LAND-SEA INTERACTIONS IN COASTAL WATERS OFF NE KALIMANTAN: *EVIDENCE FROM MICROFAUNAL COMMUNITIES*

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ABSTRACT

Microfauna (ostracoda and foraminifera) as component of sediments has been used to detect the dynamics of sea floor condition in NE Kalimantan, particularly off Nunukan and Sebatik Islands. In general, the microfaunal components tend to increase (both number of species and specimens) from near shore to the open sea. The microfauna occur rarely at locations surrounding the islands due to high content of plant remains from the land. The marine origin of microfaunas occurs very abundantly in the inner part of the study area between Tinabasan and Nunukan Islands. This finding is interested due to their occurrence as unusual forms: brownish shells, broken and articulated ostracod carapaces.

Additional interested findings are: the incidence of abraded test of Elphidium, the occurrence of dominant species of both ostracoda and foraminifera at some stations; various morphological forms of foraminiferal genus, Asterorotalia that reaches about 1% and distributed in the open sea.

The various unusual forms may relate to the dynamics of local environmental changes such as post-depositional accumulation in the sediment, biological activities, and drift currents from open sea to landward.

Keywords: Ostracoda, Foraminifera, North East Kalimantan, land-sea interaction

SARI

Mikrofauna (ostracoda dan foraminifera), sebagai komponen sedimen dapat digunakan untuk mendeteksi dinamika kondisi dasar laut di Kalimantan Timur, tepatnya di sekitar Pulau Nunukan dan Sebatik. Secara umum, komponen mikrofauna cenderung bertambah (baik dalam jumlah spesies maupun spesimen) dari perairan sekitar pantai ke arah laut lepas. Mikrofauna yang ditemukan sangat jarang di lokasi sekitar pulau-pulau disebabkan oleh keterdapatan sisa-sisa tanaman dari daratan. Mikrofauna asal lautan ditemukan sangat melimpah di bagian dalam daerah penelitian antara Pulau Tinabasan dan Nunukan. Temuan ini sangat menarik karena adanya bentukan abnormal: cangkang berwarna kecoklatan, rusak dan cangkang ostracoda berbentuk tangkupan.

Temuan tambahan yang juga menarik adalah: keterdapatan cangkang Elphidum yang rusak, keterdapatan beberapa spesies ostracoda dan foraminifera secara dominan di titik lokasi tertentu, dan kenampakan morfologi yang bervariasi dari genus foraminifera, Asterorotalia, yang mencapai 1% dan tersebar di laut lepas.

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Berbagai bentukan abnormal tersebut kemungkinan berkaitan dengan dinamika kondisi lingkungan setempat seperti akumulasi setelah pengendapan dalam sedimen, aktivitas biologis dan alur arus dari laut terbuka kearah daratan.

Kata kunci: ostracoda, foraminifera, Kalimantan Timur, interaksi daratan-lautan

INTRODUCTION

Coastal waters are transition areas between land and sea, dynamics and diverse in functions both scientific and economic aspects. They provide a number of environmental information that depends on several factors: sediment supply from rivers or from the sea, currents as media to remove or redistribute the sediments within the coastal areas and other significant factors such as human activities.

The coastal areas are interested to be understandable because of their significant environmental changes that can affect the coastal ecosystems. There are several methods for detecting the dynamic of the coastal environments and one of them is by using sensitive organisms as indicators of environmental changes. Ostracoda and foraminifera are component of sediments that are widely used to recognize environmental changes. For instance, Carbonel (1988) used ostracoda for detecting the transition zones between fresh and saline waters by recognizing their abundance, diversity, quality and morphologic variation of their shells. He resulted that various morphotypes of an ostracod species reflect the different region of the Mahakam Delta: the delta front characterized by poorly ornamented shells and strongly reticulated forms in the open waters of the delta. This usefulness has also been applied for reconstructing past marginal marine environments from Holocene sediments in Balearic Island in the Mediterranean (Boomer and Eisenhauer, 2002).

Besides ostracoda, benthic foraminifera are also useful tools for detecting marine environmental changes. Gustiantini et al (2003) studied the potential of benthic foraminifera as indicators of environmental stress by finding the abnormal tests on *Ammonia beccarii* in the Segara Anakan Lagoon, southern part of Java. Horton *et al* (2005) also recognized foraminiferal zonations in the mangroves of Kaledupa, southeast Sulawesi as sea-level indicator.

From the above mentioned, it is clear that the ostracoda and benthic foraminifera are valuable indicators to detect environmental changes in both modern and ancient environments. The purpose of the present study is to use microfaunal components for documenting sea floor condition related to land sea interaction in the study area.

STUDY AREA

The study area is a shallow marine environment that lies at the border between Indonesia and Malaysia ($117^0$31'38"–$118^0$07'10" East longitude and $3^0$51'11"–$4^0$11'34" North latitude), in North East coast of Kalimantan (Borneo). The Nunukan (a 225 sq km island with 68 km shoreline) and Sebatik (area of approximately 252 sq km with 94 km shorelines) islands are the main islands in the study area besides small islands such as Tinabasan, Bukat and Haus. The northern part of the Sebatik Island belongs to Sabah, Malaysia while the southern part belongs to East Kalimantan, Indonesia. The river inputs from the west and marine currents in the open sea as part of the Makassar Strait are the main factors influencing environmental condition of the study area.

The seafloor sediment of the study area is composed of silt, sand, clay, sandy silt, silty sand, and gravelly sand. Silt predominates almost fifty percent of the samples particularly in surrounding Nunukan Island toward the open sea. The clay component occurs in near shore area close to the Bukat and Haus Islands. In the middle part, it covers by sandy silt that distributes from the northern part down to the area surrounding the Karang Unarang into the southern part of the study area. Gravelly sand and sandy materials dominate an area in the open sea, particularly in the eastern of Sebatik Island. The gravelly sand is mainly composed of shell of mollusks and other shell fragments. The bathymetric contour of the study area shows very gentle slope of the coastal escarpment, particularly off the Nunukan Island (Noviadi et al, 2005). In the open sea, the Unarang Reef (Karang Unarang) lies in the southeast of Sebatik Island that is being a center of a dispute between Indonesia and Malaysia.

METHODS

A grab sampler was used for collecting seafloor sediments in 56 stations (St.) at water depth ranging from 14 to 43 m (Figure 1). A small portion of sediments separated for microfaunal analysis and then dried in an oven. At the same dried weight of 30 g, each sample was than washed over two, three and four phi screens. All ostracod specimens were picked from each washed residue sample. We recorded any information from benthic foraminiferal components in certain location that contain few or no ostracoda. The ostracod analysis includes identification, counting and calculating Shannon-Weaver diversity index using a computer program (Bakus, 1990).

RESULTS

All sediment samples collected in the study area contain variety microfaunal components. Some samples from surrounding the Nunukan Island contained small quantity of washed residue sediments and dominated by detritus materials (Figure 2).

The microfaunal components both ostracoda and foraminifera tend to increase from near shore to the open sea. About 18 sediment samples do not contain of ostracoda other than benthic foraminifera that occur in all samples. These microfaunas occur to be very rare at locations surrounding the Nunukan Island, but they reach the maximum abundance in one station. This station lies in the inner part of the study area between the Nunukan and Tinabasan islands. This finding is unexpected because their appearances show in unusual forms: brownish, abraded shells and the ostracod specimens have articulated carapaces dominated by certain species of *Keijella, Hemicytheridea.* Furthermore, a similar appearance also occurs for benthic foraminifera that dominated by *Asterorotalia* with broken spines and dark tests as well as for the non-biogenic materials, such as brownish sandy quartz.

In the open sea, the abundance and composition of ostracod and benthic foraminifera tend to be quite high and diverse. They reach maximum diversity and abundance in the middle outer shelf, particularly in the southern part of the study area. Several species of both groups occur dominantly at specific stations. The following is the description of the entire results of the microfaunal components in the study area.

Ostracoda

As described by Carbonel (1988) that there are four ways to detect the relationship between ostracod fauna and environmental changes: 1) quantitative study by calculating number of individuals and species, 2)

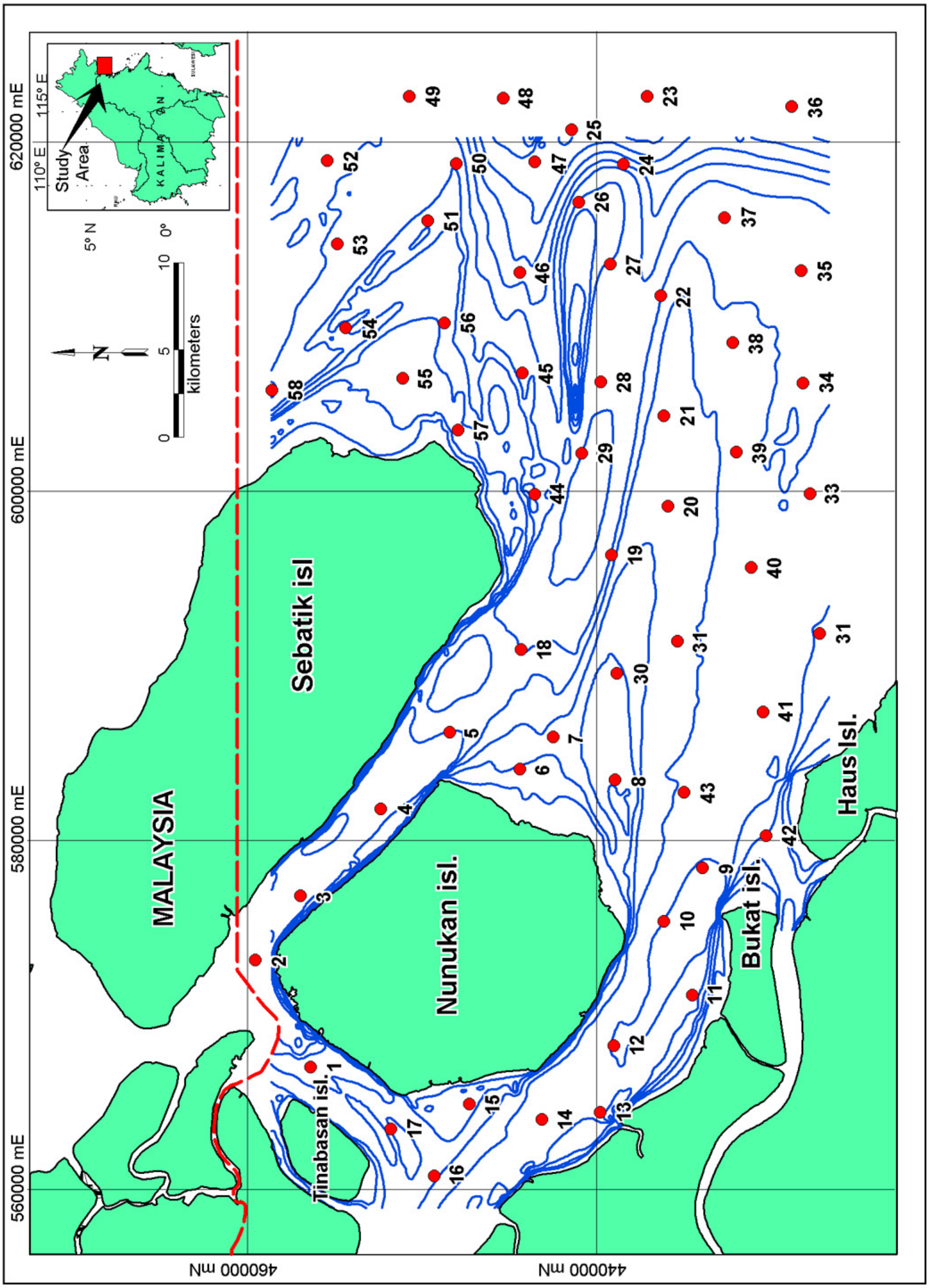

Figure 1. Study area showing sampling locations and the bathymetric contours

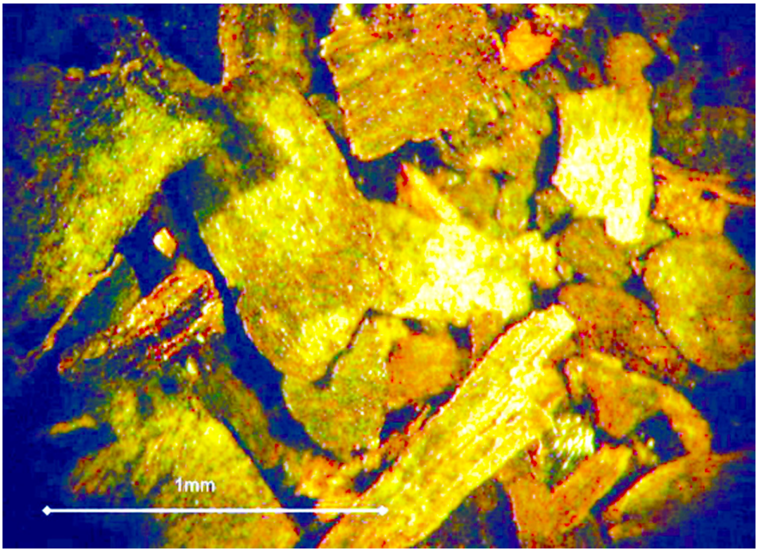

Figure 2. Plant remains dominated certain stations

qualitative way through particular species and associations of species, 3) species response through polymorphism as his study in the Mahakam Delta, and 4) the allochthonous component or fossil.

In this study, the first way has been used for detecting environmental conditions in the study area. It is found 82 species belonging to 43 genera of Ostracoda that identified from 3594 valves picked up from 38 samples (Table 1). In spite of the large number of species, most of them occur merely in very low percentage (less than 1%) in the study area. Complete taxonomic discussion and illustrations of all species present will appear in another publication. There are nine dominant species occur in the study area and widely distributed namely *Hemicytheridea* cf. *H. reticulata, Hemicytheridea reticulata, Keijella kloempritensis, Keijella multisulcus, Keijella reticulata, Phlyctenophora orientalis, Cytherella semitalis, Pistocythereis bradyiformis,* dan *Alocopocythere kendengensis.* Furthermore, several species leading in certain stations, such as: *Keijella kloempritensis* is found very abundantly (48%) at St. 01 in the inner part of the study area; about 40% of *Hemicytheridea* cf. *H. reticulata* occurs at St. 57 in the open sea; *Foveoleberis cyraeoides* reaches *34%* at St. 46 and *Phlyctenophora orientalis (32%)* occurs at St. 45.

The number of species is varies between 1 and 35 species with the diversity index between 1.19 (Stations 23, 26, 44) and 3.51 (St. 52). The low number of species that associated with shallow water, unstable or highly variable environments for microfauna occurs at sites surrounding the Nunukan Island and several sites in the southern part of the Sebatik Island. The high number of species and diversity index occurs in the open sea, particularly at St. 47 that is close to the Karang Unarang. However, this location contains a smaller amount of ostracod species that are reef-dwelling environments. It represented only by the occurrence of *Paranesidea* in low number of specimen.

The total number of specimens per station ranges from 1 to 682. The low number of ostracoda occurs in the surrounding of Nunukan Island and its number increases from the southern part of Sebatik Island toward to the open sea. Interested result is that the highest number of ostracod specimens does not occur in the open sea but in the inner part of study area, between Tinabasan and Sebatik Islands (St. 01). Most of the ostracod specimens in this station have articulated valves with brownish shells and dominated by certain species of *Keijella* (Figure 3).

Table 1. The occurrence of ostracoda in the study area

No.	Genus of ostracoda	□	Sample number																																				
		sp	1	5	6	7	9	10	19	21	22	23	24	25	26	27	29	33	34	35	36	37	38	40	41	44	45	46	47	48	49	50	51	52	53	55	56	57	58
1	*Actinocythereis*	1	2														3										13	11		1			3		2	1		15	2
2	*Alataconcha*	1																											1										
3	*Alocopocythere*	2										5					9			8			30					5				31		7	10	7	2	2	27
4	*Argilloecia*	1																													1							2	
5	*Atjehella*	1										2								1		2							1							13		37	1
6	*Paranesidea*	1															1												1										
7	*Baltraella*	1															1												1										
8	*Borneocythere*	1																																					1
9	*Bythoceratina*	2																														5		2					
10	*Bythocytheropteron*	1																									1	3											
11	*Callistocythere*	1	6																	2												2		2				1	
12	*Caudites*	1																											2										
13	*Copytus*	1																											6										
14	*Cushmanidea*	2																														4			3			9	
15	*Cytherella*	4					1					13	1		5	3	4		6	49		4	6			1	16	47	24	2		12	13	16	5	12	1	6	4
16	*Cytherelloidea*	4										22			5	1			2	37							2	21	4		2	9	4	6	2	7	1	12	4
17	*Cytheropteron*	2																											12				3						1
18	*Foveoleberis*	2										1					2			1							5	83	2	2		8		12	2				4
19	*Hemicytheridea*	3	14					2	1		8	65			1	5	14	2	68	65		7	57	1			2	4	4	2		10	65	1	3	55	32	144	6
20	*Hemikrithe*	1										6							9	7									1	3		4		4		7			
21	*Javanella*	1															1	1											1					8		1		2	
22	*Keijella*	4	213	1	1		1			7	2	23		3		4	42		21	12	1		85		1	1	34	6			1	53		45	20	1	44	9	31
23	*Keijia*	2										2								3						1		2	3	1		6		8	1	1			1
24	*Lanckacythere*	2															6						1					3						3					2
25	*Loxoconcha*	3										7								2							1		6			14	6	2			10		1
26	*Macrocypris*	1																									1												
27	*Myocyprideis*	1	15														1						5				4	2				5	9	3				8	
28	*Neocytheretta*	6								2		1					11			1			15				22	14	2			28	21	17	6	3	3	2	6
29	*Neomonoceratina*	3		1								1								3		2	5				2	6	5	1		7	5	7	1	10	6	6	5
30	*Paijenborchella*	1																											1										

Table 1 (continued)

31	*Pontocyris*	1										2											1				5	1	1			2		1					1
32	*Parakrithella*	1																									2		1							1			
33	*Phlyctenophora*	1	23									3				2	19		8				8				57	1				41	50	4	6	1	9	22	9
34	*Pistocythere*	4	27								1	10					26	9	2				47					20	4	10		8	3	10	4	1		2	8
35	*Polycope*	1																										1											
36	*Psammocythere*	1																		1							1									1		1	
37	*Schlerochilus*	1																											2					2					
38	*Sinocytheridea*	1										3																				1		1			2		
39	*Stigmatocythere*	4				1					2	9							3	15		4					3	1				1		4	5	4	2	7	4
40	*Tanella gracilis*	1																									3					2				3			
41	*Venericythere*	2										10							9								4	7	2			5	3		4	6			
42	*Xestoleberis*	3																		2									10			1			1	1		1	
43	Unidentified	4															1											4	4							1			5

Figure 3. Articulated ostracod specimens and, brownish shells

Foraminifera

As above mentioned that the data of benthic foraminifera is supplementary for supporting the ostracod study and therefore the data is not as complete as ostracoda. In the study area, the benthic foraminifera occur at all stations although some samples do not contain ostracoda. In these barren ostracod samples, the genus *Asterorotalia* appears among the plant remains and sediment materials. The appearance of this genus varied but mostly in poor preservation with broken spines.

In the open sea, the benthic foraminfera is very diverse and abundant, particularly in the eastern part of the study area. At glance, it seems that there are several species of benthic foraminifera characterized the study area such as *Asterorotalia trispinosa, Elphidium* spp., *Operculina* sp., *Brizalina* sp, *Textularia* spp., *Florilus* sp., *Cibicides* spp., and others. In fact, *Asterorotalia trispinosa* is the most dominant species that occurs from the near shore to the open sea and interestingly, this genus has many morphological variations in the open sea. The malformation specimens reach about 1% that show unusual in number of spines and in the forms of spine. Normally, this species has three tall slender spines that originated in the septal bands of the earlier convolutions. In the study area, we found this genus with two, three and four spines. Furthermore, the spines do not run from the corner as usual but the spines point out at their extremity such as close each other in one corner or run from the umbilical plug. The spines sometimes are not straight as normal forms but they show as very short,

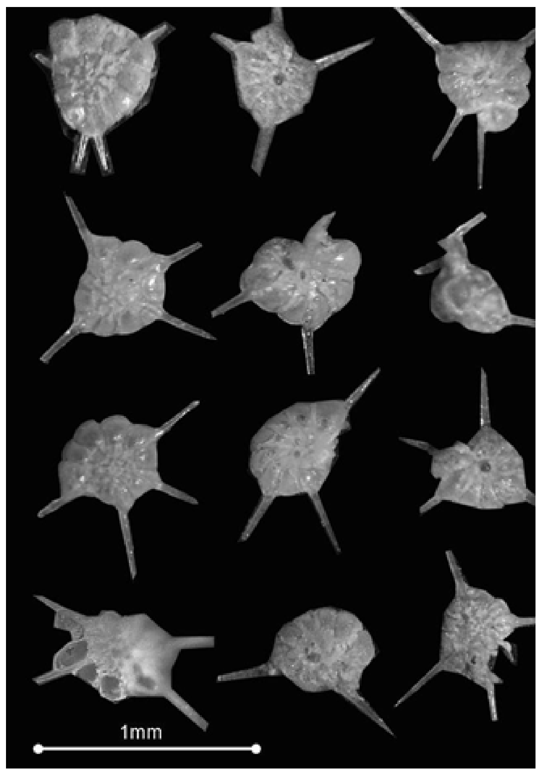

Figure 4. Various morphological types of Asterorotalia

Similar to the ostracoda that several species of benthic foraminifera also occupy certain sites as follows: *Operculina* spp. is dominant at stations 45 and 50 in the open sea and in sandy bottom sediments. Several spesies belong to Suborder Milioliina occur abundantly at Sts. 50 and 51, then species belong to suborder Textulariina characterized St. 52 in gravelly sandy bottom sediments. Furthermore, we also found abraded tests on *Elphidium* (Figure 5) abundantly at Sts. 29, 51 and 57 that are not in the open sea. This genus lost part of their chambers and became almost completely no more chambers than sutures. It is interesting to note that in an area surrounding the Karang Unarang contain a smaller amount of reef-dwelling benthic foraminifera.

Figure 5. Abraded specimen of Elphidium

Sediments

Based on the observation of the composition between skeletal and non-skeletal particles in sediment, it seems that in the study area, skeletal particles (foraminifera, ostracoda, mollusks and other shells) dominate certain stations. They are dominants in the eastern part of Sebatik Island and at St. 11 that is close to Bukat Island. Furthermore, sedimentary materials are prior than microfaunal components also appear at stations 35, 53, 54, and 57. These sedimentary materials compose mostly of silt-size quartz at stations 02, 03, 09, 11, 24, and 28 (Figure 6). This sediment type is poor in carbonate debris that indirectly influences the very low number of ostracoda and this condition is similar to a study by

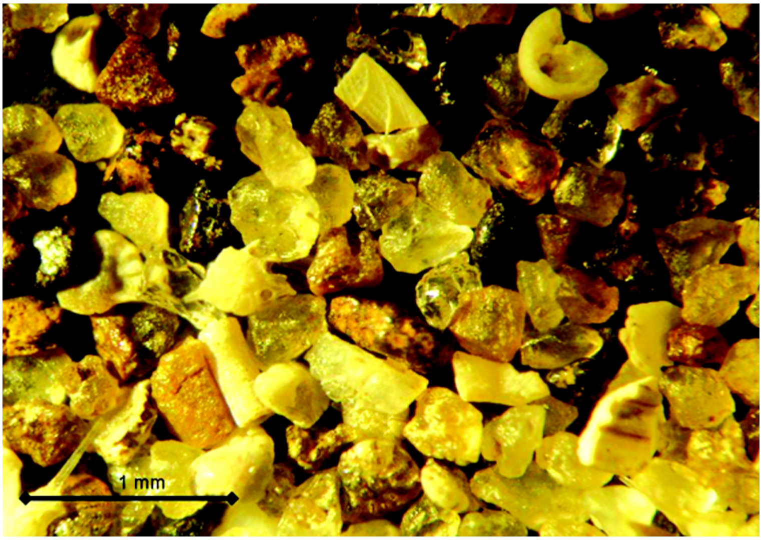

Figure 6. Sedimentary materials dominated certain sites

Whatley and Zhao (1988) in Malacca Strait. These locations also contain of plant remains among other materials that relates to oxygen at the water-sediment interface and the microfaunas will disappear when oxygen demand is less available (Carbonel, 1988).

DISCUSSION

The sea floor sediments including shell components vary systematically with changes in physical, chemical and biological condition. Any information on these shells (size, shape, chemical composition, abundance, etc.) in sediments can indicate the nature of deposition of sedimentary particles and give information for interpreting and predicting the lateral and vertical changes in sediment type (Ginsburg et al., 1963).

As component of sediments, ostracoda in the study area are less variable and abundant compared with the ostracoda from off Berau Delta, in the southern part of the present study area. It relates to the short range of the water depth (less than 50 m) that is less variable as seen in the Derawan Island. In the study area, there is a significant factor that plays role of land sea interaction. The influence of river inputs detected by the occurrences of plant remains cause the low concentration of microfaunal components. There is no ostracoda at 18 sites and 15 sites of them are located in a strait between the mainland of Kalimantan and Nunukan Island. However, we found both ostracoda and foraminifera very abundantly in the inner part of the study area. It normally relates to a calm environment with muddy ground and a high organic matter concentration, together with/as well as a temporarily and periodically lack of oxygen (Frenzel, pers. comm., 2005). In fact, they appear in poor preservation, dark color and occur among sandy bottom sediments that are subject to greater wave energy. If we also pay attention to the composition of microfaunal species, they mostly compose of marine inhabitant and the darker color concentrated within the reticulation on ostracod shells. It seems that all information point to the possibility of post-depositional accumulation in the sediment.

In the accumulated sediment materials, we also found recent microfaunal species by looking at the occurrence of white color of marine specimens among the dark specimens. Although the study area is adjacent to the rivers, there is a little record on non-marine ostracoda and foraminifera. *Myocyprideis* and *Sinocythereis* that indicates brackish to marine inhabitant appear among the marine ostracods and there is no foraminifera that typical of brackish or mangrove environments found in this area. On the other hand, the dark (brownish) microfaunal shells also appear among the normal microfaunas in the open sea although in low number. As a result, the above information can be as evidence of the land sea interactions that dominated by marine influences

The land sea interaction allows accumulate microfaunal components at certain sites. It is seen in the south of Nunukan Island that contain both ostracoda and benthic foraminifera abundantly. As seen in Figure 7 that high occurrence of ostracod specimen occurs in the southern part of the study area. The abundance of microfaunal components increases with the distance from the shore in the study area. The concentration of ostracoda is less than foraminfera that is understandable matter and it relates to the sedimentation rate by the occurrences of plant remains. In the southern part of Sebatik Island, the microfaunal materials are increase gradually compared with sediment materials

In the open sea, both ostracoda and benthic foraminifera are found to be quite abundant and diverse. Several species (*Foveoleberis cyraeoides*, *Phlyctenophora orientalis* and *Hemicytheridea reticulata)* occur dominantly at specific sites. Only few species of ostracoda

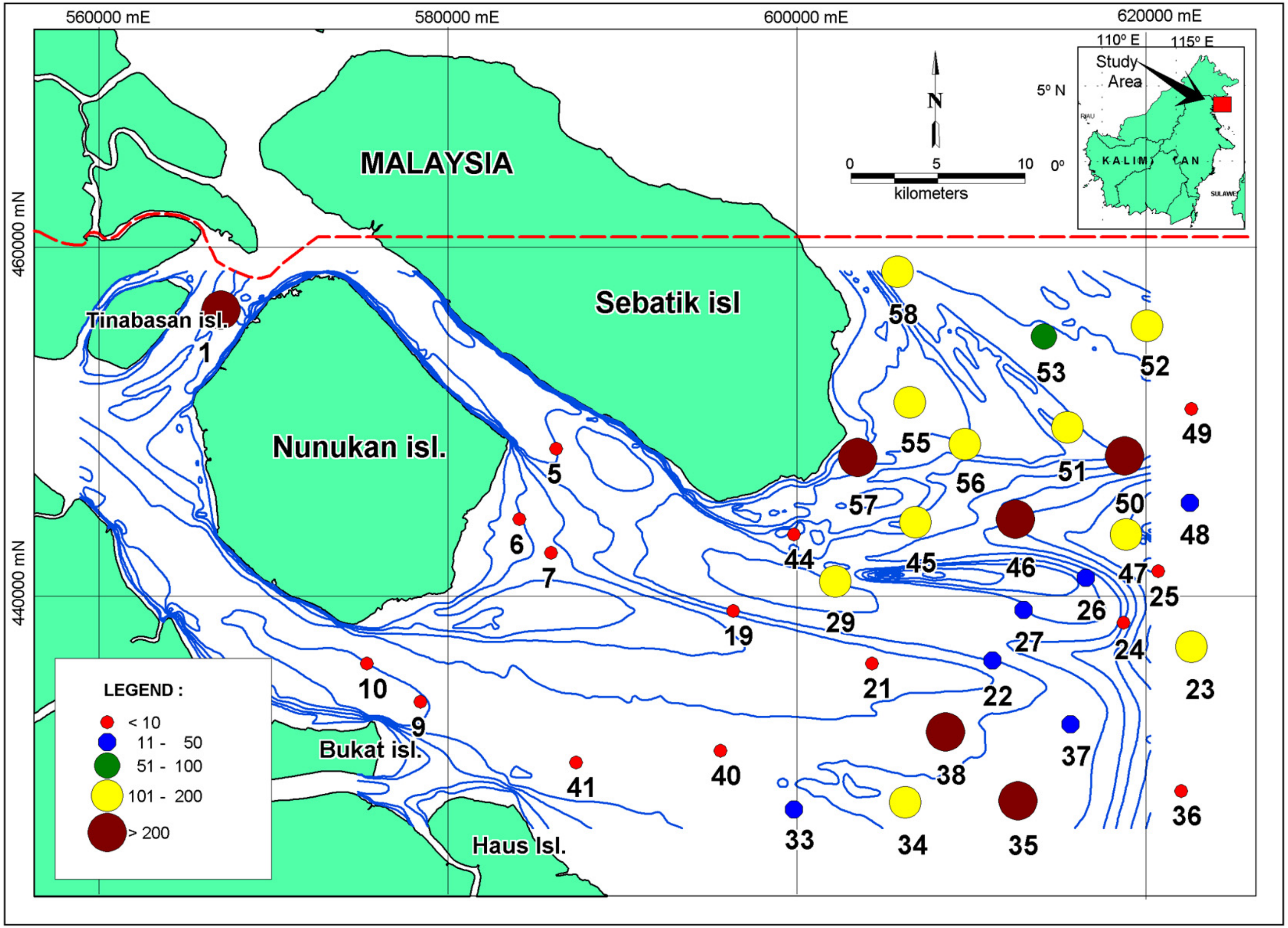

Figure 7. The distribution of the number of ostracod specimens in the study area

and foraminifera that is associated with reef-dwelling environments. This finding may reflect the degree of reef condition that is not favorable or in poor condition. Some species of both ostracoda and benthic foraminifera occur dominantly at certain stations. It may relate to the local environmental conditions as we know that the unstable environmental condition is characterized by the low diversity, large populations, and the dominance of certain species. Drift current from the north to the south (Indonesian Throughflow) is also another factor that plays a significant role in the study area. It results gravelly sand and sandy materials in the eastern – southeastern part off Sebatik Island) where the southern part dominated by finer materials (silt). These stations dominated by thick specimens of ostracoda and abraded benthic forams in certain stations indicate the influence of physical factors.

Abnormal component of sediments

We recorded abnormal components of sediments in the study area such as darker specimens, articulated shells on ostracoda, abraded specimens on *Elphidium*, various morphological shells on *Asterorotalia* and dark non-skeletal materials. The additional data is good information for indicating the condition of bottom sediments

Color

In the study area, we observed the color of microfaunal components on the empty tests of foraminifera or the hard parts of ostracoda. The empty tests of shells that do not contain of protoplasm are usually white or gray white, although specimens of some taxa are originally dark pink, pink or brown. The microfaunal specimens in the study area are mostly in normal color with an exception in dark color specimens in certain sites. The dark specimens of both ostracoda and benthic foraminifera appear among the normal specimens and vice versa. They occur very abundantly in the inner part and rarely in the open sea. The dark color also occurs on the sedimentary materials that relates to many factors such as stagnant environment or rapid sedimentation. Kaplan and Rittenberg (1963) stated that the dark sediments in the estuaries and lagoons relates to the areas with great run-off that will bind the H_2S very rapidly to form black hydrotroilite.

Discoloration of the specimen in the study area is different with the dark specimens found in the Derawan Island by Dewi and Illahude (2005). Their specimens are black and dark green with crack on foraminifer's test that relates to the occurrences of chlorite and glauconite. In the present study area, the color of specimens is from light to dark brown and very dark color on their ornamentation of ostracod shells or on the suture of foraminifer's chambers. It relates to the oxygenation as mentioned in the previous part.

In the Baltic Sea, bacteria films cause iron and manganese covers on ostracod shells that look black, grey, brown or tan, depending on oxidation (Frenzel, pers. comm.).

Articulated specimens

Most of ostracod shells would be more likely to remain as single valve after dead compared with two valve that are articulated (carapace). The ratio between valves and carapaces relates to (paleo)-environmental changes. Whatley (1988) found that the high number of articulated specimens related to the rapid burial before biological activity separate the specimens to be valves rather than post-mortem transportation. It also relates to an autochthonous association in a calm environment and possibly a high rate of sedimentation. In the present study area, the articulated specimens mostly belong to species of *Keijella* that are very abundant in the inner part. For that reason, another point should be paid attention that relates to their morphological shells. According to Whatley (1988), a high proportion of articulated specimens of certain species relates to complex hinge or strong overlap between two valves and the respond of the adductor muscle for closing the carapace: relax or tightly closed after dead naturally or due to abrupt environmental changes. Morphologically, this genus has quite complex hinge: hemiamphidont and their adductor muscle scars in a vertical row of four. It seems that the consideration on shell morphology is also important. For examples, *Candona* were always found as separate valves, on the other hand various species of *Hemicytherura* were usually encountered as articulated valves in the Thames estuary (Kilenyi, 1969 in Whatley, 1988).

Abraded specimens

It is interesting to note by finding quite high proportion of pathological specimens of *Elphidium* in certain sites. These sites cover by gravelly sand and sandy silt bottom sediments and they lie just off southeast Sebatik Island. This condition represents a high-energy environment that influence by abrupt hydrological changes both the open sea and the landward environment.

The occurrence of abraded specimens relates to several factors: ecological, mechanical and unknown causes (Boltoskoy and Wright, 1976). These factors cause morphological deformation such as chamber damage, appertural breakage, broken test, and the thickness of tests. The number of abraded specimens in the study area is not as high in Florida Keys by Toler and Hallock (1998). They found 15-35% malformed tests: broken, chipped, abnormal shape, loss of outer chambers or broken and repaired on a genus of foraminifera, *Amphistegina*. Their appearances related to reef stress environments due to environmental changes. The occurrence of abraded specimens of *Elphidium* in the study area may relate to the bed load or mechanical cause that is leading than other causes. Transport as bed load must be common in shallow–water area, as they found in less at depth shallower than 10 m with sandy bottom sediments. It is similar to the statement of Murray (1991) that such foraminiferal test becomes abraded and fragmented because of bed load transport on the inner shelf.

The question must surely arise: why *Elphidium* is the only genus that has abnormal tests in the bed load. The future deep study will be able to answer this question by observing the calcification of their tests and collecting living specimens.

Various morphological tests

In the study area, some specimens (1%) of the foraminiferal genus, *Asterorotalia,* have morphological variations. It may be due to either mechanical or ecological factors that cause the development of abnormal forms. They can also develop during the life span of the individual and others are the result of post mortem changes. The distribution of abnormal forms of this genus is concentrated in the open sea with sandy bottom sediments. If we concentrate on the composition between the normal and broken spine on *Asterorotalia*, it shows that the specimens with broken spines reach 60-70% of total specimens in the study area. Therefore, the principal cause of the test breakage and abnormal forms may be the physical energy of the environments.

In the open sea, both ostracoda and benthic foraminifera were found very abundant and very diverse. Several species of them occur dominantly at certain sites. It relates to biologic-ecologic factors in finding food supply. During time of stress, food supply is limited within the environment and the certain species will consume them as predator that are prior than other species (Phleger, 1960).

CONCLUSIONS

As component of sediments, microfaunal data are able to characterize the dynamic of the sea floor condition in the study area. The present study illustrates how microfaunal components can describe land sea interaction in sediments from the shallow water environments:

River input results barren to low microfaunal components in the area surrounding the Nunukan Island that replaced by predominance of plant remains. The marine influence detected by the occurrence of poor preservation of open marine microfaunal affinities in the inner part. The very low incidence of brackish water ostracods indicates that marine influence is leading than non-marine factors in the study area.

Genera of ostracoda *(Hemicytheridea*, *Keijella*, *Cytherella)* and one genus belongs to foraminifera *(Asterorotalia)* are typical microfauna in the study area.

Finding the value of morphological complexity and consistency of certain

microfaunal specimens are able to use for detecting the local environmental parameter. It is valuable to have other information on the environmental conditions, such as bed load transportation, biological activity, rapid sedimentation or calm water environments.

The low occurrence of reef-dwelling ostracoda and foraminifera may indicate poor condition of reef environment in the study area.

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