Holocene benthic foraminifera in two marine lakes in Misool, Raja Ampat (Indonesia)

Major Research Project

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Abstract

Marine lakes have been proposed as a unique ecosystem to assess the physical, chemical and biological interaction within a marine community. However, study on the dynamics of past community composition and biodiversity in marine lakes is still limited. Benthic foraminifera have been considered as important environmental indicators. This study investigated the diversity and distribution of foraminiferal assemblages from two marine lake sediment cores (MIS-01 and MIS-17) in Misool, Raja Ampat. A total of 6693 benthic foraminiferal specimens, which belong to 34 species were recorded from 36 samples from both cores of the marine lakes. The species were characterized by a low diversity and dominated by hyaline perforated species of *Ammonia sp*, *Brizalina semicarinata*, *Bolivina striatula*, and *Bolivina sp* Four agglutinated species include *Ammobaculites sp, Caronia exilis, Reophax irregularis, Textularia agglutinans* and porcelanous imperforated species consist of *Fissurina bispinata, Lagena sp, Quinqueloculina carinatastriata, Quinqueloculina sp* and *Quinqueloculina exsculpta*. Downcore variation of the species indicates six major break along the cores which correlates to the six main cluster of the sample with a distinguish depth boundary. Comparison of the assemblages and species diversity shows that the foraminifera from Misool are similar to the ones from Palau. Assessment of individual species and assemblage environmental preferences suggest that oxygen level and salinity might have been the driving factors behind the changes in community assemblages. In comparison to the other community, the temporal partitioning along the cores fits with those based on the mollusk community, particularly at 200 cm depth where diversity was higher than the upper layer.

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1. Introduction

1.1 General Introduction

Global climate change is and will be responsible for the change of the physical, chemical, biological, and biogeochemical properties of the ocean and coast (Pörtner et al., 2014; Subedi, 2015). These changes, which are considered to be environmental drivers, include changes in temperature, salinity, circulation, carbon dioxide, oxygen, nutrient, and light (Smithson, IPCC, 2001; Pörtner et al., 2014). They shape the physiological performance of individual cells and organisms, and ultimately determine biodiversity, ecological composition, structure, and ecosystem functioning (Parmesan and Yohe, 2003; Rosenzweig et al., 2008). Extinction of species and biodiversity, phenology changes, and shift in geographic ranges are the most recognized effect of climate change on biodiversity in the marine realm (Walther et al., 2002; Mueter and Litzow, 2008; Cheung et al. 2009). Local extinction was predicted to be most common in the tropics (Cheung et al., 2009; Hoegh-Guldberg et al. 2007) especially in a small island, which can be very rich in biodiversity (Meehl et al., IPCC, 2007). Therefore, to assess the vulnerability of biodiversity and provide a ground base to prevent the loss of biodiversity further, it is important to understand the dynamics of biodiversity.

The adaptive capacities of marine and coastal ecosystems vary among species, sectors, and geographical regions (McLean et al., 2001). Regarding movement and migration, the potential range of shift is higher in open oceans than within enclosed seas and coastal zones, which are more constrained by the physical features of the shore. Thus, study the influence of global climate change on evolution and biodiversity throughout the earth history, especially the changes in community composition; i.e., evolutionary dynamics, will be best examined from a smaller environment spatial scale (Loreau et al., 2001; Guisan and Thuiller, 2005) in the past.

Marine lakes have been proposed as unique ecosystem to assess the physical, chemical and biological interaction within a marine community (Dawson et al. 2009). This environment is a part of the non-cave open-air anchialine system, a small body of landlocked seawater that is isolated from the surrounding marine

environment and maintains a marine character through narrow submarine connection to the sea. Marine lakes generally resemble characteristic of island system (Dowson et al., 2009; Becking et al., 2013), e.g., well-defined geographically, contain unique biota with high endemism, and isolated population. Marine lakes in the Indo-Pacific region originated during the early Holocene sea level rise following the Last Glacial Maximum (LGM) approximately 7,000-12,000 BP when depressions in porous, fissured karst or lava landscape were flooded by sea level rise (Dawson et al., 2009; Becking et al., 2011). Marine lakes have been located and estimated at ~200 lakes worldwide based on the direct and indirect report as well as maps and satellite images (Dawson et al., 2009). Dawson et al. (2009) have reported a cluster of minimum ten lakes occur in several karstic setting such as Croatia, Bermuda, Vietnam, Palau, and Indonesia.

Numbers of rare and novel genera and species have been found in marine lakes and the other anchialine system (Kott, 1995; Massin and Tomascik,1996; Dawson and Hamner, 2005; Becking et al., 2013). In regards to evolutionary diversification, previous work has shown the advantage of study this isolated environment, that rapidly evolving population has been recorded and better preservation of fossil record compared to terrestrial islands (Dawson and Hammer, 2005; Martinez Garcia et al., 2009). The jellyfish *Mastigias papua* (Lesson, 1830), is one of the iconic anchialine creatures that occur in several lakes in Palau and Indonesia. It has been reported that the morphology of the lakes-species is different compared to the morphotype from the sea as the result of adaptation (Dawson, 2005). The occurrences of the marine community in the present day marine lakes are restricted to the last deglaciation flooding, making it suitable environment to assess spatiotemporal changes in marine ecology and evolution (Cleary et al., 2016).

Previous studies in marine lakes have mostly been focused on the faunal composition, especially endemic, isolated populations, and rare species (Tomascik and Mah, 1994; Kott, 1995; Dawson and Hammer, 2005; Becking et al., 2011). However, study on the dynamics of past community composition and biodiversity in marine lakes is still limited. Also, due to the occurrence of exotic species, increasing activity from tourism and aquaculture have been reported to endanger

the balance and originality of the ecosystem. Thus, understanding change in past community composition and biodiversity will also extend our knowledge on how to protect and conserve this unique system.

Benthic foraminifera are single-celled protozoa, which inhabit almost all marine environment, living either above, at, or below the sediment-water interface (Jorrisen, 1999; Murray, 2006). They are generally small (<1 mm) although some exceed 1 cm and posses a shell or test variously composed of secreted organic matter, mineral (calcite, aragonite, or silica), or agglutinated particles (Amstrong and Brasier, 2005; Murray,2006) which might be preserved in the fossil record. Smaller benthic foraminifera are the most common group and are widely used for regional stratigraphy, as paleobathimetry indicators, and as bioindicators of pollution sources (Bandy,1953; Biswas,1976; Amstrong and Brasier,2005; Nigam et al., 2006). Due to their wide environmental range and well-preserved test, they are extremely valuable not only as a current ecological indicator but also as a historical record of the previous environment (Murray, 1991; Hayward et al., 2004; Murray, 2006) Furthermore, considering their shorter generation time, benthic foraminifera have the potential to respond faster than macrofauna to change in environmental conditions in both abiotic and biotic factors (Bouchet et al., 2012). Abiotic factors include oxygen availability, water depth, salinity, temperature, tides, and substrate whereas the biotic factors consist of competition for food availability and space (Jorrisen, 1999; Murray,2006). Studying the change in the composition of foraminiferal assemblages may thus provide a powerful tool to understand how environmental change control the community dynamics.

The present study focused on the benthic foraminifer community dynamics in two recently found marine lakes of Misool Island, Raja Ampat, West Papua, Indonesia. Although there have been several studies on benthic foraminifera distribution from Raja Ampat and its surrounding region, including Misool island (Hofker, 1927; Hofker 1930; Syafron, 2011 Natsir et al.,2012), to date, no comprehensive studieson benthic foraminifera from Misool marine lakes have been published. The purpose of this study is to describe and examine two marine lakes past community dynamics based on the benthic foraminiferal assemblages from these two lakes. Eventually, with the references to the modern benthic

foraminifera, the change in past environmental condition of the lakes can be interpreted from the variation of the foraminiferal assemblages distribution and diversity. The specifics aims of this study were :

1. To provide a comprehensive database on the composition of benthic foraminifera distribution in the cores
2. To interpret the change in environmental conditions based on the variability of the foraminiferal species assemblages

Based on the objectives of the study, the following research question need to be addressed:

1. What was the species composition of the marine lakes in the past? How did they change through time?
2. What are the most dominant changes in environmental condition in the past based on the variation of the foraminiferal assemblages?

For this assessment, it is expected to find changes and pattern in assemblage composition that will imply a change in environmental condition. However, if we found no change nor pattern, then some other parameter must have been taking places as such the environment are stable over time.

1.2 Study area

Research sites were located in two "jellyfish lakes" within the karst chain of Misool islands in the district of Raja Ampat in West Papua, Indonesia. These lakes were firstly documented by Becking et al. (2014) as a result of two expeditions in 2011 and 2013 to find marine lakes. The name of each lake derives from the name of the island, MIS 01 and MIS 17. Raja Ampat is a group of majestic islands covering an area over 43,000 km2. This region consists of nearly 1500 islands with four main islands of Waigeo, Batana, Salawati, and Misool. Situated on the northwestern tip of Papua, eastern Indonesia, in the Indo-Pacific's "epicenter" of biodiversity, this region is part of the Coral Triangle Region (Hoeksema, 2007). It has been reported that this region displays some of the world’s highest diversity of both marine species and habitats (Becking et al., 2011; Allen, 2008; Allen and Erdmann 2009; Mangubhai et al. 2012).

In addition to Misool island, it is the reefs and the mangrove systems in SE Misool that encompass an area of outstanding marine biological diversity (e.g., Allen 2008; Becking et al. 2014; Mangubhai et al. 2012). This system harbours some of the most pristine reefs in Indonesia (Grantham et al. 2013; Mangubhai et al. 2012). Misool houses large perennial populations of the jellyfish *Mastigias Papua* such as those that have been extensively documented in five marine lakes in Palau (Becking et al., 2013).

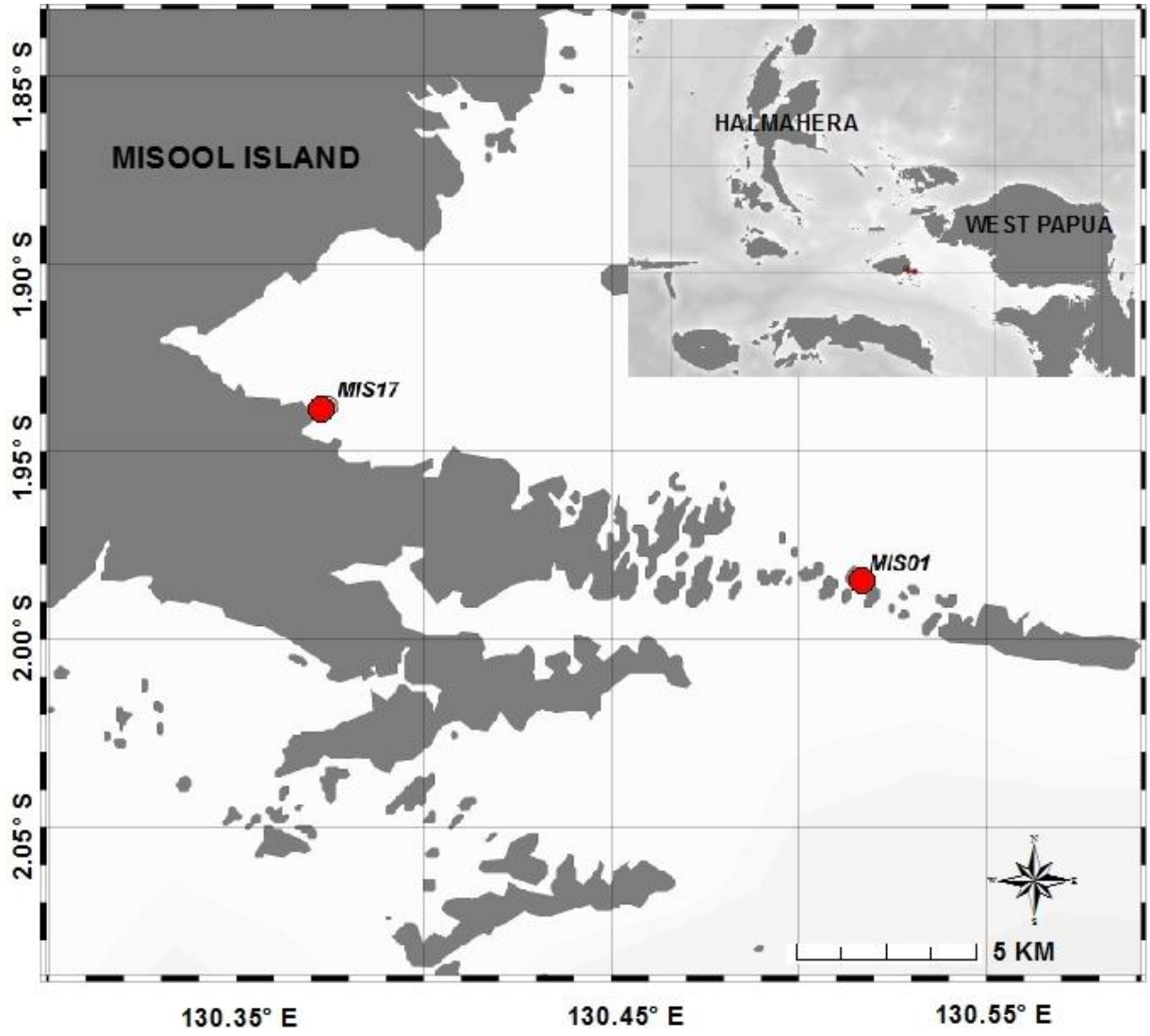

Figure 1. Map of the study area (red dots indicate core locations).

Located in the equatorial position, the climate over Misool island is mainly driven by a monsoonal system. According to Cleary et al. (2017), the southeast

monsoon from May to October, characterized by cooler sea surface temperatures (SSTs), persistent winds and strong ocean swell in the southern part of the island, is the most climatic control in the island. The annual rainfall as a whole in Papua averages 2500–4500 mm (Prentice and Hope, 2007), with Inter-annual variability in rainfall changes in respect to the El Niño Southern Oscillation (ENSO; Prentice and Hope, 2007). The average SST in Raja Ampat was 29.0 °C, with temperatures ranging from 19.3 °C to 36.0 °C for its seasonal differences (Mangubhai et al., 2012). Several main areas of cold-water upwelling have been identified at Southeast Misool which present all year, but are most intense during the southeast monsoon when strong winds from the south help drive this upwelling (Mangubhai et al., 2012).

1.3 Description of the Marine lakes

1.3.1 MIS-01

Lake MIS-01 also named as Lake 2 (Becking et al., 2014) located 01° 59' 02"S 130° 30' 58"E. The size of the lake measures 150 m long and 70 m at its maximum width. The distance is approximately 75 m to the sea. During the expedition of Becking et al. in September 2013, it was observed that the lake has a maximum depth of 20 m with a salinity of 26.6 ppt. The tidal fluctuation was also recorded showing almost identical value within the sea in both tidal amplitude and time lag. This measured value indicates that the lake is relatively well connected to the sea (Becking et al.,2014).

In comparison to the previous data, another measurement was conducted in June 2014. Another parameter was measured, namely temperature (°C), dissolved oxygen (O_2) (%), salinity (ppt) and conductivity (mS/cm). The temperature was around 30°C and increased with depth. The percentage of dissolved oxygen decreased considerably from ~60% at 4m, to 0% at 8m depth. Finally, the salinity and the conductivity are ~19.5 ppt and ~34 mS/cm for the surface water (0 – 2 m) but increase to 28.5 ppt and 50 mS/cm respectively at which they remain more or somewhat constant.

Figure 2. Satelite Image of lake MIS-01. Image taken from Google Earth Pro (2018).

1.3.2 MIS 17

Located at approximately 16.5 km from MIS-01, MIS-17, also known as lake 3 (Becking et al., 2014) situated at 01° 56' 16"S 130° 22' 28"E) (fig. 3). This lake is about 200 m long, 80 m wide, and up to 7.5 m deep. It is considered as a relatively shallow lake, separated approximately 80 m northwards in the distance to the surrounding sea. Observations by Becking et al. in June 2014 reveals that the tidal amplitude (~35 cm) within the lakes is shorter than the magnitude in the adjacent sea (100 cm). Together with recorded of minimum three hours tidal temporal lag, it was suggested that the connectivity between the lakes and the sea is moderate to low. The temperature measured increases with depth from 31°C to ~33°C at 6 m, with the dissolved oxygen of ~80% at the surface (0 – 2 m) and decreases rapidly

to 0% between 3 and 6 m depth. Finally, the salinity and the conductivity are ~29 ppt and 51 mS/cm respectively, remain more or less constant with increasing depth. In this observation, the salinity is considered lower compare to the previous measurement of 30.55 ppt in September 2013 (Becking et al., 2014).

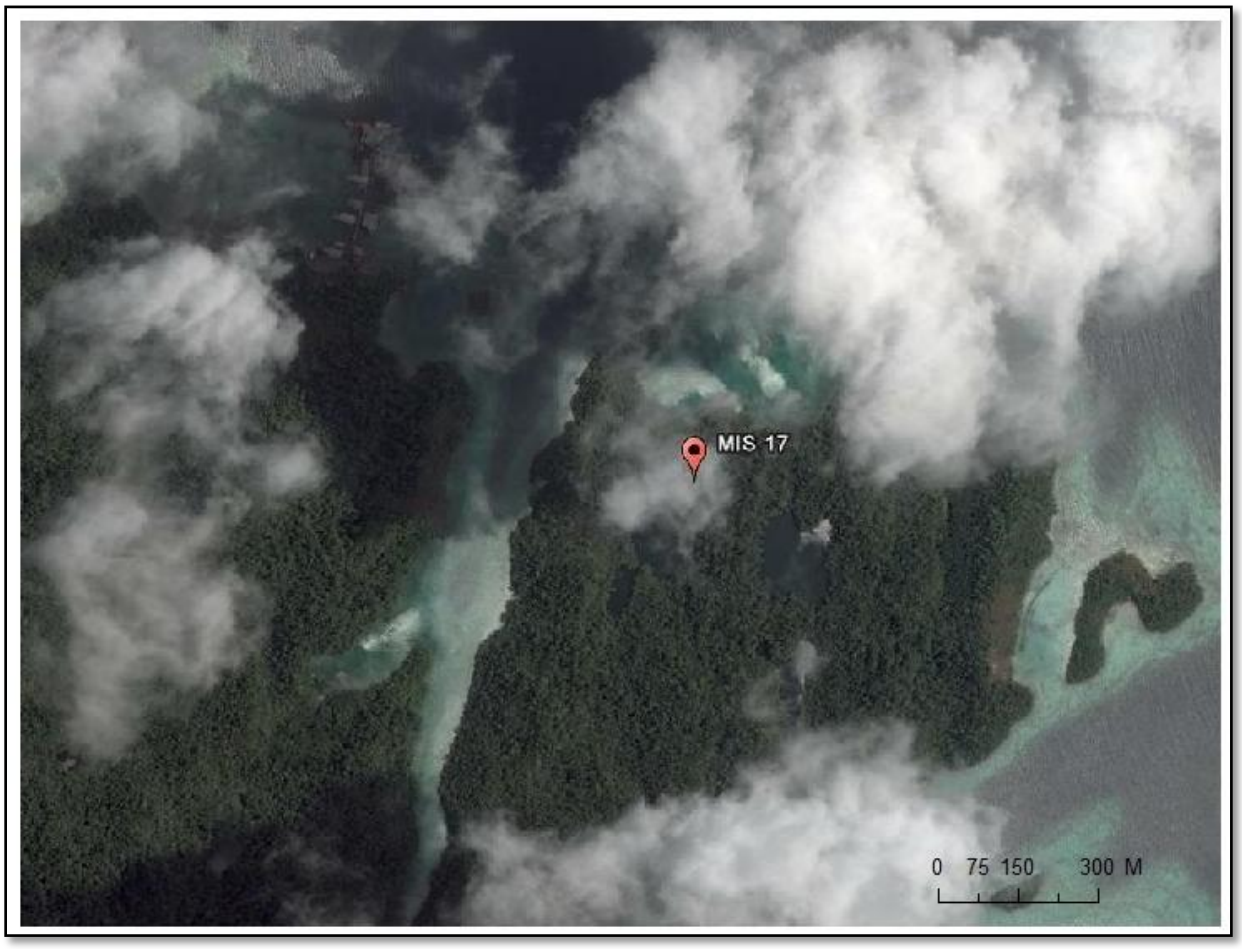

Figure 3. Satelite Image of lake MIS-17. Image taken from Google Earth Pro (2018).

2. Material and Method

2.1 Sediment cores and samples

The sediment core was taken by scuba divers using PVC tubes (core diameter 5 cm). The cores were divided longitudinally and for each of the half sediments were sliced into 2.5 – 5 cm intervals. These subsampled sediments were put in a separated labeled bag and transported to Nturalis Biodiversity Center. Aiming to fully cover the story along the two sediment core, and in regards to several previous studies (J.A.Bom, Msc.thesis, 2017 and K.A.B.Klei, Msc. Thesis, 2017), a total of 36 sediment samples (23 samples from MIS -01, 13 samples from MIS-17) were selected for analysis of this present (table 1) study.

Table 1. Summary of the core with depth and length.

Lake	Core depth (m)	Core length (cm)	Sample used for analysis (cm)
MIS-01	7.5	269	10-11, 24-26, 30-33, 38-41, 56-57, 65-68, 72-75, 86-87, 98-100, 109-112, 121-124, 133-136, 139-142, 151-154, 165-168, 171-174, 200-202, 212-215, 224-227, 230-233, 242-245, 257-258, 262-266
MIS -17	7.3	255	20-25, 25-30, 30-35, 65-70, 85-90, 120-125, 140-145, 160-165, 170-175, 180-185, 200-205, 215-220, 230-235

2.2 Sampling, processing, counting and identification of foraminiferal specimen

In the laboratory, samples were freeze-dried and subsequently washed with fresh water over sieves of 63μm, 125 μm, and 500 μm mesh opening. The residue from the washed sediment was oven dried at 50° C and store after that for further counting and identification.

Specimen density can be quite variable along the sampled cores. Within a lower density samples, a full specimen extraction is often necessary, while with higher density or concentration a full extraction cannot be performed entirely.

Therefore, to obtain a reasonable density for analysis, prior to the picking-counting and identification of the foraminiferal specimen, extraction from a representative fraction of the sample can be obtain with the help of a splitter. Samples can be split into as many fractions as necessary (1/2, 1/4, 1/8, ….), and based on the total foraminifera counted per sample, splitting fraction, and dry weight of the sediment, foraminifera density (concentration) is calculated as follow :

$$Concentration\ (n\ foram\ per\ gram) \frac{Total\ foram\ count * Splitting\ Fraction\ (\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, etc.)}{Dry\ sediment\ weight\ (gram)}$$

A preliminary investigation on foraminifera assemblages (top, middle, and bottom samples) was conducted in fraction greater than 125µm and 63µm to determine the ideal quantitative counts. As a result, using a standard light microscope, a minimum of 150 foraminiferal specimens from fraction greater than 63µm were decided to be handpicked and identified from each subsample. After foraminiferal specimens were sorted, some representative specimen were selected for evaluation using a light microscope, photomicroscope, and Scanning Electron Microscope (SEM) picture to identify morphologi¬cal features and to better resolve smaller specimens.

Detail visual information provided by the SEM images of these microfossils is key in determining and identifying the taxonomy to the species level with a higher degree of confidence (Dreher and Flocks, 2011). Each specimen was determined, if possible to species level. Specimen identification following the classification criteria of Loeblich and Tappan (1988, 1992, 1994) and several other sources; WoRMS and Marine species identification portal, The Foraminifera.eu Project portal, Foraminifera from Southwestern Pacific: New Caledonia (Debenay, 2012), and Foraminifera from Eastern Indonesia (Van Marle,1991).

2.3 Foraminiferal assemblages analysis and biodiversity index

The variability of the assemblages throughout the cores was described in terms of diversity indices using the raw data from the counting and identification of

foraminiferal assemblages. These indices include: the number of species present/species richness (S), total number of individuals (n), and Shannon diversity index (H). As a complimentary, a rarefaction curve is constructed. This curve was made to compare the number of species in the sample of different size. A smaller number of specimen, n = 100, were randomly sampled from the total sample for the standardized index and the entire sample is used for the rarefaction curve construction.

The occurences data were transformed to relative abundances (RA) percentages to normalize the sample size (Hammmer and Harper, 2006). RA was calculated as follow :

$$RA = \frac{n}{N} X100$$

RA matrix was obtained and become the starting point to conduct further data analysis.

2.4 Data Analysis

For further exploration and visualization of the complex data (foraminiferal assemblages), RA matrix is transformed with the log (x+1) transform. This transformation was made considering the nature effect of the data which are sparse (containing many zero values), noisy (order of magnitude difference between variable) and redundant (similar species composition or similar distribution in many samples) (Hammer and Harper, 2006). Furthermore, Log (x+1) transform was considered to be useful to avoid negative numbers and normalize the data (Brakstad 1992). Following the log transformation, distance or similarity matrix was constructed using Bray-Curtis similarity Index. This index was chosen for its sensitivity to abundant species, and it has been shown to work best for small samples (Krebs, 1989). The resulted matrix was then used as a primary matrix to conduct Analyses of Similarity (ANOSIM), cluster analyses and non-metrical Multidimensional Scaling (NMDS) to determine patterns, similarities, and differences between and within the samples of the two marine lakes. Analyses were performed using PAST 3.2 (Hammer and Harper, 2018)

2.4.1 Analysis of similarities (ANOSIM)

ANOSIM is a non-parametric test for difference between several groups of multivariate data point based on any distance measured (this study used Bray-Curtis distance measure)(Hammer and Harper, 2006). In ecology and biogeography, this test was used for the comparison of taxonomic composition in two or more group of samples. ANOSIM works by comparing within-group and across-group distances. Based on this idea a test statistic R based is constructed, and its significant estimated by permutating samples across groups. It was assumed that the distances within the different group are equal. Values of R near 1 indicate that the among-group dissimilarity is higher than the within-group dissimilarity, which signifies differences between groups, R=0 suggests no separation between sample groups. Negative values of R indicate that dissimilarities within groups are greater than dissimilarities between groups. In this study, ANOSIM was applied, to test for faunal composition differences within and between the cores.

2.4.2 Cluster Analysis

Cluster analysis is an explorative technique for identifying groups and subgroups in a multivariate dataset based on a given distance or similarity measure (Hammer and Harper, 2006). The resulting clusters visualized in a clustering diagram known as a dendrogram and can be interpreted for biogeography, environment, and evolution (Hammer and Harper, 2006). We used cluster analysis, based on the Bray-Curtis distance measure, to find possible groupings of samples and species. Different methods for clustering are available in PAST, in this study the unweighted pair -group average (UPGMA) method, which joints clusters based on the average distance between all members of the group was used.

2.4.3 Non-Metric Multidimensional scaling (NMDS)

NMDS is an ordination method used to project a multivariate dataset into two or three dimensions to visualize trends and grouping based on distance measure (Hammer and Harper, 2006). NMDS is almost identical to principal component

analysis (PCA) for its intention to ordinate the data in low- dimensional space. NMDS further transform the data into their ranks and compare the distance between the rank of the Euclidean distances (Hammer and Harper, 2006). NMDS have been proved to be useful when the distance measure is poorly understood because it makes very few assumptions about the nature of the data, which makes this method was also well suited for a wide variety of data. The quality of NMDS plots can be assessed from the measurement of the stress coefficient, which is the difference between the distance in ordination rank and the distance in original rank. Clarke and Warick (1994) suggested that an ideal stress coefficient for an adequate ordination should be < 0,1.

3. Result

3.1 Core Description

3.1.1 MIS -01

MIS-01 core (269 cm), was taken at 7.5 m water depth (fig. 4). The core shows several distinct layers of sediment or distinctive sedimentary facies. The most striking feature is the variability of shell material between facies; varying from scares to no shell material, to layers that are shelldominated (mollusc). The latter also shows variation; some layers are dominated by very tiny shells (~500 µm), while others contain relatively large shells (>1 cm). Two segments of the core, 75 – 98 cm and 189 – 209 cm, stand out because they consist of a lot of very thin(~0.5 – 1 cm), but very distinct layers.

3.1.2 MIS-17

The core from MIS-17 (255 cm) (fig. 5), taken at 7.3m water depth, and consists of three distinctive layers of almost a homogenous sediment. The grain size of the sediment ranges from clay to sand grain. From the surface to 255 cm depth, the sediment is characterized by a brown color with a steady transition to grayish green. A general pattern was observed in the matter of color transition of the sediment along the core. It appeared that the deeper the layer, the lighter the color. Sand dollars were dispersed throughout the cores, and small bivalves were seen in relatively high densities along the core. A sulfuric smell was detected from the depth of 160 cm downward.

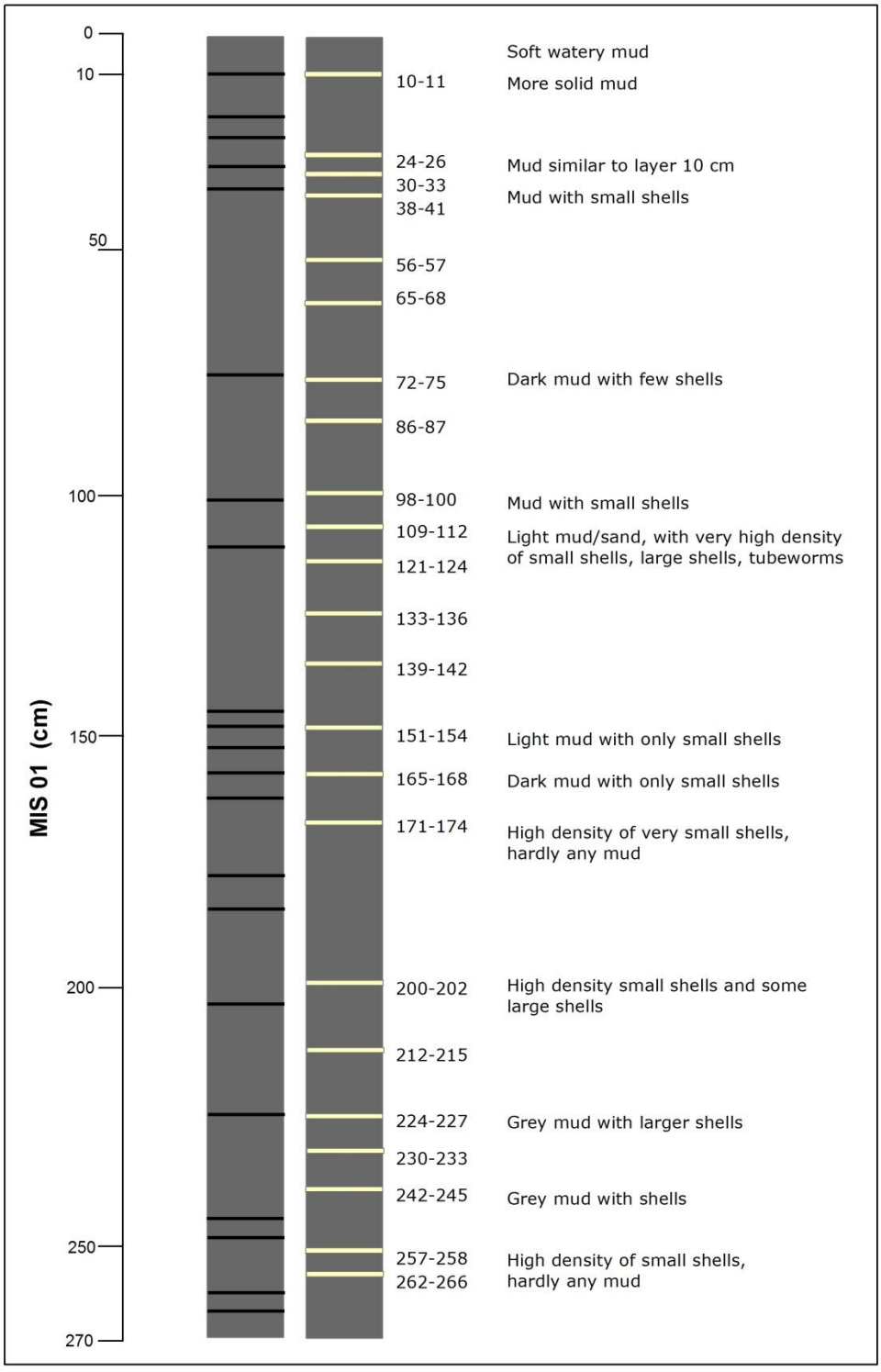

Figure 4. Simplified lithological log of MIS-01 sediment core. Black lines indicates distinctive layers, yellow line indicated the used samples

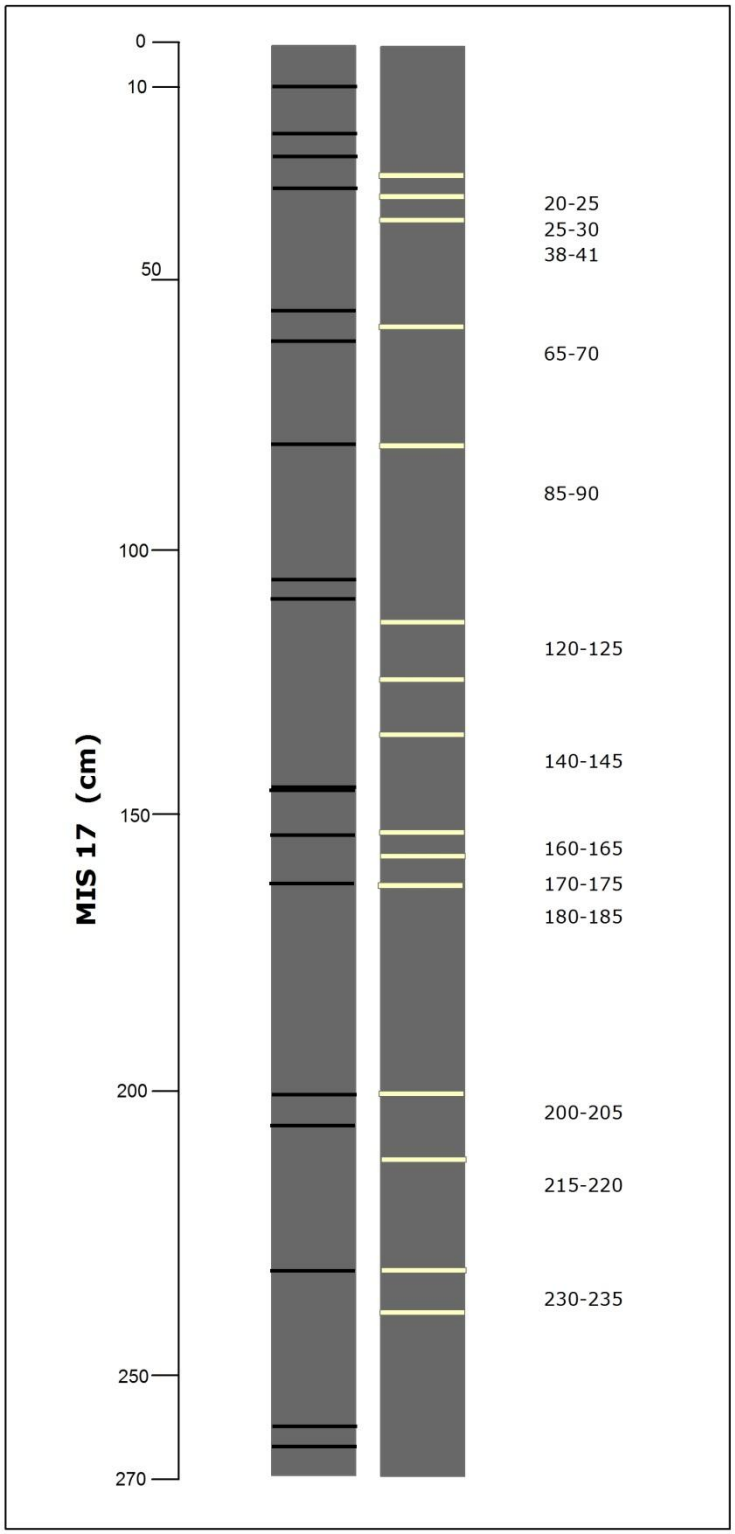

Figure 5. Simplified lithological log of MIS-17 sediment core. Black lines indicates distinctive layers,yellow line indicated the used sample.

3.2 Species diversity and distribution

3.2.1 Species Composition

A total of 6693 benthic foraminiferal specimens, representing 34 species, were identified from 36 samples in both cores (Table.2 and Table 3). These species were accounted to 7 order and 25 family (Appendix 1). Description of the encountered species can be found in Appendix 2. Each core has a speies richness of 31 species and slightly vary in species occurrences. From the total of 34 recognized species, 28 species were observed in both cores and six species; i.e., *Cancris sp., Planispirillina tuberculatolimbata, Uvigerina sp.* in MIS-01, *Cibicides sp, Murrayinella murrayi, Stomatorbina sp* in MIS-17 differentiate the cores assemblages. Approximately 74% of the total foraminiferal species in cores MIS-01 had RA value less than 3 %, whereas RA of 83 % were obtained from the cores of MIS-17. The combination of species list from both cores shows that the species were dominated by hyaline perforated species, account for 25 species in which *Ammonia sp, Brizalina semicarinata, Bolivina striatula, and Bolivina sp 1* and 2 appeared as the prominent species. Four agglutinated species include *Ammobaculites sp, Caronia exilis, Reophax irregularis, Textularia agglutinans, a*nd porcelanous imperforated species consist of *Fissurina bispinata, Lagena sp, Quinqueloculina carinatastriata, Quinqueloculina sp* and *Quinqueloculina exsculpta.*

3.2.2 Species vertical distribution in MIS-01

In figure 6 relative abundance the ten most frequent species are presented versus core depth. The first remarkable feature from the curve is the uniform mirror pattern between *Ammonia sp* and four elongated species of *Bolivina striatula, Brizalina semicarinata, Bolivina sp 1* and *Bolivina sp 2*, which occurs along the core. These species together with *Elphidium oceanicum, Bulimina marginata, Fissurina bispinata,* and *Cancris sp* dominated the upper layer of the cores (RA 5% -80 %), and create the first break at around 60 cm depth when their abundance decrease to RA <5 %. At the same time, two agglutinated species of *Caronia exilis* and *Textularia agglutinans accompanied* with *Hopkinsinella glabra* culminated at maximum 15% RA. Following the first break, another break, although in smaller

magnitude, occurs at about 90 cm level. At this point, *Bolivina tortuosa, Elphidium oceanicum, Bulimina marginata, Fissurina bispinata,* and *Cancris sp* , and species assemblages were predominantly defined as it at the top 60 cm layer. From 90 cm depth to the third break at approximately 130 cm level, *Alliatinella sp, Baginna indica, Cibicidoides sp, Nonion sp, Reophax sp* and *Rosalina orientalis* reach their peak coinciding with the drop of *Ammonia sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1, Bolivina sp 2, Nonion sp, and Cibicidoides sp*. A change in faunal composition was seen remarkably at around 165 cm level. This section were marked by the drop of dominant hyaline species of *Ammonia sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1, Bolivina sp 2, Nonion sp,* simultaneously with an increase in porcelanous imperforated species of *Quinqueloculina carinatastriata, Quinqueloculina sp,* and *Quinqueloculina exsculpta*.

Finally, the last break was visible at around 230 cm level. Further decrease in the major hyaline species and the succession of the porcelanous imperforated species was evident from this zone. Aside from the species turnover, another peculiar signal was the occurances of *Bulimina marginata, Caronia exilis* and *Baggina indica* and the encauntered of several new species; *Ammobaculites sp, Fursenkoina pauciloculata, Lagena sp*. The first three break of the faunal pattern accompanied by the culminating of the foraminiferal density. In comparison to the dominant occurring species, it was clear that from the top of the core, the density fluctuation was in correspond to the succession of *Ammonia sp*.

3.2.3 Species vertical distribution in MIS-17

In contrast to MIS-01, the assemblages in the top 60 cm depth in cores MIS-17 was defined by the succession of almost all 7 dominated species (RA 20 – 80 %) of *Ammonia sp, Quinqueloculina exsculpta, Quinqueloculina sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1 and Bolivina sp* , although downwards from 30 cm level, the trend was in an opposites line. Particularly in between 20-30 cm level, the elongated species of *Bolivina sp 2, Bolivina tortuosa, and Bolivina cf. B. suezensis,* together with *Baggina indica, Fissurina bispinata, Bulimina marginata,* and *Siphogenerina raphana* showed a minor culmination. Whereas, not until 60 cm depth that *Brizalina semicarinata, Caronia exilis, Cibicides sp and Stomatorbina sp*

reach their peak. The same mirror pattern in MIS-01 occurred; *Ammonia sp, Quinqueloculina sp, Bolivina sp 1, Reophax irregularis versus Quinqueloculina exsculpta, Bolivina striatula, Bolivina sp 2, Bolivina tortuosa, Bolivina cf. B. suezensis* around 90 cm depth. At the same time *Murrayinella murrayi* reached its peak. Subsequently, the same mirror pattern continued with two distinctive breaks at 160 cm and 220 cm depth. The occurrence of *Caronia exilis, Lagena sp, and Stomatorbina sp* was the addition at 160 cm assemblages, while *Rosalina orientalis, cibicidoides sp, Fursenkoina pauciloculata, and Allianitella sp* at 220 cm zone. Foraminiferal concentration started to climb up at approximately 85 cm depth, came to climax at around 120 cm level, and dropped at 140 cm depth. This section was marked by the succession of *Quinqueloculina sp.*

Table 2. Species Abundance Data Matrix MIS-01

Species	MIS01-10-11	MIS01-24-26	MIS01-30-33	MIS01-38-41	MIS01-56-57	MIS01-65-68	MIS01-72-75	MIS01-86-87	MIS01-98-100	MIS01-109-112	MIS01-121-124	MIS01-133-136	MIS01-139-142	MIS01-151-154	MIS01-165-168	MIS01-171-174	MIS01-200-202	MIS01-212-215	MIS01-224-227	MIS01-230-233	MIS01-242-245	MIS01-257-258	MIS01-262-266
Alliatinella sp	0	0	0	0	0	0	0	0	0	0	8	0	7	0	11	17	0	7	9	0	0	0	0
Ammobaculites sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Ammonia sp	101	140	68	72	41	68	37	42	83	85	65	84	105	119	107	118	62	42	53	51	78	57	61
Brizalina semicarinata	24	16	17	13	16	0	21	17	13	15	13	0	15	11	12	16	11	11	18	15	13	18	13
Bolivina spathulata	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	9	0	0	0	0	0	0	0
Bolivina striatula	20	11	13	28	63	0	44	34	21	30	47	23	43	53	29	28	27	18	13	21	22	15	18
Bolivina tortuosa	0	0	0	0	18	32	0	0	0	0	0	0	23	0	25	0	7	15	18	6	0	13	16
Bolivina cf. B. suezensis	0	0	0	0	0	13	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
Bolivina sp 1	26	14	19	6	21	0	16	8	5	7	8	4	21	8	9	5	8	4	3	8	4	6	5
Bolivina sp 2	6	3	5	5	8	0	17	11	8	8	17	0	5	6	5	6	4	5	8	3	5	3	5
Bulimina marginata	0	0	16	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	8
Cancris sp	0	0	7	4	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Caronia exilis	0	0	0	0	0	0	14	7	9	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Cibicidoides sp	0	0	0	0	0	0	0	0	8	15	0	21	0	12	8	15	6	8	7	11	8	0	12
Elphidium oceanicum	0	5	5	7	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elongobula sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Fissurina bispinata	0	0	8	3	14	0	0	0	15	0	0	0	5	0	0	0	0	0	0	1	0	0	0
Fursenkoina pauciloculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	5	0
Hopkinsinella glabra	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagena sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Nonion sp	0	6	2	3	0	7	6	5	0	0	15	22	0	0	15	19	12	15	8	19	23	12	18
Planispirillina tuberculatolimbata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	39	17	10	9
Quinqueloculina carinatastriata	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	3	5	5	7	3	3
Quinqueloculina sp	0	0	0	0	2	1	0	0	0	1	0	0	0	0	0	0	15	3	15	21	14	10	11
Quinqueloculina exsculpta	1	0	1	1	3	3	0	0	0	0	0	1	2	0	0	1	19	29	31	65	51	21	14
Reophax irregularis	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0
Rosalina orientalis	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Baggina indica	0	0	0	0	0	0	0	0	0	17	0	13	8	0	0	0	0	0	0	7	11	8	11
Siphogenerina raphana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Textularia agglutinans	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Uvigerina sp	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total individual per sample	178	195	161	151	196	158	155	124	162	178	182	169	253	228	221	234	177	164	196	276	280	203	204

Table 3. Species Abundance Data Matrix MIS-17

Species	MIS17-20-25	MIS17-25-30	MIS 17-30-35	MIS17-65-70	MIS17-85-90	MIS17-120-125	MIS17-140-145	MIS17-160-165	MIS17-170-175	MIS17-180-185	MIS17-200-205	MIS17-215-220	MIS17-230-235
Alliatinella sp	0	0	0	0	0	0	0	0	0	0	0	5	0
Ammobaculites sp	15	8	11	0	0	0	0	0	0	0	0	0	0
Ammonia sp	103	93	124	23	0	24	59	12	34	40	96	64	125
Brizalina semicarinata	0	0	0	10	0	0	0	0	0	20	0	6	0
Bolivina spathulata	3	6	0	0	0	0	0	0	0	0	0	16	0
Bolivina striatula	0	9	23	15	24	15	0	0	0	17	13	30	0
Bolivina tortuosa	4	0	0	2	15	21	24	0	0	0	0	0	0
Bolivina cf. B. suezensis	5	0	0	0	20	14	0	0	0	0	0	0	0
Bolivina sp 1	0	4	10	26	12	12	0	0	0	3	10	8	0
Bolivina sp 2	0	7	0	24	0	0	0	33	0	0	0	0	0
Bulimina marginata	3	0	0	0	0	0	0	0	0	0	0	0	0
Caronia exilis	0	0	0	3	0	0	7	0	0	0	0	0	0
Cibicidoides sp	0	0	0	0	0	0	0	7	0	0	0	11	0
Cibicides sp	0	0	0	6	5	0	0	0	0	0	0	0	0
Elphidium oceanicum	0	0	0	0	0	8	0	0	0	0	0	0	8
Elongobula sp	0	0	0	0	0	0	0	5	45	0	0	0	0
Fissurina bispinata	0	3	0	0	0	0	0	0	0	0	0	0	0
Fursenkoina pauciloculata	0	0	0	0	0	0	0	0	0	0	16	0	0
Hopkinsinella glabra	0	0	0	1	0	0	0	0	0	0	0	0	0
Lagena sp	0	0	0	0	0	0	4	0	1	0	0	0	0
Murayinella murrayi	0	0	0	5	8	6	0	0	0	0	0	0	0
Nonion sp	0	0	0	0	0	0	2	0	0	0	0	12	19
Quinqueloculina carinatastriata	2	0	0	0	0	5	0	0	0	0	0	0	0
Quinqueloculina sp	7	0	4	25	24	53	36	61	29	64	8	0	2
Quinqueloculina exsculpta	6	8	9	2	43	22	21	89	45	23	17	0	3
Reophax irregularis	0	21	24	35	13	0	0	0	0	0	2	0	0
Rosalina orientalis	0	0	0	0	0	0	0	6	0	0	0	15	0
Baggina indica	0	8	0	0	0	0	0	0	0	0	0	0	0
Siphogenerina raphana	0	1	0	0	0	0	0	0	0	0	0	0	0
Stomatorbina sp	0	0	0	3	0	0	4	0	0	0	0	0	0
Textularia agglutinans	26	0	0	0	0	0	0	0	0	0	0	0	0
Total individual per sample	174	168	205	180	164	180	157	213	154	167	162	167	157

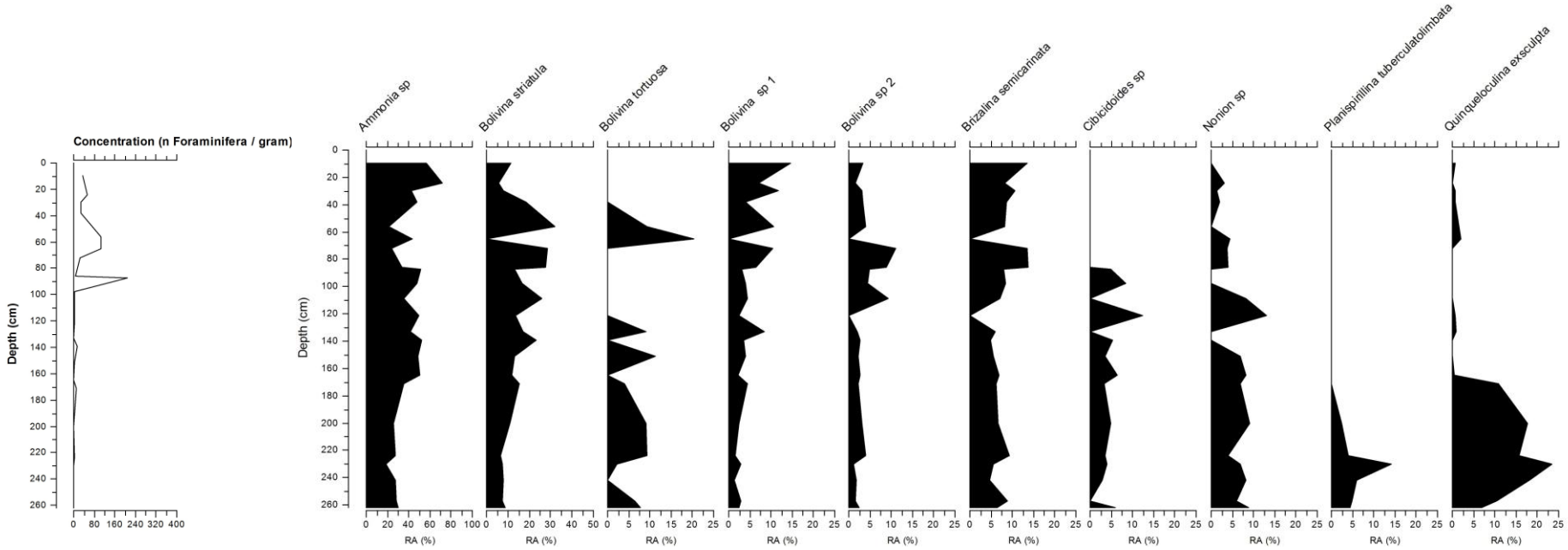

Figure 6. Relative abundances of the most representative foraminifera in cores MIS-01 plotted againts depth (cm). The graph in the left side shows the concentration of speciment calculated in each sample.

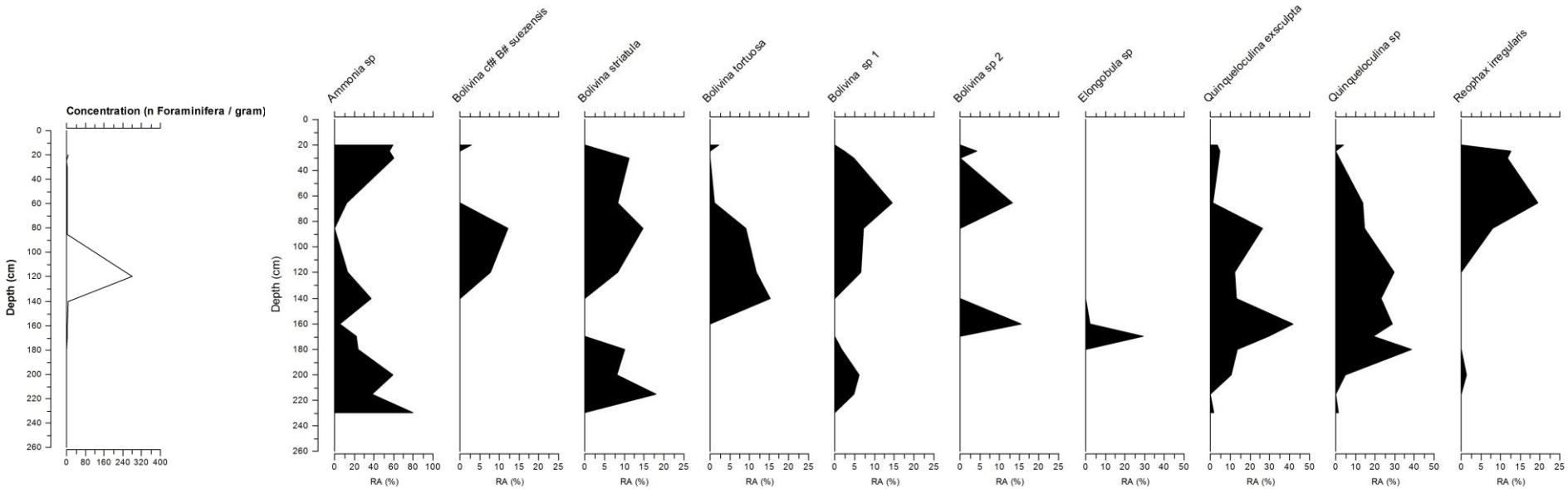

Figure 7. Relative abundances of the most representative foraminifera in cores MIS-17 plotted againts depth (cm). The graph in the left side shows the concentration of speciment calculated in each sample.

3.3 Analysis

3.3.1 Rarefaction

The fact that the sample sizes were not of the same amount for all the used samples, while it was required to compare the species from these different sizes of samples, meant that it was important to verify the effect of sample size on the species count. One way to estimate this was by specifying a certain amount of chosen samples and observing the number of species recovered from this chosen size. In this study, the chosen sample size was n=100 (Table 4 and 5). Furthermore, a rarefaction curve was plotted, which derived from the number of specimens count and species observed.

Table 4. Calculated data for rarefaction curve of lake MIS-01

Sample Code	N sp count	N of Species	Number of species standardized in Samp size n =100	Standard Error
MIS01-10-11	178	6	5,6	0,5
MIS01-24-26	195	7	6,8	0,4
MIS01-30-33	161	11	10,5	0,6
MIS01-38-41	151	11	10,6	0,6
MIS01-56-57	196	11	10,5	0,6
MIS01-65-68	158	9	8,6	0,5
MIS01-72-75	155	7	7,0	0,0
MIS01-86-87	124	7	7,0	0,0
MIS01-98-100	162	8	8,0	0,1
MIS01-109-112	178	8	7,6	0,5
MIS01-121-124	182	9	8,9	0,2
MIS01-133-136	169	8	7,2	0,7
MIS01-139-142	253	12	11,4	0,7
MIS01-151-154	228	8	7,9	0,3
MIS01-165-168	221	9	8,9	0,2
MIS01-171-174	234	10	9,3	0,6
MIS01-200-202	177	12	11,5	0,5
MIS01-212-215	164	13	12,8	0,4
MIS01-224-227	196	13	12,8	0,4
MIS01-230-233	276	15	13,7	0,9
MIS01-242-245	280	14	13,6	0,6
MIS01-257-258	203	16	15,4	0,7
MIS01-262-266	204	14	13,8	0,4

Table 5. Calculated data for rarefaction curve of lake MIS-17

Sample Code	N sp count	N of Species	Number of species standardized in Samp size n =100	Standard Error
MIS17-20-25	174	10	9,6	0,5
MIS17-25-30	168	11	10,5	0,5
MIS 17-30-35	205	7	6,9	0,2
MIS17-65-70	180	14	12,9	0,8
MIS17-85-90	164	9	8,9	0,1
MIS17-120-125	180	10	9,9	0,2
MIS17-140-145	157	8	7,8	0,4
MIS17-160-165	213	7	6,9	0,3
MIS17-170-175	154	5	4,6	0,5
MIS17-180-185	167	6	5,9	0,2
MIS17-200-205	162	7	6,8	0,4
MIS17-215-220	167	9	8,9	0,1
MIS17-230-235	157	5	4,8	0,4

Rarefaction curve of three sample (top, middle, and bottom) from both cores are shown in figure 8. A flat curve towards the larger specimen count indicates that the sample has recovered most of the species, whereas the unflattened curve suggests that we might found more species for further sample count. A flat curve was observed from almost all the sample from both cores; however, some exception was still appeared (Figure 8).

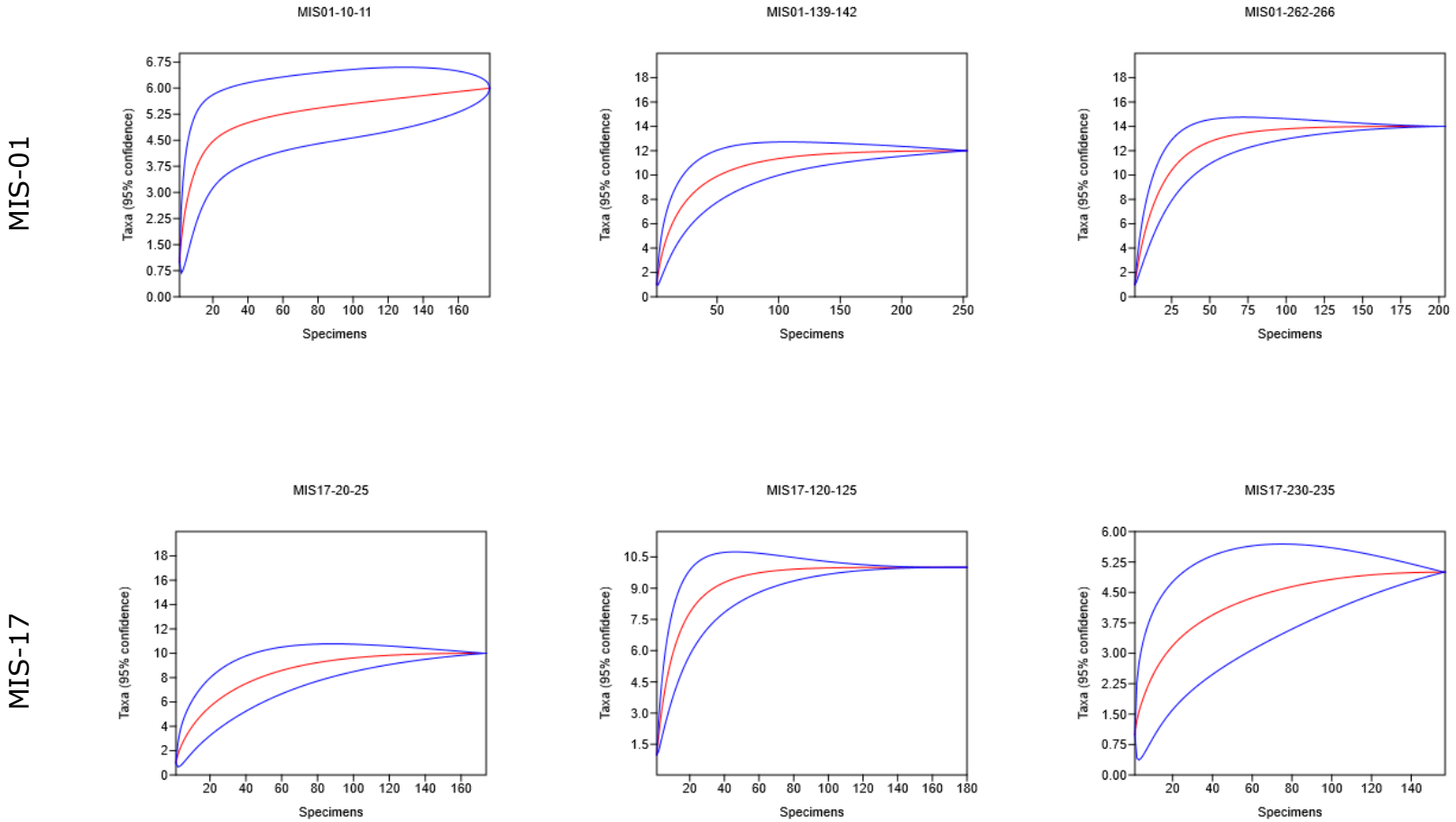

Figure 8. Rarefaction curve of three representative samples from top,middle, and bottom layer of the cores

3.3.2 Diversity Indeces

3.3.2.1 Diversity indices of MIS-01

The species richness in MIS-01 ranged between 6 and 16. Overall, the species richness started with its lowest number at the top layer of the core and increased to its first peak in between 30 and 57 cm depth. Thereafter, separated by a peak at 139-140 cm depth, two gradual fluctuations occurred. At last, from 200 to 266 cm depth, the species richness was considerably high, up to the value of 16. In contrast with the foraminiferal density, the highest amount of the species richness at the bottom layer of the core was observed when the concentration dropped.

Table 6. Diversity Indices of MIS-01

Sample	n	Number of Species	Number of species standardized in Samp size 100	Standard Error	Shannon Diversity Index
MIS01-10-11	178	6	5,6	0,5	1,3
MIS01-24-26	195	7	6,8	0,4	1,1
MIS01-30-33	161	11	10,5	0,6	1,9
MIS01-38-41	151	11	10,6	0,6	1,7
MIS01-56-57	196	11	10,5	0,6	2,0
MIS01-65-68	158	9	8,6	0,5	1,7
MIS01-72-75	155	7	7,0	0,0	1,8
MIS01-86-87	124	7	7,0	0,0	1,7
MIS01-98-100	162	8	8,0	0,1	1,6
MIS01-109-112	178	8	7,6	0,5	1,6
MIS01-121-124	182	9	8,9	0,2	1,8
MIS01-133-136	169	8	7,2	0,7	1,5
MIS01-139-142	253	12	11,4	0,7	1,9
MIS01-151-154	228	8	7,9	0,3	1,4
MIS01-165-168	221	9	8,9	0,2	1,7
MIS01-171-174	234	10	9,3	0,6	1,7
MIS01-200-202	177	12	11,5	0,5	2,1
MIS01-212-215	164	13	12,8	0,4	2,2
MIS01-224-227	196	13	12,8	0,4	2,3
MIS01-230-233	276	15	13,7	0,9	2,3
MIS01-242-245	280	14	13,6	0,6	2,3
MIS01-257-258	203	16	15,4	0,7	2,4
MIS01-262-266	204	14	13,8	0,4	2,3

Resembling the plot of the species richness (Figure 9), the Sstan plots in MIS-01 suggested that the chosen n=100 was adequate for sample comparison. In general, Shannon diversity index varied between 1.1 and 2.4. Plotted value of this index (Figure 9) was almost identical with species richness and standardized species reaches. However, it was slightly different at the top cores of 10 to 24 cm depth.

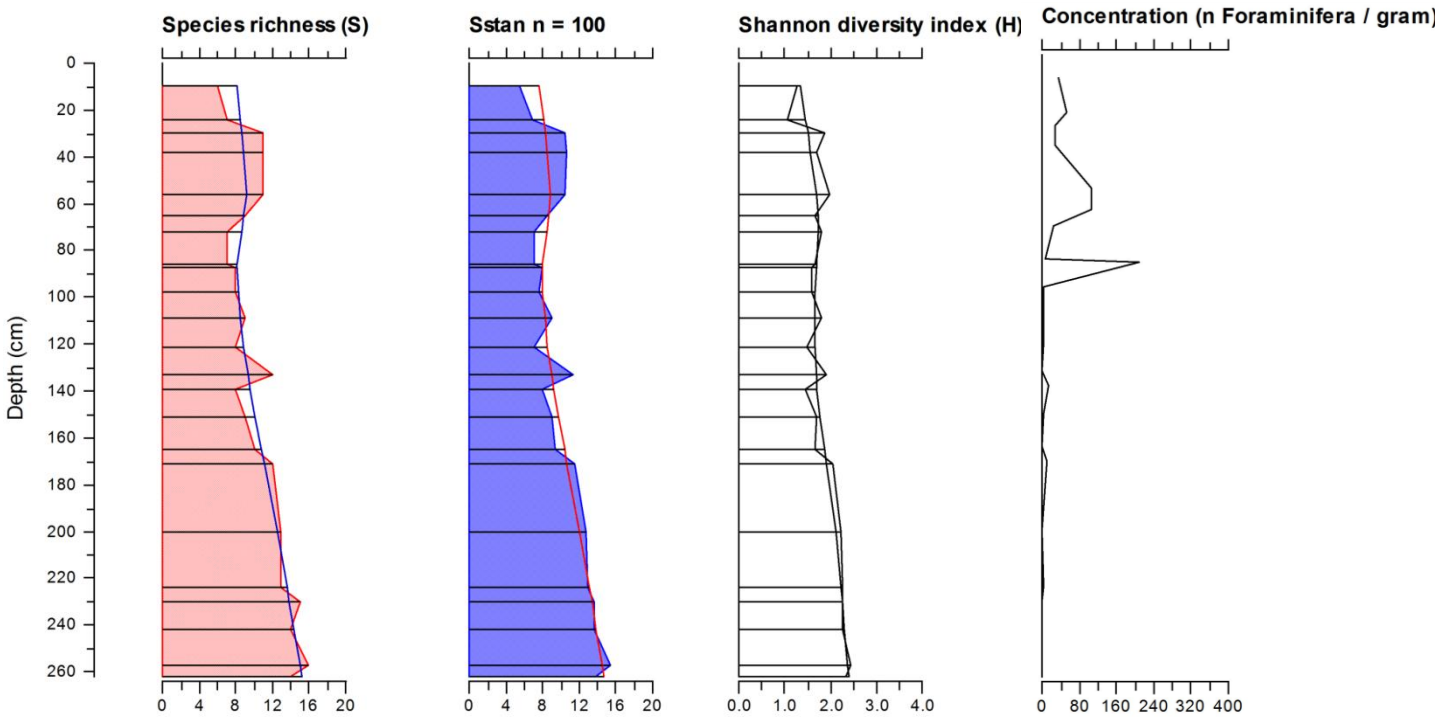

Figure 9. Diversity indices of MIS-01 sediment cores. From left to right : species richness (S), Standardize species richness (Sstan), Shannon diversity index, and foraminiferal concentration.

3.3.2.2 Diversity indices of MIS-17

The species richness of MIS-17 ranged between 5 and 14. Contrary to MIS-01, the lowest value of species richness in MIS-17 was observed at the middle of 170 – 175 cm level and bottom layer 230-235 cm depth, while the maximum richness appeared at the upper layer of 65-70 cm. The fluctuation of Sstan and Shannon diversity index (0.7 -2.3) was similar to the species richness, where in general the three indices parameters gradually decreased downwards.

Table 7. Diversity Indices of MIS-17

Sample	n	Number of Species	Number of species standardized in Samp size 100	Standard Error	Shanon Diversity Index
MIS17-20-25	174	10	9,6	0,6	1,4
MIS17-25-30	168	11	10,5	0,6	1,6
MIS 17-30-35	205	7	6,9	0,3	1,3
MIS17-65-70	180	14	13,0	0,8	2,3
MIS17-85-90	164	9	9,0	0,1	2,0
MIS17-120-125	180	10	10,0	0,2	2,1
MIS17-140-145	157	8	7,8	0,4	1,6
MIS17-160-165	213	7	6,9	0,3	1,5
MIS17-170-175	154	5	4,6	0,5	1,4
MIS17-180-185	167	6	5,9	0,2	1,5
MIS17-200-205	162	7	6,9	0,4	1,4
MIS17-215-220	167	9	9,0	0,1	1,9
MIS17-230-235	157	5	4,8	0,4	0,7

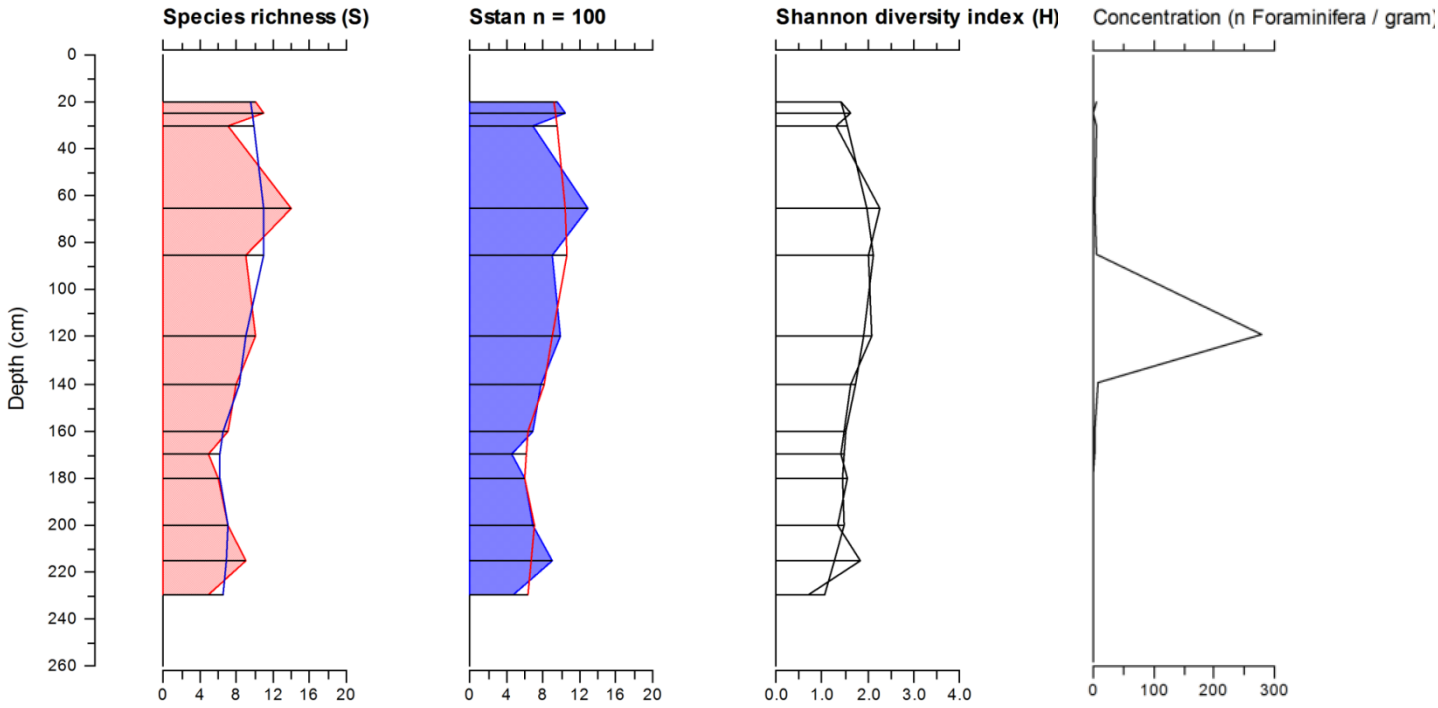

Figure 10. Diversity indices of MIS-17 sediment cores. From left to right : species richness (S), Standardize species richness (Sstan), Shannon diversity index, and foraminiferal concentration.

3.3.3 Cluster analysis and Non-metric multidimensional scaling (NMDS) plots

Cluster analysis and Non-metric multidimensional scaling (NMDS) plots were conducted in Q-mode and R-mode in log (x+1) transformed abundances data matrix for all sample from both cores. The analysis consisted of all identified species and selected species with RA range from 25 % - 100 % (*Ammonia sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1, Bolivina sp 2, Nonion sp, Bolivina tortuosa, Cibicidoides sp, Quinqueloculina sp, Quinqueloculina exsculpta, Planispirillina tuberculatolimbata, Elongobula sp, Reophax irregularis*).

3.3.3.1 Cluster analysis and Non-metric multidimensional scaling (NMDS) plots MIS-01

Dendrogram in figure 11 shows six primary clusters at approximately 67,5% similarity when all species were included and had 80% similarity with 13 most dominant species. To investigate whether the cluster analysis would generate a depth-boundary, the sample was pre-colored; red: upper samples, blue: middle samples, black lower samples. However, the expected boundary was not fully observed.

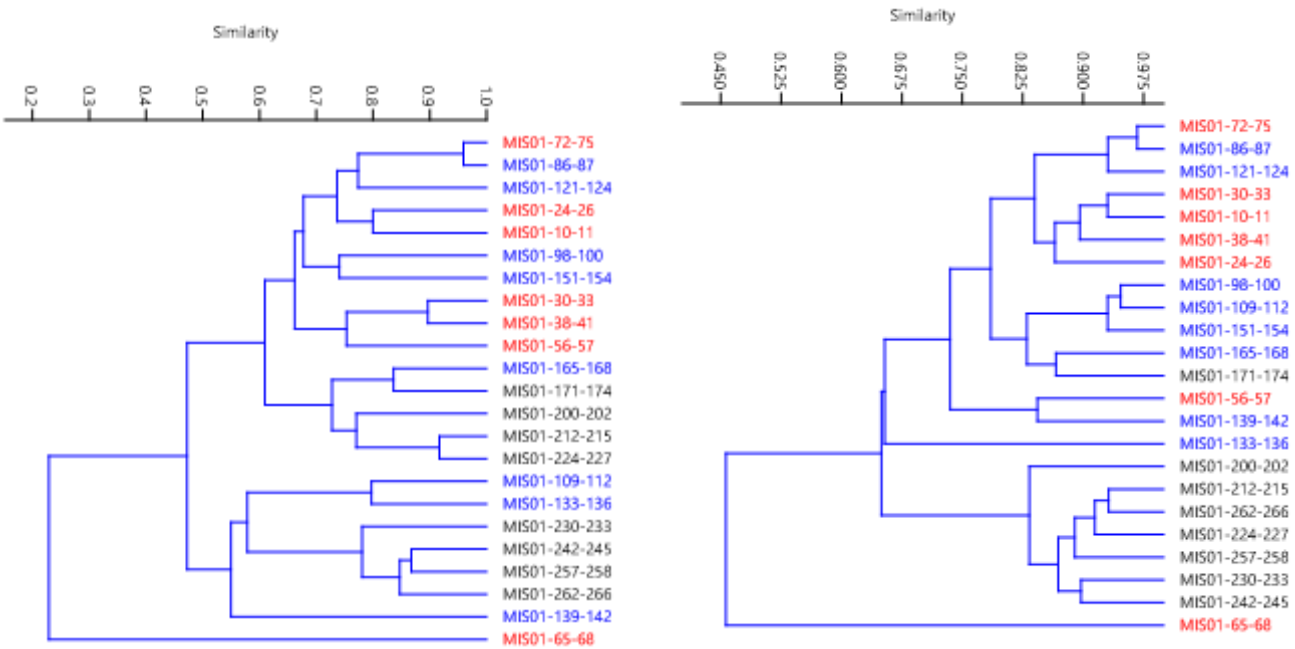

Figure 11. Dendograme plot of cluster analysis on all species (left) and selected species (right) MIS-01.

All samples within their depth division shared the same amount of cluster for both analyses, although the lower samples were strongly grouped within the selected species analysis. Separated from the other samples, MIS01-65-68 emerged as the most different sample. In addition, observation based on the sample displayed the grouping of co-occurrence species. The NMDS plot (Figure 12) grouped the samples roughly in the same arrangement as that of cluster analysis. Although the middle sample (blue dots) scattered irregularly, both vertical axis in both analysis suggested a depth separation. Within the all species analysis, a value of 0,19 stress coefficient was observed and showed 0,11 point for selected species analysis. The plots further confirmed the separation of sample MIS01-65-68 (red dots in the right corner of the map) with the other samples within the cores.

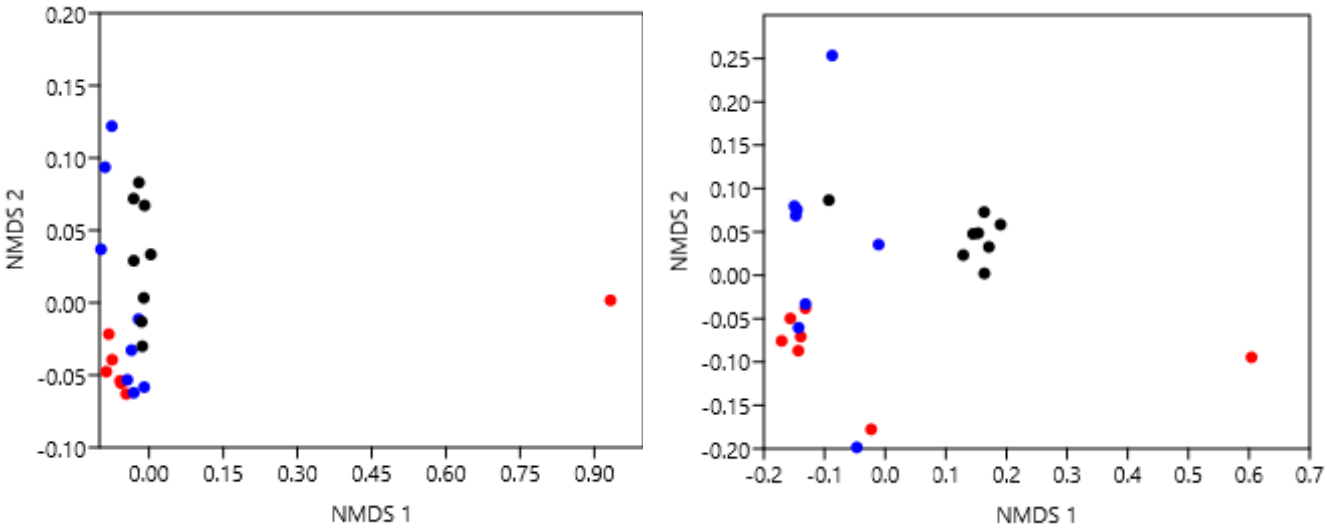

Figure 12. NMDS plot of sample from MIS-01 with log transformed abundanc data of all species (left) and selected species (right).

NMDS plots based on samples which included all identified species distributed the species randomly (figure not shown); conversely, a vertical and horizontal separations slightly emerged in the sample plots with selected species. As can be seen from figure 13, the dominant species in the upper layer of the cores were grouped together in the lower-middle axis (*Ammonia sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1, Bolivina sp 2, Nonion sp, Bolivina tortuosa, Cibicidoides*

sp). Meanwhile, species which dominated the bottom layer of the cores were scattered in the top-middle axis (*Quinqueloculina sp, Quinqueloculina exsculpta, Planispirillina tuberculatolimbata*). The estimated stress coefficient for the NMDS plot with selected species (Figure 13) was 0,13.

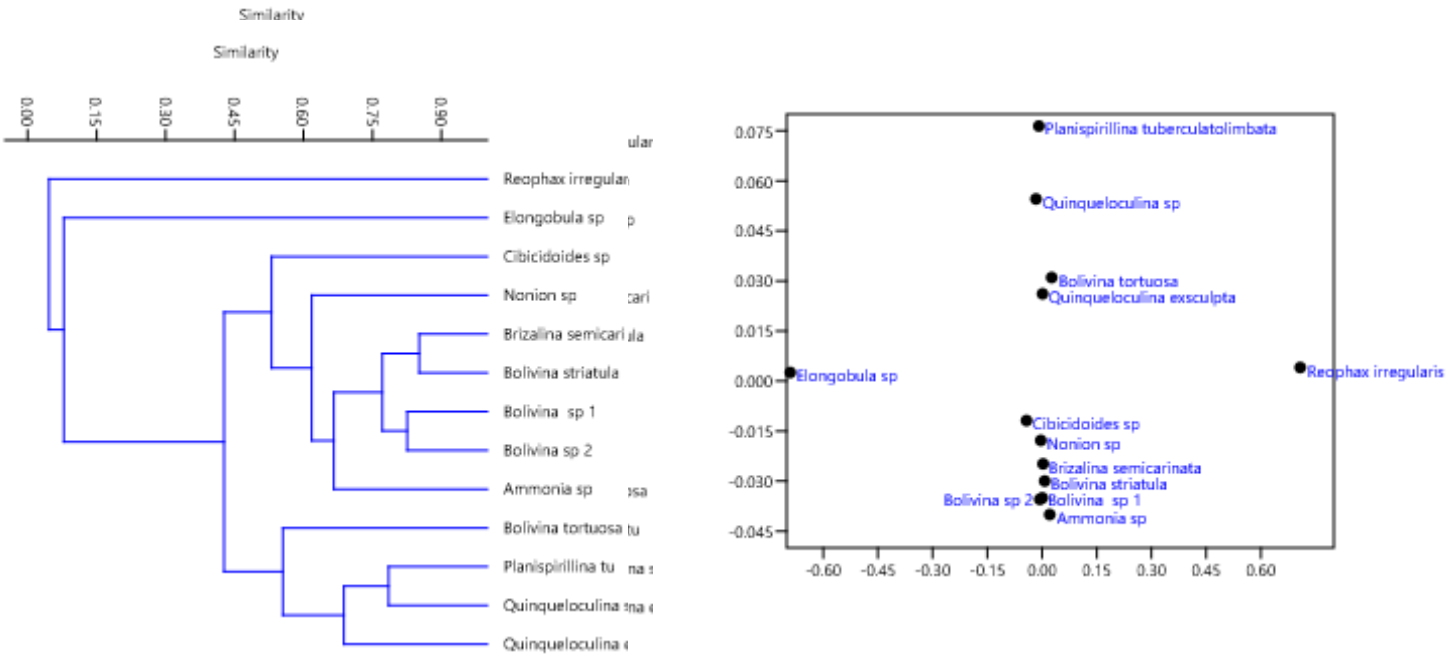

Figure 13. Dendograme plot of cluster analysis on selected species (left) and NMDS plot of selected species (right) from MIS-01.

3.3.3.2 Cluster analysis and Non-metric multidimensional scaling (NMDS) plots MIS-17

Cluster analysis revealed six main group which included all species and 4 group within selected species analysis (Figure 14). Both analysis clustered at 52,5% similarity and grouped the samples in the same number of cluster. A similar depth partition was applied to the sample in the cores; red: upper samples, blue: middle samples, black: lower samples. Unfortunately, as it was in MIS-01, there was no visible indication for an explicit grouping within this core. Another unique sample

(MIS17-215-220, was recognized for its major portioning to the other samples. As for the cluster based on the samples, the same trend in core MIS-01 was observed where the coexisted species tended to cluster together (figure 15). An explicit pattern was not firmly found in NMDS plot based on species, despite a modest horizontal axis separation of the sample in vertical gradient. Both NMDS plots based on species showed remarkably high-stress coefficient; 0,2 for all species (figure not shown), and 0,17 within the selected species. Plotting with chosen species illustrated diagonal division of the species, where the upper and lower dominant species resided in the right-bottom region of the plot and the moderate middle species occupied the upper right area.

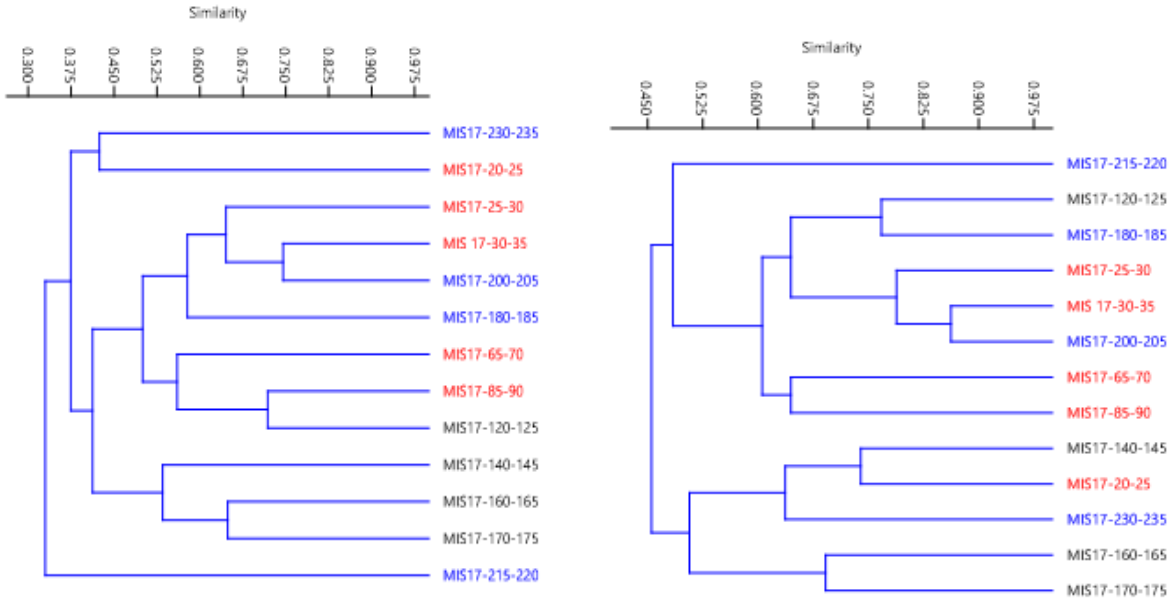

Figure 14. Dendograme plot of cluster analysis on all species (left) and and selected species (right) from MIS-17.

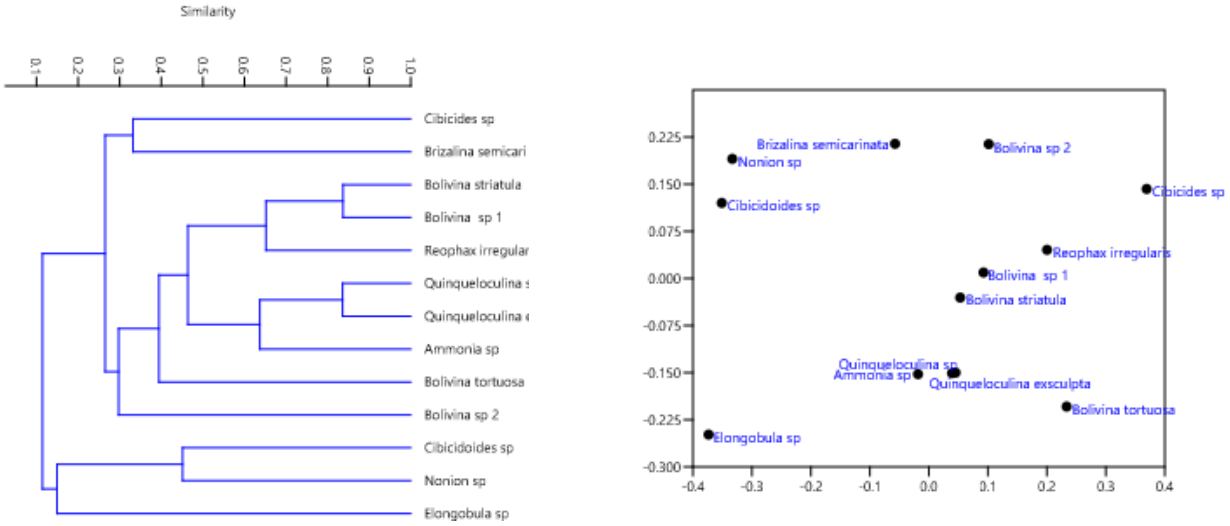

Figure 15. Dendograme plot of cluster analysis on selected species (left) and NMDS plot of selected species (right) from MIS-17.

3.3.3.3 Combined Cluster analysis and NMDS plot of MIS-01 and MIS-17

As seen in figure 16 for the Q-mode cluster, both clustering revealed two significant clusters, which each further subdivided into six subgroups. For both analyses, the sample from individual cores did not wholly cluster together, however, a visible depth separation could be observed for each of the cores. Several groups in analysis for all species shared almost the same composition in cluster from analysis on selected species: Cluster 1 in all species showed the same sample with cluster 1 in selected species analysis; cluster 2 and cluster 6 in all species analysis were in accordance to cluster 2 and 3 in selected species analysis; cluster 3 in all species agreed with cluster 6 in selected species; finally cluster 4 and 5 in all species also agreed with cluster 5 in selected species. An exceptional result was observed from both cluster for five samples of MIS 17-20-25, MIS 17-180-185, MIS 17-215-220, MIS-17 230-235 and MIS-01 65-68, these samples were grouped and they resided independently within the group where they clustered.

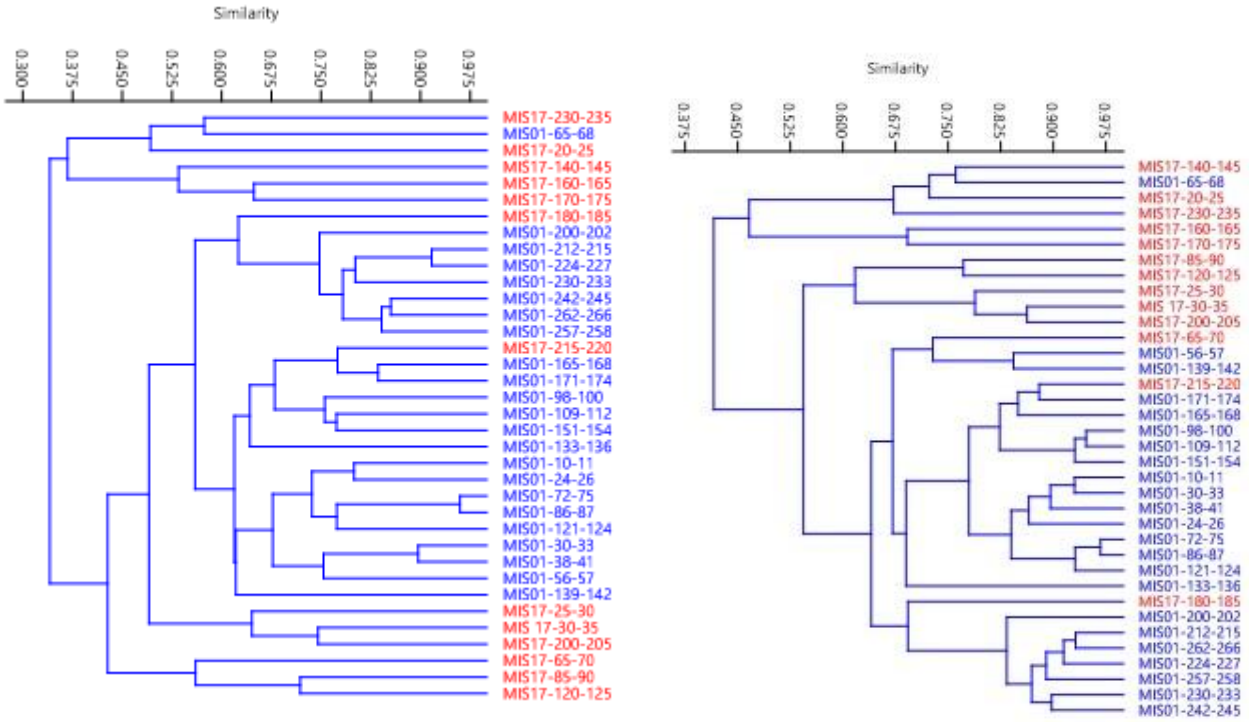

Figure 16. Dendograme plot of cluster analysis on all species (left) and and selected species (right) from both MIS 01 and MIS-17.

In order to investigate whether the species fell into natural groups, cluster analysis were conducted in R-mode using all identified species and the 13 most dominant species (*Ammonia sp, Bolivina striatula, Brizalina semicarinata, Bolivina sp 1, Bolivina sp 2, Nonion sp, Bolivina tortuosa, Cibicidoides sp, Quinqueloculina sp, Quinqueloculina exsculpta, Planispirillina tuberculatolimbata, Elongobula sp, Reophax irregularis*) from all samples in both cores.

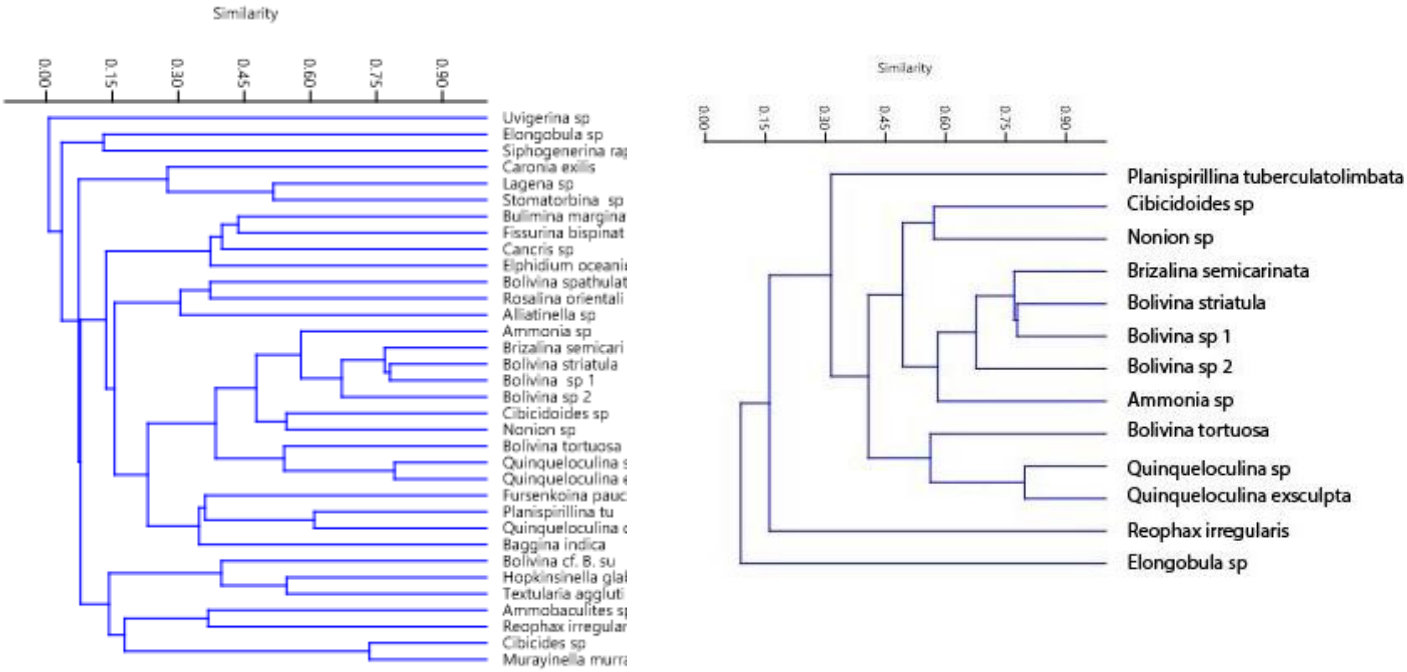

Figure 17. Dendograme plot of cluster analysis based on sample for all species (left) and selected species from both cores MIS-01 and MIS-17 (right).

Cluster analysis with all species was distinguished into five main clusters. The smallest cluster consisted of; cluster 1 separated Uvigerina sp as a single member of the cluster, cluster 2 included Elongobula sp and Siphogenerina raphana, cluster 3 consisted of Caronia exilis, Lagena sp, and Stomatorbina sp. In cluster 4, four subdivisions appeared while three subdivisions could be made in cluster 5. As for the selected species on R-mode analysis, it was clear from the dendrogram in figure17 that there were 4 significant clusters in which three of them (cluster 1,3 and 4) were represented by a single species, and cluster 2 was subdivided into four subgroups. In regards to species appearance along the cores, it was suggested from both R-mode that the cluster of the species fell into the numbers of species occurring along the cores. The dominant species; e.g, *Ammonia sp, Q. exsculpta, Bolivina sp,* and *Brizalina semicarinata* occupied the same cluster, while the rare species clustered rather individually. Assessment for trend and grouping of samples and species in both cores were conducted for both Q-mode, and R-mode data matrix, including all identified species with NMDS analysis.

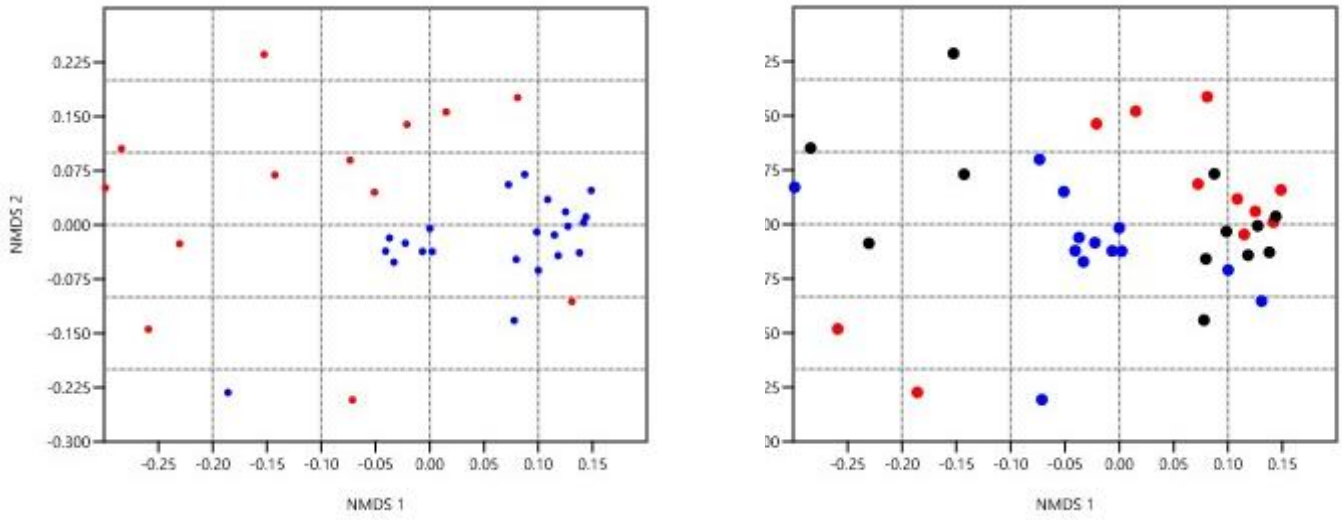

Figure 18. NMDS plot based on species for all samples in both cores (left) and selected species with depth division (right).

The first Q-mode plots (blue dots are the sample from MIS-01, red dots are the sample from MIS-17) produced horizontal and vertical separation of the two individual cores (Figure 18). In the horizontal axis, two clusters were found from cores MIS-01, which suggested a depth boundary between the upper and the lower sample within the cores. Sample from MIS-17 resembled a random spread in the horizontal axis. The vertical axis seemed to be correlated with the origin of the cores. Samples from MIS-01 dominated the lower part of the vertical axis, while most of the samples from MIS-17 scattered in a higher axis. Further observation was made by subdividing the sample from both cores to three depth categories (upper samples in red dots, middle samples in black dots, and lower sample in blue dots). Here, it can be observed that the sample was generally clustered together along the depth gradient in the horizontal axis, although some deviation still occurred. From both Q-mode plots, the obtained stress coefficient of 0,18 was relatively high.

Two R- mode plots were constructed for both all species identified and 13 most dominant species. Both NMDS plots illustrated clustered relatives to the abundance of species occurs. Projection in horizontal axis demonstrated the

clusters of the most dominant species (Ammonia sp, Q. exsculpta, Q.sp, Bolivina striatula Bolivina sp, and Brizalina semicarinata), as the intermediate and rare species scattered away from this cluster. Stress coefficient for all species analysis (0,3) was higher than the selected species analysis (0,1).

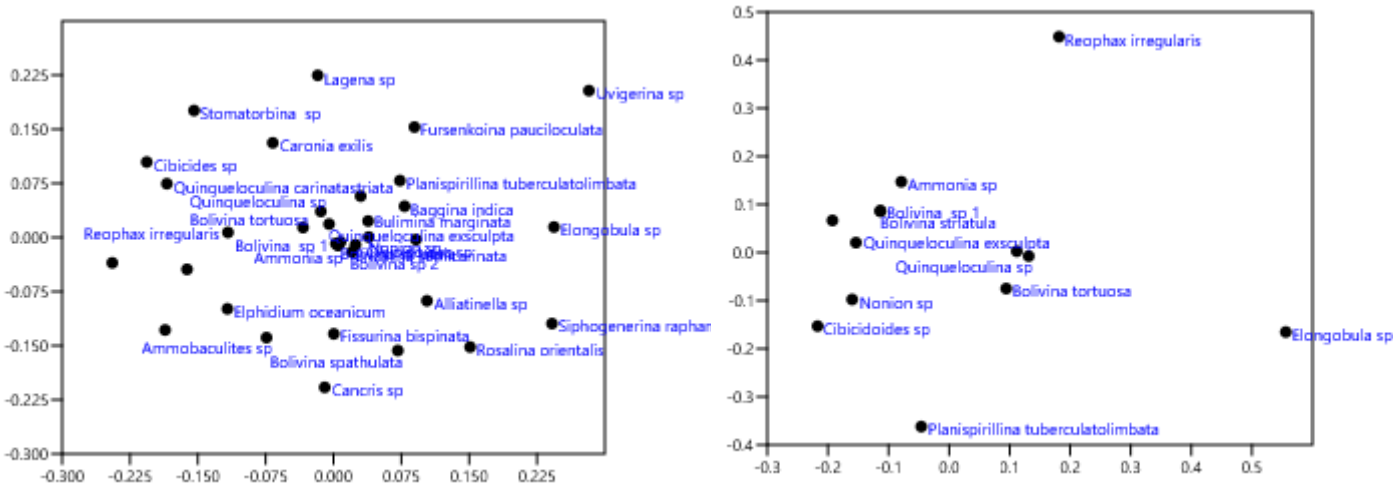

Figure 19. NMDS plot based on samples for all samples in both cores (left) and selected species (right).

3.3.4 ANOSIM

Using Bray-Curtis similarity index, One-way ANOSIM was carried out to check the difference in the species' assemblage composition between the groups of samples within the cores and between the cores. For the individual test, each core was divided into three groups (top, mid, bottom) and tested. Whereas, the test between the cores assigned the cores as two different group.

The three group of samples tested in cores MIS-01 showed in general; R = 0,38, P (SAME) = 0,0002. Pairwise between the group showed maximum R-value of 0,66 (group 1 and group 3) and a minimum value at 0,16 between group 1 and 2. The very small R –value indicated that the sample had low separation. The three group of samples tested in cores MIS-17 showed in general R = 0,32 P (SAME) = 0,0063. Pairwise between the group showed maximum R-value of 0,88 (group 2 and group 3) and a minimum value at 0,02 between group 1 and 2. This R-value

suggested that the sample had low separation. The group of samples tested in cores MIS-01: group 1, MIS-17: group 2. When the test was conducted between the cores, the assemblages composition relatively differed, although less significant (ANOSIM; R = 0,54; P= 0,0001).

4. Discussion

This study aims to investigate the dynamics of past community composition, distribution, and biodiversity of benthic foraminifera from two marine lakes in Misool Raja Ampat and eventually interpret the change in past environmental condition of the lakes. Most notably, this research will contribute as the first study of benthic foraminiferal assemblages from these lakes and provide insight into the limited understanding of past marine lakes environment in general. The composition of foraminiferal assemblages in Lake MIS-01 and lake MIS-17 from Misool was indicative of tropical marginal marine environment to tropical shelf environment (Murray, 2006). According to Amstrong and Bresier (2005), the diversity of modern benthic foraminifera from these habitats is less than from general marine and deep-sea habitats. The two studied cores were characterized by low diversity, with the domination of the hyaline genus *Ammonia, Bolivina, Brizalina, Cibicidoides* and *porcelenous genus of Quinqueloculina*. Despite the fact that the number of species found in the two studied cores was the same, the calculation and plots of the diversity indices along each cores were not entirely similar. Lake MIS-01 showed an increase in the number of species towards the deeper samples, while lake MIS-17 had a higher species diversity in the shallower samples. Since the distance from the nearby coastal was about the same, a possible explanation was the difference in the depth of the lakes. In accordance to the fact that these marine lakes were originated during the Holocene (Becking et al.,2011), it was likely that the deeper lake was flooded earlier and thus had a longerer period of colonization compared to the shallower lakes which were flooded later.

Despite the lack of study on foraminifera diversity and distribution from marine lakes environment, several studies had been reported (Lips and Langer,1999; Dondorp, unpublished data). Lipps and Langer (1999) studied the benthic foraminifera from Mecherchar Jellyfish Lake in Palau for its habitat and associated biota. The faunal composition from this site was characterized by low diversity (15 species recovered), where the species was composed of mostly thin-shelled species and highly delicate and fragile tests. The foraminiferal fauna was dominated by *Helenina sp. and Ammonia sp.,* with fewer *Elphidium sp.,*

Siphogenerina raphana, and smaller miliolids. In respect to the species composition, the nature of the test, and their low species diversity (<40 species, Botolvskoy 2013), Lips and Langer (1999) concluded that the foraminifera from Mecherchar Jelly fish lake closely resembled modern foraminiferal from organic-rich mangrove habitats. Similar to what Lips and Langer (1999) had found, a study from Dondorp (unpublish data) in Kakaban lakes, East Kalimantan revealed that the assemblages were composed of low diversity foraminiferal fauna. The fauna is composed of eight hyaline perforate species (*Elphidium cf E. singaporense, Elphidium cf E. hyalocostratum, Elphidium galearensis, Ammonia sp., Helenina sp., Aphelophragmina semilinata, Rosalina orientalis* and *Haynesina depressula*) and three porcelaenous imperforate species of the order Miliolida(*Quinqueloculina cf Q. eamesii, Quinqueloculina cf Q. exsculpta, Quinqueloculina laevigata*) and one agglutinated species (*Haplophragmoides sp*.) with *Ammonia sp* and *Elphidium* sp as the dominant species. Agglutinated tests such as *Glomospira fijiensis* and *Rheophax scorpiurus* were more abundant in Mecherchar, especially at the chemocline boundary zone, than in Kakaban with only one identified species. In comparison to the foraminiferal species composition, the domination of *Ammonia sp* from the two lakes in Misool is in general agreement within the Mecherchar Jellyfish Lake and Kakaban Lake. Although the diversity was still considered low, a higher diversity of species wqw obtained from Misool lakes where each of the lakes consisted of 31 species. Considering the similarity in the species appearance and the number of species recovered, the foraminifera from Misool seemed to have a more similar composition to the one in Mecherchar Jellyfish Lake.

The vertical distribution of species, together with the statistical analysis of the foraminifera as have been describe in the result of species diversity and distribution, indicated six major breaks which correlated to the six major cluster of the sample. These zones were primarily defined by the differences between observed dominant species *Ammonia sp, Brizalina semicarinata, Bolivina striatula, and Bolivina sp, Quinqueloculina carinatastriata, Quinqueloculina sp* and *Quinqueloculina exsculpta* and the rare co-occurrence species. Off all the recognized zone, there were two most apparent pattern species distributions, which were marked by the shift in relative abundance of *Amonia sp* and species from the

genus of *Quinqueloculina.* Approximately at 170 cm depth in MIS-01 and 160 cm depth in MIS-17, both cores displayed a decrease in the major hyaline species of *Ammonia sp* and increase in species from the genus of *Bolivina* except *Bolivina striatula* in MIS-01. An interesting feature which differentiated the cores was the highest occurrence of *Quinqueloculina exsculpta* and *Planispirillina tuberculatolimbata* in MIS-01. Both species were considered indicators of warm water environment (Hallock et al. 2003; Yanko et al. 1999; Bernhard and Gupta 1999). Cluster analysis and NMDS plots based on the sample confirmed the separation between *Ammonia sp* and species from the genus *Quinqueloculina*, particularly in MIS-01. *Ammonia sp* was the most tolerant opportunistic species, however, their relative abundance dropped once the environment shifted to dysoxic condition (Dabenai et al., 2009). Co-occurring species of the genus Bolivina further confirmed the dysaerobic condition of the environment. This eurotrophic species has been reported to be dominant in a habitat with low oxygen (Amstrong and Brasier, 2005). Furthermore, within a group of closely related *Bolivina*, Barmawidjaya et al. (1992) showed that the ornamented striatula type was limited to the sediment surface, whereas unornamented type had a clear infaunal dysoxic preference. Thus, the breaks in the cores might be associated to a warm dysoxic environment. A change in faunal composition again occurred between Ammonia sp and two species of the genus *Quinqueloculina* at around 80-90 cm depth in MIS-17. Amstrong and Brasier (2005) proposed that *Ammonia sp* and agglutinated foraminifera favored environments with low salinity, in contrast with the porcelaneous Miliolina, especially Quinqueloculina, which appeared to favor hypersaline water where salinity was more than 40 per mil. The agglutinate species of *Ammobaculites sp, Caronia exilis, Reophax irregularis, Textularia agglutinans* were most abundant in the shallower layer of both cores. Study has shown that these species were mostly found in low salinity environment, particularly in brackish lagoon and marshes (Debenay 1990; Hayward and Hollis, 1994; Amstrong and Brasier,2005). Therefore, in addition to the indication of a change in oxygen level, it could be assumed that salinity might have been another regulator for the change in species composition and the observed break.

Even though the vertical distribution differed in magnitude and fluctuation per individual species, the overall distribution of foraminifera species with a range of similar environment tolerance was witnessed from both cores. This, in fact, implied that a change must have occurred in the past environment. One way to further confirm the change in both lakes environment was by examining another fossil record from the lakes. Study on Mollusk faunal distribution was conducted by Klei (2017, unpublish data). From both mollusk descriptive and statistical analysis, it was reported that the upper and lower sample were different from ~200 cm depth in both cores and most protrude in MIS-01 while the surface sample from MIS-17 showed a higher similarity with sample from MIS-01. The diversity was higher in lower samples with eight species in MIS-01 and ten species in MIS-17. Both cores shared almost the same composition for the dominant species with a little variation in species occurrences. The 200 cm boundary was consistent with the change in grain size of the sediment. Considering the depth of this boundary and the last break at 200-230 cm of foraminifera, the fossil record of mollusks and foraminifera from both cores confirmed the change in their composition throughout the documented record. Although both fossil groups provided similar facts of changing community composition, the difference in depth and number of observed species suggested that as an environmental indicators, foraminifera was more sensitive in both lakes.

5. Conclusion and Outlook

This study documented for the first time the benthic foraminifera diversity and distribution in two poorly studied marine lakes of Misool Island, Raja Ampat. Overall, the foraminiferal fauna from both lakes was characterized by a low diversity with *Ammonia sp, Brizalina semicarinata, Bolivina striatula,* and *Bolivina sp* as the dominant species. Vertical distribution of the species indicated six major breaks which correlated to the six major clusters of the sample with a distinguished depth boundary. Comparison on the assemblages and species diversity from Kakaban Lake, East Kalimantan and Mecherchar Jellyfish Lake, Palau showed that the assemblages from Misool were more similar with the one from Palau. Assessment from the individual species and assemblages' environmental preference suggested that oxygen level and salinity might have been the driving force behind the changes in community assemblages. In comparison to the other community, the temporal partitioning along the cores fit very well with those based on the mollusk community, particularly at approximately 200 cm depth where diversity was higher than the upper layer.

The present study on the foraminifera assemblages contributes to the knowledge of the past diversity and environment of the lakes. However, further assessment should be explored to verify the results. An essential aspect of future studies is to derive an age model (C-14 dated) along the core and validate the obtained pattern and boundary between the lakes. Together with the age determination, replicated study for different core position will provide a better correlation within the lakes. Moreover, study on the chemical composition of the sediment and other biological proxies such as pollen and dinoflagellates cyst would be useful for a more accurate past environment reconstruction.

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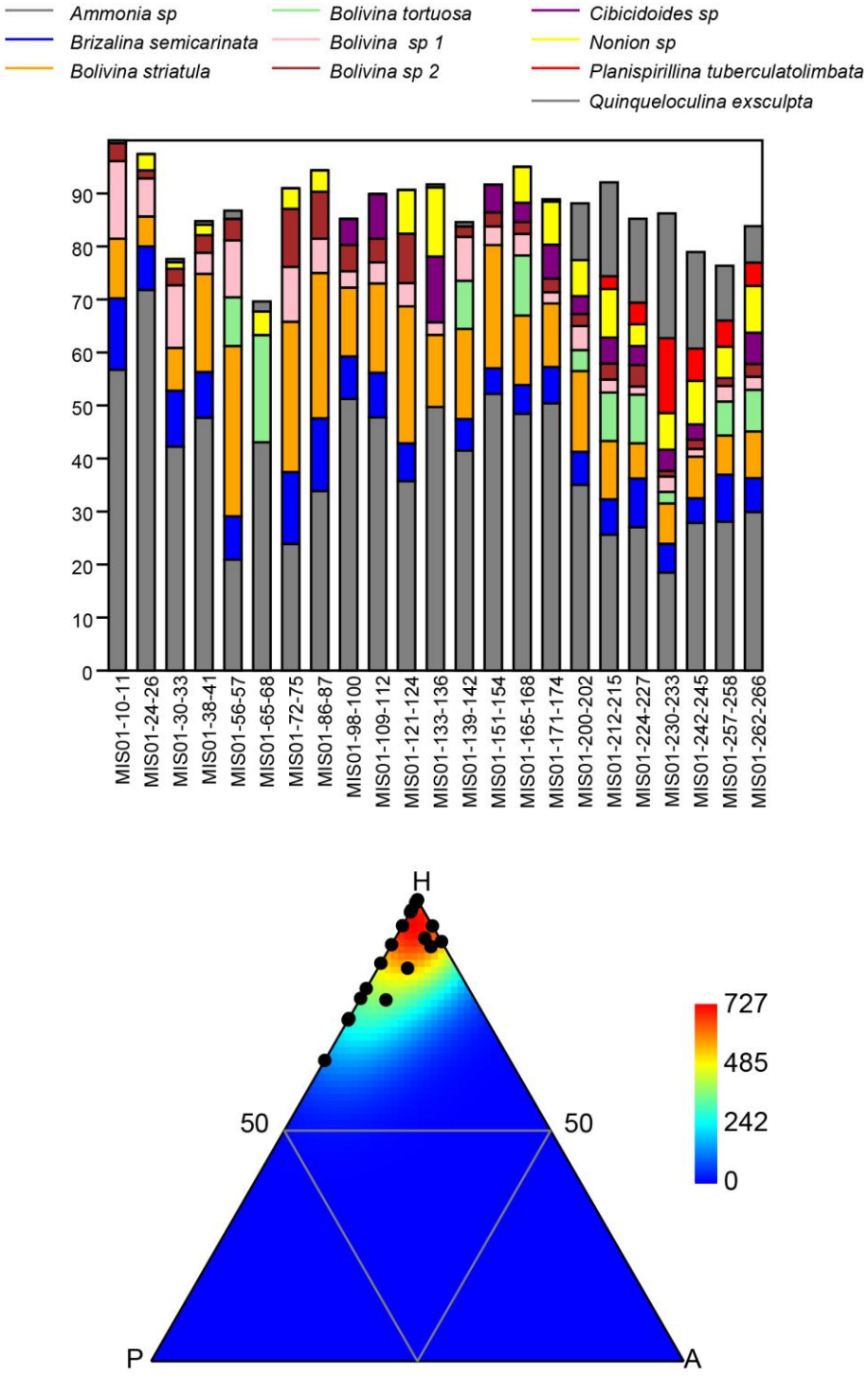
7. Appendix

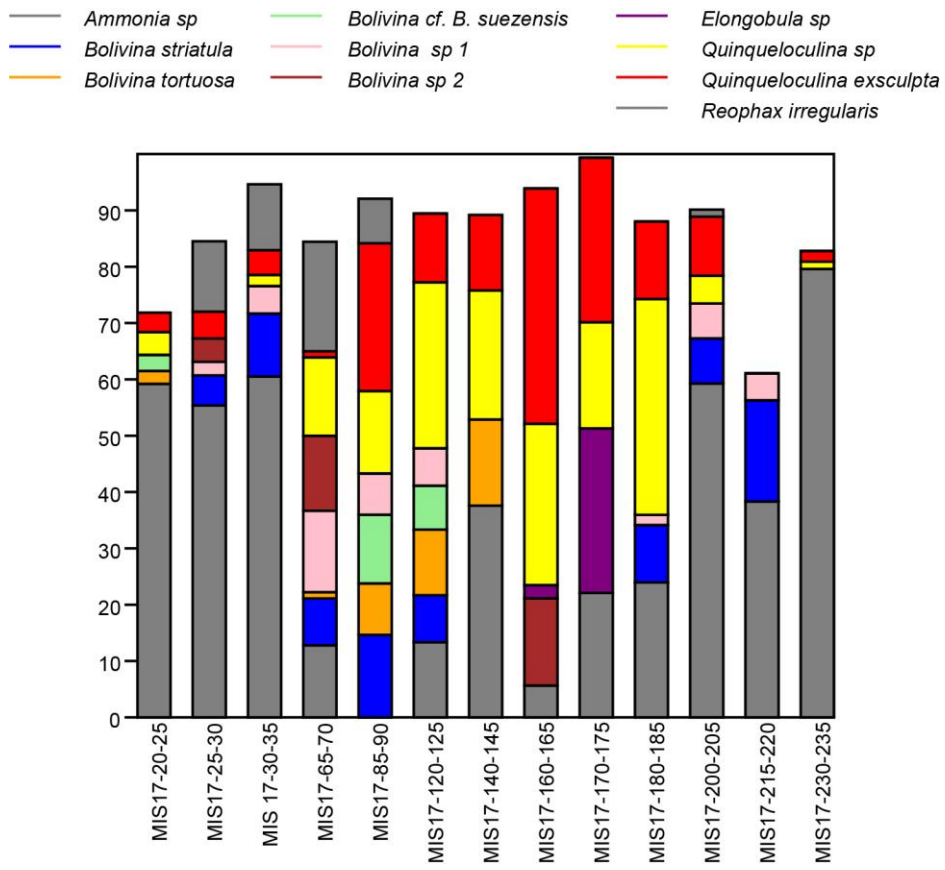
Appendix 1. List of encountered species

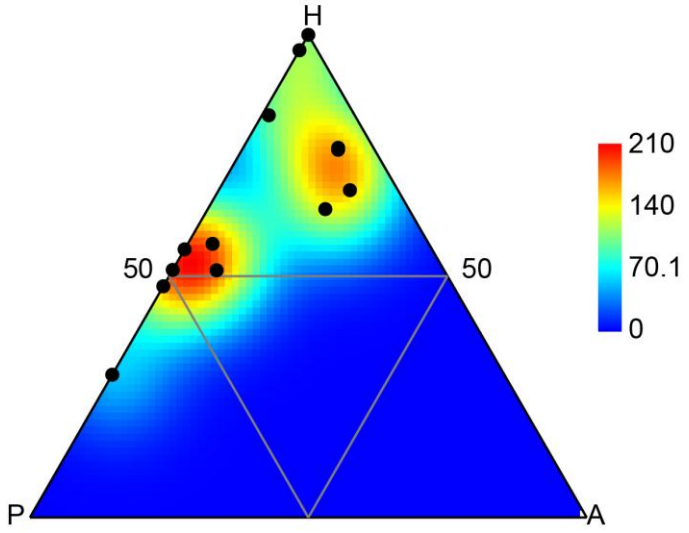
NO	Order	Family	Species
1	Lituolida	Reophacellidae	*Caronia exilis*
2	Lituolida	Reophacidae	*Reophax irregularis*
3	Textulariida	Lituolidae	*Ammobaculites sp*
4	Textulariida	Textulariidae	*Textularia agglutinans*
5	Lagenida	Ellipsolagenidae	*Fissurina bispinata*
6	Lagenida	Lagenidae	*Lagena sp*
7	Miliolida	Hauerinidae	*Quinqueloculina carinatastriata*
8	Miliolida	Hauerinidae	*Quinqueloculina sp*
9	Miliolida	Hauerinidae	*Quinqueloculina exsculpta*
10	Robertinida	Robertinidae	*Alliatinella sp*
11	Rotaliida	Ammoniidae	*Ammonia sp*
12	Rotaliida	Bagginidae	*Baggina indica*
13	Rotaliida	Bolivinitidae	*Brizalina semicarinata*
14	Rotaliida	Bolivinitidae	*Bolivina spathulata*
15	Rotaliida	Bolivinitidae	*Bolivina striatula*
16	Rotaliida	Bolivinitidae	*Bolivina tortuosa*
17	Rotaliida	Bolivinitidae	*Bolivina cf. B. suezensis*
18	Rotaliida	Bolivinitidae	*Bolivina sp 1*
19	Rotaliida	Bolivinitidae	*Bolivina sp 2*
20	Rotaliida	Bolivinitidae	*Hopkinsinella glabra*
21	Rotaliida	Buliminidae	*Bulimina marginata*
22	Rotaliida	Buliminoididae	*Elongobula sp*
23	Rotaliida	Cancrisidae	*Cancris sp*
24	Rotaliida	Cibicididae	*Cibicides sp*
25	Rotaliida	Elphidiidae	*Elphidium oceanicum*
26	Rotaliida	Fursenkoinidae	*Fursenkoina pauciloculata*
27	Rotaliida	Mississippinidae	*Stomatorbina sp*
28	Rotaliida	Murrayinellidae	*Murrayinella murrayi*
29	Rotaliida	Nonionidae	*Nonion sp*
30	Rotaliida	Parrelloididae	*Cibicidoides sp*
31	Rotaliida	Rosalinidae	*Rosalina orientalis*
32	Rotaliida	Siphogenerinoididae	*Siphogenerina raphana*
33	Rotaliida	Uvigerinidae	*Uvigerina sp*
34	Spirilinida	Planispirillinidae	*Planispirillina tuberculatolimbata*

Appendix 1.1. Stacked Diagram and ternary plot (based on wall composition) of 10 selected taxa MIS-01



Appendix 1.2. Stacked Diagrame and ternary plot (based on wall composition) of 10 selected taxa MIS-17





Appendix 2. Description of encountered species

ORDER LAGENIDA

Genus Fissurina

Fissurina bispinata (Ujiie,1963)

Classification

Phylum	Foraminifera
Class	Foraminifera incertae sedis
Order	Lagenida
Superfamily	Polymorphinoidea
Family	Ellipsolagenidae
Genus	Fissurina
Species	*Fissurina bispinata* (Ujiie,1963)

Short Description Rounded test in outline, oval in section. Test composed of calcareous hyaline wall, with smooth surface. The position of the primary aperture is terminal and the form is slit like.

Ecology

Outer reef

Genus Lagena

Lagena sp

Classification

Phylum	Foraminifera
Class	Foraminifera incertae sedis
Order	Lagenida
Superfamily	Nodosariacea
Family	Lagenidae
Genus	Lagena (Walker and Boys, 1798)
Species	*Lagena sp*

Short Description Overall test is globular to flask like with short neck. Wall material was calcareous porcelaneous. The neck shows some kind of striates ornamentation. It has a terminal aperture at the end of the neck, circular, with a small lip.

Ecology
Outer reef

ORDER LITUOLIDA

Genus Caronia

Caronia exilis (Cushman & Brönnimann, 1948)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Lituolida
Superfamily	Verneuilinoidea
Family	Reophacellidae
Genus	Caronia
Species	*Caronia exilis* (Cushman & Brönnimann, 1948)

Short Description
Test generally elongated. Short triserial chamber was found in the initial part, subsequent chamber appears to be biserial globular. Suture is identified as horizontally depress. Wall rather coarsely agglutinated and the aperture is short slit elongated at the base of the last chambers.

Ecology
Coastal Lagoon, mangrove swamp, estuary

Genus Reophax

Reophax irregularis (Parker, 1954)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Lituolida
Superfamily	Hormosinoidea
Family	Reophacidae
Genus	Reophax
Species	*Reophax irregularis* (Parker, 1954)

Short Description Test almost straight, almost cylindrical, chambers gradually increasing in size. The wall composed by agglutinated material with small to large particle, a low slit aperture is at the base of the last chambers.

Ecology

Shelf (600 m)

ORDER MILIOLIDA

Genus Quinqueloculina

Quinqueloculina exsculpta (Heron and Earland, 1915)

Classification

Phylum	Foraminifera
Class	Tubothalamea
Order	Miliolida
Superfamily	Milioloidea
Family	Hauerinidae
Genus	Quinqueloculina
Species	*Quinqueloculina exculpta* (Heron and Earland, 1915)

Short Description Test elongated, chambers inflated, suture deeply excavated, wall smoth, aperture produces in a short neck with a shorth bifurcate tooth.

Ecology

Bays

*Quinqueloculina carinatastriata (*Wiesner, 1923)

Classification

Phylum	Foraminifera
Class	Tubothalamea
Order	Miliolida
Superfamily	Milioloidea
Family	Hauerinidae
Genus	Quinqueloculina
Species	*Quinqueloculina carinatastriata* (Wiesner, 1923)

Short Description Test elongate, oval in side view, ornamented with obliq costae, aperture terminal, circular to slightly opal aperte shape on a slightly short neck with a peristomal lip, short tooth.

Ecology

Bays, outers estuary, shrimp ponds

Quinqueloculina sp

Classification

Phylum	Foraminifera
Class	Tubothalamea
Order	Miliolida
Superfamily	Milioloidea
Family	Hauerinidae
Genus	Quinqueloculina
Species	*Quinqueloculina sp*

Short Description Test longer and broad, suture fairly distinct, peripheral keeled, wall smoth with longitudinal costae , aperture subcircular at the end of a short necks short tooth

Ecology Bays

ORDER ROBERTINIDA

Genus Allatinella

Alliatinella sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Robertinida
Superfamily	Robertinoidea
Family	Robertinidae
Genus	Allatinella **(D J. Carter, 1957)**
Species	Allatinella sp

Short Description Overal test are coiled spirally, trochosspiral chamber arrangement, composed of hyaline material, different wall texture; one is finely perforated, the other side is coarsely perforated, aperture a low equatorial slit.

Ecology Coastal Bay

ORDER ROTALIIDA

Genus Ammonia

Ammonia sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Rotalioidea
Family	Ammoniidae
Genus	Ammonia (Brünnich, 1771)
Species	Ammonia sp

Short Description (type 1) Generaly Small trochospiral, 6-7 chambers, spiral side evolute, umbilical side involute, triangular to trapezoid chamber form, aperture an

arch at the base of the apertural face. Suture is oblique, deep umbilicus, wall finely perforated

Short Description (type) 2

Generaly Small trochospiral, 6-7 chambers, spiral side convex, umbilical side concave, triangular to trapezoid chamber form, apertur an arch at the base of the apertural face.suture is oblique, deep umbilicus, wall coarsely perforated.

Ecology

Coastal Bay
Coastal Lagoon,

Genus Baggina

Baggina indica (Cushman, 1921)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Discorboidea
Family	Bagginidae
Genus	Baggina
Species	*Baggina indica* (Cushman, 1921)

Short Description Test subglobular, biconvex, not umbilicate on the ventral side. Chambers arrange low trochospirally and gradually increase in length as added, suture deeply depressed, Umbilical side is strongly perforated, while the spiral side is smooth. Wall composed by hyaline material. Aperture a broad umbilical opening, at the base of the apertural face.

Ecology Shelf (600 m)

Genus Bolivina

Bolivina sphathulta (Williamson 1858)

Classification

Phylum	Foraminifera
Class	Glbothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina sphathulta* (Williamson 1858)

Short Description Overall test is elongate, hyaline wall composition, suture depressed, chambers increasing gradually, chambers biserial arrange, wall coarsely perforated, aperture a broad loop

Ecology Bay

Bolivina striatula(Chusman, 1922)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina striatula*(Chusman, 1922)

Short Description

Overal test is elongated, biserial chamber arangement, tapering and twisted. Suture flush, wall coarsely perorated, aperture slip shaped, chambers widen as they increase in number. Composed of hyaline material, biserial chamber arrangement, brick chamber form, suture slightly depressed, surface ornamented by numerous longitudinal striation, final chambers smooth, aperture an elongated opening

Ecology

Coastal Lagoon, Estuary, Bay

Bolivina tortuosa (Brady, 1881)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina tortuosa* (Brady, 1881)

Short Description Overal test is biserial - elongated, tapering and twisted. Composed of hyaline material, Biserial chamber arrangement, brick chamber form, suture flush, wall coarsely perforated, aperture slit-shaped

Ecology Shelf (600 m), Bay

Brizalina semicarinata (Belford,1966)

Classification

Phylum	Foraminifera
Class	Glbothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Brizalina
Species	*Brizalina semicarinata* (Belford,1966)

Short Description Overall test is elongate, hyaline wall composition, suture depressed, chambers increasing gradually, rounded in the upper part, biserial arranged chambers wall coarsely perforated, early part of the chamber ornamented by narrow and low longitudinal costae, aperture small and oval.

Ecology Shelf

Bolivina cf B suezensis(Said,1949)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina cf B suezensis*(Said,1949)

Short Description Overal test is biserial - elongated, composed of hyaline material, slowly increasing in width, suture oblique, ornementation consists of ribs and irregular ridges, wall coarsely perforated, apertute elliptical.

Ecology Lagoon (20 m),

Bolivina sp 1

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina sp 1*

Short Description Overall test is elongate, hyaline wall composition, suture depressed, chambers increasing gradually, chambers biserially arranged, wall coarsely perforated, aperture a broad loop

Ecology Lagoon (20 m)

Bolivina sp 2

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Bolivinitidae
Genus	Bolivina
Species	*Bolivina sp 2*

Short Description Overal test is biserial - elongated, composed of hyaline material, slowly increasing in width, suture oblique, ornementation consist of ribs wall coarsely perforated, apertute elliptical.

Ecology Lagoon (20 m)

Genus Bulimina

Bulimina marginata (d'Orbigny,1826)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Buliminoidea
Family	Buliminidae
Genus	Bulimina
Species	*Bulimina marginata* (d'Orbigny,1826)

Short Description Overal test is triserial elongated, composed of hyaline material, suture depressed, wall finely perforated, ornementation consist of spines on the edge of its chambers, apertute a loop extending up at the last chambers, with folded toothplate.

Ecology Lagoon (20 - 40 m)

Genus Cancris

Cancris sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Discorboidea
Family	Cancrisidae
Genus	Cancris (Montfort,1808)
Species	*Cancris sp*

Short Description Overal test elongated, composed of hyaline material, umbilical side more convex than the spiral side, chambers form triabulat to trapezoid, wall finely perforated, suture slightly depresed, aperture a slit at the base of the last chambers

Ecology Coastal Bay

Genus Cibicides

Cibicides sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Parrelloididae
Family	Cibicididae
Genus	Cibicides (Montford 1808)
Species	*Cibicides sp*

Short Description Overal test coilled spirally-low trochospiral chamber arrangement, wall composed by hyaline material, planoconvex, Limbate on the spiral side, suture curved in both side, test coarsely perforated in the spiral side, perforation scater on the umbilical side, aperture extraumbilical

Ecology Shelf (600 m)

Genus Cibicidoides

Cibicidoides sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Discorbinellacea
Family	Parrelloididae
Genus	Cibicidoides (Thalman,1939)
Species	*Cibicidoides sp*

Short Description Overal test coiled spirally-low trochospiral chamber arrangement, wall composed by hyaline material, chamber size grows as it is increases in number, suture flush, coarsely perforated at one side and finely perforated at the other side, umbilical side is strongly convex, spiral side is slightly flattened, a low interior marginal aperture with a lip which extends into the spiral side.

Ecology Shelf (600 m)

Genus Elongobula

Elongobula sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Glabratelloidea
Family	Buliminoididae
Genus	Elongobula (Finlay,1939)
Species	Elongobula *sp*

Short Description Overal test small, high trochospiral, chamber increasing slowly in diameter towards the aperture end, chamber quite distinct, suture finely depressed, wall smoth composed of hyaline material, very fine perforated, apertural face broadly rounded at the centre of the face.

Ecology Bay (20 - 30 m)

Genus Elphidium

Elphidium oceanicum (Cushman, 1933)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Rotalioidea
Family	Elphidiidae
Genus	Elphidium
Species	*Elphidium oceanicum* (Cushman, 1933)

Short Description Overal test coilled spirally, planispiral chamber arrangement, suture curved and depressed, wall smooth and finely perforated, ornamented with sutural bridges, wall composed by hyaline material, aperture at the based of the last chamber, obsecured by the ornamentation (fine tuberculation) .

Ecology Coastal Lagoon , Coastal Bay

Genus Fursenkoina

Fursenkoina pauciloculata(Brady, 1884)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Serioidea
Family	Fursenkoinidae (Loeblich &Tappan 1961)

Genus *Fursenkoina*

Species *Fursenkoina pauciloculata(Brady, 1884)*

Short Description Overal test is elongated, slightly compressed, chambers are irregularly arranged, composed of hyaline material, sutures distinct, wall smoth, finely perforated, aperture narrow elliptical.

Ecology Bay (10-40 m)

Genus Hopkinsinella

Hopkinsinella glabra (Millet, 1903)

Classification

Phylum Foraminifera

Class Globothalamea

Order Rotaliida

Superfamily Serioidea

Family Bolivinitidae (Loeblich &Tappan 1961)

Genus *Hopkinsinella*

Species *Hopkinsinella glabra* (Millet, 1903)

Short Description Overal test is elongated, slightly compressed, chambers are biserial - irregularly arranged, composed of hyaline material, sutures oblique depressed, wall smoth- composed of hyaline material, finely perforated, aperture subterminal on a short neck with recurved lip.

Ecology Bay (20-40 m)

Genus Murrayinella

*Murrayinella murrayi (*Heron-Allen & Erlan, 1915)

Classification

Phylum Foraminifera

Class Globothalamea

Order Rotaliida

Family Murrayinellidae

Genus Murrayinella(Farias,1977)

Species *Murrayinella murrayi (*Heron-Allen & Erlan, 1915)

Short Description: Small coiled spirally test, unnequally biconvex, chamber form triangular to trapezoid arranged trochospiral, dense hispid wall ornament, suture depressed, oblique in the spiral side, almost radial in the umbilical side, aperture extraumbilical- umbilical

Ecology Bay

Genus Nonion

Nonion sp

Classification

Phylum Foraminifera

Class Globothalamea

Order Rotaliida

Superfamily Nonionoidea

Family Nonionidae

Genus Nonion (**Monfort, 1808)**

Species *Nonion sp*

Short Description Test planispiral, compressed and symmetrical, Chambers heighten as they increase in number, suture distinct, deeply depressed, recurved, Wall finely perforated, composed by hyaline material, aperture an obscured narrow arched slit at the base of the apertural face

Ecology Lagoon, Estuary, Coastal Bay

Genus Rosallina

Rosalina orientalis (Chusman, 1925)

Classification

Phylum Foraminifera

Class Globothalamea

Order Rotaliida

Superfamily Discorboidea

Family Rosalinidae
Genus Rosallina
Species *Rosalina orientalis* (Chusman, 1925)

Short Description Small coiled, trochospiral test, convex on the spiral side, peripheral margin broadly rounded, Chamber grows as it increases in number, Limbate suture in the umbilical side ,coarsely perforated walls in the spiral side, and smooth wall in the umbilical side, aperture a low interior marginal on the umbilical side, with a distinct rim

Ecology Bay (10 -30 m)

Genus Siphogenerina

Siphogenerina raphana (Cushman, 1926)

Classification
Phylum Foraminifera
Class Globothalamea
Order Rotaliida
Superfamily Buliminoida
Family Siphogenerinoididae
Genus Siphogenerina
Species *Siphogenerina raphana* (Cushman, 1926)

Short Description: Test elongated, cylindrical. Early chambers biserially arranged, later uniserial. Wall composed by hyaline material. Suture distinct, slightly depressed, wall ornamented by several longitudinal costae, Aperture circular on a short neck.

Ecology Bay (10-30 m)

Genus Stomatorbina

Stomatorbina sp

Classification
Phylum Foraminifera

Class	Globothalamea
Order	Rotaliida
Superfamily	Discorboidea
Family	Mississippinidae
Genus	Stomatorbina (Dorreen,1948)
Species	*Stomatorbina sp*

Short Description: Test, unequally biconvex, low trochospiral coiled chambers arrangement. Suture depressed and nearly radial on the umbilical side, suture curved and oblique on the spiral side. Wall composed by hyaline material and finely perforated. Aperture a narrow slit- umbilical extra umbilical.

Ecology Shelf (600 m)

Genus Uvigerina

Uvigerina sp

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Rotaliida
Superfamily	Bulliminoidea
Family	Uvigerinidae
Genus	Uvigerina *(*d'Orbigny, 1826)
Species	*Uvigerina sp*

Short Description: Test elongated, broadly rounded in side view. early chambers triserially arranged to uniserial on towards the last chambers. Wall composed by hyaline material. Suture distinct and depressed, wall finely perforated ornamented by many low costae. Aperture terminal at the end of a short neck with lip.

Ecology Shelf (300 - 600 m)

ORDER SPIRILINIDA

Genus Planispirillina

*Planispirillina tuberculatolimbata (*Chapman, 1900)

Classification

Phylum	Foraminifera
Class	Tubothalamea
Order	Spirilinida
Family	Planispirillinidae
Genus	Planispirillina
Species	*Planispirillina tuberculatolimbata (*Chapman, 1900)

Short Description Test discoidal, gradually enlarging, coiled-tubular chambers, slightly overlapping, coarsely perforated wall on one side, the other side obscured by papilous lamellae, composed by hyaline material, the large and flat side being limbate, the opposite side is convex with rounded edge. Aperture at the end of the tabular chamber.

Ecology Shelf (200 m)

ORDER TEXTULARIIDA

Genus Ammobaculites

Ammobaculites sp

Classification

Phylum	Foraminifera
Class	Textulariidia
Order	Textulariida
Superfamily	Lituolacea
Family	Lituolidae
Genus	Ammobaculites (Chusman, 1910)
Species	*Ammobaculites sp*

Short Description Test elongated, early coiled part is larger than the latter part, chamber indistinctint, wall coarsly agglutinated from coarse and sand grain, Test elongated, early part composed of biserial chambers, chamber not distinctively marked, suture not distinct, wall consist of sandy material, aperture terminal, the surface is rough, shape is irregular

Ecology Shelf (500 m), Shelf (200 m)

Genus Textularia

*Textularia agglutinans (*d'Orbigny, 1839)

Classification

Phylum	Foraminifera
Class	Globothalamea
Order	Textulariida
Superfamily	Textularioidea
Family	Textulariidae
Genus	Textularia
Species	*Textularia agglutinans* (d'Orbigny, 1839)

Short Description Test elongated, cylindrical. chambers biserially arranged, widen and heighten as they increase in number. Wall composed by agglutinated material. Suture distinct and depressed, wall coarsely agglutinated- smoothly finish, Aperture an elongated slit at the last chambers

Ecology Lagoon, Shelf (0-80 m)

Plate	Number	Species
1	1	*Ammobaculites sp*
1	2	*Caronia exilis*
1	3	*Reophax irregularis*
1	4	*Textularia agglutinans*
1	5	*Quinqueloculina carinatastriata*
1	6	*Quinqueloculina sp*
1	7	*Quinqueloculina exsculpta*
1	8	*Fissurina bispinata*
1	9	*Lagena sp*
2	10	*Bolivina spathulata*
2	11	*Bolivina striatula*
2	12	*Bolivina cf. B. suezensis*
2	13	*Bolivina sp 1*
2	14	*Bolivina tortuosa*
2	15	*Bulimina marginata*
2	16	*Bolivina sp 2*
2	17	*Fursenkoina pauciloculata*
2	18	*Hopkinsinella glabra*
2	19	*Murrayinella murrayi*
3	20	*Brizalina semicarinata*
3	21	*Uvigerina sp*
3	22	*Siphogenerina raphana*
3	23	*Elongobula sp*
3	24	*Nonion sp*
3	25	*Alliatinella sp*
3	26	*Ammonia sp*
4	27	*Cancris sp*
4	28	*Cibicidoides sp*
4	29	*Cibicides sp*
4	30	*Elphidium oceanicum*
4	31	*Rosalina orientalis*
4	32	*Baggina indica*
4	33	*Stomatorbina sp*
4	34	*Planispirillina tuberculatolimbata*

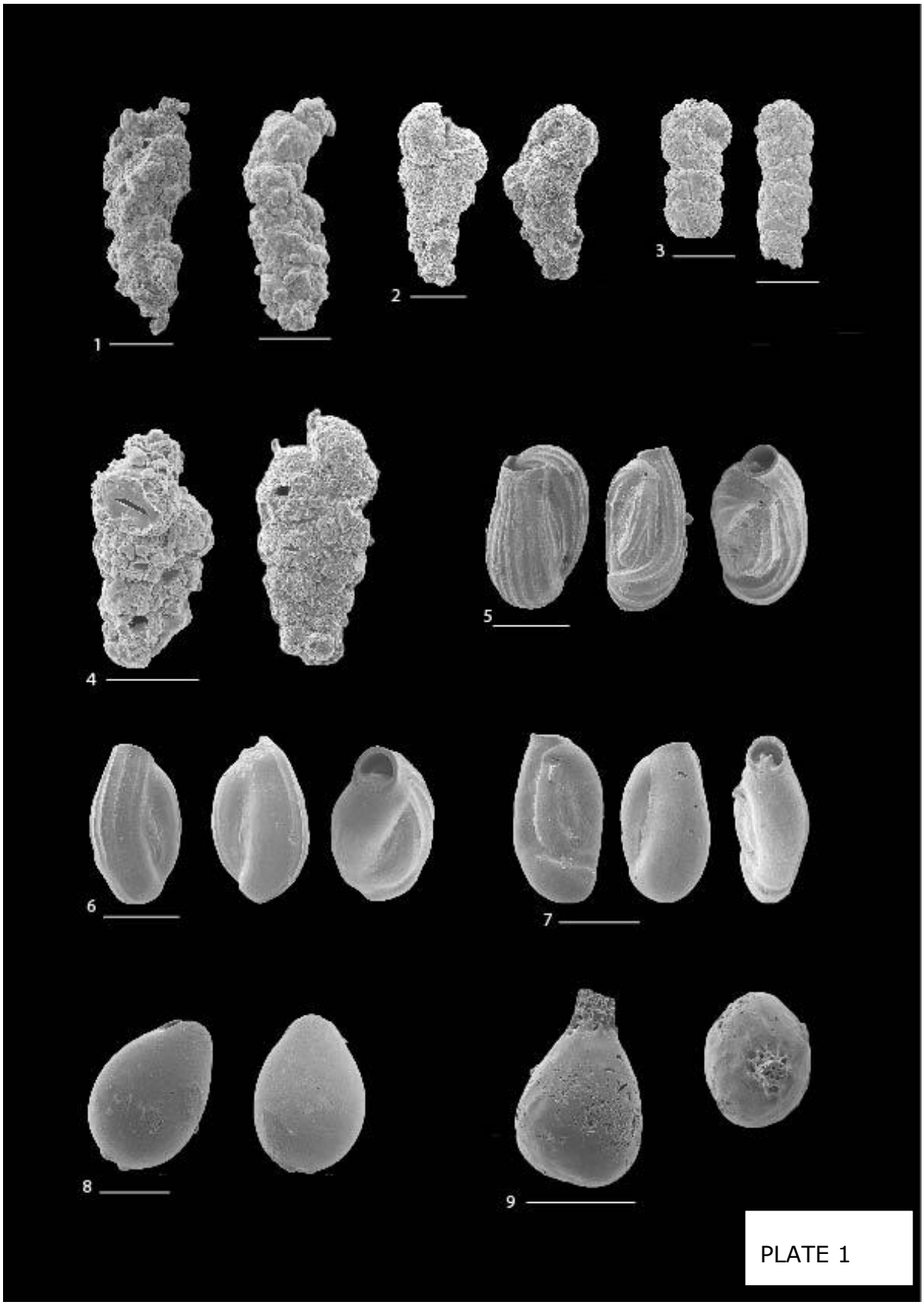


PLATE 1

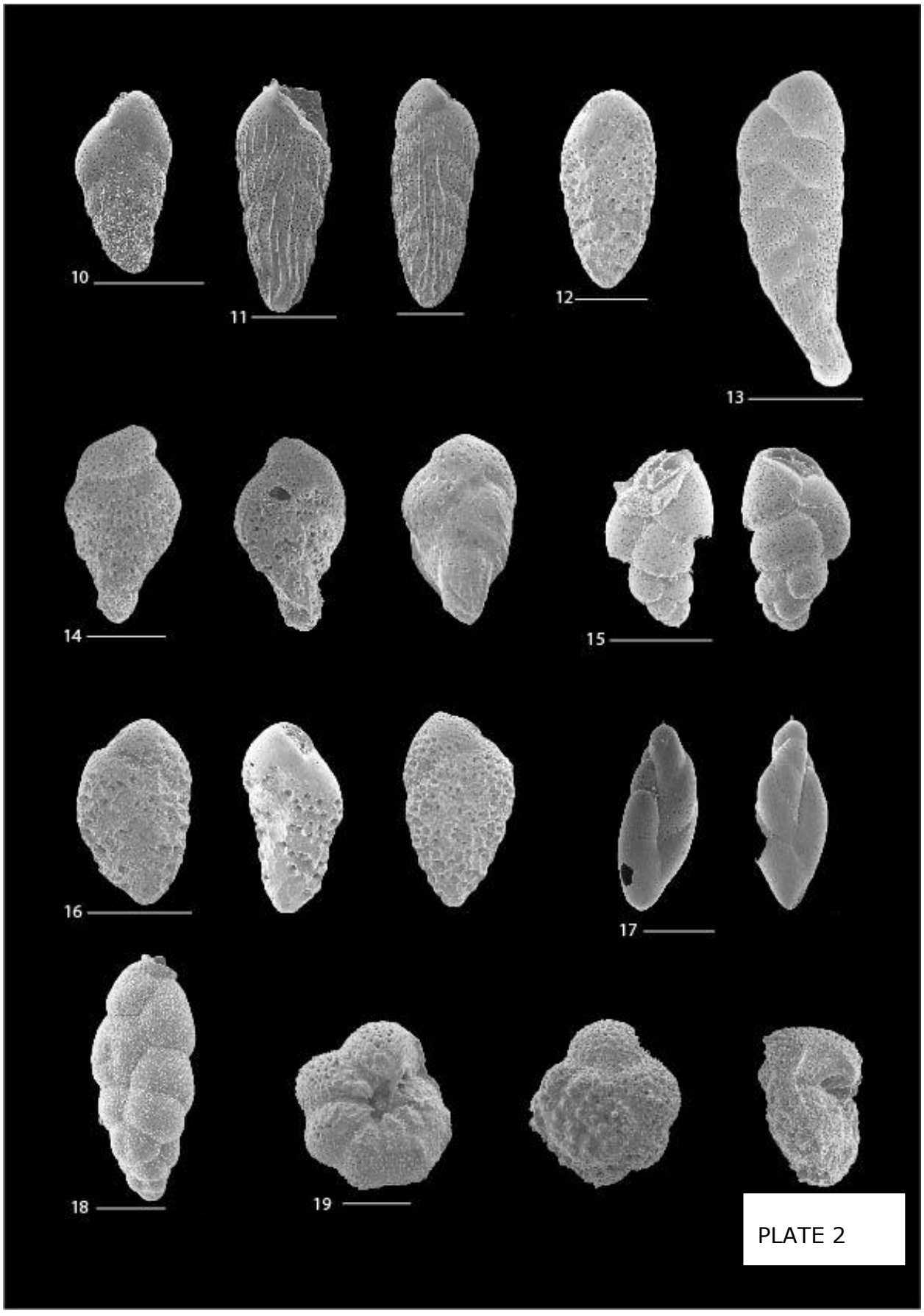


PLATE 2

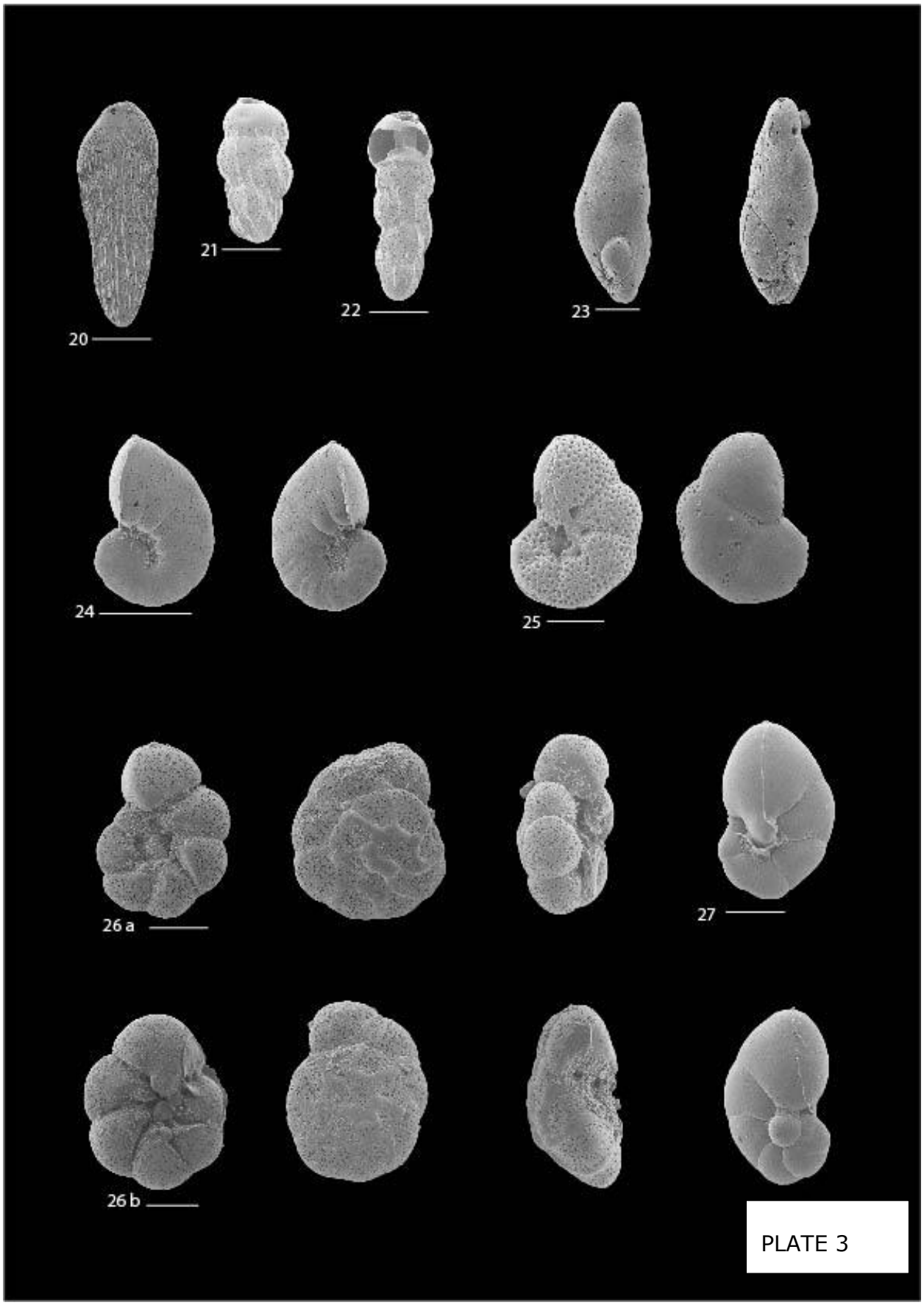


PLATE 3

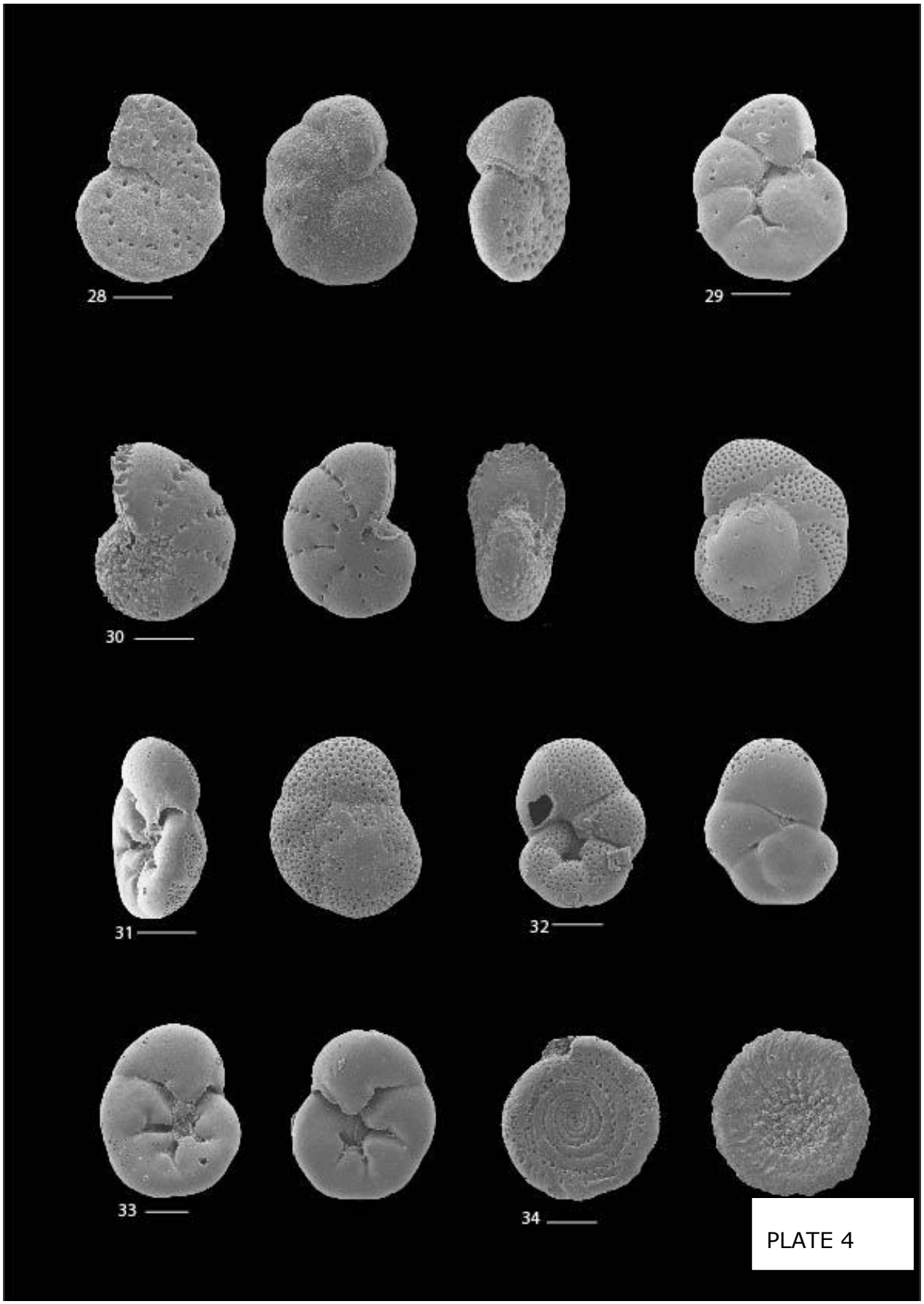


PLATE 4