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Community structure of macrozoobenthic feeding guilds in responses to eutrophication in Jakarta Bay

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ABSTRACT

Taurusman AA (2010) Community structure of macrozoobenthic feeding guilds in responses to eutrophication in Jakarta Bay. Biodiversitas 11: 133-138. The group of benthic fauna which feed on the same food sources are classified as a feeding guild. The objective of the present study was to evaluate the distribution and composition of macrozoobenthic feeding guilds along gradient of organic enrichment (trophic states) in Jakarta Bay. The result of the present study was shown that at the hypertrophic stations of the bay dominated by species of surface deposit feeding polychaetes such as, *Dodecaceria* sp., *Cirratulus* sp., *Capitella* sp., and Spionidae. The eutrophic zone of the bay was dominated by suspension feeding bivalves *Mactra* sp., *Chione* sp. The offshore area (mesotrophic zone) showed a high diversity of species and feeding guilds compared to other areas. The patterns of feeding guilds in the mesotrophic zone indicated a higher stability of macrozoobenthos community, indicated by the presence of deep-deposit feeder (e.g. *Acetes* sp.), surface deposit feeders (e.g. *Prionospio* sp.), suspension feeders (e.g. *Chione* sp.), and carnivores (e.g. *Nephthys* sp.) in comparable proportions. The structure of macrozoobenthic feeding guilds in an eutrophic coastal water is positively related to the quantity and quality of organic matters (eutrophic states), and the capability of benthic species in adaptation to such environmental condition.

Key words: macrozoobenthos, feeding guild, eutrophication, coastal water, Jakarta Bay.

INTRODUCTION

Coastal and marine pollution is one of the most notorious problems in terms of sustainable development in Indonesia, for example in the bay of Jakarta. In the last two decades the phenomena of eutrophication and heavy metal pollution have occurred in Jakarta Bay. The study of Damar (2003) and Taurusman (2007) have indicated the high input of organic matters into the bay and severe pollution occur. Base on the criteria of trophic index for marine waters (TRIX) that formulated by Vollenweider et al. (1998), Damar (2003) has characterized the Jakarta Bay into three trophic zones: hypertrophic zone (located in all river mouth and inner part of the bay), eutrophic zone (in middle part), and mesotrophic zone (in the outer part).

A fundamental question in the marine ecology study is how responses the marine animals (consumers) to the availability of food sources and hydrodynamic processes (environmental variations), and what is the role of the animals within the complexity of the marine food web. Moreover, for benthic ecology how assemblages of marine soft sediment are structured. The information of the functional aspects (e.g. feeding guilds) needs to be considered (Gray and Elliott 2009). Furthermore, the functional aspects of ecosystem are mainly feeding guilds and predator-prey relationships, inter-and intraspecific competition, production, and association. The concept of functional ecosystem is basically derived from trophic dynamics introduced by Lindeman in 1942 (Gray and Elliot 2009).

There are five reasons why the study of feeding guilds of benthic macrofauna in a marine ecosystem important to be carried out. Firstly, one of the most common approaches to understand the community structure of macrozoobenthos is by the analysis of feeding guilds (Putman and Wratten 1984). Secondly, the information of feeding guilds is needed for our understanding of benthic processes and to construct the food webs. The role of benthic macrofauna in a food web is crucial to support sustainable ability of fish and marine mammal (e.g. Grebmeier and Dunton 2000). Thirdly, the information of feeding guilds is fundamental for studying the predator-prey relationship and therefore determining the carrying capacity of an ecosystem. Fourthly, this information is fundamental in the analysis of ecological network, i.e. a linear function describes the flow into and out of an ecological compartment (Gray and Elliot 2009). Finally, for water management purposes, the concept of the macrozoobenthic feeding guilds has been adopted to be included in measuring and indexing the environmental quality, for example the ecological status quality of the European Water Framework Directive criteria (e.g. Borja et al. 2000).

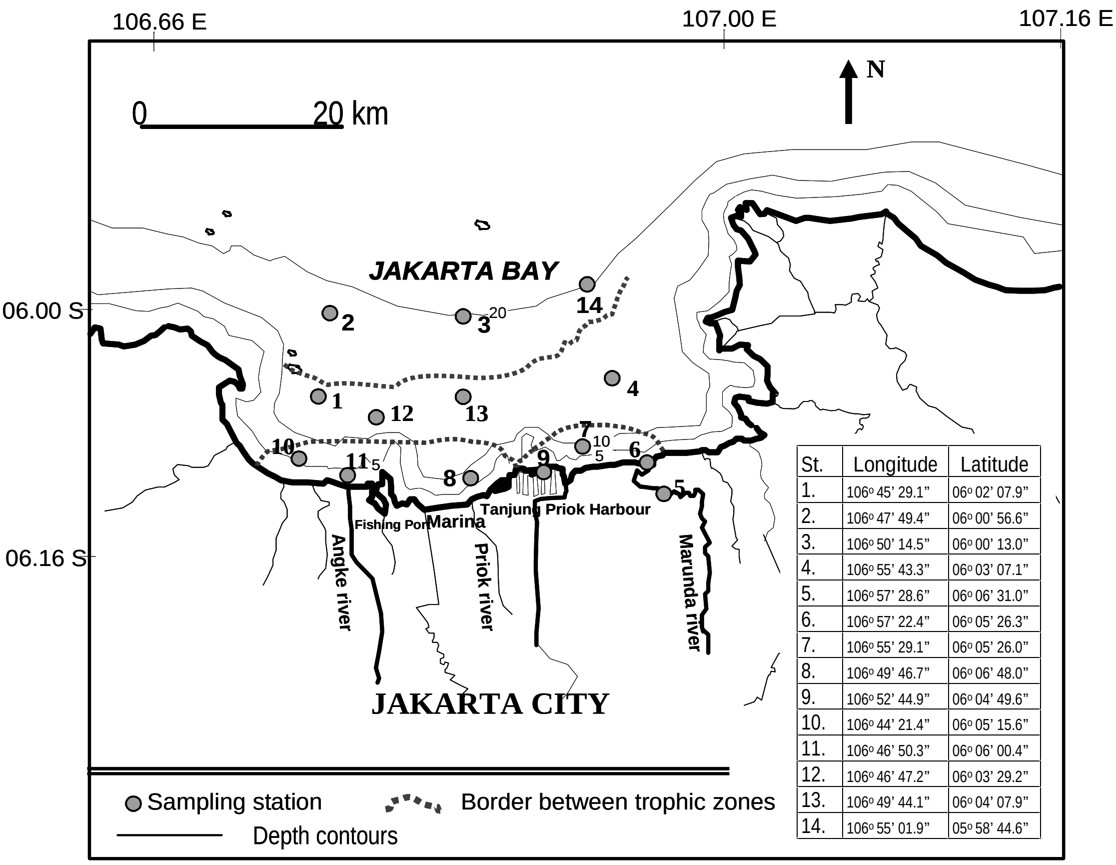
Originally, a guild is defined by Root (1967) as assemblages of species that exploit the same environmental resources. Thus the group of benthic fauna which feed on the same food sources is classified as a feeding guild.

However, Rosenberg (2001) and Diaz and Schaffner (1990) suggested to use the term ‘functional groups’ instead of feeding guilds. They argued that animals in the same feeding guild commonly compete for the same food sources, whereas such interaction does not necessarily occur within a functional group (Rosenberg 2001).

There are generally two main feeding guilds of macrozoobenthos: suspension feeders and deposit feeders. Faucald and Jumars (1979) suggested a classification of annelids (polychaetes) into 22 different feeding modes (feeding guilds) that were purposed based on feeding habits, type of food, and motility. The feeding habits are classified as: jawed, ciliary mechanisms, tentaculate, pumping, and others; three degrees of motility (motile, discretely motile, and sessile); types of foods: macrophagous modes (herbivores and carnivores) and microphagous modes (filter feeders, surface deposit feeders, and burrowers (Rosenberg 2001; Pagliosa 2005). Additionally, Rosenberg (2001) and Arruda et al. (2003) suggested that some species can successfully switch between surface deposit feeding and suspension feeding, e.g. related to the food supply like the Echinoderm *Amphiura filiformis* (brittle star) and from deposit feeders to suspension feeders such as *Macoma* sp., which is influenced by water velocity and sediment transport. If water velocity is higher, then less sediment (organic matter) accumulated in the sediment, thus by switching to suspension feeding they could easier collect food from the water.

The distribution of the dominant functional groups of macrozoobenthos is related to the total organic carbon in sediment (Denisenko 2003), food availability (Dauwe et al. 1998; Rosenberg 2001), depth and salinity (Rosenberg 2001), and physical characteristics of the substrates (Arruda et al. 2003). Sanders (1958) postulated that the distribution of certain functional groups, such as suspension feeders and deposit feeders is controlled by hydrodynamic processes that determine sediment characteristics. Low current flows allow deposition of fine particles, including organic matter. Under these conditions suspension feeders become less abundant and they are replaced by the deposit feeders.

There were limited studies about effects of organic enrichment (eutrophication) on macrozoobenthic feeding guilds in Indonesian coastal water. The study of changing structure of macrozoobenthic feeding guilds as responses to gradient organic enrichment (eutrophication states) in tropical water is important to overcome eutrophication problem. Most of the previous studies have been conducted in temperate waters (e.g. Fauchald and Jumars 1979, Diaz and Schaffner 1990, Borja et al. 2000). Therefore, the present study was conducted to evaluate the distribution and composition of macrozoobenthic feeding guilds along gradient of organic matter (trophic states) in the coastal water of Jakarta Bay. Thus, the research question of the present study is whether there are relationship between community structure of macrozoobenthic feeding guilds and eutrophication states of coastal water.



St.	Longitude	Latitude
1.	106° 45’ 29.1”	06° 02’ 07.9”
2.	106° 47’ 49.4”	06° 00’ 56.6”
3.	106° 50’ 14.5”	06° 00’ 13.0”
4.	106° 55’ 43.3”	06° 03’ 07.1”
5.	106° 57’ 28.6”	06° 06’ 31.0”
6.	106° 57’ 22.4”	06° 05’ 26.3”
7.	106° 55’ 29.1”	06° 05’ 26.0”
8.	106° 49’ 46.7”	06° 06’ 48.0”
9.	106° 52’ 44.9”	06° 04’ 49.6”
10.	106° 44’ 21.4”	06° 05’ 15.6”
11.	106° 46’ 50.3”	06° 06’ 00.4”
12.	106° 46’ 47.2”	06° 03’ 29.2”
13.	106° 49’ 44.1”	06° 04’ 07.9”
14.	106° 55’ 01.9”	05° 58’ 44.6”

Figure 1. Sampling stations in Jakarta Bay and geographical position.

MATERIALS AND METHODS

Sampling methods

Benthic macrofauna samples were taken randomly by means of a 0.023 m^2 "Petite" Ponar grab with ten hauls at each sampling station in Jakarta Bay. The samples were taken during rainy season: February 2005 in Jakarta Bay. By considering previous study of Damar (2003), the sampling location has been divided into 14 sampling stations representing the three trophic zones (Fig.1): river mouth and inner part of the bay stations to represent the hypertrophic zone (stations 5, 6, 7, 8, 9, 10, and 11); Sampling stations at the centre part of the bay (stations 1, 4, 12, and 13) to represent the eutrophic zone; and stations 2, 3, and 14 at the outer part of the bay (as mesotrophic zone).

Nine of the samples were immediately sieved on board through a 0.5 mm screen and the residue collected separately in a plastic bag, preserved in 4 % formalin and stained with rose Bengal. The 10^{th} grab of sediment was stored wet in a plastic bag, labelled and kept in ice box for organic matter and sediment grain size analysis.

Laboratory samples analysis

In the laboratory the macrozoobenthos samples were washed to remove formalin, sorted, identified to family or species level if possible, and counted (Holme and McIntyre 1984). The major taxonomic books that were used for identification of the samples were: Gosner (1971) to general analyses of all taxonomic samples; Roberts et al. (1982), Dharma (1988, 1992), Abbot (1954), especially for mollusks; Fauchald (1977), Fauvel (1923) for polychaete worms; and Yamaguchi (1993) for some of crustaceans.

In order to classify each macrozoobenthos species in Jakarta Bay, references of benthic feeding studies were used, e.g. Fauchald and Jumars (1979), Abbott (1954), Arruda et al. (2003) and Koulouri et al. (2006) for mollusks; Pagliosa (2005) and Sarkar et al. (2005) for polychaetes; Borja et al. (2000); Llansó (2002); Grall et al. (2006); French et al. (2004); Gray (1981) and Luczkovich et al. (2002). Furthermore, for this study the major five feeding categories of Fauchald and Jumars (1979) were used that are comparable to those used by most authors, namely: suspension feeders, surface (sub-surface) deposit feeders, deep- deposit feeders (burrowers), herbivores, and carnivores.

This is a simplified classification, and overlapping may occurs, because some species show an overlap in food sources (Rosenberg 2001; Grall et al. 2006; Arruda et al. 2003). The variations in classification of feeding guilds of macrozoobenthos species are observed between authors, e.g. Llansó (2002) has classified the Polychaete family Capitellidae as deep-deposit feeders, while other authors (e.g. Grall et al. 2006; Sarkar et al. 2005) have classified this group as sub-surface deposit feeders.

Data analyses

To assess the effects of organic matter and nutrients (eutrophication) on the macrozoobenthic feeding guilds, a multivariate statistics were used because it is useful and highly sensitive to detect changes in species composition which are signs of eutrophication (Gray et al. 2002). In practice, a multivariate statistical analysis of the macrozoobenthic data were applied using various routines of the PRIMER version 5.2 (*Plymouth Routines in Multivariate Ecological Research)* software package (Clarke and Gorley 2001). The PRIMER package is able to integrate the physio-chemical measurements to provide a correlative explanation for possible causes of changes observed in the fauna (Gray et al. 2002).

Statistic analysis of similarities (ANOSIM) was employed to test significance of the influence of grouping factors (stations and trophic states) by means of PRIMER Software (Clarke and Gorley, 2001). ANOSIM is a non-parametric procedure analogous to analysis of variance (ANOVA), which is based on the ranks of the value in the similarity matrix. Quinn and Keough (2002) have recommended using ANOSIM to test hypotheses about group differences in a multivariate context. The similarities relationship was calculated by change in Clarke's R value according to the following equation:

$$R = \frac{aver.rb - aver.rw}{M/2}$$

$$M = \frac{n(n-1)}{2}$$

aver. rb = average of rank similarities between the groups,
aver. rw = average of rank similarities within the groups (stations or trophic states),
n = number of involved data in the analysis.

The Clarke's R value gives an absolute measure of how separated groups are, on a scale of 0 (indistinguishable) to 1 (all similarities within groups are less than any similarity between groups).

RESULTS AND DISCUSSION

Generally, polychaetes represent the dominant benthic group in both hypertrophic and mesotrophic zones, and co-dominate in the eutrophic zone in Jakarta Bay. The hypertrophic stations of Jakarta Bay was dominated by surface deposit feeding polychaetes such as, *Dodecaceria* sp., *Cirratulus* sp., *Capitella* sp., except for station 7 which was dominated by suspension feeding Mactra sp. (Bivalve), see Tabel 1 and Figure 2.

The surface deposit feeding group was mostly abundant in estuarine stations in Jakarta Bay. These stations were characterized by shallow areas, and high water velocity, by fine sand fraction and relative lower organic content in sediment. The river station (Marunda, station 5) showed a similar pattern; this particular area was actually dominated by subsurface deposit feeders such as *Notomastus* sp. and *Capitella* sp. (Figure 2).

Table 1. Spatial distribution and composition of dominant spesies (ind/m^2) of macrozoobenthic feeding guilds related to eutrophication in Jakarta Bay.

Taxa	Trophic states and stasiun														Feeding guilds (referen.)
	Hypertrophic							Eutrophic				Mesotrophic			
	S5	S6	S7	S8	S9	S10	S11	S1	S4	S12	S13	S2	S3	S14	
Mactra sp. (Bivalvia)	0	13	13	-	83	-	13	226	26	43	74	122	0	4	SF[9,10]
Chione sp. (Bivalvia)	4	0	0	-	4	-	0	70	26	0	35	139	30	661	SF[11]
Gafrarium sp. (Bivalvia)	0	0	0	-	0	-	0	4	0	0	4	13	13	70	SF[5]
Prionospio sp. (Polychaeta)	0	39	0	-	148	-	1252	52	61	13	4	152	52	83	SDF[7]
Cirratulus sp. (Polychaeta)	0	413	4	-	470	-	217	4	4	0	0	17	87	26	SDF[5]
Dodecaceria sp. (Polychaeta)	0	30	0	-	3552	-	5657	4	30	0	0	17	13	0	SDF[5]
Notomastus sp. (Polychaeta)	61	4	0	-	17	-	74	13	0	0	0	61	57	9	sSDF[2,4,5]
Heteromastus sp. (Polychaeta)	43	0	0	-	0	-	0	0	0	0	0	22	0	0	sSDF[2,4,5]
Capitella sp. (Polychaeta)	22	39	0	-	0	-	13	0	0	0	0	4	0	0	sSDF[4,5,8]
Tellina sp. (Bivalvia)	0	0	0	-	43	-	13	4	4	0	4	83	9	113	DDF[2,3]
Lucifer sp. (Crustacea)	0	0	0	-	0	-	0	13	17	9	39	70	70	35	DDF[12]
Acetes sp. (Crustacea)	0	0	0	-	4	-	0	30	0	0	9	26	61	17	DDF[12]
Sigambra sp. (Polychaeta)	0	65	0	-	287	-	139	43	4	0	0	35	35	26	C[5,6]
Microdeutopus sp. (Crustacea)	0	0	0	-	278	-	4	0	0	0	0	4	9	0	C[5]
Nephtys sp. (Polychaeta)	0	13	0	-	35	-	30	4	0	0	0	30	100	35	C[6]
Nereis sp. (Polychaeta)	4	26	0	-	39	-	209	13	9	9	9	17	17	22	C[5]
Calanus sp. (Crustacea)	0	0	0	-	0	-	0	17	0	0	4	0	91	39	nc

Note: SF = Suspension feeder; SDF = Surface-deposit feeder; sSDF = Sub-surface deposit feeder; DDF = Deep-deposit feeder (burrower); C = Carnivores; nc = no classification;- : unavailable data. References: 1) = Koulouri et al. (2006); 2) = Grall et al. (2006); 3) = French et al. (2004); 4) = Sarkar et al. (2005); 5) = Borja et al. (2000); 6) = Llansó (2002); 7) Pagliosa (2005); 8) Gray (1981); 9) Abbot (1954); 10) Wong et al.(2003); 11) Arruda et al. (2003); 12) Luczkovich et al. (2002)

Similarly, Pagliosa (2005) showed that surface (subsurface) deposit feeding and filter feeding polychaetes were frequently observed in fine sandy sediment (inshore area) in Santa Catarina Island Bay (Brazil). Therefore, the variation in the macrozoobenthos community in the hypertrophic zone may be influenced not only by organic matter input, but also by water velocity which leads to sediment stability (Sanders 1958). In contrast to the eutrophic and mesotrophic zones, the hypertrophic zone, where organic matter input is very high, feeding guilds are characterized by a simple system that is primarily composed of surface deposit feeders and in addition carnivores become established (Pearson and Rosenberg 1978).

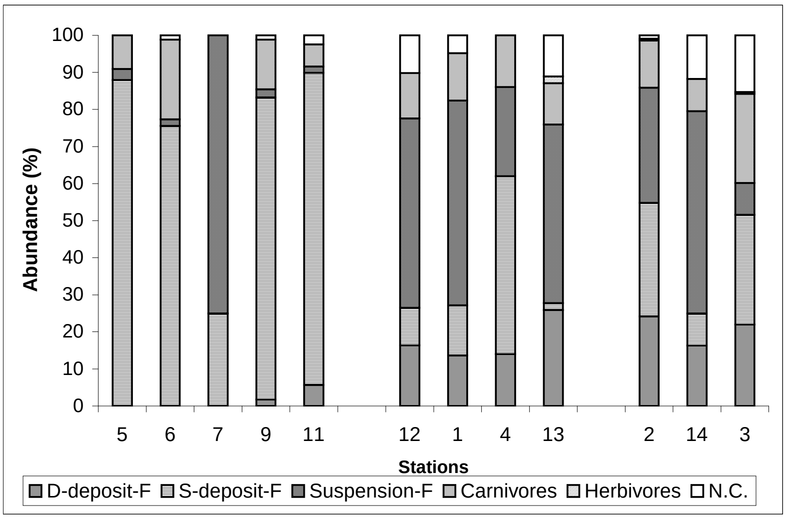


Figure 2. Spatial distribution and composition of macrozoobenthos feeding guilds in Jakarta Bay. Stations are ordered from inshore to offshore areas and grouped according to trophic zones: 5-11 (hypertrophic zone), 12-13 (eutrophic zone), and 2-3 (mesotrophic zone), N.C. (no classification)

The eutrophic zone in Jakarta Bay was dominated by suspension feeding bivalves *Mactra* sp., *Chione* sp., except station 4 which was dominated by the surface deposit feeding polychaete *Prionospio* sp.. The abundance of the deep-deposit feeding crustacean *Lucifer* sp. increased according to an increasing the silt-clay fraction in the sediment, except at station 4 (Figure 2). The explanation for this might be that station 4 is located at middle-eastern part of the bay close to the mouth of Marunda River (station 6) where similar environmental conditions may influence the community structure of the macrozoobenthos in this particular area. These are characterized by a lower silt-clay fraction and a high content of organic matter in the bottom water.

The high abundance of suspension feeders in the eutrophic zone (and station 7) may be the result of high quality of food that consists predominantly of living phytoplankton, as well as a high organic content of the material suspended in the water column and settling at the sediment-water interface (Heip 1995). The latter was demonstrated by the extreme high organic content of material collected in sediment traps in this particular area (see also Taurusman 2009). The high growth rate of cultivated green mussels in Jakarta Bay (Setyobudiandi 2004) might be also an

Table 2. Result of one-way analysis of similarity (ANOSIM) between abundance of macrozoobenthic feeding guilds and stations and trophic zones

Parameters	Statistic R	p-value	Tests
Differences between station	0.488	0.001**	Global test
Differences between trophic zone	0.281	0.001**	Global test
▪ hypertrophic vs eutrophic	0.342	0.001**	Pairwise test
▪ hypertrophic vs mesotrophic	0.306	0.001**	Pairwise test
▪ eutrophic vs mesotrophic	0.228	0.001**	Pairwise test

Note: ** = very significantly differences

indication of the high quality of suspended material. Arruda et al. (2003) suggested that suspension feeders are adapted to exploit the particulate matter and micro-organisms in suspension, and are able to benefit from sulphur-oxidizing bacteria in such intermediate to high organic matter conditions.

The offshore area (mesotrophic zone) showed a high diversity of species and feeding guilds compared to other areas. The patterns of feeding guilds indicated a higher stability of macrozoobenthos community, indicated by the presence of deep-deposit feeder (e.g. *Acetes* sp.), surface deposit feeders (e.g. *Prionospio* sp.), suspension feeders (e.g. *Chione* sp.), and carnivores (e.g. *Nepthys* sp.) in comparable proportions. According to the classical concept of diversity and stability of Elton, a more diverse community could indicate higher stability (Gray 1981).

Statistically, there was a significant difference in distribution and composition of macrozoobenthic feeding guilds in Jakarta Bay between stations with a global ANOSIM R = 0.488, p < 0.001 (Table 2). The ANOSIM analysis also revealed strong differences of macrozoobenthic feeding guilds between trophic zone (Global R = 0.281, p < 0.001). Its pairwise tests showed also there were significant differences all trophic zone in Jakarta Bay: between hypertrophic and eutrophic (R = 0.342, p < 0.001), hypertrophic and mesotrophic (R = 0.306, p < 0.001), and eutrophic versus mesotrophic (R = 0.228, p < 0.001), see Table 2.

The result of the present study shown an indication of stronger effects of organic enrichment on macrozoobenthos community in Jakarta Bay, deep deposit feeders e.g. are a group that more sensitive to effects of organic enrichment than suspension feeders (Borja et al. 2000). Again, effects of higher organic enrichment on macrozoobenthos community were indicated by a higher share of deposit feeders in total abundance in eutrophic and mesotrophic zone compared to hypertrophic zone. Additionally, surface (subsurface) deposit feeders that are classified as tolerant or even opportunistic species (Borja et al. 2000) were found to be most abundant in the hypertrophic zone in Jakarta Bay, supporting the hypothesis that they thrive at organic enrichment. Carnivores were found in all locations, but in variable percentage. This result coincides with Rosenberg (2001). He suggested that related to food availability and water depth (current), highest diversity of functional groups (feeding guilds) could be observed in off-shore sandy mud. Herbivores and suspension feeders attain highest abundance in shallow waters, whereas deposit feeders prefer areas with low water movement where the bottom is accumulating organic material and carnivores were found in all habitats, irrespective of organic enrichment or sediment characteristics.

CONCLUSION

The result of the present study can be concluded that the gradient of organic matter enrichment, indicated by different trophic zones, in Jakarta Bay lead to patterns in the distribution of macrozoobenthos species and composition of the functional groups of feeding. Surface deposit feeders were the dominant macrozoobenthic feeding guilds at the hypertrophic zone, while the eutrophic zone was dominated by suspension feeders. The mesotrophic zone showed a high diversity and all of the feeding guilds present, indicating the higher stability of the ecosystem. This result supports the hypothesis that the distribution and composition of macrozoobenthic feeding guilds in Jakarta Bay was positively related to spatial gradient of organic enrichment (trophic states) of the bay.

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