Aquatic Science & Management, Vol. 11, No. 1, 1-7 (April 2023)
Graduate Program, UNSRAT, Manado, Indonesia – Asosiasi Pengelola Sumber Daya Perairan Indonesia
Online submissions – https://ejournal.unsrat.ac.id/index.php/jasm/about/submissions#onlineSubmissions
DOI: https://doi.org/10.35800/jasm.v11i1.56113

e-ISSN 2337-5000
SINTA-3

Current condition of shallow-water benthic foraminifera in Manado bay, Indonesia

Jane M. Mamuaja*, Stephanus V. Mandagi, Markus T. Lasut

Faculty of Fisheries and Marine Science, Sam Ratulangi University, Jl. Kampus Unsrat Bahu, Manado 95115, North Sulawesi Province, Indonesia
*Corresponding author: janemamuaja@unsrat.ac.id

Received: 25 January 2023 – Revised: 30 February 2023 – Accepted: 30 February 2023

ABSTRACT: Coral reef community in Manado Bay is under pressure due to human activities in areas in and around Manado. In order to be able to wisely manage the bay area and the coral reefs in it, information about present conditions is needed. The use of marine organisms as bioindicators is one way to find information about the condition, and organisms such as foraminifera have the potential to be used as some species share the same requirement for water quality as the corals. Sampling for the foraminifera was carried out at 10 locations, and the depth of water ranged from 2.5 m to 7.0 m. The samples obtained were washed through a 63 µm sieve and dried. The separation of foraminifera tests from other sediments was done under a stereomicroscope and they were then identified to genus level. A total of 40 genera was identified among 3194 specimens. To get the FoRAM Index value, the foraminifera was categorized into three functional groups. 8 genera were categorized as symbiont-bearing group, 8 as opportunistic group, and 29 as heterotrophic group. FoRAM Index was found to be varied from 2.06 to 9.19 which indicated that Manado Bay water condition is also varied among the sampling area. In general based on the data obtained, it is assumed that water in Manado Bay is conducive for coral reef growth.

Keywords: benthic foraminifera; shallow water; FoRAM Index; Manado Bay

INTRODUCTION

Foraminifera are amoeboid protozoa that are mostly free-living in the sea, single-celled and show a character which are similar to animals (Boudagher-Fadel, 2013). These organisms can have complex carbonate skeletons and also shells which consist of sedimentary particles. The shells (called tests) are composed of chambers which will increase in number as the organisms grow. The living foraminifera have pseudopodia which help them to take food and sediment particles. Foraminifera are divided into two big groups according to their lifestyle: benthic foraminifera and planktonic foraminifera.

Foraminifera are very important both in geology and ecology. Geologically, the production of calcareous sands in the tropics contributes to around 1-2 kg/m^2/year (Cedhagen, 1996). From ecological point of view, symbiont-bearing large benthic foraminifera share similar water quality requirement with zooxanthellate corals (Hallock *et al*., 2003). And the possibility to use foraminifera assemblage as bioindicator for water quality will be very important in establishing management plan for one area.

Manado Bay is an area situated in front of Manado City. According to Manginsela *et al*. (2016), Manado Bay area has two main functions: ecological functions (as the habitat for diverse marine biotas) and community functions which support the lives of people around the area. Manado Bay has been designated as strategic area in the city of Manado spatial planning (Hudha *et al*., 2019) and this in turn will affect the ecological function of the bay. The area has also experienced a change for the last two decades due to the reclamation activities along some parts of the area. As it is also experienced by several cities in Indonesia, the government of Manado City is trying to boost its economic development by creating central business district. It is done by converting the coastline area, and this development is projected to put more pressure in Manado Bay for many years to come.

According to a study conducted by Pratasik *et al*. (2020) on coral reef conditions of Manado Bay, the coral reef has been categorized as poor to moderate condition with a percentage cover ranging from 9.8% to 40.4%. The water depths of the study were between 3 and 10 m. The conditions are understandable as the area is receiving a lot of pressure from not only reclamation activities which are still ongoing but also from three rivers which run into the bay. All the rivers have their origin in Minahasa highland and have passed through the residential areas in Manado City. The rivers brought with them some potential harmful materials from the land and the materials can potentially damage the life in the bay.

The research was aimed to study the foraminifera from shallow-water area in Manado Bay and to evaluate the FoRAM (Foraminifera for Reef Assessment and Monitoring) Index. This study is expected to find out the conditions of Manado Bay especially in relation to the possibility of the

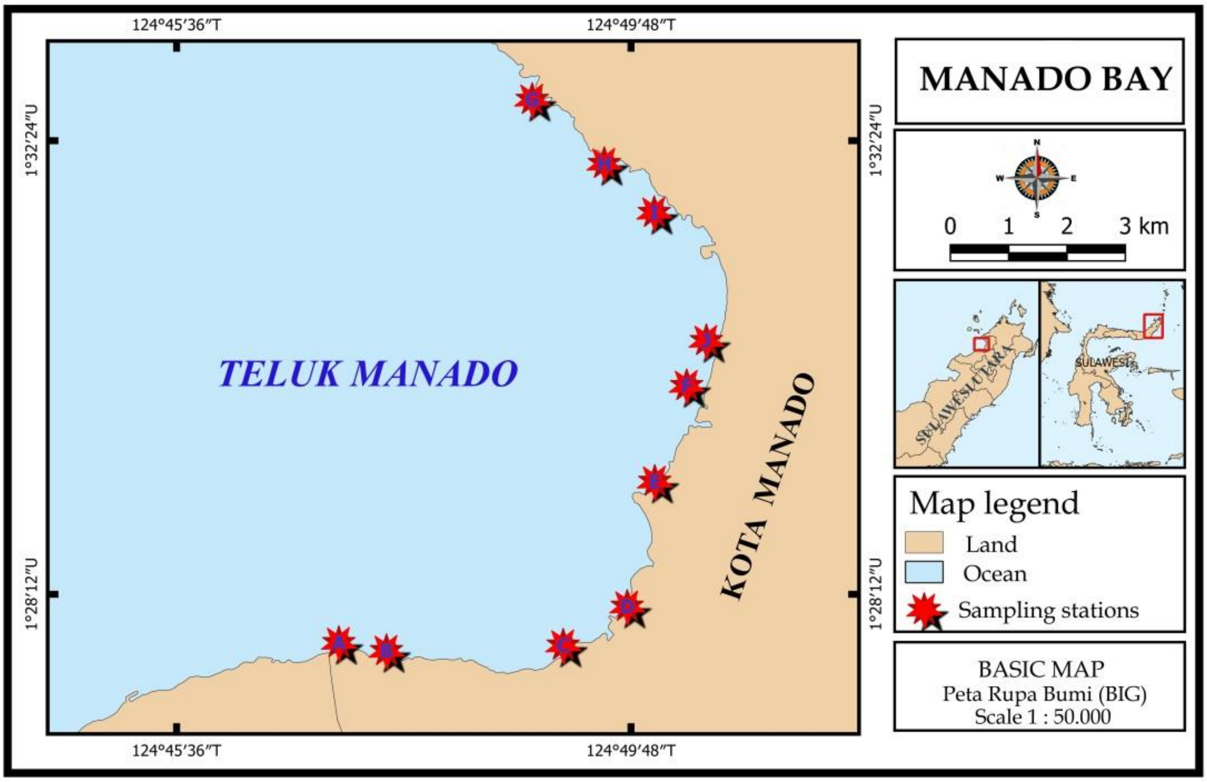

Figure 1. The locations of the study in Manado Bay

coral reef to continually grow in there. Percentage covers (as reported by Pratasik *et al.*, 2020) might represent the present condition of the coral reef visually, but by applying the index can also give information about the condition of the water itself. And this will add up another perspective of the condition of Manado Bay.

MATERIALS AND METHODS

The study area was divided into ten sites (Figure 1) with water depth varied between 2.5 m to 7 m. Sampling of sediment was done in by divers. It was done by filling plastic bags with the upper 2 cm of substrata. All samples were washed with freshwater through 63µm sieves and dried. Water samples were also collected for Nitrate and Phosphate analysis. Sampling sites were determined to represent the condition of the area: area with coral replantation activity, area near river mouth, and area near central business activities.

The sediment samples varied from muddy to sandy sediments and mostly contained terrigenous sediments. A number of > 300 specimens of benthic foraminifera tests were picked from each samples and were identified to genera level. A documentation using microscope camera was also conducted. The identification was based mostly on Loeblich and Tappan (1994), Forderer and Langer (2018), Nobes and Uthicke (2008) and Toruan (2011). The identified specimens were then crosschecked through WORMS (World Register of Marine Species) database on https://www.marinespecies.org/index.php.

The FoRAM Index was calculated using the formula FI = (10 x Ps) + (Po) + (2 x Ph), where Ps, Po and Ph represent the relative abundance of three functional group of foraminifera (symbiont-bearing, opportunistic and heterotrophic taxa). The final step was interpreting the result. For detailed information about the calculation and interpretation, see Hallock et al. (2003).

RESULTS AND DISCUSSIONS

A total of 40 genera have been identified from 3194 specimen (Table 1), and *Calcarina* sp. was found to be the most dominant taxa (38.95 %). The same genus was also found to be the most dominant in six of the eight stations. The second dominant genus was *Triloculina* sp. (10.86%) and it is followed by *Amphistegina* sp. (10.14%). The other four genera with a percentage less than 10% of each followed after that. They are *Quinqueloculina* sp. (7.83%), *Textularia* sp. (7,33%), *Ammonia* sp. (7,20%), dan *Elphidium* sp (6,39%). The least dominant genera are *Laevipeneroplis* sp., *Mikrobelodontos* sp., *Planispirinella* sp., and *Neocassidulina* sp.; each of them was only represented by one single specimen.

The water condition in relation to coral reef growth in the bay was determined by applying calculation of the FoRAM Index (Hallock *et al.*, 2003) and it is based on the proportion of each genera. Each of the genera was categorized into one of three functional groups. It is found that the symbiont-bearing group was represented by 8 genera, opportunistic by 3 genera, and the heterotrophic by 29 genera. According to Hallock et al. (2003), the use of generic-level identification as a base for calculating FoRAM Index is recommended because the generic-level is already well-

Table 1. The composition of benthic foraminifera genera found in Manado Bay

No	Genera	Station								Total
		A	B	C	D	E	G	H	I	
1	*Amphistegina* sp.	42	12	14	5	16	147	52	36	324
2	*Elphidium* sp.	33	25	13	7	22	57	36	11	204
3	*Calcarina* sp.	68	77	282	2	1	214	99	501	1244
4	*Laevipeneroplis* sp.							1		1
5	*Textularia* sp.	26	13	6	19	43	32	77	18	234
6	*Sahulia* sp.	3	1	1	3	3		3	1	15
7	*Mikrobelodontos* sp.				1					1
8	*Rosalina* sp.	1	1		3			7		12
9	*Pyrgo* sp.		1						2	3
10	*Pseudopyrgo* sp.		9			5				14
11	*Operculina* sp.	4	5			3	5	1		18
12	*Nonionoides* sp.								2	2
13	*Heterostegina* sp.	3	1	2				8	1	15
14	*Cibicides* sp.	10					1			11
15	*Peneroplis* sp.	4	4	1		1	27	28		65
16	*Eponides* sp.	2	1			2	3			8
17	*Neoconorbina* sp.	4			3	2				9
18	*Planorbulinella* sp.	10		2			1	9	5	27
19	*Amphisorus* sp.						5	5		10
20	*Cymbaloporetta* sp.	1	2			1		24		28
21	*Assanonella* sp.	3	1							4
22	*Pseudohauerina* sp.	2								2
23	*Quinqueloculina* sp.	31	37	2	58	43		63	11	250
24	*Triloculina* sp.	16	67	1	206	48		6	3	347
25	*Lachlanella* sp.	2		2					8	12
26	*Miliolinella* sp.	2			10	2		4		18
27	*Vertebralina* sp.	1	2					1	1	5
28	*Schlumbergerina* sp.		1					1		2
29	*Fijiella* sp.	2	1					3		6
30	*Bolivina* sp.	4	5	2				4		15
31	*Siphogenerina* sp.		1	1	1	1				4
32	*Ammonia* sp.	31	41		7	126		25		230
33	*Sorites* sp.	4	3	1			1	4	6	19
34	*Planispirinella* sp.	1								1
35	*Spiroloculina* sp.	4	7	1		2		4		18
36	*Neocassidulina* sp.			1						1
37	*Cornuspira* sp.				6	3				9
38	*Acervulina* sp.	2				1				3
39	*Sphaerogypsina* sp.							1		1
40	*Paracassidulina* sp.		1		1					2
	Total	320	319	333	332	325	493	468	605	3194

established and using the species-level identification tends to be inconsistent among researchers.

Two locations, namely Jembatan Bahu (the Bahu Bridge) and Kuala Jengki, were chosen to represent the areas with water input from mainland (via rivers). The results of the analysis of FoRAM Index are very different in those two locations. While Bahu Bridge shows an index of 9,19 which means that the area is conducive to coral reef growth, the result in River mouth of Jengki is at present empty of tests (this needs to be taken into account in future sampling). Our present assumption is that during sediment sampling, the area had just experienced sediment erosion which caused displacement of sediments in the area and it was replaced by other (new) sediment originating from the input of reclamation sediments or sediments from the Tondano River that entered the river mouth of Jengki which carried by water flow. The similar phenomenon was also found in Sindulang sampling site. Two other locations that have a very low FoRAM Index are the area in front of ANTRA Sario and Megamas area, at 2.13 and 2.04, respectively. Both areas are in front of central business locations. Sumale *et al.* (2022) suggested, the index ranged from 5.64 to 9.12. FoRAM Index of < 2 indicates that the water of the location is under pressure and is not suitable for coral reef growth.

Calculation of FoRAM Index had also been conducted in Bunaken Island coral reef area by Paringgi et al. (2018) and Kalalo et al. (2020). Both authors found *Amphistegina* sp. to be the dominant genus and the index was high (> 7.00).

Table 2. The result of FoRAM Index calculation

Station	Location	FoRAM Index
A	Tugu Boboca	4.91
B	Transplantation site (Malalayang)	4,34
C	Bahu Bridge	9,16
D	ANTRA Sario	2,13
E	Megamas Area	2,06
F	River mouth of Jengki	-
G	Meras	8,36
H	Batu Itang, Molas	5,25
I	Molas	9,19
J	Sindulang	-

Similar studies have also been conducted in other areas in Indonesia by several researchers (e.g. Aulia et al 2012; Nurdin et al 2014; Nurruhwati et al 2020). Aulia et al (2012) conducted a study on foraminifera in Banggai Islands in Central Sulawesi and found 75 species from 33 genera. The FoRAM Index ranged from 2.99 to 5.54. They correlated the index with coral coverage in the area and found that there was a close relationship between the two. Moreover, Nurdin et al (2014) who studied foraminifera in several islands in Kepulauan Seribu in Jakarta noted that *Amphistegina* sp. was the dominant genus and it was followed by *Calcarina* sp.

Phosphate and Nitrate analysis were also conducted in the study. Nitrate concentration were < 0.005 mg/L at all sampling stations, while phosphate ranged from < 0,005 mg/L to 0.888 mg/L (Table 2). According to Hallock et al. (2003), benthic foraminifera assemblages respond to nutrient fluxes in seawater. Large benthic foraminifera such as *Amphistegina* sp. and *Calcarina* sp. which host algal endosymbionts dominate sediment in area with low nutrient. This somewhat contrast with our findings at Bahu Bridge with the phosphate concentration of 0.888 mg/L and 0.462 mg/L, but the FoRAM Index was found to be 9.16 which indicate that water condition strongly supports the presence of symbiont-bearing foraminifera.

Our present findings indicate that the diversity of foraminifera in Manado Bay is higher than the finding in similar studies conducted in other areas in Indonesia (among others, Aulia et al 2012; Nurdin et al 2014; Nurruhwati et al 2020). And based on the calculation of FoRAM Index, we can assume that most of the areas in Manado Bay are still conducive for coral reef growth. However, continuous environmental monitoring which involved benthic organisms such as foraminifera is needed, in order to sustain the ecological function of the bay.

CONCLUSION

A total of 3194 specimens were determined from this study and 40 genera were found. From this number, 8 genera were categorized into symbiont-bearing foraminifera, 3 were from opportunistic group and 19 genera were of heterotrophic. Some of the specimens have been identified to species level, among others *Amphistegina madagascariensi*, *A. radiata*, *Ephidium craticulatum*, and *Calcarina defrancei*. Some genera need to be examined further; this is especially for *Quinqueloculina* sp. which were quite diverse. Present findings on FoRAM Index are also quite interesting because the area of study is in one long coastline in Manado Bay and the index ranged from 2.06 to 9.19. One way to make sure that the index is exactly representing the present condition is by doing monitoring program on the foraminifera assemblages in the bay.

Acknowledgements. This study is funded by Sam Ratulangi University through PNBP-RDUU 2021. We would like to our thanks the Rector of Sam Ratulangi University and the LPPM UNSRAT for that. Our gratitude also go to the Dean of Faculty of Fisheries and Marine Science for the support. *"We certify that there is no conflict of interest with any organization regarding the materials discussed in this manuscript"*.

REFERENCES

AULIA, K.N., KASMARA, H., ERAWAN, T.S. and NATSIR, S.M. (2012) Water conditions of coral reefs with foraminifera benthic as bioindicator based foram index in Banggai Islands, Province of Central Sulawesi. *Jurnal Ilmu dan Kelautan Tropis*, 4 (2), pp. 335-345.

BOUDAGHER-FADEL, M.K. (2013) *Biostratigaphic and geological significance of planktonik foraminifera*. OVPR UCL, London.

CEDHAGEN, T. (1996) Foraminiferans as food for Cephalaspideans (Gastropoda: Opisthobranchia), with notes on secondary tests around calcareous foraminiferans. *Phuket Marine Biological Center Special Publication*, 16, pp. 279-290.

FORDERER, M. and LANGER, M.R. (2018) Atlas of benthic foraminifera from coral reefs of the Raja Ampat Archipelago (Irian Jaya, Indonesia). *Micropaleontology*, 64 (1-2), pp. 1-170.

HALLOCK, P., LIDZ, B.H., COCKEY-BURKHARD, E.M. and DONNELLY, K.B. (2003) Foraminifera as bioindicators in coral reef assessment and monitoring: The FoRAM Index. *Environmental Monitoring and Assessment*, 81, pp. 221-238.

HUDHA, N., RONDONUWU, D.M. and SURYONO (2019) Kajian pengembangan pesisir Teluk Manado sebagai kota tepi pantai. *Jurnal Spasial*, 6 (3), pp. 800-809.

KALALO, R., MAMUAJA, J.M., MANENGKEY, H.W.K., KUSEN, J.D., DJAMALUDDIN, R. and MANTIRI, R. (2020) Foraminifera bentik pada terumbu karang Pulau Bunaken. *Jurnal Pesisir dan Laut Tropis*, 8 (1), pp. 56-64.

LOEBLICH A.R. and TAPPAN, H. (1994) *Foraminifera of the Sahul Shelf and Timor Sea. Cushman Foundation for Foraminiferal Research.* Inc. Museum of Comparative Zoology, Harvard University. Cambridge.

MANGINSELA, F.B., RONDO, M., RONDONUWU, A.B., KAMBEY, A.D. and LUMUINDONG, F. (2016) Ekologi Perairan Teluk Manado. *Penerbit FPIK Unsrat*.

NOBES K. and UTHICKE, S. (2008) *Benthic foraminifera of the Great Barrier Reef. Department of the Environment, Water, Heritage and the Arts*. Australian Government. Australia.

NURDIN, N., GUSTIANTINI, L., MARINA, S. and YOSI M. (2014) Analyses of foraminifers microfauna as environmental bioindicators in Kotok Besar, Kotok Kecil and Karang Bongkok Islands, Kepulauan Seribu, DKI Jakarta Province. *Bulletin of the Marine Geology,* 29 (1), pp. 21-28.

NURRUHWATI, I., ARDIANSYAH, F., YUNIARTI, YULIADI, L.P.S. and PARTASASMITA, R. (2020) Benthic foraminifera as ecological indicators in the Tunda Island Waters, Serang District, Banten Province, Indonesia. *Biodiversitas,* 21 (7), pp. 3142-3148.

PARINGGI, E.P., MAMUAJA, J.M., RAMPENGAN, R.M., OMPI, M., ROEROE, K.A. and REMBET, U. (2022) Sebaran spasial foraminifera bentik pada terumbu karang Pulau Bunaken Sulawesi Utara. *Jurnal Pesisir dan Laut Tropis,* 1 (1), pp. 33-43.

PRATASIK, S.B., SUPRIHARYONO, SAMBALI, H. and MANOPPO, L. (2020) Coral reef conditions of Manado Bay, North Sulawesi, Indonesia. *International Journal of Conservation Science*, 11(3), pp. 857-864.

SUMALE, E.V., MAMUAJA, J.M., LASUT, M.T., MANENGKEY, H.W.K., RAMPENGAN, R.M. and LALITA, J.D. (2022) FoRAM Index in Manado Bay coral reef areas, Northern Sulawesi, Indonesia. *Aquatic Science & Management,* 10 (1), pp. 30-34.

TORUAN, L.N.L. (2011) *Pendugaan kualitas ekosistem terumbu karang di Kepulauan Seribu dengan menggunakan proporsi foraminifera bentik sebagai bioindikator*. Sekolah Pascasarjana Institut Pertanian Bogor.

SUPPLEMENTS

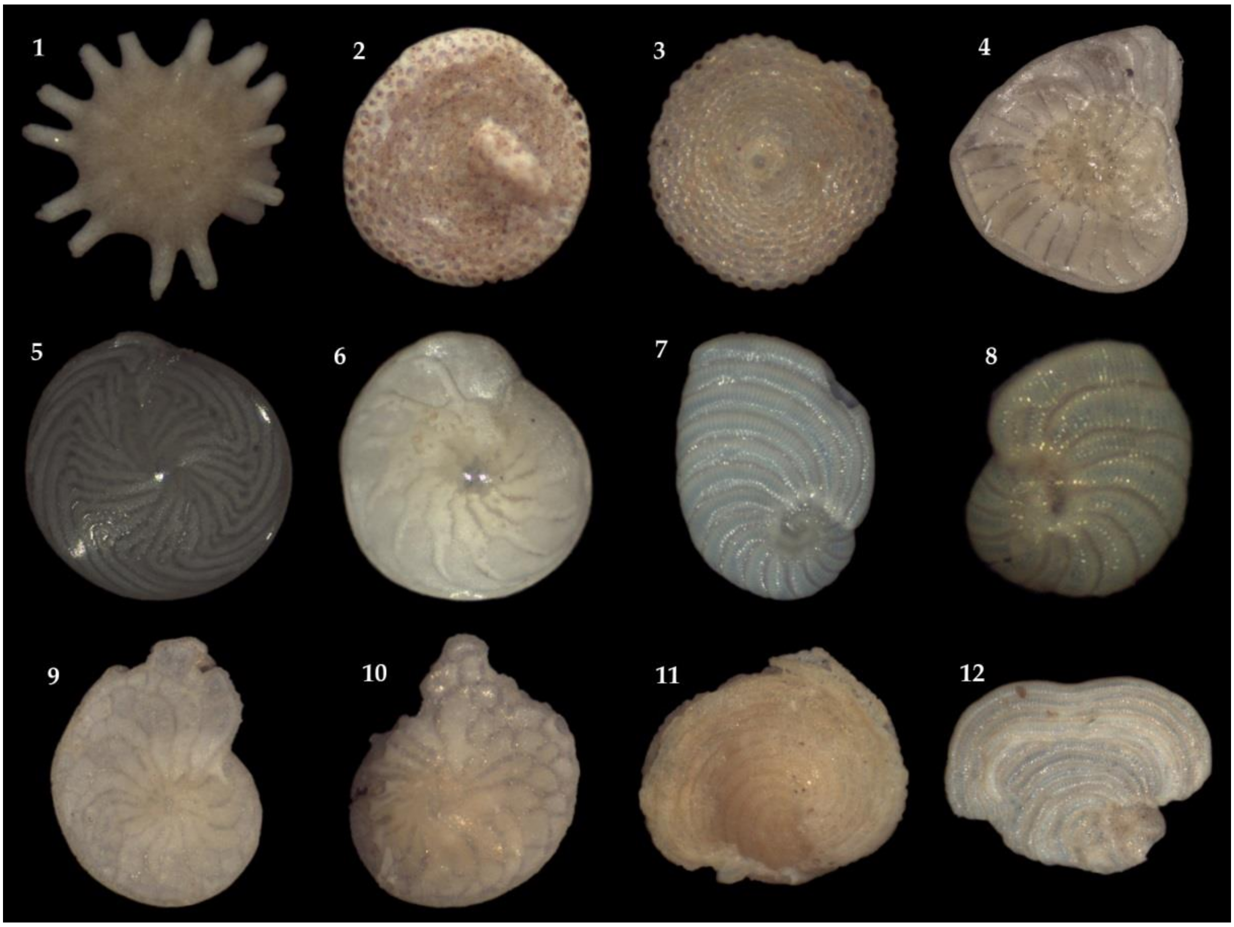

Plate 1. Benthic foraminifera of symbiont-bearing functional group: 1. *Calcarina defrancei*; 2. *Amphisorus hemprichii*; 3. *Sorites orbiculus*; 4. *Operculina ammonoides*; 5. *Amphistegina radiata*; 6. *A. madagascariensis*; 7. *Peneroplis planatus*; 8. *P. pertusus*; 9. *Heterostegina* sp.; 10. *Heterostegina* sp.; 11. *Laevipeneroplis* sp.; 12. *L. bradyi*.

Plate 2. Benthic foraminifera of opportunistic functional group: 1. *Elphidium craticulatum*; 2. *E. crispum*; 3. *Ammonia* sp.; 4. *Bolivina* sp.

Plate 3. Benthic foraminifera of heterotrophic functional group: 1. *Eponides* sp.; 2. *Vertebralina striata*; 3. *Planispirinella exiqua*; 4. *Pseudohauerina orientalis*; 5. *Assanonella tubulifera*; 6. *Fijiella* sp.; 7. *Pseudopyrgo milletti*; 8. *Siphogenerina* sp.; 9. *Lachlanella* sp.; 10. *Miliolinella* sp.; 11. *Neoconorbina* sp.; 12. *Cibicides* sp.; 13. *Mikrobelodontos bradyi*; 14. *Rosalina* sp.; 15. *Cymbaloporetta* sp.; 16. *Triloculina trigonula*; 17. *Sahulia* sp.; 18. *Cornuspira* sp.; 19. *Acervunila* sp.; 20. *Nonionoides* sp.; 21. *Spiroloculina* sp.; 22. *Textularia* sp.; 23. *Schlumbergerina alveoliniformis*; 24. *Quinqueloculina* sp.; 25. *Pyrgo* sp.; 26. *Sphaerogypsina* sp.; 27. *Agglutinella* sp.; 28. *Neocassidulina* sp.; 29. *Planorbulinella* sp.