ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

Original Paper

# THE DISTRIBUTION OF BENTHIC FORAMINIFERA IN CORAL REEFS COMMUNITY AND SEAGRASS BAD OF BELITUNG ISLANDS BASED ON FORAM INDEX

Suhartati M. Natsir[1] and Mukhammad Subkhan[2]

[1]Research Center for Oceanography–Indonesian Institute of Science
[2]Indonesian Association of Oceanologists
Jln. Pasir Putih 1, Ancol Timur, Jakarta - 14430 Indonesia

Received : February, 9, 2011 ; Accepted : September, 20, 2011

**ABSTRACT**

*To check the feasibility of the environmental for coral reefs, several monitoring strategies exist, one of which making use of the foraminiferal community structure: FORAM Index, i.e. Foraminifera in Reef Assessment and Monitoring Index. The abundance of symbiont-bearing foraminifera should parallel coral abundance, if water quality is the major environmental control. This allows for the use of these foraminifera to quantify environmental quality with respect to coral health. The aim of this study is to study the benthic foraminiferal assemblages in coral reefs community and sea grass bad of Belitung Islands and to use that information to determine the environmental quality of their coral reefs based on FORAM Index. Sediments of Belitung Islands waters were sampled for their foraminiferal fauna at six sites i.e. Nasik Strait (four sites), Kudus Island and Bago Island on April 2010. Results of benthic foraminiferal quantitative analysis of the sediments in which collected from six sampling sites of Belitung Islands show that totally collected specimens 29 species of 18 genera. The most favorable place for coral growth is the free area (absence of coral, mangrove and seagrass) of Nasik Strait, but it only has 30 specimens of benthic foraminifera, with three species of symbiont-bearing foraminifera such as Operculina and Amphistegina. Whereas, the most abundant of benthic foraminifera is Nasik Strait 1 with typical substrate coarse sand and vegetated by coral reef. In other side, segrass bad of Nasik Strait is dominated by opportunistic foraminifera and only dwelled by Heterostegian, Calcarina, Elphidium, Ammonia, Acervulina, Spirolina, Quinqueloculina and Lenticulina. Moreover, the most abundant species of all sampling sites is Peneroplis pertusus.*

**Keywords:** Distribution; benthic foraminifera; FORAM Index; Belitung islands

**Correspondence :** Phone : +62-21-64713850 ; Fax : +62-21-6471948 ; email : suhartatinatsir@yahoo.com

## INTRODUCTION

Coral reef ecosystems have a significant importance for many marine organisms and hence its conservation is a necessity. Coral reefs degradation would indirectly lead to human prosperity due to environmental perturbation (Hallock *et al.*, 2003). To check the feasibility of the environmental for coral reefs, several monitoring strategies exist, one of which making use of the foraminiferal community structure: FORAM Index, i.e. Foraminifera in Reef Assessment and Monitoring Index (Hallock *et al.*, 2003). The FORAM Index can be used to address local impacts and to assist in differentiating between the local impacts as a result of a poor water quality and those as a result of regional to global change issues. However, it is important to note that the values only reflect water and sediment quality (Hallock *et al.*, 2003). The abundance of symbiont-bearing foraminifera should parallel coral abundance, if water quality is the major environmental control. This allows for the use of these foraminifera to quantify environmental quality with respect to coral health.

The Phylum Foraminifera consists of animals generally living in the marine environment. They are sensitive to environmental change, have various distributions

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

and live only in certain sites. Shells of dead foraminifers sink down to the sea bottom and may accumulate in certain areas, then becoming a key characteristic for rock age and the geological past. Also, micropaleontology is generally based on foraminifer microfossils (Buzas and Gupta, 1982). Foraminifera naturally live abundantly in mobile sediments, with depth being an important structuring factor (Boltovskoy and Wright, 1976).

Foraminifers also associate with coral reefs. Yamano *et al.*, (2000) found that foraminifers were covering 30% of the sediment of Green Island, Great Barrier Reef, Australia, and hence were an important contributor to the coral reefs build up. The dominant foraminifer genera of the island were *Amphistegina*, *Baculogypsina,* and *Calcarina*. The aim of this study is to study the benthic foraminiferal assemblages in coral reefs community and sea grass bad of Belitung Islands and to use that information to determine the environmental quality of their coral reefs based on FORAM Index.

# MATERIALS AND METHODS

*Sampling and laboratory analysis*

Sediments of Belitung Islands waters were sampled for their foraminiferal fauna at six sites i.e. Nasik Strait (four sites), Kudus Island and Bago Island (**Fig. 1)** on April 2010. The samples were taken with a handling grab, placed in plastic bags, and preserved with a 10% formaldehyde-water solution for 24 hours. A 100 g of sediment subsample was then put into a labeled plastic bag and preserved again in a 10% formaldehyde-water solution for 24 hours. The samples were then washed with water on a filter tray (mesh size of sieve 0.063 mm; 0.250 mm; 0.5 mm; 0.1 mm and 0.2 mm) and dried in the oven at temperature 30°C. The dry samples were put into a labeled plastic bag for further analysis. Sorting the samples under a microscope with magnification 10×100 was done after evenly spreading the subsample on the extraction tray. Foraminifers were extracted and put into a foraminiferal slide. Specimens were described under a microscope with magnification 10×100 based on their morphology such as shell, chamber shape, chamber formation, number of chamber, ornamentation, aperture slope, aperture position, and additional chamber. Identification on the specimens was done on the basis of a reference collection of benthic foraminifers. Advance stages are systematic study and quantitative analysis to recognize the abundance.

*Foraminifera in the Assessment and Monitoring (FORAM) Index*

The FORAM Index (FI) was developed by Hallock *et al.,* on 2003. They have separated foraminiferal genera into three functional groups i.e. symbiont-bearing taxa, opportunistic taxa and other small, heterotrophic taxa. Symbiont-bearing taxa represent foraminiferal genera in which living in similar environments with coral. Then, opportunistic taxa are the tolerant genera on high stress environments, especially those high in chemical pollutants or organic matters that could lead to low concentration of oxygen. The last group is other small, heterotrophic taxa, consist of all small foraminifera that boom when the environmental conditions is going well like nutrition and oxygen concentration.

The collected foraminifera are identified to the genus level and then classified in the above functional group. The portion of each functional group is calculated by dividing the total number of specimens in each functional group by the total number of collected specimens of the sample. And then, FORAM Index is calculated by adding the three portion of each functional group as in the following formula:

$$\mathbf{FI = (10 \times Ps) + (Po) + (2 \times Ph)}$$

In which,

FI = FORAM Index

Ps = Ns/ T, with “Ns” the number of symbiont-bearing foraminifers, such as *Amphistegina*, *Heterostegina*, *Alveolinella*, *Borelis*, *Sorites*, *Amphisorus*, *Marginophora*.

Po = No/T, with "No" the number of opportunistic foraminifers, such as *Ammonia*, *Elphidium*, several genera from families Trochaminidae, Lituolidae, Bolivinidae, and Buliminidae.

Ph = Nh/T, with “Nh" the number of other small, heterotrophic

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

foraminifers, such as many genera of Miliolida, Rotaliida, Textulariida.

T = Number of specimens counted

The FORAM Index can be interpreted as follows:

FI > 4 = environment conducive to reef growth

3 < FI < 5 = environmental change

2 < FI < 4 = environment marginal for reef growth and unsuitable for recovery

FI < 2 = stressed conditions unsuitable for reef growth

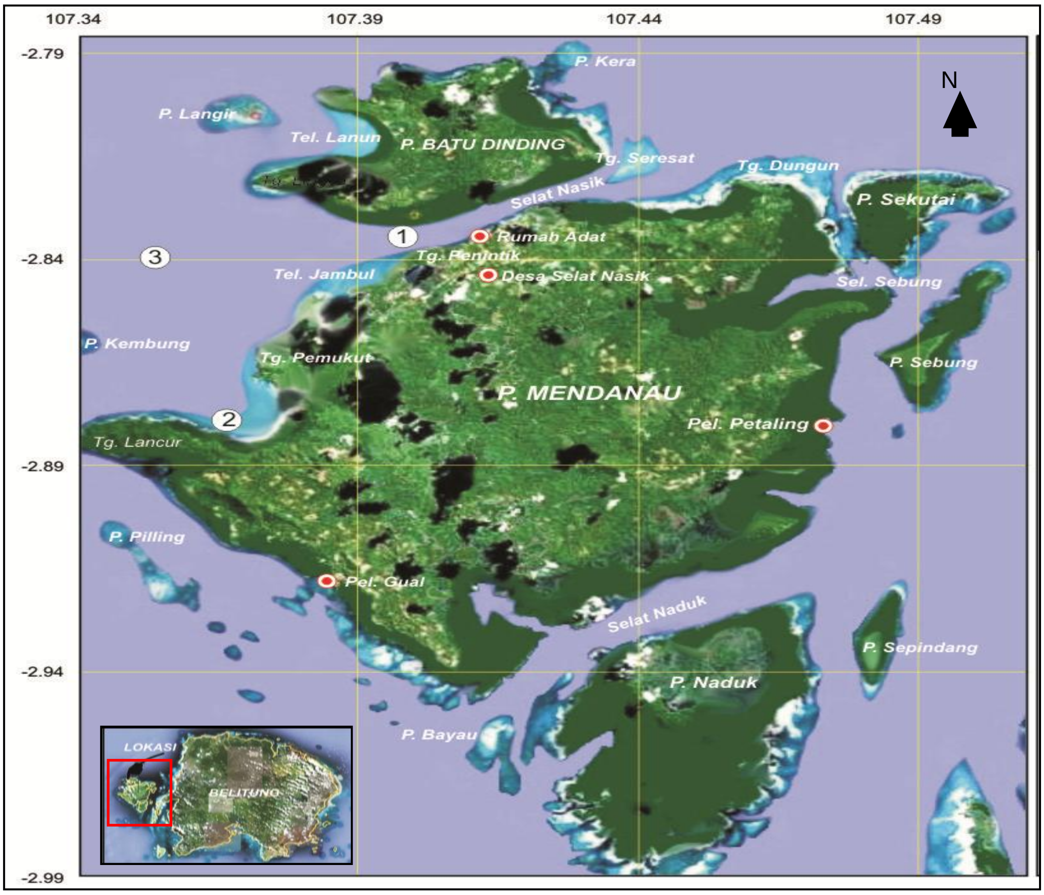


**Fig. 1.** Sampling sites of Belitung Islands

# Results And Discussions

Results of benthic foraminiferal quantitative analysis of the sediments in which collected from six sampling sites of Belitung Islands show that totally collected specimens are 315 specimens, belongs to 29 species and 18 genera. The sampling sites of Belitung Islands is lead by various community, such as coral reefs, seagrass bad, mangrove, combination of that community, even absence of them is also present. The most populated of benthic foraminifera of the sampling sites is Nasik Strait 1 that consisting of coral reefs community, with substrate coarse sand. This site totally have 176 specimens of benthic foraminifera, dominated by symbiont-bearing taxa at 58% (**Fig. 2**). On the contrary, Kudus Island is the most uncommon of benthic foraminifera with only fourteen specimens were collected over the island. Overall, the most common genera of Belitung islands are *Calcarina* and *Quinqueloculina*. The two genera are found in almost all samples from Belitung islands. *Calcarina* is represented in great

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

abundance by *Calcarina calcar*, especially in the Nasik Strait, 18 specimens are collected. Moreover, the most abundant species of all sampling sites, *Peneroplis pertusus* is counted on 42 specimens and only dwell in Nasik Strait. Result of counting of benthic foraminera from the Belitung Islands is presented in **Table 1.**

**Table 1.** Counts of collected benthic foraminifera from Belitung Islands

| Species | Samples | | | | | |
|---|---|---|---|---|---|---|
| | **Nasik Strait 1** | **Nasik Strait 2** | **Nasik Strait 3** | **Nasik Strait 4** | **Kudus Island** | **Bago Island** |
| *Acervulina inhaeren* | 4 | - | - | 4 | - | - |
| *Ammonia beccarii* | - | - | 2 | 13 | - | 6 |
| *Ammonia umbonata* | - | 3 | - | 3 | - | - |
| *Amphistegina lessonii* | - | 8 | 8 | - | - | - |
| *Amphistegina quoyii* | - | - | 8 | - | - | - |
| *Calcarina calcar* | 18 | 3 | - | 6 | 2 | 3 |
| *Elphidium craticulatum* | - | - | - | 19 | 4 | - |
| *Elphidium crispum* | 10 | - | - | - | 4 | - |
| *Hauerina bradyi* | 8 | - | - | - | - | - |
| *Hauerina fragilissima* | - | 2 | - | - | - | - |
| *Hauerina* sp. | - | - | - | - | - | 1 |
| *Heterostegina depressa* | 19 | - | - | 2 | - | 4 |
| *Lagena favoso-punctata* | 2 | - | - | - | - | - |
| *Lenticulina* sp. | - | - | - | 1 | - | - |
| *Miliolinella* sp. | 6 | - | - | - | - | - |
| *Operculina ammonoides* | 19 | 1 | 8 | - | - | - |
| *Peneroplis pertusus* | 42 | - | - | - | - | - |
| *Planorbulinella larvata* | 4 | - | - | - | - | - |
| *Quinqueloculina bouena* | - | - | 3 | 3 | 1 | 2 |
| *Quinqueloculina cultrata* | - | - | - | 2 | - | - |
| *Quinqueloculina*sp. | - | 2 | 1 | - | - | - |
| *Sorites marginalis* | 4 | - | - | - | - | - |
| *Spirolina arietina* | 9 | - | - | 3 | 3 | - |
| *Spirolina aurietina* | - | - | - | - | - | 1 |
| *Spiroloculina communis* | 10 | - | - | - | - | - |
| *Spiroloculina depressa* | 11 | 1 | - | - | - | - |
| *Spiroloculina* sp. | 8 | - | - | - | - | - |
| *Triloculina rupertiana* | 2 | - | - | - | - | - |
| *Triloculina tricarinata* | - | 2 | - | - | - | - |

The foraminiferal populations were sorted into the functional groups defined by Hallock *et al.*, (2003). The first group is the symbiont-bearing taxa, which represent foraminiferal genera that living in similar environments with coral. Then, opportunistic taxa as the second group are the tolerant genera on high stress environments, especially those high in chemical pollutants or organic matters that could lead to low concentration of oxygen. The last group is other small, heterotrophic taxa, consist of all small foraminifera that boom when the environmental conditions is going well like nutrition and oxygen concentration. Based on the functional group classification, portion of each sampling sites is relatively different depends on the

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

substrate type and perhaps other environmental conditions. The symbiont-bearing species are distributed abundantly on three sampling sites of Nasik Strait (1, 2 and 3) and one else on the Bago Island. The others are dominated by opportunistic taxa in portion of more than 50% (**Fig. 2**).

The symbiont-bearing foraminifera, such as *Calcarina*, *Heterostegina*, *Operculina*, *Sorites* and *Peneroplis* were abundantly collected in the sediment of Nasik Strait 1. Portion of 58% is achieved by the symbiont-bearing taxa as the highest than other functional groups. Opportunistic and other small, heterotrophic taxa respectively counted at 8% and 34%. Similarly, Nasik Strait 2 and Bago Island, within coral reefs community dominated by symbiont-bearing foraminifera, respectively at 48% and 41%. Of the deeper waters, such as in the sampling site of Nasik Strait 3, we found the symbiont-bearing foraminifera more abundant (80%) than other functional groups (opportunistic and other small, heterotrophic taxa). Generally, the most abundant of benthic foraminifera of the sampling sites is Nasik Strait 1 (176 specimens). In contrast, the seagrass bad community of Nasik Strait 4, and some area of Kudus Island are dominated by opportunistic foraminifera, suggest that water and sediment quality of this sites unsuitable for coral reef growth. In other side, segrass bad of Nasik Strait is only dwelled by 48 specimens of 8 genera, such as *Heterostegian*, *Calcarina*, *Elphidium*, *Ammonia*, *Acervulina*, *Spirolina*, *Quinqueloculina* and *Lenticulina*. Therefore, the number of specimens in the area may be related not only to the surrounding water conditions but also related to the sediment where they live (Suhartati, 2005; Suhartati, 2008).

The substrate type of those sites is dominated by hard substrate such as coarse sand and a number of coral rubble. Renema (2008) also encountered two species of *Amphistegina* associated with the reef slope of coral rubble or coral fragments within the sandy substrate at Thousand Islands, together with many species of *Calcarina*. Experimental research by Fujita (2004) proved that larger foraminiferal species such as *Heterostegina depressa* and *Amphistegina* spp. are commonly found under reef rubble as well as in shaded microhabitats at shallow water. Sampling site of Nasik Strait 1 located on the inner side of the Strait, nearby mainland of Mendanau Island, and then current speed must be lower than the open side. Thus, cause accumulating and increasing of nutrient flux that favorable for foraminiferal growth. When the nutrient flux increases, the benthic community shifts to increasing dominance by fleshy algae and sponges, and the foraminiferal assemblage shifts to increasing prevalence of smaller, faster growing species. Therefore, the abundance of symbiont-bearing foraminifera should parallel coral abundance, if water quality is the major environmental control (Schueth and Frank, 2008).

The abundance of symbiont-bearing foraminifera should parallel coral abundance, if water quality is the major environmental control. This allows for the use of these foraminifera to quantify environmental quality with respect to coral health by calculating FORAM Index. However, it is important to note that the values only reflect water and sediment quality (Hallock *et al.* 2003). The values are not useful for detecting changes in coral populations related to factors such as abnormally high temperatures, bleaching, physical damage from storms or coral diseases. The FI cannot measure these events effectively because foraminifera do not suffer from the same diseases as corals, and they recover very quickly after bleaching events and storms (Schueth and Frank, 2008).

The FORAM Index values of Belitung islands range from 2.94 to 8.33 (**Table 2**). The most samples are characterized by FORAM Index values greater than 4.0, indicates that water quality of the Belitung Islands is suitable for coral growth. However, some locations such as Nasik Strait 4 and Kudus island that vegetated by seagrass are respectively at 2.94 and 3.00. Refers to Hallock, *et al.,* (2003), this environment condition tends to marginal for reef growth and unsuitable for recovery. This means that, the water quality may support living coral community, but any damage to the coral cover will not followed by recovery. In such places, the substrate type is affected by mud and not a reef ecosystem. Nasik strait 4, is lied by muddy sand on Kudus Island and by coarse mud.

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

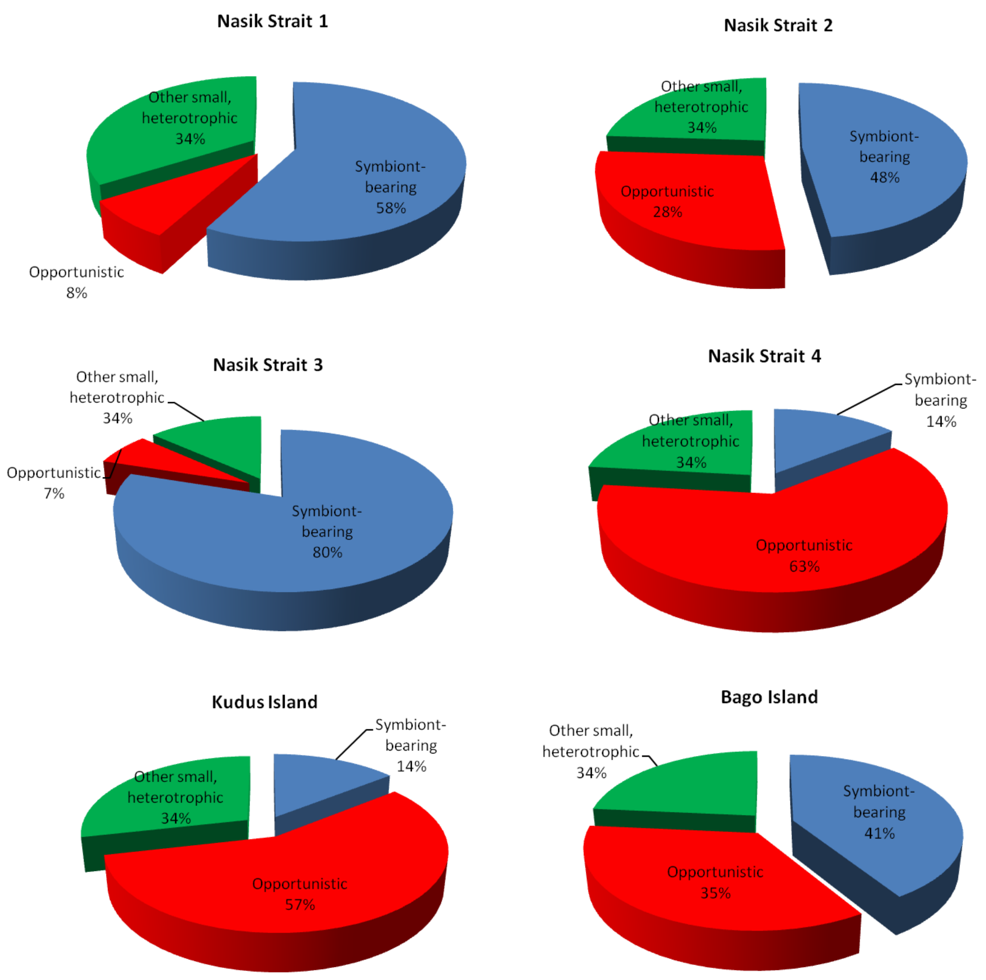


**Fig. 2.** Portion of the functional groups of collected benthic foraminifera from each sampling sites of Belitung Islands

Research on FORAM Index in the Seribu islands (excluding coral reefs community) was carried out by Dewi *et al.*, (2010) also showed a low value of forams index of 2.53 and 2.99. The most common genera of the two sampling sites are *Elphidium* and *Ammonia*. The genus *Elphidium* is represented by *E. craticulatum* and *E.crispum*, whereas, *Ammonia* represented in different number by *A. beccarii* and *A. umbonata* (**Table 1**).

**Table 2.** Environmental descriptions and FORAM Index of each sampling sites of Belitung Islands

| Sampling sites | Environmental description | FORAM Index |
|---|---|---|
| Nasik Stratit 1 | Coral reefs community, with a number of mongrove | 6,56 |
| Nasik Stratit 2 | Coral reefs community | 6,32 |
| Nasik Stratit 3 | Free waters, absence of coral, mangrove and seagrass | 8,33 |
| Nasik Stratit 4 | Seagrass bad | 2,94 |
| Kudus Island | Coral reefs community, with a number of seagrass | 3,00 |
| Bago Island | Coral reefs community, with a number of mongrove | 4,94 |

Based on the FORAM Index value, the most favorable place for coral growth is Nasik Strait 3, but it only have 30 specimens of benthic foraminifera, with three species of symbiont-bearing foraminifera such as *Operculina ammonoides*, *Amphistegina lessonii* and *A.*

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

*quoyii*. This is apparently due to water condition of this site is too deep (5-10 m), and thus affects the level of sunlight penetration. Thus, the condition is beneficial for growth and reproduction of many benthic foraminifers such as *Amphistegina lessonii* of suborder Rotaliina. Hallock in Buzas and Gupta (1982) declared that *Amphistegina lobifera* prosperously lives, grows and reproduces in shallow water (less than 3 m) with a high intensity of sunlight, whereas *A. lessonii* would thrive in deeper waters. In other side, the most abundant place of benthic foraminifera is Nasik Strait 1, with total 176 specimens. The most abundant of symbiont bearing foraminifera is *Peneroplis pertusus* that reached to 42 specimens. Other common species of such sites are *Calcarina calcar*, *Heterostegina depressa*, *Operculina amonoides* and *Sorites marginalis*. Member of *Calcarina* may be abundant on the reef flat and reef crest, or associates with algae and macroalgae, such as *Sargassum*, *Galaxaura*, and *Chelidiopsis* (ref. needed). Barker (1960) encountered these species in Admiralty Island, Pacific at a depth of 16 to 25 m, whereas, Graham and Militante (1959) encountered them in Puerto Galera Bay, Philipines, at 8.5 to 14.5 m. *Calcarina* sp. was identified by Renema and Hohenegger (2005) as *Calcarina gaudichaudii* and found most abundant in shallow coral shelf around Togian Island, North Sulawesi. In addition, this species is found associated with red algal, sea grass or under rocks.

Generally, water conditions of Bitung Islands (**Table 3**) are suitable for benthic foraminiferal growth. Foraminifera are poikilothermic organisms so their temperature depends on ambient temperature and only a few foraminifera that are eurythermal (Murray, 1973). Natland (1933), *in* Pringgoprawiro (1982) states that the foraminifera live at temperatures between 10-50°C. While the temperature was recorded during the study of ranged between 30.40°C to 31.40°C. Salinity Belitung Islands are relatively stable between 30-31 ppt, thus does not have much effect on the foraminiferal growth. Most of the benthic foraminifera are stenohaline, have a low tolerance to changes in salinity, but some species are euryhaline, they have a wide tolerance to changes in salinity and life in the marine environment near a large salinity range. It can be seen in the estuary of the river (Boltovskoy and Wright, 1976).

**Table 3.** Environmental characteristics of each sampling sites of Belitung Islands

| Sites | Salinity (ppt) | Temperature (°C) | pH | Sampling depth (m) | Substrate |
|---|---|---|---|---|---|
| Nasik Strait 1 | 30.00 | 31.40 | 7.83 | 1 | Coarse Sand |
| Nasik Strait 2 | 30.00 | 30.40 | 8.07 | 1 | Coarse Sand |
| Nasik Strait 3 | 31.00 | 30.40 | 8.14 | 5-10 | Coarse Sand |
| Nasik Strait 4 | 31.00 | 30.40 | 8.06 | 5-10 | Muddy Sand |
| Kudus Island | 32.71 | 29.98 | 7.99 | 35-90 | Coarse mud |
| Bago Island | 32.71 | 29.98 | 7.99 | 80-125 | Coarse sand |

# CONCLUSIONS

Generally, the total number of collected specimens of benthic foraminifera reaches to 315, belongs to 29 species and 18 genera. Based on the FORAM Index value, the most favorable place for coral growth is free area (absence of mangrove and seagrass) of Nasik Strait (Nasik Strait 3), but it only have 30 specimens of benthic foraminifera, with three species of symbiont-bearing foraminifera such as *Operculina ammonoides*, *Amphistegina lessonii* and *A. quoyii*. Whereas, the most abundant of benthic foraminifera is Nasik Strait 1 with typical substrate coarse sand and vegetated by coral reef, dwelled by 176 species of benthic foraminifera. Thus, the depth level of the waters is also affecting the abundance of the species. In other side, segrass bad of Nasik Strait is dominated by opportunistic foraminifera and only dwelled by 48 specimens of 8 genera, such as *Heterostegian*, *Calcarina*, *Elphidium*, *Ammonia*, *Acervulina*, *Spirolina*, *Quinqueloculina* and *Lenticulina*. Moreover, the

ISSN : 1410-5217
Accredited : 83/Dikti/Kep/2009

most abundant species of all sampling sites, *Peneroplis pertusus* is counted on 42 specimens and only dwell in Nasik Strait 1.

## REFERENCES

Barker, R.W. 1960. Taxonomic Notes. *Society of Economic Paleontologist and Mineralogist.* Special Publication No. 9. Tulsa. Oklahoma, USA. 238 pp.

Boltovskoy, E. and R. Wright. 1976. Recent Foraminifera. Dr. W. June, B.V. Publisher, The Haque, Netherland.

Buzas, M.A. and B.K. Sen Gupta. 1982. Foraminifera. Notes for a Short Course. University of Tennessee. Department of Geological Science, Louisiana.

Dewi, K.T., M.N. Suhartati, dan Y. Siswantoro. 2010. Mikrofauna (Foraminifera) Terumbu Karang Sebagai Indikator Perairan Sekitar Pulau-Pulau Kecil. *Ilmu Kelautan, Edisi khusus,* (1): 162 – 170. (in Indonesian )

Fujita, K. 2004. A Field Colonization Experiment on Small-scale Distributions of Algal Symbiont-Bearing Larger Foraminifera on Reef Rubble. *Journal of Foraminiferal Research*, v. 34, no. 3: 169–179.

Graham, J.J. and P.J. Militante. 1959. Recent Foraminifera from the Puerto Galera Area, northern Mindoro, Philippines. *Geological Science*, v. 6, p. 1-171.

Hallock, P., B.H. Lidz, E.M. Cockey-Burkhard, and K.B. Donnelly. 2003. Foraminifera as bioindicators in coral reef assessment and monitoring: the FORAM Index. *Environmental Monitoring and Assessment,* 81(1-3):221-238.

Murray, J.W. 1973. Distribution and Ecology of Living Foraminifera. The John Hopkins Press. Baltimore.

Pringgoprawiro, H. 1982. Mikropaleontologi Lanjut. Laboratorium Mikropaleontologi Institut Teknologi Bandung, Bandung. (in Indonesian )

Renema W. and J. Hohenegger. 2005. On the identity of Calcarina spengleri (Gmelin, 1791). *Journal of Foraminiferal Research* 35(1): 15-21.

Renema, W. 2008. Habitat Selective Factors Influencing the Distribution of Larger Benthic Foraminiferal Assemblages Over the Kepulauan Seribu. *Marine Micropaleontology* (68): 286–298. (in Indonesian)

Schueth, J.D. and T.D. Frank. 2008. Reef Foraminifera as Bioindicators of Coral Reef Health: Low Isles Reef, Northern Great Barrier Reef, Australia. *Journal of Foraminiferal Research,* 38( 1): 11–22.

Suhartati, M.N. 2005. Distribusi Foraminifera Bentik (Textularia) di Delta Porong, Jawa Timur. Agritek. 4 (2): 1 – 7. (in Indonesian).

Suhartati, M.N. 2008. Distribusi Foraminifera Bentik di Perairan Pulau Damar Besar dan Pulau Bidadari, Kepulauan Seribu. Agritek 5 (1): 21 – 29. (in Indonesian)

Yamano, H., T. Miyajima and I. Koike. 2000. Importance of foraminifera for the formation and maintenance of a coral sand cay: Green Island, Australia. *Coral Reefs* (19): 51-58.