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Distribution and identification of foraminiferal assemblage: offshore shelf part of northern Bay of Bengal, Bangladesh

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ABSTRACT
A total of 12 surface sediments samples were collected from different zones from the offshore area of northern Bay of Bengal, Bangladesh. All about 112 both planktonic and benthic species were identified, out of which 72 were perforated-calcareous hyaline, 28 imperforate-calcareous porcellaneous, and 12 agglutinated forms belonging to 54 genera, 26 families, and 6 orders. The analysis revealed that the Asterorotalia-Cibicides association was more common all over the study area along with Ammonia, Elphidium, and Nonion; with increasing depth planktonic Globigerina, Neogloboquadrina, Globigerinella, Globuligerina, Globigerinoides, Globorotalia, Orbulina were getting higher and the p/b ratio had been increased. Species richness was found high at the Northeastern part of the study area where 82 species had been identified. Depths of the sampling area were the main influencing factors for foraminiferal spatial distribution. Abundance and density of species were also found high in the Northeastern portion of the Bay. Moreover, the study Northeastern portion showed a great potency of foraminiferal diversity among all of the stations.

KEYWORDS*: Foraminifera; Bio-idicator; richness; Dominant-codominant; Density; Hyperhaline; p/b ratio*

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I. INTRODUCTION

Foraminifera are single-celled (protists), widely distributed and diverse organisms in marine environments. Geological ranges from the earliest Paleozoic to the present day for the last 540 million years (Bellier, 2010). Easy collection and their good fossilization potential make them a great object for study historical event like climatology, paleontology, biostratigraphy etc. On recent, they are preferred most for as a bio-indicator because of their higher sensitivity against pollution (Soulard, 2004). Individuals range from about 100 micrometers to almost 20 centimeters long. They are planktonic or benthic in mode of life, an estimated about 4,000 species living in the world's oceans today. Among them only 40 species are planktonic. Foraminiferal speciation plays an important role in ecological and paleoecological studies due to their high numerical density in marine sediments; a small amount of sediment may hold hundreds of living individuals, and many more dead shells. These excellent preservation potential of their shells make them more important component of the sediment. Benthic foraminifera dwells on or, in the sand, mud, rocks and plants at the bottom of the ocean, shows a great diversity with more than 10,000 modern taxa (Sen Gupta, 1999). A proper knowledge about the taxonomy of foraminifera provides the basis for any applicationsin paleoenvironmental or biostrati-graphic studies of these protozoa. The aimof this study is directed to identifythe foraminiferal assemblages and to know their distributional pattern across the northern shelf area of Bay of Bengal.

1.1.1 Study area: The study area covers a well portion of the Bengal shelf, the upper portion of the northern Bay of Bengal.There are 12 different sampling stations covers an area ranges between 20°N and 21°30'N latitudes and 89°30'E and 92°E longitudes; depths range from 27m up to 65m (Fig. 1); where the Ganges-Brahmaputra-Meghna Riverine network drain in to the Bay of Bengal with a huge amount of fresh water and sediments continuously. Bangladesh has a dynamic continental shelf, as the Ganges-Brahmaputra-Meghna River system has been building underwater deltas in the upper part of the shelf. This made an irregular bottom surface over the whole shelf. Holocene delta sediments hold the major part of the shelf and extend up to 80m isobath (Kuehl et al, 1989). The western shelf of Cox's Bazar-Teknaf coastal plain is overlain by the Holocene intra-deltaic sediments and extends up to 45m isobaths. Pre-Holocene sediments constitute the rest part of the shelf.The shelf has smooth and gentle sloping surface towards sea of the subaqueous part of the delta but is misshaped seaward of the eastern coastal plain of Bangladesh. The western and middle parts of the continental shelf of Bangladesh are dipping very gently with an average gradient of 0.097° and 0.062° respectively. On the contrary, the eastern part of the continental shelf of Bangladesh is steeper than other parts with an average gradient of 0.21°.

II. MATERIAL AND METHODS

2.1.1 Sample collection: The collection of 12 different surface sediment samples were carried out on a cruise of the FT Agro Food-4 (Sea Resources Group) in January 2016. Sediments were collected by Ekman grab samplerin three different transects or zones, depths ranging between 27 and 65m from the shelf off Bangladesh, upper reaches of north-eastern Bay of Bengal (Fig.1).Random sampling has been done at different depths to cover the whole study sites.A detail of the sampling such coordinates of sampling locations, CTD profiles (SBE 19plus V2 SeaCAT Profiler CTD); density and DO had been recorded (Table 1). Collected sediment sample sealed and labeled in zipper poly bags after immediate boarding on the vessel deck. Quality assured by immediate store of those samples into the cooling storage maintain the temperature at 4°C.

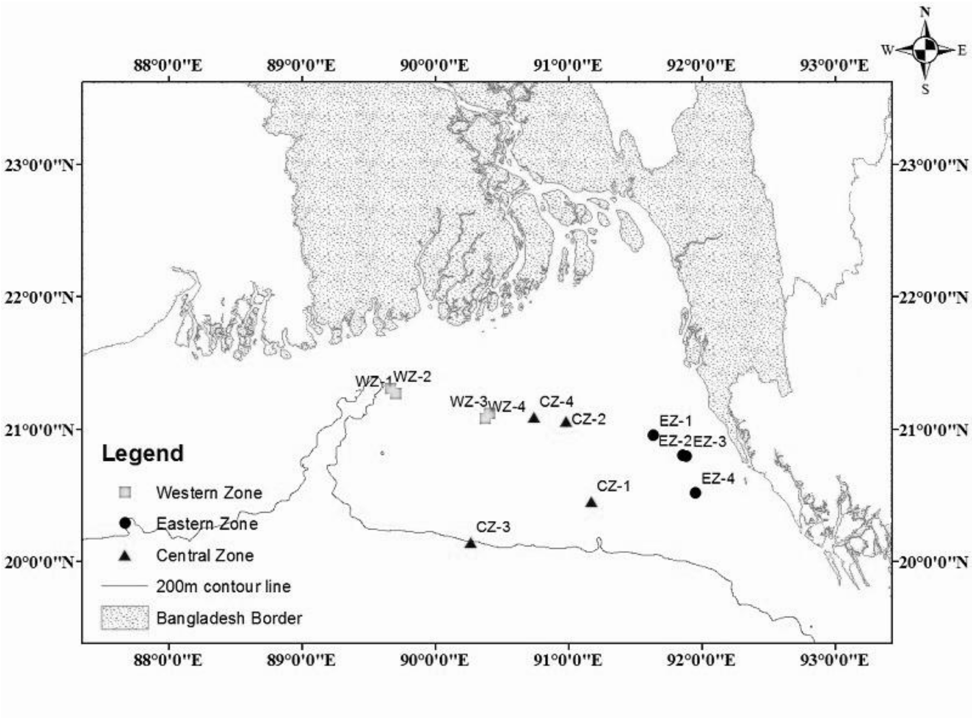


Figure 1: Study area showing sample stations

2.1.2 Sample processing and analysis: At the lab, 50 g of each sample has been taken in beaker for disintegration purpose. Then the sediments sample has been treated with hydrogen peroxide. Afterwards, the samples have been washed through a 0.063 mm (230 ASTM) sieve under low water pressure. The sand fraction has been collected and again dried at 60ºC for over-night. Collected dried samples then placed to gradually decreasing (different mesh sizes) hand sieves for sorting in different sizes. Finally the sorting fractions of each sample have been taken one after one on a picking tray and picked up the individual species using brush under the stereomicroscope (Olympus H011).

Table 1: Coordinates and physiochemical parameters of the different points of northern Bay of Bengal

Point name	Location		Depth (m)	Tem. (°C)	Salinity (‰)	Density (Kg/m3)	DO (mg/l)
	Latitude (N)	Longitude (E)					
EZ-1	20°57'00.06"	91°37'50.70"	58.6	24.51	28.88	19.33	7.07
EZ-2	20°48'01.26"	91°51'18.42"	46.4	24.48	30.77	20.30	6.98
EZ-3	20°47'51.36"	91°52'56.16"	40.3	24.21	28.67	18.83	7.12
EZ-4	20°30'49.62"	91°56'57.00"	60	26.45	30.79	19.70	6.75
WZ-1	21°16'02.76"	89°42'15.12"	46.5	25.28	30.68	19.91	6.82
WZ-2	21°18'30.78"	89°39'54.78"	41.3	25.34	30.55	19.89	6.89
WZ-3	21°06'58.50"	90°24'26.16"	42	24.53	30.21	19.86	6.98
WZ-4	21°04'45.18"	90°22'31.38"	65	-	-	-	-
CZ-1	20°27'11.58"	91°10'19.56"	63.1	25.85	31.06	20.11	6.89
CZ-2	21°03'42.60"	90°58'45.00"	27.9	24.72	28.53	18.55	7.04
CZ-3	20°08'40.50"	90°16'04.02"	42.5	25.72	30.63	19.83	6.84

CZ-4	21°05'37.92"	90°44'24.78"	28.3	25.56	30.76	19.98	6.87

*Note: EZ, WZ and CZ refer to eastern zone, western zone and central zone respectively.

III. RESULTS

Of the total 12 samples, the analysis revealed 112 species have been identified out of which 72 were perforated-calcareous hyaline forms, 28 imperforate-calcareous porcellaneous forms, and 12 agglutinated forms belong to 54 genera, 26 families and 6 orders (Table 2).Only hyaline, perforated forms include both planktonic and benthic types. There were 12 planktonic species among 72 hyaline and 112 of total species.

Table 2: Different forms of foraminifera with their order, family and genera in this study

<table>
<tr><th>Forms</th><th>Order</th><th colspan="2">Family</th><th>Genera</th></tr>
<tr><td rowspan="12">Porcellaneous (non-perforated calcareous)</td><td>Cornuspirida</td><td colspan="2">Cornuspiridae</td><td>Cornuspira</td></tr>
<tr><td rowspan="11">Miliolida</td><td colspan="2">Cribrolinoididae</td><td>Adelosina</td></tr>
<tr><td colspan="2" rowspan="7">Hauerinidae</td><td>Miliolinella</td></tr>
<tr><td>Proemassilina</td></tr>
<tr><td>Pyrgo</td></tr>
<tr><td>Quinqueloculina</td></tr>
<tr><td>Sigmoilinita</td></tr>
<tr><td>Siphonaperta</td></tr>
<tr><td>Sigmoilopsis</td></tr>
<tr><td colspan="2">Miliolidae</td><td>Triloculina</td></tr>
<tr><td colspan="2">Ophthalmidiidae</td><td>Ophthalmina</td></tr>
<tr><td colspan="2">Spiroloculinidae</td><td>Spiroloculina</td></tr>
<tr><td rowspan="7">Agglutinated</td><td rowspan="3">Lituolida</td><td colspan="2">Haplophragmoididae</td><td>Labrospira</td></tr>
<tr><td colspan="2">Spiroplectamminidae</td><td>Spirotextularia</td></tr>
<tr><td colspan="2">Trochamminidae</td><td>Ammoglobigerina</td></tr>
<tr><td rowspan="4">Textulariida</td><td colspan="2" rowspan="3">Textulariidae</td><td>Bigenerina</td></tr>
<tr><td>Siphotextularia</td></tr>
<tr><td>Textularia</td></tr>
<tr><td colspan="2">Valvulinidae</td><td>Calvulina</td></tr>
<tr><td rowspan="35">Hyaline (perforated calcareous)</td><td rowspan="6">Lagenida</td><td colspan="2" rowspan="2">Glandulinidae</td><td>Bombulina</td></tr>
<tr><td>Glandulina</td></tr>
<tr><td colspan="2" rowspan="2">Lagenidae</td><td>Lagena</td></tr>
<tr><td>Procerolagena</td></tr>
<tr><td colspan="2">Nodosariidae</td><td>Pyramidulina</td></tr>
<tr><td colspan="2">Polymorphinidae</td><td>Ramulina</td></tr>
<tr><td rowspan="29">Rotaliida</td><td colspan="2" rowspan="3">Anomalinidae</td><td>Anomalina</td></tr>
<tr><td>Anomalinoides</td></tr>
<tr><td>Heterolepa</td></tr>
<tr><td colspan="2" rowspan="3">Bolivinitidae</td><td>Bolivina</td></tr>
<tr><td>Fursenkoina</td></tr>
<tr><td>Pseudobrizalina</td></tr>
<tr><td colspan="2">Cancrisidae</td><td>Cancris</td></tr>
<tr><td colspan="2">Cassidulinidae</td><td>Islandiella</td></tr>
<tr><td colspan="2">Cibicididae</td><td>Cibicides</td></tr>
<tr><td colspan="2" rowspan="2">Elphidiidae</td><td>Cribroelphidium</td></tr>
<tr><td>Elphidium</td></tr>
<tr><td rowspan="6">Globigerinidae</td><td rowspan="8">Planktonic</td><td>Beella</td></tr>
<tr><td>Globigerina</td></tr>
<tr><td>Globigerinella</td></tr>
<tr><td>Globigerinoides</td></tr>
<tr><td>Globuligerina</td></tr>
<tr><td>Orbulina</td></tr>
<tr><td rowspan="2">Globorotaliidae</td><td>Neogloboquadrina</td></tr>
<tr><td>Globorotalia</td></tr>
<tr><td colspan="2" rowspan="5">Nonionidae</td><td>Melonis</td></tr>
<tr><td>Nonion</td></tr>
<tr><td>Nonionella</td></tr>
<tr><td>Nonionellina</td></tr>
<tr><td>Nonionoides</td></tr>
<tr><td colspan="2" rowspan="3">Rotaliidae</td><td>Ammonia</td></tr>
<tr><td>Asterorotalia</td></tr>
<tr><td>Rotalinoides</td></tr>
<tr><td colspan="2" rowspan="2">Uvigerinidae</td><td>Siphouvigerina</td></tr>
<tr><td>Uvigerina</td></tr>
</table>

Three individual species (*Asterorotaliapulchella*, *Cibicidesboueanus and Nonionellinalabradorica*) were very much common in all stations of the study (Table 3). Though*Ammonia* genera and its members were also associated with those three and made a unique association. Others species were also present in all over the offshore area but not in common. The overall sampling dominating species were *Asterorotaliapulchella, Cibicidesboueanus, Ammonia, Nonion* and its relatives.

Among planktonic species*Globigerina bulloides* was the single dominant species. Without the *G. bulloides, Neogloboquadrina sp*. was regular in most of the samples. Without those dominating species *Elphidiumcrispum, Nonionoideselongatum, Nonionoidesgrateloupii, Nonion sp., Siphonaperta sp., Sigmoilopsis sp., Spiroloculinaexcavata, Globigerina bulloides, Neogloboquadrinasp.*and*Globigerinoides sp.* were the co-dominants

Table 3: Occurrences of foraminifera species in different points of offshore area of the northern Bay of Bengal.

No.	Name of species	Study Zones											
		Eastern				Western				Central			
		1	2	3	4	1	2	3	4	1	2	3	4
1	*Rotalinoidescompressiuscula*	+	+	+	+			+	+	+	+		
2	*Ammonia dentata*	+	+	+	+	+	+	+	+	+		+	+
3	*Ammonia beccarii*	+	+	+	+	+	+	+	+	+	+	+	
4	*Ammonia tepida*	+	+	+		+	+	+			+	+	+
5	*Ammonia sp. (1)*		+		+								
6	*Rotalia sp.*					+				+			
7	**Asterorotaliapulchella*	+	+	+	+	+	+	+	+	+	+	+	+
8	*Ammonia sp. (2)*		+	+				+			+	+	
9	*Ammonia parkinsoniana*	+	+	+	+				+	+		+	
10	*Elphidiumcrispum*	+	+	+	+	+	+		+	+			
11	*Elphidium sp. (1)*		+	+						+			
12	*Elphidiummacellum*		+	+				+					
13	*Elphidiumadvenum*		+	+				+		+	+	+	
14	*Elphidiumlimbatum*			+									
15	*Cribroelphidiumexcavatum*			+						+			
16	*Elphidium sp. (2)*							+					
17	*Ammonia falsobeccarii*	+	+	+	+	+	+	+	+	+	+	+	
18	**Cibicidesboueanus*	+	+	+	+	+	+	+	+	+	+	+	+
19	*Anomalinoidesornatus*				+								
20	*Unidentified (1)*			+						+			
21	*Heterolepadutemplei*	+	+	+	+					+	+		
22	*Islandiellanorcrossi*			+						+			
23	*Melonis sp.*			+	+					+			
24	*Unidentified (2)*									+			
25	*Labrospiracrassimargo*					+	+						
26	*Anomalinapacoraensis*	+	+	+	+	+		+	+	+		+	+
27	*Unidentified (3)*			+				+					
28	*Nonionoidesturgida*			+			+			+			
29	*Nonionoidesgrateloupii*		+	+	+	+	+	+	+	+		+	
30	*Nonion sp. (1)*		+	+	+	+	+	+	+	+	+	+	
31	*Nonionellastella*		+	+			+		+	+	+	+	
32	*Nonion sp. (2)*				+	+	+					+	
33	**Nonionellinalabradorica*	+	+	+	+	+	+	+	+	+	+	+	+
34	*Nonionoideselongatum*		+	+	+	+	+	+	+	+	+	+	
35	*Nonionellaauris*	+	+	+	+	+	+	+	+	+			+
36	*Elphidiumfabum*						+	+					
37	*Nonionellinaflemingi*		+	+			+	+		+			
38	*Nonionella sp.*			+			+	+		+			
39	*Miliolinellacircularis*		+	+	+					+			
40	*Adelosinalongirostra*			+						+			
41	*Triloculina sp. (1)*		+	+					+	+	+		
42	*Triloculina sp. (2)*		+	+						+			
43	*Quinqueloculinacandeiana*		+	+						+			
44	*Triloculina sp. (3)*		+	+	+			+	+				
45	*Quinqueloculinaseminula*		+	+	+					+			
46	*Adelosinabicornis*				+								
47	*Triloculinafrigida*		+	+	+	+			+	+			

48	*Triloculinatricarinata*	+	+	+	+			+	+	+			
49	*Pyrgo sp.*				+								
50	*Quinqueloculinabuchiana*		+	+	+			+	+	+			
51	*Quinqueloculinakerimbatica*			+	+					+			
52	*Quinqueloculina sp.*		+	+									
53	*Adelosina sp.*					+					+		+
54	*Quinqueloculinalaevigata*									+		+	+
55	*Triloculinaoblonga*		+	+						+			
56	*Spiroloculinaexcavata*		+	+	+	+	+	+	+	+		+	
57	*Spiroloculinacommunis*		+		+					+			
58	*Spiroloculinaelegantissima*				+								
59	*Unidentified (4)*			+									
60	*Clavulinanovangliae*		+	+	+					+			
61	*Bigenerinanodosaria*		+	+	+					+			
62	*Textulariafoliacea*		+	+	+					+	+		
63	*Siphoextularia sp. (1)*			+									
64	*Siphoextularia sp. (2)*			+				+		+			
65	*Spirotextularia sp.*			+	+					+	+		
66	*Textularialaevigata*		+	+	+					+	+		
67	*Textularialateralis*		+	+	+					+			
68	*Pyramidulina sp.*				+								
69	*Spiroloculina sp.*			+									
70	*Unidentified (5)*			+									
71	*Sigmoilinitaasperula*			+					+	+			
72	*Proemassilinaarenaria*									+			
73	*Siphonaperta sp.*		+	+	+	+	+	+		+	+		
74	*Sigmoilopsis sp.*		+	+	+	+	+		+	+	+		+
75	*Unidentified (6)*	+	+	+	+	+		+	+	+		+	
76	*Siphouvigerinainterrupta*			+									
77	*Uvigerinaerugata*		+	+	+					+			
78	*Uvigerinasemidensa*			+	+					+			
79	*Lagenastriatiformis*		+	+									
80	*Glandulinaovula*			+	+					+			
81	*Ophthalminaspiratula*				+								
82	*Cornuspirainvolvens*									+			
83	*Bolivinastriatellata*		+	+	+					+			
84	*Bolivinaprimatumida*		+	+									
85	*Bolivinaearlandi*									+			
86	*FursenkoinaPauciloculata*		+						+				
87	*Bolivinatranslucens*									+			
88	*Pseudobrizalinalobata*			+									
89	*Procerolagenaclavata*		+										
90	*Bombulinaspinata*				+								
91	*Ramulina sp.*				+								
92	*Ramulinaglobulifera*			+						+			
93	*Bolivinatortugiana*									+			
94	*Bolivinarobusta*	+	+	+	+			+	+	+			
95	*Bolivinapontis*		+	+	+					+			
96	*Bolivinacompressa*			+									
97	*Bolivina sp.*									+			
98	*Bolivinaspathulata*									+			
99	*Globorotaliamenardii*		+	+	+					+	+		
100	*Cancrisauriculus*									+			
101	*Globigerina bulloides*	+	+	+	+		+	+	+	+	+	+	
102	*Beellapraedigitata*			+						+	+		
103	*Unidentified (7)*									+			
104	*Orbulinauniversa*	+	+	+	+			+		+			
105	*Globigerinoidessacculifera*								+				
106	*Globigerina regina*			+	+					+			
107	*Ammoglobigerinaglobigeriniformis*			+						+			
108	*Globigerinellaobesa*			+						+			
109	*Globuligerina sp.*			+						+	+		
110	*Globigerinoides sp.*		+	+	+	+	+			+		+	
111	*Neogloboquadrina sp.*		+	+	+	+	+	+	+	+			
112	*Globigerinoidesquadrilobatus*		+	+	+			+		+		+	

'*' sign denotes the cosmopolitan occurrences of foraminifera species in all stations.

Maximum richness of species found in station EZ-3, where the benthic species count was 72 and the planktonic was 10; total count of species on that sample was 82 (Fig. 2). In CZ-1, there the total countwas 78 the second highest but most planktonic specieswas found in that station. Others stations except EZ-2, more or less same in number. The lowest count of specieswas found in CZ-4, where the total count was 10 and all are benthic species.

Between the different sampling zones, eastern zone has found highly potent for different types of species, where the western zone had shown lower and almost similar richness. In case of central zone, there the result was also same as western zone except the stationCZ-1where the species richness was too much high, close as EZ-3 unlike the other stations of that zone.

In the analyzed result, the maximum abundance found in point EZ-3 which is about 49 ind/gm sample. The stations CZ-1, EZ-2, EZ-4 also showed a great relative density of 42 ind/gm, 33 ind/gm and 21 ind/gm respectively (Table 4). The lowest densitywas found in the station CZ-4.

Between the zones, western zone showed a similar criterion of density or abundance which ranges from 5-8 ind/ gm of sample. Eastern zone showed a varying degree of density, rangesfrom 2-49 ind/gm.

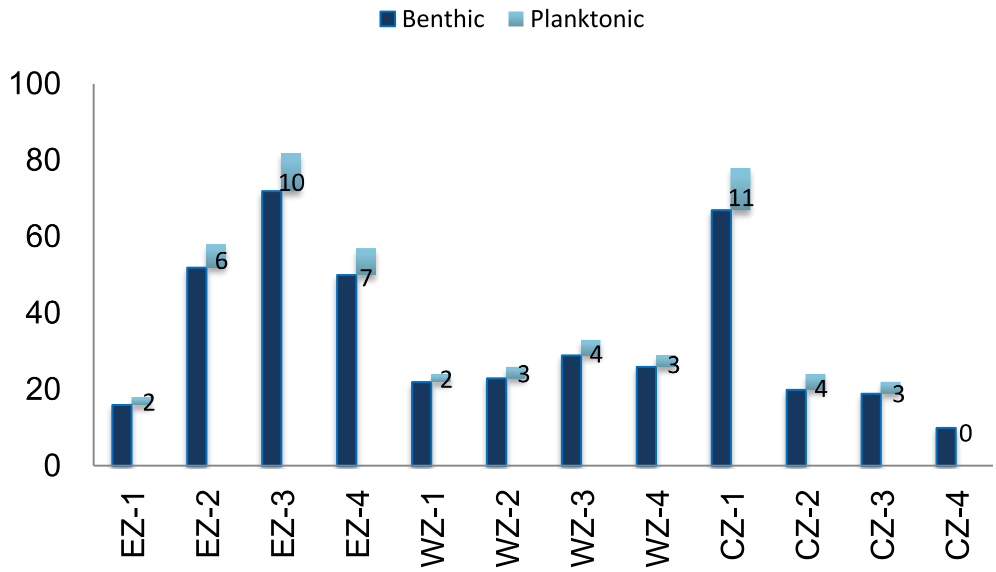


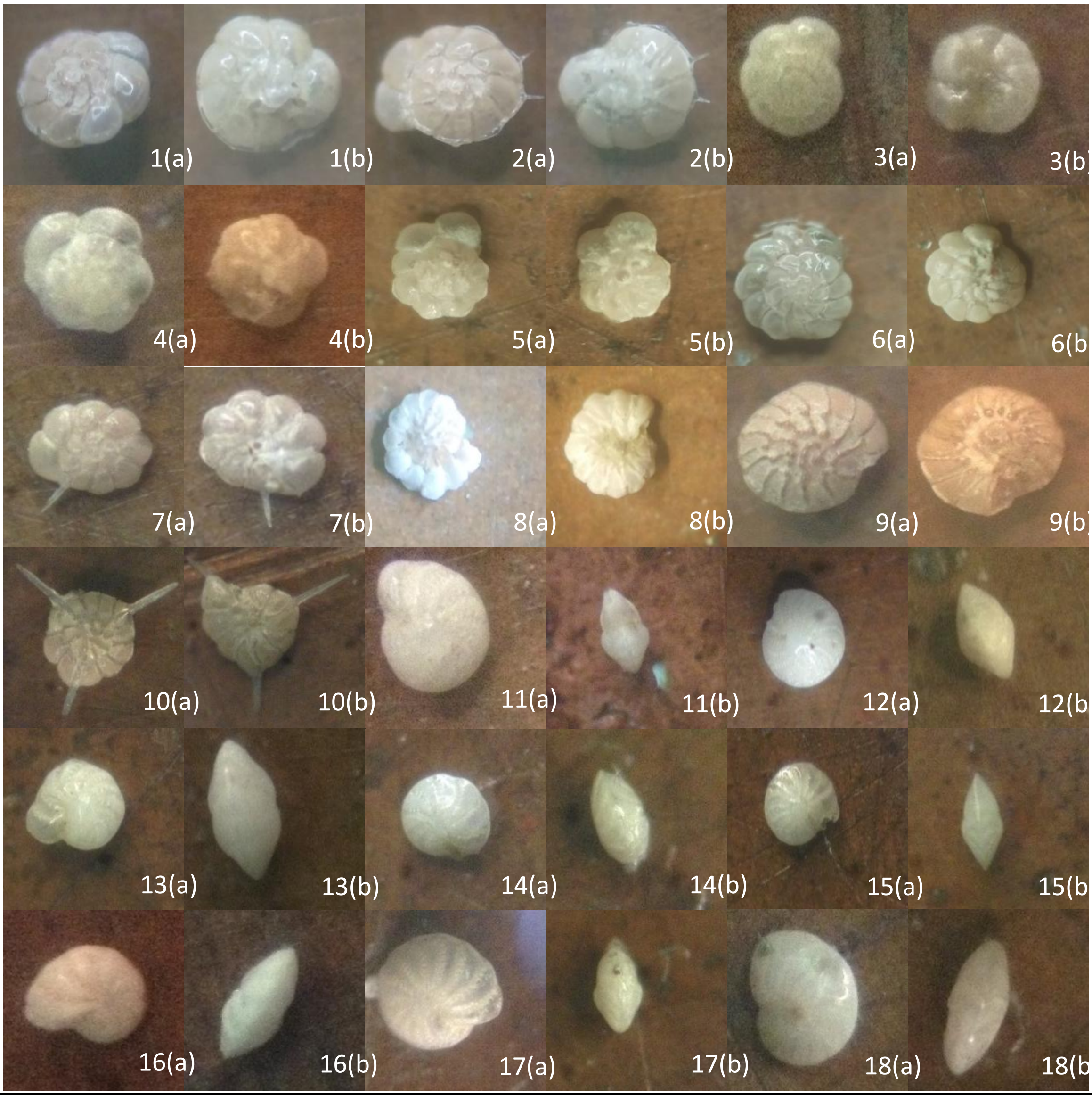
Figure 2: Species richness of foraminifera in different stations of Bay of Bengal.

Though only the EZ-1 station showed totally different criterion from EZ-2, EZ-3 and EZ-4.Similar but opposite scenario found in case of central zone, where only the CZ-1 station had shown highest density among the others of this zone (Table4).

This zone showed a great variation of density ranges from 1-42 ind/gm. The p/b ratio of foraminifers' ranges from 0-2.0, where most of the points maintain the ratio between 0.1-0.2, except CZ-4 station with no planktonic forms were found though the total species counted too much low there. (Table 4).

In this research total 72 species of hyaline, 28 species of porcellaneous and only 12 agglutinated forms were detected. Hyaline forms only consists both benthic and planktonic types of foraminfera. Highest hyaline forms were present in EZ-3 station. And the lowest count was 7 species found in CZ-4 station. Highest porcellaneous and agllutinated forms were also present in EZ-3 station.

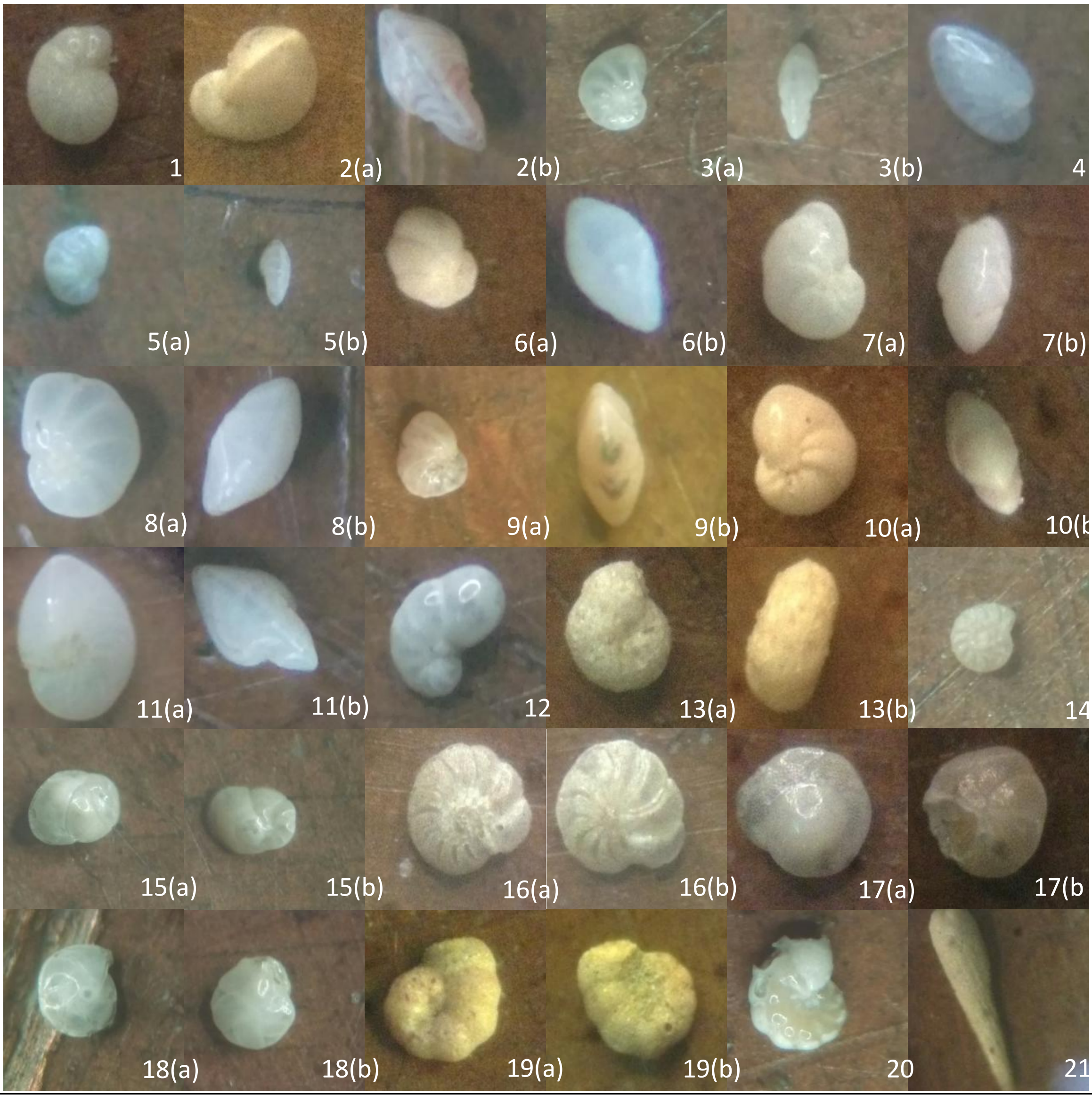
PLATE A



IV. EXPLANATION OF PLATE A

1. ***Ammonia beccarii*** (Linnaeus, 1758) (a) dorsal view & (b) ventral view; **2.*Ammonia dentata*** (Parker & Jones) (a) dorsal view & (b) ventral view;**3.** ***Ammonia falsobeccarii*** (Rouvillois, 1974) (a) dorsal view & (b) ventral view;**4.** ***Ammonia parkinsoniana*** (Sen Gupta, 1996) (a) dorsal view & (b) ventral view; **5.** ***Ammonia tepida*** (McCulloch, 1981) (a) dorsal view & (b) ventral view;**6.** ***Ammonia sp. (1)*** (Brünnich, 1772) (a) dorsal view & (b) ventral view;**7.** ***Ammonia sp. (2)*** (Brünnich, 1772) (a) dorsal view & (b) ventral view;**8.** ***Rotaliasp.*** (Lamarck, 1804)(a) dorsal view & (b) ventral view;**9.** ***Rotalinoidescompressiuscula*** (Brady, 1884) (a) dorsal view & (b) ventral view;**10.*Asterorotalia pulchella*** (d'Orbigny, 1839) (a) dorsal view & (b) ventral view;**11.** ***Elphidiumadvenum*** (Haynes, 1973) (a) side view & (b) lateral view;**12.** ***Elphidiumcrispum*** (Linnaeus, 1758) (a) side view & (b) lateral view;**13.*Elphidium limbatum*** (Chapman, 1907)(a) side view & (b) lateral view;**14.** ***Elphidiummacellum*** (Fichtel& Moll, 1798) (a) side view & (b) lateral view; **15.** ***Elphidium sp. (1)*** (de Montfort, 1808) (a) side view & (b) lateral view; **16.** ***Elphidium sp. (2)*** (de Montfort, 1808) (a) side view & (b) lateral view; **17.** ***Cribroelphidiumexcavatum*** (Terquem, 1875) (a) side view & (b) lateral view; **18.** ***Elphidiumfabum*** (Fichtel& Moll, 1798) (a) side view & (b) lateral view.

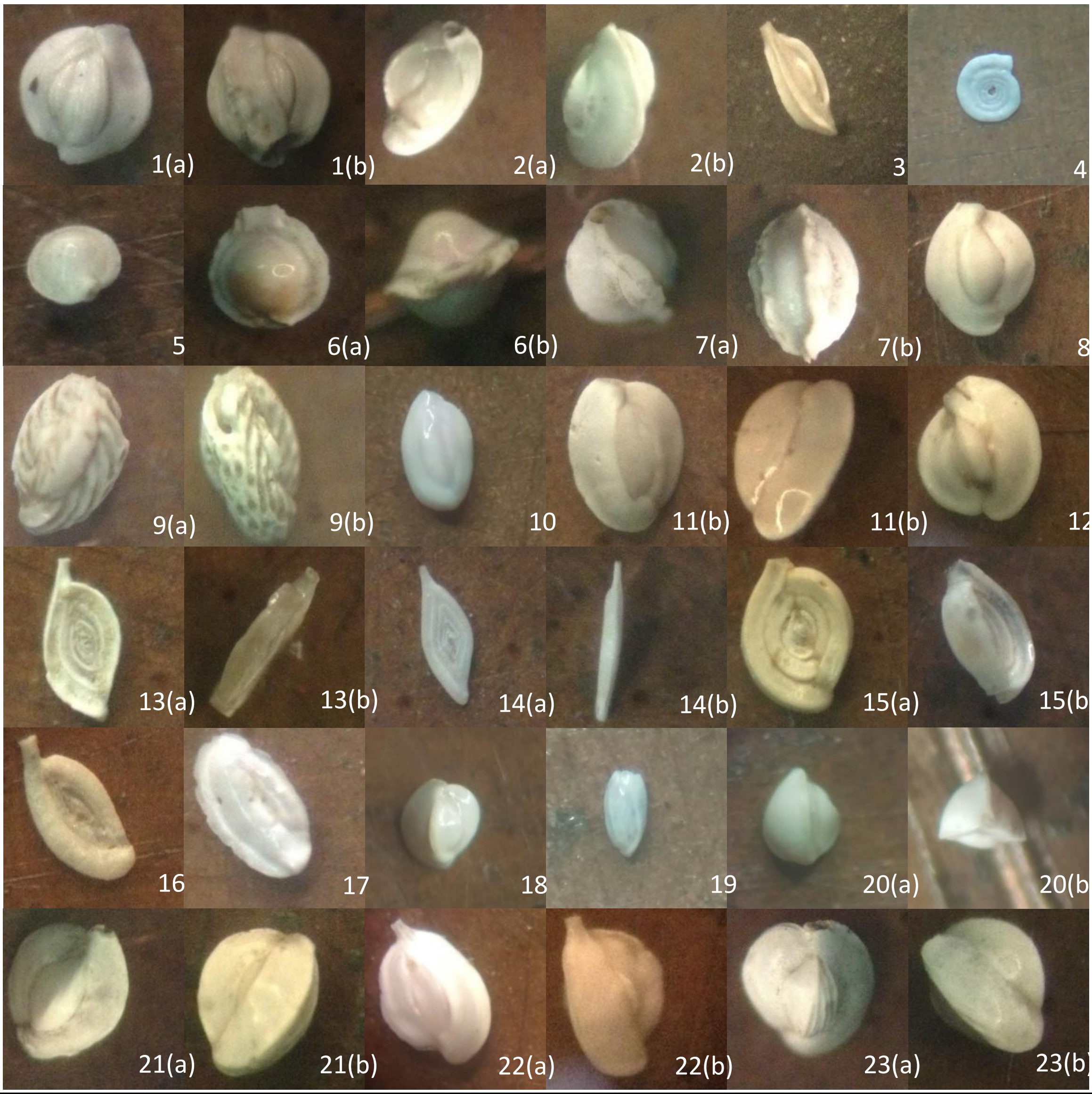
PLATE B



V. EXPLANATION OF PLATE B

1.*Melonis sp.* (de Montfort, 1808); **2. *Nonionoideselongatum***(d'Orbigny, 1852) (a) side view & (b) lateral view; **3. *Nonionoidesgrateloupii***(d'Orbigny, 1839) (a) side view & (b) lateral view; **4. *Nonionoidesturgida***(Williamson, 1858); **5. *Nonionellaauris***(d'Orbigny, 1839) (a) side view & (b) lateral view; **6. *Nonionellastella***(Cushman & Moyer, 1930) (a) side view & (b) lateral view; **7. *Nonionella sp.***(Voloshinova, 1958) (a) side view & (b) lateral view; **8. *Nonion sp. (1)*** (de Montfort, 1808) (a) side view & (b) lateral view; **9. *Nonion sp. (2)***(de Montfort, 1808 (a) side view & (b) lateral view; **10. *Nonionellinaflemingi***(Vella, 1957) (a) side view & (b) lateral view; **11. *Nonionellinalabradorica***(Dawson, 1860) (a) side view & (b) lateral view; **12. Unidentified (3)**; **13. *Anomalinapacoraensis***(Coryell &Embich, 1937**)** (a) side view & (b) lateral view; **14. *Anomalinoidesornatus*** Costa);**15. *Cancrisauriculus***(Fichtel& Moll, 1798) (a) dorsal view & (b) ventral view; **16. *Cibicidesboueanus***(d'Orbigny, 1846) (a) dorsal view & (b) ventral view; **17. *Heterolepadutemplei***(d'Orbigny, 1846) (a) dorsal view & (b) ventral view; **18. *Islandiellanorcrossi***(Cushman, 1933) (a) dorsal view & (b) ventral view; **19. *Labrospiracrassimargo***(Norman, 1892 (a & b) side view; **20. Unidentified (2)**; **21. Unidentified (4)**.

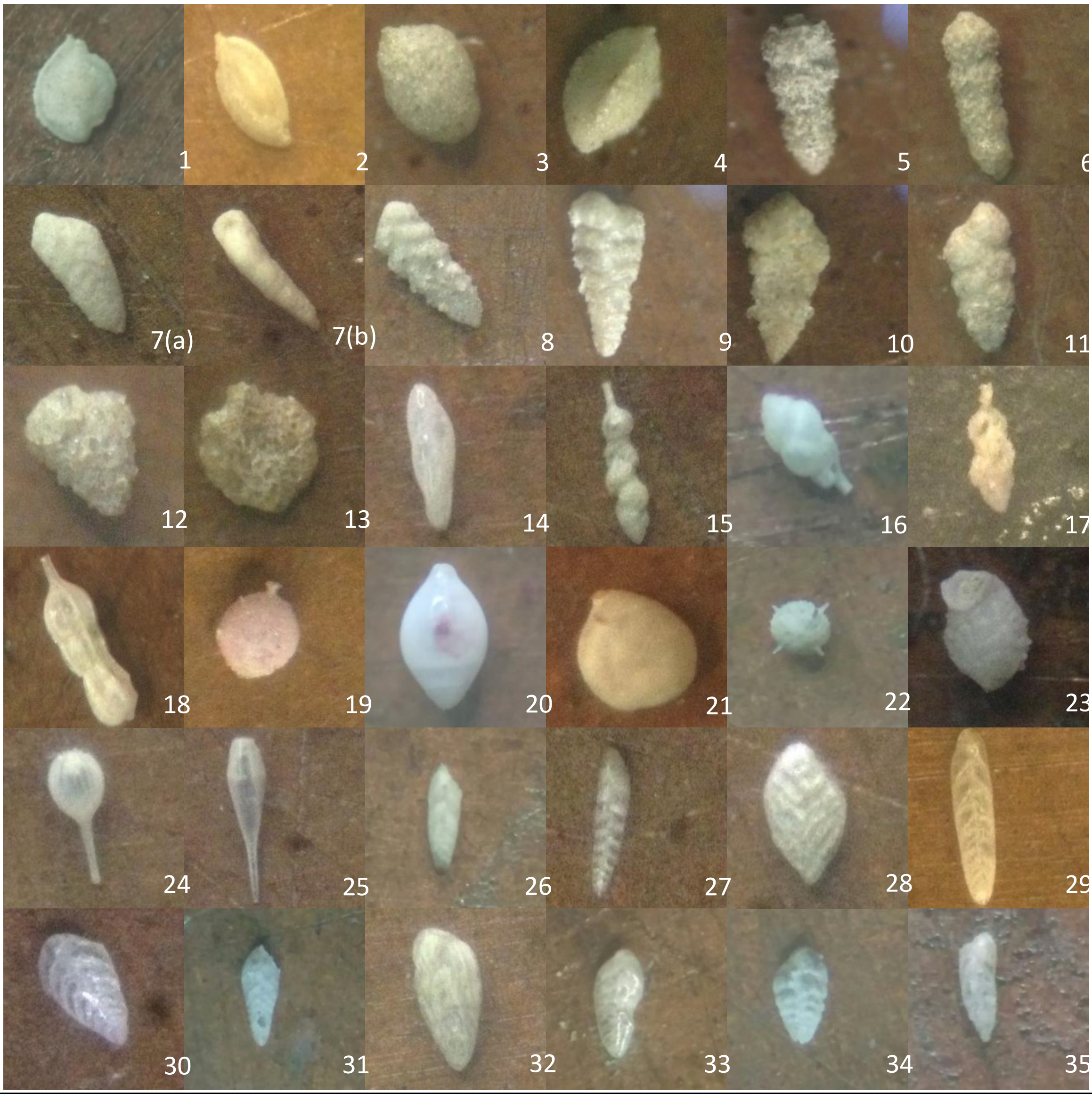
PLATE C



VI. EXPLANATION OF PLATE C

1. ***Adelosinabicornis*** (d'Orbigny, 1826) (a) 3-chambered view & (b) 4-chambered view; **2.** ***Adelosinalongirostra*** (d'Orbigny, 1846) (a) aperatural view & (b)) 4-chambered view; **3.** ***Adelosina sp.*** (d'Orbigny, 1826); **4.** ***Cornuspirainvolvens*** (Reuss, 1850); **5.** ***Miliolinellacircularis*** (Bornemann, 1855); **6.** ***Pyrgo sp.*** (Defrance, 1824) (a) side view & (b) aperatural view; **7.** ***Quinqueloculinabuchiana*** (Papp & Schmidt, 1985) (a) 3-chambered view & (b) 4-chambered view; **8.** ***Quinqueloculinacandeiana*** (d'Orbigny, 1839); **9.** ***Quinqueloculinakerimbatica*** (Heron-Allen &Earland, 1915) (a) 4-chambered view & (b) aperatural view; **10.** ***Quinqueloculinalaevigata*** (d'Orbigny, 1839); **11.** ***Quinqueloculinaseminula*** (Linnaeus, 1758) (a) dorsal view & (b) ventral view;**12.** ***Quinqueloculina sp.*** (d'Orbigny, 1826); **13.** ***Spiroloculinacommunis*** (Cushman & Todd, 1944) (a) side view & (b) lateral view;**14.** ***Spiroloculinaelegantissima*** (Said, 1949) (a) side view & (b) lateral view;**15.** ***Spiroloculinaexcavata*** (d'Orbigny, 1846) (a) side view & (b) lateral view;**16.** ***Spiroloculina sp.*** (d'Orbigny, 1826); **17.** **Unidentified (5)**; **18.** ***Triloculinafrigida*** (Lagoe, 1977); **19.** ***Triloculinaoblonga*** (Montagu, 1803); **20.** ***Triloculinatricarinata*** (d'Orbigny, 1826) (a) 3-chambered view &aperatural view; **21.** ***Triloculina sp. (1)*** (d'Orbigny, 1826) (a) 3-chambered view & (b) 2-chambered view; **22.** ***Triloculina sp. (2)*** (d'Orbigny, 1826) (a) 3-chambered view & (b) 2-chambered view;**23.** ***Triloculina sp. (3)*** (d'Orbigny, 1826) (a) 3-chambered view & (b) 2-chambered view.

PLATE D



VII. EXPLANATION OF PLATE D

1.*Proemassilina arenaria*(Brady, 1884); **2.** ***Sigmoilinitaasperula*** (Karrer, 1868); **3.** ***Sigmoilopsis sp.*** (Finlay, 1947); **4.** ***Siphonaperta sp.*** (Vella, 1957); **5.** ***Bigenerinanodosaria*** (d'Orbigny, 1826); **6.** ***Clavulinanovangliae*** (Cushman, 1922); **7.** ***Siphoextularia sp. (1)*** (Hofker, 1976) (a) side view & (b) lateral view; **8.*Siphoextularia sp. (2)*** (Hofker, 1976); **9.** ***Spirotextularia sp.*** (Saidova, 1975); **10.** ***Textulariafoliacea*** (Heron-Allen &Earland, 1915); **11.** ***Textularialaevigata*** (d'Orbigny,1826); **12.** ***Textularialateralis*** (Lalicker, 1935); **13. Unidentified (6)**; **14.** ***FursenkoinaPauciloculata*** (Brady, 1884); **15.** ***Siphouvigerinainterrupta*** (Brady, 1879); **16.** ***Uvigerinaerugata*** (McCulloch, 1981); **17.** ***Uvigerinasemidensa*** (McCulloch, 1981); **18.** ***Pyramidulina sp.*** (Fornasini, 1894); **19.** ***Bombulinaspinata*** (Cushman, 1935); **20.** ***Glandulinaovula*** (d'Orbigny, 1846); **21.** ***Ophthalminaspiratula*** (Rhumbler, 1936); **22.** ***Ramulinaglobulifera*** (Brady, 1879); **23.** ***Ramulina sp.*** (T. R. Jones, 1875); **24.** ***Lagenastriatiformis*** (McCulloch, 1981); **25.** ***Procerolagenaclavata*** (d'Orbigny,1846); **26.** ***Bolivinacompressa*** (d'Orbigny, 1846); **27.** ***Bolivinaearlandi*** (Parr, 1950); **28.** ***Bolivinapontis*** (Finlay,1939); **29.** ***Bolivinaprimatumida*** (White, 1929); **30.** ***Bolivinarobusta*** (Brady,1881); **31.** ***Bolivinaspathulata*** (Williamson, 1858); **32.** ***Bolivinastriatellata*** (Bandy, 1949); **33.** ***Bolivinatortugiana*** (McCulloch, 1981); **34.** ***Bolivinatranslucens*** (Phleger& Parker, 1951); **35.** ***Bolivina sp.*** (d'Orbigny, 1839).

PLATE E

VIII. EXPLANATION OF PLATE E

1. ***Pseudobrizalinalobata*** (Brady, 1881); **2.** ***Ammoglobigerinaglobigeriniformis*** (Parker & Jones, 1865); **3. Unidentified (1)**(a) dorsal view & (b) ventral view; **4. Unidentified (7)**; **5.** ***Orbulinauniversa*** (d'Orbigny, 1839); **6.** ***Globigerinoidessacculifera*** (Brady, 1877); **7.** ***Globorotaliamenardii*** (d'Orbigny, 1826)(a) dorsal view & (b) ventral view; **8.** ***Globigerina bulloides*** (d'Orbigny, 1826 (a & b) different side view; **9.** ***Beellapraedigitata*** (Parker,1967); **10.** ***Globigerina regina*** (Crescenti, 1966); **11.** ***Globigerinellaobesa***(Bolli, 1957); **12.*****Globigerinoidesquadrilobatus*** (d'Orbigny, 1846); **13.** ***Globigerinoides sp.*** (Cushman,1927); **14.** ***Neogloboquadrina sp.*** (Bandy, Frechis& Vincent, 1967); **15.** ***Globuligerina sp.***(Fuchs,1973).

Table 4: Species density & p/b ratio at different stations at Bay of Bengal.

Stations	Density (ind/g)	p/b ratio
EZ-1	2.06~2	0.125
EZ-2	32.96~33	0.115385
EZ-3	48.64~49	0.138889
EZ-4	20.64~21	0.14
WZ-1	7.84~8	0.090909
WZ-2	5.26~5	0.130435
WZ-3	5.74~6	0.137931
WZ-4	7.38~7	0.115385
CZ-1	41.58~42	0.164179
CZ-2	2.06~2	0.2
CZ-3	1.3~1	0.157895
CZ-4	0.74~1	0

IX. DISCUSSION

From the study, in three different forms, altogether 112 species of foraminifera have been identified belonging to 54 genera, 26 families and 6 orders in which hyaline form is dominant about 72 species comprise about 88% of total foraminifera in these samples. 28 species comprise another 8% of foraminifera are porcellaneous in form. Only 4% of Foraminifera in 12 species of agglutinated form have been present in the study samples. These biocoenoses composition of hyaline and porcellanids predominate clearly indicate warm environment under the water (Murray, 1991). Porcellanids form 50% abundance in shallow water but it decreases to 10% at 50m in depth (Murray, 1991)

From the study it found that *Ammonia beccarii*and their relatives,*Asterorotaliapulchella, Cibicidesboueanus, Elphidiumcrispum and Nonionellinalabradorica*are much abundant in most of the samples where *Asterorotaliapulchella, Cibicidesboueanus and Nonionellinalabradorica* species are common in all study sites. By comparing previous study, *Asterorotaliapulchella*never been reported from the Arabian Sea (Rao, 1998 and Mazumder, 2005). It however occurs all along the North-eastern Bay of Bengal shelf. This indicates a geographic boundary of foraminifera between the eastand west part of northern Bay of Bengal, which could be attributed to ecological differences in the two region. *Ammonia* and its relatives are facultative foraminifera which can live on all types of environment. Walton and Sloan (1990) reviewed the worldwide distribution and ecology of *Ammonia* and found its species inhabit temperatures ranging 0ºC to 35ºC and salinities from 1‰ to 90‰. According to Frerichs (1970)*Ammonia-Asterorotalia* associations are dominant in the shelf area of Bay of Bengal. *Cibicides*are abundant at shallower depths whereas, *Elphidium* spp. commonly found in algal dense area between 20 and 50 m depth (Murray, 1991).

Highest taxonomic richness found in station EZ-3 and in station CZ-1, the second highest but most planktonic species found. On the other hand lowest count found in point CZ-4, where the total count is 10 and all are benthic species. In EZ-1, the total count of species is much poorer than others of this zone. The location and depth of this zone, sediment grain size and under water current may influence their environment structure. Higher DO and lower salinity also indicate the regular mixing or turbulence of subsurface water which alter the regular pattern of Foraminifera distribution in that station. CZ-1 station showed the second most richness where the planktonic foraminifera reserved the highest richness and abundance composition compare to rest of the sampling area. According to Buzas et al. (2007), like most other organisms, planktonic foraminifera often show an increase in species richness with depth. In near-shore environments where the dominating types of foraminifera are benthic whereas, with increasing depth and distance from the coast the capability of holding larger abundance of planktonic foraminifera seen regular.

Foraminifera are perfectly suitable for environmental studies, being recorders of environmental changes because of their wide distribution over all marine environments. Foraminiferal ecology is mainly based on natural distributions of different environmental parameters. Abundance and composition of a species vary depending upon many environmental parameters such as food, oxygen, temperature, pH, salinity and as well as the biological interactions, influence the distribution of foraminifera (Colom, 1974; Boltovskoy& Wright, 1976; Murray, 1991, 2000, 2006; Sen Gupta, 1999; Buzas-Stephens &Buzas, 2005; Debenay et al., 2006; Debenay and Payri, 2010). The temperature of the water near the bottom was nearly similar in all stations (varied between 24º-26ºC) that related to a system of horizontal and vertical movements of water masses in the offshore area of northern Bay of Bengal, as well as in any other water body. Highest temperature recorded at CZ-1 station which is mainly the function of depth. In the study area with increasing depth a proportional relation of temperature have been seen which positively influence the diversity of foraminifera of that region. The results also indicated that enough oxygen presented in water near the bottom causes good intermixing of water been observed. Salinity with little variation (29-31‰) has seen in different points of the study area.

Porcelaneous foraminifera can tolerate hyperhaline environments as well as hypohaline but agglutinates and hyaline prefer the environment with low salinity. The hyperhaline environment promotes high calcite saturation, which is particularly best fitted for the porcelaneousMiliolida (Erez, 2003). Planktonic foraminifera are adapted to oceanic layers with temperatures and densities. Density of certain environment has also influence on benthic foraminiferal habitat.In this study, the overall density variation is not vary too much. However, the influence of the density among the sampling stations has lesser or not any impact on foraminiferal distribution of the study area.

Dominance is the tendency of certain species to represent a vital part of the assemblage, defined by the occurrence of the species in that assemblage (Boltovskoy, 1976). Frequent or abundant species present in all samples considered as dominant species. There are a variety of dominant assemblages have been found from overall study area. Among them, *Asterorotalia-Cibicides* assemblage is more common in eastern zone. *Ammonia* and *Elphidium* sp. have also seen more frequent in this zone. Western zone showstotally different species type assemblage, where *Nonion*spp.*are* more dominant. Planktonic *Globigerina bulloides* domination has been more common in stations EZ-4 and CZ-1; in this case depth is the main function for this type of dominance. Occurrence of the dominant species *Ammonia tepida* in the stations CZ-2 and CZ-4 which prefers shallow, saline and brackish environments (Debenay et al., 1996, 1997; Jorissen, 1987; Seiglie, 1975; Labin, 1995; Pascual, 2002) which used to indicate a restricted environment under pollution stress (Yanko et al., 1994, 1999; Alve, 1995; Debenay et al. 2000).

Though the abundance of planktonic foraminifera increased with depth, therefore the relationship between percent planktonics and water depth across the shelf and upper slope is not always proportional. Foraminiferal populations have not been significantly altered by differential dissolution; the ratio of benthic-planktonic foraminifera is a useful proxy for productivity (Berger and Diester-Haass, 1988). From this point of view the zone wise productivity can estimate and state that central zone has greater potency of productivity except CZ-4 point (where p/b ratio measured nil) than other zones..

X. LIMITATIONS

There were some limitations to cope with during the research period. The study area was limited to the outer part of the inner shelf. Sampling stations were not much organized. Sediment was collected by Ekman grab sampler for that the study samples were disturbed, lacking of SEM constraint the study a much.

XI. CONCLUSION

Hundreds of known foraminifera both planktonic and benthic species live in northern Bay of Bengal offshore surficial sediments. Most of them are rare and a few species are dominant. The dominant species are widely distributed across the seabed. Large amount of riverine discharge into the northern offshore area are greatly influence the distribution of certain types of foraminifera.Among the three forms,porcellaneous is the pre-dominant after hyaline in every points of the study area. Almost 90% species are calcareous here with an additional 2-3% other binding form.The abundance of planktonic foraminifer is also increase with increasing depth as well as the distance from the landmass.

Due to higher potency of foraminifera as a bio-indicator, sea-level change, petroleum exploration and geological dating, its importance has been increasing day by day.

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