Assessment the macrobenthic diversity and community structure in the Musi Estuary, South Sumatra, Indonesia

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ABSTRACT

The macrobentic community in the Musi Estuary is very diverse. However, it has been showing a declining trend recently due to an increase in waste from human activities entering the waters. This study aimed to assess the macrobenthic diversity and community structure and correlated to the water quality parameters of the Musi Estuary, South Sumatra. The method used was a survey collecting water quality parameters at eight observation stations. The salinity is measured with a refractometer, temperature is measured with a digital thermometer, pH is measured with a pH meter. The dissolved oxygen (DO), brightness and current are measured with a DO meter, Seichii disk, and current meter, respectively. The Ekman grab was used to collect the samples, and then we used a diversity index, a similarity index, and principal components analysis (PCA) for analysis. The results show that the water quality is found in a good condition for macrobenthos growths. The salinity is ranging between 0 and 15 ppt, temperature is about 29–30.8 °C, pH is about 7.6–8.1, the dissolved oxygen is found to be 3.2–12.5 mg/L, the brightness is about 4.71–31.67% and the current speed is about 0.02–0.08 m.s^{-1}. The analysis also indicates that the microbenthic compositions consist of 18 species, which is grouped into five classes, namely *Gastropods* 56%, *Crustacea* 22%, *Bivalve* 11%, *Actinopterygii* 6%, and *Polychaeta* 5%, with an abundance of 0,67 to 13,33 Ind. m^{-2}. The diversity index is generally in low categories ($H' < 1$), and the dominance index is more than 0.5. Based on the PCA analysis, it was found that the water quality parameters (e.g. dissolved oxygen and temperature) show significant correlation with similarity index at all observation stations. The macrobenthic diversity and community structure in the Musi Estuary is found to be increasing offshore and decreasing towards the river.

1. Introduction

The Musi Estuary is a mixed area of the fresh water from the Musi River and the salty water from the Bangka strait, South Sumatra. These water masses are seasonally varying and affected by the tides, leading to changes in water quality parameters. In addition, the Musi Estuary are also highly influenced by human activities in the estuary, result in various types of pollution, such as oil spill from shipping activities, industrial pollution, domestic pollution, and pollution from aquaculture and agricultural activities. These various types of pollution have negative impact on the growth of aquatic biota, especially benthic organisms [1–7]. The decline the water quality directly impacts the macrobenthos diversity and community survivals. Therefore, it is reported as a biological indicator of water quality [8–10]. Macrobenthos is an aquatic organism that settles at the bottom of the water. It has a relatively slow movement and long-life cycle, resulting in an ability to continuously respond to the change in water quality.

In addition, mangrove ecosystem found in the Musi Estuary is in good condition, which is suitable habitat for macrobenthos. The mangrove species found in the Musi Estuary are dominantly *Avicennia marina*, *Sonneratia alba*, and *Nypa frutican*. Note that the macrobenthos community can reproduce well in mangrove ecosystems, because there are abundant food sources and suitable environment for life, such as litter, roots, stems, and silt substrates [11–13]. This good condition of mangrove habitat in the Musi Estuary will support the presence and reproduction of macrobenthos in this area. However, high loading of anthropogenic pollutants in this area highly influences the mangrove ecosystem in such that may risk the macrobenthos community. This study is designed to assess the microbenthic diversity and community structure in the Musi Estuary.

2. Materials and methods

2.1. The study area

The study area is around the Musi estuary with a width of more than 3.5 km and a length of 27 km (Fig. 1). This area is a sea transportation route from the Bangka Strait into the Palembang City. Fishing activities

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and port activities are found in the west area of the Musi Estuary. Heavy agricultural and aquaculture activities found in the upstream of the Musi Estuary endanger aquatic biota, due to excessive anthropogenic, industrial, and agricultural wastes. Nevertheless, mangrove ecosystems are found to be in good condition, which are dominated by *Avicennia marina*, *Sonneratia alba*, and *Nypa frutican* species. The sampling was conducted at 8 observation stations. Stations 1, 2 and 3 were under the influence of sea water, while stations 4, 5 and 6 were influenced by fresh water from rivers. Note that stations 3 and 8 were located at polluted area.

2.2. Data collection and sampling processing

In-situ measurements for physical parameters (i.e. salinity, temperature, pH, and dissolved oxygen) are carried out with three repetitions at each observation station. The hand refractometer was used for salinity measurements, while a digital thermometer, pH meter and DO meter were used for temperature, water pH and dissolved oxygen (DO), respectively.

Macrobenthos samples were taken on sediments with a depth of 20 cm and a transect area of 1 × 1 m. Sampling at each station was carried out three times and then the samples were put into plastic samples and labeled by each station for further analysis. The macrobenthos sample was separated from the sediment, washed with clean water, and preserved with 8% formalin [14]. The identification procedure was following [15,16].

2.3. Data analysis

2.3.1. Macrobenthos composition and abundance

The composition and abundance of macrobenthos species [17] were estimated according to:

$$Cm = \frac{\sum ni}{N} \times 100\%, \quad (1)$$

Fig. 1. Map of sampling station.

$$B_t = \frac{n_i}{A}. \quad (2)$$

Here, *Cm* is the total percentage of species *i*, n_i is the number of individuals species *i*, *N* is the total number of individuals per station, B_t is total individuals per species *i*, and *A* is sampling area.

2.3.2. Macrobenthic diversity

The macrobenthos diversity was analyzed using the Shannon-Wiener index (H′) following [18], and the Sampson Index (C) for domination species [19], by using,

$$H' = -\sum_{i=1}^{s}\left(\frac{n_i}{N}\right)\left(\ln\frac{n_i}{N}\right), \quad (3)$$

$$C = -\sum_{i=1}^{s}\left[\frac{n_i}{N}\right]^2. \quad (4)$$

Here, n_i is the number of individuals species *i*, and *N* is the total of individuals per station.

2.3.3. Principal components analysis

The Principal Components Analysis (PCA) is used to evaluate the relationship between the physical-chemical parameters (i.e. temperature, turbidity, salinity, pH, and dissolved oxygen) and the macrobenthos abundance and diversity. This analysis identified which physical-chemical parameters influence the macrobenthos abundance and diversity at all observation stations. Note that the PCA analysis is performed using the XLSAT 2020 software.

3. Results

3.1. Water quality parameters

The dissolved oxygen (DO), salinity and brightness in the Musi Estuary show significant variations, while temperature, pH and current show slight variations (Table 1). These variations can be grouped into two categories. The first category is for the stations located towards the sea (1, 2, and 3) and the second category is for the stations located into the river (4, 5, 6, 7, and 8).

It is shown that the dissolved oxygen (DO) in the Musi Estuary is about 3.2–12.5 mg/l, which the highest value of 12.5 mg/l was found at station 3 and the lowest value of 3.2 mg/l was observed at stations 5. Note that the DO values are strongly influenced by tidal factors. The salinity is found to be in range of 0–15 ppt, which is in the category of the brackish water. The salinity observed at stations towards the sea (1, 2, and 3) shown to be higher than those observed at other stations. The observed brightness of waters is ranging from 4.71 to 31.67%, which is in low category. The observed water temperature is about 29–30.8 °C, where the highest temperature was found at station 2 and the lowest temperature was observed at station 7. It means that the temperature is found higher towards the sea than towards the river. The observed pH was found to be in range from 7.6 to 8.1, which highest pH was observed at station 3 and the lowest pH was found at station 7.

Table 1
Water quality parameters in the Musi Estuary.

Parameters	Stations							
	1	2	3	4	5	6	7	8
DO ($mg.l^{-1}$)	11,3	11,9	12,5	4,7	3,2	4,5	5,6	3,5
Salinity (ppt)	14	13	15	11	0	9	11	10
Temperature (°C)	29,6	30,8	30	29,1	30,5	29,2	29	29,1
pH	7,9	7,8	8,1	7,8	7,8	7,7	7,6	7,7
Brightness (%)	5.00	4.71	7.23	11.63	7.74	18.29	31.67	15.00
Current ($m.s^{-1}$)	0.07	0.03	0.02	0.04	0.03	0.08	0.07	0.06

The observed current was very low, which was ranging from 2 to 8 cm/s. Nevertheless, those physical parameter conditions are still in good condition for the growth of macrobenthos.

3.2. Structure of macrobenthic community in Musi estuary

The observed macrobenthos in the Musi Estuary consisted of 18 species, which are grouped into five classes namely *Gastropod* (56%), *Crustacea* (22%), *Bivalve* (11%), *Actinopterygii* (6%) and *Polychaeta* (5%) (Fig. 2). The *Gastropod* class was very dominance in the waters with 10 species. It is believed that these species have a strong ability to adapt to the environment. The observed *Crustacea* class consists of 4 species, *Bivalve* has 2 species, *Actinopterygii* and *Polychaeta* each have one species.

3.3. Macrobenthos abundance and diversity

The macrobenthos abundance shows significant variation, which was found around 0,67 to 13,33 Ind/m^2. These total individuals are high, which were found in observation stations located towards the sea area.

Based on Table 2, the highest macrobenthos was found at station 2 (13.33 Ind/m^2), while the lowest was observed at stations 6 and 7 (0.67 Ind/m^2). This may indicate that there were more species towards the sea than that observed towards the river. However, the distribution of the *Gastropod* class was almost at all observation stations, as well as the *Crustacea*. The *Bivalve* and *Actinopterygii* classes were found only at stations towards the sea, while *Polychaeta* was found at the river stations.

The most dominant species observed in the Musi Estuary were *Mactra chinesis*, *Uca vomeris*, and *Clibanarius* sp. species, then followed by the *Nassarius distorus* and *Thais* sp. (Fig. 3). *Mactra chinesis* and *Thais* sp. were found only at station 2 located towards the sea, while *Uca vomeris*, *Clibanarius* sp., and *Nassarius distorus* were found at the observation stations towards the sea and river. (See Fig. 4.)

The macrobenthos diversity index generally shows in the low category (H '<1), except for two stations (i.e. stations 1 and 2) which indicate a medium category. The dominance index value indicates that there is dominance species ($C > 0.5$), where the dominance species is found at stations located in the river. We hypothesize that the stress on the water quality may impact the survival ability of the macrobenthos species.

3.4. Relationships between physical parameters and macrobenthos abundance and diversity

Based on the PCA, cumulative eigenvalues of 79.38% and a variable minimum of 0.5 squared cosine illustrated that there were two groups

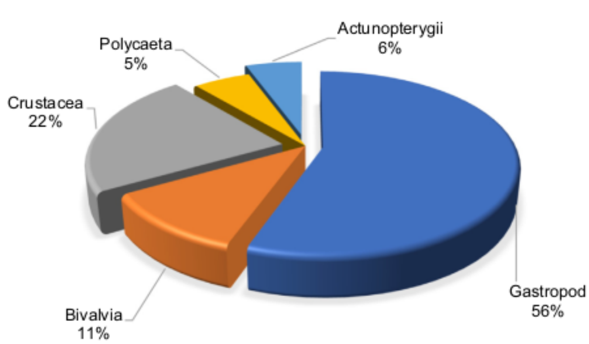

Fig. 2. Macrobenthic community structure of Musi Estuary.

Table 2
Macrobenthos species of Musi Estuary.

Groups	Species	Station							
		1	2	3	4	5	6	7	8
Gastropod	*Littoraria undolata*	+	−	−	+	−	−	−	−
Gastropod	*Telescopium* sp.	−	+	−	−	−	−	−	−
Gastropod	*Sinum* sp.	+	−	−	−	−	−	−	−
Gastropod	*Thais* sp.	−	+	−	−	−	−	−	−
Gastropod	*Natica* sp.	−	+	−	−	−	−	−	−
Gastropod	*Buccinanops sp.*	−	+	−	−	−	−	−	−
Gastropod	*Nassarius distorus*	−	−	−	+	−	−	−	−
Gastropod	*Tomlinia rapulum*	−	−	−	−	+	−	−	−
Gastropod	*Neritina* sp.	−	−	−	−	−	−	+	+
Gastropod	*Phasianotrochus* sp.	−	−	−	−	−	−	−	+
Bivalvia	*Mytilus viridis*	+	−	−	−	−	−	−	−
Bivalvia	*Mactra chinesis*	−	+	−	−	−	−	−	−
Crustacea	*Clibanarius* sp.	−	+	+	−	+	−	−	−
Crustacea	*Somanniathelphusa* sp.	−	−	+	−	−	−	−	−
Crustacea	*Uca vomeris*	+	−	−	−	−	−	+	−
Crustacea	*Scylla serrata*	−	+	−	−	−	−	−	−
Polychaeta	*Abyssoninoe* sp.	−	−	−	−	−	+	−	−
Actunopterygii	*Taenioides* sp.	−	+	−	−	−	−	−	−

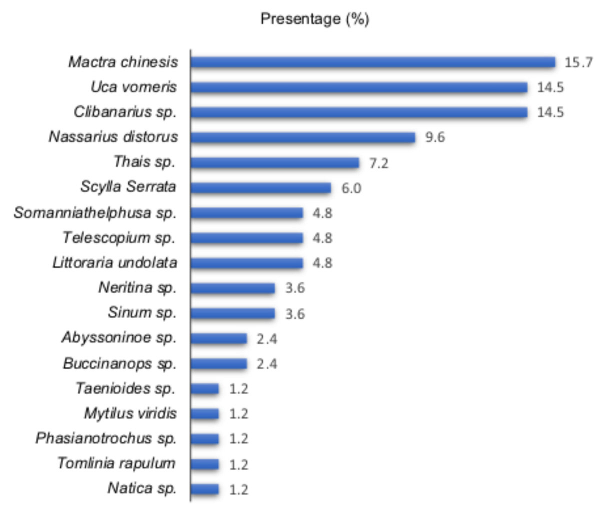

Fig. 3. Percentage of macrobenthos species.

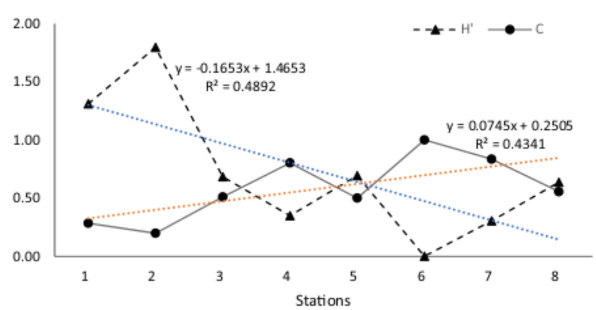

Fig. 4. Diversity index of macrobenthos.

of data with each identifier. Two groups were in axes F1 positive and F1 negative (Fig. 5A). The description of the two groups of PCA is as follows. *The first group* includes staions 1 and 2 with temperature, diversity, and macrobenthos abundance as the identifier. The temperature at these stations was relatively high (29–30.8 °C) and the total macrobenthos abundance was about 83 Ind/m^2. The diversity index is shown in low categories with H < 1. *The second group* involves stations 4, 6, 7, and 8 with the identifiers of the domination index in high category (C > 0.5). This group is dominated by the *Littoraria undolata, Nassarius distorus, Neritina* sp. and *Phasianotrochus* sp. (for *Gastropod* class), *Uca vomeris* (for *Crustacea* class), and *Abyssoninoe* sp. (for *Polychaeta* class). This indicates that there was a dominant species, which is suggested due to disturbed of environmental conditions.

The dissimilarity analysis was calculated based on the Bray-Curtis dissimilarity index, which was determined by the macrobenthos diversity and abundance at all stations in the Musi Estuary. The results show significant similarity with a strong category. Based on the dendrogram of the eight observation stations (Fig. 5b), three classes (C1, C2, and C3) obtained from the analysis shows the similarity level of about 84%. In addition, the highest value is shown in C1 class, which was the first class at 92% similarity. The C1 class was observed at stations 3, 5, 6 and 7. It was then followed by C2 class, which was found at stations 1 and 2 with about 89% similarity. The C3 class shows similarity of about 78%. These results show the existence of high level of similarity in almost at all stations except at station 4, which indicates the effect of environmental conditions on similarity of the source of the macrobenthic diversity and abundance in the Musi Estuary.

4. Discussion

The Musi Estuary waters are strongly influenced by input of water mass from the sea (Bangka Starit) and from the river as freshwater when the tides occur. The mixing process of those two water masses causes changes in parameters of water quality, such as salinity, DO, temperature, pH, and nutrient content. The DO and salinity in the Musi Estuary indicate high variations, although this condition is still relatively low compared to other places [20]. The observed water temperature shows in good conditions for macrobenthos growth. The observed pH shows relatively constant, in agreement with previous study [2]. All observation stations in the Musi Estuary waters were found to be in good condition for macrobenthos growth. Note that the quality of water can be used as an indicator of pollution [3,4,7,8].

Macrobenthos found in the Musi Estuary are grouped into five classes, namely *Gastropod, Crustacea, Bivalvia, Actunopterygii,* and *Polychaeta.* More than 50% of those macrobenthos are from the *Gastropod* class with 10 species, namely *Littoraria undolata, Telescopium* sp., *Sinum* sp., *Thais* sp., *Natica* sp., *Buccinanops* sp., *Nassarius distorus, Tomlinia rapulum, Neritina* sp. and *Phasianotrochus* sp. The ability of this class to the changes in water quality is stronger than other classes. Similar situatuion was also reported in the Douro Estuary [21], and in the Nasese Shore, Suva, Fiji Islands [5]. In addition, this class has a high level of reproduction, tolerance, and distribution [22], while other classes are also reported on the *Polyceta* of estuarine habitat along the southwest coast of India [23], and in the Gioia Canyon (Southern Tyrrhenian Sea, Italy) [24]. The abundance of macrobenthos also shows high variations. It is dominated by the *Mactra chinesis, Uca vomeris*, and *Clibanarius* sp., which were identified in the *Bivalvia* and *Crustacea* classes. This dominance was also reported for the Devi estuary–mangrove region on the east coast of India [11].

The *Crustacea* class found in the study area was consisted of 4 species, namely *Clibanarius* sp., *Somanniathelphusa* sp., *Uca vomeris*, and *Scylla serrata*. This group was found to be very active or fast movement, so that it was difficult to be discovered or captured. *Clibanarius* sp. and *Uca vomeris* is the most commonly found. These species show strong ability to adapt to changes in water quality [11,28].

The *Bivalvia* class is found in two species, namely *Mactra chinesis* and *Mytilus viridis*, which *M. chinesis* is the most commonly found. The classes of *Polychaeta* and *Actunopterygii* were found in only one species, namely *Abyssoninoe* sp. and *Taenioides* sp., respectively. Both of these classes were found to be lower individual abundance compared to other classes. This is due to their infauna (in sediment) and limited movement [29]. Aquatic environmental parameters have an impact on the diversity and abundance of *Polychaeta* [30].

Macrobenthos distribution was found to be higher in the observation station located towards the sea compared to those observed at the station located in the river flow. This might be due to the more stable water quality parameters, as shown in Table 1. However, the observed water quality in the study area is still low compared to that reported previously [31–33]. This is also indicated by the diversity index value, which shows a low category except for the observation station located towards the sea, which shows in the medium category. In addition, it is also found that there is dominance species, especially in the observation station located in the river flow. Similar situation is recorded at the Nasese Shore, Suva, Fiji Islands [34].

The relationship between water quality parameters with macrobenthos diversity and abundance is indicated by dissolved oxygen and temperature, in which it is determined by the macrobenthos diversity and abundance at the station located towards the sea. Similar condition was reported for the Niger Delta, Nigeria [35]. Meanwhile, another study indicates that salinity may explain a greater proportion of

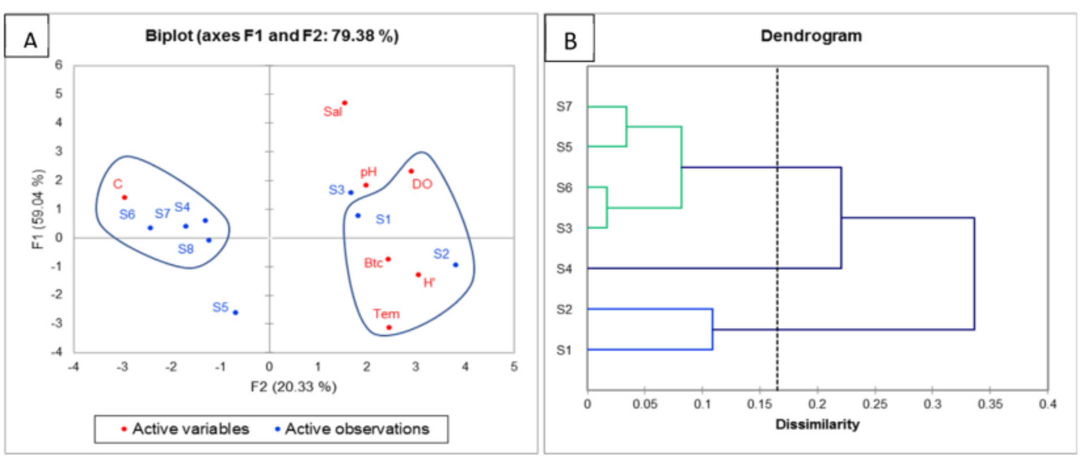

Fig. 5. Correlation between physical parameters with macrobenthos abundance and diversity (A), and similarity index (B).

the variability of macrobenthic structure than other factors in all estuaries [20].

The similarity index indicates a very strong value, except for station 4. It indicates that the macrobenthos diversity and abundance at almost all stations in the Musi Estuary is slightly different. This is the same reported in the various estuary and other coastal waters [1,2,8,20,23,24,32,36,25–27].

5. Conclusions

Macrobenthos species in the Musi Estuary waters were found to be slightly high. There were 18 species found in the Musi Estuary, which were identified into five classes, namely *Gastropod* (56%), *Crustacea* (22%), *Bivalve* (11%), *Actinopterygii* (6%), and *Polychaeta* (5%). The abundance of individuals was found higher towards the sea than towards the river. The observed diversity of species was generally in the low category, and this is because there were species that dominate in river areas. Water quality parameters indicated by DO and temperature shows a value to be increasing in the area towards the sea and slightly decreasing in the rivers.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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