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POST MORTEM FORAMINIFERA DISTRIBUTION IN ACEH WATER POST-TSUNAMI

Ricky Rositasari and Bambang S. Soedibjo

Research Center for Oceanography, Indonesia Institute of Science (LIPI), Jakarta-Indoensia

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ABSTRACT

The oceanographic research in Nangroe Aceh Darussalam waters post-tsunami was conducted on September 2006. Foraminifera which easily found as element of marine sediment was used as a tool to understand the trace effect of tsunami to marine sediment on the research area. Foraminifera is a single cell organism which has hard cover (test) as a primitive skeleton, that would remain in sediment for a long periods. Samples were carried out from west, north and east part of Nangroe Aceh Darussalam (NAD) Province waters using box-corer. The result showed there have been a mass of energy that force the sediment sliding and triggered the mixture of shallow and deep species of foraminifera in research area, particularly in western part of the waters.

Key words: foraminifera, post-tsunami, Aceh

Correspondence : Phone : +62- 21- 64713850; Fax : +62 – 21 – 64711948; email : rr6862@yahoo.com

INTRODUCTION

The earthquake and tsunami in NAD Province (Indonesia), December 2005 have caused severe impacts on marine and coastal resources and habitats. Damages of natural habitats such as coral reef and mangrove ecosystem and diminishing natural resources stocks have been reported from the tsunami impacted countries.

In geological view, earth quake had caused deformations to sea floor structure, which triggered by the huge power of water flow and earth crust movement. Since foraminifera occurred wide spread in the sediment both as a living or as post-mortem forms, the deformation of sea floor structure definitely change the population structure. The foraminiferal population structure in research site was observed in the aim to understand the impact of earth quake and tsunami on benthic living forms and on sea floor structure as the substrate in NAD Province.

Many oceanographer and geologist use foraminifera as a trace to understand the oceanographic and geologic process such Corliss (1979), Alve & Nagy (1990) and Debenay (1988). Li *et al*.,1998; Hohenegger & Yordanova (2001) stated that foraminifera significantly used to determine the source(s) of sediment and the directions of sediment transport in shallow, coastal lagoons and deep sea as well. These determinations, based on the distribution of foraminiferal assemblages and 'tracer species' (numerically abundant species that live in known physiographic units and/or ecological conditions). The tracer species show that the sediments are a mixture of grains that

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originated from other place. The variable proportions of foraminifera throughout the waters reflects the dynamic processes that control sedimentation.

De Sitter (1964) had also determined several traces of paleoenvironment based on fossilized foraminifera which found in Palembang basin; (1) Domination of *Haplophragmoides* and plant debris in the sediment indicated the paralic environment. (2) The presence of larger benthic foraminifera and planktonic foraminifera in the sites indicated shallow water area which has adequate circulation to open sea. (3) Domination of larger benthic foraminifera and the absent of planktonic foraminifera indicated shallow shelf which has un-adequate circulation to open sea. (4) The absence of sand, the presence of plant debris and the rare of planktonic foraminifera in the area indicated flat coastal waters. (5) The presence of planktonic foraminifera indicated good circulation to open shore. (6) The absence of sand and the presence of benthic species *Cassidulina* indicated deep water, and the abundance of planktonic and benthic foraminifera in bulk indicated open sea area. (7) The abundance of planktonic foraminifera and the rare of benthic foraminifera was the proxies of the oligotropic environment.

This paper would discover the use of foraminifera as a tool to understand the impact of tsunami and earth quake on benthic community.

MATERIALS AND METHODS

Samples which used in this study were collected aboard the oceanographic vessel *Baruna Jaya VIII*. Approximately 21 samples were collected from the continental shelf during the *Post tsunami expedition* in NAD (Nangroe Aceh Darussalam) waters in September 2006. (**Fig.1)** shows the map of study site, officially 32 stations were setting up to observe but several field obstacles were limiting sampling activity. There were no sediment samples for stations 28 to 32 because of heavy wave in the time of study. Several samples could not carried away ie. stations 10, 13, 16,19, 20 and 26 because of box corer operational problems. Table 1 shows the data sheet of sampling stations which were carried away including station number, location and water depth of each sampling station. Box corer was used to carry bottom sediment.

Rose Bengal staining has been carried out, test with protoplasm assumed to be alive at the time of collection will appear deep red coloration, whereas empty test (dead at the time of collection) will be unstained or have a light superficial pink coloration. In the laboratory, samples are washed on 250 μm sieve, identified in species level if possible and were counted under polarization microscope. The 250 μm fractions were examined a minimum count of 100 specimens of benthic foraminifera for each sample (Vilela, 2004). Because the test are rapidly destroyed by dissolution or bio-erosion after the death of the microorganisms, the thanatocoenose has ecological significance. Thus all the test were counted, without distiction between empty and living tests (Debenay, 1984).

Numeric data of each benthic and planktonic species were analyzed by Rank Spearman Correlation, Evenness Indices and Diversity Indices. Multidimensional Scaling based on set data of species and water depth was also proceeded to construct a "map" of configuration of the samples, in a specified number of dimensions, which attempts to satisfy all the conditions imposed by the rank of similarity matrix (Clarke and Warwick, 2001). Data analysis using ecological indices and rank correlation was carried out for mapping foraminiferal distribution within the site and beyond the water depth.

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Table 1. Location and depth of study site.

Location	Number of Station in study site	Depth (m)
Eastern waters of Aceh Province	1	470
	2	74
	3	420
	4	200
Eastern part of Benggala Strait	5	214
	6	200
	7	170
Benggala Strait	8	38
	9	214
	11	46
	12	37.5
Northern waters of Aceh Province	14	230
	15	925
Western waters of Aceh Province	17	724
	18	375
	21	305
	22	45
	23	833
	24	56
	25	15
	27	75

General setting

Nangroe Aceh Darussalam Province located in north-western edge of Indonesian region. The general bottom topography of Aceh waters was relief. The water depth range in the eastern NAD province were 74 – 470 meter. The topography of Benggala Strait range between 38 – 266 meter. Water depth in northern of NAD Province or in northern of Weh Island was deeper, range between 230 – 925. The deep offshore of Banda Aceh (375 – 724 meter) which was located in western NAD. Western waters of NAD was shallow, range from 15 – 75 meter except in the offshore of Banda Aceh and in Station 23 (833 meter).

RESULTS AND DISCUSSION

Results

Thirteen (13) species of planktonic foraminifera and fifty seven (57) species of benthic foraminifera were found in research area. Deep water specimen were dominated by planktonic foraminifera i.e. *Globigerina, Globorotalia, Globigerinoides* and *Sphaerodina.* There is no dominant benthic species in the study site. Benthic species contain in sparse distribution except *Streblus gaimardii* which abundant in station 24 and 25. *Cibicides* spp was distributed widely in shallower sea (less than 400 meter) and *Amphistegina quoyii* was

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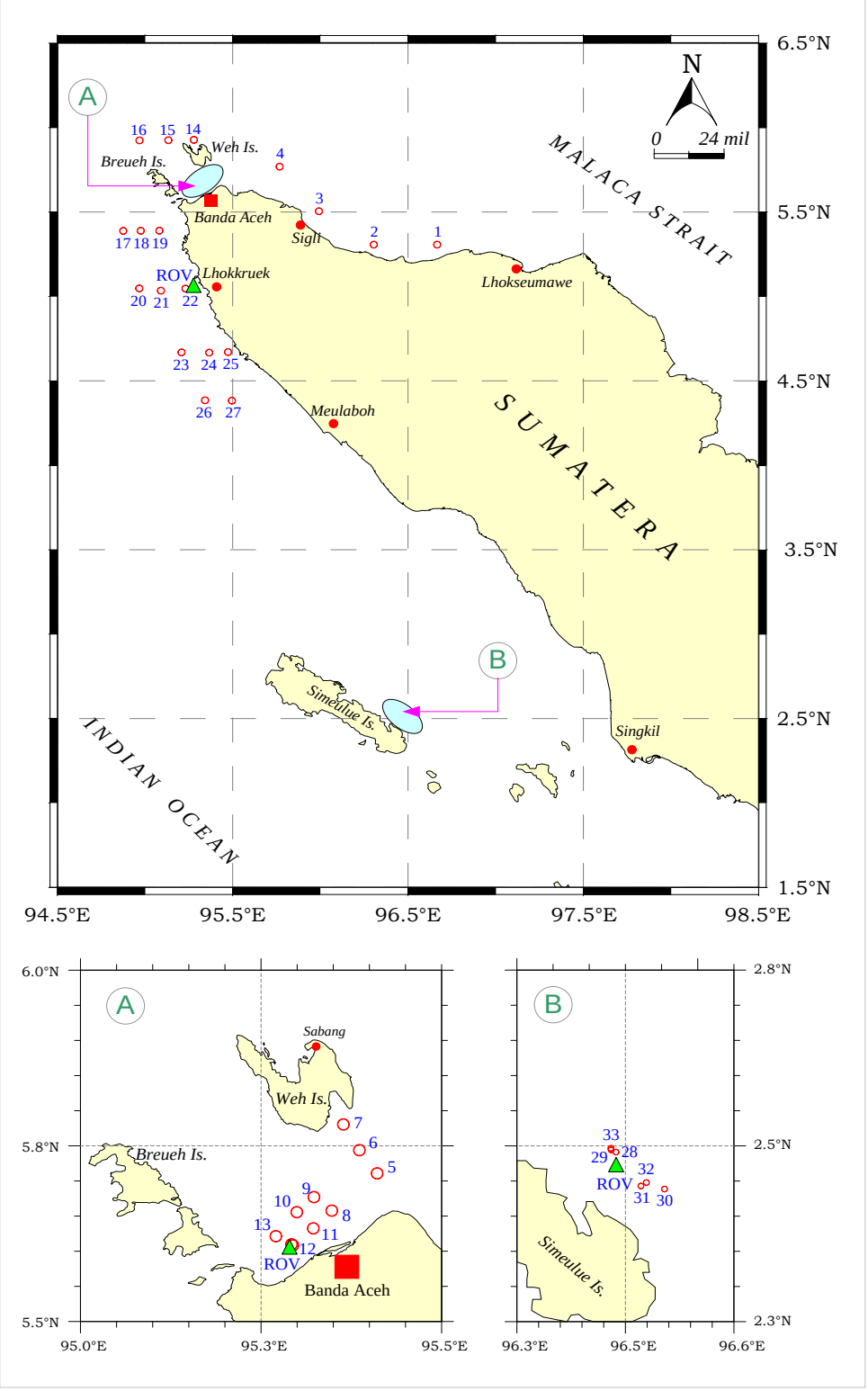

Fig. 1 Site location, The of Nangroe Aceh Darussalam waters, Indonesia.

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found unevenness in several stations. The shallow species such several benthic foraminifera i.e. *Amphistegina quoyii*, *Cibicides* sp, *Streblus gaimardii* and *Operculina ammonoides* easily found in station 2, 12, 22, 25.

Alternate of recent and fossilized specimens found in station 16, 17 and 20 which located in the offshore of Banda Aceh. This alternating specimen was assumed as evidence of vertical sediment mixing. Specimens and sediment fraction distribution in station 12 and 22 showed a trace of transported process (Fig. 2, 3 and 4). Transported specimens of foraminifera could easily identified by the color and test appearance. Transported test appeared brown-yellowish or black color and some of them have a few crack in many part of test peripheral or test in shape of almost rounded caused by major lost of the ornaments.

Correlation

Correlation (rank Spearman) between ecological indices of planktonic foraminifera to water depth was showed in Table 2. The test shows positive significant correlation between water depth and the number of species, number of population and diversity indices. The positive correlation mean that water depth would influenced to the number of species, number of population and diversity indices of planktonic species in positive way. Several symbols were used in correlation test ie. **S** number of species; **N** number of population, **H'** diversity index, **d** richness index and **J** eveness index.

Table 2. Corrrelation (rank Spearman) between ecological indices of planktonic foraminifera with depth

	S	N	H	d	j	DEPTH
S	1.000	0.893**	0.845**	0.393	-0.332	0.714**
N	0.893**	1.000	0.848**	0.044	-0.326	0.640**
H	0.845**	0.848**	1.000	0.259	0.012	0.669**
D	0.393	0.044	0.259	1.000	0.067	0.454*
J	-0.332	-0.326	0.012	0.067	1.000	-0.198

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Correlation (rank Spearman) between ecological indices of benthic foraminifera to depth was showed in Table 3. The rank Spearman test shows that water depth has negative correlation in significant value to benthic population and positive correlation to species diversity of benthic foraminifera. The result showed that in general view, number of benthic population would decrease with depth but species diversity of benthic foraminifera would increase with depth.

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Table 3. Correlation (rank Spearman) between ecological indices of benthic foraminifera with depth.

	S	N	H	d	J	DEPTH
S	1.000	0.731**	-0.295	0.915**	-0.328	-0.473*
N	0.731**	1.000	-0.376	0.433*	-0.552**	-0.591**
H	-0.295	-0.376	1.000	-0.101	0.384	0.669**
d	0.915**	0.433*	-0.101	1.000	-0.065	-0.235
J	-0.328	-0.552**	0.384	-0.065	1.000	0.566**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Discussion

Foraminiferal distribution

There is a pattern on foraminiferal distribution in Aceh waters. Deep waters samples (190 – 925 meter) dominated by planktonic foraminifera. Shallow waters (15 – 74 meter) specimen characterized by the lost of almost planktonic specimens (**Fig. 2**) and more benthic specimens appeared (**Fig. 3**) in high to moderate diversity but low in abundance. Several stations showed a strong trace of mixing condition between shallow and deep water species and also mixing between recent and fossilized specimens.

Several samples were not carried out during the sampling (Station 10, 13, 16, 19, 20 and 26) because of failure sampling process.

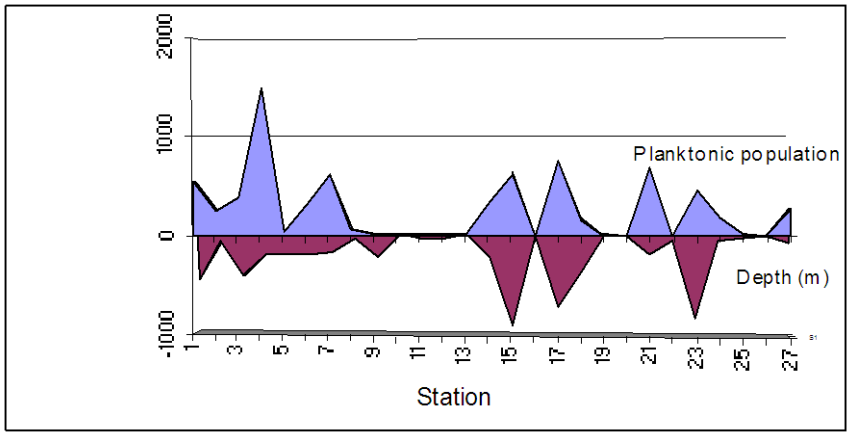

Fig. 2 The trend of planktonic specimens content to water depth.

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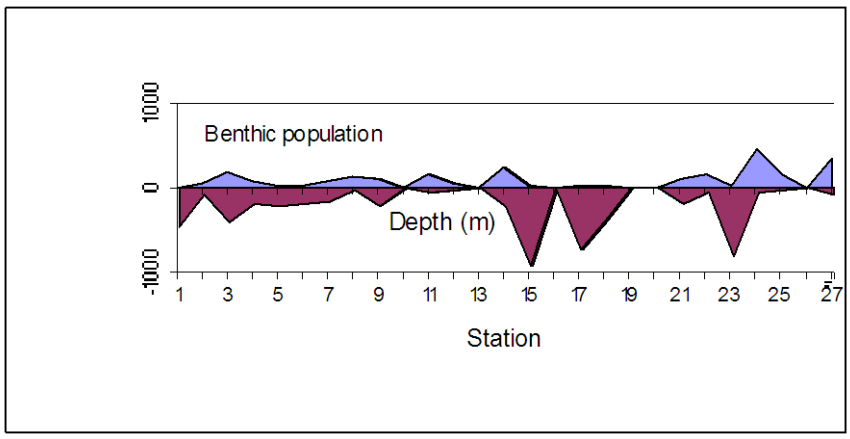

Fig. 3 The trend of benthic specimens content to water depth.

Sediment

In normal marine condition (Gilluly *et al*., 1959), there is a pattern which shows deeper marine has less coarse sediment fraction to gentle soft sediment (Silt and clay). In marine area of NAD, the pattern was hardly being found. (**Fig. 4**) shows the pattern of muddy sediment distribution in study site and its trend to water depth. Some stations appear the normal pattern that deeper water has more mud fraction, but some other stations appear otherwise. Station 8, 10, 17, 19 and 20 were the shallow area that suppose to have coarser sediment compare to the deeper area as station 6, 7 or 9, but sediment distribution in research area showed inverse condition. Another inverse condition were found in station 12, 13 and 14 which were located in deeper area (230, 925 and 724 meter) have less mud than other station which located in shallower area. This evidence assume as one of the trace of the sliding process which could be caused of tsunami.This condition was also found in species distribution of planktonic and benthic foraminifera (**Fig. 2 and Fig. 3**). Gilluly *et al.* (1959) had also stated that some of the coarser sediments had found at great depth in Indonesian seas of high relief which have doubtless slid from steep submarine slopes, exposing bare rock at their source and bringing coarse debris to areas whose sediments are normally finer.

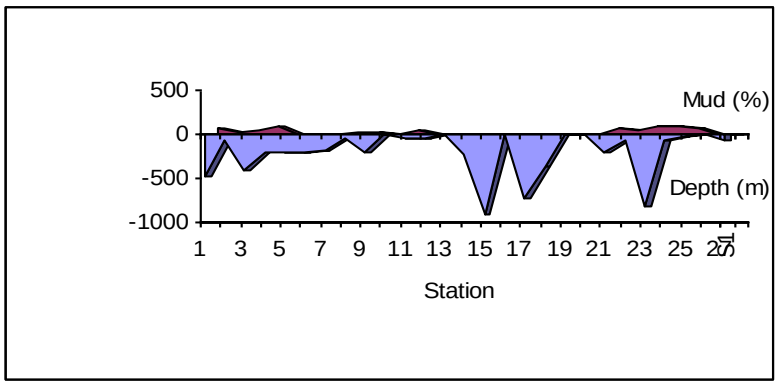

Fig. 4 The distribution of mud to water depth in Aceh waters.

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Traces of tsunami

The important information from foraminiferal data was the apparent traced of transported process of bottom sediment. *Amphistegina quoyii* and *Cibicides* sp were found abundant in St. 12 (northern part of Weh Island), water depth in the site was 230 meter. Both genus were adapted to shallow water in outer or/and inner neritic as *Amphistegina* well known as a symbion bearing foraminifera, which has close relation to light intensity. *Amphistegina* live in the fore-reef environment (Renema, 2001). The fact that these 'tracer species' are found throughout the 230 meter depth, shows that they were transported across the reef crest and shallow shelf.

Mixing and transported sediment usually found in dredging area such in harbor. This evidences indicated that the area of NAD province offshore might has significant effect of horizontal/vertical sediment movement that caused sedimentation or/and erosion process.

Cluster and MDS

Cluster analysis and MDS on benthic foraminifera shows that there are 4 major type of community in site study (**Fig. 5 and Fig. 6**) which might control by water depth. Categories was set based on water depth. First category was shallower area, second category was the deeper and respectively to the third. The interesting figure on this clustering was the presence of blending between categories. The major group showed the blended between category 1 and 2, in minor group there was blended between category 2 and 3. In second minor group there was the blended between 3 categories (1, 2 and 3). These blended cases assumed as the trace of tsunami on benthic communities. The blended process has such pattern, as category 1 and 2; 2 and 3; and 1, 2 and 3 which might be triggered by the patterned force. Station 23 which was located in western NAD has its own group, this proxy pointed that this place might has worst affect of tsunami.

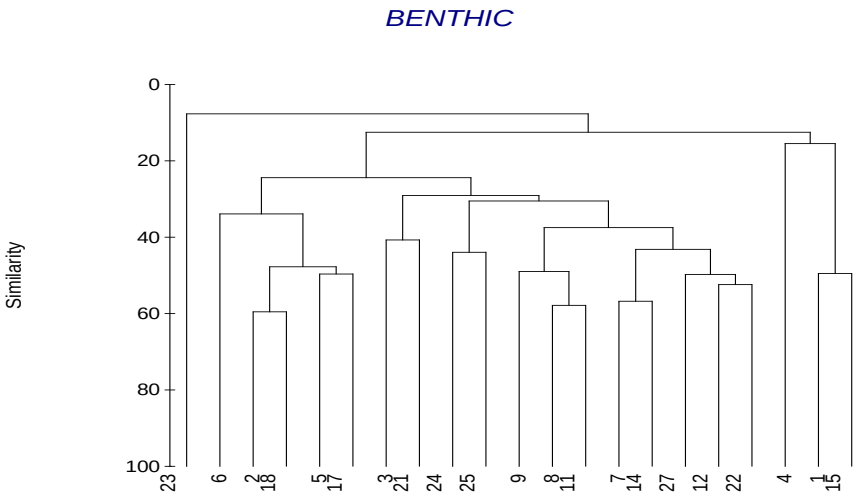

Fig. 5 Cluster analysis based on species contain of benthic foraminifera.

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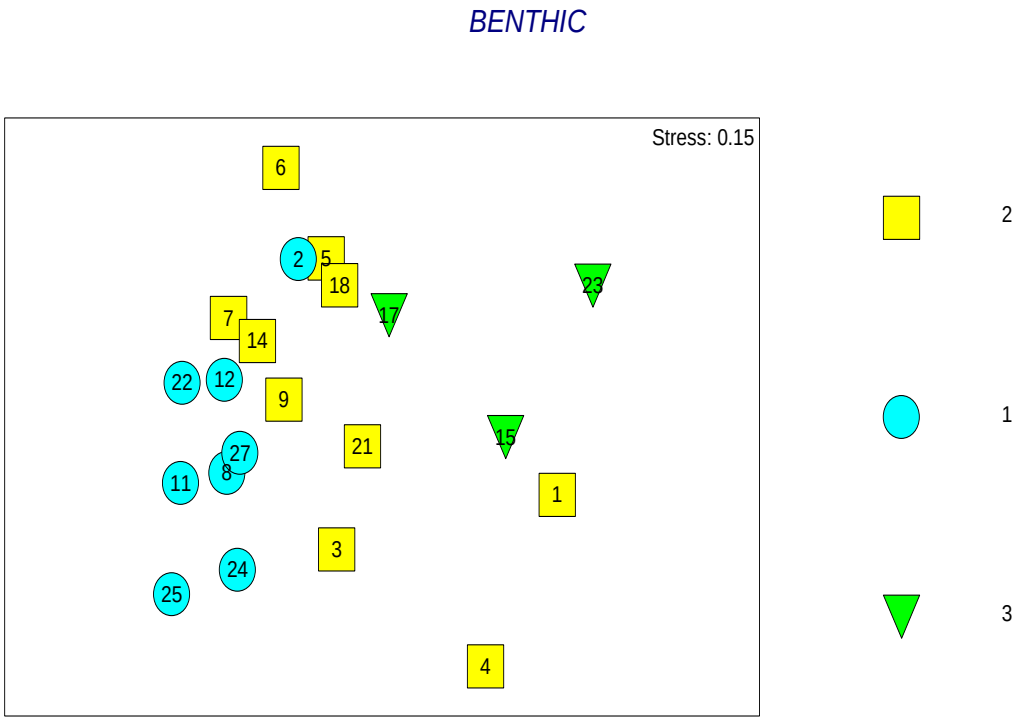

Fig. 6 MDS of benthic foraminifera to water depth category.

Cluster analysis and MDS on planktonic foraminifera showed that there were 2 major distinct group (**Fig. 7 and Fig. 8**). The distinction between those 2 major group might be caused by different water depth and/or because of it's located in different study area, since there are 4 different area in study site; Eastern NAD, Bengala Strait, Northern Weh Island and Western NAD (**Fig. 1**). First major group consist of stations within category 2, second major group consist of blended category 1, 2 and 3. These blended assume as the trace of tsunami to the soft bottom community in study area.

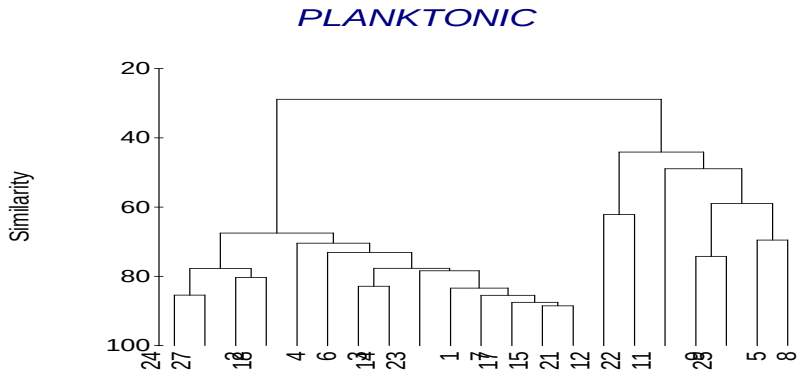

Fig. 7 Cluster analysis based on species contain of planktonic foraminifera.

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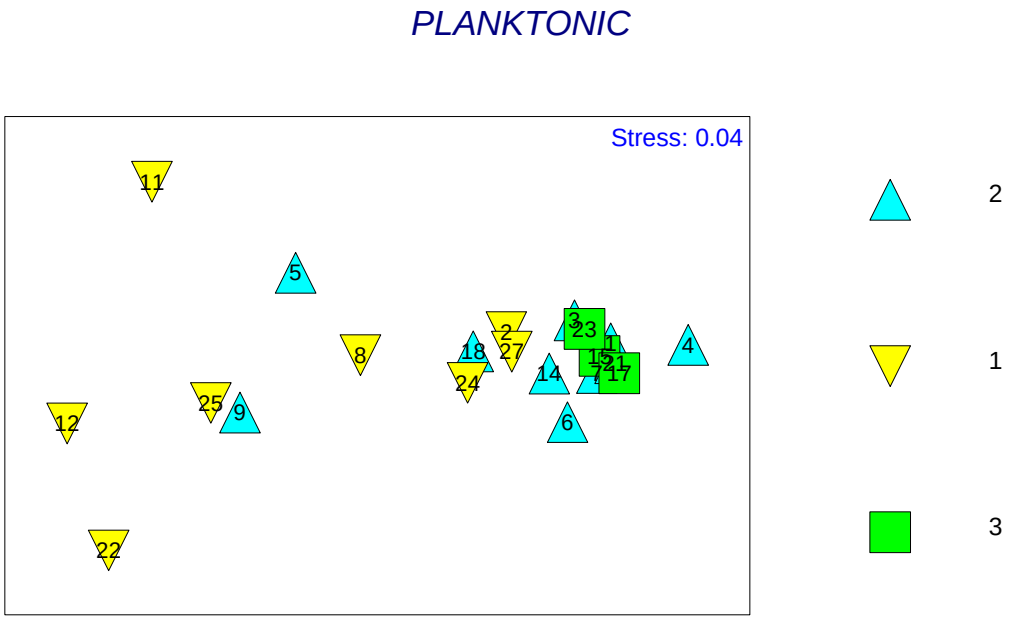

Fig. 8 MDS of planktonic foraminifera to water depth category.

CONCLUSION

The distribution of foraminiferal thanatocoenoeses (Post-mortem) in Nangroe Aceh Darussalam (NAD) confirms:
There are some differences between shallow and deep waters specimens. Deeper water dominant by planktonic foraminiferal species. In shallower area planktonic species were disappear and benthic specimen substitute the community in sparse number and narrow distribution.
Spaeroidina bulloides, *Globigerina eggeri* and *Globigerina bulloides* were the most abundance planktonic species, particularly in deeper water.
Benthic foraminifera, *Streblus gaimardii* in various size (age) and various conditions (Good or fairy) has highly abundance in station 24 and 25. *Cibicides* in various species abundant in some stations either in shallow or in deeper water.
In several stations, particularly in western waters conformed the existence of divergent on sediment and foraminiferal (planktonic and benthic) distribution. These traces might be caused by a sliding process on bottom sediment that could be triggered by tsunami.
Cluster analysis and MDS on benthic and planktonic taxa showed the clear trace of tsunami affected on certain bottom area in study site.

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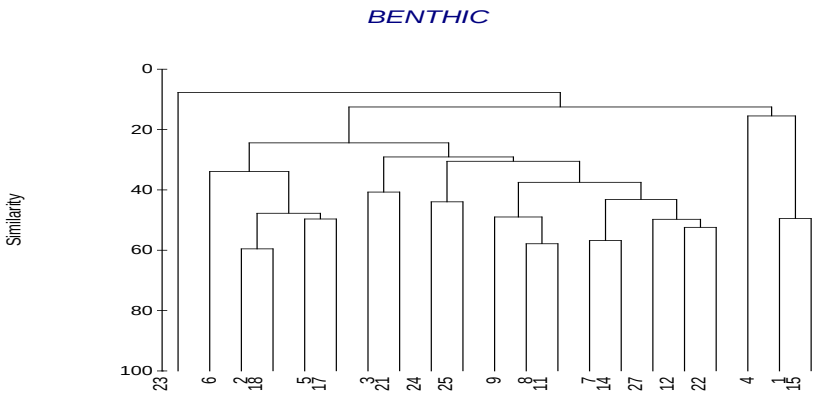

Figure 5. Cluster analysis based on species contain of benthic foraminifera.

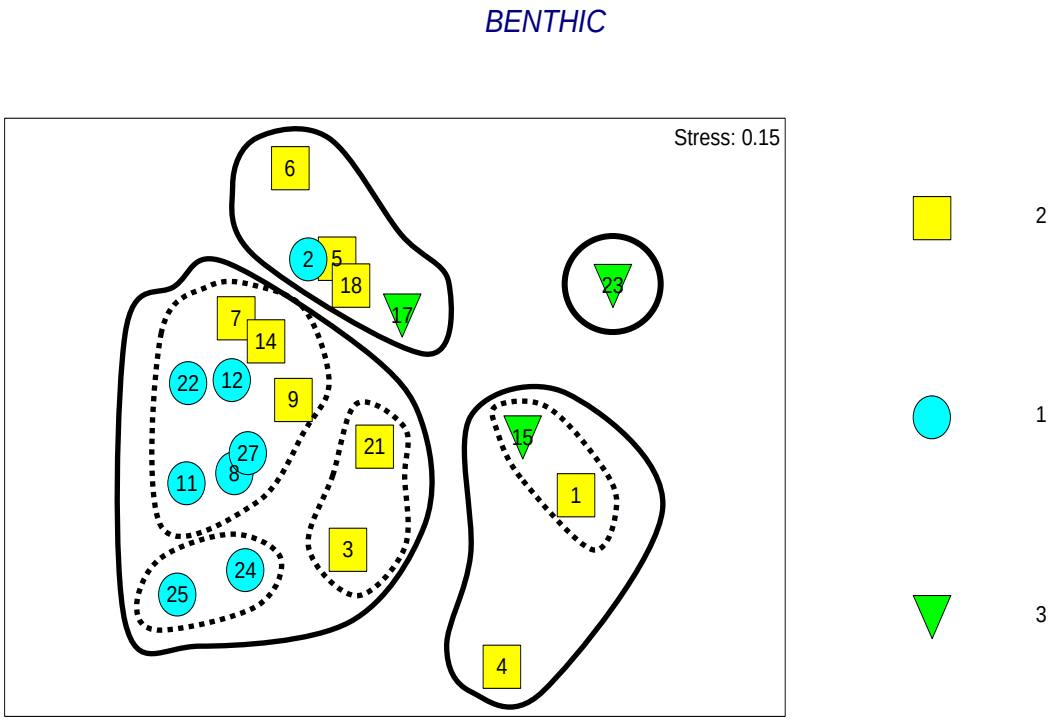

Figure 6. MDS of benthic foraminifera to water depth category.

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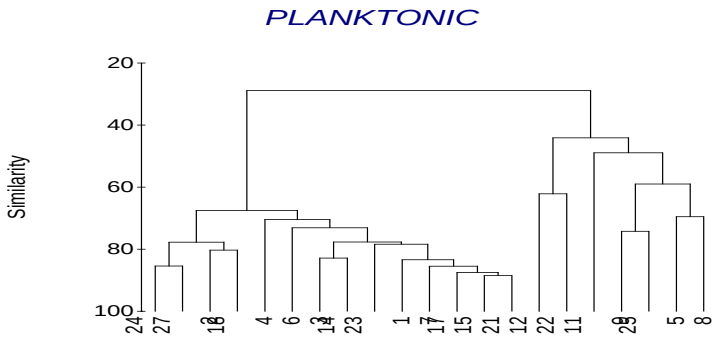

Figure 7. Cluster analysis based on species contain of planktonic foraminifera.

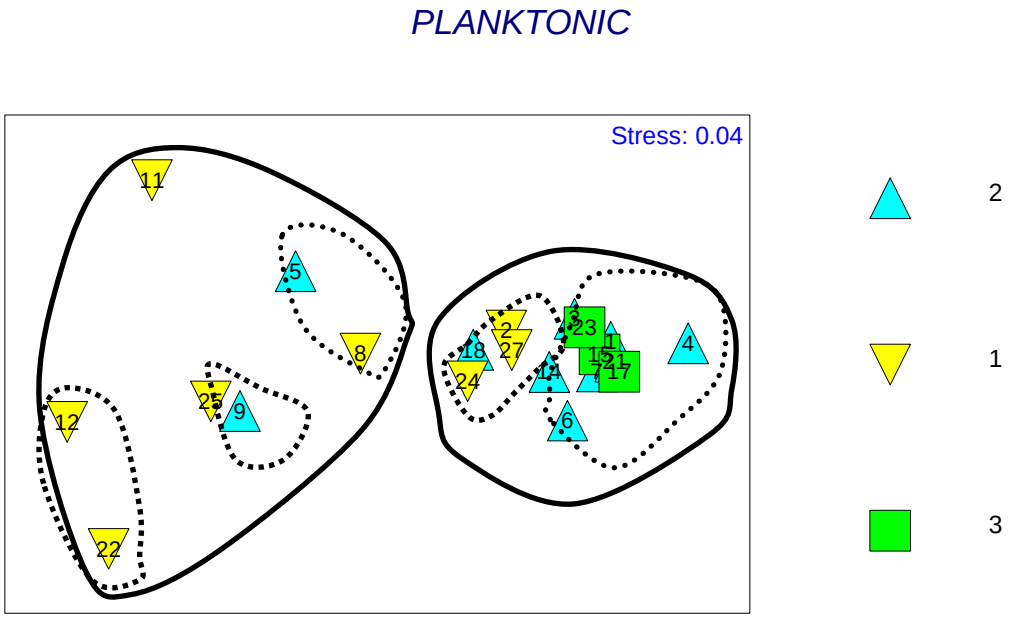

Figure 8. MDS of planktonic foraminifera to water depth category.

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Jakarta, November, 19, 2008

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Dear Sir,

Hereby I send the reviewed manuscript which I have received in October, 26, 2008.
I have undertaken revision of the manuscript as the reviewer consideration. Hope all the revision were appropriate.

Full appreciation for your help and kind.

Sincerely,

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Ricky Rositasari
Research Centre for Oceanography
Indonesian Institute of Science
Jl. Pasir Putih I, Ancol Timur
Jakarta 14430