

The Correlation Between Benthic Foraminifera and Sediment Types of South Makassar Strait

Korelasi Antara Foraminifera Bentik dan Tipe Sedimen Selat Makassar Bagian Selatan

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ABSTRACT: South Makassar Strait is located between Kalimantan and Sulawesi Islands that is an important oceanographic pathway connecting between the Pacific and Indian oceans. This area is a part of sedimentary basin that has specific seabed morphology and sediment characteristics, including foraminifera as a component of sediments. The purpose of this study is to determine community structure of benthic foraminifera related to sediment characteristics. This study used 20 top core sediment samples from water depth between 200 and 1500 m. There are identified 38 species of benthic foraminifera and some of them are characterized the study area: *Anomalinoidea colligerus*, *Lenticulina suborbicularis*, *Planulina wuellerstorfi*, and *Pseudonodosaria discrete*. The diversity index is categorized as moderate values ($1.0 \leq H' \leq 3$) and the average of evenness values is about 0.79. The dominance values are less than 0.5 indicate that there is no dominant species in the study area. In relation to sediment characteristics, it shows that the high abundance of benthic foraminifera occurs in sediment type of silty sand and sandy silt. Moderate abundance appears in sand following by low abundance in silt and sandy silt sediment types.

Keywords: benthic foraminifera, community structure, sediment types and Makassar Strait

ABSTRAK: Selat Makassar bagian selatan terletak diantara Pulau Kalimantan dan Sulawesi yang merupakan jalur oseanografik yang penting menghubungkan Samudera Pasifik dan. Wilayah ini merupakan bagian dari cekungan sedimen yang mempunyai morfologi dasar laut dan karakteristik sedimen tertentu termasuk foraminifera sebagai komponen sedimen. Tujuan dari penelitian ini adalah untuk mengetahui struktur komunitas foraminifera bentik dalam kaitannya dengan tipe sedimen dasar laut. Penelitian ini menggunakan 20 sampel sedimen bagian atas dari pemercontohan pada kedalaman antara 200 dan 1500 m. Ada 38 spesies foraminifera bentik dan beberapa diantaranya mencirikan daerah penelitian: *Anomalinoidea colligerus*, *Lenticulina suborbicularis*, *Planulina wuellerstorfi*, dan *Pseudonodosaria discrete*. Indeks keanekaragaman termasuk dalam kategori sedang ($1,0 \leq H' \leq 3$) dan nilai rata-rata keseragaman sekitar 0,79. Nilai dominasi lebih kecil dari 0,5 itu menandakan tidak ada spesies yang dominan pada lokasi penelitian. Terkait dengan karakteristik sedimen menunjukkan bahwa kelimpahan foraminifera bentik tinggi terdapat pada jenis sedimen pasir lanauan dan lanau pasiran. Kelimpahan sedang ditemukan pada jenis sedimen pasir diikuti kelimpahan rendah yang dijumpai pada sedimen lanau dan lanau pasiran.

Kata kunci: foraminifera bentik, struktur komunitas, jenis sedimen, Selat Makassar.

INTRODUCTION

The Makassar Strait is located between Kalimantan and Sulawesi Islands that is an important oceanographic pathway connecting between the Pacific and Indian oceans. This strait is divided into two basins of North and South Makassar Strait. The south Makassar Basin is interested area for many scientists. (Hidayat et al, 2012) studied that based on Airborne Laser Fluorescence survey, the South Makassar Basin Depocenter (SMBD) has petroleum potential by the presence of oil and gas indications. Inaku, (2011) has proved that the south Makassar Strait is a nutrient-rich

environment based on chlorophyll-a and sea surface temperature. Dewi (2010, in Rahardiawan et al, 2010) resulted that foraminifera from this area is dominated by planktonic foraminifera. It could reach up to 95% compared with benthic foraminifera and dominated by *Globigerinoides sacculiferus*, *Globorotalia menardii*, *Pulleniatina obliqueloculata* and *Sphaeroidinella deshiscens*. Although the number of benthic foraminifera is less than planktonic foraminifera, the purpose of the present study is to recognize the community structure of benthic foraminifera from deep water environment off South Sulawesi related to

sediment types. It is also to enrich previous study by Renema et al (2001) and Renema and Troelstra (2003) who focused on shallow water larger benthic foraminifera from Spermonde shelf, South Sulawesi.

The study area is a unique deep water environment that is combined with close many small islands and located at the edge of Sunda and Spermonde shelves. Therefore, this condition may affect seabed morphology and the sediment characteristic of the study area. Sediment type is one of the environmental factors that influences the abundance and diversity of benthic foraminifera. This benthic organism mostly live on or in the seafloor in various conditions from the rocky, sandy and muddy intertidal zone to the muddy deposits of deep sea environment. They are preserved in the shallow to the deep sea fossil record that made them important tools for reconstructing ancient oceans.

by a gravity corer (<3 m length) from the R/V Geomar 3 in 2010. In the laboratory, core top sediment samples were then washed through a sieve with mesh size of 0.063 mm and then dried in an oven at 700 C. The washed and dried sediment samples were used for foraminiferal analysis by picking of about 300 specimens under a binocular microscope. The picked specimens were then identified, calculated and documented by NIST Element software and microscopic camera. The identification of each foraminiferal specimen was based on previous taxonomic studies by Barker (1960), van Marle (1988), Loeblich and Tappan (1992), and Yassini and Jones (1994). The community structures of benthic foraminifera were calculated using the software package PAST (PAleontological STatistics; Hammer et al., 2001).

METHODS

This study used 20 selected from 28 sediment samples that collected during marine geological and geophysical survey in South Makassar Basin, Sulawesi (Figure 1 and Table 1). These samples were carried out

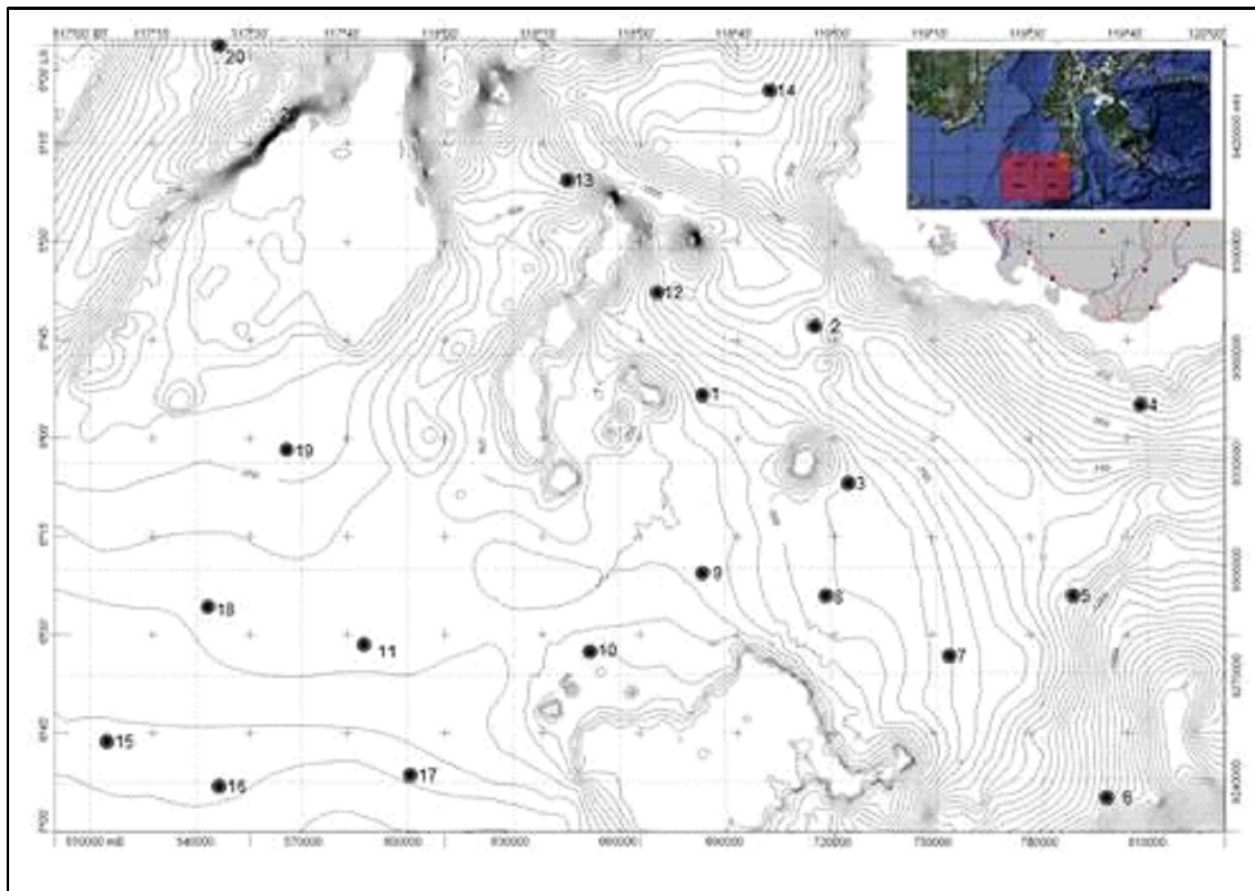


Figure 1. Sampling stations and bathymetric map of the study area

Table 1 Position of sample location and water depth

No. Stations	Stations Number appear in location map	Position		Water depth (m)
		Latitude	Longitude	
1	GM3-2010-2010-02	5°58'18" S	118°40'12" E	440
2	GM3-2010-2010-03	5°41'36" S	118°59'41" E	1126
3	GM3-2010-2009-04	6°04'55" S	119°07'57" E	630
4	GM3-2010-2010-06	5°58'24" S	119°50'13" E	582
5	GM3-2010-2009-07	6°18'05" S	119°36'13" E	950
6	GM3-2010-2009-09	6°53'54" S	119°40'19" E	1360
7	GM3-2010-2009-10	6°36'53" S	119°18'03" E	670
8	GM3-2010-2009-11	6°24'37" S	119°01'39" E	541
9	GM3-2010-2009-12	6°15'34" S	118°41'13" E	375
10	GM3-2010-2009-13	6°30'59" S	118°25'00" E	275
11	GM3-2010-1909-15	6°27'42" S	117°56'27" E	332
12	GM3-2010-1910-17	5°42'40" S	118°05'00" E	521
13	GM3-2010-1910-18	5°22'20" S	118°16'21" E	584
14	GM3-2010-2010-20	5°02'59" S	118°50'05" E	786
15	GM3-2010-1909-22	6°45'30" S	117°07'25" E	400
16	GM3-2010-1909-23	6°53'43" S	117°37'48" E	470
17	GM3-2010-1909-24	6°52'04" S	118°01'38" E	415
18	GM3-2010-1909-25	6°26'34" S	117°29'47" E	320
19	GM3-2010-1910-26	5°59'20" S	117°29'22" E	222
20	GM3-2010-1910-28	5°30'55" S	117°36'25" E	1446

RESULTS

Community structures of benthic Foraminifera

The community structures of benthic foraminifera comprises of the number of individual, number of species, diversity index, evenness and dominance of benthic foraminifera from each station (Figure 2).

Benthic foraminifera is found in all analysed sediment samples with their total number of each sample is between 13 and 300 individual at St. 12 (Table 2). The lowest number of individual occurs at Station or St 3 at 630 m water depth between a small and main islands of SW Sulawesi. The highest number is found at St. 12 in southern part that is adjacent to small islands at 521 m water depth. Eight stations (stations 2, 3, 5, 6, 8, 9, 10 and 20) have less than 100 individual; six stations (stations 13, 14, 15, 16, 17, and 18) contain of 100-200 individual and the rest samples (stations 1, 4, 7, 8, 12, and 19) have more than 200 individual of benthic foraminifera.

The number of species of benthic foraminifera is comprised of 36 species and two unidentified species (Table 2). The study area is characterized by *Anomalinoidea colligerus*, *Lenticulina suborbicularis*, *Planulina wuellerstorfi*, and *Pseudonodosaria discreta*. Although they are not dominant species in the study area but they are almost distributed widely at several stations. The minimum number of individual for several foraminiferal species is one and the maximum is 69

(St.7). This maximum number of individual belongs to *Planulina wuellerstorfi* that is found at 670 m water depth and located adjacent to small islands in the middle part of the study area. This species has limited range of distribution between at water depth between 320 and 790 m. On the other hand, *Lenticulina suborbicularis* has a wide distribution that is found at water depth between 275 and 1446 m. This species is the most common species that occurs at 16 stations of the study area.

The number of species less than 10 is found at 6 stations (Sts. 2, 3, 5, 6, 10 and 15) and its number between 10 and 20 occurs at 13 stations (1, 7, 8, 9, 11, 12,13, 14, 16, 17, 18, 19, and 20). There is only one station (St.4) that have 24 identified species of benthic foraminifera. The location of St. 4 is in between South Sulawesi and small islands.

The number of individual, diversity index and dominance are appeared in Figure 2. The highest number of individual occurs at St. 19 (222 m) and the lowest abundance is found at St. 3 (630 m).

Number of species each station between 4 (St. 3) and 24 species (St. 4). The diversity values of benthic foraminifera at St. 1 to St. 20 are medium between 1.0 H' 3. The lowest value occurs at St. 5 (1.51) and St. 4 (2.97). The value of evenness is about 0.58 (St. 6) and 0.90 (St. 8) with average value of 0.74. The dominance values are less than 0.5 ($D < 0.5$). The lowest value occur at St 4 (0.06) and the highest value is found at St. 3 (0.40).

Characteristic sediments

The study area is part of South Makassar Basin as a sedimentary basin with water depth between 200 and 1500 m. There are many small islands within this area and it is located at the edge of Sunda and Spermonde shelves. Therefore, this area may have various seabed morphologies from shallow to deep water environments.

Based on classification by Folk (1980), the study area is composed of sand (S), silt (Z), silty sand (zS) and sandy silt (sZ).The sandy silt covers 67% of the study area, followed by silty sand (10%), sand (14%), and silt (9%). There was no sediment type data at St. 19 due very small amount of sediment sample. Sandy silt is mostly distributed at water depth between 700-1500 m as part of the South Makassar Basin. While, sandy sediments cover seafloor at water depth less than 500 m that adjacent to reef environments of small islands. The various sediment types may also reflect the community

Table 2. Benthic foraminifera from the study area

No	Benthic foraminifera	Stations																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	<i>Ammonia beccarii</i>				12			11				12				6	9				
2	<i>Amphicoryna separans</i>	6						8				8	6					12	7	16	
3	<i>Anomalinoedes colligerus</i>	20			21		3	21		10	4	9	22	21	8	46	14	7	11	29	
4	<i>Astacolus crepidulus</i>	2									2		6	4		3			6		
5	<i>Bolivina robusta</i>		4		9	24	30										8	17	12		10
6	<i>Bolivina spathulata</i>	8	2	4	12	8		12	9			12		16	10			28	16	28	9
7	<i>Bulimina aculeata</i>		2		5							5					3	7			
8	<i>Bulimina implata</i>											3		6							
9	<i>Cornuspira planorbis</i>				3			2					11	6					2		1
10	<i>Ehrenbergina carinata</i>							4	3			2									
11	<i>Euvigerina flintii</i>				5		6						14								
12	<i>Gyroidina orbicularis</i>				20																
13	<i>Hyalinonetron sahalense</i>							4					4					6			
14	<i>Inaequalina disparilis</i>							6												34	3
15	<i>Laevidentalina bradyensis</i>					1	1	3				4		2		3	3	4	3	4	2
16	<i>Lagena substriata</i>	9			8				2									9	2	22	
17	<i>Lagenosolenia bradyiformata</i>				8	4	1	5				7	5							8	3
18	<i>Lenticulina suborbicularis</i>	62			32		6	34	6	8	6	39	47	9	11	30	15	14	31		2
19	<i>Llaevidentalina sidebottomi</i>											9	8		3			6			
20	<i>Nodosaria laevigata</i>			1	6		2										4	6			
21	<i>Planorbulina ungeriana</i>	17			17					9			16	13			12	12			5
22	<i>Planulina wuellerstorfi</i>	12		7	38	15	10	69	5	7			23	13	16		5	16	16		6
23	<i>Polymorphina oblonga</i>	18						12		1											
24	<i>Polymorphina pulchella</i>	14			11					14		7		8	8				4		
25	<i>Pseudonodosaria discreta</i>	21	5		19	3				6		52	27	7	14	20	8			30	
26	<i>Pulvinulina karsteni</i>		2							6			24				4		9		
27	<i>Pyrgo murrhina</i>									4			13								
28	<i>Shiponina tubulosa</i>	12			16			8	4	4	3	18	32		3		16	9			
29	<i>Siphogenerina raphana</i>										3	6								20	
30	<i>Siphotextularia fretensis</i>				4							8					2				1
31	<i>Spiroculina manifesta</i>	7						5		1	7	5							5	23	
32	<i>Triloculina marshallana</i>	26			13			13	7	16	6	11	18		7			11	5	26	4
33	<i>Truncatulina refulgens</i>			1	7		4	8	2		7						2	7			
34	<i>Uvigerina aculeate</i>				6				2												
35	<i>Uvigerina mediterranea</i>				7					3	2	19				15	12				
36	<i>Uvigerina proboscidea</i>	8	8		7	7		24	4	4			12	11	9	9		8	5		6
37	Unidentified sp.1				8							4	7		7		4				
38	Unidentified sp.2	11						3					12		3						

structure of foraminifera as part of the component of sediments itself.

Each sediment sample is characterized by certain species of benthic foraminifera and the present study categorize abundant species that has more than 25 individual. Such as at St. 7 is characterized by an abundant species of *Planulina wuellerstorfi* (69 individual). It is not as a dominant species due to there are 15 others species found at this station. While at St. 4, it is composed of 24 species and characterized by two abundant species of *Lenticulina suborbicularis* and *Planulina wuellerstorfi*. At stations 5 and 6 are found *Bolivina robusta* as a abundant species among of 6 and 8 other species. Four dominant species *Anomalinoedes colligerus*, *Pseudonodosaria discreta*, *Bolivina spathulata* and *Triloculina marshallana* occurs at St. 19 with number of individual between 26 and 30.

DISCUSSIONS

The benthic foraminifera in the south Makassar Strait occurs less abundance than planktonic foraminifera. This low number is common found in the deep water environment such as the present study area that lies between 200 and 1500 m of water depth. Boltovkoy and Wright (1976) and Haq and Boersma (1984) stated there is a correlation between water depth and the ratio of benthic and planktonic foraminifera. In general, the PB ratio is more than 90% occur at deep sea sediments.

There are 36 identified and two unidentified species of benthic foraminifera found in study area. It is characterized by several abundant species of *Anomalinoedes colligerus*, *Lenticulina suborbicularis*, *Planulina wuellerstorfi* and *Pseudonodosaria discreta*. These species are cosmopolitan species that commonly appear in the deep sea environments. Van Marle (1988) was also identified some of these species in the Banda

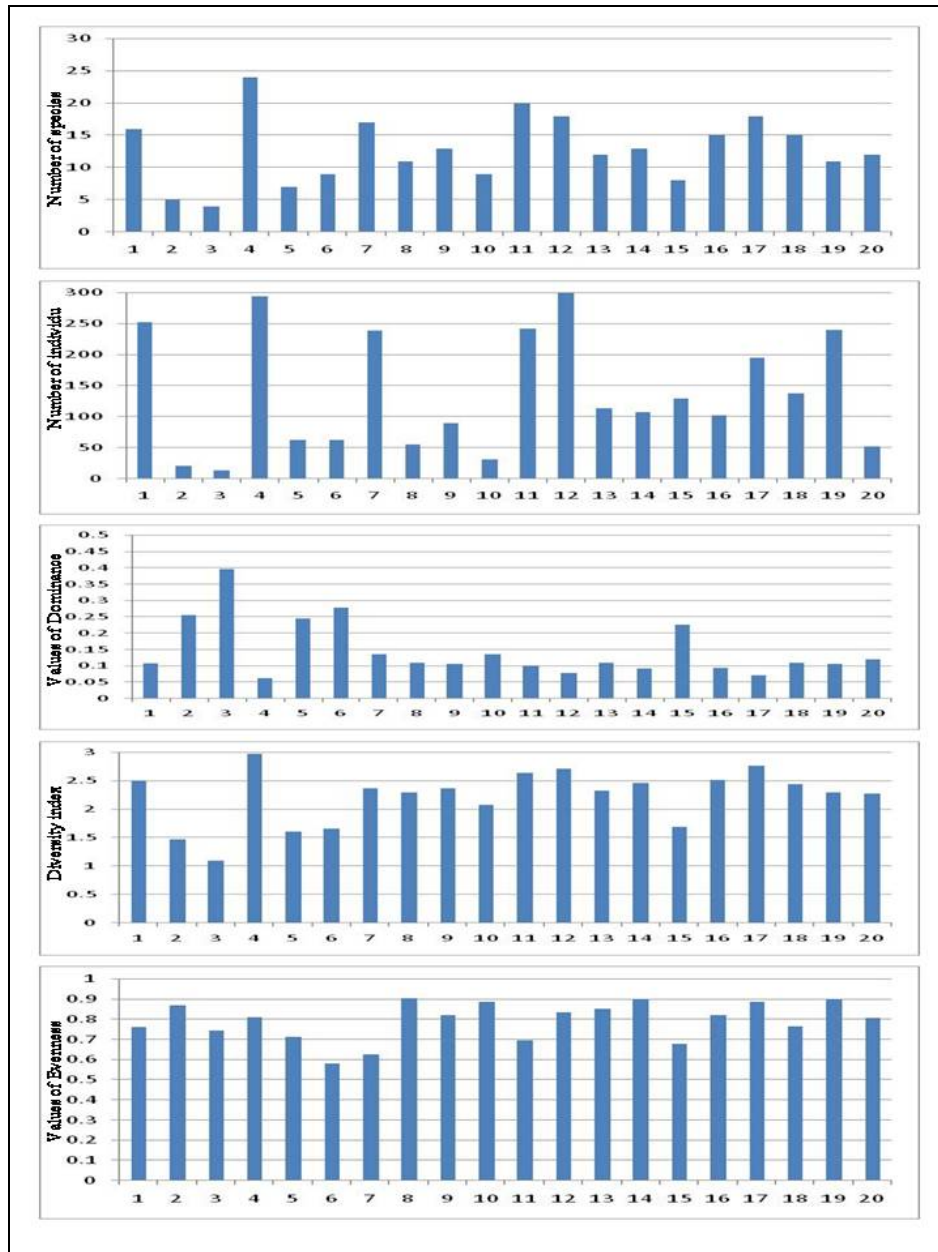


Figure 2 Community structures of benthic foraminifera

Sea. Although, the composition is different among other deep sea environment, it seems that is characteristic species found in certain location.

The diversity index is categorized as moderate values ($1,0 \leq H' \leq 3$). It could indicate that study area generally is quite favorable (moderate) for benthic foraminifera. The dominance values are less than 0.5 indicate that there is no dominant species in the study area. Each species, especially deep sea benthic foraminifera, has similar opportunity to live in the study area.

The number of individual of benthic foraminifera is then categorized by three groups: low (less than 100

individual) occurs at 8 stations, moderate (100-<200 individual) belongs to 6 stations and high (>200 individual) is found at 6 stations (Table 3). The low abundance of benthic foraminifera arises in various sediment types of sand, sandy silt or silt, the moderate abundances sandy silt and silt sediment types and the high abundance is found in silty sand and sandy silt sediments. Therefore, the various sediment types contain various abundances of benthic foraminifera. The good point is that the high abundance of benthic foraminifera is found in silty sand and sandy silt as a good indicator. The sediment type is one of many factors that influences the occurrences of benthic

Table 3. Water depth, sediment type and number of benthic foraminifera

Station (St.)	Water depth (m)	Grain size of sediments				Sediment types (Folk, 1980)	Number of foraminifera	
		Gravel	Sand	Silt	Clay			
1	440	0.00	55.20	42.50	2.40	silty sand	253	High
2	1126	0.00	10.50	85.60	3.90	sandy silt	23	Low
3	630	0.00	11.30	84.80	3.90	sandy silt	13	Low
4	582	0.00	13.80	82.50	3.60	sandy silt	294	High
5	950	0.00	2.70	88.90	8.40	silt	62	Low
6	1360	0.00	4.20	87.10	8.60	silt	63	Low
7	670	0.00	43.60	54.00	2.40	sandy silt	239	High
8	541	0.00	26.90	68.20	5.00	sandy silt	55	Low
9	375	0.00	22.30	72.70	5.10	sandy silt	90	Low
10	275	0.00	99.90	0.00	0.00	sand	31	Low
11	332	0.00	63.40	34.40	2.20	sandy silt	242	High
12	521	0.00	53.50	42.90	3.60	silty sand	310	High
13	584	0.00	18.00	76.30	5.70	sandy silt	114	Moderate
14	786	0.00	100.00	0.00	0.00	sand	107	Moderate
15	400	0.00	100.00	0.00	0.00	sand	129	Moderate
16	470	0.00	20.60	73.10	6.40	sandy silt	102	Moderate
17	415	0.00	33.80	60.40	5.80	sandy silt	195	Moderate
18	320	0.00	48.70	48.80	2.50	sandy silt	143	Moderate
19	222	0.00					240	High
20	1446	0.00	2.00	93.80	4.20	sandy silt	52	Low

foraminifera, such as water depth, current, nutrients, salinity, transparency, etc. (Boltovskoy and Wright, 1976). Dewi and Saputro (2013) has also documented that every sediment type in the Bone Bay, Sulawesi was characterized by certain species of benthic foraminifera.

CONCLUSION

The community structures of benthic foraminifera in the study area are: characterized by 38 species and represented by *Annomalinoidea colligerus*, *Lenticulina suborbicularis*, *Planulina wuellerstorfi*, and *Pseudonodosaria discrete*, the diversity values are moderate ($1.0 \leq H' \leq 3$) indicate quite good environment, the average of evenness index is 0.79, and there is no dominant species based on dominance index ($D < 0.5$).

The high abundance of benthic foraminifera occurs in sediment type of silty sand and sandy silt. Moderate abundance appears in sand following by low abundance in sandy silt and silt sediment type. Sandy silt has various abundances of benthic foraminifera that indicate there are other environmental factors control them.

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