

Multiple ecological parameters affect living benthic foraminifera in the river-influenced west-central Bay of Bengal

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Abstract

The huge riverine influx and associated processes decrease the ambient salinity, stratify the water column, modulate the oxygen-deficient zone and are also responsible for the recent acidification in the Bay of Bengal. Here, we have studied the effect of these riverine influx-dominated ecological parameters on living benthic foraminifera in the west-central Bay of Bengal. We report that the pH below 7.6 in front of the Krishna river, reduces the diversity and the richness of living benthic foraminifera on the adjacent shelf and the slope. A similar decreased diversity and richness is also observed in front of the Godavari River. We delineate three prominent assemblages, representing different depth zones with associated distinct physico-chemical conditions. The shallow water assemblage (~27 m - 100 m) is represented by *Nonionella labradorica*, *Hanzawaia nipponica*, *Brizalina dilatata*, *Ammonia tepida* and *Nonionella limbato-striata*. These species are adapted to relatively warmer temperatures and more oxygenated waters. The deepwater assemblage (~1940 m – 2494 m) includes *Bulimina* cf. *delreyensis*, *Bulimina marginata*, *Hormosinella guttifera*, *Cassidulina laevigata* and *Gyroidinoides subzelandica* and can tolerate a relatively colder temperature. The intermediate-depth assemblage (~145 m – 1500 m) dominated by *Eubuliminella exilis*, *Bolivinellina earlandi*, *Fursenkoina spinosa*, *Bolivinellina lucidopunctata*, *Globobulimina globosa*, *Fursenkoina spinosa*, *Eubuliminella cassandrae*, *Uvigerina peregrina*, *Rotaliatinopsis semiinvoluta* and *Cassidulina laevigata*, represents oxygen-deficient and organic carbon-rich environment. Besides the pH, temperature, dissolved oxygen and organic matter, we also report a strong influence of bathymetry, coarse fraction and the type of organic matter on a few living benthic foraminifera. The ecological preferences of 40 such dominant living benthic foraminifera, each representing a specific environment, have also been reported for site-specific proxy. We conclude that although the huge riverine influx affects living benthic foraminifera on the shelf, the dissolved oxygen and organic carbon mostly control benthic foraminiferal distribution in the deeper west-central Bay of Bengal.

Keywords: Foraminifera, ecology, riverine influx, organic matter, pH, Bay of Bengal

1. Introduction

The huge riverine influx creates a unique environment in the Bay of Bengal. A few of the world's largest snow and rainfall-fed rivers (Irrawaddy, Ganga, Brahmaputra, Mahanadi, Krishna, and Godavari) drain freshwater and sediments into the Bay of Bengal, creating a specific environment with associated physical and chemical parameters. The riverine influx reduces the salinity, warms the seawater and creates strong stratification (Sengupta et al., 2006). The associated sediment influx contributes enormous nutrients, sustaining the primary productivity (Prasanna Kumar et al., 2002). In addition to the riverine influx, the anthropogenic input (sulphate and nitrogen aerosols) to the Bay of Bengal significantly affects its biogeochemistry (Sarma et al., 2016). Therefore, the riverine influx primarily modulates the ambient physico-chemical conditions in the northern Bay of Bengal. Additionally, the dissolved oxygen, a critical requirement of a large fraction of marine biota, is also perennially low at the Bay of Bengal's intermediate depths (Sarma et al., 2013). As suggested by the acidification and a possibility of the bay turning into the foremost nitrogen contributor soon (Bristow et al., 2017), the increasing stress implies that it is essential to understand the effect of these critical ecological parameters on the marine biota.

Benthic foraminifera are the dominant marine biota in the continental margin sediments and are the primary component of the global carbon cycling. The large abundance, combined with the sensitivity to the ambient conditions and long-term preservation in sediments, makes benthic foraminifera a widely used proxy to reconstruct paleoceanographic changes (Saraswat, 2015a; 2015b; Saraswat et al., 2017). The precise knowledge of the influence of ambient environmental parameters on abundance and distribution, is a prerequisite to use benthic foraminiferal characteristics for paleoceanographic and paleoclimatic interpretation (Murray, 2001; Gooday, 2003; Jorissen et al., 2007; Gooday and Jorissen, 2012; Saraswat and Nigam, 2013). Various environmental parameters, including food, oxygen concentration, salinity, pH, temperature, substrate, water depth and others, influence the diversity and abundance of benthic foraminifera (Lutze and Coulbourn, 1984; Kaminski et al., 1988; Altenbach, 1992; Mackensen et al., 1995; Gooday and Rathburn, 1999; van der Zwaan et al., 1999; Ernst et al., 2002; Altenbach et al., 2003; Lei et al., 2017, 2019). The relative influence of various factors on faunal distribution, however, varies from region to region. The salinity and temperature are the major factors in riverine influx dominated continental shelves (Manasa et al., 2016). However, the deeper depth continental slope assemblages are mainly controlled by the availability of food and dissolved oxygen concentration (Gooday, 1986; Corliss and Emerson, 1990; Corliss and Chen, 1988; Rosoff and Corliss, 1992; Rathburn and Corliss, 1994; Mackensen and Douglas, 1989; Barmawidjaja et al., 1992; Jorissen et al., 1992; Nisha and Singh, 2012; Singh et al.,

2015a, 2018; Verma et al., 2018). Benthic foraminiferal abundance, diversity, species richness and evenness also depend on ambient conditions (Gibson and Buzas, 1973; Buzas and Culver, 1991; Murray, 2006; Singh et al., 2015a; 2015b). The overall benthic foraminiferal abundances and diversity decreases, whereas the abundance of abnormal or stress-tolerant specimen increases, under both naturally and anthropogenically stressed environment (Alve, 1995; Saraswat et al., 2004; Nigam et al., 2007). As the extent of stress varies regionally, the benthic foraminiferal response has to be assessed from different regions.

The fossil benthic foraminiferal assemblage is often biased by the biological and taphonomical processes, including transport, test disintegration or dissolution (Murray, 1991; Jorissen and Wittling, 1999; Berkeley et al., 2014). Therefore, living benthic foraminifera (rose-Bengal stained) provide a comparatively more reliable response to the ecological conditions. The previous studies on the distribution and ecology of living benthic foraminifera (rose-Bengal stained) from the northern Bay of Bengal are rare (Boltovskoy, 1978). The few studies documenting living benthic foraminifera from the Bay of Bengal cover a limited spatial extent, concentrating only on nearshore-beaches and estuaries (maximum 19 m water depth) (Gandhi et al., 2007; Gandhi and Solai, 2010). The influence of deep water ecological conditions on benthic foraminifera from the Bay of Bengal is rarely documented. Recently, Suokhrie et al., (2020), compared the living benthic foraminifera of the western Bay of Bengal's oxygen-deficient zone with that from a similar region in the Arabian Sea. A distinctly different benthic foraminiferal assemblage was reported from the Bay of Bengal oxygen deficient waters. However, the effect of other stressors, including salinity, temperature, pH, riverine influx on benthic foraminifera, both above and below the oxygen-deficient zone of the western Bay of Bengal, was not addressed. Therefore, we study the combined effect of multiple ambient parameters on the living (stained) benthic foraminiferal assemblage from the shallow inner shelf to the slope and further deeper region of the west-central Bay of Bengal. The main objective of this study is to establish representative living (rose-Bengal stained) benthic foraminifera assemblages characterizing a particular set of ecological niches on the shallow continental shelf to the abyssal depth in the west-central Bay of Bengal, where the freshwater influx and associated processes primarily influence the physico-chemical parameters. The baseline information will be beneficial to understand the foraminiferal response to climatic changes in the future. The precise information about benthic foraminifera's ecological preferences, will also be useful for a better reconstruction of the past environmental conditions.

2. Oceanographic setting

The west-central Bay of Bengal is strongly influenced by the riverine influx. Some of the world's largest rivers drain into the western Bay of Bengal, with an average runoff being Ganga- 11892 m³s⁻¹, Brahmaputra- 16186 m³s⁻¹, Godavari- 3180m³s⁻¹, Krishna- 1730 m³s⁻¹, Pennar- 95 m³s⁻¹ and Cauveri- 664 m³s⁻¹(Rao, 1975; Subramanian, 1979; Dai and Trenberth, 2002). The lithogenic components' contribution is ~39% in the northern bay and ~12.6% in the southern bay (Unger et al., 2003). The riverine influx is most intense during the summer monsoon and is also responsible for the salinity-controlled stratification (Gomes et al., 2000; Unger et al., 2003; Sarma et al., 2016) and surface circulation in the Bay of Bengal. The southwestern Bay of Bengal receives significant precipitation during the winter monsoon. The surface circulation (East India Coastal Current) reverses seasonally along the bay's western boundary, flowing southwards during the winter season and northward during the summer season (Vinayachandran et al., 1999; Shankar et al., 2002). The precipitation resulting from the seasonal reversal of winds in the Bay of Bengal is maximum during the summer monsoon (318 mm/month) as compared to the winter monsoon (88 mm/month) (Ramesh Kumar and Prasad, 1997). The summer precipitation causes substantial spatial variation in the salinity and temperature in the bay. The sea surface salinity varies from 29.1 psu closer to the continental margin on the inner shelf to 33.7 psu towards the open ocean. The warmer water input from the rivers is evident by the relatively higher sea surface temperature (29°C - 30°C) in the river mouths' vicinity (Durand et al., 2011; Locarnini et al., 2013). The dissolved oxygen is low at intermediate depths (~100m to ~1000m), with concentration being as low as 5 µM (Wrytki, 1971; Rao et al., 1994; Sardesai et al., 2007; Bristow et al., 2017). The shallower inner shelf water in the vicinity of the river has a higher dissolved oxygen. The chlorophyll-a concentration varies from ~0.3 mg/m³ to 2.0 mg/m³ in the western Bay of Bengal, with higher concentration closer to the river mouth (NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group, 2014). A strong wind-induced upwelling spread over ~40 km wide band, all along the eastern margin of India, is observed in the western Bay of Bengal, during the summer season (Shetye et al., 1991). As a consequence of this upwelling, salinity increases coastward (Shetye et al., 1991). The modern-day lysocline depth is at 2000 m to 2600 m, shallowing from south to north in the Bay of Bengal (Cullen and Prell, 1984).

3. Materials and methodology

3.1. Field sampling

A total of 46 surface sediment samples (35 multi-core and 11 spade-core) were collected in 2014 and 2012, during the 308th cruise of ORV *Sagar Kanya* (SK 308) and RV *Sindhu Sankalp* (SSK

35) from the west-central Bay of Bengal, respectively (Figure 1, Supplementary Table 1). The samples were collected along the coast perpendicular transects at regular depth intervals, starting from the continental shelf to the slope (27 m to 2494 m), during the pre-summer monsoon season of 2012 and 2014 (more details in Suokhrie et al., 2020). After retrieval, the top 10 cm (0-10 cm) of the sediment collected by using *Ocean Science Industries Limited (OSIL) - Maxi multi-corer* was sub-sampled at 1cm interval. Half of the sediment from each section was immediately preserved in ethanol rose-Bengal solution (2g rose-Bengal per liter of ethanol), to stain living benthic foraminifera. The top two sections (0-2 cm) were analyzed, as they contain the majority of the living benthic foraminifera in the northern Indian Ocean (Singh et al., 2018). The use of rose-Bengal stained living benthic foraminifera has been widely discussed since its introduction by Walton (1952). A study by Walker et al (1974) compared rose-Bengal and Sudan Black B stains and reported that rose-Bengal stain identified 70% of the specimens containing protoplasm. The concern also remains in differentiating the protoplasm living at the time of sample collection with the recently dead protoplasm (Bernhard, 1988). However, a majority of the tests lying in the sediments are usually devoid of protoplasm because of reproduction, predation, or growth stages (Murray and Bowser, 2000). Also, the living protoplasm (those living at the time of staining) tend to acquire deeper and denser stain up to one additional chamber. So, if the pattern of staining can be understood thoroughly, the error of over-estimating the stained living fauna can be reduced (Linshy, 2010).

The overlying bottom water in the multi-cores was collected at each station, and its salinity, pH and temperature were measured onboard by using a hand-held multimeter (S47-K/'SevenMulti') (Supplementary Table 2). The bottom water sample was not retrieved at a few multi-core stations. For these stations, salinity, temperature, dissolved oxygen, and also all the environmental data for the 11 spade core stations were downloaded from the World Ocean Atlas 2013 (Garcia et al., 2013; Locarnini et al., 2013; Zweng et al., 2013) by using the Ocean Data View software (Schlitzer, R., Ocean Data View, <http://odv.awi.de>, 2016) (Figure 2).

3.2. Laboratory analysis

The stained sediments were stored in cold-storage (4°C) for a minimum of two weeks and were then processed following the standard procedure (Manasa et al., 2016; Singh et al., 2018; Suokhrie et al., 2020). The excess ethanol rose-Bengal was removed, and the sediments were freeze-dried. The dried samples were then weighed, and ~2g of the sediment was finely powdered for total carbon, nitrogen and inorganic carbon analysis. The rest of the sample was wet sieved by using a 63 µm sieve. The >63 µm material (Coarse Fraction, CF) was dried, weighed and then transferred into plastic vials. A representative aliquot of the coarse fraction was weighed to pick a minimum of 300 living benthic

foraminifera, wherever possible. All available living benthic foraminifera were picked from a fixed 0.1 g coarse fraction, in samples where a limited number of specimens were found. The picked specimens were mounted on the micropaleontological slides for counting and identification. Only those specimens with precise pink colouration with more than one chamber completely stained were picked and counted for living benthic foraminifera. All specimens were identified by using the previously published literature. The foraminiferal treatise (Loeblich and Tappan, 1988) was followed for genus confirmation, and for species confirmation, we have referred to the foraminiferal catalog (Ellis and Messina). The genus of a few species have been shifted, as per the taxonomic shifts. *Bolivinellina* has been shifted from *Bolivina* following Saidova (1975). One species (*Ebuliminella cassandrae*) was also shifted from genus *Bulimina* to *Ebuliminella* following Revets (1993). Only those references mentioned in the main text of the paper have been added to the reference list. All other species identification references are mentioned in Supplementary Table 4 for further reading.

The sedimentary characteristics, namely total inorganic carbon (IC), total nitrogen (TN) and total carbon (TC), were analysed by using dried and finely powdered sediment (~10 mg weight). TIC was analyzed by using UIC CM 5015 CO₂ Coulometer and TC, TN by CNS elemental analyzer (Thermo Scientific). Calcium carbonate (CaCO₃) was calculated from IC and organic carbon (C_{org}) was estimated by subtracting TIC from TC.

3.3. Statistical analysis

To draw meaningful inferences from the large dataset of the relative abundance of all benthic foraminifera species identified from the western Bay of Bengal, 54 dominant species ($\geq 3\%$ abundance at a minimum of two stations) (Figure 3-6), were used for the Cluster analysis. Bray Curtis similarity index was applied through Q-mode cluster analysis by using Primer 6.1.10 software. The major clusters were identified with similar species having a particular percentage contribution in each cluster. The dominant assemblage representing a cluster and the relative contribution of each species to the respective cluster was identified by using the Simple Percentage (SIMPER) program at 100%. The Canonical Correspondence Analysis (CCA) was done to understand the influence of multiple parameters on the dominant species. The multivariate statistical package version 3.1 (Kovach, 1988) was used for CCA. The canonical correspondence analysis (CCA) provides a better insight into the cumulative effect of a set of ambient environmental parameters on the abundance of species.

4. Results

4.1. Bottom water parameters (salinity, temperature, dissolved oxygen and pH)

The salinity at the sediment-water interface was higher in the shallow regions than at the deeper regions. The salinity ranged from ~32.15 psu to 35.2 psu (Figure 2A). The dissolved oxygen varies from ~0.3 ml/l to a maximum of ~4.9 ml/l. The dissolved oxygen is low within the depth range of ~100 m to ~1000 m (Figure 2B). The previous reports suggest excessively low oxygen concentration (as low as 18 nM) at ~150 m to ~450 m (Bristow et al., 2017). The temperature at the sediment-water interface was relatively warmer ($>23^{\circ}\text{C}$) in the shallow coastal zone as compared to the deeper region ($<17^{\circ}\text{C}$) (Figure 2C). The seawater pH at the spade core stations was not available, and hence the data from the multicore stations only are plotted. The measured pH at the sediment-water interface in the study area ranges from 7.5 to 8.1. The region off Godavari and Pennar rivers has higher pH than off the Krishna river (Figure 2D).

4.2. Sediment characteristics

The fraction retained on the sieve ($>63\ \mu\text{m}$) is considered as the coarse fraction (CF) and comprises both biogenic remains (shells and tests), and terrigenous material (quartz, mica, feldspars and others). A relatively more CF is observed in the southern segment and at the shallower and deeper stations (Figure 2E). Overall, the upper slope stations (~250 to ~1000 m) have a comparatively higher finer fraction. CF varied from ~0.5% to an enormously high percentage upto ~90% at the southern stations. The influence of riverine influx on CF, by contributing terrigenous material, is evident from the increase in CF in front of the river mouths, especially in the southern part of the study area (SC42, SC43, SC44). Interestingly, the increased CF is also observed in the deeper region and is attributed to increased contribution from biogenic remains, including foraminiferal tests (Figure 2E).

The organic carbon varied from 0.3% to 1.8% in the west-central Bay of Bengal (Supplementary Table 2). The maximum %C_{org} was at the deeper depths. The influence of riverine discharge by contributing terrigenous organic matter and the fine fraction is also evident (Figure 2F). The organic carbon comes both from the terrigenous influx as well as marine productivity. These two sources' relative contribution is delineated by the organic carbon to nitrogen ratio of the organic matter (C_{org}/TN). Generally, C_{org}/TN >6.0 is considered to be of terrestrial input, as vascular plants have nitrogen depleted organic matter (Müller and Mathesius, 1999; Ramaswamy, 2008), and values <6.0 are used to infer marine input. A majority of the C_{org}/TN values are >6.0 and hence suggests that the organic matter is mainly contributed by terrestrial sources rather than by marine productivity.

Expectedly, the maximum C_{org}/TN is in front of the Godavari, Krishna and Cauvery rivers (SC37, SC38, MC30, MC31, SC40, SC39, MC27, MC28) (Figure 2G).

The biogenic skeletal remains mainly contribute $CaCO_3$ to the sediments. $CaCO_3$ concentration in the west-central Bay of Bengal ranged from 1.3% to 87.2%. $CaCO_3$ concentration increases towards the southern part of the west-central Bay of Bengal. Additionally, $CaCO_3$ is low at a few stations on the lower slope (depth > 1000 m), likely due to a reduction in the total foraminiferal abundance, which mainly contributes to the $CaCO_3$ in the sediments at these depths (Figure 2H).

4.3. Cluster Analysis

A total of 263 living benthic foraminifera have been identified (Supplementary Tables 3 and 4). The cluster analysis groups similar objects together to draw meaningful inferences from a large dataset like the number of species and their relative abundance in the western Bay of Bengal (Kaufman & Rousseeuw, 2009; Khare et al., 2017). Based on the distribution at different stations, 54 dominant species were selected for the cluster analysis. We delineate 4 major clusters at 20% similarity index, other than a few insignificant ones (Figure 7). The clusters were named as Cluster I, II, III and IV. The dominant assemblage representing a cluster and each species' relative contribution to the respective cluster is described below.

Cluster I

This cluster is represented by 6 stations, namely SC45, MC36, MC32, SC36, MC24 and MC09. The stations in this cluster are from a shallow depth (107m to 274m) except for one station MC36 (1511m). The similarity percentage (SIMPER) analysis shows that this cluster has an average similarity of 20.59% consisting of 12 species. The dominant species are *Eubuliminella exilis* (24.88%), *Bolivinellina earlandi* (19.89%), *Fursenkoina spinosa* (12.54%), *Bolivinellina lucidopunctata* (8.76%) and *Globobulimina globosa* (6.48%).

Cluster II

Fursenkoina spinosa (15.64%), *Eubuliminella cassandrae* (11.41%), *Rotaliatinopsis semiinvoluta* (11.07%), *Uvigerina peregrina* (10.4%) and *Cassidulina laevigata* (8.26%) are the dominant species in this cluster having an average similarity of 51.31%. This cluster represents a depth range of 500 m to 1518 m.

Cluster III

This cluster is represented by 5 stations (MC15, MC2, MC37, MC18, MC38) representing a depth range of ~1940 m to 2494 m with a similarity of 47.62%. 12 species comprise of this cluster and the

five most dominant ones are *Bulimina* cf. *delreyensis* (18.59%), *Bulimina marginata* (18.14%), *Hormosinella guttifera* (9.05%), *Cassidulina laevigata* (8.02%) and *Gyroidinoides subzelandica* (6.18%).

Cluster IV

The SIMPER analysis shows that the average similarity of this cluster is 34.53%. The representative benthic foraminiferal assemblage of this cluster includes 9 species of which the 5 most dominant ones are listed here, *Nonionellina labradorica* (37.85%), *Hanzawaia nipponica* (17.58%), *Brizalina dilatata* (17.31 %), *Ammonia tepida* (4.71 %), *Nonionella limbato-striata* (4.08 %).

From the spatial distribution of various clusters, it is clear that Cluster I, Cluster II and Cluster III and Cluster IV follow a depth zonation (Figure 8). Cluster IV is confined to the shallow water depth. Cluster I represents a shallow to intermediate depth zone covering the upper slope region. Cluster II mainly comprising of angular asymmetrical foraminifera, represents a wide range of intermediate water depth to deep water depth locations. The assemblages in this cluster consist of species that are indicative of an oxygen-deficient region. The species in Cluster III represent the deep-water species.

4.4. Canonical Correspondence Analysis

The dominant effect of one or a combination of several parameters, out of a set of multiple parameters in the field, on living benthic foraminiferal species, can be identified from CCA. Out of the 54 dominant species, only 40 species showed a significant relationship with at least one of the ambient environmental parameters (Figure 9). The rest of the species do not show a significant relationship with any particular parameter, as evident from the close proximity of these species to the centroid in the CCA biplot (ter Braak, 1986). From CCA, it is evident that the dissolved oxygen, coarse fraction (CF) and temperature, are the most significant parameters controlling the living benthic foraminifera species distribution in the west-central Bay of Bengal. Besides these dominant factors, C_{org} , salinity, and C_{org}/TN also influence the distribution of living benthic foraminifera.

4.5. Species Representing Specific Set of Parameter

4.5.1. Species preferring oxic, colder water with organic matter rich sediments

Ammobaculites cf. *agglutinans*, *Quinqueloculina bicarinata*, *Bolivinelina pacifica*, *Brizalina dilatata*, *Latibolivina lepida*, *Latibolivina persiensis*, *Fursenkoina pauciloculata*, *Eponides cribroreperandus*, *Nonionella auris*, *Nonionella limbato-striata*, *Nonionellina labradorica*, *Hanzawaia nipponica* and *Ammonia tepida* were positively correlated with dissolved oxygen and organic carbon, whereas negatively correlated with temperature (Figure 9). *Ammobaculites* cf. *agglutinans*, an agglutinated

benthic foraminifer, was present only at 4 stations, all shallower than ~60 m. *Quinqueloculina bicarinata* was present at three stations, all shallower than 56 m. Even *Bolivinelina pacifica* was present only upto 76 m. *Brizalina dilatata* was found at stations mostly within depths of ~300 m, beyond which <1% abundance was observed at two stations. *Latibolivina lepida* was found only at two stations with abundance varying from 4.2% (53 m) to 6.2% (52 m). Likewise, *Latibolivina persiensis* was also present at shallow depths between 40 m to 76 m, beyond which it was absent. *Fursenkoina pauciloculata* was abundant over a wider depth range (~30 m to ~1000 m) but the highest abundance was at the shallower depths. *Eponides cribrorepandus* was present only at 3 stations with relative abundance varying from 0.15% (500 m water depth) to 25% (107 m water depth). It was totally absent at stations deeper than ~500 m. *Nonionella auris* was present at most of the stations and abundant between ~200 m to ~1000 m. *Nonionellina labradorica* was present upto a depth of ~750 m. *Hanzawaia nipponica*, *Ammonia tepida* and *Nonionella limbato-striata* were abundant at stations shallower than ~150 m.

4.5.2. Species preferring oxygen deficient, warmer and hypersaline water

The species having a negative correlation with dissolved oxygen and a positive correlation with temperature and salinity were *Reophax scottii*, *Eggerella propinqua*, *Bolivinelina earlandii*, *Bolivinelina lucidopunctata*, *Bolivinelina translucens*, *Brizalina spathulata*, *Eubuliminella cassandrae*, *Eubuliminella exilis*, *Hopkinsinella glabra*, *Protoglobobulimina pupoides*, *Euvigerina globulosa*, *Uvigerina peregrina*, *Fursenkoina spinosa*, *Rutherfordoides rotundiformis*, *Suggrunda semiclara*, *Baggina irregularis*, *Cancris oblongus*, *Pullenia bulloides*, *Chilostomella oolina* and *Rotaliatinopsis semiinvoluta* (Figure 9).

Agglutinated benthic foraminifera, *Reophax scottii* was abundant only at four stations with abundance ranging from 0.14% (1069 m) to 40.96% (259 m). Other agglutinated foraminifer, *Eggerella propinqua* was abundant at depths varying from ~200 m to ~700 m except for two shallow stations at 27 m and 31 m. The species of genus *Bolivinelina* reported in the west-central Bay of Bengal include *B. translucens*, *B. earlandi* and *B. lucidopunctata*. The abundance of these three species was influenced by bathymetry, with *B. translucens* and *B. lucidopunctata* being the most abundant between 76 m to ~500 m, while *B. earlandi* was abundant from 76 m upto ~2000 m. *Brizalina spathulata* was the most abundant between ~100 m and 270 m. *Eubuliminella cassandrae* was abundant at depths >~150 up to ~1000 m, whereas *E. exilis* was present only upto a depth of 274 m. *Hopkinsinella glabra* was present only at 11 stations, with most of the stations being within ~200 m to ~900 m. *Protoglobobulimina pupoides* was present only at depth >~250 m. *Euvigerina globulosa* was present at depths >~750 m except at one shallow station (55 m). *Uvigerina peregrina* was also

dominant at deeper than 190 m with a maximum abundance of 21%. *Fursenkoina spinosa* was also abundant at stations >200 m deep, with a relative abundance ranging from 0 to a maximum of 36%. *Rutherfordoides rotundiformis* was present at stations deeper than ~100 m, except for one station at ~40 m. *Suggrunda semiclara* was present at 7 stations, of which 4 stations were on the upper slope, within a depth range of ~390 m to ~500 m. *Baggina irregularis*, *Pullenia bulloides* and *Rotaliatinopsis semiinvoluta* were abundant at stations deeper than 500 m. *Cancris oblongus* was present only at 9 stations with the highest abundance of 4.3% at 500 m depth. Similarly, *Chilostomella oolina* with a maximum relative abundance of 6.2% was present at stations deeper than ~200 m. Interestingly the maximum abundance of all the species listed above was within the oxygen deficient zone (~100 m to 1000 m).

4.5.3. Species preferring coarse sediments with high C_{org}/TN

Ammoglobigerina globigeriniformis, *Trochammina quadriloba*, *Islandiella cushmani*, *Bulimina marginata*, *Bulimina delreyensis*, *Gavelinopsis mira* and *Gyroidinoides subzelandica* were positively correlated with CF and C_{org}/TN (Figure 9). *Ammoglobigerina globigeriniformis*, an agglutinated foraminifer was present at almost all the stations with the highest abundance (~19%) at ~1980 m. *Trochammina quadriloba*, another agglutinated foraminifer, was abundant at stations deeper than ~250 m, except for 3 shallower stations with abundance $\leq 2\%$. *Islandiella cushmani* was present at most of the stations in the study area but mostly abundant at stations deeper than ~200 m. *Bulimina marginata*, *Bulimina delreyensis*, *Gavelinopsis mira* and *Gyroidinoides subzelandica* were abundant at the deeper stations (>~250 m) in the west-central Bay of Bengal. Although the CCA biplot shows influence of both CF as well as C_{org}/TN on these species, the influence of CF was more significant. Interestingly, *Hormosina guttifer* shows a positive correlation only with CF.

5. Discussion

5.1. Differential Foraminiferal Abundance on the Shelf and Slope

Interestingly, the abundance of living (stained) benthic foraminifera between ~200 m to ~1000 m was higher (~1300 specimen/g sediment), as compared to the continental shelf (~300 specimen/g sediment upto ~200 m) as well as at depths deeper than ~1500 m (~46 specimen/g sediment) (Suokhrie et al., 2020). We suggest that the lower dissolved oxygen concentration with an average of ~0.5 ml/l within the depth range of ~100 m to ~1000 m and corresponding high organic matter content, dominantly control the living benthic foraminiferal population at these depths in the western Bay of Bengal. The high % C_{org} concentration between ~250 m to 1500 m water depth is attributed to the relatively finer sediments at these depths. The finer sediments can preserve more C_{org} (Mayer, 1994).

Additionally, there is an enormous influx of both freshwater and sediments in the northern Bay of Bengal. The riverine influx is also a source of organic carbon. The immense terrestrial organic carbon contribution is further confirmed by a clear pattern of very high C_{org}/TN (~20.0) close to the river mouth as compared to low C_{org}/TN , indicating marine organic carbon, away from the river mouth (>6.0).

The foraminiferal abundance is low at stations shallower than ~100 m water depth with sediments dominated by terrestrially sourced organic matter. This low abundance is attributed to the taphonomic processes, including more disturbance or turbulence from the riverine influx leading to less proliferation and diversification of benthic foraminifera (Berkeley et al., 2014). Besides, the % C_{org} at the shallow depths is also lower than the intermediate water depth, except in front of the Godavari river mouth. The enormous freshwater runoff in the bay results in ocean surface stratification and an oligotrophic condition and thus the low organic matter on the shelf. This is also a factor for the low living benthic foraminiferal abundance at the shallow depth stations as the organic carbon is the food for benthic foraminifera. The lack or low organic carbon content in sediments is detrimental to benthic foraminifera (Duffield et al., 2014). The coarser sediments close to the river mouth are one reason for the lower % C_{org} despite the high primary productivity at these depths, as evident from the chlorophyll-a content (NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group, 2014). The intermediate depths within ~100 m to 1000 m have abundant organic matter, which leads to reduced bottom water DO, and hence the abundance of total living abundance is a positive response to the organic matter supply. The increased foraminiferal abundance at these depths is also due to the significantly reduced predatory pressure as the macrofauna are comparatively more susceptible to oxygen-deficient environments. These depths are dominated by opportunistic species that thrive well in low DO concentrations. With a decrease in organic matter, the DO concentration increases beyond ~1000 m water depth. A drastic decrease in foraminiferal abundance is seen below ~1000 m water depth in the study area, and is attributed to the increase in predatory pressure. Additionally, the environment is more food limiting than oxygen and leads to a significant reduction in the total living fauna.

5.2. Drivers of Benthic Foraminiferal Diversity and Richness

The low diversity and species richness in front of the major rivers suggests a strong riverine influx. Both the diversity and species richness are low in the southern part, suggesting a restricted environment facilitating a select few species to survive (Suokhrie et al., 2020). Incidentally, the seawater pH is very low in front of the major river mouths. Although benthic foraminifera can tolerate a wide range of pH, comparatively less alkaline pH is detrimental to calcareous tests (Saraswat et al.,

2015a). Therefore, the low diversity in low pH regions is attributed to the thin-walled benthic foraminifera's inability to survive in adverse conditions. In contrast, more diverse microenvironments in the northern part are inferred from the high diversity and richness. From our earlier work based on Canonical Correspondence Analysis (CCA) between benthic foraminiferal abundance and ambient parameters in the oxygen-deficient zone of this region, we inferred that the increased abundance of a few angular benthic foraminifera thriving as opportunistic species (*F. spinosa*, *E. cassandrae*, *U. peregrina*, *R. semiinvoluta*, *S. semiclara*, *E. propinqua* and *B. irregularis*) contributes to the overall more population of living benthic foraminifera in the oxygen-deficient zones on the slope. The dominance of a few opportunistic species is supported by low diversity and richness at these depths (Suokhrie et al., 2020). The present study's cluster analysis groupings also indicate the abundance of angular forms at the depths where dissolved oxygen is low. Such a decrease in diversity of living benthic foraminifera in a low dissolved oxygen environment has also been reported from the oxygen minimum zone (Jannink et al., 1998; Schumacher et al., 2007; Gooday et al., 2000; Suokhrie et al., 2020).

5.3. Living Benthic Foraminiferal Assemblages

From Cluster analysis, we delineate 3 faunal assemblages based on significant correlation of the assemblages to a similar set of environmental parameters in the study area. Incidentally, the assemblages dominate different depth zones as well. The details of the representative assemblages are discussed below.

5.3.1: Assemblage I (27 m - 107 m)

This assemblage comprises of Cluster IV. The dominant species are *N. labradorica*, *H. nipponica*, *B. dilatata*, *A. tepida* and *N. limbato-striata* with minor contributions from *F. pauciloculata*, *B. pacifica*, *L. persiensis* and *N. auris* (Figure 10). These species are abundant on the continental shelf (<~100 m water depth). The Assemblage I includes only calcareous benthic foraminifera. *Nonionellina labradorica* is a dominant species in this assemblage and has also been reported from the C_{org} rich fjords in the Arctic (Shetye et al., 2011). This species has been referred to as Arctic-boreo species (Seidenkrantz, 1993). Its high abundance is also reported from the oxygen-depleted environments where it sequesters chloroplast as it enables it to survive even in the anoxic conditions (Cedhagen, 1991; Bernhard and Bowser, 1999). In our study area, however, the abundant presence of *N. labradorica* is associated with the shallow inner shelf warm well-oxygenated waters with low organic carbon. We report another species belonging to the Assemblage I, namely *H.*

nipponica, with its preference for shallow, well-oxygenated waters. From the Bay of Bengal, this species has been reported as a ‘turbidity sensitive species’ (Jayaraju et al., 2010).

Similarly, *B. dilatata* is also abundant on the shallow shelf, with a rare presence at a few stations upto ~700 m. Its abundance in shallow to intermediate water depth is also reported by Gooday (1993) and Bernhard and Gupta (1999). *Brizalina dilatata* is also commonly reported from low oxygenated and high organic carbon-rich environments (Gupta and Machain Castillo, 1993; Rouchy et al., 1998; Kuhnt et al., 2007). In the present study, this species correlates well with the shallow and warmer waters. The characteristic shallow-water species *A. tepida* is also abundant on the shelf of the present study. *Ammonia tepida* is widely distributed over estuaries, shelf and salt marshes (Murray, 1991; Nisha and Singh, 2012). Most workers have reported *A. tepida* as a pollution-sensitive species (Bergin et al., 2006; Burone et al., 2007; Frontalini and Coccioni, 2008; Elshanawany, 2011; Debenay et al., 2015; Schintu et al., 2016; Saalim et al., 2017). *Ammonia tepida* is also reported as a dominant species in the modern intertidal and estuarine areas (Nigam, 1984; Adarsh and Rao, 2010). We also report *A. tepida* being abundant in shallow and warm water with a moderate organic matter supply in the study area. *Nonionella limbato-striata* is another dominant species in this assemblage, preferring the shallow and well-oxygenated waters.

Fursenkoina pauciloculata is a minor species in this assemblage. *Bolivinelina pacifica*, another dominant species of this assemblage, was earlier reported from the shallow water depths (Saidova, 2010), same as that in this study area. *Latibolivina persiensis* reported from shallow depth (Sliter 1969; Sliter, 1970; Panchang and Nigam, 2014). It has been found to prefer oligotrophic and well-oxygenated water (Abu-Zied, 2013), similar to its distribution in this study, where this species is present only in shallow, well-oxygenated water (upto 76 m). Another minor species is *N. auris* in this assemblage.

The species belonging to Assemblage I representing the shallow locations indicate that they are positively correlated with dissolved oxygen, temperature and C_{org} . The dissolved oxygen concentration is high (>3.0 ml/l) and the organic matter content is low (~0.9%) with warmer temperature on the shelf. Thus, Assemblage I represents a shallow, well-oxygenated, warm environment with relatively high organic matter in the sediments.

5.3.2: Assemblage II (~145 m- 1500 m)

The dominant species in this assemblage are *E. exilis*, *B. earlandi*, *F. spinosa*, *B. lucidopunctata*, *G. globosa* from Cluster I and *F. spinosa*, *E. cassandrae*, *U. peregrina*, *R. semiinvoluta*, *C. laevigata* from Cluster II (Figure 11).

Eubuliminella exilis has been reported as deep infaunal taxa (Jorissen, 1999) and an indicator of low oxygenated environments and unchanged supply of organic matter (Caralp, 1989; Jannink et al., 1998; Schumacher et al., 2007). Amongst the dominant species belonging to Assemblage II, *F. spinosa* is a shallow infaunal species inhabiting waters upto a depth of ~120 m (Phleger, 1963). In the present study, *F. spinosa* is abundant at depths deeper than ~200 m, indicating less depth dependence and a large influence of dissolved oxygen. The relative abundance of infaunal foraminifera is controlled by the availability of both the metabolizable organic matter and dissolved oxygen. The infaunal foraminifera are abundant in organic matter rich but oxygen-deficient environments (Jorissen et al., 1995; Van Der Zwaan et al., 1999). The higher relative abundance of *F. spinosa* at depths >200 m within the low DO concentration in the western Bay of Bengal, is more in line with its infaunal nature. The species belonging to *Bolivinelina* have been reported from shallow regions (Nigam and Chaturvedi, 2006; Nagendra et al., 2011; Panchang and Nigam, 2014; Gandhi et al., 2016). Both *B. earlandi* and *B. lucidopunctata* have been recorded from the upper slope region in the study area. *G. globosa* is another dominant species in this assemblage. Generally, rectilinear foraminifera comprising of genera like *Bolivina*, *Brizalina*, *Bulimina*, *Fursenkoina*, *Uvigerina* have previously been reported as a common indicator of low oxygenated environments by several workers (Kaiho, 1994; Gupta and Machain-Castillo, 1993; Murray, 2006; Nigam et al., 2009; Mazumder and Nigam, 2014; Das et al., 2017; Verma et al., 2018). In the study area, these species are abundant at the stations falling within a depth range of ~>100 to ~1500 m where DO concentration is minimum (0.5 ml/l). All the major species of this assemblage are significantly negatively correlated with the dissolved oxygen, suggesting that they are well adapted to low dissolved oxygen (Suokhrie et al., 2020). The type species of *E. cassandrae* is *E. exilis* (Revels, 1993). The ecology of *E. cassandrae* has been rarely described. However, like its type species, *E. cassandrae* is also abundant at the intermediate depth locations with the low oxygenated environment. *Uvigerina peregrina* is also reported from this assemblage, suggesting its preference to low dissolved oxygen at these depths, which is in line with its reported dominance within OMZ (Hermelin and Shimmiel, 1990). It has also been described as a shallow dysoxic-infaunal species (Das et al., 2017). *Rotaliatinopsis semiinvoluta* has been well documented as a low oxygen tolerant species reported from the Arabian Sea OMZ at intermediate water depths (den Dulk et al., 1998; Jannink et al., 1998; Caille et al., 2015), and a similar preference to low dissolved oxygen is also found in our study. *Cassidulina laevigata* is another intermediate to deep-water fauna and is a dominant species in this assemblage. Amongst the other minor species of this assemblage, *R. scottii* is predominantly infaunal (Kaminski et al., 1988) and a characteristic fauna of muddy substrate, sometimes present in low oxygenated fjords (Murray, 1970; Filipsson and Nordberg, 2004). The substrate seems to be a less influential factor for this species in the west-central Bay of Bengal. Here,

R. scottii is more indicative of low oxygenated conditions as its abundance increases at the stations with low DO values. *Bolivina spathulata* has been described as a deep infaunal and dysoxic species occurring in high organic flux environments (Bernhard and SenGupta, 1999; Das et al., 2017). Furthermore, *B. spathulata* has been associated with a more saline environment (Eris et al., 2011), as is also seen in the study area. *Brizalina spathulata* is often the last species to disappear before oxygen deficiency starts to inhibit any benthic life (Jonkers, 1984). In the west-central Bay of Bengal, *B. spathulata* is most common at stations between ~120 m and ~250 m. A significant drop in DO is observed at these depths. *Uvigerina peregrina* and *E. cassandrae* are minor species in this assemblage. *Trochamminopsis quadriloba* is more abundant at ~2000 m. Alve et al. (2011) reported the abundant presence of *T. quadriloba* at ~100 m. However, the depth does not seem to significantly control its abundance (Buzas et al., 1993)

The ecology of *S. semiclara* is rarely described. Here, its abundance in the intermediate waters suggests its preference for low oxygen and relatively more saline environment. *Pullenia bulloides* was earlier reported as a part of the assemblage representing the Antarctic Bottom Water (AABW) (Corliss, 1979). In the present study, *P. bulloides* prefers lower levels of oxygen, high food supply and deeper depth, as also reported by other workers [north Atlantic-Schnitker, 1979; southwestern Indian Ocean-Corliss, 1983; Gooday, 1994; south Atlantic-Mackensen et al., 1995; Off Pakistan (Arabian Sea)-Schumacher et al., 2007; southeastern Indian Ocean-Verma et al., 2013; Arabian Sea-Caulle et al., 2015]. Although the type and preservation status of the organic matter also matters (Nomaki et al., 2005; Duffield et al., 2014), the organic carbon (C_{org}) is a good indicator of the food availability for foraminifera. Some foraminifera prefer the “easily metabolizable food particles” while the infaunal forms mainly tolerate more refractory organic matter (Gooday, 1993; Jorissen et al., 1995). *Rutherfordoides rotundiformis* was found in extremely low oxygen conditions and in sapropelic sequences (Rohling et al., 1997; Mercone et al., 2001; Abu-zied et al., 2008). *Rutherfordoides rotundiformis* is the most abundant at the stations with minimum DO concentration in the present study. *Chilostomella oolina* is a deep infaunal species abundant in low oxygenated environments similar to its generic preferences (Corliss, 1991; Jorissen et al., 1999; Gooday and Rathburn, 1999; Schmiedl et al., 2003; Schumacher et al., 2007; Kuhnt et al., 2013). The survival and abundance of *C. oolina* in low oxygenated environment is attributed to its nitrate respiration strategy (Kuhnt et al., 2013). *Cassidulina carinata* and *G. globosa* are also part of this intermediate assemblage. *Cassidulina carinata* is part of the assemblage preferring high food supply (Gupta and Thomas, 1999), while *G. globosa* is often described as an abyssal species (Takata et al., 2013). *Bolivina earlandi* have been described as a deep infaunal and dysoxic species occurring in high organic flux environments

(Bernhard and SenGupta, 1999; Das et al., 2017). Genus *Chilostomella* with the characteristic unornamented and thin-walled tests was an abundant genus among organic carbon-rich and less oxygenated sediments (Kaiho 1992). *Trochamminopsis quadriloba* is another minor species in this assemblage as well as the previous assemblage. Other minor species also include *F. pauciloculata* abundant in the low oxygenated regions of the Indian waters (Mazumder and Nigam, 2014) and *N. auris* is an indicator of high organic carbon rich environments (Wefer et al., 1994; Bhaumik and Gupta, 2007). In the west-central Bay of Bengal, *B. marginata* is a deep infaunal species (Jorissen et al., 1999). Both *B. marginata* and *B. cf. delreyensis*, are abundant at depths deeper than ~2000 m, on the slope. Although *B. marginata* is often used as oxygen-deficient water proxy, we report a strong negative influence of temperature on the abundance of both *B. marginata* and *B. cf. delreyensis*, in the study area. *Baggina irregularis* is also part of the same assemblage that prefers less oxygenated waters. This species' ecology is not well known, although they are reported from the Bay of Bengal (Panchang and Nigam, 2014). In short, all the species described above are abundant in more saline, organic matter rich and poorly oxygenated environment.

5.3.3: Assemblage III (~1940 m – 2494 m)

A set of 12 species from Cluster III (*B. cf. delreyensis*, *B. marginata*, *H. guttifer*, *C. laevigata*, *G. subzelandica*, *C. carinata*, *G. mira*, *N. ampullacea*, *P. bulloides*, *U. peregrina*, *A. globigeriniformis* and *T. quadriloba*) has been clubbed together in Assemblage III. The dominant species of this assemblage are *B. cf. delreyensis*, *B. marginata*, *H. guttifer*, *C. laevigata* and *G. subzelandica* (Figure 12). *Bulimina marginata* is a deep infaunal species (Jorissen et al., 1999). Both *B. marginata* and *B. cf. delreyensis*, are abundant at depths deeper than ~2000 m, on the slope. Although, *B. marginata* is often used as oxygen deficient water proxy, the abundance of these two species at deeper colder waters (>1500 m) is suggestive of a strong negative influence of temperature on the abundance of both *B. marginata* and *B. cf. delreyensis*. The dominant agglutinating species in this assemblage is *H. guttifer*, which represents deep-water assemblages (Bernhard et al., 2009; Enge et al., 2012). *C. laevigata* is a shallow to deep infaunal species (Singh et al., 2012). *Gyroidinoides subzelandica* is a part of the same assemblage. All these species are significantly negatively correlated with the ambient temperature as the deeper waters have colder temperature. Additionally, the species in Assemblage III are also influenced by the type of organic matter (marine origin) and sediment texture, evidenced from the relatively lower C_{org} content in the samples at these depths.

The other minor species in this assemblage like *C. carinata*, *U. peregrina* and *P. bulloides* also represent Assemblage III indicating that these species have a wide range of abundance from the intermediate to the deep waters in the study area. *U. peregrina* is a dominant species in Assemblage III

which suggests its preference for the environmental conditions prevalent at the intermediate waters rather than the deep waters. *Gavelinopsis mira*, *N. ampullacea* in Assemblage III, also have a significant preference for colder water with lower CF abundance and marine organic matter.

6. Conclusions

The spatial distribution of living benthic foraminifera and its comparison with the ambient parameters in the riverine influx dominated west-central Bay of Bengal, suggests a strong influence of multiple ecological parameters, mainly the dissolved oxygen, coarse fraction and temperature to some extent. The organic carbon content is high (~1.4 % on average) at intermediate depths (~100 m to ~1000 m) where bottom water dissolved oxygen is at its lowest (~0.5 ml/l on average). The maximum living benthic foraminiferal abundance at these depths with limited diversity indicates high abundance of a few opportunistic species. The high C_{org}/TN suggests that $C_{org}\%$ is mostly of terrestrial origin, especially closer to the river mouths. Three significant faunal assemblages delineated from the statistical analysis give more insight on the ecological preferences of foraminifera in the west-central Bay of Bengal. The shallow water (~27 m to 100 m) assemblage comprising of *N. labradorica*, *H. nipponica*, *B. dilatata*, *A. tepida* and *N. limbato-striata* represents well oxygenated warmer waters with low $C_{org}\%$ and coarser sediment. The intermediate water (~145 m to ~1500 m) assemblage comprising of *E. exilis*, *B. earlandi*, *F. spinosa*, *B. lucidopunctata*, *G. globosa*, *F. spinosa*, *E. cassandrae*, *U. peregrina*, *R. semiinvoluta* and *C. laevigata* assemblage represents poorly oxygenated, colder waters with high $C_{org}\%$. The deep water (~1940 m to ~2494 m water depth) assemblage comprising of *B.cf. delreyensis*, *B. marginata*, *H. guttifera*, *C. laevigata* and *G. subzelandica* represents high $C_{org}\%$ but relatively higher bottom water dissolved oxygen than the intermediate water depth. We also report the specific preference of 40 dominant species each influenced by a set of environmental parameters. The ecological preferences of foraminiferal species and foraminiferal assemblages delineated from this study can be utilized as proxies in sub-surface samples to understand paleo-ecology and paleoclimatic changes from the west-central Bay of Bengal.

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Legend to Figures and Tables

- Figure 1: The location of surface sediment samples in the west-central Bay of Bengal. Multicore stations are marked with red circles and green squares represent spade core stations. The major rivers draining in the area are marked by thin black lines. The bathymetry is marked by coloured contours.
- Figure 2: Bottom water environmental parameters measured onboard from the water collected in multicores along with data downloaded from the World Ocean Atlas (Garcia et al., 2013; Locarnini et al., 2013; Zweng et al., 2013), and analysed sediment characteristics in the western Bay of Bengal. A. Salinity (psu), B. dissolved oxygen (ml/l), C. temperature (°C), D. pH (The pH data in the southern part of the region is not available as we could not collect samples from the sediment-water interface), E. coarse fraction (CF%), F. organic carbon (%C_{org}), G. organic carbon/total nitrogen (C_{org}/TN) and H. calcium carbonate (CaCO₃%). The stations are marked by black inverted triangles. The thin black lines mark the bathymetric contours.
- Figure 3: The dominant living benthic foraminifera (relative abundance $\geq 3\%$ at least 3 stations) in the west-central Bay of Bengal 1. *Hormosinella distans* (Brady, 1881) 2-4. *Hormosinella guttifera* (Brady, 1881) 5. *Reophax scottii* Chaster, 1892. 6. *Ammobaculites agglutinans* (d'Orbigny 1846) 7. *Ammoglobigerina globigeriniformis* (Parker and Jones, 1865) 8. *Trochamminopsis quadriloba* (Hoglund, 1947); (a) Ventral view (b) Dorsal view 9. *Eggerella propinqua* (Brady, 1884) 10. *Textularia oceanica* Cushman, 1932; 11. *Spiroloculina convexa* Said, 1949; (a)(b)(c) 12. *Quinqueloculina bicarinata* d'Orbigny, 1878; (a) 4-chambered view (b) Apertural view (c) 3-chambered view. 13-14. *Bolivinellina earlandi* (Parr, 1950) 15. *Bolivinellina lucidopunctata* (Conato, 1964). 16. *Bolivinellina pacifica* (Cushman and McCulloch, 1942) 17. *Bolivinellina translucens* (Phleger and Parker, 1951) 18-19. *Brizalina dilatata* (Reuss, 1850); 20. *Bolivina mekranensis* (Haque, 1970); 21. *Brizalina spathulata* (Williamson, 1858) 22. *Latibolivina lepida* 23. *Latibolivina persiensis* (Lutze, 1974). 24. *Cassidulina carinata* Silvestri, 1896; (a) Ventral view showing aperture (b) Dorsal view; 25. *Cassidulina laevigata* d'Orbigny, 1826, (a) Dorsal view, (b) Ventral view showing aperture.
- Figure 4: 1. *Globocassidulina oblonga* (Reuss, 1850); (a) Ventral view (b) Dorsal view. 2-3. *Islandiella cushmani* (Stewart and Stewart, 1930); (a) and (b) Side views (c) Apertural view 3. *Eubuliminella cassandrae* Revets 1993 4-5. *Eubuliminella exilis* (Brady, 1884) 6. *Hopkinsinella glabra* (Millett, 1903) 7. *Bulimina* cf. *delreyensis* Cushman and Galliher,

1934 8. *Bulimina marginata* d'Orbigny, 1826 9. *Globobulimina globosa* Leroy, 1944 10. *Protoglobobulimina pupoides* (d'Orbigny 1846) 11. *Euuvigerina globulosa* (Egger, 1895) 12-13. *Neouvigerina ampullacea* (Brady, 1884) 14. *Uvigerina peregrina* Cushman, 1923 15. *Fursenkoina pauciloculata* (Brady, 1884) 16. *Fursenkoina spinosa* (Heron-Allen and Earland, 1932) 17. *Fursenkoina schreibersiana* (Czjzek, 1848) 18. *Rutherfordoides rotundiformis* (McCulloch, 1977) 19. *Suggrunda alata* (Seguenza 1862); (a) Side view (b) Lateral view showing aperture; 20. *Suggrunda semiclara* (McCulloch 1977); (a) Side view (b) Lateral view showing aperture 21. *Baggina irregularis* McCulloch, 1977; (a) Ventral view (b) Dorsal view.

Figure 5: 1. *Cancris oblongus* (Williamson, 1858); (a) Ventral view (b) Dorsal view; 2. *Eponides cribrorepandus* (Asano and Uchio, 1951); (a) Ventral view (b) Dorsal view; 3. *Gavelinopsis mira* (Cushman, 1922); (a) Ventral view (b) Lateral view (c) Dorsal view; 4. *Pseudoeponides japonicum* Uchio, 1950; (a) Dorsal view (b) Ventral view 5. *Nonionella auris* (d'Orbigny, 1839); (a) Side view (b) Apertural view (c) Side view showing the last chamber flap covering the umbilicus. 6. *Nonionella limbato-striata* Cushman 1931 7. *Nonionellina labradorica* (Dawson, 1860); (a) and (c) Side views (b) Apertural view 8. *Melonis (?) chathamensis* McCulloch, 1977; (a) and (c) Side views (b) Apertural view 9. *Pullenia bulloides* (d'Orbigny, 1846); (a) and (b) Side views (b) Apertural view.

Figure 6: 1. *Chilostomella oolina* Schwager 1878. 2. *Gyroidinoides subzelandica* Hornibrook, 1961; (a) Dorsal view (b) Apertural view (c) Ventral view 3. *Rotaliatinopsis semiinvoluta* (Germeraad, 1946); (a) and (c) Side views (b) Apertural view 4. *Hanzawaia nipponica* Asano, 1944; (a) Ventral view (b) Apertural view (c) Dorsal view 5. *Ammonia tepida* Cushman, 1926); (a) Dorsal view (b) Ventral view.

Figure 7: Cluster analysis using Bray-Curtis similarity at 20% similarity level. The four identified clusters have been shaded in different colours as Cluster I, II, III and IV.

Figure 8: Distribution of the four clusters in the western Bay of Bengal. A clear depth preference of the clusters is evident. Cluster I and II - Intermediate water, Cluster III - deep water, and Cluster IV - shallow water.

Figure 9: Canonical Correspondence Analysis (CCA) between species abundance and environmental parameters. The arrows represent environmental parameters- C_{org} =Organic Carbon, C_{org}/TN =organic carbon/total nitrogen, CF=coarse fraction, DO=dissolved oxygen, T=temperature, S=salinity, D=depth. The triangles represent the species (modified from Suokhrie et al., 2020).

Figure 10: Surface distribution (relative abundance) of dominant living benthic foraminifera from Cluster IV representing Assemblage I and having a significant positive correlation with dissolved oxygen and temperature. *Nonionella labradorica*, *Hanzawaia nipponica*, *Brizalina dilatata*, *Ammonia tepida* and *Nonionella limbato-striata*. The stations are marked by black inverted triangles. The thin black lines mark the bathymetric contours.

Figure 11: Relative abundance of species representing intermediate depth assemblage (Assemblage II), having significant negative correlation with dissolved oxygen and positive correlation with organic carbon. *Eubuliminella exilis*, *Bolivinellina earlandi*, *Fursenkoina spinosa*, *Bolivinellina lucidopunctata*, *Globobulimina globosa*, *Fursenkoina spinosa*, *Eubuliminella cassandrae*, *Uvigerina peregrina*, *Rotaliatinopsis semiinvoluta* and *Cassidulina laevigata*. The stations are marked by black inverted triangles. The thin black lines mark the bathymetric contours.

Figure 12: Surface distribution (relative abundance) of dominant living benthic foraminifera representing deep water assemblage (Assemblage III), having a significant negative correlation with CF and C_{org}/TN , in the west-central Bay of Bengal. *Bulimina* cf. *delreyensis*, *Bulimina marginata*, *Hormosinella guttifera*, *Cassidulina laevigata* and *Gyroidinoides subzelandica*. The stations are marked by black inverted triangles. The thin black lines mark the bathymetric contours.

Supplementary Table 1: The details of the sampling locations for multicore as well as spade core.

Supplementary Table 2: The details of stations and ambient physico-chemical parameters at each station. Also given are the measured sedimentary characteristics (CF, C_{org} , C_{org}/TN and $CaCO_3$). The salinity and pH at the sediment water interface were measured from the water retrieved in multi-core tops. The DO and other data for the spade core station were retrieved from the World Ocean Atlas 2013 (Garcia et al., 2013; Locarnini et al., 2013; Zweng et al., 2013).

Supplementary Table 3: The relative abundance of the dominant species having at least >3% abundance at a minimum of two stations.

Supplementary Table 4: Check-list of living benthic foraminiferal species found in the surface sediments of the western Bay of Bengal. The maximum relative abundance of the species and the depth of the respective station is also provided.

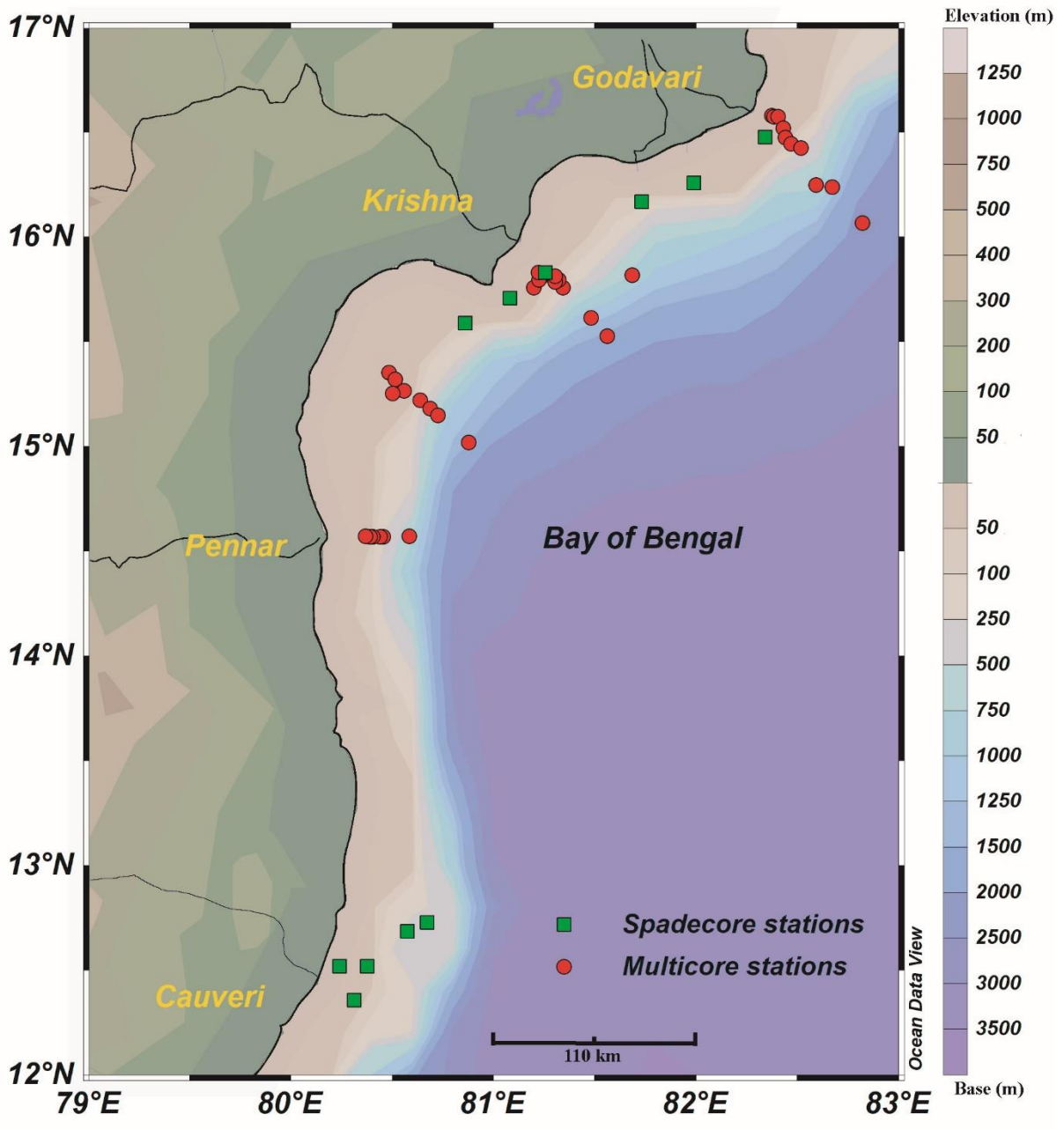


Figure 1

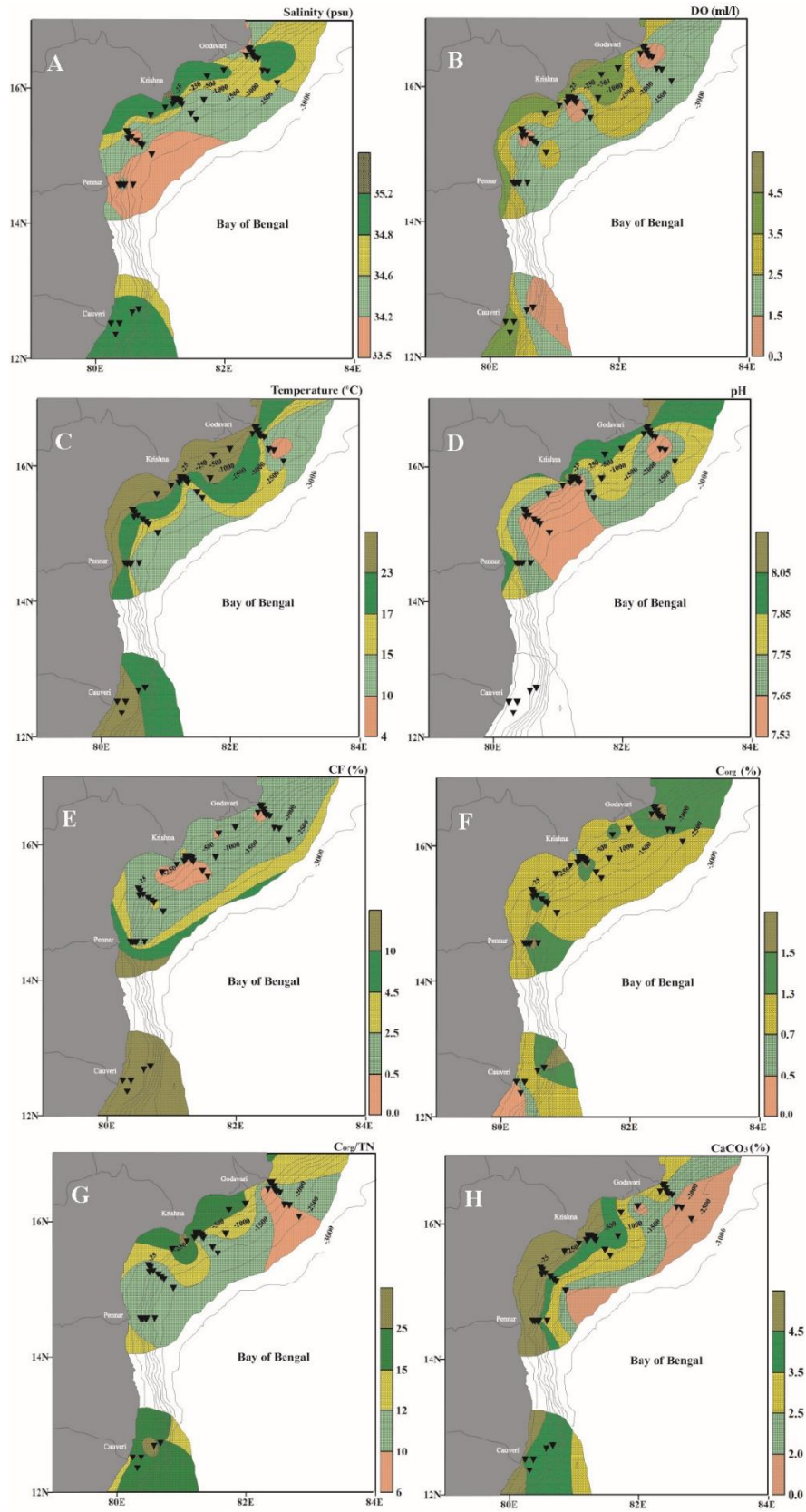


Figure 2

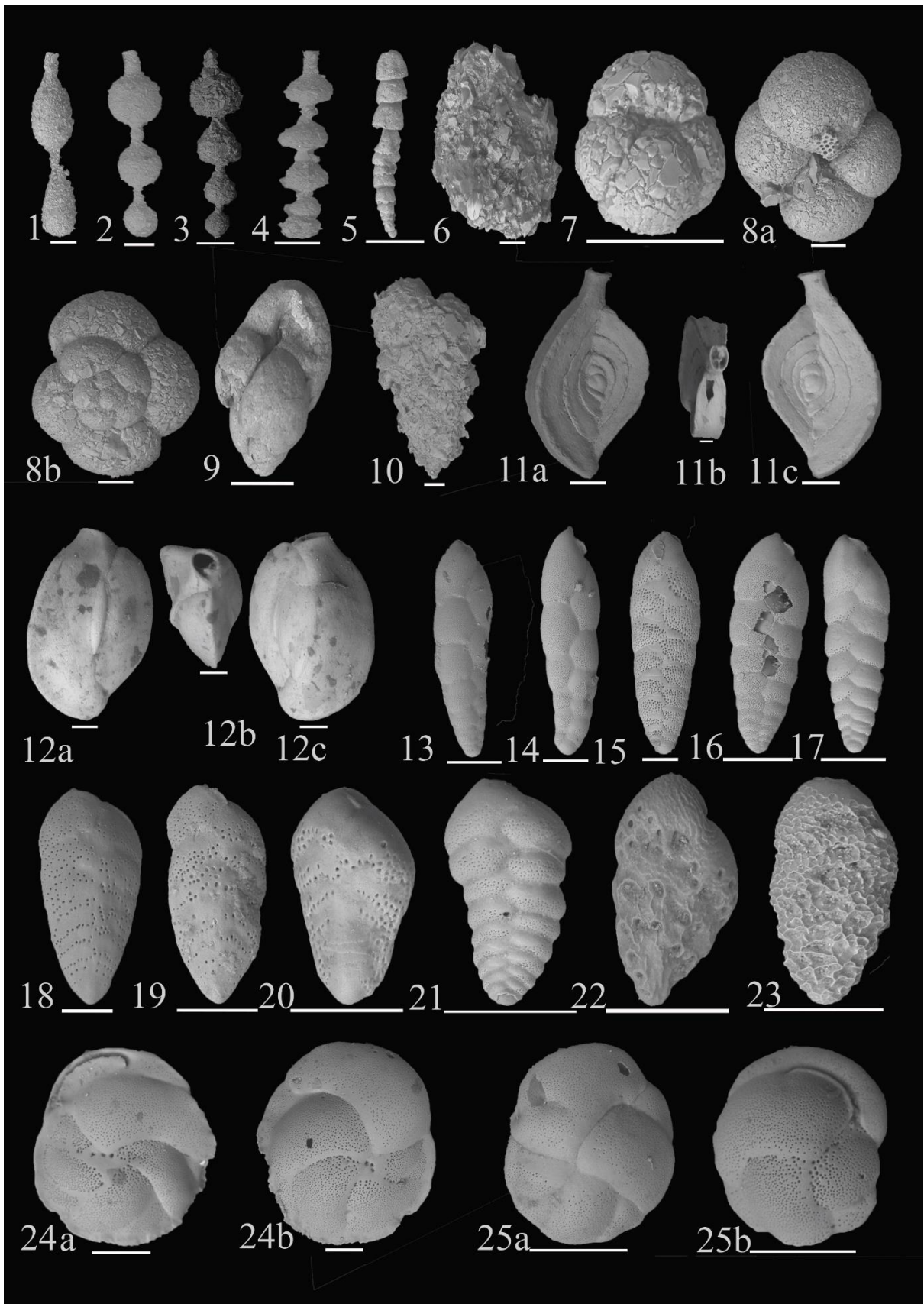


Figure 3

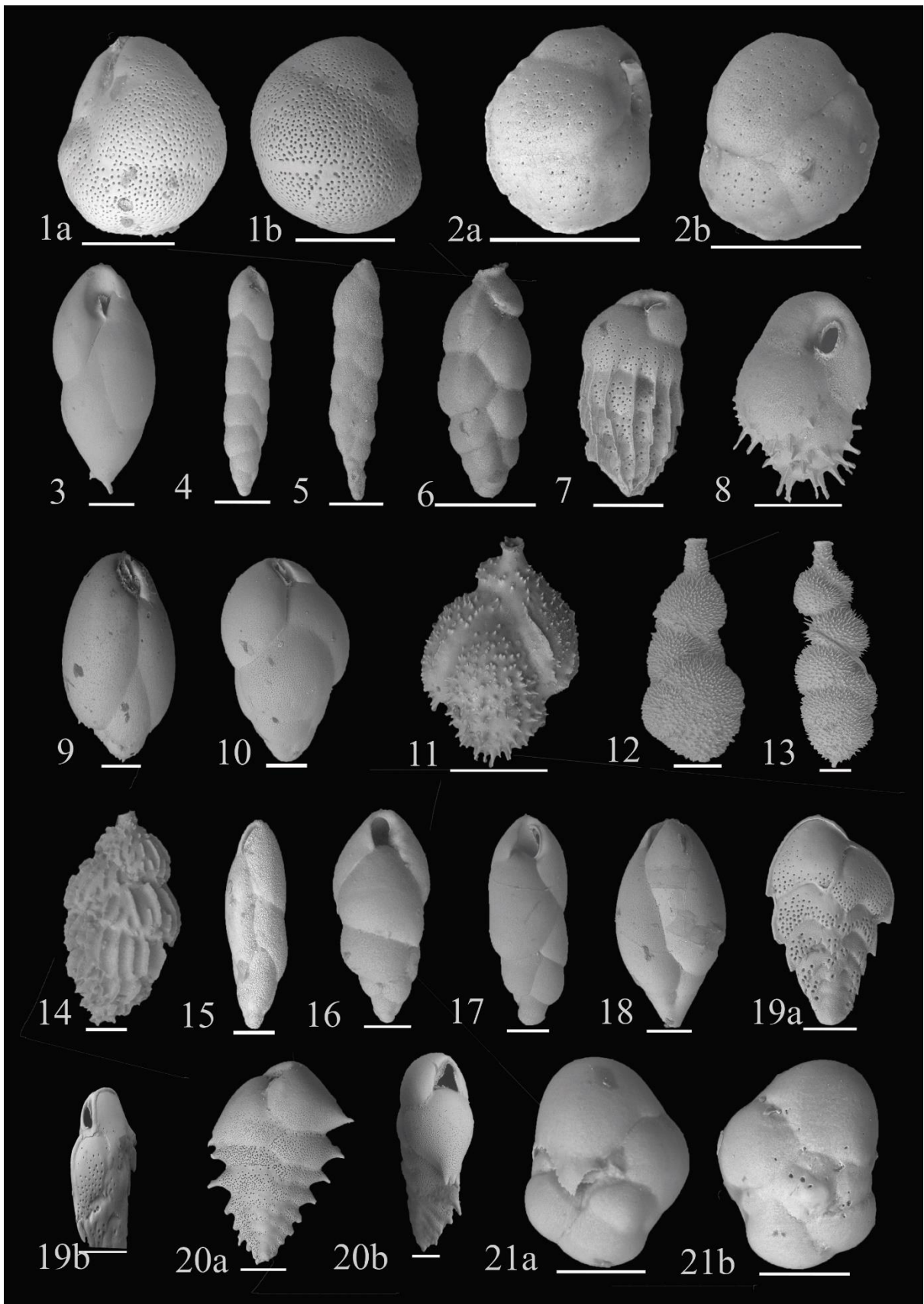


Figure 4

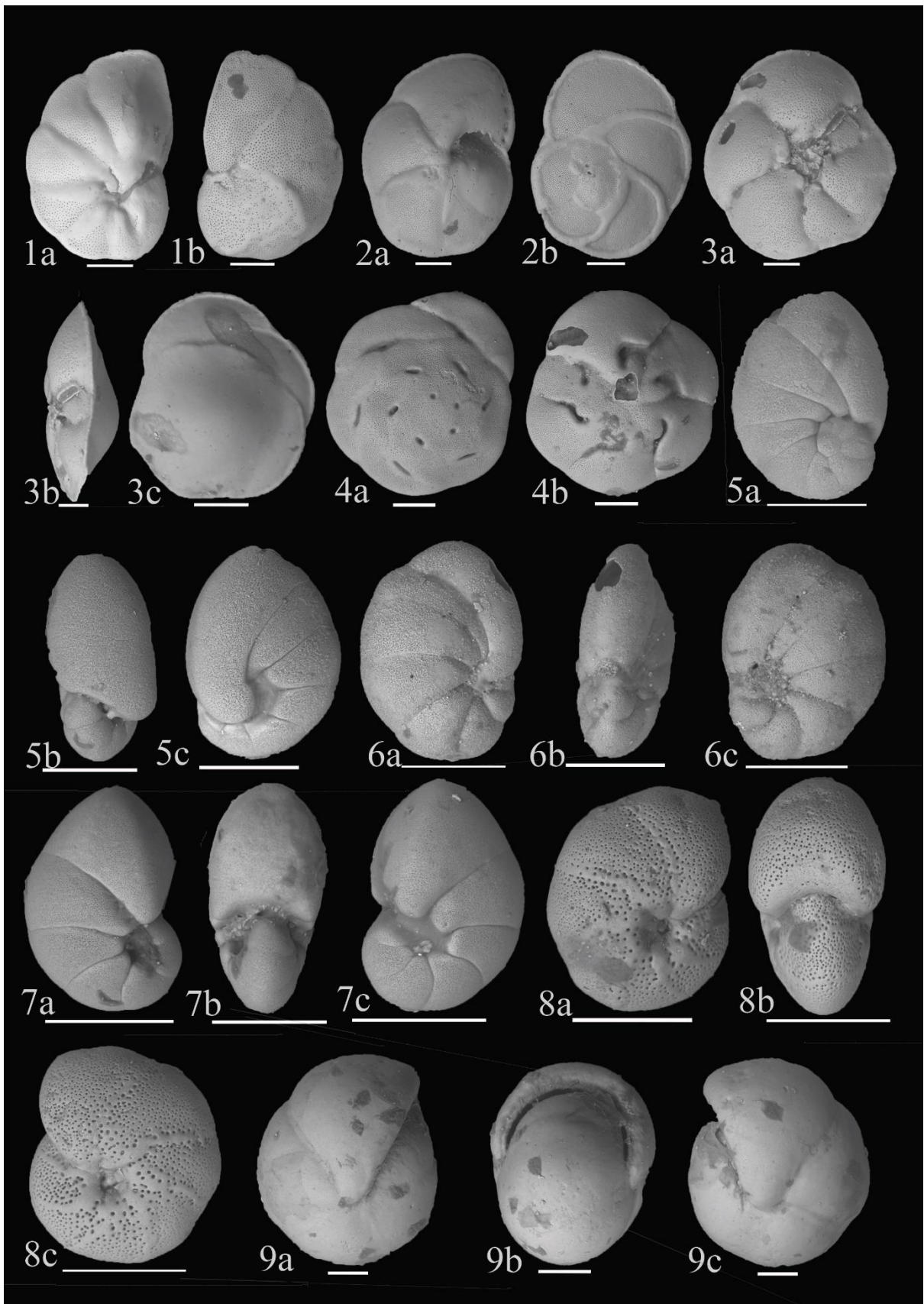


Figure 5



Figure 6

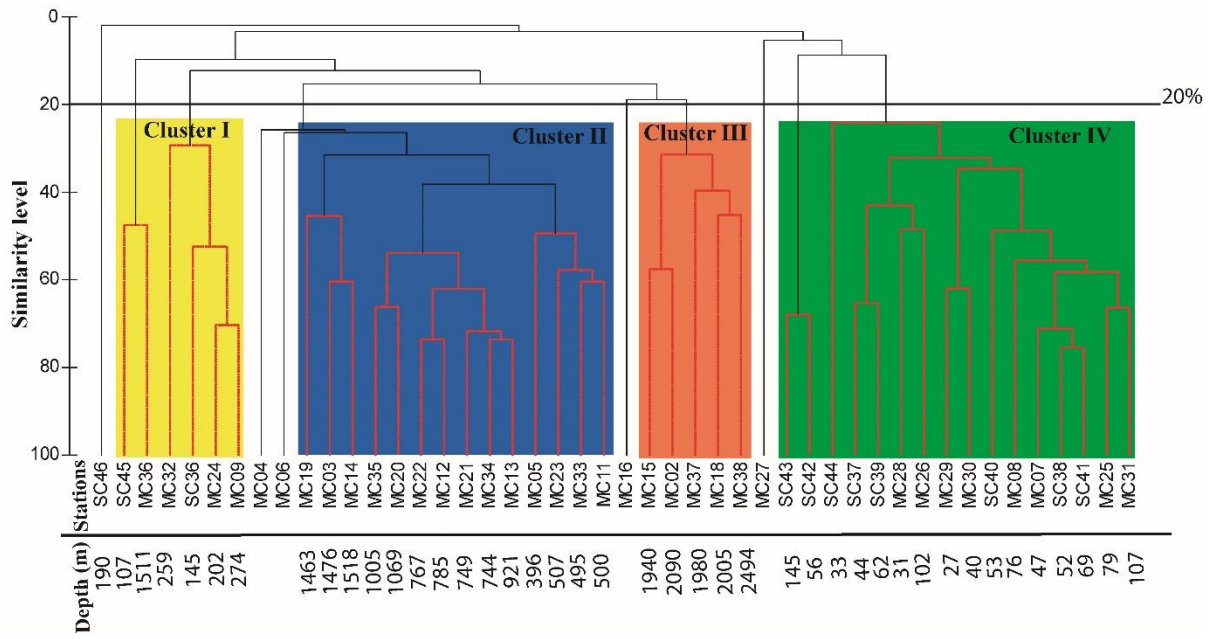


Figure 7

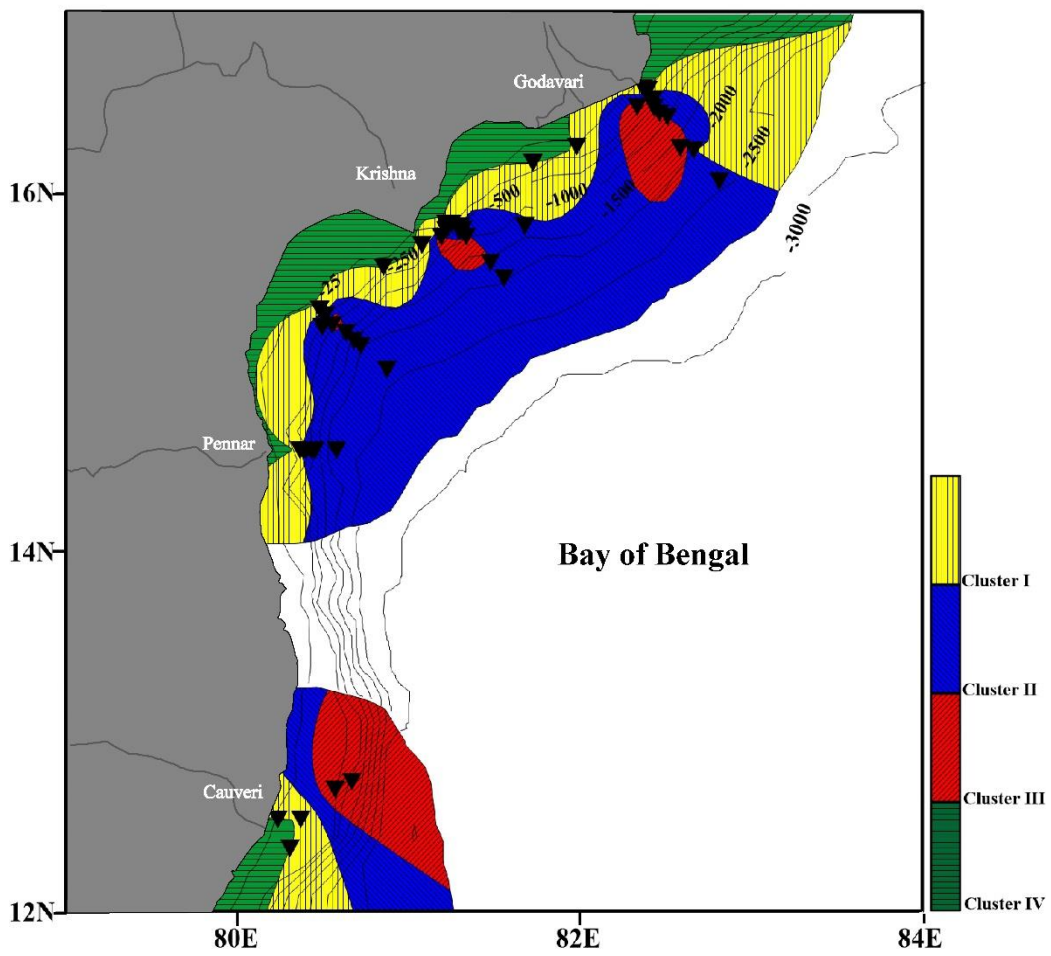


Figure 8

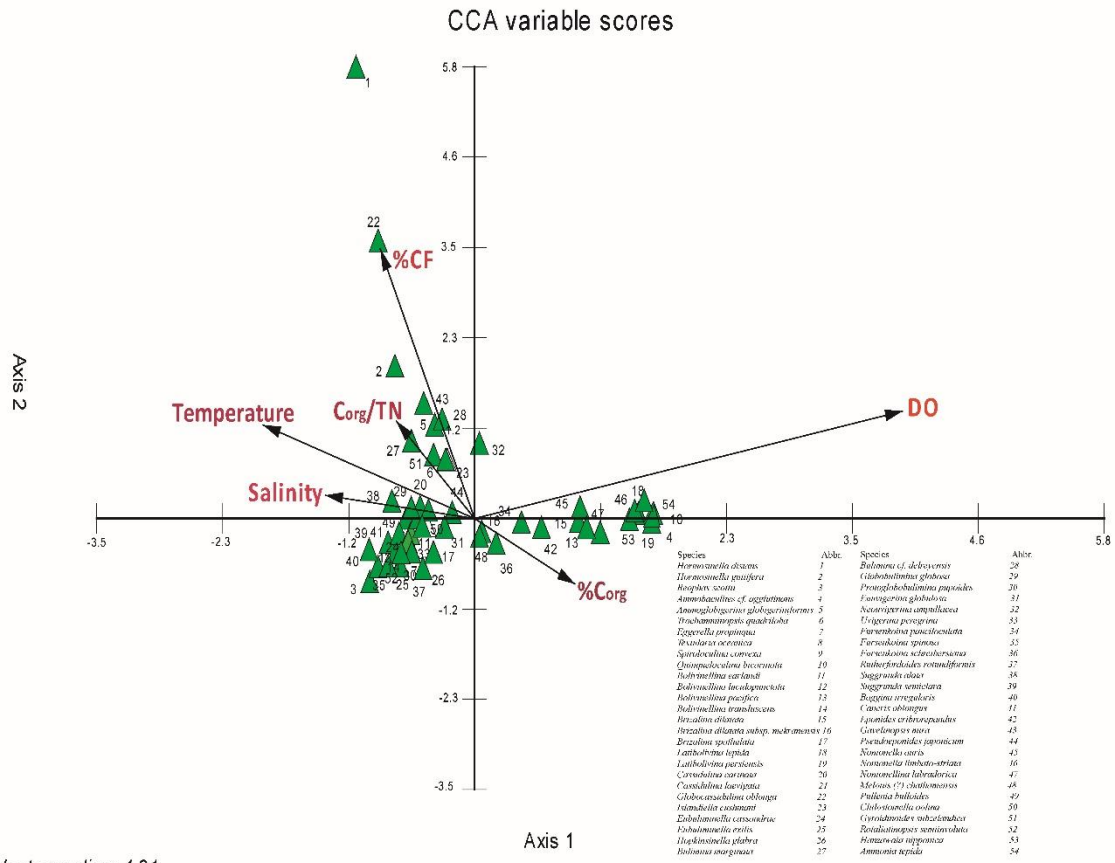


Figure 9

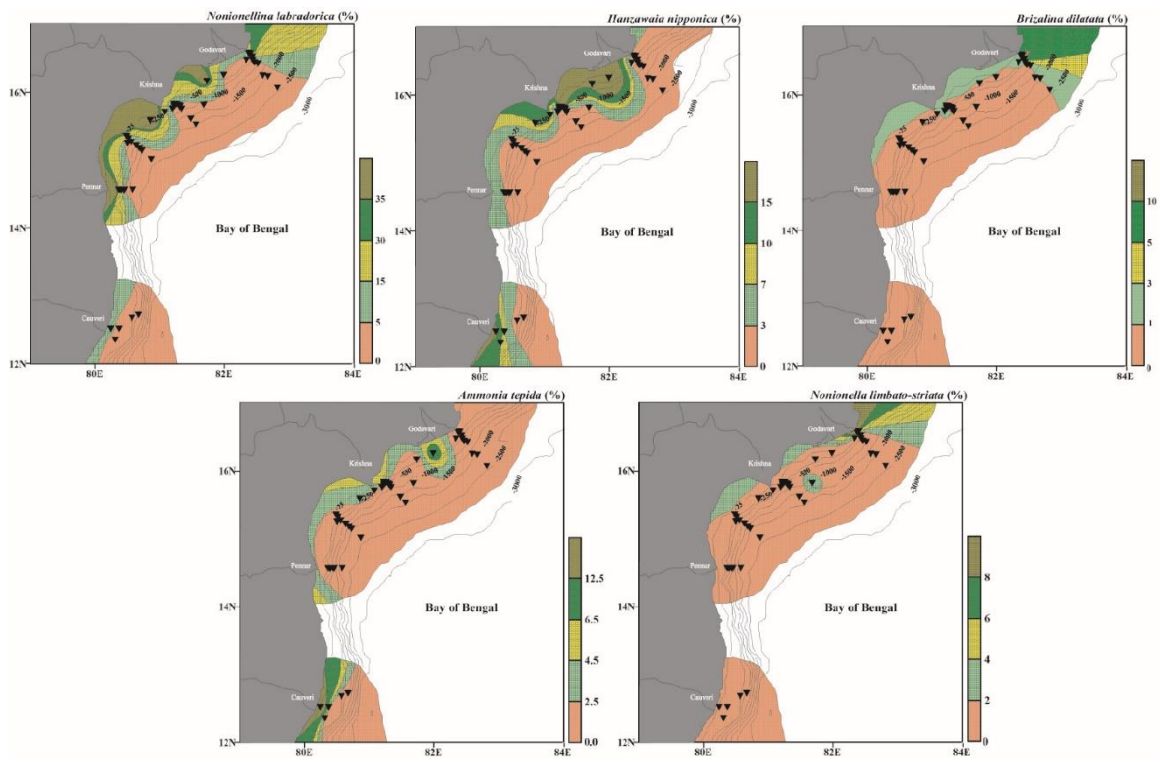


Figure 10

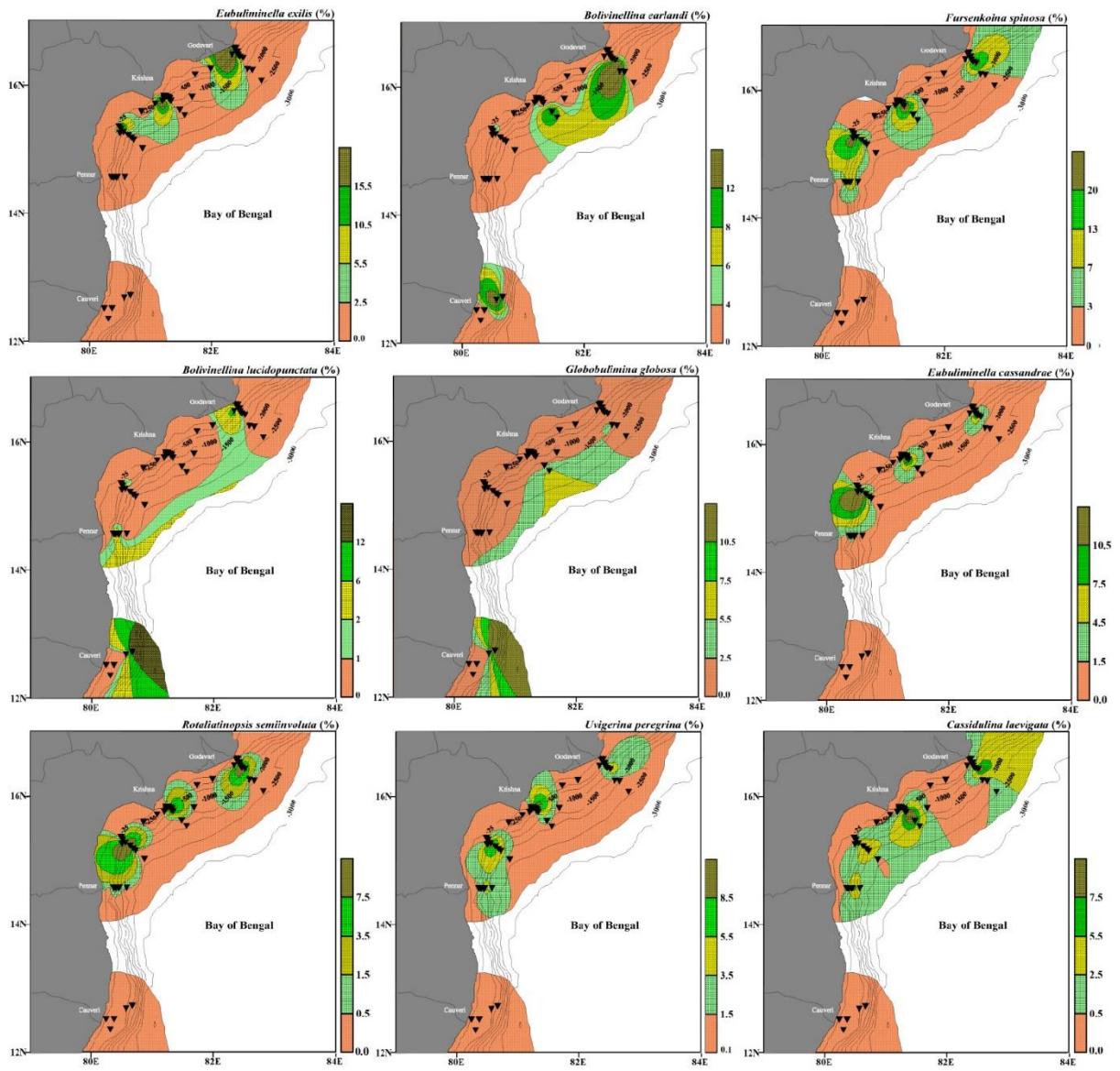


Figure 11

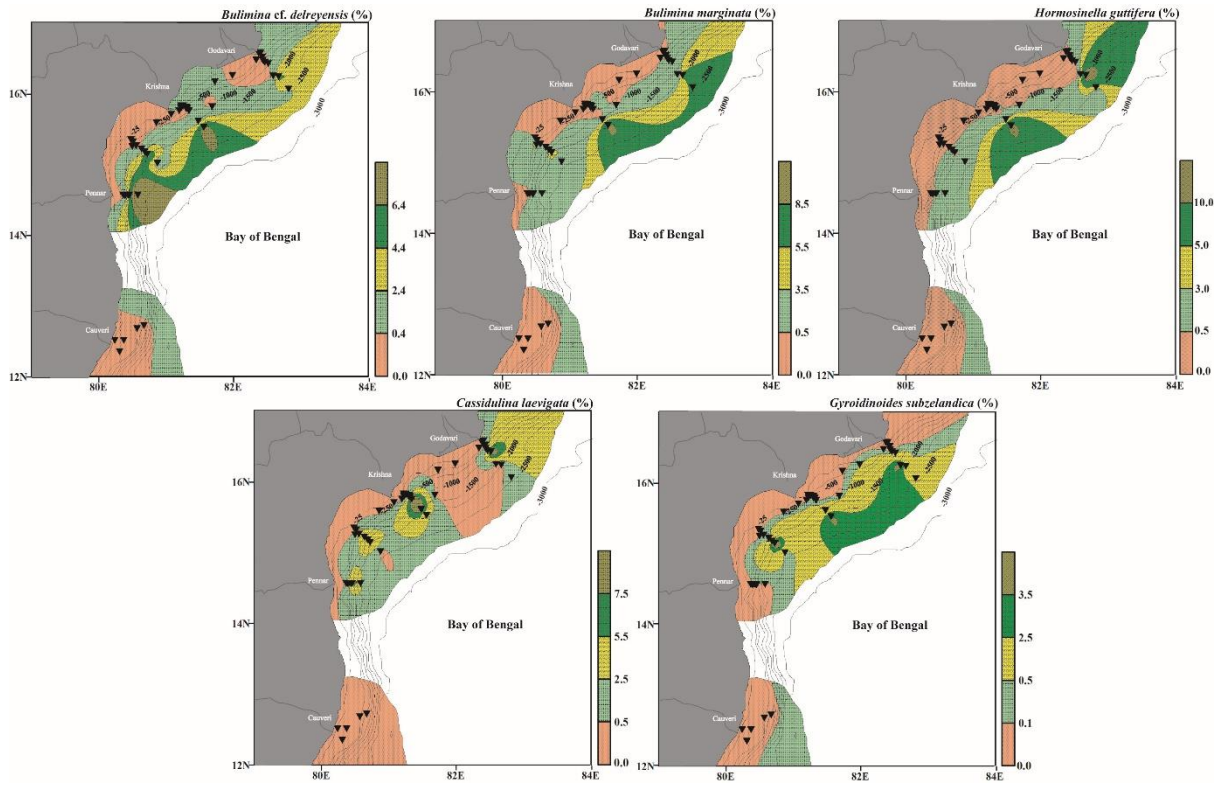


Figure 12

Supplementary table 1: Sample Details

Sl. No.	Sample	Latitude (°N)	Longitude (°E)	Depth (m)
1	MC 02	14.55	80.94	2090
2	MC 03	14.57	80.59	1476
3	MC 04	14.57	80.46	979
4	MC 05	14.57	80.44	397
5	MC 06	14.57	80.41	244
6	MC 07	14.57	80.39	47
7	MC 08	14.57	80.37	76
8	MC 09, 10	15.35	80.49	275
9	MC 11	15.32	80.52	500
10	MC 12	15.27	80.56	786
11	MC 13	15.25	80.50	921
12	MC 14	15.22	80.64	1519
13	MC 15	15.18	80.69	1940
14	MC 16	15.15	80.73	2482
15	MC 18	15.02	80.88	2006
16	MC 19	15.27	81.79	1463
17	MC 20	15.53	81.56	1069
18	MC 21	15.61	81.48	749
19	MC 22	15.76	81.35	768
20	MC 23	15.80	81.32	507
21	MC 24	15.78	81.30	202
22	MC 25	15.81	81.31	80
23	MC 26	15.76	81.20	103
24	MC 27	15.80	81.24	55
25	MC 28	15.79	81.23	32
26	MC 29	15.82	81.69	27
27	MC 30	15.83	81.22	40
28	MC 31	16.58	82.38	107
29	MC 32	16.57	82.39	2593

30	MC 33	16.57	82.41	496
31	MC 34	16.52	82.43	744
32	MC 35	16.47	82.44	1006
33	MC 36	16.44	82.47	1511
34	MC 37	16.42	82.52	1981
35	MC 38	16.25	82.60	2495
36	SC-36	16.24	82.67	145
37	SC-37	16.06	82.82	44
38	SC-38	16.48	82.34	52
39	SC-39	16.26	81.99	62
40	SC-40	16.17	81.73	53
41	SC-41	15.83	81.26	69
42	SC-42	15.71	81.08	56
43	SC-43	15.59	80.86	52
44	SC-44	12.35	80.31	33
45	SC-45	12.52	80.38	107
46	SC-46	12.52	80.24	190

Supplementary table 2: Bottom water hydrography and measured sedimentary characteristics (CF%, C_{org}, C_{org}/TN and CaCO₃%). Salinity, Temperature and DO downloaded from WOA2009 and pH measured onboard. We do not have pH values for the SC stations.

Bottom water Hydrography and sedimentary characteristics									
Station	DO (ml/l)	Salinity (psu)	T (°C)	pH	CF (%)	C_{org} (%)	C_{org}/TN	CaCO₃ (%)	Depth (m)
MC29	4.48	33.15	23.68	8.12	1.17	1.26	14.11	3.49	27.3
MC28	4.2	35.35	23.61	8.15	3.63	0.64	15.49	5.08	31.6
SC44	4.59	34.855	26.63		71.54	0.52	14.67	4.41	33
MC30	4.11	32.61	23.46	8.15	0.46	1.52	13.28	3.40	40
SC37	4.36	34.876	26.01		1.46	1.22	15.55	1.60	44
MC07	4.47	34.7	23.27	7.7	4.96	0.91	11.36	9.92	47
SC38	4.15	34.89	25.6		0.32	1.41	15.80	3.19	52
SC435	4.15	34.89	25.6		94.81	0.85		47.57	52
SC40	4.01	34.892	25.55		0.50	0.97	31.95	4.88	53
MC27	4.01	34.28	23.29	8.05	0.78	0.87	12.65	4.46	55.1
SC42	3.98	34.896	25.43		96.45	0.39		4.43	56
SC39	4.01	34.904	25.18		1.83	0.76	24.30	4.43	62
SC41	3.41	34.914	24.89		0.09	1.07	15.26	5.36	69
MC08	3.1	33.9	14.9	7.6	1.71	0.97	11.12	6.54	76
MC25	2.72	34.52	23.15	9.6	1.04	0.87	11.94	4.06	79.5
MC26	1.34	34.69	22.31	7.86	0.37	1.03	11.78	3.84	102.6
SC45	1.83	34.947	23.38		94.24	1.33	34.53	87.20	107

MC31	1.25	34.62	22.07	7.66	0.83	1.65	12.47	2.32	107.3
SC36	0.47	33.95	23.34	7.91	0.20	1.60	6.72	2.97	145
SC46	0.53	34.958	21.71		66.58	1.53	15.13	47.57	190
MC24	0.35	34.908	21.71		0.54	1.19	11.21	3.95	202
MC06	0.31	34.93	17.55	7.58	1.04	1.70	9.80	5.86	243.8
MC32	0.3	34.11	15.92	7.55	0.41	1.46	10.52	2.21	259.3
MC09	0.46	35.5	15.38	7.68	0.57	1.39	10.94	5.69	274
MC05	0.41	34.87	11.63	7.58	1.08	1.65	10.73	4.96	396.6
MC33	0.3	34.32	9.67	7.76	0.48	1.48	10.66	3.04	495.6
MC11	0.39	33.67	9.58	7.58	0.66	1.35	10.92	5.27	500.3
MC23	0.44	34.65	9.46	7.53	0.29	1.18	11.54	4.23	507.3
MC34	0.5	34.42	6.56	7.58	0.54	1.51	10.14	2.85	744.4
MC21	0.46	34.67	6.52	7.62	0.41	1.48	10.59	3.94	749.2
MC22	0.46	35.18	6.4	7.6	0.62	1.57	10.05	3.79	767.8
MC12	0.58	34.37	6.27	7.57	0.57	1.39	10.65	5.02	785.9
MC13	0.84	34.11	5.4	7.55	0.71	1.45	10.32	4.30	921
MC04	0.88	34.412	5.11		0.35	1.21	11.30	4.58	978.5
MC35	0.94	34.71	4.99	7.57	0.58	1.54	10.93	2.43	1005.8
MC20	1.03	34.7	4.71	7.61	0.55	1.68	9.70	4.55	1069
MC 19	1.03	34.18	4.25	7.57	0.44	1.12	11.00	3.07	1463
MC03	1.57	34.21	4.24	7.64	1.11	1.83	11.91	3.50	1476

MC36	1.74	34.79	4.22	7.56	0.68	1.31	9.65	1.68	1511.1
MC14	1.8	33.78	4.22	7.6	0.40	1.46	9.86	2.82	1518.8
MC15	2.28	35.17	4.22	7.64	4.78	1.15	10.56	3.67	1940.4
MC37	1.95	35.12	4.23	7.78	0.95	1.35	9.94	1.35	1980.6
MC18	2.41	34.44	4.23	7.71	0.18	1.23	11.50	3.10	2005.6
MC02	2.37	33.98	4.23	7.68	1.80	1.40	10.11	3.22	2090
MC16	2.93	33.17	4.26	7.53	0.25	1.06	11.68	1.94	2481.6
MC38	2.38	34.61	4.26	7.76	1.18	1.18	9.70	2.05	2494.9

Supplementary Table 3: Excel file of 54 dominant species and their relative abundances

Supplementary table 4: Check-list of living benthic foraminiferal species found in the surface sediments of the west-central Bay of Bengal. The maximum relative abundance of the species and the depth of the respective station is also provided.

Sl. No.	Species	Original name	Source	Maximum abundance (%)	Station	Depth (m)
1	<i>Lagenaminna ampullacea</i> (Brady, 1881)	<i>Reophax ampullacea</i> Brady, 1881	Barker, 1960, pl. 30, fig. 6	1.06	MC38	2494
2	<i>Lagenamina difflugiformis</i> (Brady, 1879)	<i>Reophax difflugiformis</i> Brady, 1879	Barker, 1960, pl. 30, fig 1-3	4.81	MC38	2494
3	<i>Lagenamina tubulata</i> (Rhumbler, 1931)	<i>Saccamina tubulata</i> Rhumbler, 1931	EMFORCAT-27570	0.41	MC18	2005
4	<i>Saccamina sphaerica</i> Brady, 1871	<i>Saccamina sphaerica</i> Brady, 1871	Barker, 1960, pl. 18, fig. 11-15, 17	1.60	MC38	2494
5	<i>Astrammmina</i> sp. Thomas, 1990	<i>Astrammmina</i> sp. Thomas, 1990	Thomas, 1990, pl. 2, fig. 1	0.31	MC19	1463
6	<i>Jaculella acuta</i> Brady, 1879	<i>Jaculella acuta</i> Brady, 1879	EMFORCAT-9687	54.93	MC16	2481
7	<i>Ammodiscus tenuis</i> (Brady, 1884)	<i>Operculina incertus</i> d'Orbigny, 1839	EMFORCAT-80024	0.15	MC11	500
8	<i>Ammodiscoides turbinatus</i> Cushman, 1909	<i>Ammodiscoides turbinatus</i> Cushman, 1909	Loeblich and Tappan, 1988, pl. 36, fig. 10-12	0.27	MC37	1980
9	<i>Ammovertellina prima</i> Suleymanov, 1959	<i>Ammovertellina prima</i> Suleymanov, 1959	Loeblich and Tappan 1988, pl.39, fig. 1-7	0.53	MC38	2494
10	<i>Glomospira gordialis</i> (Jones and Parker, 1860)	<i>Trocammina squamata</i> var. <i>gordialis</i> Jones and Parker, 1860	Barker, 1960, pl. 38, fig. 7-9	0.82	MC37	1980

11	<i>Hormosinella distans</i> (Brady, 1881)	<i>Lituola distans</i> Brady, 1881	Barker, 1960, pl. 31, fig. 18-22	13.38	MC16	2481
12	<i>Hormosinella guttifera</i> (Brady, 1881)	<i>Reophax guttifera</i> Brady 1881 in Barker, 1960, pl. 31, fig 10-15	Barker, 1960, pl. 31, fig 10-15	17.3	MC37	1980
13	<i>Reophax bilocularis</i> Flint, 1899	<i>Reophax bilocularis</i> Flint, 1899	Kuhnt et al. in Hart, Kaminski and Smart (eds), 2000, no. 7, p. 261-298, fig. 9-10	2.74	MC37	1980
14	<i>Reophax dentaliniformis</i> (Brady, 1881)	<i>Reophax dentaliniformis</i> Brady, 1881	Barker, 1960, pl. 30, fig. 21-22	2.23	MC20	1069
15	<i>Reophax fusiformis</i> (Williamson, 1858)	<i>Proteonina fusiformis</i> Williamson, 1858	Barker, 1960, pl. 30, fig. 7-10	1.17	MC16	2481
16	<i>Reophax scottii</i> Chaster, 1892	<i>Reophax scottii</i> Chaster, 1892	EMFORCAT-18740	40.96	MC32	259
17	<i>Psammolingulina</i> af. <i>papillosa</i> (Neugeboren, 1856)	<i>Lingulina papillosa</i> Neugeboren, 1856	Loeblich and Tappan, 1988, pl. 45, fig. 3, 4	1.59	MC14	1518
18	<i>Hormosina globulifera</i> Brady, 1879	<i>Hormosina globulifera</i> Brady, 1879	Barker, 1960, pl. 39, fig. 1-4, 6	0.70	MC16	2481
19	<i>Hormosina pilulifera</i> Brady, 1884	<i>Reophax pilulifera</i> Brady 1884, in Barker, 1960	Barker, 1960, pl. 30, fig. 18-20	2.05	MC18	2005
20	<i>Haplophragmoides</i> sp.	<i>Haplophragmoides subglobosum</i> Cushman, 1910	Barker, 1960, pl. 34, fig. 7	0.53	MC38	2494
21	<i>Trochamminita irregularis</i> Cushman and Bronnimann, 1948	<i>Trochamminita irregularis</i> Cushman and Bronnimann, 1948	Loeblich and Tappan, 1988, pl. 51, fig. 1-6	1.92	MC21	749
22	<i>Cribrostomoides</i> cf. <i>bradyi</i> Cushman, 1910	<i>Cribrostomoides bradyi</i> Cushman, 1910	EMFORCAT-3487	1.70	MC05	396
23	<i>Cribrostomoides subglobosus</i> (Cushman, 1910)	<i>Haplophragmoides subglobosum</i> Cushman, 1910	Zheng and Fu, 2001, p. 337, pl. 34, fig. 2-4	17.15	MC24	202

24	<i>Cribrostomoides</i> af. <i>subglobosus</i> Cushman, 1910	<i>Haplophragmoides subglobosum</i> Cushman, 1910	Barker, 1960. Pl. 34, fig. 9	3.49	MC22	767
25	<i>Ammoscalaria tenuimargo</i> (Brady, 1882)	<i>Haplophragmium tenuimargo</i> Brady, 1882	Barker, 1960, pl. 33, fig. 13-16	0.53	MC38	2494
26	<i>Discammina compressa</i> (Goes, 1882)	<i>Lituolina irregularis</i> var. <i>compressa</i> Goes, 1882	EMFORCAT-11242	4.54	MC14	1518
27	<i>Glaphyrammina americanus</i> (Cushman, 1910)	<i>Ammobaculites americanus</i> Cushman, 1910	EMFORCAT-272	0.14	MC34	744
28	<i>Trochamminoides</i> sp.1	<i>Trochamminoides</i> sp.1	Loeblich and Tappan, 1988, pg. 70, pl. 53, fig. 1, 2.	1.28	MC29	27
29	<i>Ammobaculites agglutinans</i> (d'Orbigny, 1846)	<i>Spirolina agglutinans</i> d'Orbigny, 1846	EMFORCAT-76816	4.79	MC19	1463
30	<i>Ammobaculites</i> cf. <i>agglutinans</i> (d'Orbigny, 1846)	<i>Spirolina agglutinans</i> d'Orbigny, 1846	EMFORCAT-76816	9.09	SC44	33
31	<i>Eratidus foliaceus</i> (Brady, 1881)	<i>Haplophragmium foliaceum</i> Brady, 1881	EMFORCAT-38589	0.92	MC29	27
32	<i>Nouria polymorphinoides</i> Heron-Allen and Earland, 1914	<i>Nouria polymorphinoides</i> Heron-Allen and Earland, 1914	EMFORCAT-14274	2.87	MC31	107
33	<i>Alveolophragmium orbiculatum</i> Shchedrina, 1936	<i>Alveolophragmium orbiculatum</i> Shchedrina, 1936	EMFORCAT-262	0.23	MC23	507
34	<i>Cyclammmina japonica</i> Asano, 1950	<i>Cyclammmina japonica</i> Asano, 1950a	Hanagata in Bubik and Kaminski (eds), 2004, no. 8, p. 151-166, pl. 1, fig. 15	9.62	MC9	274
35	<i>Ammoglobigerina globigeriniformis</i>	<i>Lituola nautiloidea</i> Lamarck var.	EMFORCAT-12230	19.50	MC37	1980

	(Parker and Jones, 1865)	<i>globigriniformis</i> Parker and Jones, 1865				
36	<i>Portatrochammina</i> sp.1	<i>Portatrochammina</i> sp.1	Loeblich and Tappan, 1988	6.25	SC43	52
37	<i>Trochammina</i> <i>simplissima</i> (Cushman and McCulloch, 1948)	<i>Trochammina</i> <i>pacifica</i> Cushman var. <i>simplissima</i> Cushman and McCulloch, 1939	EMFORCAT- 33644	3.84	MC37	1980
38	<i>Trochamminopsis</i> <i>quadriloba</i> (Hoglund, 1948)	<i>Trochammina pusilla</i> Hoglund, 1947	Loeblich and Tappan, 1988, pg. 122, pl. 129, fig. 1- 3	10.54	MC19	1463
39	<i>Karreriella arubiana</i> McCulloch, 1981	<i>Karreriella arubiana</i> McCulloch, 1981	McCulloch, 1981, pl. 8, fig. 25	3.52	MC21	749
40	<i>Globotextularia</i> <i>anceps</i> (Brady, 1884)	<i>Haplophragmium</i> <i>anceps</i> Brady, 1884	Loeblich and Tappan, 1988, pg. 143, pl. 150, fig. 1- 7	6.31	MC37	1980
41	<i>Rhumlerella</i> <i>humboldti</i> (Todd and Bronnimann, 1957)	<i>Eggerella humboldti</i> Todd and Bronnimann, 1957, pl. 2, fig. 26	EMFORCAT- 47206	0.99	MC22	767
42	<i>Verneuilinulla advena</i> (Cushman, 1922)	<i>Verneuilinulla advena</i> Cushman, 1922	EMFORCAT- 42658	1.49	MC22	767
43	<i>Eggerella propinqua</i> (Brady, 1884)	<i>Verneuilina</i> <i>propinqua</i> Brady, 1884	EMFORCAT- 23841	5.50	MC32	259
44	<i>Eggerella conica</i> Zheng, 1988	<i>Eggerella conica</i> Zheng, 1988	EMFORCAT- 75373	0.64	MC19	1463
45	<i>Eggerella</i> sp. 1	<i>Eggerella</i> sp. 1	Loeblich and Tappan, 1988	9.76	MC21	749
46	<i>Bigenerina nodosaria</i> d'Orbigny, 1826	<i>Bigenerina nodosaria</i> d'Orbigny, 1826	EMFORCAT- 1302	0.55	MC29	27
47	<i>Sahulia conica</i> (d'Orbigny, 1839)	<i>Textularia conica</i> d'Orbigny, 1839	EMFORCAT- 21667	12.50	SC43	52
48	<i>Textularia</i> aff. <i>abbreviata</i> d'Orbigny, 1846	<i>Textularia abbreviata</i> d'Orbigny, 1846	EMFORCAT- 77631	1.16	MC22	767

49	<i>Textularia agglutinans</i> d'Orbigny, 1839	<i>Textularia agglutinans</i> d'Orbigny, 1839	EMFORCAT-21586	6.25	SC43	52
50	<i>Textularia calva</i> Lalicker, 1935	<i>Textularia calva</i> Lalicker, 1935	EMFORCAT-21638	0.11	MC30	40
51	<i>Textularia horrida</i> Egger, 1893	<i>Textularia horrida</i> Egger, 1895	EMFORCAT-21789	0.18	MC29	27
52	<i>Textularia oceanica</i> (Cushman, 1932)	<i>Textularia foliacea</i> Heron-Allen and Earland var. <i>oceanica</i> Cushman, 1932	EMFORCAT-21752	10.00	SC42	56
53	<i>Spirillina helenae</i> Chapman and Parr, 1937	<i>Spirillina helenae</i> Chapman and Parr, 1937	EMFORCAT-20653	0.27	MC37	1980
54	<i>Adelosina laevigata</i> d'Orbigny, 1826	<i>Adelosina laevigata</i> d'Orbigny, 1826	EMFORCAT-59	0.16	MC21	749
55	<i>Spiroloculina communis</i> Cushman and Todd, 1944	<i>Spiroloculina communis</i> Cushman and Todd, 1944	EMFORCAT-32811	0.65	SC41	69
56	<i>Spiroloculina convexa</i> (Said, 1949)	<i>Spiroloculina communis</i> Cushman and Todd var. <i>convexa</i> Said, 1949	Said, 1950, pl. 1, fig. 38, EMFORCAT-38792	6.25	SC43	52
57	<i>Spiroloculina subcommunis</i> McCulloch, 1981	<i>Spiroloculina subcommunis</i> McCulloch, 1981	McCulloch 1981, p. 38, pl. 23, fig. 1	0.47	SC37	44
58	<i>Quinqueloculina bicarinata</i> d'Orbigny, 1878	<i>Quinqueloculina bicarinata</i> d'Orbigny, 1826	EMFORCAT-46164	18.75	SC43	52
59	<i>Quinqueloculina blackbeachiana</i> McCulloch, 1977	<i>Quinqueloculina blackbeachiana</i> McCulloch, 1977	McCulloch 1977, pg.483, pl.211, fig. 9-11	3.74	SC40	53
60	<i>Quinqueloculina buchiana</i> d'Orbigny, 1846	<i>Quinqueloculina buchiana</i> d'Orbigny, 1846	EMFORCAT-18165	0.18	MC29	27
61	<i>Quinqueloculina laevigata</i> d'Orbigny, 1839	<i>Quinqueloculina laevigata</i> d'Orbigny, 1839	EMFORCAT 18314	0.73	MC29	27

62	<i>Quinqueloculina lamarckiana</i> cf. d'Orbigny, 1839	<i>Quinqueloculina lamarckiana</i> d'Orbigny, 1839	EMFORCAT-18316	0.23	MC30	40
63	<i>Quinqueloculina pygmaea</i> Reuss, 1850	<i>Quinqueloculina pygmaea</i> Reuss, 1850	EMFORCAT-18425	0.29	MC29	27
64	<i>Quinqueloculina schlumbergeri</i> (Wiesner, 1923)	<i>Miliolina schlumbergeri</i> Wiesner, 1923	EMFORCAT-44337	0.53	MC38	2494
65	<i>Quinqueloculina seminula</i> (Linnaeus, 1758)	<i>Serpula seminulum</i> Linnaeus, 1758	EMFORCAT-20290	6.25	SC43	52
66	<i>Quinqueloculina stelligeri</i> Schlumbergeri, 1893	<i>Quinqueloculina stelligeri</i> Schlumbergeri, 1893	EMFORCAT-80751	3.71	MC28	31
67	<i>Quinqueloculina trigonula</i> Terquem, 1876	<i>Quinqueloculina trigonula</i> Terquem, 1876	EMFORCAT-18523	8.66	MC28	31
68	<i>Miliolinella elongata</i> (Kruit, 1955)	<i>Miliolinella circularis</i> (Bornemann) var. <i>elongata</i> Kruit, 1955	EMFORCAT-61285	1.25	MC27	55
69	<i>Miliolinella diversiformis</i> (McCulloch, 1977)	<i>Scutuloris diversiformis</i> McCulloch, 1977	McCulloch, 1977, p. 568, pl. 235, fig. 6	0.65	SC41	69
70	<i>Miliolinella lamellidens</i> (Reuss, 1863)	<i>Quinqueloculina lamellidens</i> Reuss, 1863	Haake, 1975, p. 40, pl. 5, fig. 104	2.67	SC40	53
71	<i>Miliolinella oblonga</i> (Montagu, 1803)	<i>Vermiculum oblongum</i> Montagu, 1803	EMFORCAT-23766 Matoba 1970, p. 56, pl. 3, fig. 6a-b	3.71	MC28	31
72	<i>Pseudopyrgo milletti</i> (Cushman, 1917)	<i>Biloculina milletti</i> Cushman, 1917	Loeblich and Tappan 1988, pg. 342, pl. 351, fig. 17, 18	11.00	MC26	102
73	<i>Pyrgo</i> subsp. <i>depressus</i> <i>abdosulcatus</i> Yassini and Jones, 1995	<i>Pyrgo depressus</i> subsp. <i>abdosulcatus</i>	Yassini and Jones, 1995, pg. 205, fig. 238-239	25.00	SC45	107

		Yassini and Jones, 1995				
74	<i>Pyrgo nasutus</i> Cushman, 1935	<i>Pyrgo nasutus</i> Cushman, 1935	EMFORCAT- 18079	0.60	MC2	2090
75	<i>Triloculina tricarinata</i> d'Orbigny, 1826	<i>Triloculina tricarinata</i> d'Orbigny, 1826	EMFORCAT- 22205	0.53	SC40	53
76	<i>Triloculinella bhallai</i> Sarkar and Gupta, 2008	<i>Triloculinella bhallai</i> Sarkar and Gupta, 2008	Sarkar and Gupta, 2008, pg, 180, pl, 1, fig. 11-13; pl. 2, fig. 1-5	0.18	MC29	27
77	<i>Sigmoilina elliptica</i> Galloway and Wissler, 1927	<i>Sigmoilina elliptica</i> Galloway and Wissler, 1927	EMFORCAT- 20364	0.14	MC33	495
78	<i>Spirosigmoilina tschokrakensis</i> forma <i>Angusta</i> Gherke, 1938	<i>Sigmoilina tschokrakensis</i> forma <i>Angusta</i> Gherke, 1938	Panchang and Nigam, 2014, pl. XIV, fig. 9 a-b	0.27	MC27	55
79	<i>Sigmoilopsis schlumbergeri</i> (Silvestri, 1904)	<i>Sigmoilina schlumbergeri</i> Silvestri, 1904	EMFORCAT- 20370	0.16	MC8	76
80	<i>Grigelis</i> sp.	<i>Grigelis</i> sp.	Loeblich and Tappan 1988	0.16	MC22	767
81	<i>Laevidentalina phiala</i> (Costa, 1856)	<i>Nodosaria phiala</i> Costa, 1856	EMFORCAT- 13558 Panchang and Nigam, 2014, pl. XV, fig. 18	0.16	MC3	1476
82	<i>Pseudonodosaria glanduliniformis</i> (Dervieux, 1894)	<i>Nodosaria radricula</i> var. <i>glanduliniformis</i> Dervieux, 1894	EMFORCAT- 28405 Panchang and Nigam, 2014, pl. XV, fig. 27	0.68	MC14	1518
83	<i>Pseudonodosaria</i> sp.	<i>Pseudonodosaria</i> sp.	Saraswat, 2006	0.53	MC38	2494
84	<i>Pyramidulina catesbyi</i> (d'Orbigny, 1839)	<i>Nodosaria catesbyi</i> d'Orbigny, 1839	EMFORCAT- 79945	0.15	MC11	500
85	<i>Pyramidulina</i> sp.	<i>Pyramidulina</i> sp.	Panchang and Nigam 2014, pl. XVI, fig. 6	0.15	MC11	500
86	<i>Lenticulina camiarta</i> Poag, 1966	<i>Lenticulina camiarta</i> Poag, 1966	EMFORCAT- 55647	3.99	MC23	507

87	<i>Lenticulina</i> aff. <i>deformis</i> (Reuss, 1851)	<i>Robulina deformis</i> Reuss, 1851	EMFORCAT- 18937	0.27	MC37	1980
88	<i>Lenticulina</i> <i>lucidiformis</i> (McCulloch, 1981)	<i>Robulina lucidiformis</i> McCulloch, 1981	McCulloch, 1981, pl. 27, fig. 3	0.59	MC33	495
89	<i>Lenticulina pliocaena</i> (Silvestri, 1898)	<i>Polymorphina</i> <i>pliocaena</i> Silvestri, 1898	EMFORCAT- 17185	0.41	MC18	2005
90	<i>Hemiorbulina obesa</i> (Cushman, 1923)	<i>Marginulina glabra</i> d'Orbigny <i>obesa</i> Cushman, 1923	EMFORCAT- 11635	0.16	MC35	1005
91	<i>Hemiorbulina</i> sp.	<i>Hemiorbulina</i> sp.	Saraswat, 2006.	0.47	MC15	1940
92	<i>Hyalinonetrion</i> <i>elongata</i> (Ehrenberg, 1844)	<i>Miliolina elongata</i> Ehrenberg, 1844	Yassini and Jones 1995, p. 207, fig. 273	0.63	MC3	1476
93	<i>Lagena</i> cf. <i>flatulenta</i> Loeblich and Tappan, 1953	<i>Lagena flatulenta</i> Loeblich and Tappan, 1953	McCulloch 1977, p. 282, pl. 32, fig. 27	1.60	MC38	2494
94	<i>Lagena laevis</i> (Montagu, 1803)	<i>Vermiculum leave</i> Montagu, 1803	Barker 1960, pl. 56, figs. 7-9	0.16	MC21	749
95	<i>Lagena oceanica</i> Albani, 1974	<i>Lagena oceanica</i> Albani, 1974		1.08	SC38	52
96	<i>Lagena</i> af. <i>striata</i> (d'Orbigny, 1839)	<i>Oolina striata</i> d'Orbigny, 1839	EMFORCAT- 15035	0.53	MC38	2494
97	<i>Lagena striatiformis</i> McCulloch, 1981	<i>Lagena striatiformis</i> McCulloch, 1981	McCulloch, 1981, p. 96, pl. 32, fig.10	0.16	MC8	76
98	<i>Lagena substriata</i> Williamson, 1848	<i>Lagena substriata</i> Williamson, 1848	EMFORCAT- 10249	13.00	MC27	55
99	<i>Lagena</i> sp.1	<i>Lagena</i> sp.1	Panchangand Nigaam 2014	0.16	MC35	1005
100	<i>Pygmaeoseistron</i> <i>hispidula</i> (Cushman, 1913)	<i>Lagena hispidula</i> Cushman, 1913	EMFORCAT- 9984	1.06	MC38	2494

101	<i>Krebsina pilasensis</i> (McCulloch, 1977)	<i>Krebsina pilasensis</i> McCulloch, 1977	Loeblich and Tappan, 1988, pg. 420, pl. 458, figs 12-15	2.47	MC37	1980
102	<i>Homalohedra</i> sp.	<i>Homalohedra</i> sp.	Saraswat, 2006. Pl. 7, fig. 33a-c	1.20	MC2	2090
103	<i>Fissurina earlandi</i> Parr, 1950	<i>Fissurina earlandi</i> Parr, 1950	EMFORCAT- 38414	0.31	MC13	921
104	<i>Fissurina spinosa</i> (Sidebottom, 1912)	<i>Lagena fasciata</i> (Egger) var. <i>spinosa</i> Sidebottom, 1912	EMFORCAT- 9905	2.55	MC19	1463
105	<i>Fissurina labiata</i> (Buchner, 1940)	<i>Lagena laevigata</i> (Reuss) var. <i>labiata</i> Buchner, 1940	EMFORCAT- 42097	0.31	MC13	921
106	<i>Lagenosolenia inflatiperforata</i> McCulloch, 1977	<i>Lagenosolenia inflatiperforata</i> McCulloch, 1977	McCulloch 1977, pl. 64, fig. 8	0.12	MC12	785
107	<i>Parafissurina acomposita</i> McCulloch, 1977	<i>Parafissurina acomposita</i> McCulloch, 1977	McCulloch 1977, pl. 71, fig. 16	0.31	MC13	921
108	<i>Parafissurina</i> cf. <i>impariliformis</i> McCulloch, 1977	<i>Parafissurina impariliformis</i> McCulloch, 1977	McCulloch, 1977, pl. 71, fig. 23	0.16	MC35	1005
109	<i>Parafissurina ventricosa</i> (Silvestri, 1904)	<i>Lagena ventricosa</i> Silvestri, 1904	EMFORCAT- 10313	0.32	MC35	1005
110	<i>Hoeglundina bradyi</i> (Galloway and Wissler, 1927)	<i>Epistomina bradyi</i> Galloway and Wissler, 1927	EMFORCAT- 6354	2.40	MC2	2090
111	<i>Bolivina adelaidana</i> (Cushman and Kleinpell, 1934)	<i>Bolivina marginata</i> Cushman var. <i>adelaidana</i> Cushman and Kleinpell, 1934	EMFORCAT- 1788	0.32	MC35	1005
112	<i>Bolivina pseudolobata</i> Yassini and Jones, 1995	<i>Bolivina pseudolobata</i> Yassini and Jones, 1995	Yassini and Jones, 1995, fig. 555-557	1.19	MC36	1511

113	<i>Bolivina subspinescens</i> Cushman, 1911	<i>Bolivina subspinescens</i> Cushman, 1911	EMFORCAT-1950	0.45	MC14	1518
114	<i>Bolivina tortuosa</i> Brady, 1884	<i>Bolivina tortuosa</i> Brady, 1884	Barker, 1960, pl. 52, fig. 31-34	0.15	MC11	500
115	<i>Bolivinellina earlandi</i> (Parr, 1950)	<i>Bolivina earlandi</i> Parr, 1950	EMFORCAT-38250	40.23	MC36	1511
116	<i>Bolivinellina lucidopunctata</i> (Conato, 1964)	<i>Bolivinellina lucidopunctata</i> Conato, 1964	EMFORCAT-56125	20.46	MC5	396
117	<i>Bolivinellina pacifica</i> (Cushman and McCulloch, 1942)	<i>Bolivina acerosa</i> Cushman var. <i>pacifica</i> Cushman and McCulloch, 1942	EMFORCAT-34590	9.09	SC44	33
118	<i>Bolivinellina seminuda</i> (Cushman, 1911)	<i>Bolivina seminuda</i> Cushman, 1911	EMFORCAT-1932	9.09	SC44	33
119	<i>Bolivinellina translucens</i> (Phleger and Parker, 1951)	<i>Bolivina translucens</i> Phleger and Parker, 1951	McCulloch 1981, pg. 127, pl. 45, fig. 2	45.82	MC6	243
120	<i>Bolivinita</i> sp.	<i>Bolivinita</i> sp.	Rana, 2010, pl. 14, fig. 15.	1.76	MC21	749
121	<i>Brizalina difformis</i> (Williamson, 1858)	<i>Textularia variabilis</i> var. <i>difformis</i> Williamson, 1858	EMFORCAT-22038	1.12	MC32	259
122	<i>Brizalina dilatata</i> (Reuss, 1850)	<i>Bolivina dilatata</i> Reuss, 1850	EMFORCAT-1664	37.14	SC37	44
123	<i>Brizalina mekranensis</i> (Haque, 1970)	<i>Bolivina dilatata</i> Reuss subsp. <i>mekranensis</i> Haque 1970	EMFORCAT-61579	5.07	SC36	145
124	<i>Brizalina hadai</i> (Uchio, 1962)	<i>Bolivina hadai</i> Uchio, 1962	EMFORCAT-59314	35.19	MC27	55
125	<i>Brizalina lowmani</i> (Phleger and Parker, 1951)	<i>Bolivina lowmani</i> Phleger and Parker, 1951	EMFORCAT-39775	0.42	MC32	259
126	<i>Brizalina makiyamai</i> (Ishizaki, 1944)	<i>Bolivina makiyamai</i> Ishizaki, 1944	EMFORCAT-38254	0.65	MC31	107

127	<i>Brizalina robusta</i> (Brady, 1881)	<i>Bulimina (Bolivina) robusta</i> Brady 1881 in Brady, 1884	Barker, 1960, pl. 53, fig 7	0.81	MC6	243
128	<i>Brizalina spathulata</i> (Williamson, 1858)	<i>Textularia variabilis</i> var. <i>spathulata</i> Williamson, 1858	EMFORCAT-22039	16.05	MC31	107
129	<i>Brizalina striatula</i> (Cushman, 1922)	<i>Bolivina striatula</i> Cushman, 1922	EMFORCAT-1957	4.22	MC29	27
130	<i>Brizalina subspathula</i> (Boomgart, 1949)	<i>Bolivina subspathula</i> Boomgart, 1949	EMFORCAT-37544	18.47	SC38	52
131	<i>Brizalina substriata</i> (Egger, 1893)	<i>Bolivina substriata</i> Egger, 1893	EMFORCAT-73640	3.38	MC32	259
132	<i>Brizalina</i> sp.	<i>Brizalina</i> sp.		0.11	MC26	102
133	<i>Latibolivina doniezi</i> (Cushman and Wickenden, 1929)	<i>Bolivina doniezi</i> Cushman and Wickenden, 1929	Sliter, 1970, pl. 2, fig. 6-8	2.47	MC28	31
134	<i>Latibolivina lepida</i> (Sliter, 1969)	<i>Bolivina lepida</i> Sliter, 1969	Sliter, 1969, p. 1, pl. 1, fig. 1-3	6.25	SC43	52
135	<i>Latibolivina persiensis</i> (Lutze, 1974)	<i>Bolivina persiensis</i> Lutze, 1974	Lutze, 1974, pg. 25, pl. 5, fig. 81	8.55	SC40	53
136	<i>Latibolivina pseudoplicata</i> (Heron-Allen and Earland, 1930)	<i>Bolivina pseudoplicata</i> Heron-Allen and Earland, 1930	EMFORCAT-1876	0.30	MC7	47
137	<i>Latibolivina subreticulata</i> (Parr, 1932)	<i>Bolivina subreticulata</i> Parr, 1932	EMFORCAT-1981	2.72	MC28	31
138	<i>Cassidulinoides bradyi</i> (Norman, 1881)	<i>Cassidulina bradyi</i> Norman, 1881	Barker, 1960, pl. 54, figs. 6-10	8.12	MC9	274
139	<i>Cassidulina carinata</i> (Silvestri, 1896)	<i>Cassidulina laevigata</i> d'Orbigny var. <i>carinata</i> Silvestri, 1896	EMFORCAT-2786	4.79	MC19	1463
140	<i>Cassidulina laevigata</i> d'Orbigny, 1826	<i>Cassidulina laevigata</i> d'Orbigny 1826	EMFORCAT-2782	11.97	MC20	1069

141	<i>Cassidulina neocarinata</i> (Thalmann, 1950)	<i>Cassidulina laevigata</i> d'Orbigny var. <i>carinata</i> Cushman, 1922	Rodrigues <i>et al.</i> 1980, pg. 58, pl. 5, fig. 3, 4	2.39	MC11	500
142	<i>Evolvocassidulina orientalis</i> (Cushman, 1922)	<i>Cassidulina orientalis</i> Cushman, 1922	EMFORCAT-73729	2.58	MC23	507
143	<i>Globocassidulina gemma</i> (Todd, 1954)	<i>Cassidulina gemma</i> Todd, 1954	EMFORCAT-43291	4.28	MC23	507
144	<i>Globocassidulina oblonga</i> (Reuss, 1850)	<i>Cassidulina oblonga</i> Reuss, 1850	EMFORCAT-2810	9.15	MC16	2481
145	<i>Globocassidulina subglobosa</i> (Brady, 1881)	<i>Cassidulina subglobosa</i> Brady, 1881	EMFORCAT-38308	3.82	MC15	1940
146	<i>Islandiella cushmani</i> (Stewart and Stewart, 1930)	<i>Cassidulina cushmani</i> Stewart and Stewart, 1930	Matoba and Yamaguchi, 1982, pg. 1045, pl. 2, fig. 1	8.27	MC11	500
147	<i>Eubuliminella cassandrae</i> Revets, 1993	<i>Eubuliminella cassandrae</i> Revets, 1993	Reverts, 1993, pg. 143, pl. 2, fig. 8-11	23.50	MC12	785
148	<i>Eubuliminella exilis</i> (Brady, 1884)	<i>Bulimina elegans</i> var. <i>exilis</i> Brady, 1884	Reverts 1993, p. 141, pl. 1, fig. 1-7	53.01	SC36	145
149	<i>Eubuliminella</i> sp.	<i>Eubuliminella</i> sp.		0.14	MC36	1511
150	<i>Neobulimina</i> (?) <i>texturatiformis</i> McCulloch, 1977	<i>Neobulimina</i> (?) <i>texturatiformis</i> McCulloch, 1977	McCulloch 1977, pg. 243, pl. 104, fig. 21	71.60	MC26	102
151	<i>Cassidelina nodosa</i> (Stewart and Stewart, 1930)	<i>Virgulina nodosa</i> Stewart and Stewart, 1930	EMFORCAT-23970	1.60	MC38	2494
152	<i>Stainforthia</i> af. <i>complanata</i> (Egger, 1893)	<i>Virgulina schreibersiana</i> Czjzek var. <i>complanata</i> Egger, 1893	EMFORCAT-23993	1.91	MC15	1940
153	<i>Stainforthia loeblichii</i> (Feyling-Hanssen, 1954)	<i>Virgulina loeblichii</i> Feyling-Hanssen, 1954	EMFORCAT-43961	0.28	MC32	259

154	<i>Hopkinsinella glabra</i> (Millett, 1903)	<i>Uvigerina auberiana</i> d'Orbigny var. <i>glabra</i> Millett, 1903	Loeblich and Tappan, 1988, pg. 516, pl. 567, fig 1-5	4.96	MC5	396
155	<i>Sagrinella convallaria</i> cf. (Millett, 1900)	<i>Bolivina convallaria</i> Millett, 1900	EMFORCAT-72710	0.16	MC3	1476
156	<i>Sagrinella lobata</i> (Brady, 1881)	<i>Bolivina lobata</i> Brady, 1881	EMFORCAT-38273	6.25	SC43	52
157	<i>Siphogenerina virgula</i> (Brady, 1879)	<i>Sagrina virgula</i> Brady, 1879	EMFORCAT-20069	0.30	MC7	47
158	<i>Bulimina marginata</i> d'Orbigny, 1826	<i>Bulimina marginata</i> d'Orbigny, 1826	EMFORCAT-2317	9.44	MC18	2005
159	<i>Bulimina aculeata</i> d'Orbigny, 1826	<i>Bulimina aculeata</i> d'Orbigny, 1826	Barker, 1960, pl. 51, fig. 7-9	6.62	MC2	2090
160	<i>Bulimina</i> cf. <i>aculeata</i> d'Orbigny, 1826	<i>Bulimina aculeata</i> d'Orbigny, 1826	Barker, 1960, pl. 51, fig. 7-9	3.74	MC38	2494
161	<i>Bulimina biserialis</i> (Millett, 1900)	<i>Bulimina marginata</i> d'Orbigny var. <i>biserialis</i> Millett, 1900	EMFORCAT-72578	0.53	SC40	53
162	<i>Bulimina costata</i> d'Orbigny, 1826	<i>Bulimina costata</i> d'Orbigny, 1826	Cushman and Parker, 1946, pg. 115, pl. 27, fig. 2, 3	4.21	MC2	2090
163	<i>Bulimina</i> cf. <i>delreyensis</i> Cushman and Galliher, 1934	<i>Bulimina delreyensis</i> Cushman and Galliher, 1934	McCulloch 1977, pg. 245, pl. 104, fig. 9	12.04	MC2	2090
164	<i>Bulimina</i> cf. <i>mexicana</i> (Cushman, 1922)	<i>Bulimina inflata</i> d'Orbigny var. <i>mexicana</i> Cushman, 1922	EMFORCAT-2298	2.40	MC2	2090
165	<i>Bulimina rostratiformis</i> McCulloch, 1977	<i>Bulimina rostratiformis</i> McCulloch, 1977	McCulloch, 1977, pg. 245, pl. 104, fig. 8	4.09	MC14	1518
166	<i>Bulimina subornata</i> Brady, 1884	<i>Bulimina subornata</i> Brady 1884	EMFORCAT-2477	6.66	MC5	396
167	<i>Bulimina</i> sp.	<i>Bulimina</i> sp.	Saraswat, 2006, pg. 183, pl. 17, fig. 15a. b	0.83	MC27	55

168	<i>Globobulimina globosa</i> Leroy, 1944	<i>Globobulimina globosa</i> Leroy, 1944	EMFORCAT-30728	6.77	MC18	2005
169	<i>Praeglobobulimina spinescens</i> (Brady, 1884)	<i>Bulimina pyrula</i> d'Orbigny var. <i>spinescens</i> Brady, 1884	EMFORCAT-2415	3.48	MC18	2005
170	<i>Protoglobobulimina pupoides</i> (d'Orbigny, 1846)	<i>Bulimina pupoides</i> d'Orbigny, 1846	EMFORCAT-76935	6.35	MC32	259
171	<i>Buliminella elegantissima</i> (d'Orbigny, 1839)	<i>Bulimina elegantissima</i> d'Orbigny, 1839	EMFORCAT-2246	0.62	MC5	396
172	<i>Euuvigerina asperula</i> (Czjzek, 1848)	<i>Uvigerina asperula</i> Czjzek, 1848	Boltovkoy, 1980/1981, pl. 3, fig. 25-28;	0.45	MC14	1518
173	<i>Euuvigerina attenuata</i> (Cushman and Renz, 1941)	<i>Uvigerina auberiana</i> d'Orbigny var. <i>attenuata</i> Cushman and Renz, 1941	EMFORCAT-32147	2.46	MC7	47
174	<i>Euuvigerina auberiana</i> (d'Orbigny, 1839)	<i>Uvigerina auberiana</i> d'Orbigny, 1839	EMFORCAT-23033	1.45	MC25	79
175	<i>Euuvigerina globulosa</i> (Egger, 1895)	<i>Uvigerina globulosa</i> Egger, 1895	EMFORCAT-23133	22.22	MC4	978
176	<i>Euuvigerina proboscidea</i> (Schwager, 1866)	<i>Uvigerina proboscidea</i> Schwager, 1866	EMFORCAT-23218	0.45	MC14	1518
177	<i>Uvigerina ampullacea</i> (Brady, 1884)	<i>Uvigerina asperula</i> Czjzek var. <i>ampullacea</i> Brady, 1884	EMFORCAT-23031, 38158	10.64	MC8	76
178	<i>Uvigerina</i> aff. <i>azuana</i> Bermudez, 1949	<i>Uvigerina azuana</i> Bermudez, 1949	EMFORCAT-37442	1.55	MC5	396
179	<i>Uvigerina bifurcata</i> d'Orbigny, 1839	<i>Uvigerina bifurcata</i> d'Orbigny, 1839	Barker, 1960, pl. 74, fig. 13	0.31	MC5	396
180	<i>Uvigerina canariensis</i> d'Orbigny, 1839	<i>Uvigerina canariensis</i> d'Orbigny, 1839	Barker, 1960, pl. 74, fig. 1-3	1.25	SC39	62

181	<i>Uvigerina mediterranea</i> Hofker, 1932	<i>Uvigerina mediterranea</i> Hofker, 1932	Hofker, 1932, p. 118, fig. 32a-g	2.79	MC5	396
182	<i>Uvigerina peregrina</i> Cushman, 1923	<i>Uvigerina peregrina</i> Cushman 1923	Schonfeld, 2006, pg. 359, pl. 1, fig. 14-18	21.83	MC23	507
183	<i>Uvigerina pigmaea</i> d'Orbigny, 1826	<i>Uvigerina pigmaea</i> d'Orbigny, 1826	Schonfeld, 2006, pg. 357, pl. 1, fig. 6-11	0.22	MC14	1518
184	<i>Uvigerina yabei</i> Asano, 1938	<i>Uvigerina yabei</i> Asano, 1938	EMFORCAT-36746	20.00	SC46	190
185	<i>Reussella</i> cf. <i>aculeata</i> Cushman in McCulloch, 1977	<i>Reussella aculeata</i> Cushman in McCulloch, 1977	McCulloch 1977, pg. 246, pl. 106, fig. 24	1.25	SC39	62
186	<i>Fursenkoina cornuta</i> (Cushman, 1913)	<i>Virgulina cornuta</i> Cushman, 1913	EMFORCAT-23926	2.58	MC23	507
187	<i>Fursenkoina floridana</i> (Cushman, 1920)	<i>Virgulina floridana</i> Cushman, 1920	EMFORCAT-23942	0.60	MC2	2090
188	<i>Fursenkoina pauciloculata</i> (Brady, 1884)	<i>Virgulina pauciloculata</i> Brady, 1884	EMFORCAT-23972	4.62	MC7	47
189	<i>Fursenkoina spinosa</i> (Heron-Allen and Earland, 1932)	<i>Virgulina schreibersiana</i> Czjzek var. <i>spinosa</i> Heron-Allen and Earland, 1932	Cushman, 1937, pl. 5, fig. 2-3; EMFORCAT-24001	33.33	MC4	978
190	<i>Fursenkoina schreibersiana</i> (Czjzek, 1848)	<i>Virgulina schreibersiana</i> Czjzek, 1848	EMFORCAT-23988	5.30	MC27	55
191	<i>Rutherfordoides rotundiformis</i> (McCulloch, 1977)	<i>Rutherfordia rotundiformis</i> McCulloch, 1977	McCulloch, 1977, pg. 249, pl. 105, fig. 6-10	22.22	MC4	978
192	<i>Suggrunda alata</i> (Seguenza, 1862)	<i>Vulvulina alata</i> Seguenza, 1862	Cushman 1937, p. 106, pl. 13, fig. 3-11	15.95	MC33	495
193	<i>Suggrunda pygmaea</i> (Brady, 1881)	<i>Bolivina pygmaea</i> Brady, 1881	Barker, 1960, pl. 53, fig. 5-6	9.15	MC23	507

194	<i>Suggrunda semiclara</i> (McCulloch, 1977)	<i>Bolivina semiclara</i> McCulloch, 1977	McCulloch, pg. 258, pl. 105, fig. 13	12.91	MC23	507
195	<i>Siphonodosaria recta</i> (Palmer and Bermudez, 1936)	<i>Ellipsonodosaria recta</i> Palmer and Bermudez, 1936	EMFORCAT- 6140	0.30	MC7	47
196	<i>Baggina irregularis</i> McCulloch, 1977	<i>Baggina irregularis</i> McCulloch, 1977	McCulloch, 1977, pg. 342, pl. 137, fig. 1-3	4.06	MC34	744
197	<i>Baggina bubnanensis</i> McCulloch, 1977	<i>Baggina bubnanensis</i> McCulloch, 1977	McCulloch, 1977, pg. 342, pl. 137, fig. 5	25.00	SC45	107
198	<i>Cancris</i> cf. <i>carinatus</i> (Millet, 1904)	<i>Pulvinulina oblonga</i> Williamson var. <i>carinata</i> Millett, 1904	McCulloch, 1977, pg. 343, pl. 136, fig. 3, 5, 7	3.87	MC27	55
199	<i>Cancris oblongus</i> (Williamson, 1858)	<i>Rotalina oblonga</i> Williamson, 1858	EMFORCAT- 19857	4.26	MC11	500
200	<i>Cancris</i> <i>pseudocarinatus</i> McCulloch, 1977	<i>Cancris</i> <i>pseudocarinatus</i> , McCulloch, 1977	McCulloch 1977, pg. 345, pl. 135, fig. 12, 13	3.00	MC31	107
201	<i>Eponides</i> <i>cribrorepandus</i> (Asano and Uchio, 1951)	<i>Poreponides</i> <i>cribrorepandus</i> Asano and Uchio, 1951	EMFORCAT- 79587	25.00	SC45	107
202	<i>Eponides</i> cf. <i>cribrorepandus</i> (Asano and Uchio, 1951)	<i>Poreponides</i> <i>cribrorepandus</i> Asano and Uchio, 1951	EMFORCAT- 79587	2.93	MC27	55
203	<i>Discorbis falsiformis</i> McCulloch, 1981	<i>Discorbis</i> (?) <i>falsiformis</i> McCulloch, 1981	McCulloch, 1981, pl. 65, fig. 4	1.08	SC38	52
204	<i>Discorbis</i> sp.	<i>Discorbis</i> sp.		0.47	SC37	44
205	<i>Strebloides advenus</i> (Cushman, 1922)	<i>Discorbia advena</i> Cushman, 1922	EMFORCAT- 5814	0.84	MC8	76
206	<i>Gavelinopsis mira</i> (Cushman, 1922)	<i>Discorbis mira</i> Cushman 1922	EMFORCAT- 5883	21.08	MC2	2090

207	<i>Rosalina columbiensis</i> af. (Cushman 1925)	<i>Discorbis columbiensis</i> Cushman, 1925	Lankford, 1973, pg. 127, pl. 5, fig. 10	0.30	MC7	47
208	<i>Rosalina</i> cf. <i>globularis</i> d'Orbigny, 1826	<i>Rosalina globularis</i> d'Orbigny, 1826	EMFORCAT-19172	4.16	MC21	749
209	<i>Rosalina</i> sp.	<i>Rosalina</i> sp.	Loeblich and Tappan, 1988	16.57	MC38	2494
210	<i>Sphaeroidina bulloides</i> d'Orbigny, 1826	<i>Sphaeroidina bulloides</i> d'Orbigny, 1826	Loeblich and Tappan 1988, pg. 564, pl. 617, fig. 1-6	0.93	MC16	2481
211	<i>Murrayinella nicaraguaensis</i> (McCulloch, 1977)	<i>Globotruncana nicaraguaensis</i> McCulloch, 1977	McCulloch 1977, pg. 423, pl. 178, fig. 8-9	3.20	SC40	53
212	<i>Schackoinella sarmatica</i> Weinhandl, 1958	<i>Schackoinella sarmatica</i> Weinhandl, 1958	EMFORCAT-54413	1.25	SC39	62
213	<i>Cibicidoides</i> cf. <i>arubiana</i> McCulloch, 1977	<i>Cibicidoides arubiana</i> McCulloch, 1977	McCulloch 1977, pl. 69, fig. 1	1.36	MC14	1518
214	<i>Pseudoparrella obesa</i> (Bandy and Arnal 1957)	<i>Epistominella obesa</i> Bandy and Arnal, 1957	Matoba and Yamaguchi, 1982, pl. 3, fig. 3	2.40	MC35	1005
215	<i>Hyalinea balthica</i> (Schroeter, 1783)	<i>Nautilus balthicus</i> Schroeter, 1783	EMFORCAT-37878; Barker, 1960, pl. 112, fig. 1, 2	1.40	MC23	507
216	<i>Cibicides pokuticus</i> Ayzenshtat, 1954	<i>Cibicides pokuticus</i> Ayzenshtat, 1954	EMFORCAT-50941	1.28	MC29	27
217	<i>Fontbotia wullestorffi</i> (Schwager, 1866)	<i>Anomalina wuellerstorffi</i> Schwager, 1866	EMFORCAT-771	4.81	MC38	2494
218	<i>Caribbeanella katasensis</i> (Ujie, 1956)	<i>Pseudocibicidoides katasensis</i> Ujie, 1956	EMFORCAT-48340	20.00	SC42	56
219	<i>Pseudoeponides japonicum</i> Uchio, 1950	<i>Pseudoeponides japonicum</i> Uchio, 1950	EMFOCAT-72201	4.64	MC35	1005

220	<i>Amphistegina lobifera</i> Larsen, 1976	<i>Amphistegina lobifera</i> Larsen, 1976	Panchang and Nigam, 2014, pl. XXXIII, fig. 2a-b	6.25	SC43	52
221	<i>Amphistegina papillosa</i> (Said, 1949)	<i>Amphistegina radiata</i> var. <i>papillosa</i> Said, 1949	EMFORCAT- 38211	12.50	SC43	52
222	<i>Nonionella auris</i> (d'Orbigny, 1839)	<i>Valvulina auris</i> d'Orbigny, 1839	EMFORCAT- 23597	15.04	MC29	27
223	<i>Nonionella</i> af. <i>lata</i> Cushman and Valentine, 1930	<i>Nonionella lata</i> Cushman and Valentine, 1930	Cushman and Parker, 1939, pg. 34, pl. 9, fig. 14	0.50	MC28	31
224	<i>Nonionella limbato-</i> <i>striata</i> Cushman, 1931	<i>Nonionella limbato-</i> <i>striata</i> Cushman, 1931	EMFORCAT- 14046	16.33	MC29	27
225	<i>Nonionella turgida</i> (Williamson, 1858)	<i>Rotalina turgida</i> Williamson, 1858	Cushman, 1930, p. 15, pl. 6, fig. 1-4	9.09	SC44	33
226	<i>Nonionella</i> sp.1	<i>Nonionella</i> sp.1	Loeblich and Tappan 1988	0.62	MC7	47
227	<i>Nonionella</i> sp. 2	<i>Nonionella</i> sp. 2	Loeblich and Tappan 1988	1.31	MC20	1069
228	<i>Nonionellina labradorica</i> (Dawson, 1860)	<i>Nonionina labradorica</i> Dawson, 1860	EMFORCAT- 14167	55.26	SC41	69
229	<i>Nonionoides grateloupi</i> (d'Orbigny, 1839)	<i>Nonionina grateloupi</i> d'Orbigny, 1839	EMFORCAT- 14150	1.85	MC7	47
230	<i>Evolutononion shanxiense</i> (Wang, 1964)	<i>Evolutononion shanxiense</i> Wang, 1981	EMFORCAT- 79247; Loeblich and Tappan, 1988, p. 616, pl. 691, fig. 8-13	37.15	MC27	55
231	<i>Pseudononion japonicum</i> Asano, 1938	<i>Pseudononion japonicum</i> Asano, 1938	Loeblich and Tappan 1988, pl. 692, fig. 1-5	1.08	MC38	2494
232	<i>Melonis affinis</i> (Reuss, 1851)	<i>Nonionina affinis</i> Reuss, 1851	EMFORCAT- 14069	3.02	MC37	1980
233	<i>Melonis asymmetrica</i> Yassini and Jones, 1995	<i>Melonis asymmetrica</i> , Yassini and Jones, 1995	Yassini and Jones, 1995, pg. 170, fig. 915, 918-919	0.24	MC28	31

234	<i>Melonis chathamensis</i> (?) McCulloch, 1977	<i>Melonis chathamensis</i> (?) McCulloch, 1977	McCulloch 1977, pl. 180, fig. 5	6.41	SC40	53
235	<i>Pullenia bulloides</i> (d'Orbigny, 1846)	<i>Pullenia bulloides</i> d'Orbigny, 1846	Loeblich and Tappan, pl. 696, fig. 3, 4	9.49	MC13	921
236	<i>Pullenia quadriloba</i> (Reuss, 1867)	<i>Pullenia compressiuscula</i> Reuss var. <i>quadriloba</i> Reuss, 1867	EMFORCAT- 17856	0.47	SC37	44
237	<i>Pullenia subcarinata</i> (d'Orbigny, 1839)	<i>Nonionina subcarinata</i> d'Orbigny, 1839	Barker, 1960, pl. 84, fig. 14	1.61	MC12	785
238	<i>Allomorphina pacifica</i> Cushman and Todd, 1949	<i>Allomorphina pacifica</i> Cushman and Todd, 1949	Barker, 1960, pl. 55, fig. 24-26	0.14	MC34	744
239	<i>Chilostomella oolina</i> Schwager, 1878	<i>Chilostomella oolina</i> Schwager, 1878	EMFORCAT- 28134	5.06	MC36	1511
240	<i>Chilostomella ovoidea</i> Reuss, 1850	<i>Chilostomella ovoidea</i> Reuss, 1850	EMFORCAT- 2935	11.11	MC4	978
241	<i>Svratkina</i> sp.	<i>Svratkina</i> sp.	McCulloch 1977	0.61	MC7	47
242	<i>Osangularia</i> cf. <i>culter</i> (Parker and Jones, 1865)	<i>Planorbulina farcta</i> (Fichtel and Moll) var. <i>ungeriana</i> (d'Orbigny) subvar. <i>culter</i> Parker and Jones, 1865	EMFORCAT- 16284	3.40	MC14	1518
243	<i>Oridorsalis umbonata</i> (Reuss, 1851)	<i>Rotalina umbonata</i> Reuss, 1851	EMFORCAT- 19939	6.02	MC2	2090
244	<i>Oridorsalis</i> sp. 1	<i>Oridorsalis</i> sp. 1	Loeblich and Tappan 1988	3.57	MC37	1980
245	<i>Gyroidinoides subzelandica</i> Hornibrook, 1961	<i>Gyroidinoides subzelandica</i> Hornibrook, 1961	EMFORCAT- 54105	6.22	MC15	1940
246	<i>Rotaliatinopsis semiinvoluta</i> (Germeraad, 1946)	<i>Pulleniatina semiinvoluta</i> ? Germeraad, 1946	Loeblich and Tappan, 1988, pg. 634, pl. 714, fig. 7- 11	27.21	MC13	921

247	<i>Hanzawaia concentrica</i> (Cushman, 1918)	<i>Truncatulina concentric</i> Cushman, 1918	EMFORCAT-22756, 81728	2.75	MC29	27
248	<i>Hanzawaia nipponica</i> Asano, 1944	<i>Hanzawaia nipponica</i> Asano, 1944	EMFORCAT-36346	43.75	SC39	62
249	<i>Hanzawaia</i> sp.	<i>Hanzawaia</i> sp.	Loeblich and Tappan 1988	0.13	MC27	55
250	<i>Pararotalia?</i> <i>minuta</i> (Takayanagi, 1955)	<i>Rotalia?</i> <i>minuta</i> Takayanagi, 1955	Matoba, 1970, pl. 6, fig. 5a-c, 6a-c, 7a-c	1.39	MC27	55
251	<i>Pararotalia nipponica</i> (Asano, 1936)	<i>Rotalia nipponica</i> Asano, 1936	Matoba, 1970, pg. 57, pl. 6, fig. 3a-c, 4a-c	4.94	MC37	1980
252	<i>Ammonia tepida</i> (Cushman, 1926)	<i>Rotalia beccari</i> (Linne) var. <i>tepida</i> Cushman, 1926	EMFORCAT-19332	9.52	SC37	44
253	<i>Ammonia sobrina</i> (Schupack, 1934)	<i>Rotalia beccari</i> (Linne) var. <i>sobrina</i> Schupack, 1934	EMFORCAT-19330	6.52	SC38	52
254	<i>Asterorotalia trispinosa</i> (Thalmann, 1933)	<i>Rotalia pulchella</i> Thalmann, 1932	EMFORCAT-31179	4.58	MC29	27
255	<i>Asterorotalia dentata</i> (Parker and Jones, 1865)	<i>Rotalia beccari</i> (Linne) var. <i>dentata</i> Parker and Jones, 1865	EMFORCAT-19317	0.24	MC28	31
256	<i>Asterorotalia</i> cf. <i>dentata</i> (Parker and Jones, 1865)	<i>Rotalia beccari</i> (Linne) var. <i>dentata</i> Parker and Jones, 1865	EMFORCAT-19317	0.33	MC8	76
257	<i>Asterorotalia inflata</i> (Millet, 1904)	<i>Rotalia schroeteriana</i> Parker and Jones var. <i>inflata</i> Millet, 1904	EMFORCAT-72313	17.43	MC29	27
258	<i>Pseudorotalia schroeteriana</i> (Parker and Jones, 1868)	<i>Rotalia schroeteriana</i> Parker and Jones, 1868	EMFORCAT-77581	0.13	MC27	55
259	<i>Rotalidium annectens</i> (Parker and Jones, 1865)	<i>Rotalia beccari</i> (Linne) var. <i>annectens</i> Parker and Jones, 1865	EMFORCAT-19314	0.30	MC7	47

260	<i>Calcarina spengleri</i> (Gmelin, 1791)	<i>Nautilus spengleri</i> Gmelin, 1791	EMFORCAT- 75692	0.69	MC27	55
261	<i>Elphidium craticulatum</i> (Fichtel and Moll, 1798)	<i>Nautilus craticulatus</i> Fichtel and Moll, 1798	EMFORCAT- 74056	0.13	MC31	107
262	<i>Elphidium</i> af. <i>crispum</i> (Linnaeus, 1758)	<i>Nautilus crispus</i> Linnaeus, 1758	EMFORCAT- 12581	0.11	MC30	40
263	<i>Elphidium macellum</i> (Fichtel and Moll, 1978)	<i>Nautilus macellus</i> Fichtel and Moll, 1978	EMFORCAT- 74918, 74920	1.46	MC29	27