

Ecological preferences of living benthic foraminifera from the Mahanadi river-dominated north-western Bay of Bengal: A potential environmental impact assessment tool

Syed Mohammad Saalim^{1,2*}, Rajeev Saraswat^{1#}, Rajiv Nigam¹

1 Micropaleontology Laboratory, Geological Oceanography Division,
National Institute of Oceanography, Goa, India

2 Currently at: National Center for Polar and Ocean Research, Goa, India
For Correspondence: * sa_saalim2006@hotmail.com; # rsaraswat@nio.org

Abstract

The ecological preferences of living benthic foraminifera from the riverine influx dominated eastern continental margin of India have been studied. The living benthic foraminifera were abundant on the upper slope (~100–700 m). Three distinct species assemblages were identified. Assemblage 1 (*Ammonia beccari*, *Pseudononion costiferum*, *Hanzawaia nipponica*, *Bolivina frondalis*, *Bolivina dilatata*, *Bolivina striatula*, *Asterorotalia milletti*) representing warmer, well-oxygenated water and coarse substrate with low organic carbon is restricted to the inner shelf. Assemblage 2 includes species (*Verneuilinella propinqua*, *Ammodiscus incertus*, *Buliminella dubia*, *Rotaliatinopsis semiinvoluta*, *Bolivina lowmani*, *Fursenkoina spinosa*) thriving in the regions with abundant food availability and low oxygen concentration on the continental slope. The species in Assemblage 3 (*Globocassidulina subglobosa*, *Epistominella exigua*, *Gyroidinoides subzelandica*, *Reophax longicollis*, *Adercotryma glomeratum*, *Cystamina pauciloculata*, *Spiroplectammina biformis*) prefer deeper waters with moderate organic carbon and dissolved oxygen. The information of the ecological niches of benthic foraminifera will help in environmental impact assessment and paleoecological studies.

Keywords: Benthic foraminifera, ecology, freshwater, organic carbon, environmental impact, Bay of Bengal

1. Introduction

The marginal marine regions are severely affected by anthropogenic activities (Harley et al., 2006; Halpern et al., 2015). A lot of efforts are made to understand the precise impact of anthropogenic activities on marine environment (Dailianis et al., 2018; Sany et al., 2014; Gissi et al., 2020). The anthropogenic impact on marine environment includes change in the abundance and diversity of marine flora and fauna (Occhipinti-Ambrogi and Savini, 2003; Harley et al., 2006). The benthic foraminifera are the dominant constituent of the meiofauna community in the marginal marine regions (Sen Gupta, 1999). The high sensitivity of benthic foraminifera to the ambient environment and its abundance in marine sediments has led to the widespread application in environmental impact assessment studies (Alve 1995; Saalim et al., 2017; Damak et al., 2020; Bouchet et al., 2012; Bouchet et al., 2021). Assessing the impact of anthropogenic activities requires the understanding of the ecological preferences of benthic foraminifera. The benthic foraminifera population and distribution depends on several ecological factors (organic carbon, dissolved oxygen, water depth, temperature, salinity, pH and grain size) (Gooday, 2003; Murray, 2006; Saraswat & Nigam, 2013; Singh et al., 2021). The factors dominantly modulating benthic foraminifera population and diversity vary, depending on a multitude of parameters, including depth, distance from the continental margin, type and extent of material influx. The deep sea population is mainly influenced by the dissolved oxygen and organic carbon (Vander Zwaan 1999; Gooday, 2003; Jorissen, 2007; Singh et al., 2021). However, the amount of sediment and water discharge, energy conditions, pollution, and coastal hypoxia modulate the distribution and abundance of benthic foraminifera in the shallow waters (Nigam et al., 1992; Alve, 1995; Manasa et al., 2016; Saalim et al., 2017; Saraswat et al., 2017; Suokhrie et al., 2018). Thus, the unique ecological niches and microhabitat of specific benthic foraminifera are confined to the explicit environments. The decades of research in different oceanic regimes has helped to establish the distinct ecological preferences of benthic foraminifera. A few regions like the marginal marine regions of the Indian Ocean are, however, still poorly explored.

The ecological niche of a particular benthic foraminifera species includes both the biotic and abiotic factors. Therefore, a shift in the ambient conditions is likely to affect the benthic foraminifera. Thus benthic foraminifera are ideally suited to reconstruct the environmental conditions in the past. The precise knowledge of the ecological preferences of benthic foraminifera is also required to reconstruct the past environmental conditions in a region. The enormous amount of freshwater discharge by the monsoon and snow fed rivers leads to highly stressed conditions in the continental margins of India. The massive debouching affects the ambient physio-chemical characteristics and benthic ecology in the western Bay of Bengal (Suokhrie et al., 2020; 2021). The tremendous discharge

brings warm low saline water causing stratification (Sengupta et al., 2016), along with high nutrient and coarser grains making it more stressful for the marine benthic fauna to proliferate (Manasa et al., 2016). The perennially low oxygen concentration at the intermediate depths of the western Bay of Bengal (Sarma et al., 2013; Uday Bhaskar et al., 2021) also creates stressed environment affecting benthic foraminifera. Despite the uniqueness and complexity of the region, benthic foraminiferal studies are scarce from this tropical ocean margin. A majority of the efforts to understand the effect of ambient physico-chemical characteristics on benthic foraminiferal distribution in the western Bay of Bengal, are confined to the very shallow regions (offshore locations and beaches) (Khare et al., 2007 and references within). The studies pertaining to the distribution of benthic foraminifera off Mahanadi (Bhatia and Bhalla, 1959; Rao, 1964; Rao et al., 1974; Rao et al., 1979; Rao et al., 2000; Jayalakshmi and Rao, 2003; Naidu et al., 1990; Barik et al., 2019) are limited and restricted to only estuaries and coastal region. Additionally, studies based on living (stained) benthic foraminifera are rare from the region. Only a few studies included the effect of ambient bottom water conditions on benthic foraminifera (Rao et al., 2000; Manasa et al., 2016; Saraswat et al., 2017; Saalim et al., 2019 Suokhrie et al., 2021). A comprehensive study of the ecology of benthic foraminifera from the shelf to the deeper regions of the western Bay of Bengal is non-existent. Therefore, there is a need to document the distribution of benthic foraminifera and its ecological preferences from the western Bay of Bengal. The understanding of the relationship between the ambient bottom water conditions and their effect on benthic foraminifera at present will also act as baseline data to delineate any future shift in ecological niches, in response to anthropogenic/natural stressors.

2. Regional settings

We have focussed on the Mahanadi basin, between the Mahanadi and Godavari rivers in the western Bay of Bengal. The western Bay of Bengal receives an immense freshwater flux of $1.6 \times 10^{12} \text{ m}^3$ per year from the major rivers (Ganga, Brahmaputra, Mahanadi, Godavari, Cauvery and Krishna; UNESCO, 1979). The annual sediment discharge by these rivers is $1.4 \times 10^9 \text{ t}$ (Madhupratap et al., 2003). Mahanadi contributes $\sim 1,895 \text{ m}^3/\text{sec}$ of freshwater and $15 \times 10^6 \text{ mt}$ of sediment annually (Chakrapani and Subramanian, 1990; Coleman and Huh, 2004). The sediment size decreased with water depth in front of the Mahanadi River, with sand and silt being dominant close to the river mouth (Bejugam and Nayak, 2017). The maximum riverine flux ($6352 \text{ m}^3/\text{sec}$) is in the summer monsoon season, whereas the minimum ($759 \text{ m}^3/\text{sec}$) is during the winter monsoon season (Panda et al., 2013). The warmer freshwater lowers the salinity, stratifies the water column and suppresses vertical mixing, leading to low biological productivity (Prasanna Kumar, 2002) as compared to the Arabian Sea (Madhupratap et al., 2003). However, the north-western Bay of Bengal's high productivity is due to

the eddies, which provide nutrients to the stratified water column (Prasanna Kumar et al., 2004). The high productivity leads to an oxygen-depleted water column at intermediate depths of ~100 - 1000 m in the Bay of Bengal (Naqvi et al., 1979; Sarma et al., 2013; Udaya Bhaskar et al., 2021). Interestingly, despite of the very low dissolved oxygen, no severe anoxic zones have so far been reported from the bay (Bristow et al., 2017). The oxygen concentration varies between ~0.2 to 3.0 ml/l at the intermediate depths (Garcia et al., 2018). Also, a seasonal coastal hypoxia and stratification have been reported on the continental shelf of the western Bay of Bengal (Sarma et al., 2013).

3. Materials and Methods

A total of 42 surface sediment samples were collected from a water depth of 28 m to 2540 m by using the multi-corer (OSIL Maxicorer) as well as spade corer (Fig. 1, Table 1). The sediment samples from the multi-corer were collected along three transects (MC39 to MC68) in the cruise onboard ORV *Sagar Kanya* (SK308) in January 2014. Additionally, four transects from the shelf region were sampled during the RV *Sindhu Sankalp* cruise SSK35 (SC23 to SC35) by using the spade corer during May-June 2012. The top section (0-1 cm) of the multi-corer and spade core samples were used to study the modern distribution of living benthic foraminifera. The added advantage of multi-corer is the retrieval of a completely intact sediment-water interface. The multi-corer samples thus help in better ascertaining the ecological preferences of benthic foraminifera and its relationship with the ambient physico-chemical parameters. The samples were divided into two halves, and one half was stained onboard by using rose-Bengal ethanol solution (2 g rose-Bengal in 1 l of ethanol) to identify living foraminifera. The rose-Bengal stained samples were stored for a minimum of two weeks and then processed following the standard sediment processing procedure (Manasa et al., 2016; Saalim et al., 2019). The samples were freeze-dried, weighed and washed by using a 63 µm sieve. The freeze-drying of sediment samples has a few limitations, as it may cause the breakage of the fragile, thin shelled specimens, and thus likely affect the counts of dead benthic foraminifera (Saraswat et al., 2020). However, the present study deals with only living benthic foraminifera and is not affected by freeze-drying of sediment samples (Saraswat et al., 2020). The >63 µm sieved material (coarse fraction) was dried and stored in plastic vials. A small aliquot of the dried coarse fraction was weighed and used to pick living benthic foraminifera. A minimum of 300 stained specimens were picked from each sample by using a stereo-zoom microscope (Olympus SZX 12) and mounted on the micropaleontological slides. In samples where a sufficient number of stained specimens was unavailable, a standard 1 g coarse fraction was used to pick stained benthic foraminifera. The picked benthic foraminifera were identified upto species level. The foraminifera treatise (Loeblich and Tappan, 1988) and Ellis and Messina catalogue (1940-2019) was followed for the generic classification and segregation of the

specimens based on their morphological characteristics. The relative abundance of each species was counted in all the surface samples.

The generic distribution of benthic foraminifera helps in delineating the broader environmental niches, while the species microhabitat needs to be understood in regions where the regional settings dominate the ecological distribution. In order to understand the ecological preferences of benthic foraminifera, the species with >3% abundance at a minimum of 2 stations were used for canonical correspondence analysis (CCA) and correlation by using Multi-Variate Statistical Package (MVSP) in Statistica 6 software. The biodiversity index, a measure of the species diversity, is a good way to assess the broader species assemblage/community level response to the ambient parameters. It has two basic components, namely the number of species present (species richness) and their relative abundance (species evenness), which changes based on various ecological factors. The species abundance data from all the stations were used to calculate the Shannon Wiener index (H), Fisher α index and Species Evenness (E), by using Primer 6 software.

The ambient parameters (salinity, pH, and dissolved oxygen) at the sediment-water interface were measured onboard from the water collected in the multicores. The dissolved oxygen (DO) (Gouretski and Koltermann, 2004) at the spade core stations, and bottom temperature data (Locarnini et al., 2013) for all the stations was acquired from the 'World Ocean Atlas 2013' by using 'Ocean Data View software' (Schlitzer, 2017). A minimum of ~5 g dry sediment was powdered and homogenized in a mortar pestle for the total carbon (TC), nitrogen (TN), and inorganic carbon (TIC) analysis. TC and TN were analysed by using a CNS Thermoflash analyser (FLASH 2000 Thermo Scientific). The error estimated from the repeat analysis of NC Soil standard during the sample run was 0.3% for TC and 0.01% for TN. The inorganic carbon was measured by using a UIC CM 5015 CO₂ coulometer. The organic carbon (C_{org}) was estimated by subtracting TIC from TC.

4. Results

4.1 Ecological parameters

The bottom water salinity varied from 32.2 to 34.9 psu and was the highest at stations in-between the river mouths on the outer shelf [station SC 28 (100 m), SC 25 (106 m), SC 26 (122 m), and SC 33 (114 m)]. The lowest salinity was at station MC 40 (29 m) (Fig. 2a). The ambient temperature at the sediment-water interface varied from ~5 – 25 °C, and decreased with increasing depth (Fig. 2b). As expected, the lowest temperature was at deeper stations [station MC 59 (2240 m)], and the highest was on the inner shelf [station SC 35 (31 m)]. The bottom water DO varied from 0.2 to 3.0 ml/l (Fig. 2c). The %C_{org} varied from the highest of 2.1% to the lowest of 0.1% (Fig. 2d). The highest %C_{org} was at

the intermediate and deeper depths. The organic carbon to nitrogen ratio (C_{org}/N) ranged from a maximum of 13.8 to a minimum of 7.4 (Fig. 2e). The shallow locations had a higher C_{org}/N . The coarse fraction (CF) ranged from a minimum of 0.3% to a maximum of 88.0% (Fig. 2f). The terrigenous material brought by the rivers dominated the CF. As expected, the shallow sampling locations on the continental shelf had higher CF.

4.2 Living (stained) benthic foraminifera

The living benthic foraminifera were abundant on the upper slope (~100 – 700 m) and the population decreased at further deeper stations (Fig. 3). The highest abundance (4666/g sediment) was at 225 m (MC 52), and the lowest (5/g sediment) was at 99 m (SC 28). Out of the three transects, living benthic foraminifera abundance was higher in the northern transect, possibly due to the influence of the Mahanadi river. However, the station with the highest living benthic foraminifera abundance was in the middle transect and was not affected by either the Mahanadi or Godavari rivers, but by a small stream known as the Vamasdhara River.

A total of 10642 living benthic foraminifera were picked and identified from the north-western Bay of Bengal. The picked specimens belong to 285 species falling under 158 genera, 57 subfamily, 61 family, 31 superfamily and 8 suborder (Table 2). Out of the total living benthic foraminifera, 119 species were agglutinated and 166 were calcareous. The surface distribution clearly suggests the abundance of distinct fauna at different depths. The most abundant benthic foraminifera on the continental shelf to upper slope region were calcareous (*Bolivina pacifica*, *Bolivina dilata*, *Buliminella elegantissima*, *Ebuliminella exilis*, *Rotaliatinopsis semiinvoluta*, *Hanzawaia nipponica*, *Ammonia beccari*, *Nonionellina labradorica* and *Nonion boueanum*). The agglutinated benthic foraminifera (*Adercotryma glomeratum*, *Reophax longicollis*, *Spiroplectammina biformis*, *Hormosinella distans*, *Cystammina pauciloculata*, *Ammoglobigerina globigeriniformis*, and *Karriella arubiana*) dominated the deeper stations. We also identified 72 dominant living benthic foraminifera species belonging to 52 genera, based on >3% relative abundance at a minimum of two stations.

4.3 Biodiversity indices

The species diversity and richness was higher at the deeper depths, and low at the intermediate depths. The species diversity varied from a minimum of 1.1 to a maximum of 3.5 (Fig. 4a). The Pielou's evenness varied from a minimum of 0.49 to a maximum of 1.00 (Fig. 4b), and the species richness ranged from a lowest of 0.9 to the highest of 16.7 (Fig. 4c). The Pielou's evenness (J') also had the same trend, being higher at the deeper depths as compared to the shelf, with a few exceptions like the stations influenced by the Mahanadi river at intermediate depths in the first transect.

4.4 Ecological preferences of benthic foraminifera

To understand the ecological preferences of benthic foraminifera, CCA has been performed on 72 species with >3% relative abundance at a minimum of two stations. The biplot represented the ecological preferences of these species. The most significant parameters that influenced the ecological distribution of benthic foraminifera in the western Bay of Bengal are depth, temperature, %C_{org} and dissolved oxygen (Fig. 5).

4.4.1 Species associated with depth and temperature

Out of the 72 dominant species used for CCA and correlation analysis, 22 species were positively correlated, and 8 species were negatively correlated with water depth (Fig. 6). As the temperature decreases with water depth, the relationship of these species with temperature was also explored. A total of 25 species were negatively correlated with ambient temperature, and 16 were positively correlated (Fig. 9A). Interestingly, almost all the species that are positively correlated with depth are negatively correlated to temperature. Also, a majority of the species having higher relative abundance at deeper depth and negatively correlated to ambient temperature were agglutinated (*Lagenammina ampullacea*, *Reophax longicollis*, *Hyperammina friabilis*, *Hormosinella distans*, *Hormosinelloides guttifer*, *Reophax tortilis*, *Adercotryma glomeratum*, *Cystammina pauciloculata*, *Spiroplectammina biformis*, *Karrieriella arubiana*) (Table 3, Fig. 6). The calcareous species *Globocassidulina subglobosa*, *Epistominella exigua*, *Heterolepa bradyi*, *Gyroidinoides subzelandica*, *Rotorbinella campanulata* were positively correlated with water depth and negatively correlated with temperature. Out of the 25 species that were positively correlated with ambient temperature, only 3 species, namely *Pseudononion costiferum*, *Hanzawaia nipponica*, and *Ammonia beccari* had a significant correlation (Fig. 9A).

4.4.2 Species associated with %C_{org}, dissolved oxygen and coarse fraction (>63 µm)

Amongst the dominant species, 14 were positively correlated with %C_{org}, 15 were positively correlated with dissolved oxygen, and 11 species were positively correlated with the coarse fraction. However, out of the total 15 species preferring high %C_{org}, only 4 (*Verneuillinella propinqua*, *Buliminella dubia*, *Ammodiscus incertus* and *Rotaliatinopsis semiinvoluta*) had a significant positive correlation (Table 3, Fig. 7A). Interestingly, the same species were also significantly negatively correlated with the dissolved oxygen in the north-western Bay of Bengal (Table 3). Apart from these four species, *Fursenkoina spinosa*, and *Bolivina lowmani* were also significantly negatively correlated with the dissolved oxygen (Fig. 8A). *Pseudononion costiferum*, *Ammonia beccari* and *Hanzawaia nipponica* were significantly positively correlated with dissolved oxygen (Table 3, Fig. 8B). *Pseudononion*

costiferum, *Ammonia beccari*, *Bolivina frondalis* and *Triloculina oblonga* were significantly negatively correlated with %C_{org} (Table 3, Fig. 7B). The same species along with *Hanzawaia concentrica*, except *Pseudononion costiferum*, are significantly positively correlated with the coarse fraction (Table 3, Fig. 9B).

4.4.3 Species associated with C_{org}/N and salinity

From the CCA plot, it is clear that species, namely *Bolivina dilatata*, *Bolivina subspathulata*, *Fursenkoina pauciloculata* were positively influenced by C_{org}/N (Fig. 10A). It is also inferred that *Bolivina striatula*, *Asterorotalia milletti* were negatively correlated with the ambient salinity (Fig. 10B). Apart from these, no other species was either positively or negatively significantly correlated with C_{org}/N and salinity. All of these species inhabit shallow water depths. The high C_{org}/N represents increased amount of terrigenous organic matter contribution in the region dominated by these species.

5. Discussion

We document the comprehensive distribution pattern of living (stained) benthic foraminifera from the river-dominated continental margin in the north-western Bay of Bengal. The most striking feature is the excessive abundance of living (stained) agglutinated benthic foraminifera, not reported from the tropical oceanic margins. The proportion of agglutinated to calcareous benthic foraminifera was significantly higher at the lower slope to bathyal depths (~1000 – 2500 m) (Saalim et al., 2019). In contrast, calcareous species dominated the living benthic foraminifera population on the continental shelf and upper slope (~100 – 700 m).

We observed the highest living benthic foraminifera population on the upper slope in all the three sampled transects. The high benthic foraminiferal abundance on the upper slope is attributed to a combination of increased food availability and low predatory pressure due to deficient oxygen concentration. The benthic foraminiferal abundance is strongly influenced by the food availability (Van Der Zwaan et al., 1999), the quality/quantity of organic matter (Jorissen et al., 1995) and dissolved oxygen concentration in the ambient water (Singh et al., 2021; Suokhrie et al., 2021). The river-dominated shelf margin of the north-western Bay of Bengal is influenced by the huge terrestrial flux and well-oxygenated waters. The coarser grains and well oxygenated waters help in both the consumption and oxidation of the organic matter (Burdige, 2007) and thus reduced %C_{org} on the continental shelf adjacent to river mouths. The surface sediments at the intermediate depths are enriched in %C_{org} due to the high productivity, depleted dissolved oxygen concentration and fine grained texture (Bejugam and Nayak, 2017). The higher sedimentation rate also helps in quick burial of the sinking organic matter (Ingall and Cappellen, 1990). Thus, the increased organic carbon at the

upper slope facilitates the increase in standing stock of living benthic foraminifera. The dominance of thin-shelled calcareous benthic foraminifera on the upper slope of the north-western Bay of Bengal, is the result of high organic matter and depleted oxygen conditions (Sen Gupta and Machain-Castillo, 1993; Mazumder and Nigam, 2014; Singh et al., 2018; Suokhrie et al., 2020).

5.1 Ecological preferences of benthic foraminiferal species

Benthic foraminifera distribution is primarily governed by the strong environmental gradients in the north-western Bay of Bengal. The two major rivers (Mahanadi and Godavari) and a tributary (Vamsadhara) modulate the physiography of the region, and thus also the foraminifera distribution (Fig. 3). The region is under the constant influence of terrigenous flux and has stressed ecological niches. The depth, temperature, organic matter, dissolved oxygen, coarse fraction, salinity and C_{org}/N , are amongst the most significant environmental variables strongly influencing the distribution of benthic foraminifera in the western Bay of Bengal, as evident from the CCA biplot (Fig. 5).

5.1.1 Water depth and ambient temperature

The spatial distribution of living benthic foraminifera in the north-western Bay of Bengal is strongly influenced by the water depth and temperature (Fig. 5). Although, not being considered a controlling ecological factor in several other regions (Wollenburg and Kuhnt 2000; Jorissen et al., 2007), depth and temperature play a major role in controlling benthic foraminifera distribution in the north-western bay. The maximum number of species were either positively associated with water depth (22) or negatively correlated with ambient temperature (25). A total 16 species were significantly positively correlated with the water depth, thus, making it the most dominant ecological factor. The water depth influences the distribution of benthic foraminifera as an independent environmental parameter (Phleger, 1960). However, the combined effect of hydrostatic pressure, temperature, organic flux, water mass characteristics, and carbonate dissolution cannot be isolated from it (Hayward et al., 2002). Thus, the maximum number of species positively correlated with water depth is by far the highest with any parameter from the north-western Bay of Bengal. Although debatable, we consider the water depth as an independent ecological parameter affecting the distribution of benthic foraminifera off the western Bay of Bengal. However, we agree that the depth also includes the strong influence of both the temperature and organic carbon in this region.

The relative abundance of agglutinated foraminifera increased with a simultaneous decline in calcareous species with increasing depth. Amongst the 16 species significantly positively correlated with water depth, a majority (10) were agglutinated and only 6 were calcareous. The temperature and organic flux decreased with the increase in hydrostatic pressure. The deep-sea has a relatively stable

physiographic environment and is food limited, as compared to the shallow regions where food availability is considerably higher (Gooday and Rathburn, 1999). The organic matter flux helps in determining the bathymetric distribution of benthic foraminifera (Van Der Zwaan et al., 1999). The foraminifera distribution below 1000 m is considered to be depth-dependent with a reduced influence of organic matter flux (Altenbach et al., 1999). Also, the agglutinated benthic foraminifera can survive on refractory materials, whereas calcareous species require fresh labile organic matter (Gooday, 2003). Therefore, the most abundant agglutinated species *Lagenammina ampullacea*, *Reophax longicollis*, *Hyperammina friabilis*, *Hormosinella distans*, *Hormosinelloides guttifer*, *Reophax tortilis*, *Adercotryma glomeratum*, *Cystammina pauciloculata*, *Spiroplectammina biformis*, *Karrerella arubiana* are depth-dependent in the north-western Bay of Bengal. Most of these species belong to the multi-chambered *Hormosinella* and single-chambered *Lagenammina*. Both these genera are highly abundant in fine sediments at deeper water depths (Gooday et al., 2010). *Hormosinella* and *Lagenammina* species have been widely reported from the Arabian Sea oxygen minimum zone (Taylor and Gooday, 2014; Cauille et al., 2015). Unlike the Arabian Sea, where they are related with enhanced organic flux and hypoxic zones, these species are depth-dependent with preference for finer substrate, in the north-western Bay of Bengal. A few of these species (*Adercotryma glomeratum*, *Cystammina pauciloculata*) are present from the shelf to deeper depth in the north-west European Sea (Murray and Alve, 2011). However, *Spiroplectammina biformis* is restricted to fjords and marginal marine regions, with only a few occurrences in the shelf region of the north-west European Sea (Murray and Alve, 2011). *Adercotryma glomeratum*, *Cystammina pauciloculata* and *Spiroplectammina biformis* are shallow infaunal and tolerant to dysoxic conditions (Alve and Nagy 1990; Schönfeld 1997; Kuhnt, 2000; Murray and Alve 2000). We also report a similar ecological preference of these species, with the exception that *Spiroplectammina biformis*, *Adercotryma glomeratum*, and *Cystammina pauciloculata*, were abundant on the slope to bathyal depths in the north-western Bay of Bengal.

The calcareous benthic foraminifera (*Globocassidulina subglobosa*, *Epistominella exigua*, *Heterolepa bradyi*, *Gyroidinoides subzelandica*, *Rotorbinella campanulata*) having a significant positive correlation with water depth in the north-western Bay of Bengal are typically found in the shelf to the deep-sea environment of the world oceans (Gooday, 1994; Jorissen et al., 2007). The genera *Globocassidulina*, *Epistominella*, *Cibicidoides*, *Gyroidinoides*, and *Rotorbinella* are associated with deep water-mass, prefer finer sediments and are abundant from the shelf to bathyal depths (Murray, 1991). *Epistominella exigua* has been used as a robust proxy to determine the past seasonality from the central Bay of Bengal (Saraswat et al., 2005). However, the abundant living population of *Epistominella exigua*, *Globocassidulina subglobosa*, and *Heterolepa bradyi* has also been reported

from the oxygen deficient zones with enhanced productivity in the north-eastern Arabian Sea (Caulle et al., 2014). *Gyroidinoides subzelandica* has also been reported from a similar environment in the central-western Bay of Bengal (Suokhrie et al., 2020), suggesting their close affinity with food availability at the intermediate depths (upper slope) of the Indian margin. Interestingly, the highest %C_{org} was at the intermediate depths in the north-western Bay of Bengal, whereas these species are abundant from lower slope to bathyal depths. Additionally, here the species are significantly related to water depth than the %C_{org} (Fig. 5). The possible reason for this contrasting relationship could be the moderately high organic matter and relatively higher DO on the lower slope to bathyal depths, as compared to the upper slope. *Epistominella exigua* was the most abundant at well-oxygenated depths below the Arabian Sea OMZ (Gooday et al., 2000). Thus the higher abundance of calcareous benthic foraminifera *Globocassidulina subglobosa*, *Epistominella exigua*, *Heterolepa bradyi*, *Gyroidinoides subzelandica*, *Rotorbinella campanulata* and agglutinated species *Hyperammina friabilis* (tubular forms), *Lagenammina ampullacea* (globular forms), *Reophax longicollis*, *Hormosinella distans*, *Hormosinelloides guttifera*, *Reophax tortilis* (Hormosinaceans), *Adercotryma glomeratum*, *Cystammina pauciloculata*, *Spiroplectammina biformis*, *Karrieriella arubiana* (shallow infaunal) is depth-dependent but with a strong influence of organic carbon in the north-western Bay of Bengal.

Apparently, almost all the species significantly correlated with water depth are negatively correlated to temperature. The temperature decreases with increasing depth. The region is characterised by a strong gradient in the bottom water temperature due to the large freshwater flux. The warm and fresh riverine influx influences the salinity and temperature of the water column (Durand et al., 2011). Thus, the species *Pseudononion costiferum*, *Hanzawaia nipponica*, *Ammonia beccari*, which showed a significant positive correlation with ambient temperature, are abundant at shallow water depths. As the influence of riverine discharge is maximum at the river mouths, all these species are abundant from a depth of 31 to 55 m, with the warmest bottom water temperatures. These species have a large temperature tolerance range (0 – 30°C) (Murray, 1991). *Pseudononion costiferum*, *H. nipponica* and *A. beccari* are abundant in the coastal and shelf region of both the Arabian Sea (Setty and Nigam, 1984) and the Bay of Bengal (Rao and Rao, 1974), confirming their preference for shallow warm water niches. Thus, the temperature, along with the water depth, is by far the most significant environmental factors affecting the abundance and distribution of a large number of benthic foraminifera in the north-western Bay of Bengal.

5.1.2 Organic carbon (%C_{org}), dissolved oxygen (DO) and coarse fraction (>63 µm)

Ammodiscus incertus, *Verneuilinella propinqua*, *Buliminella dubia*, and *Rotaliatinopsis semiinvoluta* are significantly positively (negatively) correlated with %C_{org}. These species are confined to only ~200

to 1000 m with the highest %C_{org} and dysoxic conditions, clearly representing the oxygen-deficient zone (ODZ) of the western Bay of Bengal. The significance of water depth and temperature as an ecological factor in the present study is a regional phenomenon. The widely accepted major limiting ecological factors affecting benthic foraminifera distribution in any region are the availability of organic matter and dissolved oxygen concentration (Van Der Zwaan et al., 1999; Jorissen et al., 2007). Both the organic matter and dissolved oxygen along with the coarse fraction considerably modulate benthic foraminifera distribution in the north-western Bay of Bengal (Fig. 5). The western Bay of Bengal is characterised by two monsoon (South-West summer and North-East winter) seasons (Wyrtki, 1971). The monsoon seasonality drastically affects the physiographic conditions of the water column due to the continuous discharge of nutrients, fresh water and sediments (Qasim, 1977; Gomes et al., 2000; Sarma et al., 2013). The increased nutrient input enhances the productivity in the region and affects the DO concentration. The oxygen is utilized by the microbes feeding on the abundant organic matter available at the intermediate depths (Rao et al., 1994; Sarma et al., 2013). Also, the excessive microbial population coupled with restricted ventilation leads to deficient oxygen condition at the intermediate depths of ~200-1000 m in the western Bay of Bengal (Sarma et al., 2013). However, the low DO concentration leads to dysoxic conditions in the Bay of Bengal, unlike the complete anoxic condition in the Arabian Sea. The low DO severely affects the macrofauna at the intermediate depths (Levin, 2003; Hughes et al., 2009) and thus, reduces the predatory pressure on benthic foraminifera (Pheleger and Soutar, 1973; Gooday et al., 2009). The reduced predatory pressure, in turn enhances the benthic foraminiferal population in the ODZ of the north-western Bay of Bengal. DO only affects the benthic foraminifera population when it reaches below <1 ml/l (Jorissen et al., 1995; Gooday, 2003). The opportunistic species' abundance increases in low oxygen, as they are largely dependent on enriched organic matter flux. Thus, the highest living population found at the upper slope in the north-western Bay of Bengal, is due to the enhanced %C_{org} and the abundance of low oxygen tolerant species. These depths are marked by the lowest DO concentration (~0.5 ml/l).

The reported presence of *R. semiinvoluta* in the north-western Bay of Bengal matches with that from the intense ODZ of the Arabian Sea (Jannink et al., 1998; Schumacher et al., 2007; Cauille et al., 2014). Recently, *V. propinqua* and *R. semiinvoluta* were also reported from the ODZ of the central-western Bay of Bengal (Suokhrie et al., 2020). We report *A. incertus* and *B. dubia* from a water depth of ~200 – 1000 m and their affinity to the higher organic carbon in the north-western Bay of Bengal ODZ. Panchang and Nigam (2014) reported *B. dubia* and *A. incertus* from the deltaic region off Myanmar. Interestingly, Rao et al., (2013) reported *A. incertus* in a short core from deep (2000 m) Bay of Bengal. However, the living population of *B. dubia* and *A. incertus* has not been reported from the

Bay of Bengal. *Ammodiscus* sp. was reported from the OMZ of the Arabian Sea by several authors (Jannink et al., 1998; Schumacher et al., 2007; Caille et al., 2014; Mazumder and Nigam, 2014). Schumacher et al., (2007) reported it from 300 to 1000 m water depth from the ODZ of the Arabian Sea, which is coeval with the north-western Bay of Bengal. *Ammodiscus incertus* has also been reported from the deeper water depths of the north Atlantic and Panama Basin (Schroder et al., 1986; Kaminski et al., 1988).

Apart from the four opportunistic species, *Fursenkoina spinosa*, and *Bolivina lowmani* are also significantly negatively correlated with the dissolved oxygen. The two taxa are however, not related to %C_{org} and show a greater preference to dysoxic conditions persistent in the study area. *Fursenkoina spinosa* is a common low oxygen tolerant species (Suokhrie et al., 2020). *Bolivina lowmani* has not been reported from the ODZ of the Bay of Bengal, but from the ODZ of the eastern Arabian Sea (Mazumder and Nigam, 2014). The two species were the most abundant within the intense ODZ in the western Bay of Bengal. *Bolivina lowmani* was confined to 225-280 m, and *F. spinosa* was abundant between ~500 to 750 m, suggesting a clear depth preference of benthic foraminifera, within the ODZ. *Bolivina lowmani* is indicative of high organic carbon and polluted sediments (Seiglie, 1968). Platon and Sen Gupta (2001) reported their dominance in highly stressed, near anoxic conditions of the Louisiana continental shelf. Thus, we report *A. incertus*, *V. propinqua*, *B. dubia*, and *R. semiinvoluta*, *B. lowmani* and *F. spinosa* as representative taxa of the oxygen-deficient zone in the north-western Bay of Bengal.

Pseudononion costiferum, *Ammonia beccari* and *Hanzawaia nipponica* are positively correlated with the dissolved oxygen. All these species are abundant in well-oxygenated shallow waters. *Pseudononion costiferum*, *Ammonia beccari*, *Bolivina frondalis* and *Triloculina oblonga* show a significant negative correlation with %C_{org}. Interestingly, these species, along with *Hanzawaia concentrica*, except *P. costiferum*, are also significantly positively correlated with the coarse fraction. The large riverine flux in the region increases the coarse fraction with enriched DO concentration. This increase in coarse fraction and dissolved oxygen on the continental shelf leads to a poor preservation of organic carbon. *Ammonia beccari*, *Bolivina frondalis* and *Triloculina oblonga*, *Hanzawaia concentrica* show a stronger preference for such regions with abundant coarse fraction and DO, rather than %C_{org}, which otherwise is considered the most significant factor limiting the distribution of benthic foraminifera. *Ammonia beccari* has been extensively reported from the shallow depths and coarser substrates (Setty and Nigam, 1982; Mendes et al., 2004; Anbuselvan and Senthil Nathan, 2019). *Ammonia beccari*, *P. costiferum*, *T. oblonga*, *B. frondalis* and *H. concentrica* are the most common stress-tolerant species in the turbid regions across river mouths, estuaries and polluted marine

environments (Setty & Nigam, 1984; Rao et al., 1979; Kathal et al., 2000; Goineau et al., 2011; Saalim et al., 2017). Thus, the distinct dominance of these species exhibits a strong association with the coarse fraction and DO in the riverine influx dominated shallow continental shelf of the north-western Bay of Bengal.

5.1.3 C_{org}/N and Salinity

A large variation in both the C_{org}/N and salinity from the river mouth to the deep sea in the north-western Bay of Bengal, is distinctly echoed in the living benthic foraminiferal distribution. *Bolivina dilatata*, *Bolivina subspathulata*, and *Fursenkoina pauciloculata* show a significant positive relation with C_{org}/N. C_{org}/N is the measure of relative contribution of oceanic and terrestrial productivity and helps in ascertaining the amount of organic matter influx from the terrestrial region (Meyers, 1997). The higher terrestrial flux also leads to diagenetic re-mineralization of nitrogen in the marine sediments thus increasing the C_{org}/N in the region (Bejugam and Nayak, 2017). Several authors have discussed the effect of terrestrial organic flux on the distribution of benthic species (Mojtahid et al., 2009; Goineau et al., 2011; Dessandier et al., 2016). In the north-western Bay of Bengal, humongous river discharge increases the C_{org}/N on the shallow shelf. However, these rectilinear taxa have been previously reported as OMZ indicator species from both the western (Mazumder and Nigam, 2014) and eastern Indian margin (Suokhrie et al., 2020). We did not find any inverse relation of these species with DO, but a strong positive correlation with C_{org}/N. These species are abundant in the shallow waters (Mendes et al., 2004), preferably muddy substrate (Murray, 1991). We report a strong association of these species with terrestrial organic matter, marking them to be more opportunistic species than previously considered just as indicators of hypoxic zones.

Surprisingly, despite of the region being influenced by the large freshwater flux, only two species, *Bolivina striatula* and *Asterorotalia milletti*, have a strong negative correlation with the ambient salinity. The minimal role of salinity is also confirmed by the fact that none of the species exhibits any relation with increased salinity at deeper water depths. Previously, the high abundance of *B. striatula* in two stratified coastal lagoons off Brazil suggested their tolerance to hyposaline conditions (Debenay et al., 1998). Also, *Asterorotalia milletti* prefers low saline conditions in the shallow regions of the western Bay of Bengal. *Asterorotalia* is one of the endemic genera from the western Bay of Bengal, which can be used as a site-specific proxy for the reconstruction of past hyposaline conditions (Panchang and Nigam, 2012; Rao et al., 2013; Saraswat et al., 2017). Thus, *Bolivina striatula* and *Asterorotalia milletti* are two representative taxa of hyposaline conditions in the north-western Bay of Bengal.

5.2 Assemblages based on ecological factors

Based on ecological preferences, benthic foraminifera can be grouped into three distinct assemblages in the north-western Bay of Bengal (Table 4). Assemblage 1 dominated by *A. beccari*, *P. costiferum*, *H. nipponica*, *B. frondalis*, *B. dilatata*, *B. striatula*, and *A. milletti* is restricted to shallow water depths and is strongly affected by the river runoff with varying DO, temperature, coarse fraction, C_{org}/N and salinity. Assemblage 2 includes *V. propinqua*, *A. incertus*, *B. dubia*, *R. semiinvoluta*, *B. lowmani* and *F. spinosa*, dominated by highly opportunistic species preferring high food availability and depleted oxygen condition in the ODZ. Assemblage 3 comprise of *G. subglobosa*, *E. exigua*, *G. subzelandica*, *R. longicollis*, *A. glomeratum*, *C. pauciloculata*, and *S. biformis*, influenced by depth, moderate organic matter flux, and DO concentration.

5.3 Diversity of benthic foraminifera

In the western Bay of Bengal, living (stained) benthic foraminiferal species diversity, richness and evenness varied spatially across the three studied transects. The total living benthic foraminifera abundance was the maximum at the shelf to upper slope region and is inversely related to diversity. The intermediate depths have high organic carbon and dysoxic conditions, which is characterised by high benthic foraminifera population and less species diversity (Phleger and Soutar, 1973). Thus, the low diversity and richness at the intermediate depths in the north-western Bay of Bengal can be attributed to the high organic carbon flux and oxygen-deficient conditions. Also, the high $\%C_{org}$ and low oxygen concentration leads to the enhanced calcareous foraminifera species abundance (Gooday et al., 2000). In general, the abundance of calcareous benthic foraminifera decreases with the increasing water depth since the amount of fresh labile organic matter decreases with increasing depth. The agglutinated benthic foraminifera, on the other hand, can feed on readily available refractory material (Gooday, 2003) resulting in their increased abundance at deeper depths. The highest abundance of calcareous foraminifera is closely associated with the production of fresh organic matter at the intermediate depths. Although, the total living benthic foraminifera population decreased, the diversity increased with increasing depth. The number of species increases rapidly after the intermediate depths below 1000 m. Both the Fisher's α -index and Shannon–Wiener (H) diversity indices rapidly increased below 1000 m and then remained uniform up to the bathyal depths. Pielou's evenness (J') also exhibited similar trends with a few exceptions influenced by the Mahanadi river at intermediate depths in the first transect. The low evenness is due to the strong dominance of *Buliminella elegantissima* (67%) at station MC 65 (water depth 260 m) and *Bolivina dilatata* at two station MC 66 (41%) (water depth 105 m) and at station SC 25 (37%) (water depth 106 m). The two species have been reported from the sediments with excessively high organic carbon content (Eichler et al., 2007) and very low

dissolved oxygen (Sen Gupta and Machain-Castillo, 1993). Therefore, diversity is rather more dependent on DO concentration rather than food availability alone in the north-western Bay of Bengal. Setty and Nigam, (1982) also observed an inverse relation of diversity with the carbon flux. However, the highest living population is modulated by enhanced food availability. The dissolved oxygen of the bottom waters increased with the increasing depth and thus helped in the high diversity from the upper slope to deeper depths. The high diversity at bathyal depths is also attributed to the reduced predation and competition from metazoans (Gooday et al., 2012). A general trend of increase in diversity from shelf to bathyal depths have been recorded from the world oceans (Szarek et al., 2006).

6. Conclusion

Living (stained) benthic foraminifera distribution has been documented from a river-dominated continental shelf margin in the north-western Bay of Bengal. The maximum living benthic foraminifera abundance was on the shelf to upper slope region and is inversely related to diversity. Based on the ecological preferences, benthic foraminiferal species have been clubbed into 3 assemblages. Assemblage 1 (*Ammonia beccari*, *Pseudononion costiferum*, *Hanzawaia nipponica*, *Bolivina frondalis*, *Bolivina dilatata*, *Bolivina striatula*, and *Asterorotalia milletti*) consists of species associated with temperature, coarse fraction, C_{org}/N, salinity, and DO, which are strongly affected by the river runoff and restricted to shallow water depths. Assemblage 2 represents opportunistic species *Verneuilinella propinqua*, *Ammodiscus incertus*, *Buliminella dubia*, *Rotaliatinopsis semiinvoluta*, *Bolivina lowmani*, and *Fursenkoina spinosa* which are highly dependent on food fluxes and linked to depleted oxygen. Assemblage 3 includes *Globocassidulina subglobosa*, *Epistominella exigua*, *Gyroidinoides subzelandica*, *Reophax longicollis*, *Adercotryma glomeratum*, *Cystammina pauciloculata*, and *Spiroplectammina biformis* which are majorly influenced by depth, moderate carbon flux and DO concentration. The species diversity and richness was high at the deeper depths while the intermediate depths had poor diversity and richness. The low diversity and richness at the intermediate depth (~250 to 1000 m) is attributed to oxygen-deficient conditions and enhanced organic flux. The distinct ecological preferences of species and the assemblages will help in environmental impact assessment and reconstructing paleoecological conditions from the river-dominated continental margin of the north-western Bay of Bengal.

CRedit authorship contribution statement

Syed Mohammad Saalim: Data curation, Writing-Original draft preparation, Methodology, Software. **Rajeev Saraswat** Conceptualization, Visualization, Investigation, Reviewing and Editing, Supervision. **Rajiv Nigam:** Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Legend to Figures and Tables

- Figure 1:** Location of surface sediment samples (multicores in red-filled inverted triangles and spade cores in blue filled inverted triangles) in the western Bay of Bengal. The colored contours are bathymetry in meters. The blue lines mark the prominent rivers in the study area.
- Figure 2:** The salinity (psu) (a), temperature (°C) (b), dissolved oxygen (ml/l) (c) at the sediment water interface, and %C_{org} (d), C_{org}/N (e) and coarse fraction (%) (f) in the core top sediments of the western Bay of Bengal. The bathymetry is marked by the numbered contour lines. The black-filled inverted triangles represent the sample locations.
- Figure 3:** The total living benthic foraminifera (#/g sediment) in the western Bay of Bengal. The bathymetry is marked by the numbered contour lines. The black-filled inverted triangles represent the sample locations.
- Figure 4:** Biodiversity indices, a) Shannon diversity index ($H' \log_e$), b) Pielou's evenness and c) Margalef richness, in the western Bay of Bengal. The bathymetry is marked by numbered contour lines. The black-filled inverted triangles represent the sample locations.
- Figure 5:** Canonical Correspondence Analysis (CCA) biplot of dominant foraminifera species and the environmental variables in the western Bay of Bengal. The blue triangles denote the benthic foraminifera species and the arrows represent the environmental variables. The abbreviated environmental variables are DO = Dissolved Oxygen, Temp = Temperature, %C_{org} = Organic Carbon, C_{org}/N = Organic Carbon/Nitrogen, CF = Coarse fraction and D = Depth. Abbreviated species are listed in Table 3.
- Figure 6:** The relative abundance of species having significant positive correlation with water depth and negatively correlated with ambient temperature.
- Figure 7:** The relative abundance of species having significant (A) positive and (B) negative correlation with %C_{org}.
- Figure 8:** The relative abundance of species having significant (A) positive and (B) negative correlation with dissolved oxygen.
- Figure 9:** The relative abundance of species having significant positive correlation with (A) temperature and (B) coarse fraction.
- Figure 10:** The relative abundance of species having significant (A) positive correlation with C_{org}/N and (B) negative correlation with salinity.
- Figure 11:** Three dominant assemblages in the western Bay of Bengal. Assemblage I, (1) *Ammonia beccari* Linnaeus 1758 a) Ventral view b) dorsal view; (2) *Pseudonion costiferum* (Cushman 1926) a) Ventral view b) dorsal view; (3) *Hanzawaia nipponica* Asano 1944 a) Ventral view b) dorsal view; (4) *Bolivina frondalis* McCulloch 1977 a) side view b) lateral view; (5) *Bolivina dilatata* (Reuss 1850) a) side view b) lateral view; (6) *Bolivina striatula* (Cushman 1922) a) side view b) lateral view; (7) *Asterorotalia milletti* (Millet 1904) a) Ventral view b) dorsal view. Assemblage II, (8) *Verneuilinella propinqua* (Brady 1884); (9) *Ammodiscus incertus* (d'Orbigny 1839); (10) *Buliminella dubia* Barbat & Johnson 1934; (11) *Rotaliatinopsis semiinvoluta* (Germeraad 1946) a) Ventral view b) Dorsal view; (12) *Fursenkoina spinosa* (Heron-Allen and Earland 1932); (13 – 14) *Bolivina lowmani* (Phleger & Parker 1951). Assemblage III, (15) *Globocassidulina subglobosa* (Brady 1881) a) side view b) side view; (16) *Epistominella exigua* (Brady 1884) a) Ventral view b) dorsal view; (17) *Gyroidinoides subzelandica* Hornibrook 1961 a) Ventral view b) lateral view; (18 – 19) *Reophax longicollis* (Wiesner 1931); (20 – 21) *Adercotryma glomeratum* (Brady 1878) a) Side view b) Apertural view; (22) *Cystamina pauciloculata* (Brady 1879); (23)

Spiroplectammina biformis (Parker & Jones 1865) a) Side view b) Side view. Scale bar = 100 μm .

Table 1: Details of surface sediment samples.

Table 2: Checklist of living benthic foraminiferal species reported from the western Bay of Bengal and its maximum abundance.

Table 3: Details of correlation analysis between ambient environmental variables and species relative abundance. The significant values are marked in red. The marked correlations are significant at $p < 0.05$.

Table 4: Assemblages associated with preferred ecological parameters.

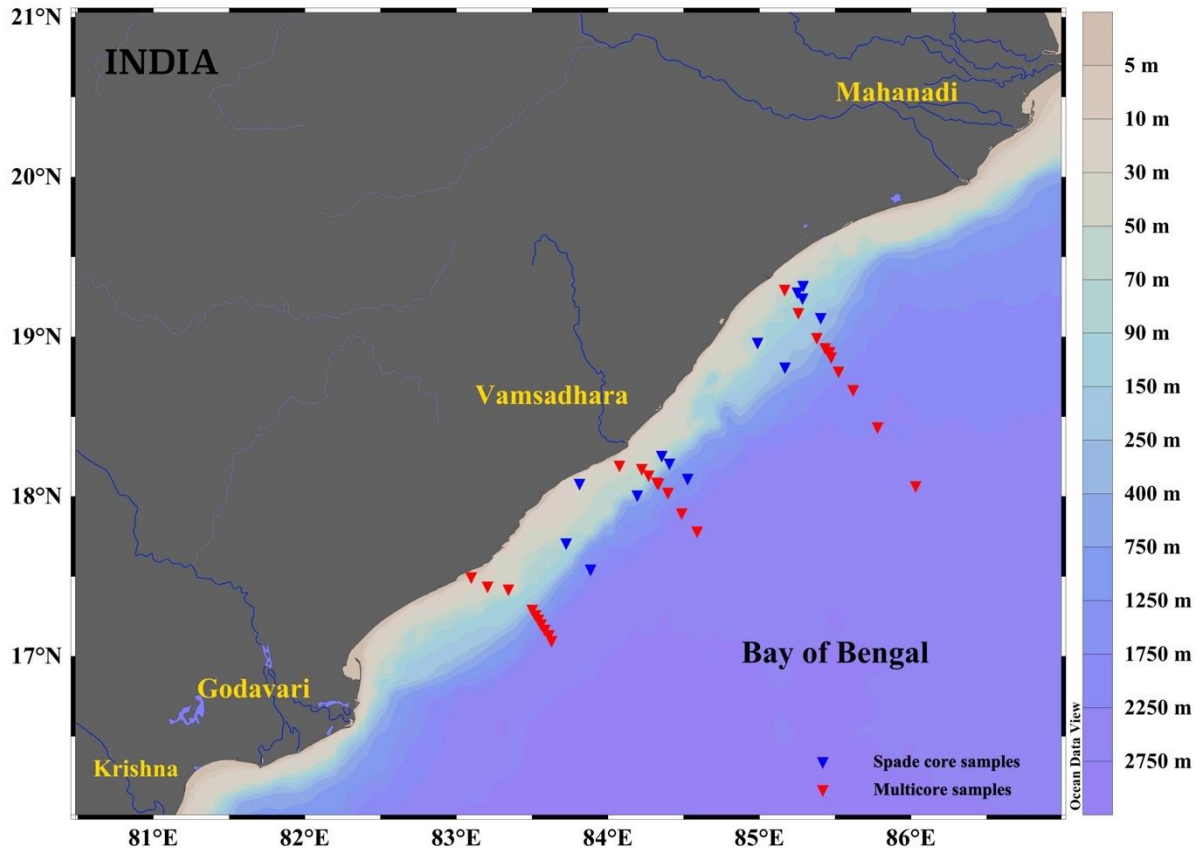


Figure 1

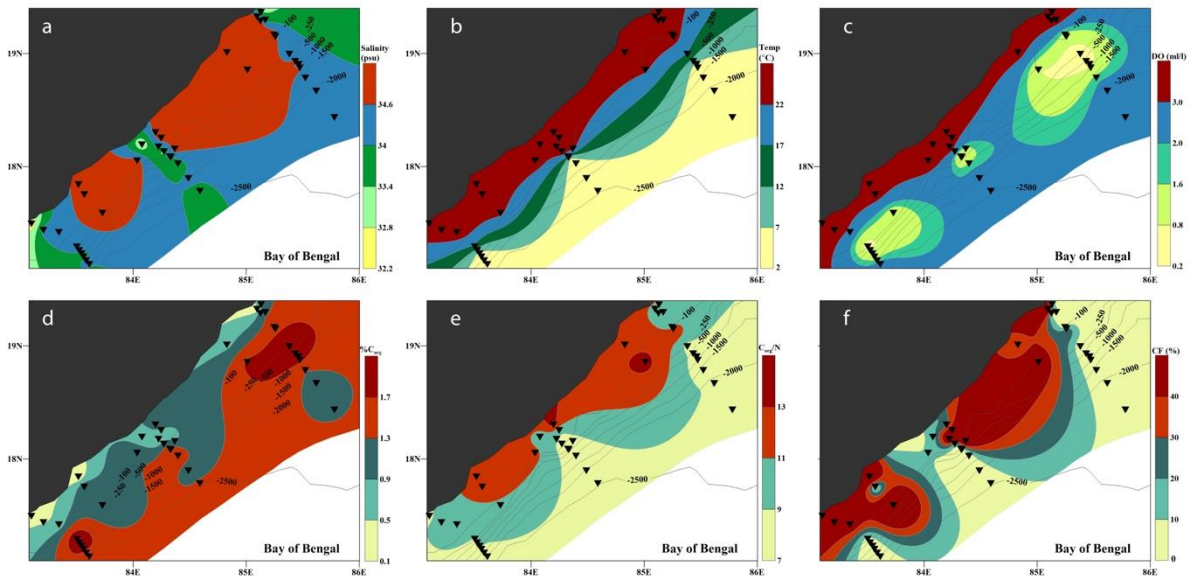


Figure 2

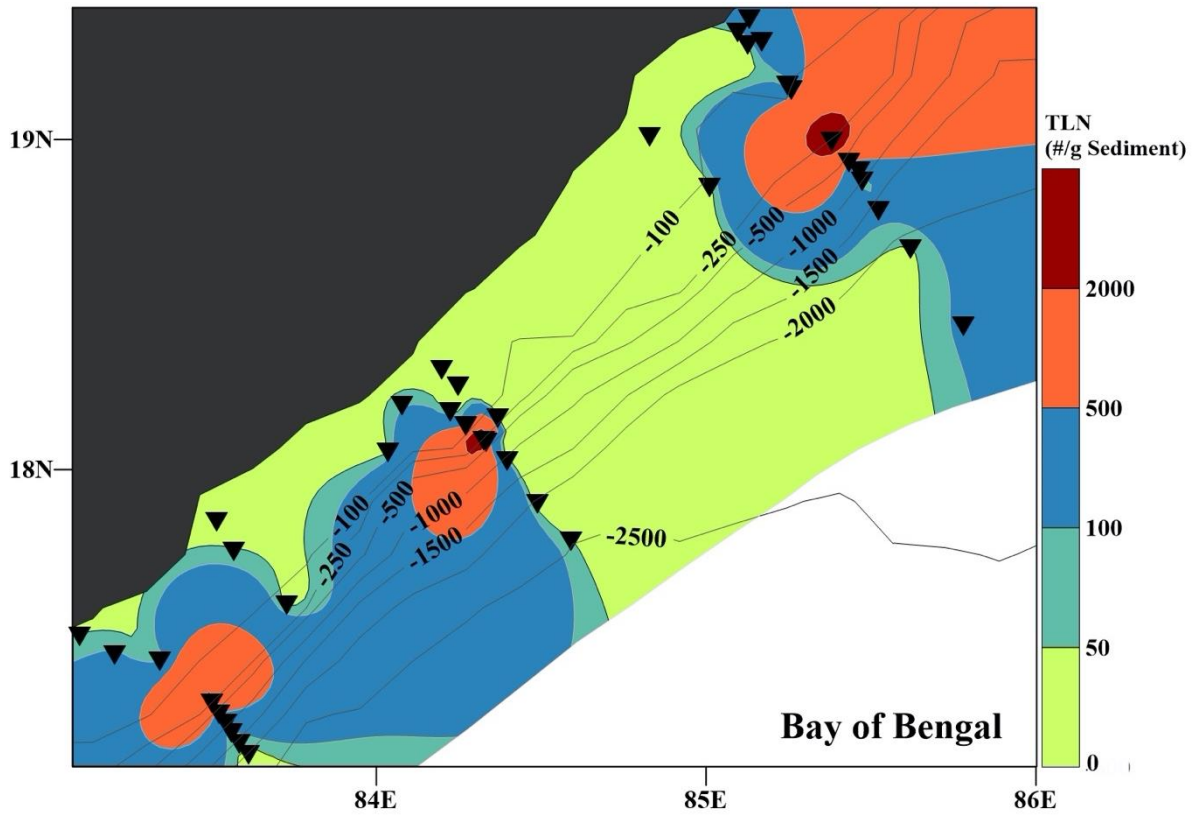


Figure 3

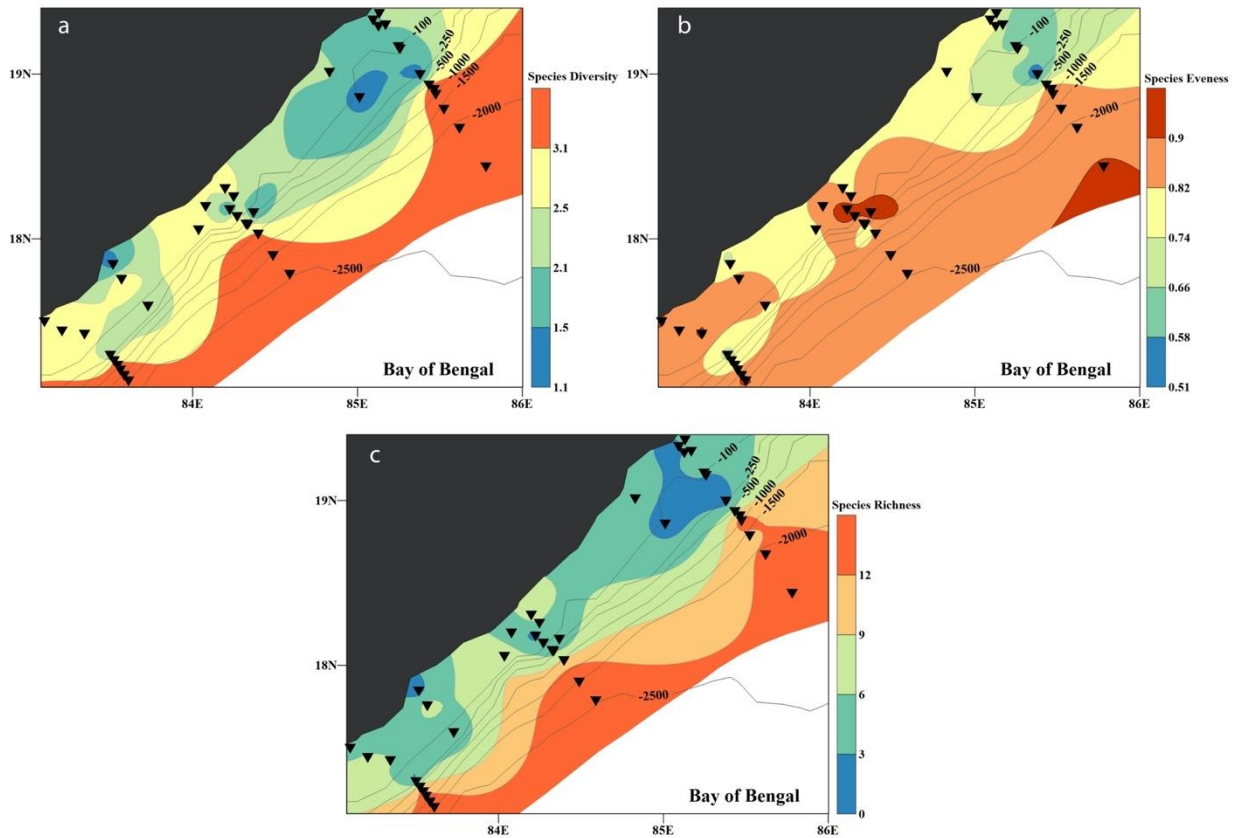
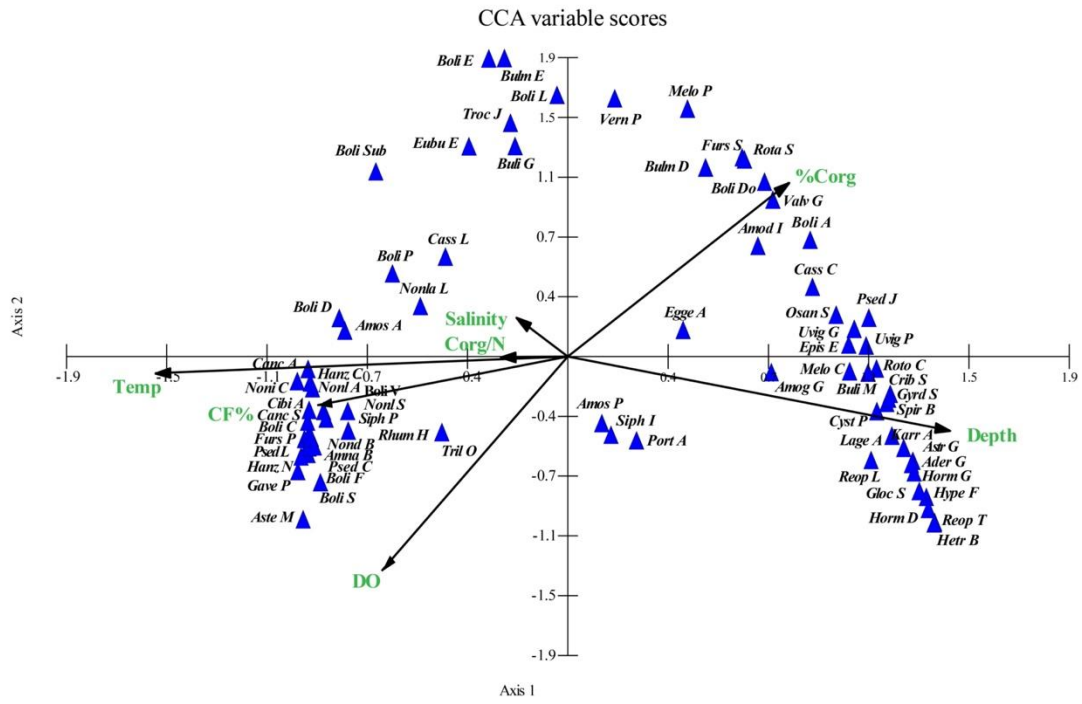


Figure 4



Vector scaling: 1.53

Figure 5

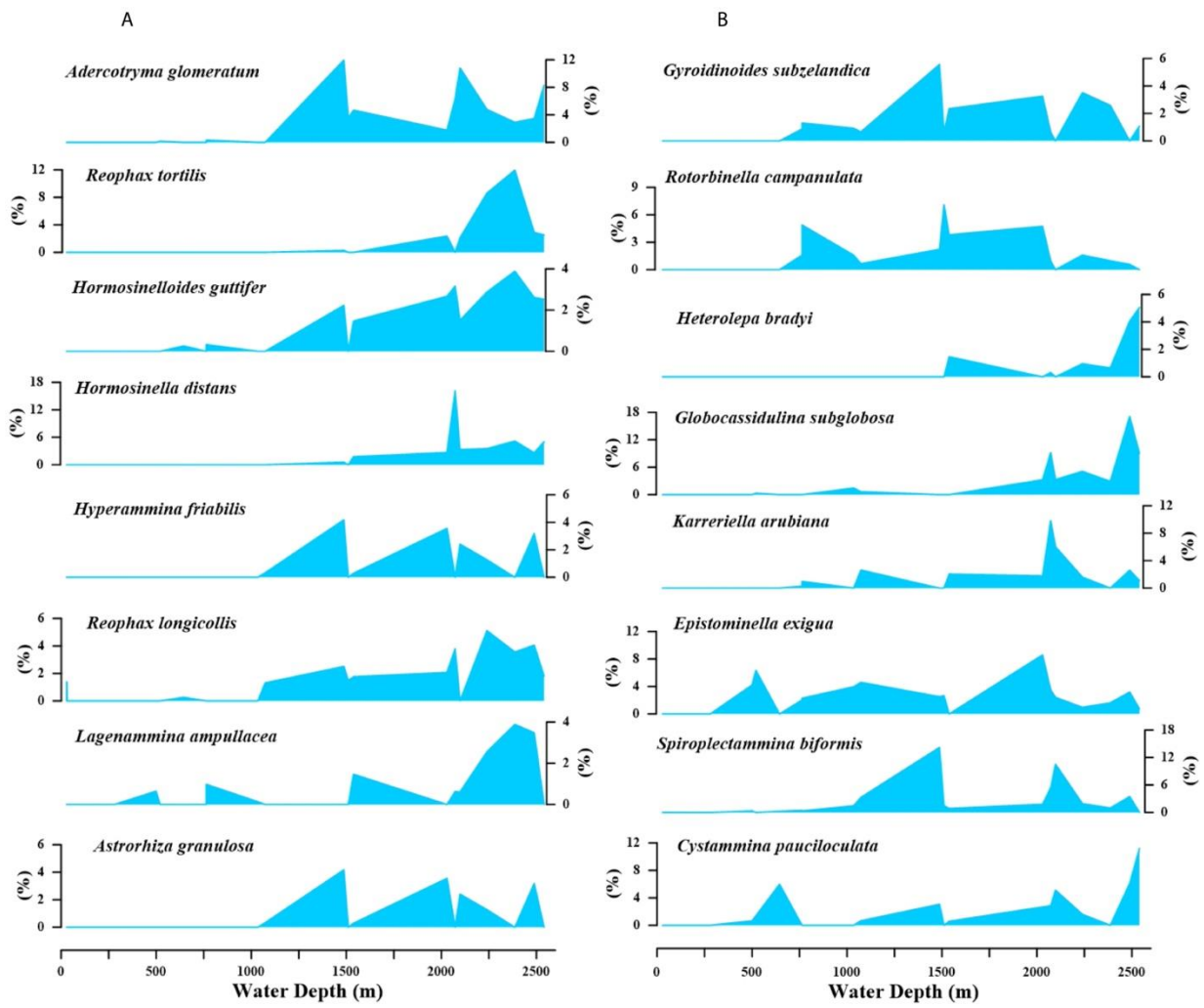


Figure 6

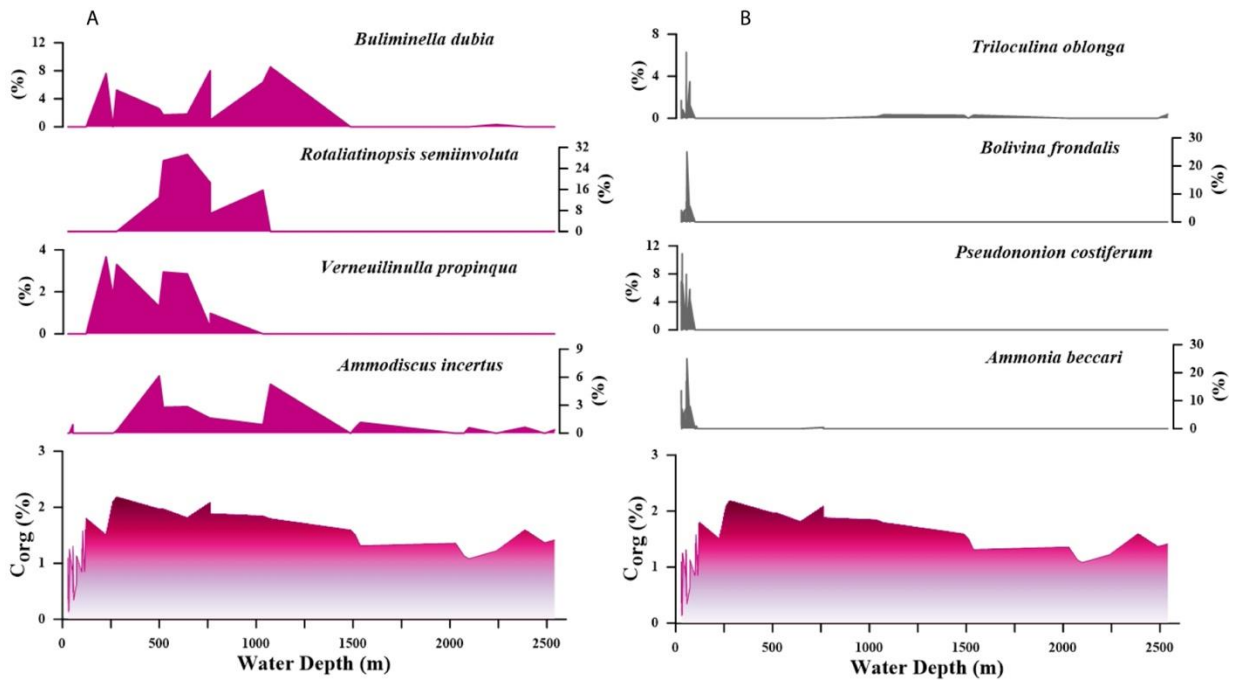


Figure 7

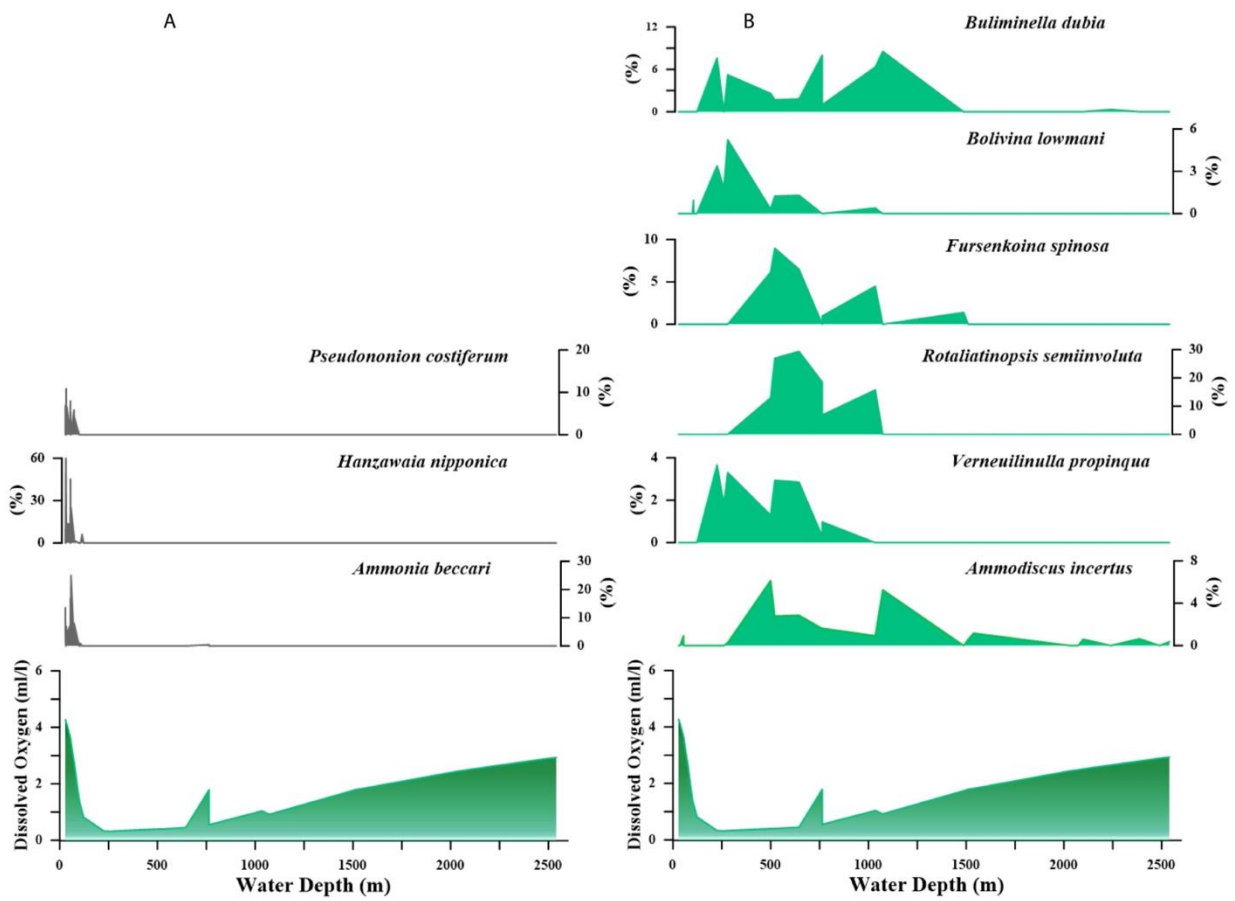


Figure 8

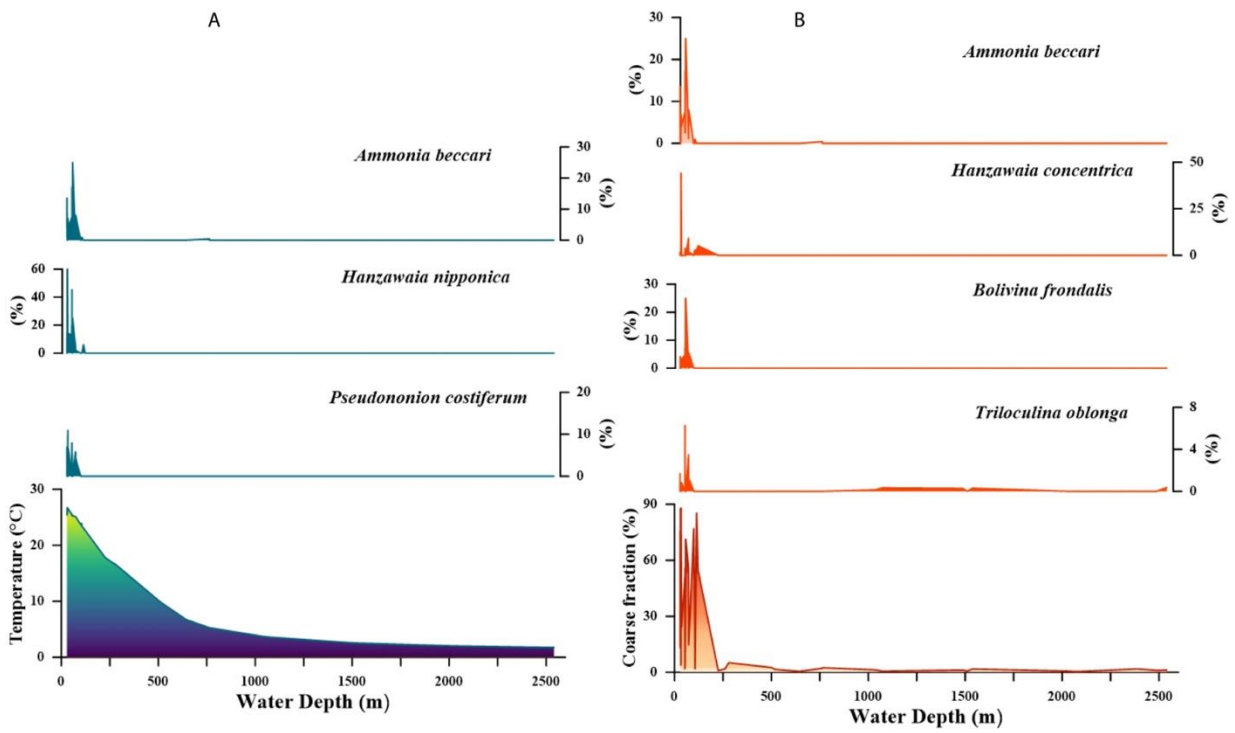


Figure 9

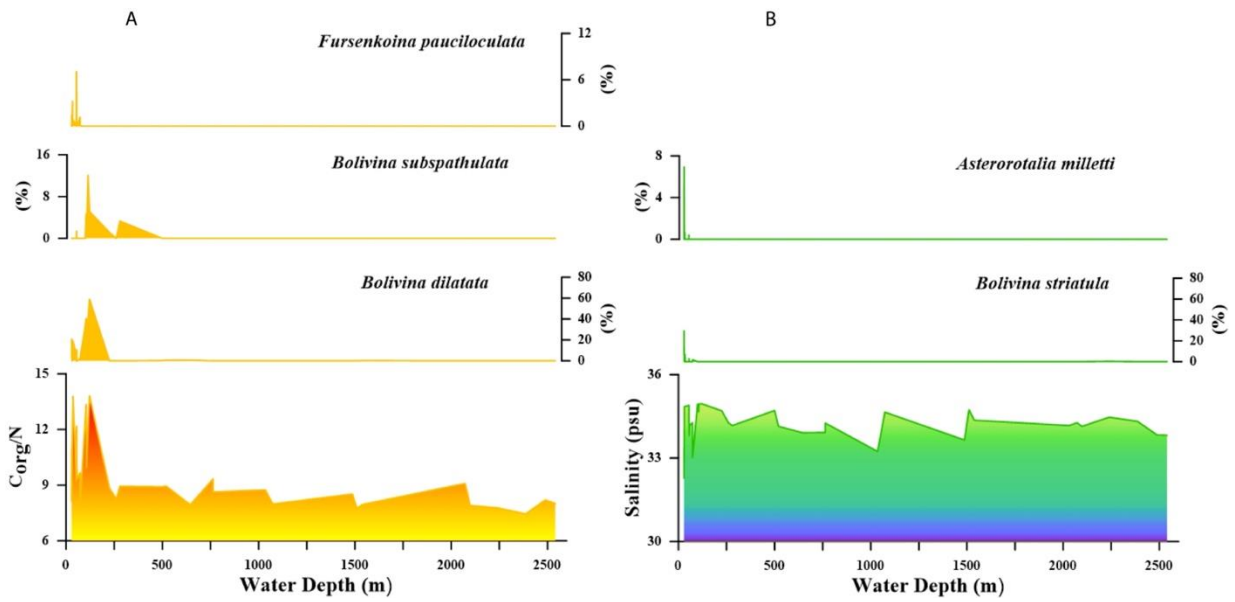


Figure 10

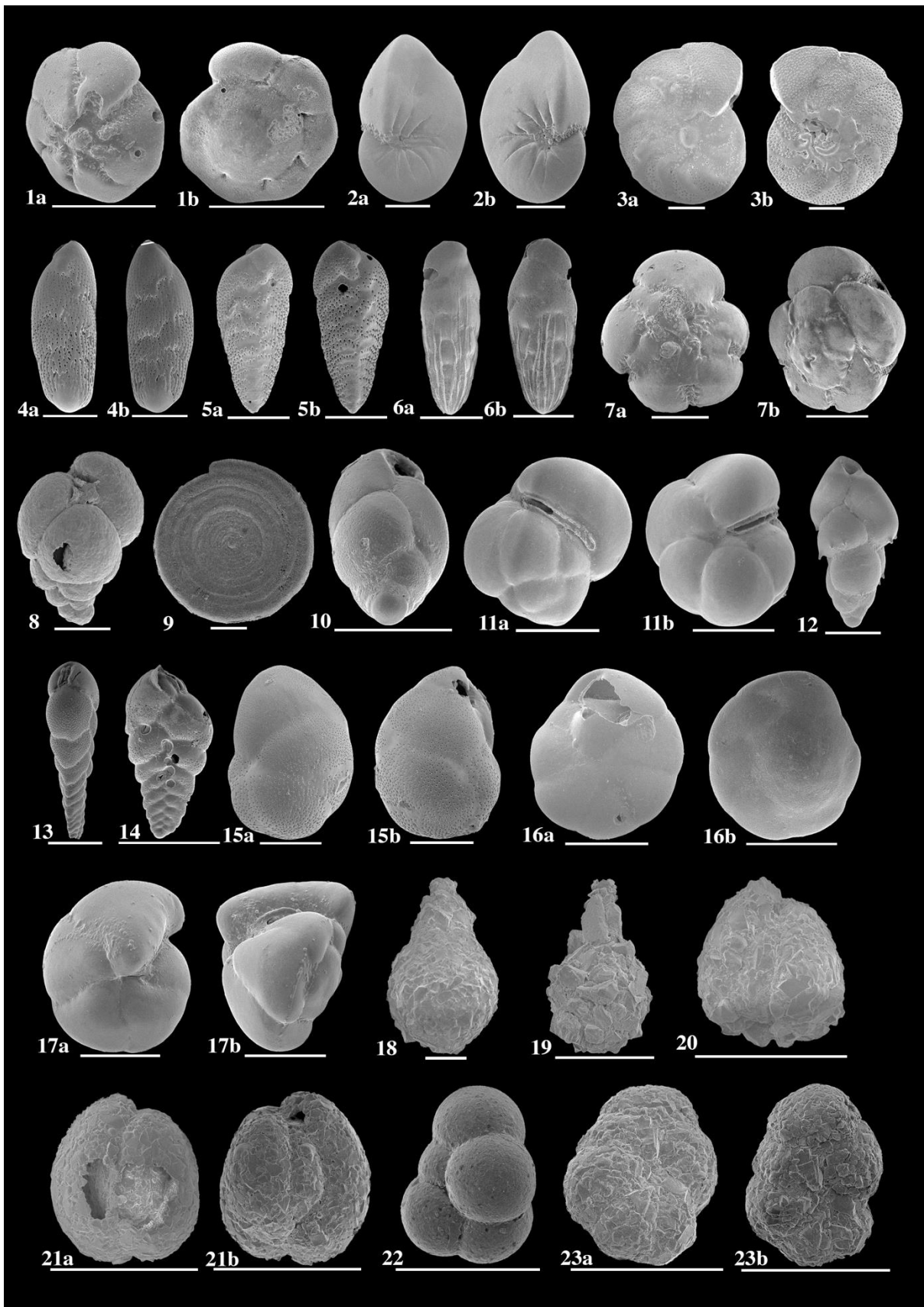


Figure 11

Table 1

S. No.	Station	Latitude (°N)	Longitude (°E)	Depth (m)
1	MC39	17.43803	83.20588	55
2	MC40	17.49533	83.09932	29
3	MC41	17.41915	83.34438	73
4	MC42	17.29228	83.50057	280
5	MC43	17.25863	83.52270	520
6	MC44	17.23038	83.54337	763
7	MC45	17.20157	83.56112	1035
8	MC46	17.16793	83.58455	1511
9	MC47	17.13438	83.61157	2030
10	MC48	17.09627	83.62983	2540
11	MC49	18.19430	84.07718	30
12	MC50	18.17477	84.22538	58
13	MC51	18.13225	84.27062	73
14	MC52	18.08732	84.32512	225
15	MC53	18.08293	84.33375	645
16	MC55	18.02547	84.39765	1487
17	MC56	17.89632	84.48818	2098
18	MC57	17.78215	84.58953	2489
19	MC58	18.06608	86.03245	2386
20	MC59	18.43532	85.78015	2240
21	MC60	18.66708	85.61938	2073
22	MC61	18.78293	85.52295	1538
23	MC62	18.87300	85.47325	1073
24	MC63	18.90518	85.46400	763
25	MC64	18.93067	85.43410	500
26	MC65	18.99423	85.38023	260
27	MC66	19.14943	85.25822	105
28	MC67	19.29557	85.16852	55
29	MC68	19.36475	85.13093	29

30	SC23	19.32365	85.09455	34
31	SC24	19.28688	85.12625	55
32	SC25	19.16407	85.24755	106
33	SC26	18.85470	85.01125	122
34	SC27	19.00917	84.82957	55
35	SC28	18.15670	84.36817	100
36	SC29	18.25195	84.24898	54
37	SC30	18.30137	84.19748	36
38	SC31	18.12533	83.65423	33
39	SC32	18.05268	84.03562	55
40	SC33	17.58963	83.72785	114
41	SC34	17.75277	83.56742	54
42	SC35	17.84037	83.51667	31

Table 2.

S. No.	Species	Maximum Abundance (%)
1.	<i>Nodellum membranaceum</i> (Brady, 1879)	0.7
2.	<i>Aschemonella scabra</i> Brady, 1879	0.3
3.	<i>Astrorhiza arenifera</i> Shchedrina, 1946	0.3
4.	<i>Bathysiphon rusticus</i> Folin, 1886	0.3
5.	<i>Marsipella elongata</i> Norman, 1878	4.8
6.	<i>Rhabdammina linearis</i> Brady, 1879	3.2
7.	<i>Rhabdammina absoluta</i> Saidova, 1975	3.0
8.	<i>Rhabdammina abyssorum</i> Sars in Carpenter, 1869	2.7
9.	<i>Psammosiphonella discreta</i> (Brady, 1881)	1.7
10.	<i>Rhizammina algaeformis</i> Brady, 1879	1.4
11.	<i>Astrorhiza granulosa</i> (Brady, 1879)	4.2
12.	<i>Lagenammina ampullacea</i> (Brady, 1881)	3.5
13.	<i>Lagenammina arenulata</i> (Skinner, 1961)	0.7
14.	<i>Lagenammina asymmetrica</i> (Shchedrina, 1984)	2.2
15.	<i>Lagenammina cushmani</i> (Collins, 1958)	1.3
16.	<i>Lagenammina difflugiformis</i> (Brady, 1879)	2.9
17.	<i>Reophax longicollis</i> (Wiesner, 1931)	5.1
18.	<i>Saccammina testacea</i> (Flint, 1899)	0.3
19.	<i>Lagenammina tubulata</i> (Rhumbler, 1931)	0.6
20.	<i>Saccammina sphaerica</i> Brady, 1871	2.9
21.	<i>Technitella spiculosa</i> Zheng & Fu, 2001	0.3
22.	<i>Thurammina papyracea</i> Cushman, 1913	0.6
23.	<i>Hyperammina friabilis</i> Brady, 1884	3.6
24.	<i>Hyperammina laevigata</i> Wright, 1891	1.5
25.	<i>Saccorhiza ramosa</i> (Brady, 1879)	1.9
26.	<i>Jaculella obtusa</i> Brady, 1882	1.8
27.	<i>Ammodiscoides turbinatus</i> Cushman, 1909	2.5
28.	<i>Ammodiscus incertus</i> (d'Orbigny, 1839)	6.1
29.	<i>Ammodiscus intermedius</i> Höglund, 1947	0.7
30.	<i>Arenoturrspirillina catinus</i> (Höglund, 1947)	2.7
31.	<i>Ammovevertellina prima</i> Suleymanov, 1959	0.3
32.	<i>Glomospira gordialis</i> (Jones and Parker, 1860)	2.1
33.	<i>Glomospira hoeglundi</i> Zheng & Fu 2001	3.3
34.	<i>Glomospira charoides</i> (Jones and Parker, 1860)	1.8
35.	<i>Hormosinella distans</i> (Brady, 1881)	16.1
36.	<i>Hormosinelloides guttifer</i> (Brady, 1881)	3.9
37.	<i>Leptohalysis catella</i> (Höglund, 1947)	5.1
38.	<i>Nodulina dentaliniformis</i> (Brady, 1881)	4.5

39.	<i>Reophax eximius</i> Zheng, 1988	1.6
40.	<i>Reophax fusiformis</i> (Williamson, 1858)	0.6
41.	<i>Reophax gibberus</i> Zheng & Fu, 2001	2.0
42.	<i>Reophax pulchrus</i> Zheng, 1988	0.7
43.	<i>Reophax subcapitatus</i> Zheng & Fu, 2001	0.4
44.	<i>Reophax tenuis</i> Parr, 1950	0.7
45.	<i>Reophax tortilis</i> Zheng & Fu, 2001	12.0
46.	<i>Subreophax aduncus</i> (Brady, 1882)	3.1
47.	<i>Hormosina globulifera</i> Brady, 1879	1.2
48.	<i>Subreophax monile</i> (Brady, 1881)	1.0
49.	<i>Hormosinella mexicana</i> (Cushman, 1920)	1.3
50.	<i>Cribrostomoides anomalinoides</i> (Rhumbler, 1931)	0.3
51.	<i>Cribrostomoides subglobosus</i> (Cushman, 1910)	18.0
52.	<i>Labrospira columbiensis</i> (Cushman, 1925)	1.8
53.	<i>Labrospira crassimargo</i> (Norman, 1892)	1.6
54.	<i>Cribrostomoides evoluta</i> (Natland, 1938)	6.1
55.	<i>Cribrostomoides nitida</i> (Goës, 1896)	4.1
56.	<i>Cribratomoides</i> sp.	17.0
57.	<i>Haplophragmoides bonplandi</i> Todd & Brönnimann, 1957	1.7
58.	<i>Haplophragmoides neobradyi</i> Uchio, 1960	2.0
59.	<i>Cribrostomoides sphaerilocula</i> (Cushman, 1910)	1.9
60.	<i>Cribrostomoides jeffreysii</i> (Williamson, 1858)	1.4
61.	<i>Cribrostomoides wiesneri</i> (Parr, 1950)	2.5
62.	<i>Ammoscalaria agrestiformis</i> Zheng & Fu, 2001	17.0
63.	<i>Ammoscalaria pseudospiralis</i> (Williamson, 1858)	8.7
64.	<i>Discammina compressa</i> (Goës, 1882)	2.3
65.	<i>Glaphyrammina americanus</i> (Cushman, 1910)	2.6
66.	<i>Lituotuba lituiformis</i> (Brady, 1879)	0.7
67.	<i>Ammobaculites exiguus</i> Cushman & Brönnimann, 1948	1.5
68.	<i>Ammobaculites paradoxus</i> Clark, 1994	1.2
69.	<i>Ammobaculites robustus</i> Zheng & Fu, 2001	0.3
70.	<i>Eratidus foliaceus</i> (Brady, 1881)	1.4
71.	<i>Adercotryma glomeratum</i> (Brady, 1878)	12.1
72.	<i>Ammosphaeroidina sphaeroidiniformis</i> (Brady, 1884)	1.0
73.	<i>Cystammina pauciloculata</i> (Brady, 1879)	11.1
74.	<i>Recurvoides contortus</i> Earland, 1934	4.8
75.	<i>Recurvoides turbinatus</i> (Brady, 1881)	0.6
76.	<i>Recurvoidatus trochaminiformis</i> (Saidova, 1961)	2.5
77.	<i>Cyclammina trullissatta</i> (Brady, 1879)	0.3
78.	<i>Spiroplectammina biformis</i> (Parker & Jones, 1865)	14.2
79.	<i>Spiroplectammina typica</i> Lacroix, 1931	0.3
80.	<i>Lacroixina</i> sp.	0.1

81.	<i>Parvigenerina sp.</i>	2.4
82.	<i>Pseudobolivina sp.</i>	0.3
83.	<i>Ammoglobigerina globigeriniformis</i> (Parker & Jones, 1865)	9.2
84.	<i>Ammoglobigerina latestoma</i> Zheng & Fu, 2001	0.3
85.	<i>Ammoglobigerina pygmaea</i> (Höglund, 1947)	0.3
86.	<i>Cystamminoides quadriloculus</i> Zheng, 2001	3.6
87.	<i>Paratrochammina challengeri</i> Brönnimann & Whittaker, 1988	0.3
88.	<i>Paratrochammina simplissima</i> (Cushman & McCulloch, 1948)	2.3
89.	<i>Portatrochammina antarctica subsp. antarctica</i> (Parr, 1950)	6.7
90.	<i>Portatrochammina murrayi</i> Brönnimann & Zaninetti, 1984	0.8
91.	<i>Portatrochammina antarctica subsp. wiesneri</i> (Parr, 1950)	1.6
92.	<i>Trochammina nana</i> (Brady, 1881)	0.6
93.	<i>Paratrochammina globorotaliformis</i> (Zheng, 1988)	3.5
94.	<i>Trochammina hadai</i> Uchio, 1962	1.3
95.	<i>Trochammina inflata</i> (Montagu 1808)	3.7
96.	<i>Trochammina japonica</i> Ishiwada, 1950	13.9
97.	<i>Trochammina pintoii</i> Brönnimann & Whittaker, 1980	2.1
98.	<i>Trochammina squamata</i> Jones & Parker, 1860	2.8
99.	<i>Trochammina triloba</i> Zheng & Fu, 2001	1.2
100.	<i>Polskiammina asiatica</i> (Polski, 1959)	0.3
101.	<i>Rotaliammina mayori</i> Cushman, 1924	1.0
102.	<i>Arenoparrella mexicana</i> (Kornfeld, 1931)	1.9
103.	<i>Karrerulina conversa</i> (Grzybowski, 1901)	0.1
104.	<i>Globotextularia anceps</i> (Brady, 1884)	6.0
105.	<i>Rhumblarella humboldti</i> (Todd & Brönniman, 1957)	9.7
106.	<i>Eggerelloides advenus</i> (Cushman, 1922)	7.9
107.	<i>Eggerella bradyi</i> (Cushman, 1911)	1.0
108.	<i>Verneuiliinulla conica</i> (Zheng, 1988)	0.6
109.	<i>Verneuiliinulla propinqua</i> (Brady, 1884)	3.7
110.	<i>Karrieriella arubiana</i> McCulloch, 1981	9.9
111.	<i>Karrieriella pusilla</i> Parr, 1950	1.7
112.	<i>Martinottiella communis</i> (d'Orbigny, 1846)	0.3
113.	<i>Textularia hystrix</i> Jones, 1994	0.3
114.	<i>Textularia candeiana</i> d'Orbigny, 1839	1.4
115.	<i>Textularia foliacea</i> Heron-Allen & Earland, 1915	2.3
116.	<i>Textularia neolancea</i> McCulloch, 1981	0.6
117.	<i>Prolixoplecta parvula</i> (Cushman, 1922)	2.5
118.	<i>Siphotextularia concava</i> (Karrer, 1868)	0.3
119.	<i>Siphotextularia pseudoconcava</i> Zheng, 1988	1.6
120.	<i>Spirillina helenae</i> Chapman & Parr, 1937	0.6

121.	<i>Adelosina longirostra</i> (d'Orbigny, 1826)	0.3
122.	<i>Spiroloculina elegantissima</i> Said, 1949	0.3
123.	<i>Spiroloculina tenuiseptata</i> Brady, 1884	0.3
124.	<i>Sigmoilopsis minuta</i> (Collins, 1958)	1.2
125.	<i>Quinqueloculina cuvieriana</i> d'Orbigny, 1839	0.6
126.	<i>Siphonaperta distorquata</i> (Cushman, 1954)	0.3
127.	<i>Quinqueloculina lamarckiana</i> d'Orbigny, 1839	0.3
128.	<i>Quinqueloculina pygmea</i> Reuss, 1850	11.9
129.	<i>Quinqueloculina schlumbergeri</i> (Wiesner, 1923)	0.3
130.	<i>Miliolinella lutea</i> (d'Orbigny, 1839)	3.0
131.	<i>Triloculina oblonga</i> (Montagu, 1803)	6.3
132.	<i>Miliolinella subrotunda</i> (Montagu, 1803)	0.8
133.	<i>Triloculina tricarinata</i> d'Orbigny in Deshayes, 1832	0.4
134.	<i>Sigmoilopsis elliptica</i> (Galloway & Wissler, 1927)	0.3
135.	<i>Sigmoilinita delacaboensis</i> McCulloch 1977	0.3
136.	<i>Sigmoilopsis zeaserus</i> Vella, 1963	0.6
137.	<i>Nodosaria simplex</i> Silvestri, 1872	0.1
138.	<i>Laevidentalina translucens</i> (Parr, 1950)	0.3
139.	<i>Lenticulina camiarta</i> Poag, 1966	1.6
140.	<i>Lenticulina pliocaena</i> (Silvestri, 1898)	1.0
141.	<i>Lenticulina subcarinata</i> (Cushman, 1917)	0.3
142.	<i>Astacolus crepidula</i> (Fichtel & Moll, 1798)	0.1
143.	<i>Hemirobulina galapagoensis</i> (McCulloch, 1977)	0.3
144.	<i>Hyalinonetrion elongatum</i> (Ehrenberg, 1844)	0.3
145.	<i>Lagena setigera</i> Millett, 1901	0.3
146.	<i>Lagena striata</i> (d'Orbigny, 1839)	1.0
147.	<i>Lagena hispidula</i> Cushman, 1913	0.3
148.	<i>Oolina lineata subsp. communis</i> McCulloch, 1977	0.3
149.	<i>Fissurina calostoma</i> (Fornasini, 1901)	0.3
150.	<i>Cerebrina clathrata</i> (Brady, 1884)	0.3
151.	<i>Fissurina labiosa</i> McCulloch, 1977	0.3
152.	<i>Fissurina semimarginata</i> (Reuss, 1870)	0.4
153.	<i>Parafissurina impisinna</i> McCulloch, 1977	0.3
154.	<i>Hoeglundina elegans subsp. bikiniensis</i> McCulloch, 1977	0.7
155.	<i>Hoeglundina heterolucida</i> McCulloch, 1981	4.6
156.	<i>Cassidelina spinescens</i> (Cushman, 1911)	1.2
157.	<i>Bolivina victoriana</i> Cushman, 1936	2.5
158.	<i>Bolivina earlandi</i> Parr, 1950	8.8
159.	<i>Bolivina pacifica</i> Cushman & McCulloch, 1942	44.0
160.	<i>Bolivinelina translucens</i> (Phleger & Parker, 1951)	2.6
161.	<i>Bolivinita quadrilatera</i> (Schwager, 1866)	1.9
162.	<i>Bolivinita</i> sp.	1.3

163.	<i>Bolivina acerosa</i> Cushman, 1936	1.2
164.	<i>Bolivina catanensis</i> Seguenza, 1862	9.4
165.	<i>Bolivina dilatata</i> Reuss, 1850	41.1
166.	<i>Bolivina frondalis</i> McCulloch, 1977	25.0
167.	<i>Bolivina lowmani</i> Phleger & Parker, 1951	5.2
168.	<i>Bolivina spathulata</i> (Williamson, 1858)	25.0
169.	<i>Bolivina striatula</i> Cushman, 1922	30.1
170.	<i>Bolivina subspathulata</i> Boomgaard, 1949	12.1
171.	<i>Bolivina doniezi</i> Cushman & Wickenden, 1929	4.9
172.	<i>Bolivina subreticulata</i> Parr, 1932	1.0
173.	<i>Bolivina variabilis</i> (Williamson, 1858)	15.1
174.	<i>Cassidulina carinata</i> Silvestri, 1896	10.1
175.	<i>Cassidulina laevigata</i> d'Orbigny, 1826	6.1
176.	<i>Paracassidulina minuta</i> (Cushman, 1933)	0.6
177.	<i>Evolvocassidulina</i> sp	2.6
178.	<i>Globocassidulina gemma</i> (Todd, 1954)	3.6
179.	<i>Globocassidulina oblonga</i> (Reuss, 1850)	3.3
180.	<i>Globocassidulina subglobosa</i> (Brady, 1881)	17.1
181.	<i>Neocassidulina abbreviata</i> (Heron-Allen & Earland, 1924)	3.9
182.	<i>Islandiella islandica</i> (Nørvang, 1945)	0.6
183.	<i>Eubuliminella exilis</i> (Brady, 1884)	35.4
184.	<i>Fursenkoina hadai</i> (Uchio, 1962)	0.6
185.	<i>Virgulina nodosa</i> Stewart and Stewart, 1930	0.2
186.	<i>Stainforthia brevis</i> McCulloch, 1977	1.4
187.	<i>Fursenkoina complanata</i> (Egger, 1893)	0.3
188.	<i>Stainforthia loeblichii</i> (Feyling-Hanssen, 1954)	0.8
189.	<i>Hopkinsinella glabra</i> (Millett, 1903)	2.8
190.	<i>Sagrinella convallaria</i> (Millett, 1900)	6.7
191.	<i>Pseudobrivalina lobata</i> (Brady, 1881)	0.7
192.	<i>Bulimina aculeata</i> d'Orbigny, 1826	1.3
193.	<i>Fursenkoina spinosa</i> (Heron-Allen & Earland, 1932)	1.6
194.	<i>Bulimina biserialis</i> Millett, 1900	1.0
195.	<i>Bulimina gibba</i> Fornasini, 1902	9.4
196.	<i>Bulimina marginata</i> d'Orbigny, 1826	11.7
197.	<i>Bulimina striata</i> d'Orbigny in Guérin-Méneville, 1832	2.5
198.	<i>Globobulimina notovata</i> (Chapman, 1941)	0.3
199.	<i>Bulimina rostratiformis</i> McCulloch, 1977	3.5
200.	<i>Bulimina</i> sp.	0.7
201.	<i>Globobulimina pacifica</i> Cushman, 1927	2.8
202.	<i>Praeglobobulimina spinescens</i> (Brady, 1884)	1.6
203.	<i>Protoglobobulimina pupoides</i> (d'Orbigny, 1846)	0.6
204.	<i>Buliminella elegantissima</i> (d'Orbigny, 1839)	67.1

205.	<i>Buliminella dubia</i> Barbat & Johnson, 1934	8.6
206.	<i>Uvigerina auberiana</i> d'Orbigny, 1839	3.2
207.	<i>Uvigerina globulosa</i> Egger, 1893	6.5
208.	<i>Siphouvigerina proboscidea</i> (Schwager, 1866)	5.9
209.	<i>Siphouvigerina ampullacea</i> (Brady, 1884)	0.7
210.	<i>Siphouvigerina interrupta</i> (Brady, 1879)	3.8
211.	<i>Uvigerina azuana</i> Bermúdez, 1949	1.4
212.	<i>Uvigerina canariensis</i> d'Orbigny, 1839	0.6
213.	<i>Uvigerina crassicostata</i> Schwager, 1866	0.6
214.	<i>Uvigerina parvula</i> Cushman & Thomas, 1929	4.5
215.	<i>Uvigerina pygmaea</i> d'Orbigny, 1826	1.5
216.	<i>Uvigerina schwageri</i> Brady, 1884	1.0
217.	<i>Uvigerina yabei</i> Asano, 1938	3.0
218.	<i>Fijiella simplex</i> (Cushman, 1929)	0.6
219.	<i>Tosaia symmetrica</i> McCulloch, 1977	0.2
220.	<i>Fursenkoina pauciloculata</i> (Brady, 1884)	7.1
221.	<i>Fursenkoina spinosa</i> (Heron-Allen and Earland, 1932)	9.0
222.	<i>Rutherfordoides rotundiformis</i> (McCulloch, 1977)	3.0
223.	<i>Bolivina alata</i> (Seguenza, 1862)	7.8
224.	<i>Bolivina pygmaea</i> (Brady, 1881)	0.6
225.	<i>Virgulinella pertusa</i> (Reuss, 1861)	1.3
226.	<i>Baggina philippiensis</i> (Cushman, 1921)	16.7
227.	<i>Cancris auricula</i> (Fichtel & Moll, 1798)	16.7
228.	<i>Cancris oblongus</i> (Williamson, 1858)	4.1
229.	<i>Cancris sagra</i> (d'Orbigny, 1839)	8.1
230.	<i>Cibicorbis aspera</i> Clark, 1993	4.7
231.	<i>Quadrimorphina laevigata</i> (Phleger & Parker, 1951)	1.0
232.	<i>Valvulineria glabra</i> Cushman, 1927	7.6
233.	<i>Donsissonia</i> Sp.	0.8
234.	<i>Oridorsalis tener</i> (Brady, 1884)	0.3
235.	<i>Ioanella tumidula</i> (Brady, 1884)	0.6
236.	<i>Ammonia advena</i> (Cushman, 1922)	1.4
237.	<i>Rotorbinella campanulata</i> (Galloway & Wissler, 1927)	7.1
238.	<i>Gavelinopsis praegeri</i> (Heron-Allen & Earland, 1913)	20.0
239.	<i>Rosalina</i> sp.	0.8
240.	<i>Sphaeroidina bulloides</i> d'Orbigny in Deshayes, 1828	1.6
241.	<i>Globotruncana nicaraguensis</i> McCulloch, 1977	3.8
242.	<i>Schackoinella sarmatica</i> Weinhandl, 1958	2.3
243.	<i>Heterolepa bradyi</i> (Trauth, 1918)	5.1
244.	<i>Epistominella exigua</i> (Brady, 1884)	8.6
245.	<i>Hyalinea balthica</i> (Schroeter, 1783)	1.0
246.	<i>Cibicides malayaensis</i> LeRoy, 1944	1.5

247.	<i>Cibicides refulgens</i> Montfort, 1808	4.1
248.	<i>Cibicidina walli</i> Bandy, 1949	0.6
249.	<i>Cibicidoides wuellerstorfi</i> (Schwager, 1866)	0.3
250.	<i>Pseudoepionides japonicus</i> Uchio in Kawai et al., 1950	8.2
251.	<i>Pseudononion costiferum</i> (Cushman, 1926)	11.1
252.	<i>Nonion commune</i> (d'Orbigny, 1846)	5.0
253.	<i>Nonion sloanii</i> (d'Orbigny, 1839)	5.0
254.	<i>Nonionella auricula</i> Heron-Allen & Earland, 1930	19.0
255.	<i>Pseudononion limbatostriatum</i> (Cushman, 1931)	4.5
256.	<i>Nonionella monicana</i> Zalesny, 1959	1.7
257.	<i>Nonionella stella</i> Cushman & Moyer, 1930	31.4
258.	<i>Nonionellina labradorica</i> (Dawson, 1860)	30.0
259.	<i>Nonion boueanum</i> (d'Orbigny, 1846)	37.1
260.	<i>Nonionoides grateloupii</i> (d'Orbigny, 1839)	3.2
261.	<i>Melonis chathamensis</i> McCulloch, 1977	3.6
262.	<i>Melonis pompiloides</i> (Fichtel and Moll, 1798)	3.9
263.	<i>Pullenia bulloides</i> (d'Orbigny, 1846)	2.6
264.	<i>Pullenia compressa</i> Seguenza, 1880	1.3
265.	<i>Chilostomella oolina</i> Schwager, 1878	1.6
266.	<i>Nuttallides decorata</i> (Phleger & Parker, 1951)	3.8
267.	<i>Osangularia</i> sp.	4.5
268.	<i>Oridorsalis umbonatus</i> (Reuss, 1851)	0.3
269.	<i>Gyroidina orbicularis</i> d'Orbigny in Parker, Jones & Brady, 1865	1.2
270.	<i>Gyroidinoides subzelandica</i> Hornibrook, 1961	5.6
271.	<i>Gyroidina lamarckiana</i> (d'Orbigny, 1839)	3.0
272.	<i>Rotaliatinopsis semiinvoluta</i> (Germeraad, 1946)	29.3
273.	<i>Hanzawaia concentrica</i> (Cushman, 1918)	44.1
274.	<i>Hanzawaia nipponica</i> Asano, 1944	60.0
275.	<i>Murrayinella takayanagii</i> (Matoba, 1970)	1.7
276.	<i>Ammonia beccari</i> (Linnaeus, 1758)	25
277.	<i>Ammonia pauciloculata</i> (Phleger & Parker, 1951)	1.4
278.	<i>Ammonia sobrina</i> (Schupack, 1934)	2.8
279.	<i>Asterorotalia dentata</i> (Parker and Jones, 1865)	0.3
280.	<i>Asterorotalia milletti</i> Billman, Hottinger & Oesterle, 1980	7.0
281.	<i>Asterorotalia trispinosa</i> (Thalman 1933)	1.7
282.	<i>Rotalidium annectens</i> (Parker & Jones, 1865)	0.6
283.	<i>Criboelphidium subgranulosum</i> (Egger 1857)	3.8
284.	<i>Elphidium advenum</i> (Cushman, 1922)	0.6
285.	<i>Elphidium crispum</i> (Linnaeus, 1758)	0.3

Table 3

Species	Abbr.	Depth	Salinity	Temp	DO	%Corg	CF%	Corg/N
<i>Astrorhiza granulosa</i>	Astr G	.5600	-.1402	-.4710	-.0075	.0314	-.2426	-.2593
		p=.000	p=.401	p=.003	p=.964	p=.851	p=.142	p=.116
<i>Lagenammia ampullacea</i>	Lage A	.6416	.0017	-.4885	.0112	.0877	-.2493	-.3690
		p=.000	p=.992	p=.002	p=.947	p=.600	p=.131	p=.023
<i>Reophax longicollis</i>	Reop L	.8142	-.0787	-.6348	.0567	.0174	-.3381	-.4275
		p=.000	p=.638	p=.000	p=.735	p=.918	p=.038	p=.007
<i>Hyperammia friabilis</i>	Hype F	.6619	.0618	-.5160	.0319	.0410	-.2633	-.3554
		p=.000	p=.712	p=.001	p=.849	p=.807	p=.110	p=.029
<i>Ammodiscus incertus</i>	Amod I	.0732	.1108	-.3684	-.4983	.4583	-.2545	-.3014
		p=.662	p=.508	p=.023	p=.001	p=.004	p=.123	p=.066
<i>Hormosinella distans</i>	Horm D	.6411	-.0209	-.4706	.0633	-.0484	-.2394	-.2478
		p=.000	p=.901	p=.003	p=.706	p=.773	p=.148	p=.134
<i>Hormosinelloides guttifer</i>	Horm G	.8908	-.0816	-.6769	.0534	.0384	-.3424	-.4241
		p=.000	p=.626	p=.000	p=.750	p=.819	p=.035	p=.008
<i>Reophax tortilis</i>	Reop T	.6295	.0116	-.4264	.0921	.0444	-.2088	-.3388
		p=.000	p=.945	p=.008	p=.582	p=.791	p=.208	p=.037
<i>Cribrostomoides subglobosus</i>	Crib S	.2469	.0709	-.2975	-.0949	.0101	-.1526	-.2176
		p=.135	p=.672	p=.070	p=.571	p=.952	p=.360	p=.189
<i>Ammoscalaria agrestiformis</i>	Amos A	-.3167	.2533	.3975	.3832	-.1814	.0283	.4203
		p=.053	p=.125	p=.013	p=.018	p=.276	p=.866	p=.009
<i>Ammoscalaria pseudospiralis</i>	Amos P	.0927	-.2381	-.1135	.1105	-.1368	.0892	-.0863
		p=.580	p=.150	p=.497	p=.509	p=.413	p=.594	p=.606
<i>Adercotryma glomeratum</i>	Ader G	.7497	-.1126	-.6230	-.0043	.0130	-.3191	-.3996
		p=.000	p=.501	p=.000	p=.979	p=.938	p=.051	p=.013
<i>Cystammia pauciloculata</i>	Cyst P	.6578	-.1775	-.5400	-.0577	.0970	-.2983	-.3619
		p=.000	p=.286	p=.000	p=.731	p=.563	p=.069	p=.026
<i>Spiroplectammia biformis</i>	Spir B	.5196	-.1265	-.5081	-.0896	.0614	-.2688	-.3002
		p=.001	p=.449	p=.001	p=.593	p=.714	p=.103	p=.067
<i>Ammoglobigerina globigeriniformis</i>	Amog G	.4131	-.2178	-.4780	-.1034	.0769	-.1861	-.3838
		p=.010	p=.189	p=.002	p=.537	p=.646	p=.263	p=.017
<i>Portatrochammina Antarctica subsp. antarctica</i>	Port A	.5376	.1797	-.3583	.1800	-.0572	-.3133	-.0352
		p=.000	p=.280	p=.027	p=.280	p=.733	p=.055	p=.834
<i>Trochammina japonica</i>	Troc J	-.1724	.1461	.0851	-.4199	.2231	-.0963	.0107
		p=.301	p=.381	p=.611	p=.009	p=.178	p=.565	p=.949
<i>Rhumblerella humboldti</i>	Rhum H	-.2378	-.3536	.2913	.3671	-.2654	-.0375	.0910
		p=.151	p=.029	p=.076	p=.023	p=.107	p=.823	p=.587
	Egge A	.0857	.0645	-.2470	-.1983	.1565	-.1463	-.2026

<i>Eggerelloides advenus</i>		p=.609	p=.701	p=.135	p=.233	p=.348	p=.381	p=.222
<i>Verneuillinulla propinqua</i>	Vern P	-.1578	.0446	-.0960	-.6463	.5072	-.2568	-.2287
		p=.344	p=.790	p=.566	p=.000	p=.001	p=.120	p=.167
<i>Karreriella arubiana</i>	Karr A	.5767	.0032	-.4886	-.0200	-.0462	-.2570	-.2573
		p=.000	p=.985	p=.002	p=.905	p=.783	p=.119	p=.119
<i>Triloculina oblonga</i>	Tril O	-.2182	-.1329	.2831	.2559	-.4589	.5074	.1120
		p=.188	p=.426	p=.085	p=.121	p=.004	p=.001	p=.503
<i>Bolivina earlandi</i>	Boli E	-.1463	.0766	.0551	-.4027	.3000	-.1435	-.1154
		p=.381	p=.648	p=.743	p=.012	p=.067	p=.390	p=.490
<i>Bolivina pacifica</i>	Boli P	-.4029	.3473	.3831	-.2362	.1094	.2554	.2618
		p=.012	p=.033	p=.018	p=.153	p=.513	p=.122	p=.112
<i>Bolivina catanensis</i>	Boli C	-.1952	.2570	.2555	.2622	-.0884	-.0322	.2173
		p=.240	p=.119	p=.121	p=.112	p=.598	p=.848	p=.190
<i>Bolivina dilatata</i>	Boli D	-.3448	.2307	.4045	-.0604	.0351	.3079	.6447
		p=.034	p=.163	p=.012	p=.719	p=.834	p=.060	p=.000
<i>Bolivina frondalis</i>	Boli F	-.2833	-.0223	.3619	.3314	-.5052	.5188	.1118
		p=.085	p=.895	p=.026	p=.042	p=.001	p=.001	p=.504
<i>Bolivina lowmani</i>	Boli L	-.1710	.0437	.0158	-.5353	.4378	-.1725	-.1169
		p=.305	p=.794	p=.925	p=.001	p=.006	p=.300	p=.484
<i>Bolivina striatula</i>	Boli S	-.2274	-.4622	.2825	.3853	-.2621	.0868	.1074
		p=.170	p=.003	p=.086	p=.017	p=.112	p=.605	p=.521
<i>Bolivina subspathula</i>	Boli Sub	-.2460	.2716	.2379	-.3478	.2634	.2416	.4993
		p=.136	p=.099	p=.150	p=.032	p=.110	p=.144	p=.001
<i>Bolivina doniezi</i>	Boli Do	.0065	-.0518	-.2625	-.2992	.3914	-.1730	-.1068
		p=.969	p=.758	p=.111	p=.068	p=.015	p=.299	p=.523
<i>Bolivina variabilis</i>	Boli V	-.3500	.0556	.4446	.3397	-.4414	.4414	.2557
		p=.031	p=.740	p=.005	p=.037	p=.006	p=.006	p=.121
<i>Cassidulina carinata</i>	Cass C	.2192	-.1319	-.4676	-.3754	.3969	-.2878	-.2573
		p=.186	p=.430	p=.003	p=.020	p=.014	p=.080	p=.119
<i>Cassidulina laevigata</i>	Cass L	-.2893	-.1711	.2332	-.0847	-.0164	.1324	-.0745
		p=.078	p=.304	p=.159	p=.613	p=.922	p=.428	p=.657
<i>Globocassidulina subglobosa</i>	Gloc S	.7293	-.1215	-.5027	.0906	-.0004	-.2549	-.2950
		p=.000	p=.467	p=.001	p=.589	p=.998	p=.122	p=.072
<i>Eubuliminella exilis</i>	Eubu E	-.1591	.2275	.1371	-.2577	.1090	-.1441	-.0001
		p=.340	p=.170	p=.412	p=.118	p=.515	p=.388	p=1.00
<i>Bulimina gibba</i>	Buli G	-.1541	.1417	.0670	-.3547	.2201	.0151	.2241
		p=.356	p=.396	p=.690	p=.029	p=.184	p=.929	p=.176
<i>Bulimina marginata</i>	Buli M	.4669	-.0321	-.5400	-.2193	.2249	-.2995	-.3466
		p=.003	p=.848	p=.000	p=.186	p=.175	p=.068	p=.033
<i>Buliminella elegantissima</i>	Bulm E	-.1174	.0199	.0403	-.3308	.3242	-.1238	-.1421
		p=.483	p=.906	p=.810	p=.042	p=.047	p=.459	p=.395

<i>Bulminella dubia</i>	Bulm D	-.0179	-.0169	-.2754	-.5195	.5051	-.2753	-.2262
		p=.915	p=.920	p=.094	p=.001	p=.001	p=.094	p=.172
<i>Uvigerina globulosa</i>	Uvig G	.3838	.0068	-.5187	-.2366	.2389	-.2893	-.3079
		p=.017	p=.968	p=.001	p=.153	p=.149	p=.078	p=.060
<i>Siphouvigerina proboscidea</i>	Siph P	-.3126	-.0054	.3948	.3258	-.3845	.3317	.1388
		p=.056	p=.974	p=.014	p=.046	p=.017	p=.042	p=.406
<i>Siphouvigerina interrupta</i>	Siph I	-.0453	.0221	.0977	.1259	-.3509	.3650	.0382
		p=.787	p=.895	p=.560	p=.451	p=.031	p=.024	p=.820
<i>Uvigerina parvula</i>	Uvig P	.3805	-.0650	-.5775	-.2728	.3437	-.3185	-.3468
		p=.018	p=.698	p=.000	p=.098	p=.035	p=.051	p=.033
<i>Fursenkoina pauciloculata</i>	Furs P	-.3048	.2845	.3954	.3990	-.2494	-.0137	.4939
		p=.063	p=.083	p=.014	p=.013	p=.131	p=.935	p=.002
<i>Fursenkoina spinosa</i>	Furs S	-.0185	-.0998	-.2552	-.4805	.4127	-.2205	-.1917
		p=.912	p=.551	p=.122	p=.002	p=.010	p=.184	p=.249
<i>Bolivina alata</i>	Boli A	.1460	-.1864	-.3339	-.2809	.2277	-.1962	-.2197
		p=.382	p=.263	p=.040	p=.088	p=.169	p=.238	p=.185
<i>Cancris auriculus</i>	Canc A	-.2216	.1733	.2855	.2040	-.3057	.4254	.0893
		p=.181	p=.298	p=.082	p=.219	p=.062	p=.008	p=.594
<i>Cancris sagra</i>	Canc S	-.2980	.0716	.3859	.2785	-.4072	.3664	.1014
		p=.069	p=.669	p=.017	p=.090	p=.011	p=.024	p=.545
<i>Cibicorbis aspera</i>	Cibi A	-.2633	-.1082	.3367	.1939	-.3506	.3869	.0421
		p=.110	p=.518	p=.039	p=.243	p=.031	p=.016	p=.802
<i>Valvulineria glabra</i>	Valv G	.0330	-.1799	-.2984	-.2955	.4231	-.1969	-.1152
		p=.844	p=.280	p=.069	p=.072	p=.008	p=.236	p=.491
<i>Gavelinopsis praegeri</i>	Gave P	-.3320	-.0224	.4209	.4127	-.3529	.2180	.2183
		p=.042	p=.894	p=.009	p=.010	p=.030	p=.189	p=.188
<i>Heterolepa bradyi</i>	Hetr B	.6044	-.1239	-.3966	.0930	.0240	-.1956	-.2745
		p=.000	p=.459	p=.014	p=.579	p=.886	p=.239	p=.095
<i>Epistominella exigua</i>	Epis E	.5285	-.0539	-.6558	-.3466	.3684	-.3964	-.3579
		p=.001	p=.748	p=.000	p=.033	p=.023	p=.014	p=.027
<i>Pseudoeponides japonicus</i>	Psed J	.2131	.0738	-.3058	-.1423	.1331	-.1665	-.2332
		p=.199	p=.660	p=.062	p=.394	p=.426	p=.318	p=.159
<i>Pseudononion costiferum</i>	Psed C	-.4422	-.1882	.5711	.5920	-.5707	.3388	.3859
		p=.005	p=.258	p=.000	p=.000	p=.000	p=.037	p=.017
<i>Nonion commune</i>	Noni C	-.1464	-.2724	.1830	.0274	-.0572	-.0181	-.1248
		p=.380	p=.098	p=.271	p=.870	p=.733	p=.914	p=.455
<i>Nonionella auricula</i>	Nonl A	-.2948	-.4008	.3702	.3759	-.2268	-.0347	.0566
		p=.072	p=.013	p=.022	p=.020	p=.171	p=.836	p=.736
<i>Pseudononion limbatostriatum</i>	Psed L	-.2307	-.0412	.2925	.3188	-.1996	.1275	.1192
		p=.163	p=.806	p=.075	p=.051	p=.230	p=.446	p=.476
<i>Nonionella stella</i>	Nonl S	-.2728	.0037	.3545	.3856	-.2864	.0714	.3887
		p=.097	p=.982	p=.029	p=.017	p=.081	p=.670	p=.016

<i>Nonionellina labradorica</i>	Nonla L	-.4279	.1229	.3963	.1144	.0146	.1065	.4165
		p=.007	p=.462	p=.014	p=.494	p=.931	p=.524	p=.009
<i>Nonion boueanum</i>	Nond B	-.2933	-.0531	.3711	.3717	-.3152	.1941	.2870
		p=.074	p=.752	p=.022	p=.022	p=.054	p=.243	p=.081
<i>Melonis chathamensis</i>	Melo C	.3313	.0866	-.3410	-.1421	.1890	-.2097	-.1963
		p=.042	p=.605	p=.036	p=.395	p=.256	p=.206	p=.238
<i>Melonis pompiloides</i>	Melo P	-.0613	.0385	-.1506	-.4019	.3419	-.1649	-.1291
		p=.715	p=.819	p=.367	p=.012	p=.036	p=.323	p=.440
<i>Osangularia</i> sp.	Osan S	.2911	-.1402	-.4869	-.2894	.4027	-.2903	-.2384
		p=.076	p=.401	p=.002	p=.078	p=.012	p=.077	p=.150
<i>Gyroidinoides subzelandica</i>	Gyrd S	.5994	-.0971	-.5946	-.1091	.1703	-.3083	-.3619
		p=.000	p=.562	p=.000	p=.514	p=.307	p=.060	p=.026
<i>Rotaliatinopsis semiinvoluta</i>	Rota S	-.0204	-.1460	-.2988	-.4726	.4728	-.2388	-.1974
		p=.903	p=.382	p=.068	p=.003	p=.003	p=.149	p=.235
<i>Hanzawaia concentrica</i>	Hanz C	-.3112	.0640	.3786	.0505	-.2482	.5304	.3574
		p=.057	p=.703	p=.019	p=.763	p=.133	p=.001	p=.028
<i>Hanzawaia nipponica</i>	Hanz N	-.3875	.2404	.4987	.4921	-.3929	.2811	.3078
		p=.016	p=.146	p=.001	p=.002	p=.015	p=.087	p=.060
<i>Ammonia beccari</i>	Amna B	-.4304	-.0849	.5465	.5311	-.6065	.5718	.1561
		p=.007	p=.612	p=.000	p=.001	p=.000	p=.000	p=.349
<i>Asterorotalia milletti</i>	Aste M	-.2062	-.5911	.2556	.3560	-.4268	.2798	-.0449
		p=.214	p=.000	p=.121	p=.028	p=.008	p=.089	p=.789
<i>Rotorbinella campanulata</i>	Roto C	.4501	.0348	-.5667	-.2212	.2201	-.3048	-.3462
		p=.005	p=.836	p=.000	p=.182	p=.184	p=.063	p=.033

Table 4

S. No	Assemblages	Temp	Depth	DO	%C_{org}	Remarks
1	<i>Ammonia beccari</i> , <i>Pseudononion costiferum</i> , <i>Hanzawaia nipponica</i> , <i>Bolivina frondalis</i> , <i>Bolivina dilatata</i> , <i>Bolivina striatula</i> , and <i>Asterorotalia milletti</i>	<22 °C	Restricted Shallow waters (31 – 55 m)	~ 4 ml/l	0.1 – 0.9	Species strongly affected by river discharge
2	<i>Verneuillinella propinqua</i> , <i>Ammodiscus incertus</i> , <i>Buliminella dubia</i> , <i>Rotaliatinopsis semiinvoluta</i> , <i>Bolivina lowmani</i> , and <i>Fursenkoina spinosa</i>	7–17°C	Intermediate depth (250 – 1000 m)	~ 0.5- 1.6 ml/l	> 1.7	Opportunistic species majorly dependent on food availability
3	<i>Globocassidulina subglobosa</i> , <i>Epistominella exigua</i> , <i>Gyroidinoides subzelandica</i> , <i>Reophax longicollis</i> , <i>Adercotryma glomeratum</i> , <i>Cystammina pauciloculata</i> , and <i>Spiroplectammina biformis</i>	2–7 °C	Deep Sea (1000 – 2500 m)	2 – 4 m/l	0.9 – 1.5	Species dependent on moderate carbon flux