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Original Paper

RECENT FORAMINIFERAL COMMUNITIES IN MAKASSAR STRAIT

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ABSTRACT

Makassar strait is the very unique waters, the bottom topography was steep and complex, the waters mass was also exceptional since Indonesian through flow carried flavor water from Pacific warm pool to the area. To describe the exceptional of Makassar Strait hydrological characteristics through recent foraminiferal community structure as a proxy, Oceanographical Expedition in Makassar Strait was conducted in October 2004. Research Vessel of Baruna Jaya VII was used to carry out the research activities. Sediment layers are an essential tool on recording hydrological information in such period of time, and each certain layer preserved certain information as a bench mark data at a time period. The result shows that there are 5 genera of planktonic foraminifera which generated a bulk in sediment surface. Deep chlorophyll maximum in oceanic region of Makassar Strait was prominent factor generated living planktonic foraminifera in research location. Benthic community was formed by 164 species from 78 genera. Water depth was affected to benthic foraminiferal diversity, distribution and species diversity, which reveal that water depth was limiting factor to benthic foraminiferal assemblage. Uvigerinid was the important taxa which make up 46 to 57 % of the benthic specimen, particularly in river input yield adjacent area. Uvigerina asperula may considered as an indicator of OMZ (Oxygen minimum zone) in Makassar Strait.

Keywords: *Distribution, foraminifera, Makassar Strait*

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INTRODUCTION

Among the most abundant and readily studied microfossils are the foraminifera, a group of single-celled protozoans that construct chambered shells (tests) of almost infinite variety (Loeblich and Tappan, 1964). Tests are either calcareous (composed of calcium carbonate secreted by the organism) or agglutinated (composed of a variety of grains selected from the seabottom and cemented together to form the test). Typically about the size of a sand grain, foraminifera display such an array of shell forms and surface textures that appears fascinating. Modern foraminifera, like their fossilized ancestors, inhabit salt water environments ranging from open marine to brackish (estuaries, salt marshes, etc.). Hence, foraminifera occur in a wide variety of sediments and sedimentary rocks, often in great abundance, and can be collected in most geographic regions.

Benthic foraminifera exist on most offshore and oceanic reef in the Indonesian Archipelago, since the benthic foraminifera play a role as dominant producers of calcareous reefal sediment (Tomascik *et al.*,1997). Major diversity of existing foraminifera are benthic, however some families are pelagic. Troelstra & Kroon (1989); Barmawidjaya *et al.,* (1989) worked on foraminifera as indicator for paleoclimate and paleooceanography in several Indonesian waters such as Banda Sea, Makassar Strait and Mollucas Sea. Ding *et al.(*2002) investigated planktonic foraminifera assemblages and sedimentation rates in the Indonesian Archipelago and found the evidence that Makassar and Lombok straits were important pathways of heat transport from the Pacific to Indonesian Archipelago.

The Indo-Pacific biodiversity peak is located within a relatively small area called the

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East Indies Triangle (Briggs, 2007) covering Sulawesi, Halmahera and Papua. Indo-Pacific biodiversity peak developed based on the abundance and the diversity of coral reefs which would also be analogous with other element of the system as foraminifera. Foraminifera has contributed extensively to the cementation and stability of reefs construction, that revealed both coral and foraminifera have similar water quality requirements. The objective of this study is to describe the exceptional of Makassar Strait hydrological characteristics through recent foraminiferal community structure as a proxy. Foraminiferal characteristics as a single organism or as a part of community was remarkable proxy on various oceanographic aspect within its period of time. Basically each sediment layer represented different period of time. Witasari & Rositasari (2010) noted that 5 cm of sediment surface in Cirebon coastal waters represented 12 years periods. And every single disparity of foraminiferal community in projection of time and space were useful proxy on oceanographical history.

MATERIAL AND METHODS

Study Area

Makassar Strait is a narrow passage of the west-central Pacific Ocean, Indonesia, extending 500 miles (800 km) northeast–southwest from the Sulawesi Sea to the Java Sea. The strait passes between Kalimantan on the west and Sulawesi on the east, and is 80 to 230 miles (130 to 370 km) wide. It is a deep waterway containing numerous islands, the largest of which are Laut and Sebuku Islands. The schematic of cross section bottom profile (**Fig. 2**) shows that the coastal waters of Makassar is shallower than Sulawesi and have steep slope on both sides. Waworuntu *et al.* (2001) developed a simple three layer model of water column based on its densities in two locations in Makassar Strait. The mean thickness of the first layer was 200 m, the second one was 300 m, and the third one was 1600 m. In the upper layer the water mass was characterized by the salinity maximum of the North Pacific Subtropical water and the second was characterized by the North Pacific intermediate water salinity minimum (Hautala *et al*., 1996).

Makassar Strait is a certain waters, since Indonesian Through Flow carry Pacific warm and saline water, high relief topography and the complexity of sedimentation influenced by several huge river flow (Karangan, Bangalun, Mahakam and Saluang) and apparently being proved that upwelling is periodic phenomenon in Makassar Strait (Hadikusumah, 2006). The bottom topography of Makassar Strait was a steep slope, 5 to 10 m in Mahakam delta adjacent to more than 2500 m in the off shore area **Fig. 2**. Bottom sediment was dominated by mud (silt and clay) (Helfinalis, 2010) in various scale of compactness. The surface sediment in southern part of Mahakam Delta was highly compacted than in northern area that revealed sedimentation process in northern delta was active. Makassar Strait topographic relief and sedimentation pattern would generate strong possibility of oxygen minimum zone (OMZ) triggered by high organic river input in slope area. OMZ is interesting phenomenon in deep oceanic waters which was hardly to discover by several institution on their exploration activities (Karmini, 1989; Troelstra *et al*., 1989 and Rositasari 2005).

Sampling technique

The bottom sediment was sampled using Piston core from 26 stations established on the study site (**Fig. 1**). The topography of Makassar Strait is shown in **Fig.2**. The uppermost layer of bottom sediment was used for foraminiferal observation. Sediment was disaggregated in wet sieved through a 125 mesh-size. Specimen observation based on total population (living plus dead specimens). Total specimen counting method was widely used by many researchers on ecological study. The methods was carried out on the study of benthic foraminiferal assemblage change over the last 50 years in Osaka Bay (Tsujimoto *et al*., 2006), benthic foraminiferal response to bottom water characteristics (Kumar & Manivannan, 2001), benthic foraminifera distribution in high polluted sediments (Vilela *et al.,* 2004), foraminiferal assemblages and their distribution relative to environmental stress in the paralic environments (Debenay, 1990) and benthic foraminifera of the oxygen minimum zone (Perez-Cruz and Machain 1990).

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Data analysis

Primer 5.0 Program was used in uni-variable analyses. Shannon-Wienner diversity indices ($H'_{(log2)}$), Pielou evenness indices (J'), and Margalef species richness indices (d) (Clarke & Warwick 2001) were used in the research. $H'_{(log2)}$ indices range value based on Mendez *et al.*, (2008); 0-2 indicate low, 2-4 intermediate and > 4 high diversity. J' indices range on 0 to 1 value, the higher value indicates evenness distribution among species in the research area (Anonim 2003). Fatela's formulation was used to indicate species domination (Mendez *et al.*, 2008); >20% values indicate species domination, 10-20% were general, 5-10% were supplement, 1 -5% were rare/coincident species.

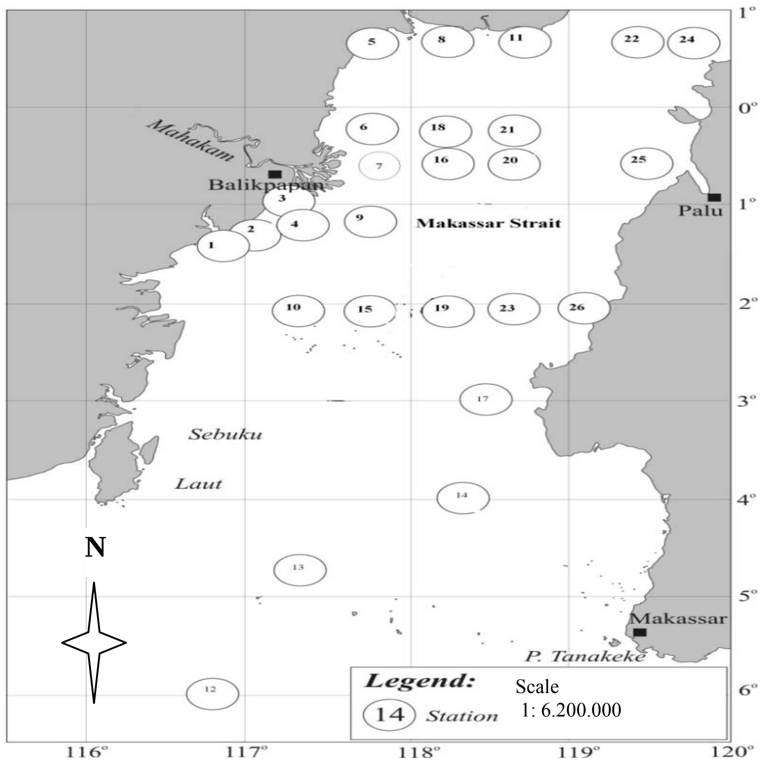

Fig 1. Study site, Makassar Strait

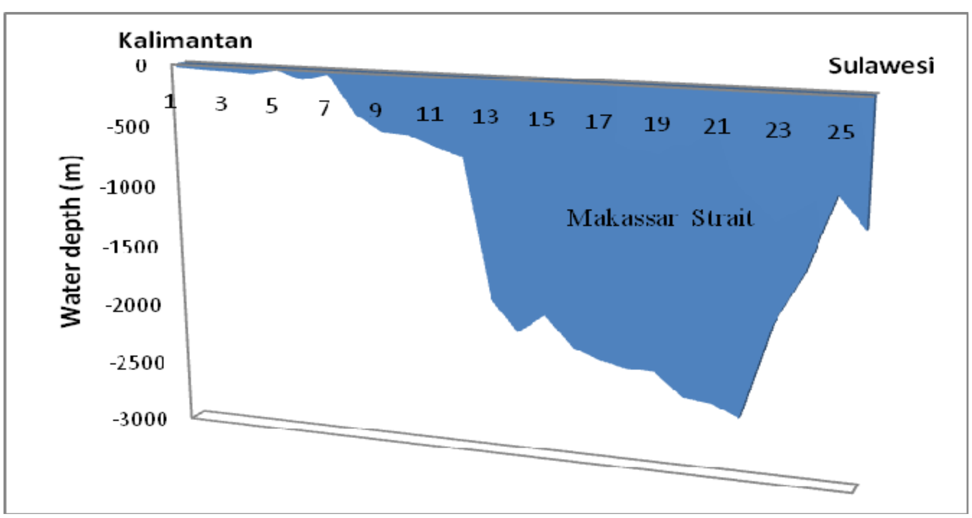

Fig 2. The schematic of Makassar strait bathymetric.

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RESULTS AND DISCUSSION

Planktonic foraminifera

The abundance of planktonic foraminifera found as major assemblage in the study site, more than 5000 specimen were found in each station. The test size of these taxa were also apparent in the range of 1 mm diameter. Five genera of planktonic foraminifera were found abundantly in the study site, i.e. *Globigerina, Globigerinoides, Globorotalia, Sphaeroidina* and *Orbulina.*

Planktonic foraminifera test was formed a major sediment fraction in the study site. Rositasari (2005) found a thick assemblage of planktonic foraminiferal test in the trench area (1884 – 2966 meters) of Makassar Strait, named globigerina ooze. Fourteen planktonic species were found in the trench area of Makassar Strait (Rositasari, 2005). Toelstra and Kroon; Adisaputra; and Barmawidjaja (*In* Tomascik *et al.,* 1997) found that the planktonic foraminifera fauna is a characteristic of oceanic regions with well developed Deep Chlorophyll Maximum (DCM). Planktonic foraminifera has a role as a host to several single algae species, since the niche of living planktonic foraminifera is within sea surface layer column. The dense population of the taxa in the study site would describe that Makassar Strait also developed Deep Chlorophyll Maximum which supported by the rich nutrient water from North Pacific Subtropical and North Pacific Intermediate water (Hautala *et al.,*1996).

Planktonic foraminifera has a potential capability in reconstructing the paleo-environments, since the assemblage and individual tests keep on being at the upper layer of water for a long period. Kuroyanagi and Kawahata (2004) found that the distribution of each foraminiferal species is controlled by various factors such as temperature, chlorophyll-*a* concentration, and light intensity. Žarić *et al.,* (2005) reported that *Globigerinoides ruber* and *G. sacculifer* have widest range of sea surface temperature tolerance (9.7 to 31°C). Visser *et al*., (2003) analyzed the oxygen isotopes and Mg/Ca ratios of planktonic foraminiferal shells in Core taken from the Makassar Strait in the heart of the Indo-Pacific warm pool and found that sea surface temperature (SST) increased by 3.5–4.0°C during the last two deglaciations. This temperature increase was parallel to the global increase of atmospheric CO_2 and the warming of Antarctica.

Benthic foraminiferal assemblage

The benthic foraminifera in research area was marked by poor to intermediate species contain, ranging from 2 to 39 taxa. Only a few species have maximum frequency, the values greater than 15 % and most taxa have maximum frequency less than 10 %. The few important species with high frequency were make up 46 to 57 % of the specimen.

Several species were found abundant in patchy distribution, as *Uvigerina asperula* at station 22, *Cibicides* sp at station 7, *Euuvigerina aculeta* at station 19 and 20, and *Spiroloculina communis* in station 15. There are also some species which was abundant in moderate level as *Bolivina nitida, Gavelinonion* spp, *Euuvigerina peregrine, Cibicides praecintus* and *Quinqueloculina* spp*.*

Benthic foraminiferal assemblage in Makassar Strait has a major equity with Pacific species, particularly in Philippine marine waters which was reported by Graham dan Militante (1959). Dominant benthic species based on Fatela's equation (Mendez *et al*., 2008) was Uvigerina (27,054%). The subsidiary or accessories genera were Bolivina (8,823 %), Euuvigerina (8,002 %) and Cibicides (7,022 %). The other 119 genera were characterized as rare/coincidentally genera.

Three genera of the Uvigerinid was found in Makassar Strait ie. Uvigerina, Euuvigerina, dan Neouvigerina. The Uvigerinid found as dominant genus in almost stations, particularly in Station 22. Larkin *et al*. (2006) found *Uvigerina* in Pakistan margin Oxygen Minimum Zone as opportunistic and highly competitive calcareous species. This species ingested a high proportion of phytodetrital material and plays a central role in organic matter cycling on the seafloor. The high abundant of *Uvigerina asperula* in Station 22, *Euuvigerina aculeate* in Station 21 and 22 might indicate the low oxygen content in bottom layer, There are river inputs and phytoplankton blooms in the Makassar Strait (Abu Daya, 2004), and significant phytoplankton blooms are modulated by monsoonal variations in regional currents and the eddy field (Asanuma *et al.*, 2003). Nutrient rich water tends to decrease oxygen content in the water column to anoxic level (Hallock and Schlange, 1986). The highly abundance of Uvigerinid particularly *Uvigerina asperula* in the soft bottom of Makassar Strait would noted that *Uvigerina asperula* might be considered as an indicator of OMZ (Oxygen minimum zone) in research site. Future research would need to figure the hydrological characteristics in research location and its correlation to the Uvigerinid as single organisms or as a population.

Table 2. Ecological indices of benthic foraminifera in Makassar Strait, 2004

Station	S	N	d	J'	H'(loge)	Water depth (m)
1	12	18	3,805	0,953	3,419	-617
2	21	70	4,707	0,950	4,176	-1737
3	14	112	2,755	0,896	3,414	-1994
4	31	218	5,571	0,909	4,508	-2161
5	8	10	3,040	0,973	2,921	-988
6	24	43	6,115	0,947	4,344	-1765
7	49	199	9,068	0,634	3,562	-2216
8	41	95	8,783	0,899	4,817	-1839
9	34	84	7,447	0,932	4,741	-474
10	11	15	3,692	0,946	3,272	-54
11	60	154	11,713	0,813	4,803	-461
12	25	88	5,360	0,900	4,179	-740
13	3	4	1,442	0,946	1,500	-2399
14	22	96	4,600	0,786	3,507	-2074
15	38	400	6,175	0,810	4,254	-83
16	37	178	6,947	0,826	4,306	-81
17	8	19	2,377	0,847	2,542	-2205
18	14	23	4,146	0,872	3,321	-2423
19	29	66	6,683	0,908	4,414	-1353
20	26	64	6,011	0,905	4,257	-2522
21	25	219	4,453	0,799	3,714	-559
22	16	651	2,315	0,358	1,435	-339
23	45	158	8,691	0,863	4,739	-71
24	15	65	3,353	0,931	3,639	-38
25	61	120	12,532	0,883	5,237	-29
26	22	85	4,726	0,951	4,241	-43

Note: S species number
N population number within the species
H'(loge) diversity index
J' Pilou evenness index
d Species richness index

The average value of diversity index of benthic foraminifera in Makassar Strait was 3,818 **(Table 3).** This value indicated that species diversity in study area was categorized as intermediary. The diversity index trend to water depth was shown in **Fig. 3**. The trend indicated that benthic foraminiferal diversity index decrease with depth. Haq and Boersma (1984), noted that in most marine area, benthic species decrease in deeper bottom waters. The increase of water deep will also increase the complexity of many oceanographic factors, such as nutrient, oxygen content, water pressure, temperature and salinity.

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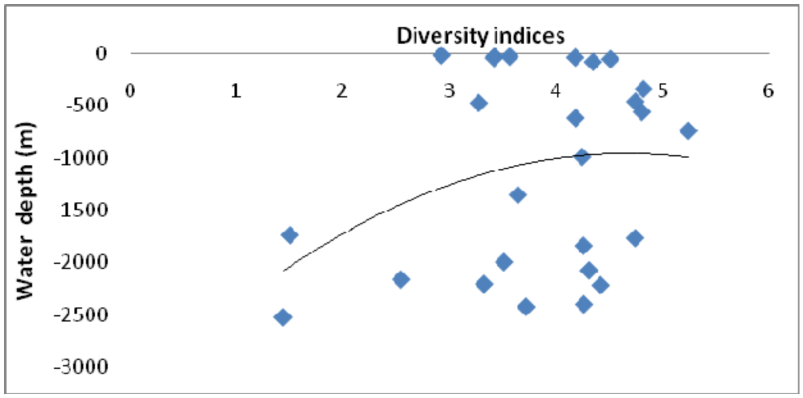

Fig.3. Diversity indices

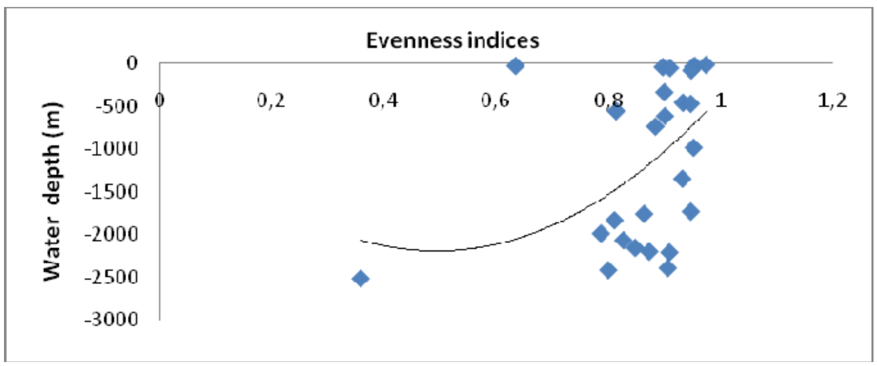

Fig .4. Evenness indices (J)

The weak trend of evenness index to water depth show that Pilou index decrease to water depth. The indices values were centered in 0,8 to 1 **(Fig. 4)** that there was burly assumption that water depth has a weak relation to benthic distribution. This pattern indicated that benthic foraminifera in Makassar strait distributed almost even in research area.

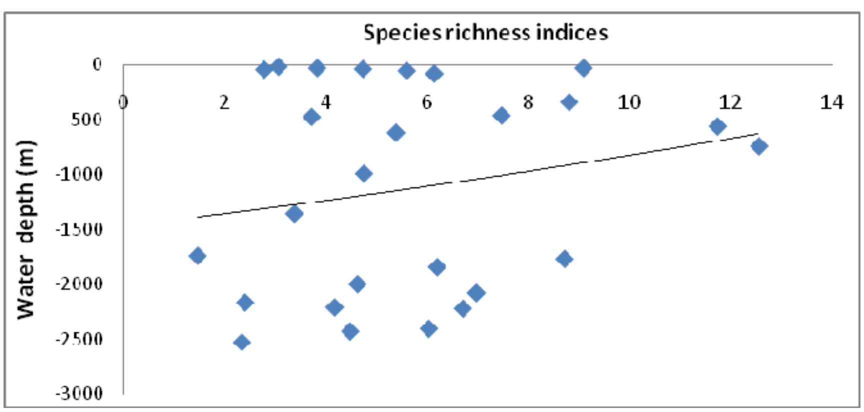

Fig. 5. Species richness indices (d)

The richness index of benthic foraminifera in study area was categorized as intermediary scale. The average value of the indices was 5.632. The highest richness found in station 25 (12.532) and the lowest richness located in station 13 (1.442). The richness index trend to water depth indicated that the richness of benthic foraminifera was decrease to water

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depth **(Fig 5).** Distribution pattern of benthic foraminifera was burly influenced by sediment type (Lee and Anderson, 1991), benthic species distribution was influenced by sediment movement, which triggered by water circulation (Rositasari, 2002) and by the deep of water (Haq & Boersma, 1984).

The decrease trend of diversity, evenness and richness indices of benthic foraminifera to water depth in Makassar strait were close related to the upwelling evidence, which drowned nutrient-depleted surface water. During upwelling 'season' many benthic living forms including foraminifera would desperate to find favorable place to live and grow, particularly in deeper areas that the diversity and richness of the taxa depleted.

CONCLUSION

Globigerina ooze formed a major fraction of bottom sediment in Makassar Strait, dominated by five genera; *Globigerina, Globigerinoides, Globorotalia, Sphaeroidina* and *Orbulina*. Globigerina ooze in the bottom sediment reveal to the active generation of living planktonic foraminifera in surface layer water column. Deep chlorophyll maximum in oceanic region of Makassar Strait was prominent factor generated living planktonic foraminifera in resesearch location.

Diversity, evenness and richness indices of benthic foraminifera in Makassar Strait tend to decrease to water depth, that reveal water depth was limiting factor to benthic foraminiferal assemblage. The highly abudance of *Uvigerina asperula* might considered as a proxy of OMZ (Oxygen minimum zone) in view of the fact that organic rich river inputs and phytoplankton blooms modulated by monsoonal variations in regional currents and the eddy field ensue in Makassar Strait.

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