Analyses of Foraminifers Microfauna as Environmental Bioindicators in Kotok Besar, Kotok Kecil and Karang Bongkok Islands, Kepulauan Seribu, DKI Jakarta Province

Analisis Mikrofauna Foraminifera Sebagai Bioindikator Lingkungan di Pulau Kotok Besar, Kotok Kecil dan Pulau Karang Bongkok, Kepulauan Seribu, Provinsi DKI Jakarta

Nazar Nurdin, Luli Gustiantini, Siti Marina and Mira Yosi

Marine Geological Institute, Jl. Dr. Junjunan No.236, Bandung

Email : nazznur@yahoo.com

(Received 03 February 2014; in revised form 2 May 2014; accepted 14 May 2014)

ABSTRACT : Kepulauan Seribu is a well-known destination of marine tourism in Indonesia. Inevitably, the place has been affected by human activities. Hence it is important to preserve and conserve the area so as it is still suitable for reef community to grow and develop. One of the methods to evaluate the feasibility for reef environment is calculated by FoRAM Index (FI) values. Benthic foraminifera as a tool for environmental bioindicators were collected from 15 marine surface sediment samples in the vicinity areas of Kotok Besar, Kotok Kecil and Karang Bongkok islands in Kepulauan Seribu to assess the FI values. Approximately 20 genera of benthic foraminifera were found in the study area. The genera are dominated by Amphistegina and Calcarina along with Operculina, Quinqueloculina, Peneroplis, and Discorbis. The finding signifies reef flat environment as the dominant morphology, although the presence of fore slope is also observed particularly at the western part of Kotok Besar island. The assemblages of Operculina and Quinqueloculina suggest that the abundance of benthic foraminifera is influenced not only by the morphology of seafloor, but also by tidal current and terrestrial influence. The FI formula using foraminifers found in the study area results values above 4, thus the area can be reviewed as a decent environment for reef growth and development.

Keywords: benthic foraminifera; bioindicator; FoRAM Index; coral community; seafloor morphology

ABSTRAK : *Kepulauan Seribu terkenal sebagai tujuan wisata laut di Indonesia, sehingga dapat dipastikan tempat ini dipengaruhi oleh aktifitas manusia. Oleh sebab itu sangat penting untuk menjaga dan melindungi kelestarian lingkungannya sehingga tetap cocok bagi komunitas karang untuk hidup dan berkembang. Salah satu metode untuk mengevaluasi kelayakan lingkungan terumbu adalah dengan menghitung nilai FoRAM Index (FI). Untuk analisis ini, foraminifera bentik dikoleksi dari 15 sampel sedimen permukaan laut dari daerah sekitar Pulau Kotok Besar, Kotok Kecil dan Pulau Karang Bongkok di Kepulauan Seribu. Hasil penelitian menunjukkan sekitar 20 genera foraminifera bentik yang ditemukan di daerah penelitian. Foraminifera didominasi oleh Amphistegina dan Calcarina, sedangkan jenis lain yang juga cukup berlimpah adalah Operculina, Quinqueloculina, Peneroplis, dan Discorbis. Hal ini menunjukkan lokasi penelitian memiliki jenis morfologi rataan karang sebagai morfologi dominan, walaupun kehadiran lereng karang (fore slope) juga teramati terutama pada bagian barat pulau Kotok Besar. Distribusi kelimpahan Operculina dan Quinqueloculina menunjukkan bahwa kelimpahan foraminifera bentik selain dipengaruhi oleh morfologi dasar laut juga dipengaruhi oleh pasang surut dan pengaruh terestrial. Hasil perhitungan FI berdasarkan foraminifera di wilayah penelitian menunjukkan nilai FI > 4 sehingga daerah ini dapat ditinjau sebagai lingkungan yang layak untuk pertumbuhan karang dan perkembangannya.*

Kata kunci*: foraminifera bentik; bioindikator; FoRAM Index; komunitas koral; morfologi dasar laut*

INTRODUCTION

Kepulauan Seribu is considered as one of famous tourist destinations in Indonesia. The area consists of ~110 islands. In addition, Kepulauan Seribu water is also well-known as a place with a high growth of reef community where their variety and abundance as well as the ecosystem are considered as specific and unique among other locations in Indonesia. These virtues take Kepulauan Seribu into consideration as a conservation area as mentioned in Natsir (2010) and Toruan, et al.

(2013), other than the fact that a number of the islands in Kepulauan Seribu are already implied environmental quality degradation.

Hallock, et al. (2003) has developed a quantitative method that relates water quality to reef health based on the abundance of foraminifers. The method is called Foraminifera in Reef Assessment and Monitoring (FoRAM) Index (FI) where the abundance of foraminifers associated with reef indicates the abundance of reef, in which water quality is assumed as the main factor that influence the environment. In other words, foraminifers can be argued as an indicator to determine the environmental conditions in terms of reef health (Schueth and Frank, 2008). As the area geographically located in Coral Triangle, therefore the analysis is applicable in Indonesian water as previously observed by Dewi, et al. (2010), Natsir (2010), Natsir and Subkhan (2012) and Toruan, et al. (2013).

Foraminifera, especially benthic foraminifera, are potentially bioindicators as they are characterized by their sensitivity toward environmental changes. Their microscopic size also benefits for measuring their abundance since they are distributed as components in marine sediments. Murray (2006) in Wilson et al. (2010) mentioned that the distribution of foraminiferal ecology is already well-known. Additionally, foraminifers can be simply collected and are always so highly abundant that they are reliable to record useful data for statistical analytic purpose.

Several genera of foraminifers are recognized to be used in the formula of FI. Javaux and Scott (2003) revealed several foraminifers that associated with reef, i.e. *Acervulina inhaerens, Ammonia beccarii, Amphistegina lessonii, Archaias angulatus, Clavulina tricarinata, Cibicides refulgens, Elphidium advenum,* and *Elphidium sagrum*. Nobes and Uthicke (2008) mentioned that several genera found in the Great Barrier Reef, such as *Amphistegina, Calcarina, Peneroplis, Alveolinella,* and *Heterostegina* are genera associated with algae, whereas genera of *Elphidium, Ammonia,* and *Pararotalia* are attributed as opportunists of foraminiferal taxa.

Considering the conditions above, this study was conducted in order to understand the relationship between the foraminiferal assemblages and the environment in the study area. This study covered the area part of Regency of Kepulauan Seribu, northwestern offshore to ward Jakarta, in which Kepulauan Seribu belongs to Special Capital Region of Jakarta, Indonesia. The study area is located between 106° 31'24.10" – 106° 35'5.89" E and 5° 40'20.00"-5° 42'46.53" S in the vicinity of Kotok Besar, Kotok Kecil, and Karang Bongkok islands (Figure 1). This area is located in the District of Kepulauan Seribu Selatan, the southern part of Kepulauan Seribu.

The corrected depth in the study area is ranging from 1.13m to 61.7m (Figure 2). Corrected depths are measured using 24-hour tide gauge related to mean sea level (MSL). Maximum depths are found in the northern and southeastern part of Karang Bongkok island (Figure 3). Karang Bongkok island stands at ~0.86 ha and is surrounded by ~240 ha shoal which only elevated on low tide; whereas Kotok island stands at 0.2 km2 and surrounded by atoll or barrier reef.

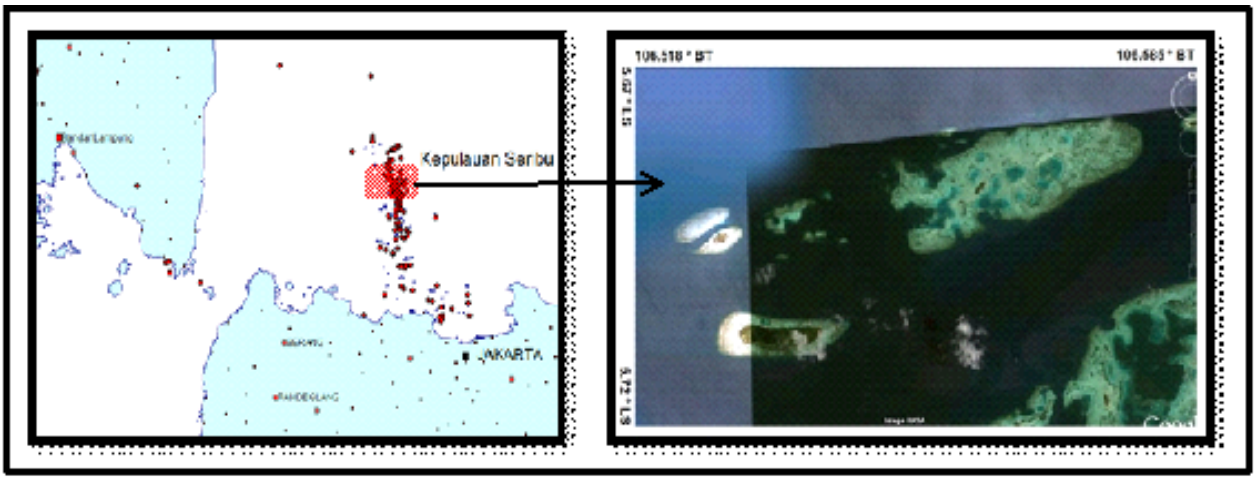

Figure 1. Map view of Kotok islands (right-hand side figure) shows an up-close bird's eye view in the vicinity of Kotok islands, Kepulauan Seribu, revealing reef community around the islands in shallow water (light green color), whilst elevated shoal can be recognized in the shallower water (white color), zoomed in from the index map (left-hand side map). (Yosi, et al., 2011)

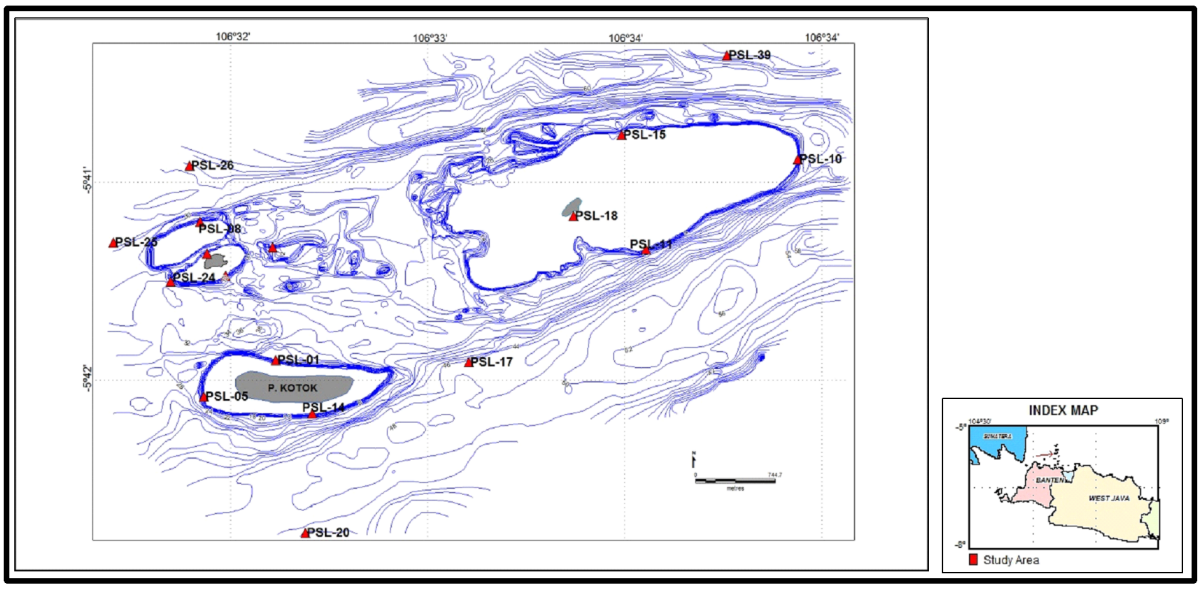

Figure 2. Bathymetric map around Kotok Besar, Kotok Kecil, and Karang Bongkok waters with contour interval of 2m, and sample locations (red triangles). Maximum depths are found in the north and southeastern part of Karang Bongkok island. Wide areas of shoal around the islands are elevated mostly only during low tide. (Yosi, et al., 2011)

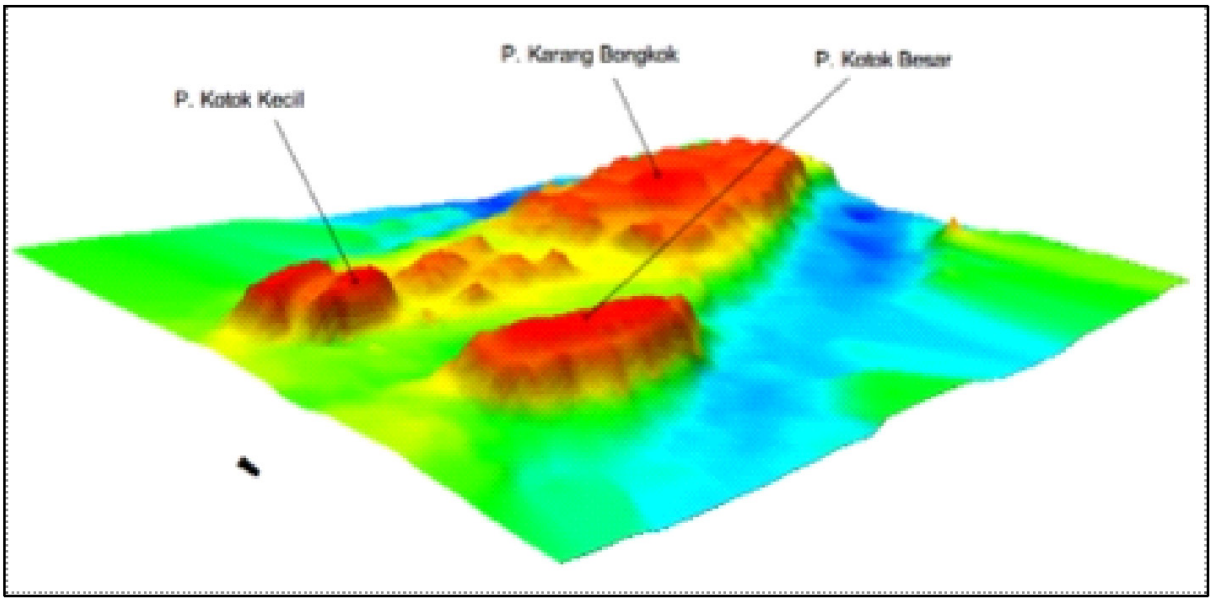

Figure 3. Seafloor morphology around Kotok Besar, Kotok Kecil, and Karang Bongkok islands (red color). Depth ranging from shallower (orange), usually occupied by reef, to deeper (blue) (Yosi, et al., 2011).

METHODS

Microfaunal analyses of benthic foraminifera were observed from 15 selected surface sediment samples, comprises 5 samples from Kotok Besar island, 4 samples from Kotok Kecil island, and 6 samples from Karang Bongkok island, as shown at Figure 4. Samples were collected based on seafloor geomorphology study in Kepulauan Seribu conducted by Yosi, et al. (2011) from Marine Geological Institute.

Analyses were conducted in micropaleontology laboratory. Previously, sediments were washed using several sizes of sieves. Preparing to analyze, the samples were dried in the oven at the temperature of lower than 65 C. Upon examining the samples, approximately 300 specimens of benthic foraminifera were collected and separated from > 150µm size fraction of sediment. The foraminiferal genera were identified referring to Barker (1960), Loeblich and

Tappan (1994), and Yassini and Jones (1995) classifications.

Reef environment identification was analyzed using the formula of FoRAM (Foraminifera in Reef Assessment and Monitoring) Index (FI) proposed by Hallock et al. (2003):

$$FI = (10\ Ps) + (Po) + (2\ Ph)$$

where:

FI = FoRAM Index

Ps = Ns/T ("Ns" is number of specimens of foraminiferal taxa associated with reef: A*mphistegina, Heterostegina, Alveolinella, Borelis, Sorites, Amphisorus, Marginophora.*

Po = No/T ("No" is number of specimens of opportunist foraminiferal taxa: *Ammonia, Elphidium,* and some of Trochaminidae, Lituolidae, Bolivinidae, and Buliminidae.

Ph = Nh/T ("Nh" is number of other small heterotrophic foraminiferal taxa: some of Miliolida, Rotaliida, Textulariida, etc.

T = total number of foraminiferal specimens counted.

Application of FI based on Hallock et al. (2003) interpretation in Natsir (2010) is as follows:

FI 4 = environment is suitable for reef growth.

FI varying between 3 and 5-6 indicates decreasing environmental change.

2 < FI < 4 = environment is marginal for reef growth that the conditions are unsuitable for recovery after community destruction.

FI 2 = environment is unsuitable for reef growth.

RESULTS

Generally, the benthic foraminifera found in the study area of Kotok Besar, Kotok Kecil and Karang Bongkok waters, comprise 20 genera (Table 1). The most common ones are *Amphistegina* and *Calcarina* which associated with coral reef. The average percentages are 26.78% and 11.84%, respectively. The other genera with adequate abundance are *Operculina, Quinqueloculina* spp., *Peneroplis,* and *Discorbis* (Table 1).

The result concludes the percentage of genera associated with reef is dominant with average percentage of 53.73%. From this type, *Amphistegina* is the most dominant and the most common genus due to its presence at all locations, followed by *Calcarina* spp. The percentages of opportunistic and heterotropic genera are 34.67% and 11.51% respectively. The opportunistic type is dominated by *Quinqueloculina* which also found at all locations, the average percentage is 12.18%, the highest percentages are at PSL 39, northern part of Karang Bongkok island and at PSL 20, the southern part of Kotok Besar island. The heterotropic type is dominated by *Discorbis* with average percentage is 6.42%.

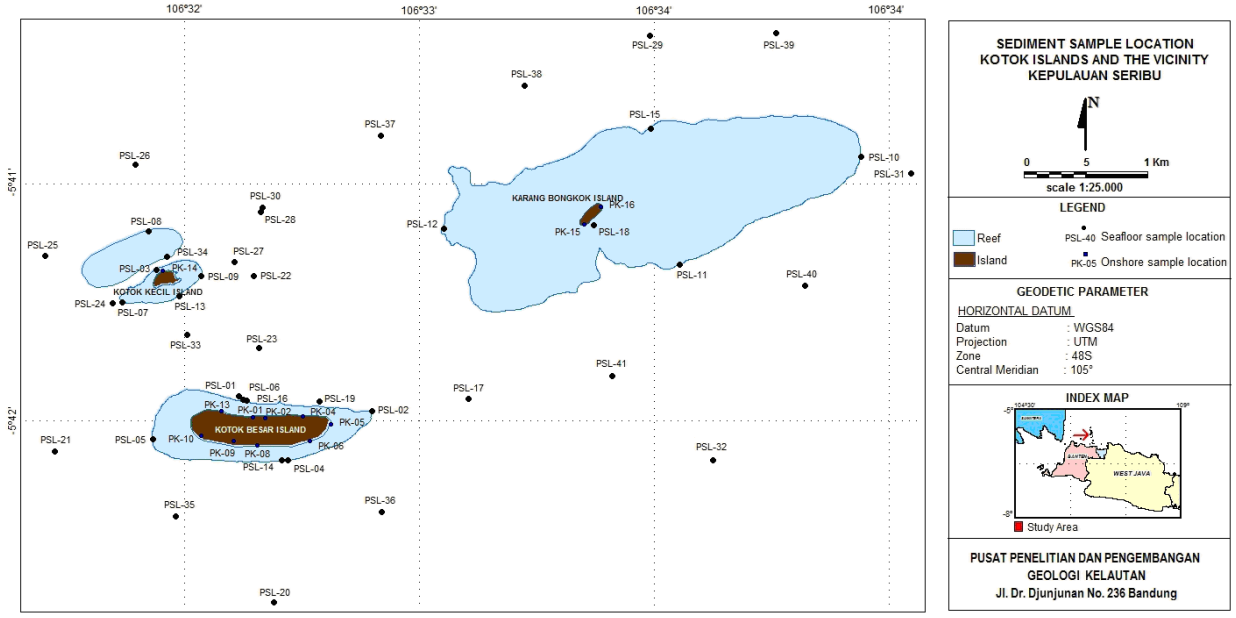

Figure 4. Samples location, retrieving surface sediment samples in shallow waters around Kotok Besar, Kotok Kecil and Karang Bongkok islands. (Yosi et al., 2011)

Table 1. Tabulation of distribution percentage of benthic foraminifera around Kotok Besar, Kotok Kecil and Karang Bongkok islands.

No.	Genus	Kotok Besar island					Kotok Kecil island				Karang Bongkok island						Abundance (%)	
		PSL-01	PSL-05	PSL-14	PSL-17	PSL-20	PSL-03	PSL-13	PSL-24	PSL-27	PSL-10	PSL-11	PSL-15	PSL-18	PSL-32	PSL-39	Avg.	Group
1	*Amphistegina*	29.67	74	16.33	41.33	13.33	18.33	16.67	30.33	34.67	48.33	9	15.33	1	37.67	15.67	26.78	
2	*Amphisorus*	1.33	0.67	1.33			1.67	1			1.33	1.33	3	1.67		0.33	0.91	
3	*Calcarina spp.*	1.33	5.33	22.33	0	2	12.67	22.67	8	15.67	36.67	20.67	14.67	3.33	4.33	8	11.84	
4	*Peneroplis*	6	1	3.33	0.33	0.33	12.67	8	0.67	1.67	0.33	7.33	1	3.33	2		3.2	53.73
5	*Operculina*	20.67	0.33	0.67	13	26.67	0.33	0.67	21.67	8	1.67		6	43.33	9	6.33	10.56	
6	*Baculogypsinoides*	0.33	2			0.33	0.33				0.67				1	2	0.44	
7	*Spiroloculina*	1.33	0.33	0.67	1.67	5	9	1.67	0.67	0.67	1	4.33	3.33	1.67	1.67	6	2.6	
8	*Elphidium*	6	4.67	6.33	5.67	1	3.33	6.67	16.33	12	2.33	1	9.67	7.67	8.33	0.33	6.09	
9	*Ammonia*	1.67	0.67	1.33			3.67	2.33	2	2	1.67	3.67	4	4.67			1.84	34.67
10	*Quinqueloculina spp.*	6	4.33	4	23.67	39.33	8.33	1.67	7.33	9.33	1	2.67	6.33	8.33	15.67	44.67	12.18	
11	*Pararotalia*	12.33	2	34			22.67	36	1	0.33	0.33	48	14.67	4.67	3.33		11.96	
12	*Valvulineria*						1	1		0.67			2.67	0.33			0.38	
13	*Planorbulinella*		0.67	1		6.67	0.33		1	0.33					1.33	9.67	1.4	
14	*Lachlanella*	0.67	0.33	0.67	0.33		0.33	0.33	0.67	3	0.67	0.33	1	1.33	0.67	0.33	0.71	
15	*Textularia*	2		1	0.33	1.33	2.67	0.67	4.33	2	0	0.67	4	6.33	2.67	4.67	2.18	11.51
16	*Discorbis*	9.67	3.67	6.33	13.33	3.67	2.67	0.67	5.67	8.33	4	1	14.33	12.33	9	1.67	6.42	
17	*Guttulina*	0.67			0.33					0.33							0.09	
18	*Massilina*	0.33															0.02	
19	Unidentified foram									0.67					3.33	0.33	0.31	
	Ps	59.33	83.33	44	54.67	42.67	46	49	60.67	60	89	38.33	40	52.67	54	32.33		
	Po	27.33	12	46.33	31	45.33	47	48.33	27.33	24.33	6.33	59.67	38	27	29	51		
	Ph	13.33	4.67	9	14.33	11.67	7	2.67	11.67	15.33	4.67	2	22	20.33	17	16.67		
	FoRAM Index	**6.47**	**8.55**	**5.04**	**6.06**	**4.95**	**5.21**	**5.44**	**6.57**	**6.55**	**9.06**	**4.47**	**4.82**	**5.94**	**6.03**	**4.08**		

DISCUSSION

Calcarina, Peneroplis and *Baculogypsina* usually are abundant in reef flat, whereas *Amphistegina* is abundant in fore slope. *Operculina* is mostly found in shelf or open sea, while Miliolid (*Quinqueloculina,* etc.) and *Peneroplis* are found in restricted platform and lagoon (Hallock and Glenn, 1986). Most of the islands in Kepulauan Seribu have wide reef flat areas, sloping at the edge to fore slope with the gradient up to 70^{o} at the depth varied from 10 m to 75 m bsl (Natsir, 2010).

Generally, the study area is a reef flat with some sample locations shows fore slope areas, particularly where *Amphistegina* percentage is high. Fore slopes can be located in the western part of Kotok Besar island (PSL-05) and in the eastern part of Karang Bongkok island where the percentages of *Amphistegina* are of 74% and 48.33%, respectively.

From PSL-18 (Karang Bongkok island) and PSL-20 (Kotok Besar island) samples, the abundance of *Operculina* genus is 43.33% in PSL-18 and 26.67% in PSL-20. The values based on *Operculina* distribution refer to the influence of tidal current that flooded the low areas (basins) (PSL-20) in the reef flat (PSL-18) during high tide, implying a good water condition for *Operculina* growth to increase. An enclosed area where PSL-20 sited causes a relatively high abundance of *Quinqueloculina* until 39.33%; whereas the abundance distribution in PSL-39 (Karang Bongkok island) of 44.67% suggesting an enclosed transitional reef area. The deepest location in this area is still influenced by terrestrial, forming a lagoon suitable for *Quinqueloculina* to grow.

The FI values from all of the analyzed sediment samples are above 4, i.e. 4.08 - 9.06, revealing that the environments are very conducive for reef to grow. It is typical for an environment where the influence of terrestrial is quite a distance from the land. The islands in the study area are located about ~60-70 km in the far northwest from the Jakarta Bay which make the environment is still suitable for reef to develop well. The previous research at Kotok Besar island (Natsir, 2010) and at Karang Bongkok island (Toruan et al., 2013) also concluded that the environment condition of both area are considered conducive for coral reef growth.

Nevertheless, preserving the environment is absolutely needed to conserve the reef community in Kepulauan Seribu as the tourist destination nowadays concerns with environmental degradation. In fact, from the study area southward approaching the mainland the environment has already degraded, e.g. Nirwana island where Natsir (2010) observed that the FI values in this area are below 2, and is showing the environment is not feasible anymore for reef to develop. A similar condition also occurs in Onrust island near Jakarta Bay, exhibiting a bad condition of coral reef. The condition is shown by higher percentages of several opportunistic genera compared to that of genera associated with coral reef (Toruan et al., 2013). On the other hand, oil spill from oil rigs/ platforms in the western part of Kepulauan Seribu are potentially damaging the area especially when the

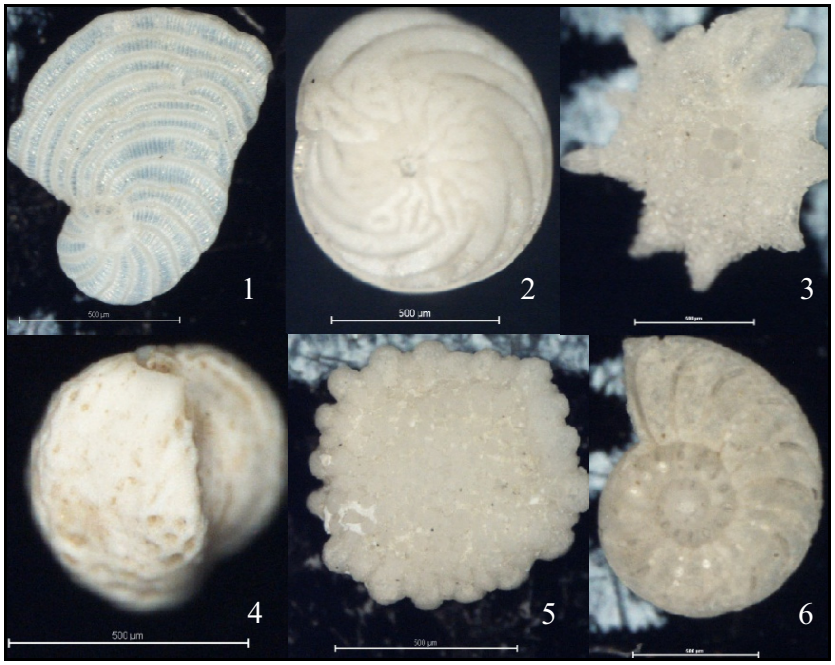

Figure 5. Foraminifera characterizing reef environment: 1.Peneroplis, 2. Amphistegina, 3. Calcarina, 4. Quinqueloculina, 5. Planorbulinella, 6. Operculina

Southwest Monsoon blows from the west to the east, likewise the Northeast Monsoon brings along pollutants of heavy metal and seston (suspended particulate matters) from the east (Jakarta Bay) to the west (Miharja and Pranomo, 2001).

Calcarina, Peneroplis, and *Baculogypsina* genera are generally abundant in reef flat, whereas *Amphistegina* genus is abundant in fore slope. *Operculina* genus is usually found in open shelf, whilst the Miliolid Order, such as *Quinqueloculina* etc., and *Peneroplis* are found in a restricted platform and lagoon (Hallock and Glenn, 1986). Knowingly, most of the islands in Kepulauan Seribu have widely enough of reef flat areas edged by fore slopes sloping down up to 70 varied on bathymetry of 10 m to 75 m depth (Noor, 2003).

Based on genera found in the study area, the area encompasses reef flat with some locations are of fore slopes, determined specifically as *Amphistegina* found abundantly in some of sediment samples. The fore slopes are located on PSL-05, west of Kotok Besar island, and PSL-10, east of Karang Bongkok island, determined by 74% and 48.33% of *Amphistegina*, respectively.

CONCLUSIONS

Foraminifera from genera of *Amphistegina, Calcarina, Peneroplis, Discorbis,* and *Baculogypsina* are dominantly found in the study area. Those genera are typically characterizing reef flat and fore slope of reef environments. On the other side, the abundance of *Operculina* and *Quinqueloculina* genera found in the area also shows the influences of tidal current and terrestrial from the islands in the vicinity. The FI value of more than 4 suggests that the littoral environment around Kotok Besar, Kotok Kecil and Karang Bongkok islands are very conducive for reef development.

ACKNOWLEDGEMENTS

First of all, we would like to show our gratitude to Geomorphology Team of Kotok Islands research survey which conducted the survey on April 2011. We also to appreciate personal discussions with colleagues as well as the help from the technicians in the laboratory of micropaleontology in Marine Geological Institute, Bandung.

REFFERENCES

[1] Barker, R.W., 1960, Taxonomic Notes. *Society of Economic Paleontologists and Mineralogists*, Special Publication no. 9, 238p.

[2] Dewi, K.T., Natsir, S.M., Siswantoro, Y., 2010, Mikrofauna (foraminifera) terumbu karang sebagai indikator perairan sekitar pulau-pulau kecil. *Indonesian Journal of Marine Sciences Ilmu Kelautan,* vol I, Edisi Khusus: 162-170.

[3] Hallock, P. and Glenn, E.C., 1986, Larger foraminifera: A tool for paleoenvironmental analysis of Cenozoic carbonate depositional facies. *Palaios 1:*55-64.

[4] 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,* vol. 81(1–3): 221–238.

[5] Javaux, E.J. and Scott, D.B., 2003, *Illustration of modern benthic foraminifera from Bermuda and remarks on distribution in other subtropical/ tropical areas*. Paleontologia Electronica, no 6 (4), 29p.

[6] <http://palaeo-electronica.org/2003_1/benthic/ issue1_03.htm> [Accessed on 30 November 2011].

[7] Loeblich, A.R. Jr. and Tappan, H., 1994, *Foraminifera of the Sahul Shelf and Timor Sea.* Cushman Foundation for Foraminifera Research, Spesial Publication No. 31 Los Angeles, Carnifornia, 161p.

[8] Miharja, D.K., and Pranomo, W.S., 2001, *Kondisi perairan Kepulauan Seribu*. Final internal report, Report of spatial planning in the Regency of Kepulauan Seribu, 34 pp. (unpublished).

[9] Natsir, S.M., 2010, Foraminifera bentik sebagai indikator kondisi lingkungan terumbu karang perairan Pulau Kotok Besar dan Pulau Nirwana, Kepulauan Seribu. *Oseanologi dan Limnologi di Indonesia*, 36 (2): 181-192.

[10] Natsir, S.M., and Subkhan, M., 2012, The distribution of benthic foraminiferal assemblages in Serasan Islands of Riau Islands. *Proc. Soc. Indon. Biodiv. Intl. Conf.,* vol. 1: 113-117.

[11] Nobes, K. and Uthicke, S., 2008, *Benthic Foraminifera of the Great Barrier Reef: A guide to species potentially useful as Water Quality Indicators.* Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns, 44p.

[12] Noor, A., 2003, *Analisis Kebijakan Pengembangan Marikultur di Kabupaten Administrasi Kepulauan Seribu, Propinsi DKI Jakarta*. Postgraduate Program – IPB: 56-88.

[13] Schueth, J. and Frank, T.D., 2008, Reef foraminifera as bio-indicators of coral reef health: Low Isles Reef, northern Great Barrier Reef, Australia. *Journal of Foraminiferal Research*, vol. 38 (1):11-22.

[14] Toruan, L.N.L., Soedharma, D., and Dewi, K.T., 2013, The composition and distribution of benthic foraminifera at coral reef ecosystem in Thousands island, *Jurnal Ilmu dan Teknologi Kelautan Tropis*, vol. 5 (1): 1-16.

[15] Wilson, B., Jones, B. and Birjue, K., 2010, Paleo-environmental interpretations based on foraminiferal abundance biozones, Mayo Limestone, Trinidad, West Indies, including alpha and beta diversities. *Palaios*, 25: 158-166.

[16] Yassini, I. and Jones, B.G., 1995, *Foraminiferida and ostracoda from estuarine and shelf environments on the southeastern coast of Australia.* University of Wollongong Press, Wollongong, 484p.

[17] Yosi, M., Astjario, P., Nurdin, N., Herawati, E., Hernawan, U., Budiono, K., 2011, Penelitian geomorfologi dasar laut, Kepulauan Seribu, DKI Jakarta. Progress Report, Department of Energy and Mineral Resources, Bandung, 103p, unpublished.