Diversity and Distribution of Benthic Invertebrates in the West Port, Malaysia

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***Abstract*—**The purpose of this paper is to describe the main characteristics of macroinvertebrate species in response to environmental forcing factors. Overall, 23 species of Mollusca, 4 species of Arthropods, 3 species of Echinodermata and 3 species of Annelida were identified at the 9 sampling stations during four sampling periods. Individual species of Mollusca constituted 36.4% of the total abundance, followed by Arthropods (27.01%), Annelida (34.3%) and Echinodermata (2.4%). The results of Kruskal-Wallis test indicated that a significant difference ($p < 0.05$) in the abundance, richness and diversity of the macro-benthic community in different stations. The correlation analysis revealed that anthropogenic pollution and natural variability caused by these variations in spatial scales.

***Keywords*—**Benthic invertebrates, Diversity, Malaysia, West Port.

I. Introduction

BIO-ASSESSING and surveillance are practical methods to monitor health status of ecological receptors in the marine environment. In recent decades, biological indicators have been widely applied to assess adverse effects of pollutants in aquatic ecosystems [1]-[4].

Bio-indicators act as receptors, which respond to stressors by their alternation in population or histological structures [5], [6]. According to the National Academy of Science, bio-indicators are practical in promoting the knowledge of environmental issues, supporting environmental characteristics and improving existing methods to assess ecological risk in the marine environment [5]-[8]. In sediments, macrobenthic organisms are an important biological indicators of environmental change due to their close relation to sediments, high sensibility to chemicals contaminates, and their ability to absorb and accumulate in different types of compounds, especially heavy metals [9]-[12].

The major objectives of this project are as follows: (1) to assess the diversity and distribution of benthic communities, and (2) to evaluate the ecological condition between several stations with high degrees of natural variability and different levels of anthropogenic effects. Information on the ecological potential of habitat suitability can serve as the utmost important basis for scientifically sound marine spatial planning.

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II. Material And Methods

A. Description of Study Area and Sample Collection

West Port has developed among mangrove Islands and mudflats [13]-[15]. Samples were collected from West Port, which located on the western coastal region (03°00 N to 101°24'E) of peninsula Malaysia at the north end of the Malacca Strait, and is over 573 km^2 **(**Fig. 1). In this research, 9 stations were selected from three transects parallel to the coastline with three different distances.

Sediment samples were collected by the Petersen grab sampler (0.07 m^2) at low tide (every 3 months) from November 2011 to October 2012. Each replicate was then sieved on a 0.5-mm mesh screen to sort benthic organisms, including macrobenthic (greater than 0.5 mm). The organisms were then transferred into a plastic container, preserved in a 99.9% ethanol alcohol with Rose Bengal, and stored to identify their lowest practical taxonomic level by a dissecting microscope.

B. Biological Assessment

In present study, Shannon–Wiener Index was used to assess diversity of benthic organisms [16]. This index is based on the theory that individual species are randomly sampled from indefinitely large populations, and it also assumes that all the species are represented in the sample [17].

In this research suitable benthic indices and models have been proposed to assess health status based on benthic communities such as the AZTI Marine Biotic Index (AMBI), BI and M-AMBI. These indices were designed to classify the ecological quality of the estuary and coastal water according to the response of soft bottom macrobenthic population to changes in water quality.

The benthic organisms were divided into 5 ecological groups GI, GII, GIII, GIV and GV based on their sensibility and respond to anthropogenic stress [18]. For the AZTI reports, group GI is the relative abundance of very sensitive species to pollution, and are present under unpolluted areas, group GII is the relative abundance of species indifferent to organic enrichment, group GIII is the relative abundance of tolerant species to excess of organic material enrichment, group GIV is the relative abundance of second order opportunistic species and mainly small sized polychaet, and group GV is the relative abundance of first-order opportunistic species such as deposit feeders. These indices were estimated by the software was downloaded at http://www.azti.es [19].

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Fig. 1 Location of the sampling stations in West Port Malaysia

Statistical analyses were performed using Microsoft Excel and SPSS 17 software (SPSS, Chicago, IL). Significant difference from each group was evaluated via Kruskal-Wallis one-way nonparametric ANOVA (level of significant is 0.05). Nonparametric correlation method (Kendall's tau-b) was used to obtain the correlation coefficient among physicochemical parameters in water and sediment.

III. Result

A. Spatial and Temporal Distribution

The results of the spatial and temporal distributions of benthic communities are summarized in **Error! Reference source not found.** Generally, 23 species of Mollusca, 4 species of Arthropods, 3 species of Echinodermata and 3 species of Annelida (2 polychaetes and one oligochaete) were identified at the 9 sampling stations during four sampling periods.

Individual species of Mollusca constituted 36.4% of the total abundance, followed by Arthropods (27.01%), Annelida (34.3%) and Echinodermata (2.4 %) (Fig. 2). The results of Kruskal-Wallis test showed a significant ($p < 0.05$) difference in the composition of the macro-benthic community between stations during the year.

Stations 3 and 6 were numerically dominated by Mollusca species that constituted more than 50% of the total abundance at these stations. With respect to average abundance, the Mollusca include *Anadara nodifera*, *Nassarius jacksonianus* and *Cerithium* sp, which were also conspicuous members of the benthic community at these stations (Table I).

Crustacean species dominated at stations 4 and 5, especially *Xenophthalmus pinnotheroides* and *Excirolana* sp, whereas Annelida species (Lumbrineridae) were numerically dominant at stations 1, 7, 8 and 9 over the different seasons surveyed (Table I).

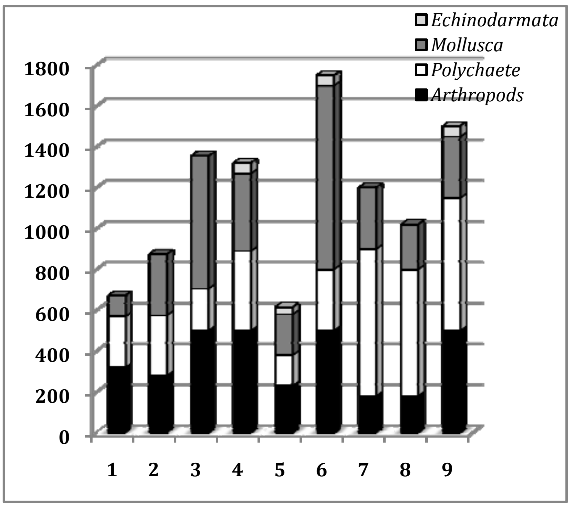

Fig. 2 Total abundance (individuals m^{-2}) of macro-faunal taxa in different stations over different time intervals

TABLE I
TOTAL ABUNDANCE (INDIVIDUALS M^{-2}) OF MACRO-FAUNAL TAXA IN DIFFERENT STATIONS OVER DIFFERENT TIME INTERVALS

Taxa and ecological groups	1	2	3	4	5	**6**	7	8	9	9
Mactra sp (I)	0	13.7	17	23	15	45	0	0	11	11
***Mactra luzonica* (I)**	11	8.75	25	5	5	31	0	10	20	20
Mactra Pellucida (I)	0	0	12	0	15	0	0	0	0	0
Spisula ravenal (I)	0	0	0	1.2	0	11	0	7	17	17
Merona cornucopiae (I)	0	0	0	11	0	11	0	0	0	0
***Codakia tigerina* (I)**	11	0	15	27	11	62	0	0	0	0
Arcuatula arcuatula (I)	0	0	0	5	6.2	6.2	0	0	0	0
Tellina foliacea (I)	0	0	15	6.2	15	25	0	0	12	12
Barantolla sp (I)	0	0	8.7	0	0	18	0	0	20	20
Barbatia fusca (I)	20	15	25	0	0	32	0	0	0	0
Tellina sp (I)	0	0	0	12	6.2	18	0	0	0	0
Tellina tenuis (I)	0	0	0	10	0	20	0	0	0	0
Tellina albenia (I)	0	0	0	0	0	12	0	0	0	0
Tellina staurella (I)	0	0	16	0	0	0	0	0	0	0
Donax sp (I)	0	0	6.2	0	0	1.2	0	0	0	0
Crossostra sp (ns)	0	0	33	0	0	30	0	0	0	0
Anadar nodifera (IV)	23.7	75	125	51.0	15	61	19	105	92	92
Chlamys sp (I)	0	0	47	0	0	0	0	0	0	0
Litorina coccinea (I)	0	106	161	0	0	107	0	0	0	0
Cerithim sp (II)	31.2	45	116	121	60	137	0	0	42	42
Nassarius jacksoniasus (II)	0	0	0	40	25	260	80	60	42	42
Natica sp (II)	0	0	0	30	13	42.5	0	0	17	17
Scaphander lignarius (I)	7.5	11.2	0	10	0	21.2	0	0	0	0
Amphipholis gracillima (I)	0	0	0	65	37	35	0	0	60	60
Salmacis sp (ns)	0	0	0	0	1.25	16.2	0	0	0	0
Balanus sp (ns)	16.5	38.7	61.2	16	0	67	0	0	0	0
Alpheus sp (II)	0	0	12.5	30	15	19	12	11	10	10
Uca sp (I)	0	0	0	51	3.7	42	0	0	20	20
Xenophthalmodes pinnotheroides	144	156	307	72	181	246	41	42	101	101
Excirolana hirsuticauda (II)	26.2	46.2	15	277	0	122	117	105	320	320
Lipiniella sp (II)	0	0	0	75	0	50	151	126	225	225
Lumbricillus sp (V)	210	210	170	297	140	145	331	285	295	295
Glycerna alba (IV)	40	60	40	0	0	35	143	132	78.7	78.7

B. Disturbance Analysis

Several ecological indices were applied to assess sediment quality based on the response of the soft-bottom macro benthic structure to changes in the environment.

Some stations were significantly higher in terms of the average value of the total number of individuals, diversity or richness, such as stations 3, 6, 9 (along the mangrove edge in the North and West Ports) and 4 (close to the liquid berth in the West Port) (Table II).

Other stations that were close to the berth line (1, 2, 5, 7 and 8) showed relatively lower abundance, richness and diversity (Table II).

Based on the AMBI model, significant variation in pollution level was found in different stations. In general, West Port was classified as slightly polluted port (BI: 2, AMBI: 2.1, M-AMBI: 0.85) because the most of the stations (3, 4, 5, 6) were slightly polluted in this port.

At these stations, the benthic community was dominated by ecological group GI and GII (sensitive species). Some stations, such as 1, 2, 7, and 8, were classified as moderately polluted. Ecological groups IV and V (48.9-62.5%) were dominate in this community.

Ecological group III (tolerant to pollution) was not found in West Port, which had an unbalanced benthic composition.

TABLE II
SUMMARY RESULTS OF ECOLOGICAL INDICES TO ASSESS POLLUTION LEVEL BASED ON THE BENTHIC RESPONDS

Stations	Abundance	Diversity	Richness	BI	AMBI	M-AMBI	Status
1	541.75	2.49	10.00	3	3.95	0.43	Moderate
2	786.25	2.89	11.00	3	3.88	0.48	Moderate
3	1231.25	3.33	18.00	2	2.48	0.68	Good
4	1241	3.42	21.00	2	2.46	0.72	Good
5	566	3.03	17.00	2	1.81	0.68	Good
6	1736	4	28.00	2	1.76	0.85	Good
7	1075	2.64	8.00	3	4.01	0.42	Moderate
8	885	2.75	10.00	3	3.80	0.46	Moderate
9	1386.76	3.13	16.00	3	4.05	0.55	Good

TABLE III
CORRELATION COEFFICIENT BETWEEN BENTHIC COMMUNITIES AND PHYSICOCHEMICAL PARAMETERS

*Physicochemical Parameters	Abundance	Richness	Diversity
Al	0.24	-0.029	-0.01
As	-0.45	-0.09	-0.01
Cd	-0.48	-0.09	-0.14
Cr	0.14	-0.24	-0.21
Cu	-0.40	0.20	0.21
Fe	0.42	-0.1	0.11
Hg	0.28	0.24	0.17
Mn	0.65	-0.067	-0.039
Ni	0.35	-0.06	-0.019
Pb	0.23	-0.12	-0.07
V	0.32	-.14	-0.13
Zn	0.12	0.16	0.11
Fine fraction	0.58	0.53	0.55
TOC	0.52	0.54	0.53
PAHs	-0.08	-0.57	-0.46
Depth	-0.51	-0.52	-0.54

*Details about physicochemical parameters were published by Tavakoly Sany et al 2012 and 2013[13], [20]

The correlation analysis was good agreement to assess benthic responds to variation of the contaminant. It was individually estimated for each station because of the differences in the physicochemical characteristic and contaminants sources.

In the West Port the significant negative correlation ($-0.4 < r < -0.5$) was found between benthic abundance and some parameters such as As, Cd and Cu, only PAHs component had significant negative correlation with diversity and richness of benthic structure. Fe, Mn, fine fraction and TOC showed the significant positive correlation with benthic communities (Table III).

IV. DISCUSSION

More recently, efforts have been made to explore the correlation between multiple parameters in sediment and the distributions of benthic communities. These parameters include concentrations of organic compounds, salinity, oxygen levels, sediment type, hydrodynamic environment, food availability and anthropogenic stress which is the primary parameter constraining the structure of a benthic community [21]-[24]. In this research, the spatial changes were found among the most sensitive species.

The results indicated that TOC, particle size and depth controlled the spatial distribution of benthic species because the abundance, diversity and richness of the macro-benthic community were strongly correlated with TOC, fine particle size and depth. Over one year study period, stations near the berth line supported relatively lower abundance, diversity and richness than stations near the mangrove edge. Every sampling location along the mangrove edge had a similar configuration, with shallow water (6.8-11.2 m) and high organic content (11.98-17.04%) in a soft and muddy substratum (63.42-73.77) suitable for settlement by diverse species, factors that may cause species abundance to increase. The locations along the mangroves are located far (1500 -2000 m) from point sources of anthropogenic discharges, another potential reason for their higher species diversity.

Most of the sampling stations along the berth line and in the middle of the strait are in deeper water (12.5-21.60 m) with coarser and sandy sediments (40.21-50.3%), to causes of reduced species diversity, especially at stations in the vicinity of the cement outlets and the container terminal berth. Anthropogenic stress can be another cause of reduced benthic structure because the stations along the berth line are close to anthropogenic discharges from port activities and industrial outlets, which may suppress benthic community development. The results of our correlation analysis supported a negative effect of anthropogenic stress (heavy metals and PAHs) on benthic composition. According to these results As, Cd and Cu exhibited significant negative correlations with the abundance of the benthic communities. Similarly, the total concentration of PAHs exhibited a significant negative correlation with the diversity and richness of benthic species.

The effect of PAHs on the benthic community has been frequently examined in several studies, which indicate that opportunistic species (ecological groups V and IV) with high abundances are replaced with other ecological groups when the benthic communities are exposed to PAH contamination [24]-[26]. The results of spatial distribution indicated that the abundances of common opportunistic species (*Lumbricillus* sp and *Glycerna alba*) increased greatly at stations 1, 2, 7 and 8, where *Lumbricillus* sp was a dominant species, and diversity and richness were significantly decreased (Table I and Fig. 2).

Similarly, the correlation analysis revealed that the benthic community is moderately exposed to anthropogenic stress at these stations (Table III).

A high proportion of the sediment samples that were collected in the vicinity of the cement outlet (stations 1 and 2) were polluted with cement (more than 50%); this may hinder the development of benthic structures.

V. Conclusion

In this research, there were greatest spatial changes in the diversity and abundance of benthic communities. The biological indices (AMBI, M-AMBI and BI) and correlation analyses are in good agreement, confirming the response of benthic communities to changes of contaminant levels at the different stations. The present data showed that in the West Port, the variation of the macro-benthic community was primarily related to sediment characteristics (TOC and fine particles size) and that releases of anthropogenic pollution are secondary disturbances that hinder benthic development.

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