent formation of air bubbles in the cell. Over filling of cell was avoided because this would yield a depth greater than 1 mm and could produce an invalid count. Lengthy examination was avoided that permit large air spaces caused by evaporation to develop in the chair.

The S-R cell was moved vertically along the first column of squares and the organisms in each square of the row were counted. Cells were identified by their gross morphology, special structures and shape. The identified phytoplanktons were photographed with a camera at a magnification of 10 × 10 X. Chain forming diatoms were counted as filamentous and solitary forms as individual cells. Identification was done followed by Thomas (1997) and Khondker (2008).

Phytoplankton counting formula

i) The number of cells/L (N) of each species was calculated following the methods of Sarojoni and Sarma (2001):

$N = n \times v/V$

Where,

N = mean cell no. in 1 ml of sample

v = volume of concentrate and

V = volume of seawater filtered.

ii) Species richness (D_f) was used to estimate the number of species in the sample. Species richness was calculated following the methods of Margalef (1958):

$D_f = (S-1) / Ln(N)$

Where,

S = total number of species in a sample.

N = total number of cells in a sample

iii) Shannon-wiener index (H´) was used to calculate the species diversity in a certain area following the methods of Poole (1974):

$H' = -\sum_{i=1}^{s} P_i \times log_2 P_i$ and $P_i = n/N$

Where,

S = number of species in a sample

n = total number of cells of one species in a sample

N = total number of all species in the sample

2.6. Data analysis

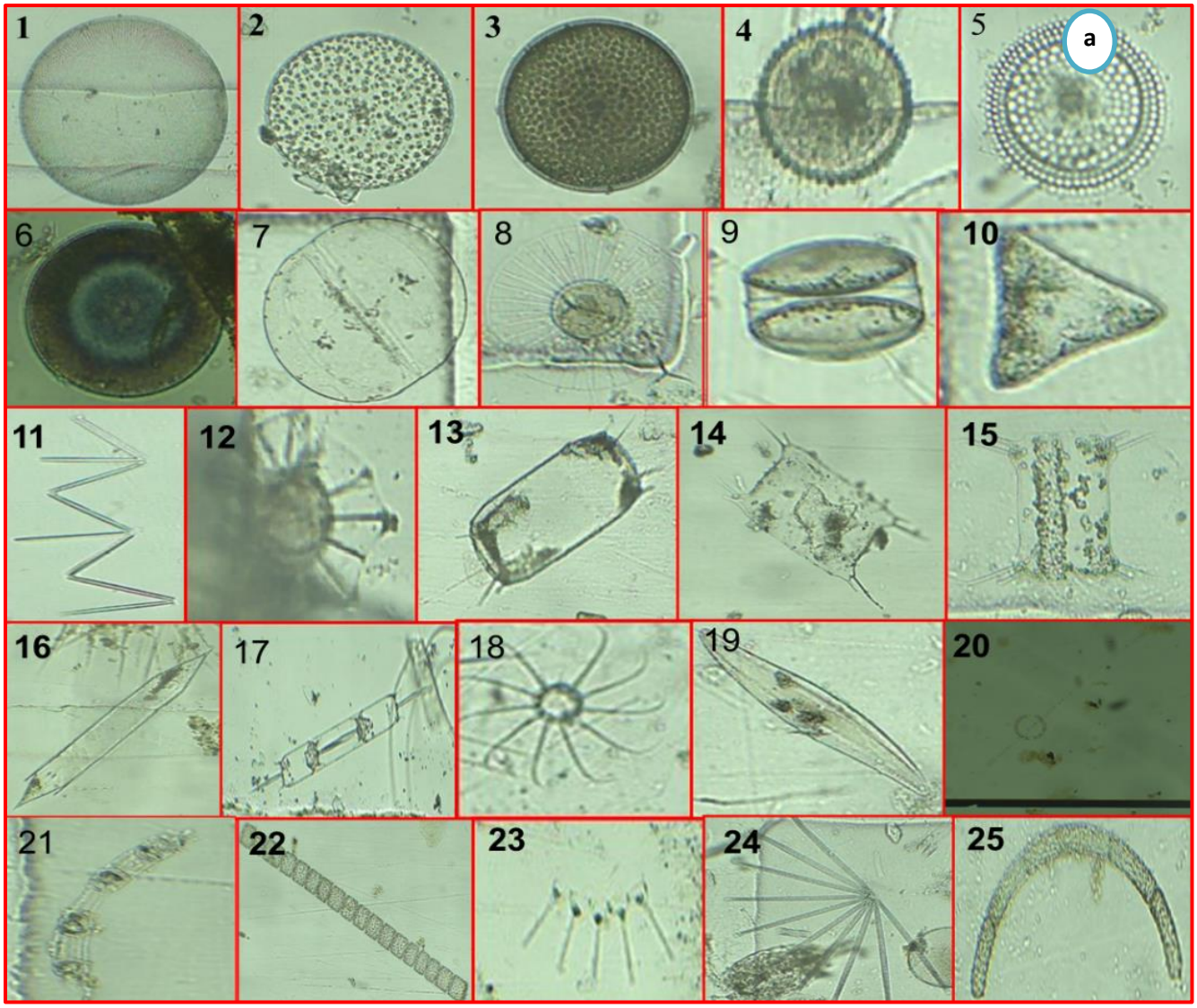
Data were analyzed using Microsoft Excel (version-13) and results were presented in tabular and graphical forms. Data were presented as mean±sd (standard deviation) or otherwise not mentioned. One-way ANOVA (analysis of variance) was employed to

test the significance among different depths at 5% level of significance. To meet the ANOVA requirement, Levene test was carried out to check the homogeneity of the data.

RESULTS AND DISCUSSION

Phytoplankton identification

In this study, a total of 70 phytoplankton species were identified from four cruises of the northern Bay of Bengal, Bangladesh. Among the recorded species, majority of the phytoplankton species were grouped as Bacillariophyceae or marine diatoms (52 species) followed by Dinophyceae or dinoflagellates (15 species) and Chlorophyceae or green algae (3 species) (Fig. 2 and 3). Islam and Aziz (1975) and Aziz and Islam (1979) reported 64 marine phytoplankton species and 22 marine dinoflagellates species from the north-eastern Bay of Bengal, respectively that was nearly similar with the findings of this study. However, Achary et al. (2014) reported 219 marine phytoplankton species in Bacillariophyta, Cyanophyta and Dinophyta group from the coastal waters of south-west Bay of Bengal that was different from the current study. This might be varied because of seasonal differences since Achary et al. (2014) collected samples for one year covering all seasons. However, this study covered only the winter season. Again, this study could not find any species in Cyanophyta group rather it identified species in Chlorophyceae group.



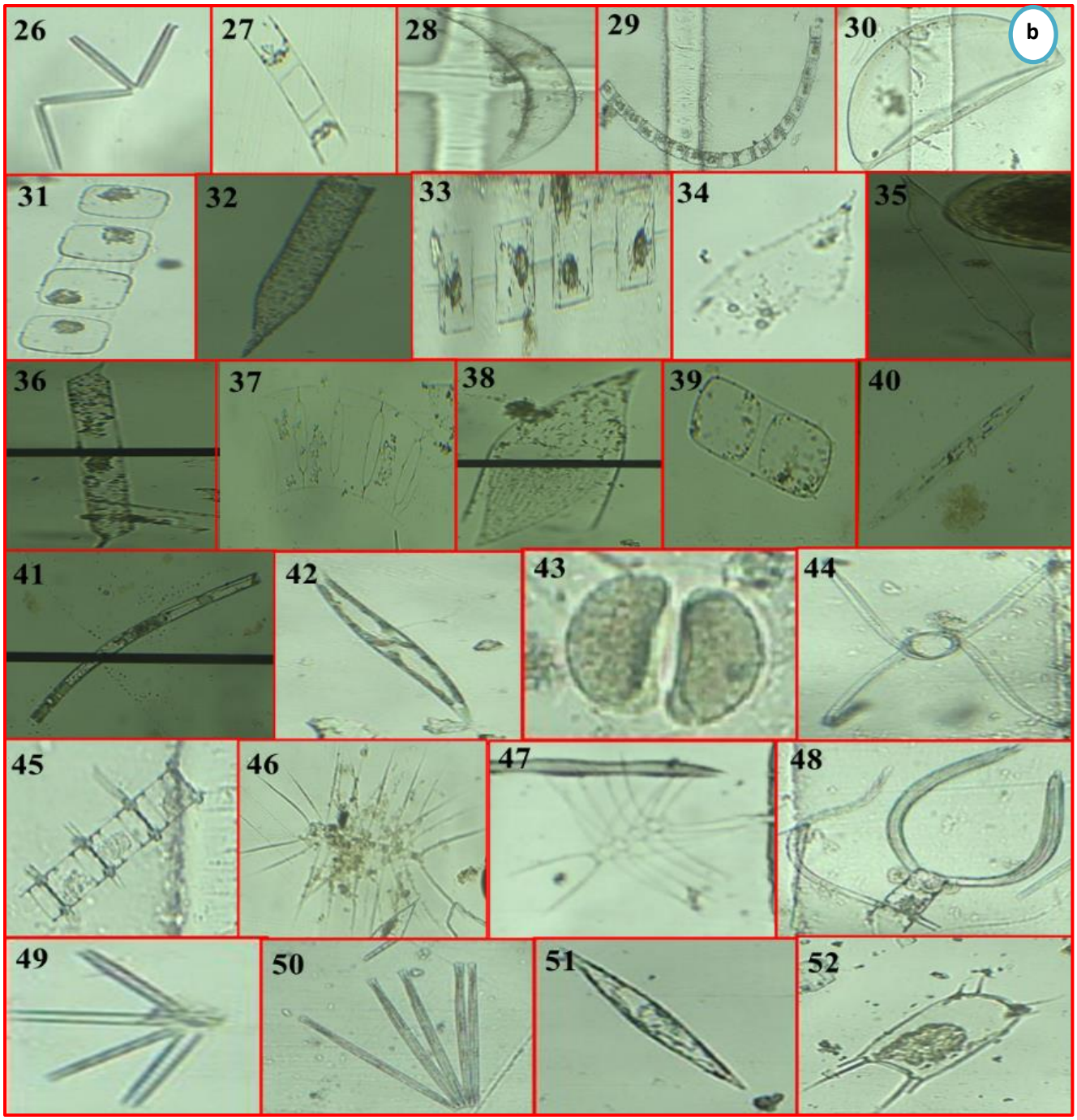


Fig. 2a and 2b. Photographs of phytoplankton species belongs to Bacillariophyceae group or marine diatom: 1. *Coscinodiscus radiates*, 2. *Thalassiosira mala*, 3. *T. leptopus*, 4. *T. angulate*, 5. *Cyclotella comta*, 6. *Coscinodiscus sp.*, 7. *Palmeria hardmaniana*, 8. *Planktoniella sol*, 9. *T. punctigera*, 10. *Lithodesmium undulatum*, 11. Thalassionema sp., 12. *Planktoniella sp.*, 13. *Odontella mobiliensis*, 14. *O. longicruris*, 15. *O. aurita*, 16. *Rhizosolenia calcar*, 17. *Ditylum brightwellii*, 18. *Bacteriastrum varians*, 19. *Pleurosigma directum*, 20. *Chaetoceros* sp., 21. *Hemiaulus sinensis*, 22. *Melosira moniliformis*, 23. *Asterionellopsis glacialis*, 24. *Thalassiothrix frauenfeldii*, 25. *Guinardia flaccida*, 26. *Thalassiothrix sp.*, 27. *Biddulphia sinensis*, 28. *R. curvata*, 29. *Skeletonema costatum*, 30. *Palmeria hardmaniana*, 31. *Melosira juergensii*, 32. *R. bergonii*, 33. *L. undulatum*, 34. *R. styliformis*, 35. *R. hebetate*, 36. *R. alata*, 37. *Eucampia zodiacus*, 38. *R. robusta*, 39. *Stephanopyxis palmeriana*, 40. *Haslea trompii*, 41. *Leptocylindrus sp.*, 42. Gyrosigma acuminatum, 43. Coscinodiscus wailesii, 44. *Chaetoceros danicus*, 45. *C. lorenzianus*, 46. *C. coarctatus*, 47. *C. brevis*, 48. *C. diversus*, 49. *Thalassionema nitzschioides*, 50. *Lioloma pacificum*, 51. *Pleurosigma sp.* and 52. *O. sinensis*.

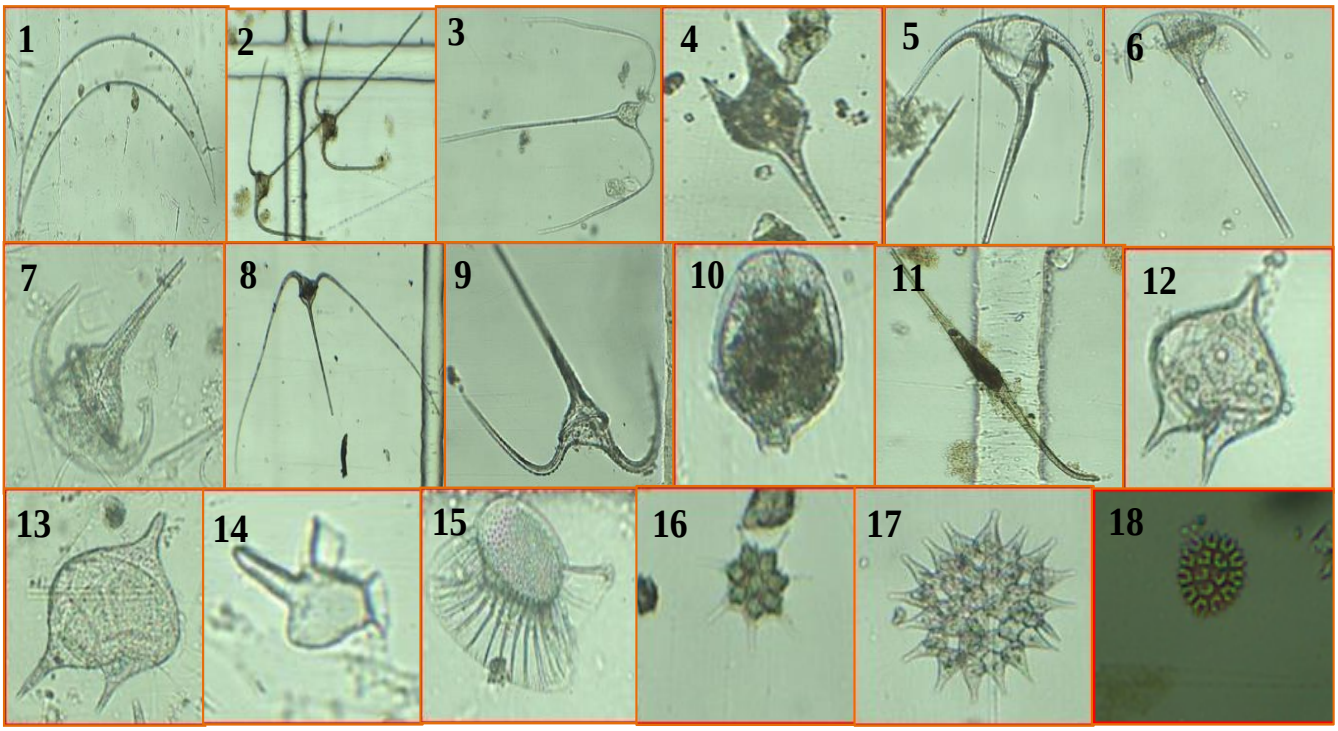


Fig. 3. Photographs of phytoplankton species belongs to Dinophyceae group or dinoflagellates: 1. *Pyrocystis lunula*, 2. *Ceratium horridum*, 3. *C. trichoceros*, 4. *C. hirundinella*, 5. *C. symmetricum*, 6. *C. declinatum*, 7. *C. arietinum*, 8. *C. carriense*, 9. *C. macroceros*, 10. *Peridinium gatunense*, 11. *C. fusus*, 12. *Protoperidinium claudicans*, 13. *P. depressum*, 14. *Dinophysis caudate* and 15. *D. tripos*; and Chlorophyceae group or green algae: 16. *Pediastrum simplex*, 17. *P. duplex* and 18. *P. tetras*.

Group-wise phytoplankton diversity

This study found that phytoplankton species diversity in Bacillariophyceae group was the most dominated group among the four cruises followed by Dinophyceae and Chlorophyceae (Table 1). In all cruises, more than 74% of phytoplankton species were in the group of Bacillariophyceae or marine diatom. In second cruise, no phytoplankton species in Chlorophyceae group was recorded. Phytoplankton abundance was varied depending on cruise time. Achary et al. (2014), Madhav and Kondalarao (2004) reported phytoplankton community was predominated mainly by diatoms followed by dinoflagellates. Diatoms such as *Thalassiosira sp., Chaetoceros sp., Coscinodiscus radiates, Rhizosolenia sp.* and *Thalassiothrix sp.* were found to be very common in this study that was in line with Achary et al. (2010).

Overall, phytoplankton abundance was ranged in between 8 to 3,190 cells/L. In December, the abundance was the highest (3,190 cells/L) and at the end of February, the abundance was the lowest (8 cells/L) (Table 1). In this study, the average phytoplankton abundance was found 12,238±7,281 cells/L. Achary et al. (2014) observed phytoplankton density was ranged between 15,000 to 448,000 cells/L and 11,000 to 230,000 cells/L in coastal waters away from 0.5 km and 9 km from shorelines respectively. Though the lower values of the findings of Achary et al. (2014) were in line with the present study, the upper limit was very high than the findings of this study. This might be differed because of seasonal differences of sampling phytoplankton.

Table 1. Group-wise phytoplankton diversity collected from surface water of the northern Bay of Bengal, Bangladesh

Cruise name	Cruise date	No. of stations	Sampling coordinates	Percentage of species diversity			Phytoplankton abundance (cells/L) at surface water
				Bacillariophyceae	Dinophyceae	Chlorophyceae	
1st cruise (BNS Karotoa)	26.01.2017 to 28.01.2017	10	20.8-21.5 N 89.36-90.08 E	81.66	16.67	1.67	10-2,580
2nd cruise (BNS Turag)	12.02.2017 to 16.02.2017	21	20.41-21.51 N 89.24-90.16 E	81.25	18.75	0	12-2,250
3rd cruise (BNS Kapotakkho)	21.02.2017 to 27.02.2017	11	20.50-21.25 N 89.25-90.05 E	74.63	22.39	2.98	8-1,963
4th cruise (BNS Turag)	30.12.2017 to 02.01.2018	19	20.83-21.47 N 89.42-89.75 E	78.79	16.67	4.54	55-3,190

Table 2. Phytoplankton abundance (cells/L) at different depth of water collected from northern Bay of Bengal, Bangladesh

Cruise name	1st cruise (BNS Karotoa)	2nd cruise (BNS Turag)	3rd cruise (BNS Kapotakkho)	4th cruise (BNS Turag)
Sampling position	20.8-21.5 N 89.36-90.08 E	20.41-21.51 N 89.24-90.16 E	20.50-21.25 N 89.25-90.05 E	20.83-21.47 N 89.42-89.75 E
Station no.	10	20	24	24
Total sample no.	12	55	47	52
Depth (m)	Phytoplankton abundance (cells/L)			
5	16(3), 32(1)	16(2), 32(1), 48(2), 80(1), 112(4), -(2)	16(1), -(3)	144(1), 400(1)
10	16(3)	16(1), 64(1), 80(1), -(3)	32(1), -(1)	16(2), 32(2), 64(1), 80(3), 96(1), 112(2), 144(2), 160(2), 256(1), 272(1), 352(1), -(4)
15	16(2)	16(2), 64(1), 112(1), 3,664(1), -(9)	-(6)	240(1), 384(1)
20			-(3)	
30		-(2)	16(2), 64(1), -(3)	80(1), 112(1)
40			16(1), -(4)	
45		-(1)		
50	48(1)	4,848(1), -(9)	16(1), -(6)	16(5), 96(1), 80(1), 112(1), 160(1), 816(1), -(8)
70			-(2)	
80		-(3)	32(2), -(1)	
90	-(2)	16(3), -(4)	-(6)	
100				16(1), 80(1), -(2)
150			-(2)	-(1)
200				16(1)
250			-(1)	

Depth-wise phytoplankton abundance and distribution

This study found that phytoplankton abundance and distribution was varied depending on water depth. Table 2 and Fig. 4 showed that phytoplankton abundance and distribution was comparatively lower in higher water depth than upper part of the northern Bay of Bengal. Phytoplankton abundance was also varied from station to station at same water depth. For example, at 5 m depth of the Bay of Bengal, different number of phytoplankton cells/L were recorded and it was ranged from 0 to maximum 400 cells/L (Table 2). The number in parenthesis indicated the frequency on how many times the similar number of phytoplankton cells/L were also recorded from different stations at 5 m depth. In addition, at 5 m depth of a few stations, no phytoplankton cells/L was found and it was indicated as "-". Differences in phytoplankton abundance and distribution might be varied because of differences in light and nutrients availability. At higher depth of water light and nutrients availability is lower than upper part of the Bay of Bengal.

*Number in parenthesis indicates sampling frequency on how many times similar number of phytoplankton cells/L were recorded from different stations and "-" indicates cells/L not found.

The highest number of phytoplankton (39,342 cells/L) was recorded at surface water (0 m depth) and the lowest number of phytoplankton (16 cells/L) observed in 200 m depth (Fig. 4). Phytoplankton abundances significantly varied depending on depths ($p < 0.05$). The reasons behind this might be associated with higher level of light and nutrients availability at surface water than other depth. This study found negatively correlation (r = - 0.333) between phytoplankton abundance and water depth that phytoplankton abundance decreased with increasing water depth. Sarojini and Sarma (2001) studied vertical distribution of phytoplankton in the upper 200 m water column at 5 stations around the Andaman and Nicobar Islands and showed that phytoplankton density was higher around 25 m depth of the Bay of Bengal and increasing depth the density was significantly decreased. The findings of this study is in line with Sarojini and Sarma (2001). The vertical distribution and abundance of phytoplankton species in ocean varied by the availability of light, nutrients and mixed layer depth (Kiefer and Kremer, 1981; Prestidge and Taylor, 1995).

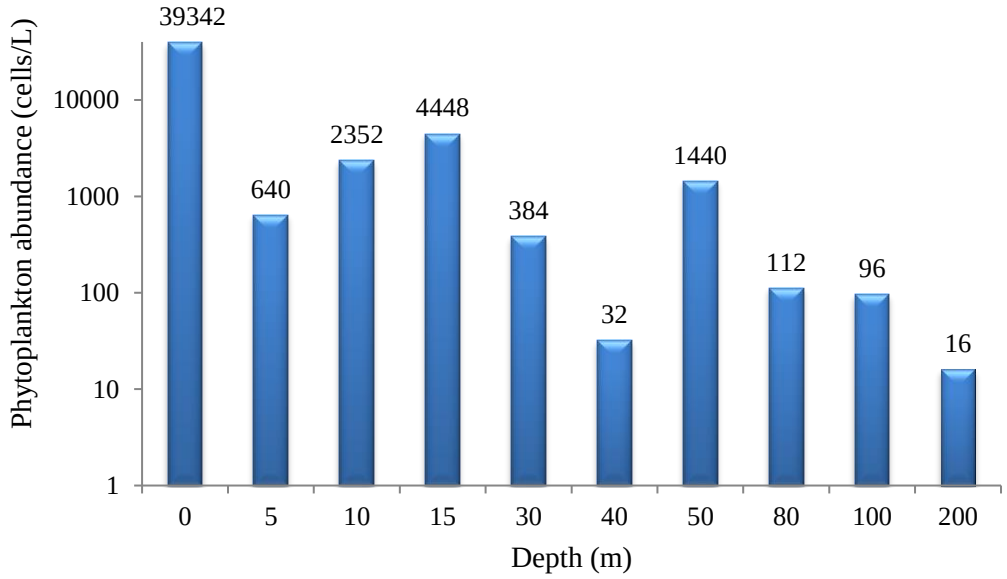


Figure 4: Phytoplankton abundance at different depth of water of the northern Bay of Bengal, Bangladesh

Phytoplankton richness and Shannon-wiener index

Species richness index (D_f) showed that the highest phytoplankton richness was found in surface water since maximum 70 species were recorded in surface water than other depth (Table 3). However, no species richness value was found at 100 m and 200 m depth because only one species was recorded at that depth. The Shannon-wiener index (H´) showed that phytoplankton species was moderately distributed at surface water than higher depth of the water. High phytoplankton density and species diversity in the surface water might be related with heavy rainfall, high turbidity caused by run-off, reduced salinity, decreased temperature and pH in surface water. This is being supported by Ei-Gindy and Dorghan (1992) who stated that phytoplankton abundance and diversity depend on several environmental factors that are variable in different seasons and regions.

Table 3: Richness and Shannon-wiener indices to assess phytoplankton distribution at different depth of water

Depth (m)	Total no. of species (N)	Cells/L	Species richness (D_f)	Shannon-wiener index (H´)
0	70	39,432	16.24104	
5	15	640	3.295284	
10	7	2,352	1.412265	
15	12	656	2.589152	
30	5	384	0.94151	0.58
40	2	32	0.235377	
50	4	1,440	0.706132	
80	3	112	0.470755	
100	1	96	0	
200	1	16	0	

Phytoplankton cumulative energy fixation in carbon compounds (primary production) is the basis for the vast majority of oceanic and some freshwater food chains. The production of fish depends on the productivity of zooplankton which in turns depends on the phytoplankton. So, for high production of fish, high production of phytoplankton is needed. That is why it is very important to understand the phytoplankton abundance, distribution and diversity if marine waters. The findings of this study might help to understand the current marine phytoplankton status to take any strategy for sustainable marine resource or fishery management and to maintain biogeochemical cycles in the ocean.

CONCLUSIONS

This study assessed marine phytoplankton abundance, diversity and distribution from the northern Bay of Bengal of Bangladesh. Vertical distribution of phytoplankton species was also assessed at a depth of 0 to 250 m. A total of 70 marine phytoplankton species were identified that were grouped into Bacillariophyceae (52 species), Dinophyceae (15 species) and Chlorophyceae (3 species). Vertical distribution of phytoplankton showed that the highest number of phytoplankton (cells/L) was recorded in surface water (0 m) and the lowest phytoplankton number was observed in 200 m depth because of differences in light attenuation and nutrient concentrations. Abundance of phytoplankton species was negatively correlated with water depth and number of cells/L was significantly decreased at higher depth. This study showed the current status of marine phytoplankton abundance, diversity and distribution from the northern Bay of Bengal, Bangladesh that might be used as a baseline study for future works. The findings might be considered as a useful tool for further ecological assessment and monitoring of the phytoplankton in the Bay of Bengal, Bangladesh. Based on this study scientific management strategy should be taken to control and manage the marine ecosystem.

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