Benthic Foraminifera in South Waigeo Waters, Raja Ampat, West Papua

Foraminifera Bentik di Perairan Waigeo Selatan, Raja Ampat, Papua Barat

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ABSTRACT: Waigeo Island is one of four large islands of the Raja Ampat group, West Papua Province. This area lies in the heart of the coral triangle region as the most marine bio-diversity on Earth. Coral reef ecosystem of the Waigeo is a favorable habitat for various organisms including foraminifera. Foraminifera have been proven as useful indicator of water quality surrounding the coral reef environment since FORAM Index was formulated. It gives additional importance of foraminifera beside their common uses on micropalaeontology for petroleum industry and palaeoecology. Therefore, it is very important to obtain data of the benthic foraminifera from various coral reef environments in Indonesia, such as around Waigeo Island. Sediment samples of this study were collected from 12 sites in southern part off Waigeo Island, on July 2011. Observation on benthic foraminifera shows that the study area is dominated by symbiotic bearing benthic foraminifera, *Amphistegina lessonii,* belongs to Suborder Rotaliina. This occurrence increases the values of FORAM Index (FI) at certain sites. Generally, the values of FI from most sites are high (FI>4) that provide a good indication for reef growth or recovery. The values of FI less than 2 are found at RJ3 and RJ4 indicate stress environment for reef growth and they are dominated by opportunistic and heterotrophic functional groups of *Elphidium* and *Quinqueloculina*.

Keywords: benthic foraminifera, high value FI, Waigeo Island, West Papua

ABSTRAK: *Pulau Waegio merupakan salah satu dari empat pulau besar di Kepulauan Raja Ampat, Provinsi Papua Barat. Wilayah in terletak di jantung segitiga terumbu karang sebagai pusat paling kaya keanekaragaman hayatinya di bumi. Ekosistem terumbu karang Waigeo merupakan habitat yang cocok bagi kehidupan berbagai organisme termasuk foraminifera. Foraminifera telah terbukti sebagai indikator kualitas air sekitar terumbu karang setelah diformulasikan Indeks FORAM. Dengan demikian foraminifera telah mempunyai kegunaan tambahan selain fungsi umum dalam bidang mikropaleontologi pada industri perminyakan dan paleoekologi. Oleh karena itu sangat penting untuk mendapatkan data foraminifera bentik dari ekosistem terumbu karang di wilayah Indonesia, seperti perairan Pulau Waigeo.*

Sampel sedimen untuk studi ini diambil di 12 titik lokasi sebelah selatan Pulau Waigeo pada bulan Juli 2011. Hasil pengamatan memperlihatkan bahwa daerah penelitian di dominasi foraminifera bentik yang bersimbose dengan terumbu karang, Amphistegina lessonii, anggota Subordo Rotaliina. Kehadirannya meningkatkan nilai FI dari titik lokasi tertentu. Sebagian besar titik lokasi mempunyai nilai FI>4 memberi indikasi bahwa kondisi perairannya kondusif untuk pertumbuhan karang yang terletak di ekosistem terumbu karang. Secara umum, nilai FI di sebagian besar titik lokasi tinggi (>4) yang member indikasi kondisi lingkungan bagus bagi pertumbuhan karang. Nilai FI rendah (<2) mengindikasikan lingkungan tertekan bagi kehidupan karang dan ditunjukkan dengan kemunculan kelompok oportunis dan heterotrofik dari Elphidium dan Quinqueloculina.

Kata kunci: foraminifera bentik, nilai FI tinggi, Pulau Waigeo, Papua Barat

INTRODUCTION

Raja Ampat is a group of majestic islands, located on the northwestern tip of the West Papua Province of Indonesia. This group of islands covers an area over 43,000 km^2 in the heart of the 'Coral Triangle' as the richest and most diverse region of modern coral reefs (McKenna et al. in Palomares and Heymans, 2006). This area has four large islands of Waigeo, Batanta, Salawati and Misool and surrounded by hundreds of smaller islands that 10 of them are inhabitant islands.

Coral reef ecosystems have significant importance for many marine organisms and hence its conservation is a necessity. Coral reefs degradation would indirectly influence to human prosperity due to environmental perturbation (Hallock et al., 2003). To check the feasibility of the environmental for coral reefs, several monitoring approaches have been done and one of them is based on foraminiferal community structure by calculating the FORAM Index (Foraminifera in Reef Assessment and Monitoring Index). This index is formulated by Hallock et al., (2003) that 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. 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 (Hallock et al., 2003).

A particular species of foraminifera is a symbiont with coral reef ecosystems and require the same water quality with a variety of reef-forming organisms, and so that they can be used as bio-indicators for the of coral reefs health (Hallock et al. 2003). It has been demonstrated by several researchers such as Schueth and Frank (2008) which examined the condition of coral reef at Low Isles, Great Barrier Reef, Australia. Dewi et al (2010) started to apply this formula on reef environments surrounding several small islands in Indonesia. From these previous studies, it can be seen that foraminifera is useful for environmental studies beside for common topics such as on micropaleontology for petroleum industry and paleoecology. Thus, it is very important to obtain data on the benthic foraminiferal assemblages and its distribution from various reef environments in Indonesia. Due to the importance of foraminifera, this study is done to recognize the distribution of benthic foraminifera assemblages in south Waigeo waters, Raja Ampat, west Papua Province.

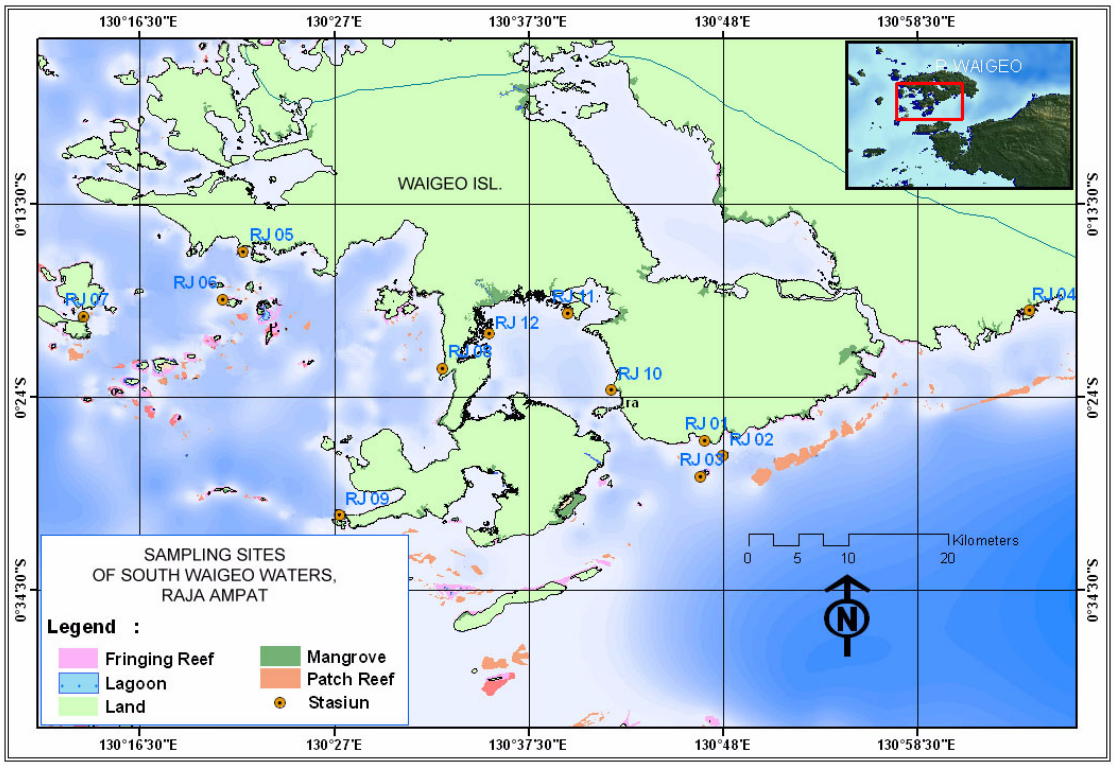

Figure 1. Sampling sites of South Waigeo Waters, Raja Ampat, West Papua Province

METHODS

A number of 12 sediment samples (site numbers from RJ1 to RJ12) were collected from South Waigeo Waters, Raja Ampat, West Papua, on July 2011 (Figure 1). The samples were carried out by a diver using a handling grab to have less impact on reef condition. The sampling sites are situated around the coral reef ecosystem at water depth range from 3 to 11 m. The collected samples are placed into plastic tube, and then preserved with a mixed solution of Rose bengal and 10% formaldehyde until submerged perfectly, and left them for 24 hours. Living organisms will appear red as a result of protoplasm in the dye absorption, while the empty shell will remain white. 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 flow 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 an oven with temperature of 30 C. The dry samples were then put into a labeled plastic bag for further analysis. Sorting the samples under a microscope with magnification 10,000 was done after evenly spreading the subsample on the extraction tray. Foraminiferal specimens were extracted and put into a foraminiferal slide. Specimens were described under a microscope with magnification 10,000 based on their morphology of shell or test such as shape, suture, types of aperture, ornamentation, last chamber, test composition etc. Identification on the specimens was done based on several references: Barker (1960), Cushman (1969), Albani (1979), Van Marle (1988), Loeblich and Tappan (1992).

Advance stages were quantitative analysis to recognize abundance, diversity index and distribution of benthic foraminifera in the sampling sites. For each samples, the diversity indices i.e. species richness [S], Shannon index [H], Dominance [D], and Evenness [E] were calculated using the software package PAST (PAleontological Statistics; Hammer et al., 2001).

The FORAM Index (FORAM = FOraminifera in Reef Assessment and Monitoring) was also calculated that is fully explained by Hallock et al (2003). The collected benthic foraminifera are identified to the genus and then they were classified into three functional groups i.e. symbiont-bearing, opportunistic and other small, heterotrophic taxa. It is calculated from the relative proportions of the three functional groups above in an assemblage.

RESULTS

Waigeo Islands of Raja Ampat is located in the northwestern tip of Indonesia's Papuan "Bird's Head Seascape" that is surrounded by small islands where coral reefs ecosystem. This area is a part of the coral triangle region that contains a high biodiversity of many biota including algal symbiont bearing organisms such as foraminifera. The foraminifera, particularly larger foraminifera, are important components of reef ecosystems related to carbonate production (Hallock, 1984). In the further study, Hallock et al. (2003) revealed that the larger foraminifera are important contributors to beach sands of Indo-Pacific reef environments where water quality favors coral growth.

The present study recognized 5,202 individuals of benthic foraminifera belong to 39 species that are distributed in the south of Waigeo Island (Table 1). All of them are member of three suborder of Miliolina, Rotaliina and Textulariina. Based on their shell (test) material composition, Albani (1979) stated that Miliolina characterized by their calcareous test, porcelaneous, and generally with a layer pseudochitin. Agglutinated material occasionally found on the walls and in late embryonic stages it was become imperforate. Suborder Rotaliina is specifically characterized by their hyaline or calcareous perforate test wall. While, the test of Textulariina (agglutinated foraminifera) consists of foreign materials that cemented by $CaCO_3$ and SiO_3.

The most common specimens on the sediment samples belong to Suborder Rotaliina (3,812 individual or 73.28%) compared with other two suborder and it has 29 species dominated by *Amphistegina*. Suborder Milioliina reach 26.11% that is represented by eight species of *Quinqueloculina, Sprirologulina* and *Triloculina*. The lowest group (0.62%) is suborder Textulariina that is represented by *Textularia pseudogramen* and *Textularia indenta*. Most of the collected benthic foraminifera from the study area were indicators for shallow marine water environment such as *Amphistegina, Quinqueloculina, Operculina, Pseudorotalia, Elphidium* as resulted by Biswas, (1976) in the Sunda Shelf.

The number of species present in an area is partly related to the number of individuals or specimens (Murray, 2006). The number of species in a sample or study area is termed species richness (S). The number of species is varied between 4 (station RJ4 and RJ11) and 16 (at shallow sites). The lowest dominance [D], highest Shannon index [H] and highest evenness [J] characterized by fine sand substrate at site RJ9 (Table 2). Species evenness index is high if there is no dominant particular species (Odum, 1971). The values of Shannon indexes (H) in the study area are varied from 0.980 to 2.134 (Table 2). This occurrence describe that benthic foraminiferal diversity was generally low, except for sites RJ5 and RJ6 that indexes of more than 2. Species and individual richness of these sites relatively high compared with other sites. The locations of the two sites are surrounded by fringing reefs and patch reef became favorable sites for living foraminifera. They

Table 1. Number of collected benthic foraminifera of South Waigeo Waters, Raja Ampat

Species	Number of sample sites											
	RJ1	RJ2	RJ3	RJ4	RJ 5	RJ6	RJ7	RJ8	RJ9	RJ10	RJ11	RJ12
Ammonia beccarii	-	-	4	2	9	-	-	-	-	-	-	-
Amphistegina lessonii	46	21	-	4	21	467	149	120	37	106	125	114
Amphistegina quoyii	-	92	-	-	-	-	-	-	-	-	-	-
Anomalinella rostrata	-	-	-	-	-	-	-	-	2	-	-	-
Baculogypsina sphaerulata	-	-	-	-	-	80	323	141	26	31	-	-
***Biloculina* sp.**	2	-	-	-	-	-	-	-	-	-	-	-
Calcarina calcar	196	56	-	-	25	124	93	116	30	-	-	21
Cancris indicus	-	-	-	-	-	2	-	-	-	-	-	-
Elphidium advenum	-	-	36	-	-	-	-	-	-	-	-	-
Elphidium arietina	-	-	-	-	-	-	-	-	11	-	-	-
Elphidium craticulatum	-	-	-	19	-	27	8	-	18	24	-	52
Elphidium crispum	4	-	30	14	-	-	-	21	21	-	-	11
Gaudryina rugulosa	-	-	-	-	-	-	6	9	-	11	-	-
Heterostegina depressa	21	135	-	-	-	16	18	-	17	18	38	-
Marginopora vertebralis	-	-	-	-	-	-	-	-	-	-	26	-
Miliolinella oblonga	-	-	-	-	-	7	-	-	-	-	-	-
Miliolinella subrotundata	-	-	-	-	8	-	-	-	-	-	-	-
Operculina ammonoides	40	-	-	-	-	-	-	-	-	-	-	-
Peneroplis planatus	-	-	-	-	17	-	-	-	-	-	-	-
***Planorbulina* sp.**	-	-	-	-	-	2	-	-	-	-	-	-
Planorbulinella larvata	-	-	-	-	-	-	7	2	-	-	-	-
Pseudomasilina macilenta	-	-	-	-	-	11	-	-	-	-	-	-
***Pyrgo* sp.**	-	-	-	-	-	3	-	-	-	-	-	-
Quinqueloculina cultrata	-	-	-	-	54	36	18	19	-	-	-	-
Quinqueloculina granulocostata	23	20	-	-	11	54	12	-	-	19	-	-
Quinqueloculina parkery	20	-	-	-	-	-	-	3	-	-	-	-
Quinqueloculina seminulum	21	-	-	-	10	-	-	-	-	-	-	-
***Quinqueloculina* sp. 1**	8	16	35	-	-	-	-	46	-	-	-	35
***Quinqueloculina* sp. 2**	-	-	-	-	46	-	-	-	-	-	-	-
***Quinqueloculina* sp. 3**	-	-	-	-	51	-	-	-	-	-	-	-
Quinqueloculina tropicalis	20	-	-	-	-	9	-	-	-	-	-	-
Quinqueloculina venusta	7	24	-	-	-	21	18	-	-	-	-	-
Sorites marginalis	6	28	-	-	-	-	-	-	8	-	6	-
***Spiroloculina* sp.**	-	-	-	-	-	-	-	-	12	-	-	-
Tinoporus sp.	14	-	-	-	-	198	435	40	-	-	-	-
Tinoporus spengleri	214	268	-	-	-	-	-	-	-	-	-	-
Triloculina tricarinata	-	-	-	-	-	6	-	-	-	-	-	-

require a shelter such as the coral reefs against hydrodynamic energy (Murray, 2006). The lowest value is located at site RJ11 due to dominance by single species of *Amphistegina lessonii* (64.11%) of total individuals at the station. The term evenness (J) is used to describe how individuals are divided between species (Murray, 2006). Species evenness value [J] illustrates that the presence of species at each station relatively balanced. Species evenness values ranged from 0.382 to 0.856 and the diversity is more than 1 indicating relatively good community (Daget, 1976). The value of species richness index Margalef [d] found in all sites ranged from 0.569 to 2.152 where the lowest is found at site RJ11 that contains only four species.

The most common species of this study was *Amphistegina lessonii*. This species was also the most abundant at all stations and a total of 1,210 individuals have been collected. During the study, *Amphistegina* was represented by two species of *Amphistegina lessonii* and *Amphistegina quoyii* that can live, grow and reproduce well in waters deeper than 3 m. In contrast, *Amphistegina lobifera* is abundantly live in shallower than 3 m with a high intensity of sunlight (Buzas and Sen Gupta, 1982). It was supported by Renema (2008) that found two species of *Amphistegina* and some species of *Calcarina* in the reef slope on the coral rubbles or fragments in Seribu Islands, Java Sea. Before that, Phleger (1960) mentions that *Amphistegina. lessonii* is an inhabitant of depositional environment of middle neritic zone to outer that characterized by depth of 20-200 m. This species dwell in the zone along with other *Amphistegina radiata* and

Table 2. Species count [S], individual count [N], dominance [D], Shannon diversity index [H], evenness [J] and FORAM index [FI] of the collected benthic foraminifera of south Waigeo waters, Raja Ampat

Samples	Species count [S]	Individuals count [N]	Dominance [D]	Shannon [H]	Evenness [J]	Margalef [d]	FORAM Index [FI]
RJ1	15	642	0.220	1.930	0.459	2.166	8.51
RJ2	9	660	0.239	1.735	0.630	1.232	9.27
RJ3	5	123	0.249	1.454	0.856	0.831	1.43
RJ4	4	39	0.379	1.104	0.754	0.819	1.92
RJ5	10	252	0.147	2.075	0.797	1.628	3.96
RJ6	16	1,063	0.252	1.810	0.382	2.152	8.62
RJ7	11	1,087	0.276	1.561	0.433	1.430	9.47
RJ8	10	517	0.196	1.815	0.614	1.440	8.39
RJ9	10	182	0.131	2.134	0.845	1.729	6.91
RJ10	6	209	0.311	1.460	0.718	0.936	7.77
RJ11	4	195	0.468	0.980	0.666	0.569	10.00
RJ12	5	233	0.322	1.330	0.756	0.734	6.37

others such as *Baculogypsinoides spinosus, Calcarina spengleri* and *Heterostegina suborbicularis*. But in another study, Natsir (2010) recognized all of the species of *Amphistegina* above found in the shallower waters on Pari Islands of Seribu Islands

DISCUSSION

Generally, the number of benthic foraminifera collected from the samples in the study area is more than a hundred individuals, except for RJ4, which only consists of 39 individuals (Table 2). At the side of *Amphistegina lessonii*, we recognized *Calcarina calcar* that also occurs almost in all stations. These two species are identified as functional group of symbiont-bearing foraminifera which require a same water quality with coral forming organisms (Hallock *et. al.,* 2003). To the westward of the Waigeo waters, there are two sites (RJ6 and RJ7) contain more than a hundred individuals. These sample sites were dominated by sandy sediment and contain abundantly of the two symbiont-bearing foraminifera of *Amphistegina lessonii* and *Calcarina. calcar*. This occurrence tends to increase the value of FORAM Index of the sites.

Based on Hallock et al (2003) classification, the foraminifera grouped into three functional groups, i.e. symbiont bearing, opportunistic and other small, heterotrophic taxa. Symbiont-bearing taxa represent foraminiferal genera that 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 consists of all small foraminifera that boom when the environmental conditions is going well like nutrition and oxygen concentration (Hallock et al*.,* 2003).

The most common foraminifera in the study area was symbiont bearing taxon of *Amphistegina lessonii* (79.07%). It is recognized as the most common species in the study area and distributed almost in every sample site. Whereas, the opportunistic and other small heterotrophic taxa reached 6.69% and 14.24%, respectively. The FORAM index value is varies between 1.43 and 10.00 (Table 2). This index was high at majority sites (FI>4) indicate that conditions are conducive to reef growth or recovery due to the ecosystem of the sites were dominated by coral reefs. It supported by Renema (2008) that encountered two species of *Amphistegina* associated with the reef slope of coral rubble or coral fragments within the sandy substrate at Seribu Islands, together with many species of *Calcarina*. Another case at sample sites of RJ 3, RJ4, and RJ5 that have FI values of 1.43, 1.92, and 3.96, respectively indicate marginal environment for reef growth and unsuitable for recovery and even stressed conditions unsuitable for reef growth.

CONCLUSIONS

This study recognized 5,202 individuals of benthic foraminifera belong to 39 species from the 12 sample sites of Waigeo waters, Raja Ampat, West Papua Province. It is dominated by symbiont-bearing benthic foraminifera, *Amphistegina lessonii* (1210 individuals) and it is collected at every sample site. The foraminiferal assemblages in the study area contain three suborder of Rotaliina (73.28%), Miliolina (26.11%) and Textulariina (0.62%). Most of benthic foraminifera collected from the study area were indicators for shallow marine environment such as *Amphistegina, Quinqueloculina, Operculina, Pseudorotalia,* and *Elphidium*. The high occurrence of *Amphistegina lessonii* increases the FORAM Index of the sites. This index was high at majority sites (FI>4) indicate that conditions are conducive to reef growth or recovery due to the ecosystem of the sites were dominated by coral reefs. Another case with RJ 3, RJ4,

and RJ5 that have FI values of 1.43, 1.92, and 3.96, respectively indicate marginal environment for reef growth and unsuitable for recovery and even stressed conditions unsuitable for reef growth. Values of Shannon index (H) ranged from 0.980 to 2.134 that describe the benthic foraminiferal diversity was generally low, except for RJ5 and RJ6 (more than 2). Species and individual richness of these sites relatively high compared with that in other sites. The locations of the two sites are surrounded by fringing reefs and patch reef became favorable living sites for foraminifera.

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