MACROBENTHIC COMMUNITY STRUCTURES OF THE OFFSHORE AREA OF MIMIKA DISTRICT, PAPUA

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ABSTRACT

The study on macrobenthic community structures was carried out in the offshore area of Mimika district, Papua in 2005. Steep mountain slopes and some of the highest rainfall rates in the world, have generated tremendous sediment loads that have settled in the alluvial plain and been carried out into the estuaries and the Arafura Sea, creating a massive area of deposited natural sediments.

The objective of this study was to determine how the benthic community structures of the offshore area (Arafura Sea) changes as a result of environmental conditions. To accomplish the objective, samples were collected from 40 stations which were divided into 4 contours (layers) of water depth, i.e. 5, 10, 20 and 40 m. Stations of each contour depth were established perpendicular to the river mouths of Mimika district. The results showed the bottom sediments were mostly silt-clay fractions except the deeper area (40 m depth) which was dominated by very fine sand fraction. Diversity indices, Shannon index (H') and Pielou's evenness (e) index ranged from 1.00-3.50 and 0.20-0.92 respectively. These indices tended to increase in the deeper areas. In total 266 species of macro-benthos were collected from the study area. Contrary to this, the densities tended to decrease in deeper areas with the range of 195.00 – 4110.00 individualsm^{-2}. Polychaetes was the the dominant group, 50.80 – 71.80 % of the total family of macrobenthos. Among the macrobenthos, there were some families and group of taxa which had high densities such as Sipuncula, Nemertea and crustaceans including Ampeliscidae, Gammaridae and Israeidae. Among the polychaete group were the families Spionidae, Owenidae, Sternaspidae, Cossuridae, Capitellidae, Nephtyidae, Magelonidae and Pilargidae. Based on density, macrobenthos of the study area shows relatively high production. High rates of sedimentation of Ajkwa estuary does not influence the structure of macrobenthic communities in the offshore area.

Keywords: Benthos, Offshore, Mimika, Papua, Indonesia

INTRODUCTION

The study of macrobenthic community structures was carried out in the offshore area of Mimika district, Papua province in 2005. The highland rivers of Papua bring large sediment loads from the mountain to the lowland and then to the estuaries and Arafura Sea due to the steep mountain slopes and high rainfall rates (some of the highest rainfall rates in the world) (Collison *et al.*, 1997). The coastal region of Mimika is classified as a shallow, windy, high energy area with tidal variation greater than 3 meters. The straits of the southern coast of Papua near Amamapare harbor are influenced by rivers carrying fine mud (silt and clays) and sand into the sea for several kilometers and creating deposits of 3 to 4 meter depths.

Benthic community structure has been most recently studied as interdisciplinary studies of anthropogenic effects on marine ecosystem. Many characteristics of benthic assemblages make them useful indicators, the most important of which are related to their exposure to stress and the diversity of their response (Bilyard, 1987). The structure of benthic assemblages also reflects natural variation relating to salinity, sediment type, latitude and depth (Heip and Cracymeersch, 1995).

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The study was carried out in 2005, in conjunction with the monitoring program conducted by PT Freeport-Indonesia. The objective of this study was to determine the benthic community structures in the offshore area (Arafura Sea) of Mimika district in relation to the contours of water depth and sediment types.

MATERIALS AND METHODS

The study area is the offshore waters of Mimika district, located in the western half of Papua (Fig. 1). The coast is open to the Arafura Sea and subjected to moderate wave and current. Five large estuaries (Tipuka, Ajkwa, Minajerwi, Mawati and Otakwa) and two smaller estuaries (Kokonau and Kamora), discharge their water to the coastal waters. Generally, the rivers in this area flow in a meandering pattern forming numerous distributaries, lowland swamps and estuaries as they approach the sea.

Method of Sampling

The survey was carried out in November (24-25), 2005 using a catamaran vessel, Akapoma. Transects were established perpendicular to the beach with one transect corresponding to each of the rivers, except for the Kokonau, Ajkwa and Otakwa rivers where two transects for each river were established. Along each transect a station was established at a contour depth of 5, 10, 20 and 40 m. The rivers included the Kokonau (Co), Kamora (K), Tipoeka (T), Ajkwa (A), Minajerwi (MI), Mawati (MA) and Otakwa (OT). These overall extent from the first to the last transect was about 25 km (Fig. 1).

River	Contour of water depth			
	5 m (layer I)	10 m (layer II)	20 m (layer III)	40 m (layer IV)
Kokonau	Co 1, Co 9	Co 2, Co 10	Co 3, Co 11	Co 4, Co 12
Kamora	K 1	K 2	K 3	K 4
Tipoeka	T 5	T 6	T 7	T 8
Ajkwa	A 1, A 5	A 2, A 6	A 3, A 7	A 4, A 8
Minajerwi	Mi 1	Mi 2	Mi 3	Mi 4
Mawati	Ma 1	Ma 2	Ma 3	Ma 4
Otakwa	Ot 5, Ot 13	Ot 6, Ot 14	Ot 7, Ot 15	Ot 8, Ot 16

Samples for analyzing benthic community were collected by using a Smith McIntyre grab (0.1 m^2) deployed from the winch located on the back platform of the vessel. Sediment samples were taken two times at each station and a small portion of this sample was taken for sediment analyses and copper concentration. The remainder was washed through a 0.5 m^2 sieve. The materials

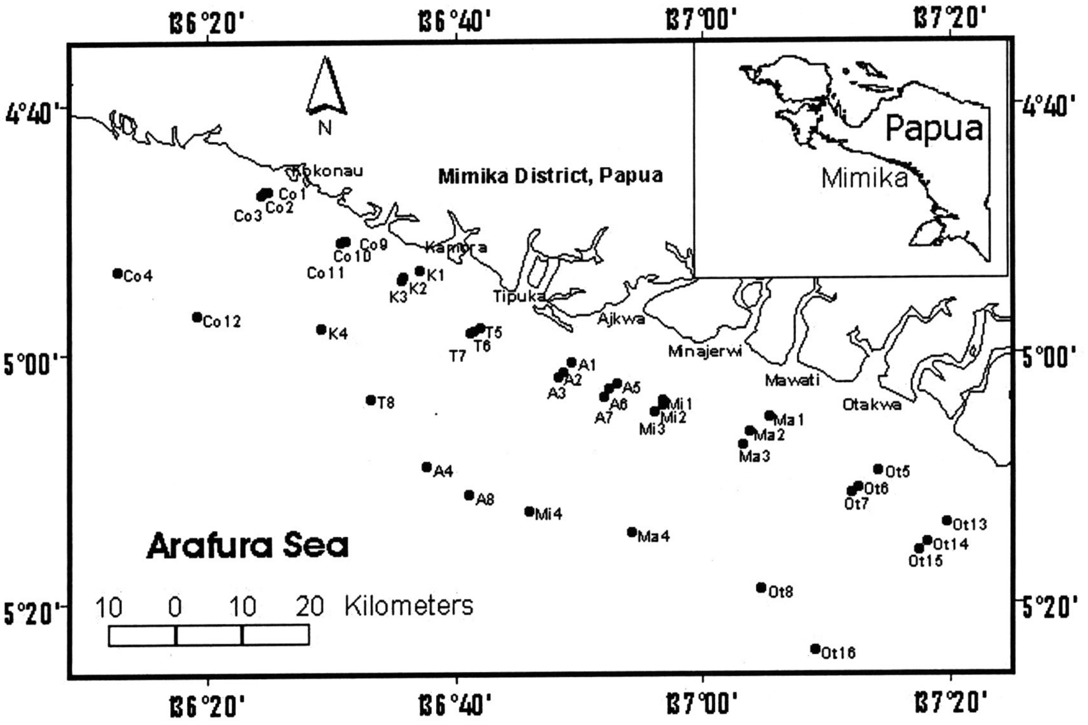

Figure 1. The sampling sites, Mimika district Papua

remained on the sieve were fixed in 10% formaldehyde on board the vessel. In the laboratory the animals were removed by visual inspection in illuminated white plastic trays. Animals were transferred to 70% ethanol and then identified and counted.

Sediment analyses were carried out in Timika Environmental Laboratory (TEL). Measurement of the total copper concentrations was as follows, the sediment was dried under the heat of a flood light, then 0.5 g of dried sample was digested in a beaker using ultra-pure nitric acid at 80°C until almost dry, after that the sample was diluted with 50 ml of DI Water and then analyzed by flame AAS.

Grain size of sediment was analyzed by using Particle Sizer with the range of 0.1μm – 1250μm.

Method of Analysis

Species diversity (H') of each station was calculated by Shannon Index, as follows:

$$H' = -\sum_{i=1}^{S} P_i \ln P_i$$

Species evenness (E) was calculated by Pielou's index as follows:

$$E = \frac{H'}{\ln S}$$

Where H' is the index of species diversity, S is the number of species, and P_i is the proportion of total sample belonging to ith species.

Spearman rank correlation was chosen to test the correlation between physico-chemical variables and benthic community descriptor.

One-way Analysis of variance tests (ANOVA) was used to test for significant differences of diversity and density among the contour depth.

RESULT

The water depths, number of stations, depth range, particle size and copper concentrations in sediment at each contour depth are listed in Table 1. Sediment textures showed high variation among stations. Very fine sediment (mud) was found at layer II (10 m depth) and layer III (20 m depth). Some coarser sediments sand, sandy mud and muddy sand) were found at the shallow area (layer I) and predominated at the deeper area (layer IV). The mean copper concentrations in sediment ranged 2.5 – 208.9 mgkg^{-1}.

In total, the range of numerical densities at the 40 sampling stations was 195–4,110 individualsm^{-2}, with an average of 1,050 individualsm^{-2} showing a high density of macrobenthos present at the offshore area of Mimika district. The numerical density at layer I (5m) ranged 195 – 4,110 with the average of 1,608 ind.m^{-2} (Fig. 2). The lowest density (195 ind.m^{-2}) was found at St. Co9 which was perpendicular to the river Kokonao. Only polychaetes, mollusks and echinoderms could be collected from this station with very low abundances. The highest density (4,110 ind.m^{-2})was found at St.Ma1which was perpendicular to the river Mawati. This station was dominated by *Owenia* sp. (polychaetes) with very high abundance.

At layer II the density ranged between 580 – 1,630 ind.m^{-2} with the average of 1,021 ind.m^{-2} (Fig. 3). The highest density (1,630 ind.m^{-2}) was found at St. Mi2 which was perpendicular to the Minajerwi river. Two species of polychaetes were dominant namely *Cossura* sp.2 and *Sternaspis* sp.1 (Appendix 1).

The density of macrobenthos at layer III and IV ranged 245 – 955 and 345 – 2,995 ind.m^{-2} respectively with the average of 580 and 991 ind.m^{-2} respectively (Figs. 4 and 5). The highest density at 40 m depth (layer IV) was found at St.

Table 1. Contour depth (layer of water depth), number of stations, depth range, particle size and copper concentration in sediment.

Contour depth	5m (layer I)	10m (layer II)	20m (layer III)	40m (layer IV)
Number of stations	10	10	10	10
Depth range	3.0 - 7.0	8.0 – 14.0	18.0 – 23.0	37.0 – 45.0
Median grain size: mean	45.2	12.2	10.0	124.9
range	12.0 – 123.0	11.0 – 15.0	8.0 – 13.0	28.0 – 171.0
Copper concentrations in sediment (mg/kg): mean	164.4	208.9	160.3	2.5
range	4.4 – 936.2	114.0 – 490.7	10.2 – 354.8	0.2 – 5.4

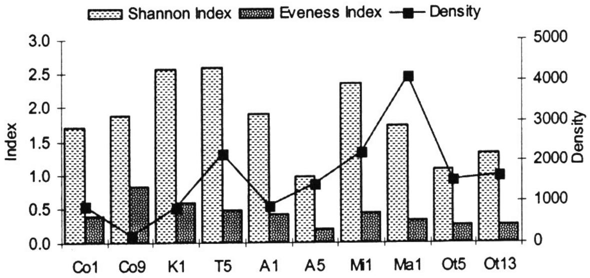

Figure 2. Diversity and evenness indices and density of macrobenthos at layer I

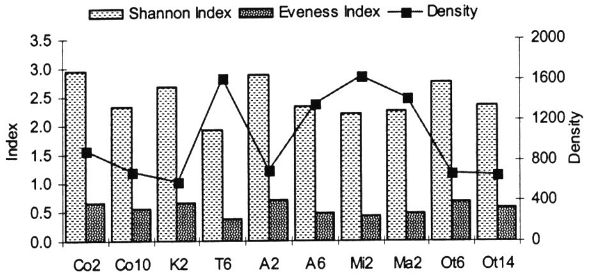

Figure 3. Diversity and evenness indices and density of macrobenthos at layer II

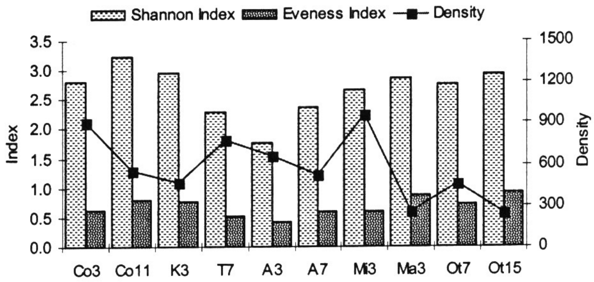

Figure 4. Diversity and evenness indices and density of macrobenthos at layer III.

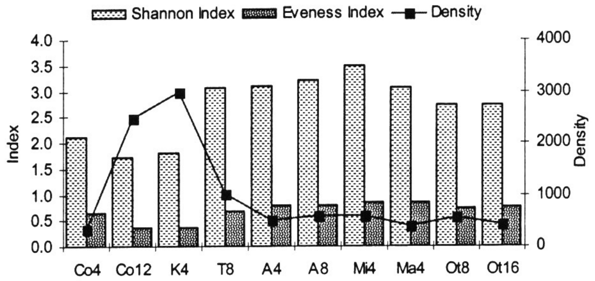

Figure 5. Diversity and evenness indices and density of macrobenthos at layer IV

K4, perpendicular to the river Kamora which was dominated by the polychaetes, *Prionospio steenstrupi* (Appendix 1). The result of one-way ANOVA test indicated that numerical density showed significantly difference between 5 m and 20 m contour depth (Table 2). The highest density at 40 m depth (layer IV) was found at St. K4, perpendicular to the river Kamora which was dominated by the polychaetes, *Prionospio steenstrupi*.

The diversity indices (H') at layers I, II, III and IV ranged 1.0-2.6, 1.9-2.9, 1.8-3.2 and 1.7-3.5 respectively with the average of 1.8, 2.5, 2.7 and 2.7 respectively (Figs. 2, 3, 4 and 5). The diversity indices tended to increase in deeper water as indicated by one-way ANOVA test (Table 2).

Table 2. One-way ANOVA test

A. Density

Multiple Comparisons

Dependent Variable: SQ_DEN

	(I) DEPTH	(J) DEPTH	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	5	10	6.68968	4.56762	.152	-2.5739	15.9533
		20	14.44790*	4.56762	.003	5.1843	23.7115
		40	8.96639	4.56762	.057	-.2972	18.2300
	10	5	-6.68968	4.56762	.152	-15.9533	2.5739
		20	7.75822	4.56762	.098	-1.5054	17.0218
		40	2.27671	4.56762	.621	-6.9869	11.5403
	20	5	-14.44790*	4.56762	.003	-23.7115	-5.1843
		10	-7.75822	4.56762	.098	-17.0218	1.5054
		40	-5.48151	4.56762	.238	-14.7451	3.7821
	40	5	-8.96639	4.56762	.057	-18.2300	.2972
		10	-2.27671	4.56762	.621	-11.5403	6.9869
		20	5.48151	4.56762	.238	-3.7821	14.7451

*. The mean difference is significant at the .05 level.

B. Species diversity

Multiple Comparisons

Dependent Variable: DIVERSITY
LSD

(I) DEPTH	(J) DEPTH	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
5	10	-.65700*	.22369	.006	-1.1107	-.2033
	20	-.85000*	.22369	.001	-1.3037	-.3963
	40	-.89800*	.22369	.000	-1.3517	-.4443
10	5	.65700*	.22369	.006	.2033	1.1107
	20	-.19300	.22369	.394	-.6467	.2607
	40	-.24100	.22369	.288	-.6947	.2127
20	5	.85000*	.22369	.001	.3963	1.3037
	10	.19300	.22369	.394	-.2607	.6467
	40	-.04800	.22369	.831	-.5017	.4057
40	5	.89800*	.22369	.000	.4443	1.3517
	10	.24100	.22369	.288	-.2127	.6947
	20	.04800	.22369	.831	-.4057	.5017

*. The mean difference is significant at the .05 level.

The evenness indices (even individuals distributions among species) were not high (Figs 2, 3, 4 and 5) with the highest average of 0.68 and 0.69 (Figs 2 and 5). This indicated that many dominant species existed in the study areas.

In total 266 species of macrobenthos were collected from the study area (Appendix 1) and polychaetes was the dominant group accounted for 51.33 % followed by the crustaceans (20.35%), mollusks (10.62%) and echinoderms (3.98%). The miscellaneous group included brachiopods, chordates, cnidarians, nemerteans, sipunculids and unidentified species accounted for 17.69% (Table 3).

Table 3. Percent composition of major taxa of macrobenthos from the study area 2005.

Major taxa	%
Polychaeta	51.33
Crustacea	20.35
Mollusca	10.62
Echinodermata	3.98
Miscellaneous group	17.69

Based on the high abundance, layer I was dominated by polychaetes (*Owenia* sp.), crustaceans (*Ampelisca* sp. and *Eriopisa* sp.) and sipunculid (*Apionsoma* sp.). Polychaetes (*Sternaspis* sp. and *Cossura* sp.), crustaceans (*Ampelisca* sp.) and sipunculids (*Apionsoma* sp.) dominated layer II. Layer III was dominated by polychaetes (*Sternaspis* sp., *Cossura* sp, and *Poechilochaetus* sp,) and crustaceans (*Eriopisa* sp. and *Idunella* sp.) and layer IV was dominated by polychaetes (*Paraprionospio steenstrupi* and *Paraprionospio malmgreni*), crustaceans (Ostracoda, *Ampelisca* sp. and *Apseudes* sp.) and sipunculids (*Apionsoma* sp.) (Appendix 1).

The correlation between physico-chemical parameters and bethic community structure is listed in Table 4. There was positive correlation between median grain size of sediment particle and water depth. The bottom sediment of shallower layers consisted of silt-clay fraction and the deeper layer had coarser sediment (Fig. 6).

Figure 7 shows the composition of dominant group of taxa based on the high abundance. Polychaeta belong to the phylum Annelida was the dominant group at each layer of water depth ranging from 50 % to 80 %. The second dominant taxa was small crustaceans which was included in the phylum Arthropoda. Nemertea and miscellaneous group comprised of lesser taxa (sipunculids, echiurids, anthozoans, ascideans, chordates, etc.) were poorly represented.

Table 4. Spearman rank correlation coefficient between physico-chemical variable and benthic community descriptor.

	Depth (m)	Diversity index (H')	Evennes index (E)	Density (ind./m²)	Cu (mg/kg)	Med. Grain size (μ)
Depth	1.00					
H'	0.47	1.00				
E	0.43	**0.86**	1.00			
Density	-0.21	**-0.50**	**-0.71**	1.00		
Cu	-9.38	-0.20	-0.27	0.03	1.00	
Med. grain size	**0.67**	0.09	0.08	0.07	-0.43	1.00

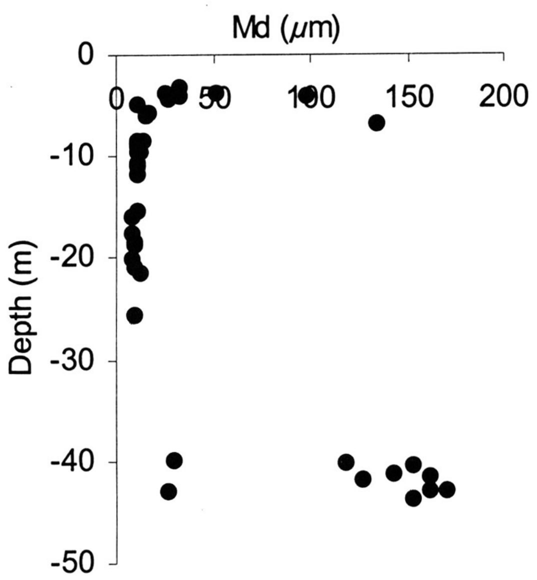

Figure 6. Correlation between median grain size and water depth (Md = median gran size).

Dominant family of macrobenthos at each layer of water depth is illustrated in Figure 8. Layer I (5 m depth) was dominated by Owenidae, Capitellidae, Sternaspidae, Cossuridae and Spionidae (Polychaeta), Gammaridae and Ampeliscidae (Crustacea) with Owenidae, Gammaridae and Ampeliscidae were the prominent families. Families Spionidae, Cossuridae and Sternaspidae were the prominent families of layer II. At layer III and IV, families Sternaspidae, Spionidae and Gammaridae were the prominent ones.

DISCUSSION

The overall average of macrobenthic density of the study area was 1050 ind.m^{-2} showing a high density of the offshore area of Mimika district. Kastoro (1992) found the average densities of macrobenthos from Banten Bay (West Java, Indonesia) and the offshore area of Jakarta Bay (Jakarta, Indonesia) were 840.70 and 370.20 ind.m^{-2} respectively. Chatananthawej and Bussarawit (1987) studied the macro-benthic fauna along the west coast of Thailand in the Andaman Sea found the overall average density of macrobenthos was 889 ind.m^{-2}. The average density of 386.60 ind./m² was found in the offshore of Tukang coast, southwest Taiwan which showed

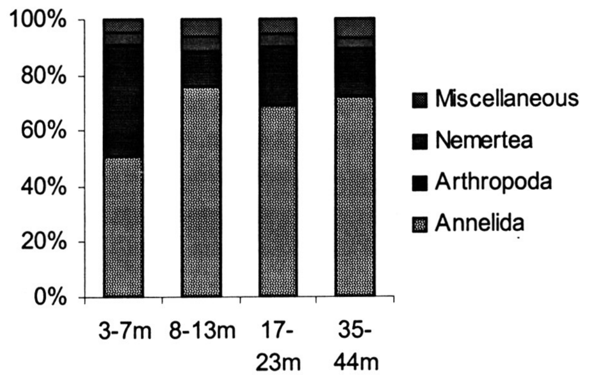

Figure 7. Taxa composition of macrobenthos of layer III and 35-44m: layer IV. 3-7m: layer I, 8-13m: layer II, 17-23m:

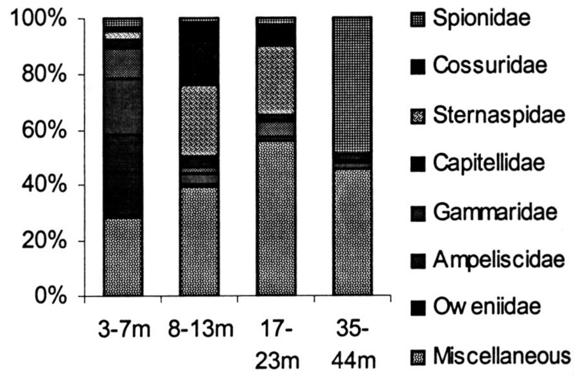

Figure 8. Dominant family of macrobenthos of study area 2005.

a low production in shallow waters facing to the open sea (Kuwabara and Akimoto, 1986). High density of macrobenthos of the study area might be due to the nutrient load discharged into this area.

Rivers in Mimika district are surrounded by dense mangrove forests. Mangrove root, branch and leaf litters are decomposed by bacteria on the bottom resulting detritus production which was spread out to the estuaries due to the tidal activities. Estuaries as a class of habitats rank along with tropical rain forest are naturally productive ecosystems (Odum, 1971). The water containing the organic matter will be flushed down to the ocean caused by the continuous flow of fresh water from the river to the estuary and mixed with sea water. Most of them will be flushed down to the ocean to compensate for the next coming fresh water and a small amount will be evaporated (Nijbakken, 1986).

The density of macrobenthos of the study area tended to decrease in deeper water. The abundance of macrobenthic fauna declines with depth is a phenomenon which has been found in many other regions of the sea (Seidefaden *et al.*, 1968; Ansari *et al.*, 1977). The density of benthos in the soft sediment decreased with the increasing depth (6000 ind./m^2 on continental shelf down to 25-100 ind.m^{-2} on the abyssal plain), as might be expected because of declining productivity with depth (Sanders and Hessler, 1969).

The diversity of macrobenthos of present study tended to increase in deeper water. Kastoro (1992) found the diversity index (H') were higher in the offshore area of Jakarta Bay compared with those in the estuarine area of Jakarta Bay. Kobawara and Akimoto (1986) also found the diversity index of macrobenthos of the offshore area of Tukang, southwest Taiwan were higher in deeper stations compared with those in shallow stations. Other workers have suggested that benthic macro-invertebrate diversity increases from shallow areas to deep sea (Sanders, 1968; Grassle and Maciolek, 1992). Besides, the bottom sediment of the deeper layer of the present study is coarser than those in shallower layer consisting of fine sand, sandy mud and muddy sand.

This various types of sediment provide habitats for greater diversity of benthic species to settle down. The present study recorded that polychaetes was the major component of macrobenthos based on the density and number of species. Polychaetes occur in almost all benthic marine and estuarine sediments (Fauchald, 1977). They are often the dominant component of macrobenthos both in terms of number of species and individuals (Grassle and Maciolek, 1992). Many factors influence the distribution and abundance of polychaetes, including sediment structure, organic content, depth, salinity and temperature. Polychaete densities are lower in exposed sandy beaches and in coarser sub-tidal sediments than in finer sediments (Knox, 1977 in Hutchings, 1998). Since the bottom sediment of the study area dominated by fine sediment, polychaetes were the dominant group.

CONCLUSION

Based on the density, macrobenthos of the study area show relatively high production. In total 266 species of macrobenthos collected from the study area show relative high diversity if it is compared with the other areas of Indonesian waters, such as Banten Bay (121 species) and offshore area of Jakarta Bay (155 species) (Kastoro, 1992) and Java Sea (373 species) (De Wilde *et al.*, 1989).

Density of macrobenthos tends to decrease in deeper water and diversity tends to increase. Among the macrobenthos, polychaete is the dominant group (50 – 80 %).

The Ajkwa estuary in particular receives not only natural sediment but also some fraction of tailings resulting high rates of sedimentation. New islands are forming throughout the estuary, and the estuary itself is moving further out into the sea. It is assumed that high rates of sedimentation will have the deleterious effects on macrobenthic communities of the offshore area of Ajkwa estuary. According to the results of present study, the diversity index (H') of St. A1 located at layer I (5m depth) which is perpendicular to the Ajkwa river mouth is higher than those at stations Ot5 which is perpendicular to the Otakwa river mouth (control estuary) (Fig.2). It seems the high rates of sedimentation of Ajkwa estuary and copper concentrations in sediment did not influence the macrobenthic communities of the off shore area.

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Appendix I. List of species of macrobenthos (two grab samples) at each layer of water depth (contour depth) 2005

No.	Species	Family/Order	Layer I	Layer II	Layer III	Layer IV
	Annelida/Polychaeta					
1	*Acoetes* sp.	Acoetidae	1	-	-	-
2	*Aglaophamus* sp.	Nephtyidae	1	9	1	6
3	*Amphicteis* sp.	Ampharetidae	1	2	-	-
4	*Aricidea* sp.	Paraonidae	1	-	1	4
5	*Ancistrosyllis* sp.	Pilargidae	-	9	8	-
6	*Ampharete* sp.	Ampharetidae	-	4	9	3
7	*Aonides* sp.	Spionidae	-	4	2	15
8	*Axiothella* sp.	Maldanidae	-	2	2	6
9	*Boccardia* sp.	Spionidae	-	-	-	2
10	*Cabira* sp.	Pilargidae	1	8	2	1
11	*Chloeia* sp.	Amphinomidae	10	-	2	-
12	*Chloeia violacea*	Amphinomidae	5	6	-	1
13	*Chone* sp.	Sabellidae	-	-	-	5
14	*Chaetopterus* sp.	Chaetopteridae	-	-	-	2
15	*Cirratulus* sp.	Cirratulidae	12	25	7	2
16	*Cirratulus* sp.	Cirratulidae	1	4	-	-
17	*Cirratulus* sp.	Cirratulidae	4	6	-	-
18	*Cossura* sp.	Cossuridae	9	15	1	2
19	*Cossura* sp.1	Cossuridae	36	230	64	1
20	*Cossura* sp.2	Cossuridae	5	208	52	3
21	*Cossura* sp.3	Cossuridae	-	-	49	3
22	*Clymenella* sp.	Maldanidae	1	1	1	5
23	*Diopatra* sp.	Onuphidae	5	3	6	1
24	*Epidiopatra* sp.	Onuphidae	1	-	-	-
25	*Eunice* sp.	Eunicidae	-	-	-	9
26	*Eunice* sp.1	Eunicidae	-	3	-	5
27	*Eunice* sp.2	Eunicidae	-	-	-	2
28	*Eunice* sp.2	Eunicidae	-	-	-	2
29	*Euclymene* sp.	Maldanidae	-	-	1	9
30	*Euniphysa* sp.	Euniphysidae	-	-	2	2
31	*Exogone* sp.	Syllidae	28	1	-	4
32	*Flabelligera* sp.	Flabelligeridae	-	4	3	-
33	*Flabelligera* sp.1	Flabelligeridae	-	-	-	1
34	*Flabelligera* sp.2	Flabelligeridae	-	-	-	1
35	*Glycinde* sp.	Goniadidae	27	11	2	7
36	*Glycera* sp.	Glyceridae	-	6	-	5
37	*Glycera* sp.1	Glyceridae	14	15	16	17
38	*Glycera* sp.2	Glyceridae	6	4	3	12
39	*Lycera* sp.3	Glyceridae	-	-	1	-
40	*Goniada* sp.	Goniadidae	27	11	2	7
41	*Goniada* sp.1	Goniadidae	8	-	5	-
42	*Goniada* sp.2	Goniadidae	6	-	2	-
43	*Gyptis* sp.	Hesionidae	1	4	2	2
44	*Hesione* sp.	Hesionidae	5	15	7	4
45	*Heteromastus* sp.	Capitellidae	34	30	2	28
46	*Hyalonoechia* sp.	Onuphidae	-	-	-	2
47	*Isolda* sp.	Ampharetidae	-	-	5	3
48	*Laonice* sp.	Spionidae	1	-	-	-
49	*Lianira* sp.	Sigalionidae	-	-	2	-
50	*Laetmonice* sp.	Aphroditidae	-	-	1	-
51	*Leonates* sp.	Nereidae	6	1	-	4
52	*Lumbrineris* sp.	Lumbrineridae	1	-	-	1

Appendix 1. (continued)

No.	Species	Family/Order	Layer I	Layer II	Layer III	Layer IV
53	*Lumbrineris* sp.1	Lumbrineridae	1	9	-	1
54	*Lumbrineris* sp.2	Lumbrineridae	-	7	1	7
55	*Lumbrineris* sp.3	Lumbrineridae	2	-	-	-
56	*Lumbrineris* sp.4	Lumbrineridae	-	-	-	2
57	*Levinsenia* sp.	Paraonidae	-	-	-	2
58	*Lepidonotus* sp.	Polynoidae	1	13	3	1
59	*Lumbrinerides* sp.	Lumbrineridae	22	4	21	2
60	*Lumbrinerides* sp.1	Lumbrineridae	2	-	-	-
61	*Lumbrinerides* sp.2	Lumbrineridae	4	-	-	-
62	*Lepidasthenia* sp.	Polynoidae	2	10	5	-
63	*Magelona* sp.	Magelonidae	-	6	1	9
64	*Magelona* sp.1	Magelonidae	30	40	11	17
65	*Magelona* sp.2	Magelonidae	20	23	17	11
66	*Magelona* sp.3	Magelonidae	8	9	-	2
67	*Maldane* sp.	Maldanidae	10	-	7	9
68	*Malmgreniella* sp.	Polynoidae	-	5	3	3
69	*Mediomastus* sp.	Capitellidae	18	12	6	2
70	*Mellina* sp.	Ampharetidae	5	11	16	8
71	*Minuspio* sp.	Spionidae	7	3	-	19
72	*Myriochelle* sp.	Owenidae	-	6	-	-
73	*Nephtys* sp.	Nephtyidae	-	4	3	21
74	*Nephtys* sp.1	Nephtyidae	21	33	31	24
75	*Nephtys* sp.2	Nephtyidae	10	21	18	1
76	*Nephtys* sp.3	Nephtyidae	-	5	7	1
77	*Nematonereis unicornis*	Nereidae	-	-	-	6
78	*Nerinides* sp.	Nereidae	21	1	1	19
79	*Notomastus* sp.	Capitellidae	49	41	15	16
80	*Onuphis* sp.	Onuphidae	2	-	-	-
81	*Ophiodromus* sp.	Hesionidae	2	-	-	-
82	*Ophelia* sp.	Opheliidae	-	1	1	-
83	*Opistrosyllis* sp.	Syllidae	-	-	-	2
84	*Owenia* sp.	Owenidae	927	-	-	-
85	*Parandalia* sp.	Pilargidae	-	4	10	-
86	*Parandalia* sp.1	Pilargidae	-	1	2	5
87	*Parandalia* sp.2	Pilargidae	-	-	1	3
88	*Paraonis* sp.	Paraonidae	-	-	1	5
89	*Paranaitis* sp.	Phyllodocidae	2	-	-	2
90	*Paralacydonia* sp.	Lacydonidae	8	6	1	30
91	*Perinereis* sp.	Nereidae	2	-	-	2
92	*Pectinaria* sp.	Pectinariidae	2	-	-	-
93	*Pista unibranchiata*	Terebellidae	-	3	-	-
94	*Pista* sp.	Terebellidae	-	1	6	-
95	*Phyllodoce* sp.	Phyllodocidae	1	-	-	15
96	*Platynereis* sp.	Nereidae	1	-	-	4
97	*Poechilochaetus* sp.	Poechilochaetidae	-	1	33	3
98	*Polycirrus* sp.	Terebellidae	-	1	6	3
99	*Polydora* sp.	Spionidae	4	-	-	-
100	*Prionospio* sp.	Spionidae	-	-	2	-
101	*Prionospio ehlersi*	Spionidae	9	6	2	12
102	*Prionospio jibata*	Spionidae	-	2	1	-
103	*Prionospio lighti*	Spionidae	-	3	-	-
104	*Prionospio malmgreni*	Spionidae	16	1	3	59
105	*Prionospio pinnata*	Spionidae	1052	35	19	3
106	*Prionospio steenstrupi*	Spionidae	48	20	12	831
107	*Pulliella* sp.	Capitellidae	16	-	-	-

Appendix 1. (continued)

No.	Species	Family/Order	Layer I	Layer II	Layer III	Layer IV
108	*Scalibregma* sp.	Scalibregmidae	2	2	1	18
109	*Scoloplos* sp.	Orbiniidae	1	-	2	1
110	*Scololepis* sp.	Spionidae	-	-	-	1
111	*Sigalion* sp.	Sigalionidae	1	3	1	4
112	*Sigambra* sp.	Pilargidae	1	8	4	2
113	*Sigambra* sp.1	Pilargidae	4	18	28	3
114	*Sigambra* sp.2	Pilargidae	3	19	9	2
115	*Spiophanes* sp.	Spionidae	1	1	1	3
116	*Spiochaetopterus* sp.	Chaetopteridae	-	1	-	-
117	*Stenelais* sp.	Aphrodiidae	2	-	3	-
118	*Stenelais* sp.1	Aphroditidae	-	8	-	-
119	*Sternaspis* sp.1	Sternaspidae	68	415	163	4
120	*Sternaspis* sp.2	Sternaspidae	21	106	121	4
121	*Stylaroides* sp.	Flabelligeridae	-	4	9	10
122	*Synelmis* sp.	Pilargidae	-	2	-	1
123	*Terebellides* sp.	Terebellidae	1	-	-	-
124	*Terebellides stroemi*	Terebellidae	-	2	2	8
125	*Trochochaeta* sp.	Trochochaetidae	-	-	1	-
	Arthropoda/Crustacea					
126	*Acetes* sp.	Sergestidae	-	-	1	1
127	*Alpheus* sp.	Alpheidae	-	5	17	-
128	*Ampelisca* sp.	Ampeliscidae	645	54	19	41
129	*Anchysquilla* sp.	Squillidae	5	2	-	-
130	*Apseudes* sp.	Apseudidae	17	5	4	38
131	*Atylus* sp.	Atylidae	-	-	1	4
132	*Byblis* sp.	Ampeliscidae	-	6	4	13
133	*Caprella* sp.	Caprellidae	9	-	-	-
134	*Callianassa* sp.	Callianassidae	-	9	22	3
135	*Carcinoplax* sp.	Goneplacidae	-	1	1	-
136	*Cerapus* sp.	Corophidae	22	3	-	4
137	*Charybdis* sp.	Portunidae	-	-	-	1
138	*Cirolana* sp.	Cirolanidae	4	3	13	1
139	*Clorida* sp.	Squillidae	1	15	3	1
140	*Colurostylis* sp.	Bodotriidae	-	6	-	1
141	*Cyclaspis* sp.	Bodotriidae	30	18	80	19
142	*Cyathura* sp.	Anthuridae	19	-	-	16
143	*Diogenes* sp.	Diogenidae	5	-	-	13
144	*Ericthonius* sp.	Corophidae	1	-	1	-
145	*Grandidierella* sp.	Aoridae	14	1	-	2
146	*Eriopisa* sp.	Gammaridae	340	48	60	5
147	*Gammaropsis* sp.	Isaeidae	2	-	-	-
148	*Gnathia* sp.	Gnathiidae	-	-	-	1
149	*Idotea* sp.	Idoteiidae	2	-	-	-
150	*Idunella* sp.	Liljeborgidae	11	12	33	-
151	*Jassa* sp.	Ischyroceridae	-	-	11	-
152	*Leptochelia* sp.	Anthuridae	-	1	-	12
153	*Leucothoe* sp.	Leucothoidae	-	2	2	1
154	*Leucosia* sp.	Leucosiidae	-	-	-	2
155	*Malacanthura* sp.	Anthuridae	1	-	-	-
156	*Macrophthalmus* sp.	Ocypodidae	-	-	-	2
157	*Monoculodes* sp.	Oedicerotidae	4	2	2	1
158	*Munida* sp.	Galatheidae	-	-	-	1
159	*Mysis* sp.	Mysidae	4	-	4	1
160	*Neasticilla* sp.	Arcturidae	-	-	-	1
161	*Neodorippe* sp.	Dorippidae	1	-	-	-

Appendix 1. (continued)

No.	Species	Family/Order	Layer I	Layer II	Layer III	Layer IV
162	*Ogyrides* sp.	Ogyriidae	12	-	4	3
163	Ostracoda	Ostracoda	43	1	1	111
164	*Paraphoxus* sp.	Phoxocephallidae	-	-	-	8
165	*Palaemon* sp.	Palaemonidae	1	1	2	-
166	*Periclimenes* sp.	Palaemonidae	-	-	1	-
167	*Photis* sp.	Isaeidae	78	6	17	13
168	*Pinnixa* sp.	Pinnotheridae	1	-	-	-
169	*Pontonides* sp.	Ogyriidae	3	3	5	7
170	*Portunus* sp.	Portunidae	1	-	1	2
171	*Pycnogonum* sp.	Pycnogonidae	-	-	-	1
172	*Randalia* sp.	Leucosiidae	1	-	-	-
173	*Stathmos* sp.	Sphaeromatidae	1	-	-	5
174	*Tanais* sp.	Tanaidae	1	-	-	5
175	*Typhlocaricinus* sp.	Goneplacidae	-	2	16	5
176	*Upogebia* sp.	Upogebiidae	1	3	18	20
177	*Urothoe* sp.	Hautoriidae	10	-	-	1
178	*Xenophthalmus* sp.	Xanthidae	24	49	1	9
	Mollusca					
179	*Anodontia* sp.	Lucinidae	-	-	-	7
180	*Arcopsis* sp.	Arcidae	-	1	-	-
181	*Amygdalum* sp.	Mytilidae	-	-	-	1
182	*Azorinus* sp.	Solecurtidae	-	-	-	1
183	*Barrimysia* sp.	Montacutidae	1	-	-	-
184	*Bulla* sp.	Bullidae	3	-	-	-
185	*Cardomya (Cardomya)* sp.	Cuspidariidae	-	-	-	1
186	*Chlamys* sp.	Pectinidae	-	-	-	1
187	*Corbula* sp.	Corbulidae	1	-	-	-
188	*Corbula (Notocorbula)* sp.	Corbulidae	-	-	2	1
189	*Cylichna* sp.	Cylichnidae	-	-	1	-
190	Chaetodermomorpha	Chaetodermatidae	-	-	2	2
191	*Dentalium* sp.	Dentaliidae	-	1	-	1
192	*Exotica (Exotica)* sp.	Tellinidae	-	1	1	-
193	*Frigidocardium* sp.	Cardiidae	-	-	-	1
194	*Gari (Gari)* sp.	Psammobiidae	-	-	-	2
195	*Gastrochaena* sp.	Gastrochaenidae	-	-	-	2
196	*Hexacorbula* sp.	Corbulidae	1	1	-	1
197	*Laternula* sp.	Laternulidae	1	-	-	-
198	*Linga (Bellucina)* sp.	Lucinidae	-	-	1	-
199	*Modiolus* sp.	Mytilidae	-	-	-	4
200	*Nuculana (Nuculana)* sp.	Nuculanidae	-	2	3	-
201	*Nucula* sp.	Nuculidae	-	1	-	-
202	*Oliva* sp.	Olividae	1	-	-	-
203	*Pitar* sp.	Veneridae	-	-	-	1
204	*Psammotetra (Psammotetra)* sp.	Tellinidae	-	1	-	-
205	*Ringicula* sp.	Ringiculidae	-	-	1	1
206	*Solen* sp.	Solenidae	1	-	-	-
207	*Tellina (Semelangulus)* sp.	Tellinidae	2	2	6	29
208	*Tellina (Merisca)* sp.	Tellinidae	-	1	-	5
209	*Tellina (Angulus)* sp.	Tellinidae	-	1	-	-
210	*Tellina (Acropagia)* sp.	Tellinidae	-	-	-	3
211	*Tellina (Cyclotellina)* sp.	Tellinidae	-	-	-	6
212	*Timoclea (Glycodonta)* sp.2	Veneridae	1	-	-	-
213	*Timoclea (Timoclea)* sp.	Veneridae	-	-	-	1
	Echinodermata					
214	*Amphioplus (Amphioplus)* sp.	Amphiuridae	1	-	-	-

Appendix 1. (continued)

No.	Species	Family/Order	Layer I	Layer II	Layer III	Layer IV
215	*Amphioplus* sp.	Amphiuridae	-	1	1	2
216	*Amphioplus (Lymanella)* sp.	Amphiuridae	-	-	-	1
217	*Amphiura* sp.	Amphiuridae	1	6	8	4
218	*Amphiuridae*	Amphiuridae	4	3	3	7
219	*Holothuria* sp.	Holothuriidae	-	-	-	6
220	*Laganum* sp.	Laganidae	-	-	-	2
221	*Lovenia* sp.	Loveniidae	-	2	-	-
222	*Lovenia subcarinata*	Loveniidae	-	-	2	-
223	Loveniidae	Loveniidae	-	-	5	-
224	Synaptidae	Synaptidae	11	15	-	1
225	Spatangoidea	Loveniidae	1	-	-	-
226	Temnopleuridae	Temnopleuridae	-	-	-	1
	Miscellaneous Group					
227	*Apionsoma* sp.	Phascolosomatidae	96	74	15	33
228	*Aspidosiphon* sp.	Aspidosiphonidae	-	-	-	1
229	*Lingula* sp.	Lingulidae	-	-	-	4
230	*Sipunculus* sp.	Sipunculidae	2	-	-	1
231	Ascidiacea 4	Ascideacea	1	1	-	1
232	Actinaria	Actinaria	5	-	-	1
233	Athecata C	Nephtyidae	-	-	-	1
234	Athecata D	Nephtyidae	-	-	-	1
235	Athecata E	Nephtyidae	1	3	-	10
236	Dendronephthya	Nephtyidae	-	-	-	1
237	Hydrozoa	Plumaridae	-	5	-	-
238	*Phascolion* sp.	Phascolionidae	-	-	-	7
239	*Stycalium* sp.	Virgulariidae	1	-	-	-
240	*Stycalium* sp.2	Virgulariidae	-	1	-	-
241	Sponge	Porifera	-	-	-	1
242	*Themites* sp.	Themistidae	-	-	1	-
243	Unidentifed sp.1		-	-	9	4
244	Unidetified sp.13		-	1	-	-
245	Unidentified sp.21		-	1	-	-
246	*Amblychaeturichtys hexenema*	Gobiidae	1	-	-	-
247	*Apocryptodon* sp.	Gobiidae	-	1	1	-
248	*Bregmaceros nectabanus*	Bregmacerotidae	-	3	11	-
249	*Bregmaceros* sp.	Bregmacerotidae	-	1	1	-
250	*Bathygobius* sp.	Gobiidae	-	-	-	1
251	*Ctenopauchen microcephalus*	Gobiidae	2	2	2	-
252	*Glossogobius* sp.	Gobiidae	-	-	-	1
253	Gobiidae	Gobiidae	1	-	-	-
254	*Parachaeturichtys polynema*	Gobiidae	-	4	-	-
255	*Taenioides rubicundus*	Gobiidae	-	2	1	-
256	*Valenciennea* sp.	Gobiidae	1	2	-	-
	Nemertea					
257	Enopla 2	Nemertea	1	-	-	-
258	Enopla 5	Nemertea	92	36	7	1
259	Enopla 10	Nemertea	15	1	2	-
260	Enopla 11	Nemertea	-	-	1	-
261	Lineidae 1	Lineidae	5	10	2	7
262	Lineidae 2	Lineidae	16	7	18	10
263	Lineidae 3	Lineidae	34	42	22	21
264	Lineidae 7	Lineidae	-	-	2	-
265	Lineidae 15	Lineidae	-	-	1	-
266	Lineidae 17	Lineidae	-	-	1	-