Universiti Malaysia Terengganu Journal of Undergraduate Research *e-ISSN: 2637-1138*
Volume 1 Number 2, April 2019: 19-25

DISTRIBUTION AND DIVERSITY OF FORAMINIFERA IN THE NORTHWEST OF SARAWAK OFFSHORE WATERS, MALAYSIA

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Abstract: A study on distribution and diversity of benthic foraminifera in surface sediments was carried out in Northwestern Sarawak waters, Malaysia. The range of water depth at the study site was between 43 m and 71 m. A total of seven sediment samples were taken for this study. As a result, 11 genera were identified from a total of 1,222 individuals of foraminifera. 200 individuals were picked out from each sample. The 11 genera that were identified from the study site included *Heterolepa* spp., *Textularia* spp., *Quinqueloculina* spp., *Operculina* spp. *Pseudorotalia* spp., *Amphistegina* spp., *Cylindroclavulina* spp., *Elphidium* spp., *Ammobaculites* spp., *Asterorotalia* spp. and *Bolivina* spp.. The common genera found in the sediments of the study areas were *Heterolepa*, *Textularia*, *Quincoloculina*, *Operculina* and *Pseudorotalia*. The highest and lowest values of Fisher alpha and Shannon-Wiener indices were shown at Station C287 and Station B482 respectively. The highest value of Fisher alpha was 3.23 and the lowest value was 1.97. The highest and lowest values of Shannon-Wiener were 2.30 and 1.91. The highest index value of diversity was 3.23 at depth 67.76 m and the lowest value was 1.53 at depth 45.54 m and 68.45 m. From this study, depth is not the main factor that influences the diversity of benthic foraminiferal in northwestern Sarawak waters.

Keywords: benthic foraminifera, Sarawak waters, species diversity.

Introduction

Foraminifera are useful indicators of the paleoenvironmental condition as they hold an evolutionary history that extend back to the Cambrian (Debenay, 2012). The classifications of the tests or shells are determined by the characteristics of the test wall composition and the arrangement of the chambers. The basic wall of the foraminifera is mostly built from organic matter such as sediment and calcium carbonate. Foraminifera can be divided into two groups, which are agglutinated and calcareous. The test of the agglutinated is mostly built from foreign particles collected in the sediment and cemented together to form a shell. The calcareous test can be subdivided into three major groups, which are microgranular, porcelaneous and hyaline. Calcareous test is constructed together from a single crystal of calcite and the suborder carterina is believed to secrete spicules of calcite which are then cemented together to form the test (Debenay, 2012). Environmental parameters such as temperature, turbidity, depth, substrate, hydrodynamic energy and pH are often-interrelated to determine the occurrence of large benthic foraminifera (Mihaljevi et al., 2014).

In the observation of the distribution of the sediment, benthic foraminifera are commonly used to indicate the depth of deposition of the sediment and successful for the shallow parts of the continental margins (Zoochi, 1960). The most important measurable environmental parameter that can affect the distribution of foraminifera is depth but it can only affect it indirectly (Renema, 2002). In shallow-marine environments, habitat heterogeneity is typically facilitated through a range of tidal regimes and wave energy (Robert & Ormand, 1987; Mihaljevic et al., 2014). Since foraminifera quickly respond to the temperature and environmental changes, they have been used to reconstruct paleoenvironmental conditions (Murray, 2006; Cosentino et al., 2017). As foraminifera are influenced by the bathymetry, physicochemical characteristics of sediment and water quality, their abundance and distribution can be used to interpret palaeoenvironmental conditions, palaeomonsoons, palaeotemperature, palaeodepth, tsunami, sediment transport and pollution profiles (Yahya et al., 2014). The resulting benthic foraminiferal distribution usually exhibits a zonation that roughly coincides with increasing water depth, but absolute depth and taxonomic composition of zonation vary from region to region (Hayward, 2010). The aims of this study are to document the distribution of foraminifera in Sarawak waters and to identify the dominant species of foraminifera in Sarawak waters.

Study Area

Kuching, Sarawak, has a tropical rainforest climate and receives the annual Southeast monsoon. The overall monthly mean temperature in Sarawak is about 27°C

with small annual fluctuations of approximately 1.5-2 °C (Tangang et al., 2006). According to Ramzah & Phil (2007), Kuching is situated in the most western of Sarawak, the area where the heaviest rainfall appears (Kanamori et al., 2013). The location of samples was near Teluk Datu, Kuching, Sarawak. The average depth at the study area was 55m.

Methodology

A total of eight sediment samples were collected by Jabatan Mineral dan Geologi (JMG) in August 2008. Samples were placed in air tight container and kept in archives at JMG warehouse.

Sample Processing

Sediment sub-samples were collected from the bulk samples kept in JMG warehouse and placed in zip-lock plastic bags. Then the sub-samples were carefully transferred to UMT laboratory for further analysis. In the laboratory, samples were soaked overnight to allow sediment to soften. The soaked samples were then wet-washed through 63 µm sieve and the residue on the sieve was transferred onto weighing boats to be oven-dried (Li et al., 2005) at 50°C for 1-2 days. The samples were then ready for sorting. For picking and sorting process, the samples were spread out on picking tray and fine artist brush (#000) size was used to sort the specimens. The picking and sorting were carried out with the aid of stereo microscope. A total of 200 individual specimens of foraminifera were picked randomly and sorted from each sample. In samples with less 200 specimens, all specimens were picked (Culver et al., 2013). The specimens were placed onto a special micro paleontological slide that had been coated with special glue (Scott et al., 2012). The specimens that had been sorted were observed under Scanning Electron Microscopy (SEM) for detailed identification. Scanning microscope is particularly useful to observe a minute and solid specimen or complex surface topography of a bulk specimen with the dimension far less that optical limit (Honjo & Okada, 1968). The foraminifera's specimens were covered with film of electro-conductive material with uniform thickness. Then the specimens were observed using the SEM. The identification of foraminifera was carried out based on Loeblich & Tappan (1988) and Culver (1994). The software used to identify the distribution and diversity of the foraminifera was Primer version 6 (Clarke et al., 2006). This software was used to analyse the species diversity using fisher alpha (α), Shannon Index, Evenness Index and Dominant Index.

Results

A total of 11 benthic foraminiferal genera were identified in seven surface samples from northwestern Sarawak waters (Table 1). The benthic foraminifera were dominated by calcareous group mostly from hyaline group of test. Overall, *Heterolepa* spp. was the most abundant benthic foraminifera (18%) with a total of 238 individuals collected from all samples. Meanwhile, the rare genus was identified as *Asterorotalia* spp. (3%). The *Textularia* spp. from agglutinated group was the most common agglutinated representative that occurred in all samples with an average of 2 individuals per sample. Figure 1 and 2 show the SEM images of some foraminifera species collected from Sarawak's waters.

Table 1: The relative abundance of foraminiferal genera in seven surface samples.

Samples	**A504**	**A651**	**A674**	**B457**	**B482**	**B469**	**C287**	**no. sp.**	**Relative Abundance (%)**
Amphistegina	36	0	37	20	0	0	0	93	8
Textularia	35	26	27	31	28	23	25	195	16
Cylindroclavulina	31	0	16	17	0	4	0	68	6
Heterolepa	16	48	17	57	34	33	33	238	19
Operculina	33	24	6	7	4	48	20	142	12
Quinqueloculina	21	20	15	11	30	45	27	169	14
Elphidium	10	6	4	7	4	10	6	47	4
Ammobaculites	0	9	4	6	35	1	2	57	5
Asterorotalia	0	25	0	1	0	11	0	37	3
Pseudorotalia	0	0	54	7	42	16	14	133	11
Bolivina	0	0	0	0	0	23	20	43	4
Total	182	158	180	164	177	214	147	1222	

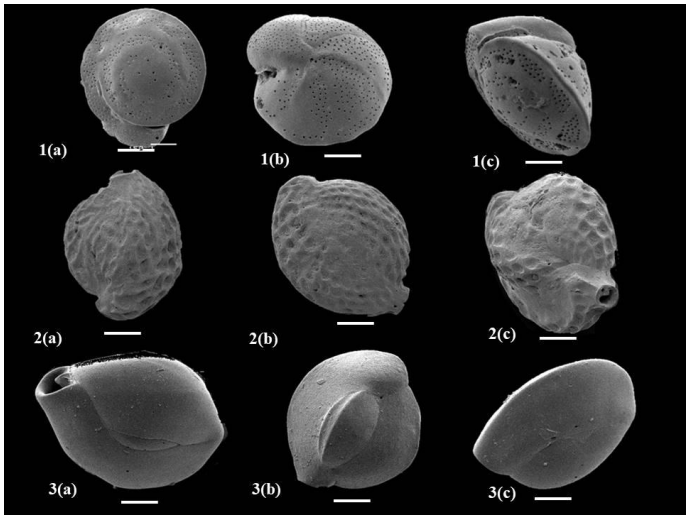

Figure 1: Scanning electron microscope (SEM) images of benthic foraminifera. 1) *Heterolepa* spp. 1(a) Dorsal view (100µm x150), 1(b) Posterior view (100µm x160), 1(c) Ventral view (100µm x180). 2) *Quinqueloculina* spp. species A 2(a) Posterior view (100µm x100), 2(b) Dorsal view (100µm x100), 2(c) Ventral view (200µm x90). 3) *Quinqueloculina* spp. species B 3(a) Ventral view (100µm x230), 3(b) Dorsal view (100µm x120), 3(c) Posterior view (100µm x220).

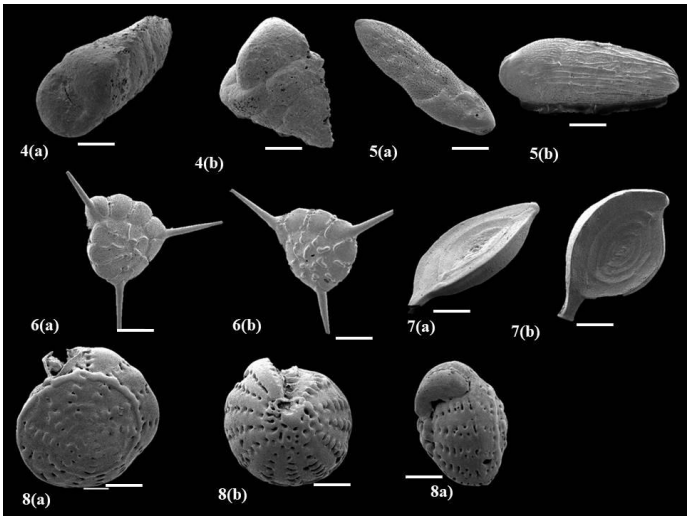

Figure 2: Scanning electron microscope (SEM) images of benthic foraminifera. 4) *Textularia* spp., 4(a) Ventral view (100µm x140), 4(b) Dorsal view (100µm x130), 5 (a) *Bolivina* spp. species A (100µm x200), 5(b) *Bolivina* spp. species B (100µm x200), 6(a) and 6(b) *Asterorotalia pulchella* sp. (scale bar: 100µm), 7) *Spiroloculina* spp. 7(a) Ventral view (200µm x90), 7(b) Dorsal view (200µm x6), 8) *Pseudorotalia* spp. 8(a) Dorsal view (200µm x70), 8(b) Posterior view (200µm x65), 8(c) Ventral view (200µm x65).

The common (>10% relative abundant) and rare taxa (<5% relative abundant) found in seven samples are listed in Table 2. The relative abundance of the five genera that have common genus are *Textularia* spp.(16%), *Heterolepa* spp.(19%), *Operculina* spp.(12%), *Quinqueloculina* (14%), *Pseudorotalia* spp.(11%).

Table 2: Common and rare genus that were found in seven surface samples from northwestern Sarawak's waters.

Common Genus	Relative Abundance (%)	Rare Genus	Relative Abundance (%)
Textularia	16	*Elphidium*	4
Heterolepa	19	*Asterorotalia*	3
Operculina	12	*Bolivina*	4
Quinqueloculina	14		
Pseudorotalia	11		

Generic Diversity

Species richness and diversity of benthic foraminifera in northwestern Sarawak's waters are listed in Table 3. The maximum number of genera was found in station C287(S=13) and the minimum number of genera was found in station B482(S=9). Station C287 had the most diverse benthic foraminiferal assemblages (α=3.23, H'=2.30, d=2.14) while the least diverse of benthic foraminiferal was station B482 assemblages (α=2.0, H'=1.90, d=1.53).

Table 3: The genus diversity of benthic foraminifera that were collected in northwestern Sarawak's waters. Number of species(S), species richness (d), Pielou's evenness (J'), Fisher's alpha (α) and Shannon-wiener (H').

Station	S	N	d	Pielou's evenness(J')	Fisher alpha	Shannon wiener H'(loge)
A504	9	185	1.53	0.88	1.98	1.93
A651	11	177	1.93	0.86	2.60	2.06
A674	11	188	1.91	0.84	2.55	2.02
B457	12	166	2.15	0.79	2.97	1.96
B482	9	189	1.53	0.87	1.97	1.91
B469	12	225	2.03	0.86	2.71	2.13
C287	13	178	2.32	0.90	3.23	2.30

Discussion

There were 11 genera of benthic foraminifera identified from northwestern Sarawak waters. Based on the results, foraminiferal assemblages were mainly dominated by calcareous form. According to Lacuna (2013), the high concentration of $CaCO_3$ in the sediment was due to the presence of appreciable broken gastropod shells and coral fragment. The most abundant genus was *Heterolepa* spp. (18%) and followed by *Operculina* spp. (10%) and *Pseudorotalia* spp. (10%) from calcareous group. The main factor controlling faunal compositions and the distribution of benthic foraminifera was carbon flux (Mackensen et al., 1995; Szarek et al., 2009). The cause of formation of shells benthic foraminiferal may also of the carbon cycle that and the strength of the biological pumping of carbon in the ocean that caused variations of benthic foraminiferal (Lowemark et al., 2005). From the previous study, less than 20% of the species were commonly occuring along Sunda transect which were *Heterolepa* spp., *Asterorotalia* spp., *Textularia* spp. and *Triloculina* spp. (Szarek et al., 2006) which could also be found in this study area.

The agglutinated foraminiferal found in the samples were *Ammobaculites* spp. (5%), *Cylindroclavulina* spp. (6%) and *Textularia* spp. (16%). The highest number of *Textularia* spp. was found in sample A504 and B457. Meanwhile, the *Cylindroclavulina* spp. and *Ammobaculites* spp. were mostly found in samples A504 and B482. The type of sediment found in Sample A504 was probably medium grained. According to Setty and Nigam (1982), the agglutinated genera and species are dominant in medium grained zones where the organic carbon content varies. Different grain sizes of sediments contain different dominant genus of benthic foraminifera. The distribution pattern of the benthic foraminifera reflects the faunal response to slight varying of environmental conditions such as food supply, water depth, oxygenation, grain size and currents (Srazek et al., 2006).

The genera that were found in the samples had many different variations. This might be caused by the type of sediment in certain sampling area, which was fine grained sediment. The observation on foraminiferal population and diversity are at its highest in very fine grained sediments (Setty and Nigam, 1982; Lacuna, 2013). Past studies showed that foraminifera are normally common in fine-grained sediment and less abundant coarse sands and with some occurring in silt and clay sediments than in muds (Gooday, 1988; Lacuna, 2013). The South China Sea is one of the basins with the highest diversity of recent benthic foraminiferal faunas in tropical regions (Zheng and Fu, 1994; Srazek, 2009). The sampling site is located in South China Sea which experiences annual monsoon that can disturb current movement and also sediment movement. Since the samples were taken from the surface core, it could possibly affect the distribution and diversity of the benthic foraminiferal. The number of benthic foraminifera species occurring in all the China seas is estimated at approximately 2000, with 1600 species recognized in the assemblages of the entire South China Sea (Zheng and Fu, 1994; Szarek et al., 2006). Both values of Fisher alpha and Shannon-Wiener index from samples taken at northwestern Sarawak waters showed highest values (α=3.23; H'=2.30) at station C287. Since the depth of samples was between 43m to 71m, it might influence the diversity of benthic foraminifera in that area. The benthic foraminiferal number and the Shannon-Wiener index are related to bathymetry and in general, the benthic foraminiferal number is inversely related with water depth (Mendes et al., 2004). Based on Szarek (2009), the middle and lower bathyal depths have a slight increase of diversity and very slight decrease in dominance for living fauna with the value of Shannon-Wiener index. The diversity index in this study area showed the range between 1.53 and 2.32. Compared to the values of previous studies, the range value of diversity index at Sunda Shelf (South China Sea) was between 3.2 and 4.4 (Szarek et al, 2006). A previous study at Southeast coast of Iligan Bay, Mindanao, Philippines showed the highest value of Fisher alpha at 8.58 and the lowest value at 4.19. According to Szarek (2009), the ratio between agglutinated and calcareous test increased steadily with increasing water depth where the upper bathyal zone composed mainly of calcareous tests while the middle bathyal zone and deeper, the foraminiferal fauna is generally dominated by the agglutinated form. The previous study showed the benthic foraminiferal number was inversely related with water depth (Mendes et al., 2004). However, this study showed the value of the index of diversity did not show any correlation with the depth since the highest value was 2.32 at depth 67.76 m and the lowest value was 1.53 at depth 45.54 m and 68.45 m.

Conclusion

Seven surface sediments from water depth between 43 m and 71 m of northwestern Sarawak waters contained eleven genera of benthic foraminifera. The benthic foraminifera can be classified into three groups which are agglutinated, hyaline and porcelanous. The hyaline group which is represented by *Heterolepa*, *Operculina* and *Pseudorotalia* dominated in the assemblages in the study area. Highest diversity index of benthic foraminifera was located at the station C287 with 67.76 m of depth and the lowest value at station A504 and B482 in northwestern Sarawak waters.

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