

# Using the Benthic Foraminifera as an Indicator of Holocene Sea Level Rise from Eastern Coastal Margin of Bangladesh

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**Abstract:** The study examined the utility of intertidal foraminifera to assess the Holocene sea-level rise using benthic foraminiferal ( $>63\ \mu\text{m}$ ) assemblages both qualitatively and quantitatively from 20 closely spaced (around 1 km) locations. These sampling points were divided into four regions mainly Teknaf, Bordel, Inani and Himchori region. These surficial sediment samples were collected across the supratidal, intertidal (low tide and high tide) and dune environment along the shelf region. A total of 250 species belonging to 50 genera and 40 families were recorded. The Teknaf zone is noticed by *Nonion-Elphidium* assemblage which shows Intertidal to Marsh zone of environment of deposition. The Bordel area is demarcated as *Nonion-Elphidium* assemblage which shows also Intertidal to Marshy environment of deposition. The Inanizone is demarcated as *Discorbis-Eponides*; *Epistomina-Operculina*; and *Cibicides* assemblage respectively which shows Supratidal environment of deposition. The Himchori is demarcated by *Anomalina-Elphidiella* assemblage which shows Intertidal zone of environment of deposition. It interprets that the environment was suitable for benthic forams and a shift of coast line towards land, during the transgression phase. This study confirms that from bottom to middle of the shore a calcareous foraminifera biofacies characterizes Bay or Lagoonal environment with marine influence. An agglutinated biofacies from the middle to top represents brackish lagoon with less marine influence. In the shoreline the period of high-frequency sea-level oscillations can be confirmed by the bottom calcareous biofacies followed by the top agglutinated one.

**Keywords:** Holocene; Sea level rise; Bangladesh; Biofacies; Foraminifera.

## Introduction

Sea level or mean sea level is the average height of the ocean's surface between high and low tide. Throughout Earth's history, sea level has constantly changed. The recent transition of the earth system from a glacial to an interglacial state produced a dramatic, global sea-level response. Oscillations between glacial and interglacial climatic conditions during the Quaternary have been characterized by the transfer of immense volumes of water between ice sheets and the oceans (Broecker and

Denton, 1989; Alley and Clark, 1999; McManus et al., 1999; Lambeck et al., 2002). Since the latest of these oscillations, the Last Glacial Maximum (between about 30,000 and 19,000 years ago), approximately  $50 \times 10^6\ \text{km}^3$  of ice has melted from the land-based ice sheets, raising global sea level in regions distant from the major glaciation centres (far-field locations) by about 130 metres (e.g. Lambeck et al., 2002).

Unclear predictions surrounding climate change, associated sea-level rise and potential impacts upon coastal environments have placed an emphasis on

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the importance of sea-level change. Sea level change determination from geological evidence includes sedimentary records, diatom analysis, pollen analysis, carbon dating etc. (Tooley, 1992). Past sea-level fluctuations have also been measured using biological and geomorphological forms of evidence. One such biological proxy is salt-marsh foraminifera, which have been used as a high-resolution indicator of past sea-level change, based on the assumption that surface foraminiferal assemblages are similar in composition to buried fossil foraminifera. This biostratigraphic indicator responds more rapidly to sea-level change (Long, 1992; Allen, 1995; Reed, 1995). They respond more rapidly than their lithostratigraphic counterparts (Long, 1992; Allen, 1995; Reed, 1995). Foraminifera are eukaryotic unicellular organisms with the general characteristics of protists (Langer and Hottinger, 2000). Their exoskeletons are commonly made up of calcium carbonate while the rest have agglutinated shells made up of sediments or shells of dead organisms. Due to their diversity which is a function of their ecological adaptation, each environment is characterized by different foraminiferal assemblages. Their small size, sensitivity to slight changes in the environment and ability to preserve these changes in their hard part give them an immense applicability in the field of paleoclimatic reconstruction and environmental monitoring.

The well-defined foraminiferal zones that subdivide salt marshes provide accurate indicators of former sea level during the Holocene. Employing foraminifera to determine former sea level requires their modern distributions and controlling environmental variables to be established. The microfaunal zones with foraminiferal assemblages (1A = *T. macrescens*; 1B: *T. macrescens*, *T. compnata*, *H. maeensis*; IIA: *T. macrescens*, *T. data*, *M. fusca*, *T. comprimata*, *A. mexicana*) (Gordon, 1980). This is particularly important because differences between rates of sea-level rise and sedimentation cause shifts in the elevation and spatial distribution of foraminiferal zones (Thomas and Varekamp, 1991). Scott and Medioli (1980b); Horton (1999); Horton et al. (1999a); and Horton et al. (2003) consider duration and then frequency of tidal exposure to be the most important variables controlling the distribution of foraminifera within the intertidal zone, with salinity the next most significant variable. However, the effect of salinity is much more pronounced where there is considerable mixing with fresh water, such as at the landward margins of a salt-marsh.

Fossil foraminifera are widespread indicators of

past tidal environments on low to high latitude coasts. Statistically significant populations in small sediment samples (e.g., from 1 cm thick samples of 1 to 5 cm diameter cores; Birks, 1995) and high preservation potential enable estuarine and marsh foraminifera to be used for environmental reconstruction that span thousands of years (e.g., Horton and Edwards, 2006). Estuarine and salt-marsh foraminifera generally consist of agglutinated species that are restricted to vegetated marshes and calcareous species of mudflats and sandflats (e.g., Phleger and Walton, 1950; Scott and Medioli, 1978; Horton and Edwards, 2006). Because the species composition of foraminiferal assemblages is sensitive to the duration and frequency of tidal flooding (Scott and Medioli, 1978; Horton and Edwards, 2006). Differences in modern intertidal assemblages can be used to develop transfer functions to reconstruct former sea levels based on fossil assemblages (e.g., Guilbault et al., 1995; Horton et al., 1999; Gehrels, 2000; Horton and Edwards, 2006; Leorri et al., 2010; Kemp et al., 2013a).

Bradshaw (1968) suggested that the following factors are beneficial to foraminifera living in marsh habitats: (a) lowering of temperature in shade provided by larger and smaller marsh vegetation such as grass, algal mats and algal clumps; (b) protection from desiccation provided by algal cover; and (c) availability of diatoms and other algae as food.

In salt marsh environment the productivity is very high (Chapman, 1977; Valiela, 1995) though there are problems with measurement of total productivity in salt marshes (Long and Mason, 1983). This ecosystem is marked by abundant dissolved nutrients, energy-rich reduced compounds and particulate matter. Because of low current velocities, the grain size of most surficial marsh sediment is fine. A pure sand substrate is usually too mobile for marsh grasses to take hold but salt marshes are common on sandy silt substrates (Chapman, 1977). In marsh substrates, pore water salinity is higher than that of sea water. All of these factors are suitable for foraminiferal assemblages in salt marsh environment.

The present research deals with the investigation of the Holocene Sea Level changes along the Eastern coastal margin of Bangladesh region. From the recovered forams, develop the Holocene Sea Level fluctuations in the study area and to develop quantitative estimation of the Sea Level change from the presence with fossil evidence prepare assemblage zone. This research applies intertidal foraminifera as precise indicators of relative sea-level change at the eastern coastal zone (Cox's Bazar to Teknaf) of Bangladesh.

## Methods of the Study

To assess the Holocene sea-level rise using benthic foraminiferal ( $>63 \mu\text{m}$ ) assemblages both qualitatively and quantitatively, about 82 samples (about 1 kg) from 20 closely spaced (around 1 km) locations from Teknaf to Cox's Bazar Beach were collected with GPS location. These sampling points were divided into four regions like Teknaf, Bordel, Inani and Himchori. These surficial sediment samples were collected across the supratidal, intertidal (low tide and high tide) and dune environment along the shelf region. These 82 samples were gone under sieving process and out of them 40 samples were selected for microscopic observations.

## Result and Discussion

A total of 250 species belonging to 50 genera and 40 families are recorded. Based upon detailed investigations of the samples it has been found that the major constituents of benthic foraminiferal assemblages in this study are *Nonion*, *Massilina*, *Elphidium*, *Eponides*, *Eponidella*, *Trochamminoides*, *Discorbis*, *Anomalina*, *Epistomina*, *Cyclammina*, *Operculina*, *Discorbinella*, *Polystromellina*, *Cibicides*, *Discammina*, *Astrorhiza*, *Trilocurena*, *Quinqueloculina*, *Globorotalia*, *Globotextularia*, *Jadammina*, *Valvulineria*

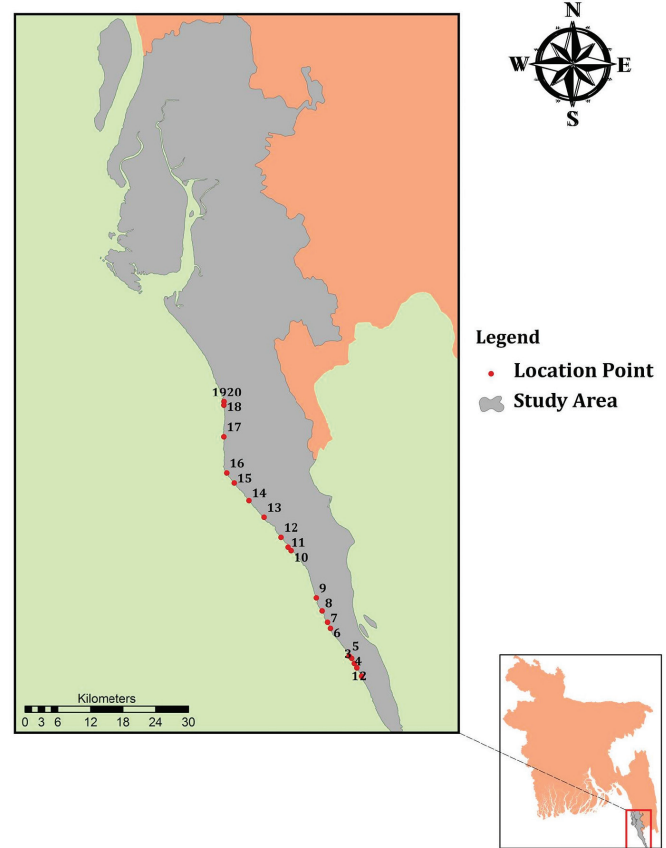


Figure 1: Location map of the study area.

Table 1: The biozonation and paleoenvironment of Teknaf region beach sand, Cox's Bazar

| Sample ID | GPS location                   | Representative foraminifera                                                                                                                                                                                                                                                                                 | Assemblage zone      |
|-----------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|
| 1         | N20°50'24.36"<br>E92°16'32.52" | Epistomina, Elphidium, Pseudomassilina, Elphinoidea, Eponoides, Massilina                                                                                                                                                                                                                                   | Elphidium            |
| 2         | N20°51'14.04"<br>E92°16'04.44" | Trochammina, Jadammina, Cytherella, Elphidium, Eponoides, Quinqueloculina, Miliammina, Massilina                                                                                                                                                                                                            | Trochammina          |
| 3         | N20°51'40.32"<br>E92°15'49.68" | Nonion, Anomalina, Massilina, Dentostomina, Elphidium, Elphidiella, Hantkenina, Eponides, Discammina, Eponidella, Assilina, Adelosina                                                                                                                                                                       | Nonion               |
| 4         | N20°52'10.92"<br>E92°15'34.56" | Nonion, Massilina, Elphidium, Hantkenina, Eponides, Trochamminoides, Trilocurena, Operculinoides, Eponidella                                                                                                                                                                                                | Nonion, Elphidium    |
| 5         | N20°52'24.96"<br>E92°15'18.72" | Nonion, Anomalina, Massilina, Dentostomina, Elphidium, Discorbis, Hantkenina, Eponides, Quinqueloculina, Valvulineria, Discorbinella                                                                                                                                                                        | Nonion, Massilina    |
| 6         | N20°55'08.04"<br>E92°13'28.92" | Nonion, Anomalina, Massilina, Elphidium, Discorbis, Trochammina, Epistomina, Eponides, Cyclammina, Operculina, Operculinoides, Eponidella, Discorbinella, Polystromellina                                                                                                                                   | Nonion, Anomalina    |
| 7         | N20°55'44.76"<br>E92°13'11.28" | Nonion, Massilina, Elphidium, Astrorhiza, Schackoina, Cibicides, Cyclammina, Discammina, Notorotalia, Orbitolina, Anomalina, Massilina, Elphidium, Astrorhiza, Trochammina, Robulus, Trilocurena, Quinqueloculina, Globorotalia, Operculina, Polystromellina, Spirophthalmidium, Pseudomassilina, Jadammina | Nonion, Elphidium    |
| 8         | N20°56'52.08"<br>E92°12'39.24" |                                                                                                                                                                                                                                                                                                             | Anomalina, Elphidium |

and *Pseudomassilina* and planktonic foraminiferal assemblages are *Schackoina*, *Trochammina*, *Hantkenina* and *Hastigerinoides*.

Out of 20 sections 1 to 8 numbered sections are regarded as Teknaf region. Teknaf region is demarcated as *Nonion-Elphidium* assemblage zone which shows Intertidal to Marsh zone of environment of deposition that reflect that the area was permanently submerged.

The sections from 9 to 16 are represented as Bordel region. Bordel region is demarcated as *Nonion-Elphidium* assemblage zone which shows Intertidal to Marsh zone of environment of deposition. Moreover, this zone is represented by abundant species of ostracode, gastropod shell that reflect that the area was permanently submerged. It interprets that the environment was suitable for benthic forams and a shift of coast line towards land, during the transgression phase.

The sections from 17 to 19 are represented as Inani region. The zone is demarcated as *Discorbis-Eponides*; *Epistomina-Operculina* and *Cibicides* assemblage zone respectively which shows supratidal zone of environment of deposition. Moreover, this zone is represented by abundant species of larger and planitic forams that reflect that the area was not permanently submerged rather seasonal tide plays vital role of their presence. It interprets that the environment was suitable for benthic forams and a shift of coast line towards land during the tidal influence.

The section 20 is represented as Himchori region. The zone is demarcated as *Anomalina-Elphidiella* assemblage zone which shows intertidal zone of environment of deposition. Moreover, this zone is represented by abundant species of *Elphidium* interprets that the environment was suitable for benthic forams

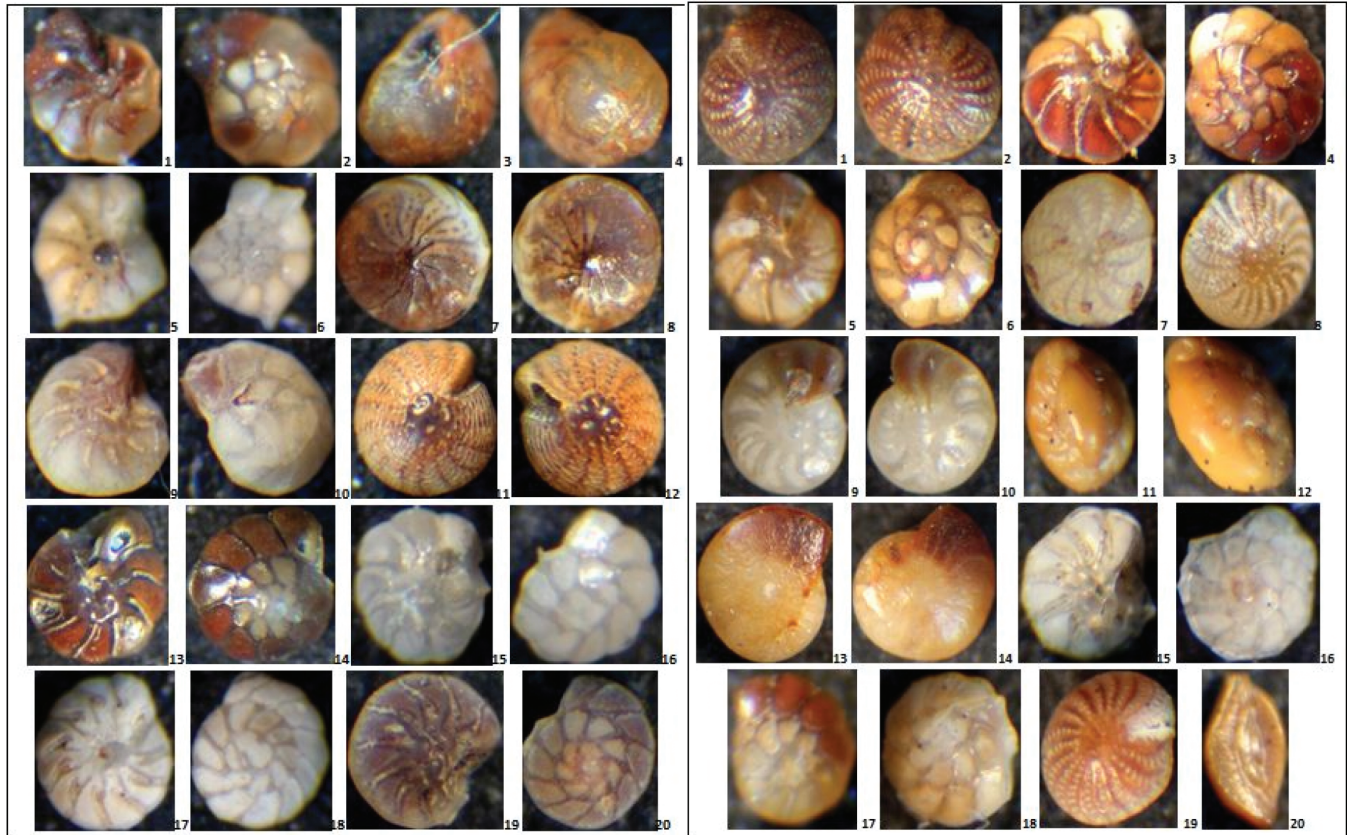


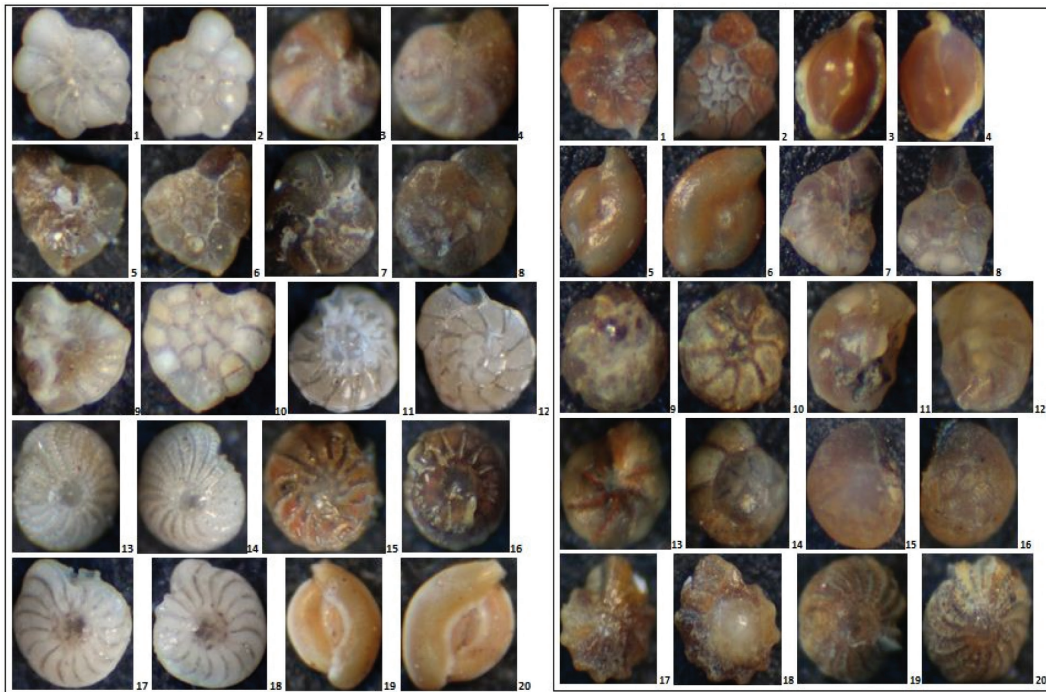
Figure 2: Representative foraminiferal assemblages from Teknaf region beach sand, Cox's Bazar.

Left: 1, 2 *Polystrommamminanitida*; 3, 4 *Epistominaelegans* (d'Orbigny); 5, 6 *Trochamminaarenosa* (Cushman and Waters); 7, 8 *Operculina granulosa* (Leymerie); 9, 10 *Eponoidesrepandus* (Fitchell and Moll); 11, 12, 13, 14 *Anomallinarostrata* (Gümbel); 15, 16 *Epistomina elegans* (d'Orbigny); 17, 18 *Eponoidesrepandus* (Fitchell and Moll); 19, 20 *Cyclamminacancellata* (Brady).

Right: 1, 2, 19 *Elphidiumlessonii* (d'Orbigny) Ventral and Dorsal view; 3, 4 *Robulusstephensoni* (Cushman); 5, 6 *Anomallinarostrata* (Gümbel); 7, 8 *Anomalinelarostrata* (Brady) Ventral and Dorsal view; 9, 10 *Trochammina inflatus*; 11, 12 *Pseudomassilinaaustralis* (Cushman); 13, 14 *Robulusmacrodiscus*; 15, 16 *Polystrommamminanitida*; 17, 18, 19 *Involutinasp*; 20 *Spirophthalmidiumacutimargo* (Brady).

**Table 2:** The biozonation and paleoenvironment of Bordel region beach sand, Cox's Bazar

|    |                                |                                                                                                                                                                                                                                                                                                                                     |                                     |
|----|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| 9  | N20°58'09.12"<br>E92°12'04.32" | <i>Nonion</i> , <i>Massilina</i> , <i>Elphidium</i> , <i>Astrorhiza</i> , <i>Cibicides</i> , <i>Eponides</i> , <i>Trilocurena</i> , <i>Quinqueloculina</i> , <i>Globorotalia</i> , <i>Operculinoides</i> , <i>Discammina</i> , <i>Eponidella</i> , <i>Endothyra</i> , <i>Globotextularia</i> , <i>Orbitolina</i> , <i>Jadammina</i> | <i>Nonion</i> , <i>Massilina</i>    |
| 10 | N21°02'48.84"<br>E92°09'32.76" | <i>Anomalina</i> , <i>Elphidium</i> , <i>Discorbis</i> , <i>Astrorhiza</i> , <i>Hantkenina</i> , <i>Quinqueloculina</i> , <i>Cyclammina</i> , <i>Globorotalia</i> , <i>Discammina</i> , <i>Ammonia</i> , <i>Miliammina</i>                                                                                                          | <i>Elphidium</i>                    |
| 11 | N21°03'09"<br>E92°09'14.76"    | <i>Nonion</i> , <i>Anomalina</i> , <i>Massilina</i> , <i>Elphidium</i> , <i>Discorbis</i> , <i>Schackoina</i> , <i>Eponides</i> , <i>Quinqueloculina</i> , <i>Cyclammina</i> , <i>Globorotalia</i> , <i>Pseudomassilina</i> , <i>Hastigerinoides</i>                                                                                | <i>Elphidium</i>                    |
| 12 | N21°04'08.04"<br>E92°08'33"    | <i>Nonion</i> , <i>Anomalina</i> , <i>Elphidium</i> , <i>Discorbis</i> , <i>Schackoina</i> , <i>Eponides</i> , <i>Trilocurena</i> , <i>Operculina</i> , <i>Valvulineria</i> , <i>Pseudomassilina</i> , <i>Hastigerinoides</i>                                                                                                       | <i>Anomalina</i> , <i>Elphidium</i> |
| 13 | N21°06'06.84"<br>E92°06'52.56" | <i>Massilina</i> , <i>Elphidium</i> , <i>Epistomina</i> , <i>Trilocurena</i> , <i>Quinqueloculina</i> , <i>Globorotalia</i> , <i>Eponidella</i> , <i>Discorbinella</i> , <i>Orbitolina</i> , <i>Pseudomassilina</i>                                                                                                                 | <i>Elphidium</i>                    |
| 14 | N21°07'45.84"<br>E92°05'22.56" | <i>Nonion</i> , <i>Dentostomina</i> , <i>Elphidium</i> , <i>Hantkenina</i> , <i>Trochammina</i> , <i>Epistomina</i> , <i>Quinqueloculina</i> , <i>Polystromellina</i> , <i>Pseudomassilina</i> , <i>Cribrorhantkenina</i> , <i>Cycloclypeus</i>                                                                                     | <i>Nonion</i>                       |
| 15 | N21°09'29.88"<br>E92°03'55.80" | <i>Nonion</i> , <i>Massilina</i> , <i>Discorbis</i> , <i>Trochammina</i> , <i>Eponides</i> , <i>Trilocurena</i> , <i>Notorotalia</i> , <i>Entzia</i> , <i>Astrononion</i>                                                                                                                                                           | <i>Eponides</i>                     |
| 16 | N21°10'29.28"<br>E92°03'10.80" | <i>Nonion</i> , <i>Massilina</i> , <i>Discorbis</i> , <i>Astrorhiza</i> , <i>Cibicides</i> , <i>Eponides</i> , <i>Trilocurena</i> , <i>Operculina</i> , <i>Carterina</i> , <i>Orbitolina</i>                                                                                                                                        | <i>Discorbis</i> , <i>Cibicides</i> |

**Figure 3:** Representative foraminiferal assemblages from Bordel region beach sand, Cox's Bazar.

**Left:** 1, 2 *Carterinaspiculotesta*; 3, 4 *Anomalinellarostrata* (Brady); 5, 6, 9, 10 *Eponoidesrepandus* (Fitchell and Moll); 7, 8 *Discorbisvesicularis* (Lamarck); 11, 12 *Astrononionstelligerum* (d'Orbigny); 13, 14 *Orbitolinasp* (Lamarck); 15, 16 *Cibicidesrefulgens* (Montfort); 17, 18 *Robulusmacrodiscus*; 19, 20 *Quinqueloculinaseminula* (Linné).

**Right:** 1, 2, 7, 8 *Cribrorhantkenina inflata* (Howe); 3, 4 *Dentostominabermudianana* (Carman); 5, 6 *Quinqueloculinaseminula* (Linné); 9, 10, 11, 12 *Trochamminadiagonis* (Carsey); 13, 14 *Eponoidesrepandus* (Fitchell and Moll); 15, 16, 17, 18 *Cycloclypeusguembelianus* (Brady); 19, 20 *Elphidium lesson* (d'Orbigny).

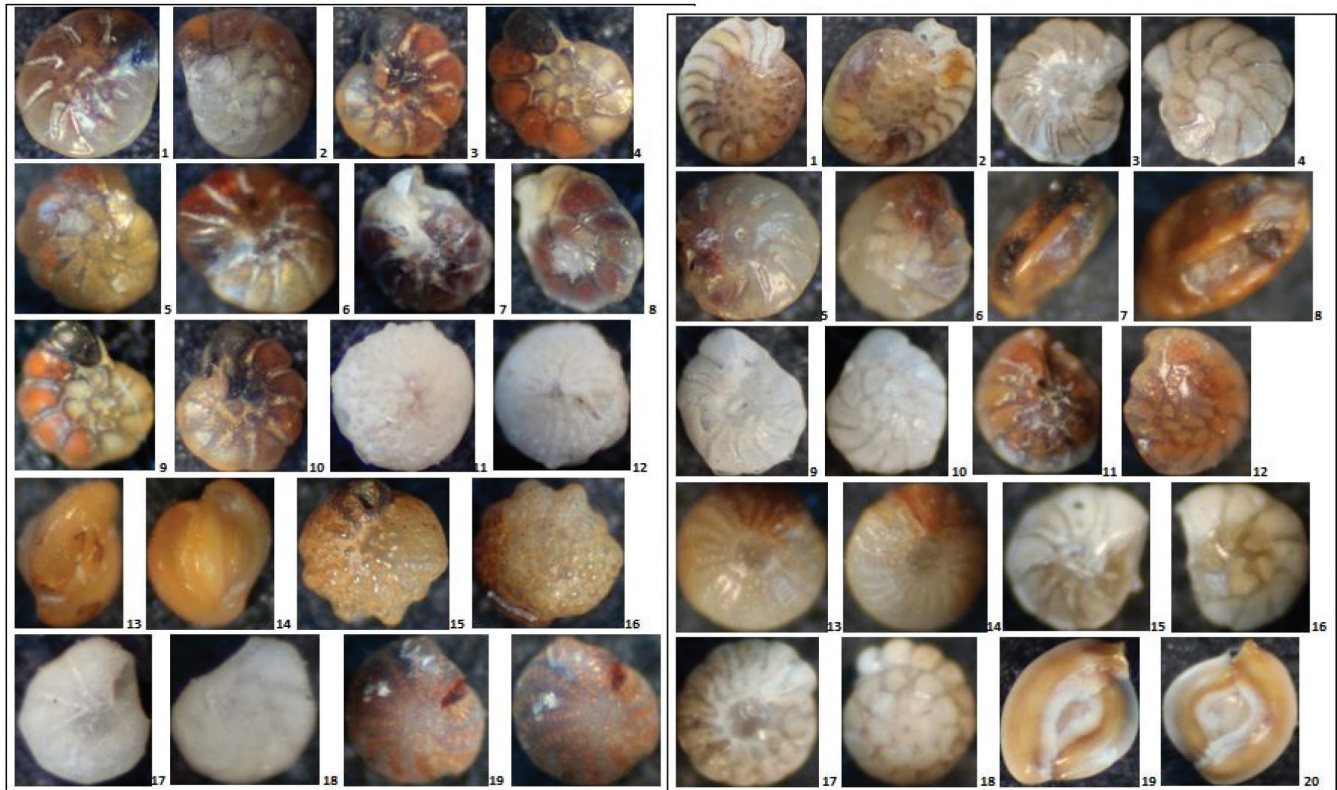
and a shift of coast line towards land, during the transgression phase.

The proportions of these three types of walls (agglutinated, hyaline, porcelaneous) in a sample of foraminifera are also characteristic of particular environments in modern seas and oceans. For example, assemblages characterized by high proportions of

calcareous, hyaline taxa are found in intertidal and subtidal zone. Assemblages dominated by calcareous, porcelaneous species are found at supratidal zone characterize shallow tropical environments. This study confirms that from bottom to middle of the shore (Figure 6) a calcareous foraminifera biofacies characterizes bay or lagoonal environment with marine influence.

**Table 3: The biozonation and associated paleoenvironment of Inani region beach sand, Cox's Bazar**

|    |                                |                                                                                                                                                |                               |
|----|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| 17 | N21°14'03.84"<br>E92°02'53.88" | <i>Nonion, Dentostomina, Elphidium, Discorbis, Cibicides, Robulus, Eponides, Trilocurena, Quinqueloculina, Operculina, Carterina, Sigmella</i> | <i>Discorbis, Eponides</i>    |
| 18 | N21°17'11.04"<br>E92°02'54.24" | <i>Nonion, Anomalina, Epistomina, Eponides, Globorotalia, Operculina, Sigmella</i>                                                             | <i>Epistomina, Operculina</i> |
| 19 | N21°17'32.28"<br>E92°02'54.60" | <i>Elphidium, Cibicides</i>                                                                                                                    | <i>Cibicides</i>              |



**Figure 4: Representative foraminiferal assemblages from Inani region beach sand, Cox's Bazar.**

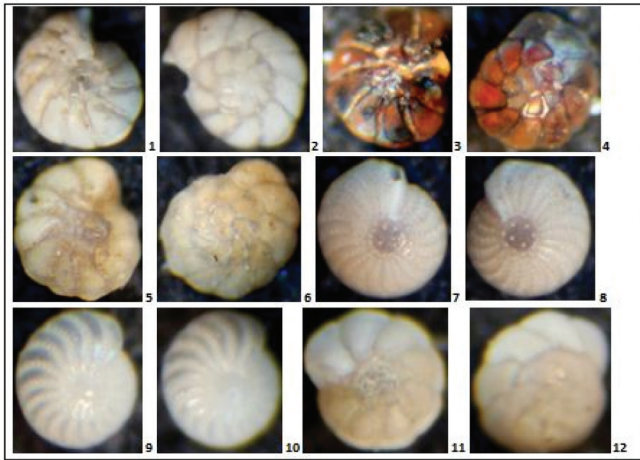
**Left:** 1, 2 *Discorbis vesicularis* (Lamarck); 3, 4 *Eponoides repandus* (Fitchell and Moll); 5, 6 *Cibicides refulgens* (Montfort); 7, 8 *Eponoides repundus*; 9, 10 *Robulus stephensoni* (Cushman); 11, 12 *Operculina granulosa* (Leymerie); 13, 14 *Trilocurena circularis*; 15, 16 *Carterina spiculotesta*; 17, 18 *Cyclammina elegans* (Cushman and Jarvis); 19, 20 *Elphidium lessonii* (d'Orbigny).

**Right:** 1, 2 *Robulus macrodiscus*; 3, 4 *Nonion labradoricum*; 5, 6 *Cyclammina elegans* (Cushman and Jarvis); 7, 8 *Dentostomina bermudiana* (Carman); 9, 10 *Trilocurena circularis*; 11, 12 *Discorbis vesicularis* (Lamarck); 13, 14 *Elphidium lessonii* (d'Orbigny); 15, 16 *Discorbis vesicularis* (Lamarck); 17, 18 *Discorbis vesicularis* (Lamarck); 19, 20 *Sigmella edwardsi* (Schlumberger).

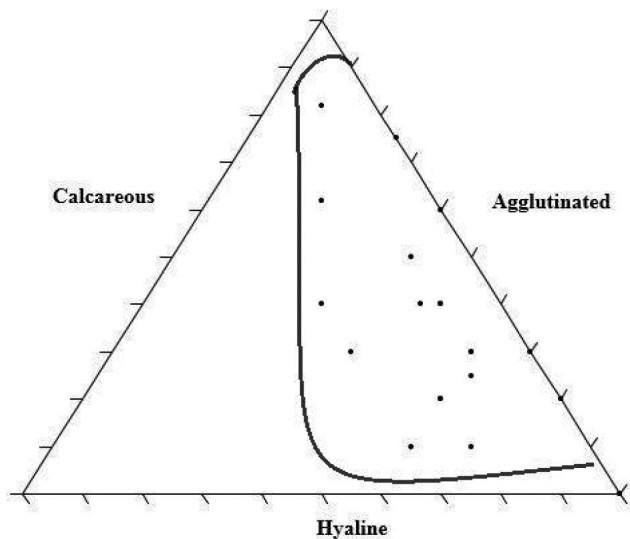
**Table 4: The biozonation and associated paleoenvironment of Himchori region beach sand, Cox's Bazar**

|    |                                |                                                                                                                                                  |                                       |
|----|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|
| 20 | N21°17'32.28"<br>E92°02'54.60" | <i>Anomalina</i> , <i>Elphidium</i> , <i>Elphidiella</i> , <i>Astrorhiza</i> , <i>Trochammina</i> ,<br><i>Cibicides</i> , <i>Trochamminoides</i> | <i>Anomalina</i> , <i>Elphidiella</i> |
|----|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|

An agglutinated biofacies from the middle to top represents brackish lagoon with less marine influence. In the shoreline the period of high-frequency sea-level oscillations can be confirmed by the bottom calcareous biofacies followed by the top agglutinated one.



**Figure 5: Representative foraminiferal assemblages from Himchori region beach sand, Cox's Bazar. 1, 2 *Trochamminoides proteus* (Karrer); 3, 4 *Robulusstephensoni* (Cushman); 5, 6 *Anomalinellarostrata* (Brady); 7, 8 *Elphidiumlessonii* (d'Orbigny); 9, 10 *Elphidellaarctica* (Parker and Jones); 11, 12 *Cibicidesrefulgens*.**



**Figure 6: Shell-type ratio triangular diagram showing fields defined by benthic foraminiferal assemblages (modified from Murray, 1974).**

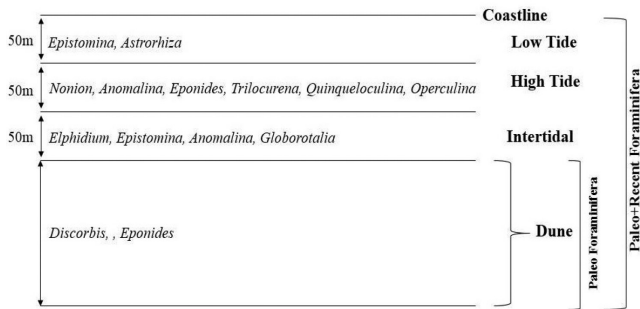
### Shoreline Configuration and Relative Sea Level Change

Much of the coast of Bangladesh experiences a large tidal range, reaching up to 6 m or more at Sandwip Island (Barua, 1997). Large errors in shoreline change could result if one image was acquired at low tide and the other at high tide, particularly on an intertidal substrate of gentle gradient as characteristic of much of the Bay of Bengal (Jimenez et al., 1997). In order to minimize such shoreline-change error in the two images, the time of image capture was noted and tidal conditions at that time determined from tidal records held with the Bangladesh Inland Water Transport Authority (BIWTA). Only Landsat images showing good agreement in terms of tidal stage in each of 1989 and 2009 were selected for shoreline analysis.

The coastal zone of Cox's Bazar was the least eroded among the six mainland coastal sections. It showed an erosion of 10.0 km<sup>2</sup> and an accretion of 37.6 km<sup>2</sup>; one rapidly accreting spot in the coastal zone was identified along the shoreline of Moheshkhali. A total area of 33.32 km<sup>2</sup> was accreted along about 16 km length of shoreline. The southernmost tip of the country, the Teknaf peninsula, showed erosion that resulted in a decrease in the total length of the mainland of the country by 2.4 km (Sarwar and Woodroffe, 2013).

In the present study (Figure 7) *Nonion* show their maximum concentration in the high tidal environment, sometimes they are also found in the dune environment where they together with genera *Eponides* constitute a large part of the benthic foraminifera with muddy substrate. The second large population is *Elphidium* which are available in the intertidal and dune environment with sandy-silty substrate. *Anomalina* is found both in the high tide and intertidal environment with sandy substrate. *Discorbis* and *Epistomina* are found in respectively in the dune with muddy substrate and low tide environment with sandy substrate.

Substantial changes in shoreline configuration have been reconstructed during the Holocene evolution of this large delta complex (Goodbred and Kuehl, 2000b), and paleo-shorelines for 3,000 yrs BP, 5,000 yrs BP, 7,000 yrs BP and 9,000 yrs BP show little consistency in accretionary or erosional trend as sea level rose to its present level and as the Ganges delta occupied



**Figure 7: Assemblage biozone of foraminifera at Cox's Bazaar sea beach.**

successive lobes from west to east, before occupying the Meghna estuary. The geomorphological processes associated with the formation of an active delta and its subsequent abandonment and erosion, as along the Gangetic tidal plain, provide only a first-order indication of likely shoreline trends. The relative sea-level history of Bangladesh during the Holocene remains incompletely understood (Rashid et al., 2013).

Sedimentological, palynological data indicate that mangrove community developed under transgressive condition in and around Maheshkhali and Kutubdia Island areas during Mid Holocene time (7000 to 5500 years BP) leading to the locally wide-spread deposition of organic-rich sediments. During Holocene time global rise and fall of Eustatic Sea Level play an important role not only on the depositional environment but in creating a geomorphic feature on the island. Recurrent occurrence of freshwater and mangrove pollen in Maheshkhali and Kutubdia Island area indicates that these areas have undergone cyclic marine and non-marine influence. Since the Last Glacial Maximum (about 20,000 years ago), sea level has risen by over 120 m at locations far from present and former ice sheets, as a result of loss of mass from these ice sheets. There was a rapid rise between 15,000 and 6,000 years ago at an average rate of 10 mm/yr. Based on geological data, global average sea level may have risen at an average rate of about 0.5 mm/yr over the last 6,000 years and at an average rate of 0.1 to 0.2 mm/yr over the last 3,000 years. Vertical land movements are still occurring today as a result of these large transfers of mass from the ice sheets to the ocean. During the last 6,000 years, global average sea level variations on time-scales of a few hundred years and longer are likely to have been less than 0.3 to 0.5 m. First transgression was noticed around 6000-5500 cal BP and then a subsequent regression of the bay had been observed from around 5500 cal BP. This was again followed by another small scale transgression episode occurred around 2500—2000 cal BP. So, the

palynomorph assemblages from the Holocene sediment sample indicate that Maheshkhali and Kutubdia Island and its surrounding area were an intertidal environment occupied by mangrove community (Kibria et al., 2015).

The Cox's Bazaar to Teknaf beach is a fossil backslope, hypersaline small basin on the eastern coastal margin, Bangladesh. The surface sediments of the bay were investigated for their benthic foraminiferal content in order to correlate, in general, with environmental factors such as temperature, salinity, pH, sediment grain size, organic matter and, in particular, with tidal elevations to develop a training set for predicting sea-level changes in the bay. Hierarchical cluster analysis divided the benthic foraminifera in the bay into four distinct faunal assemblages.

During the last ~4,500 yrs, the bay has experienced a major regression phase, by becoming more restricted in terms of seawater circulation and probably increasing tidal energy. Three main stratigraphic surfaces were recognized, which limit transgressive, transgressive/highstand and regressive facies. The present channel morphology represents a tidal scouring surface or a tidal diastem, which erodes and truncates regressive facies bedding. Foraminiferal biofacies, which change from marine to brackish and mangrove tidal-flat environments, support the seismic stratigraphic interpretation. Absence of mangrove biofacies at one of the two cores is also an indication of modern tidal ravinement.

The above studies confirm that from bottom to middle of the cores a calcareous foraminifera biofacies characterizes bay or lagoonal environment with marine influence. An agglutinated biofacies from the middle to top represents brackish lagoon with less marine influence. In those cores the period of high-frequency sea level oscillations can be confirmed by the bottom calcareous biofacies followed by the top agglutinated one.

The rate of relative sea-level rise is also likely to be locally variable. A better understanding of this sea-level rise variability would help to depict trends in shoreline change. The combination of long-term delta dynamics, episodic extreme storm events, and localized human intervention make it very difficult to determine consistent overall trends in shoreline change or forecast how particular sections of coast will respond to future climate change. Such an analysis will require other lines of investigation and data. A combined work on  $C^{14}$  dating as well as intertidal salt marshes foraminifera is needed to locate the paleobeach location which can help to identify the recent sea level variation.

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