The impact of organic waste contamination on the macrozoobenthos community and its potential as a bioindicator in Labuange Bay waters, Barru Regency, South Sulawesi Province

Mudian Paena¹, Rajuddin Syamsuddin², Chair Rani² and Haryati Tandipayuk²

¹Research Institute for Brackishwater and Fisheries Extension, Maros, Indonesia
²Marine Science and Fisheries Department, Hasanuddin University, Makassar, Indonesia

Email: mudianpaena@yahoo.co.id

Abstract. Superintensive shrimp farming (Litopenaeus vannamei) has been developed since 2012 in Barru district, South Sulawesi. Organic waste from uneaten shrimp feed has been discarded into Labuange waters during superintensive farming development. Accumulated organic waste in the sediment of Labuange sediment has an impact on the presence of macrozoobenthos. The study aims to analyze the structure of the macrozoobenthos community and its potential as a bioindicator of organic waste pollution in Labuange waters, Barru Regency, South Sulawesi. The study was conducted using a survey method. A sampling of Labuange sediment for macrozoobenthos analysis was carried out at six stations with six replications, respectively. The type of identified macrozoobenthos was then analyzed by CCA (Canonical Correlation Analysis) using PAST (Paleontological Statistics) software to calculate the strength of the relationship between the characteristics of the sediment and the macrozoobenthos indicator. Species and abundance of macrozoobenthos were analyzed using analysis of variance (ANOVA) to find out the differences of species and abundance of macrozoobenthos in each station. The results showed differences in macrozoobenthos abundance in each station, and found ten types of macrozoobenthos which had potential as an organic waste bioindicator, whose presence was directly related to the characteristics of sediments, in the form of organic carbon, organic matter, phosphate, pHf, redox potential and N-total namely Nassarius absconditus, Tenagodus sp., Nassarius sp., Tellina radiata, Tellina sp., Pinna sp., Vexillum sp., Arenicola sp., Cerithium sp., and Cerithium salebrosum. Based on the macrozoobenthos diversity index, heavy pollution was occurred at stations 1, 3, 4, 5, and 6, while station 2 was in moderate pollution.

1. Introduction

Human activity in the coastal area may result in a disruption that affects the shallow-water benthic community. One of the common pollutants found in the highly contaminated area is organic matter that produces organic enrichment. This might lead to changes in species number, abundance, and biomass of the benthic community as the first indicator of environmental impact [1]. Superintensive shrimp farming activity surrounding waters of Labuange Bay has contributed to organic waste in a coastal area, namely in the form of dissolved waste and sediment. Organic waste that settles at the bottom will affect the characteristics of water sediment.
This condition of bottom waters and poor water quality are factors causing the loss of macrozoobenthos [2]. Low oxygen concentration leads to hypoxia, which further changes the temporal-spatial structure of the macrozoobenthos community in the bottom waters [3]. High organic content in the sediment indicates low species richness and diversity [4]. The study of benthic, particularly related to macrozoobenthos, is the most useful tool to assess environmental impact. The effect resulted from polluted air or sediment in the environment could be obtained from the study of the benthic community [1].

Based on those descriptions above, a study to analyze the structure of the macrozoobenthos community and its potential as a bioindicator of organic waste pollution in the waters of Labuange Bay, Barru Regency, South Sulawesi Province.

2. Methods
Samples of macrozoobenthos were collected using van veen grab to sample sediment surface area of 0.12 m². Sampling for macrozoobenthos collection was conducted in 6 stations; a total of 6 replications was done at the different sections in each station (Figure 1). Moreover, sample of sediment was analyzed in the Laboratory of Marine Ecology of the Faculty of Marine Science and Fisheries of Hasanuddin University. In the laboratory, the sample of benthos was stored in a plastic bag and labeled according to the sampling station, followed by identification. Samples of macrozoobenthos were classified based on taxa. The identification of macrozoobenthos was made using the book of identification for shell [5] and the book of crustacean identification [6].

Figure 1. Map of macrozoobenthos sampling location in the waters of Labuange Bay, Barru Regency, South Sulawesi.
Macrozoobenthos that has been identified was calculated for its abundance using the formula [7] as follows:

\[ K = \frac{(b \times 10.000)}{a} \]  

where:
- \( K \) = Macrozoobenthos species abundance (Ind/m²)
- \( a \) = Opened jaws (grab) area of van veen grab sampler (cm²)
- \( b \) = Total number of individual caught (ind)

Diversity of macrozoobenthos was analyzed following the Shannon-Wiener index [8] using the formula:

\[ H' = - \sum \left( \frac{N_i}{N} \right) \log_2 \left( \frac{N_i}{N} \right) \]

where:
- \( H' \) = Species diversity index
- \( N_i \) = Number of individual of particular species
- \( N \) = Total number of individual

Evenness index of macrozoobenthos was determined using Shannon-Wiener index [9] with formula as follows:

\[ E = \frac{H'}{H_{\text{max}}} \]

where:
- \( E \) = Evenness Index (0 – 1)
- \( H' \) = Species Diversity Index
- \( H_{\text{max}} \) = Maximum Diversity Index
- \( H_{\text{max}} = \log S \) (S = total number of macrozoobenthos species in each station)

Dominance index was computed using the formula [10]:

\[ D = \Sigma (p_i^2) \quad P_i = n/N \]

where:
- \( D \) = Dominance Index
- \( n_i \) = Number of individual of particular species
- \( N \) = Total number of individual

The value of macrozoobenthos diversity obtained from the calculation was further compared to the category of water pollution level. Diversity index below one (1<) indicates heavy pollution, the value of one to three (1-3) shows moderate pollution, and above 3 (>3) reveals no pollution [8].

Later, macrozoobenthos that has been identified as compared to the literature to determine macrozoobenthos species commonly known as a bioindicator of organic waste contamination. The species of bioindicator identified was further analyzed by CCA (Canonical Correlation Analysis) using the software PAST (Paleontological Statistics) to compute the correlation between sediment characteristics and observation station and macrozoobenthos as an indicator. Data of macrozoobenthos species and abundance were analyzed using ANOVA to observe differences in each station.

3. Results and Discussion
The identification result of macrozoobenthos collected in all of the sampling stations is presented in Table 1. There were 55 macrozoobenthos species found in the waters of Labuange Bay that were distributed in all sampling stations.
Table 1. Macrzoobenthos species by class identified in Labuange Bay, Barru Regency of South Sulawesi Province.

| Class/Species             | Smaragdia sp.          | Stomatella sp.         |
|---------------------------|------------------------|------------------------|
| Gastropoda                |                        |                        |
| *Aliculastrum solida*     |                        |                        |
| *Alvania* sp.             |                        |                        |
| *Aspella* sp.             |                        |                        |
| *Atys* sp.                |                        |                        |
| *Boreotrophon* sp.        |                        |                        |
| *Cellana* sp.             |                        |                        |
| *Cerithium* sp.           |                        |                        |
| *Cerithium salebrosum*    | Bivalvia               |                        |
| *Conus* sp.               | Barbatia sp.           |                        |
| *Cypraea* sp.             | Codakia sp.            |                        |
| *Diadora* sp.             | Epicodakia sp.         |                        |
| *Engina* sp.              | Liochonca sp.          |                        |
| *Eptonium* sp.            | Soletellina donaciodes|                        |
| *Euchelus* sp.            | Tellina radiata        |                        |
| *Iniforis* sp.            | Tellina sp.            |                        |
| *Mastonia* sp.            | Tracryadium sp.        |                        |
| *Mitra* sp.               | Pinna sp.              |                        |
| *Monodonta* sp.           |                        |                        |
| *Nassarius absconditus*   | Clypeaster sp.         |                        |
| *Nassarius arcularia plicatus* |                |                        |
| *Nassarius siquijorensis* |                        |                        |
| *Nassarius* sp.           | Dentalium bisexangulatum|                      |
| *Nerita* sp.              | Dentalium sp.          |                        |
| *Notocochlis* sp.         |                        |                        |
| *Olivia amethystine*      | Arenciola sp.          |                        |
| *Olivia* sp.              |                        |                        |
| *Pisania* sp.             | Ophiura sp.            |                        |
| *Polinices* sp.           |                        |                        |
| *Rissoina* sp.            | Portunus pelagicus     |                        |
| *Sinum* sp.               | Odontadactylus lairostris|                     |
The number of species identified in this study covered seven different classes of macrozoobenthos, dominated by Gastropoda of 69% (38 species) and Bivalvia of 16% (9 species), while Echinoidea, Scapopoda and Malacostraca contributed to 4% of a total number of each (2 species); also Polychaeta and Ophiuroidea was 2% of each (1 species) (Figure 2). Out of 55 species identified, there were 16 species, commonly known as bioindicators in the study of environmental impact (Table 2). According to Table 2, out of macrozoobenthos classes, there were 2 classes that did not have a contribution as bioindicator species for organic waste, namely Echinoidea and Ophiuroidea. The class Gastropoda contributed to the most bioindicator species amounted to 56% (9 species), followed by Bivalvia of 19% (3 species), Scapopoda of 13% (2 species), Polychaeta and Malacostraca of 6% of each (1 species) (Figure 3).

Table 2. Identification result of macrozoobenthos species in the waters of Labuange Bay as a bioindicator for organic waste pollution.

| Class/Species | Class/Species |
|---------------|---------------|
| **Gastropoda** | **Bivalvia** |
| Aliculastrum solida | Tellina radiata |
| Atys sp. | Tellina sp. |
| Cerithium sp. | Pinna sp. |
| Nassarius absconditus | Scapopoda |
| Nassarius sp. | Dentalium bisexangulatum |
| Olivia sp. | Dentalium sp. |
| Stomatella sp. | Polychaeta |
| Tenagodus sp. | Arenicola sp |
| Vexillum sp. | Malacostraca |
| Portunus pelagicus |

![Figure 2. Percentage of macrozoobenthos species abundance by class](image)
Figure 3. Percentage of macrozoobenthos as a bioindicator for organic waste pollution by macrozoobenthos class.

The composition of macrozoobenthos species by class in Labuange Bay is listed in Table 3. Based on the identification result of macrozoobenthos collected in each sampling station, class of Gastropoda and Polychaeta were consistently found in all stations. In contrast, macrozoobenthos of class Scapopoda was only found at Station 3, 4, 5 and 6; Bivalvia was found in all stations except for Station 1; class Echinoidea was only found at Station 3 and 5, class Ophiuroidea was exclusively found at Station 1, while Malacostraca was only found at Station 1 and 2.

Table 3. Composition of macrozoobenthos at each Station by class in the waters of Labuange Bay.

| Class        | St 1 | St 2 | St 3 | St 4 | St 5 | St 6 |
|--------------|------|------|------|------|------|------|
| Gastropoda   | 73   | 74   | 63   | 76   | 78   | 71   |
| Polychaeta   | 7    | 5    | 6    | 4    | 4    | 8    |
| Malacostraca | 7    | 0    | 0    | 0    | 0    | 0    |
| Crustacea    | 13   | 4    | 0    | 4    | 0    | 7    |
| Bivalvia     | 0    | 17   | 12   | 8    | 9    | 7    |
| Echinoidea   | 0    | 0    | 6    | 0    | 5    | 0    |
| Scapopoda    | 0    | 0    | 13   | 8    | 4    | 7    |

According to the result of the analysis of variance, the sampling station did not affect macrozoobenthos abundance and number of species sampled in Labuange Bay. The highest average abundance of macrozoobenthos was found at Station 1, which reached 863±177 ind/m², while the lowest average abundance was obtained at Station 2 and 6, respectively of 614±244 and 614±132 ind/m². Furthermore, the average abundance of macrozoobenthos at Station 3, 4, and 5 was 658±331, 702±331, and 716±91 ind/m², respectively (Figure 4A). The highest species number of macrozoobenthos was found at Station 2, 4 and, those were 10±3, 10±3 and 10±2 species, respectively; conversely, Station 1 and 6 obtained the lowest number of species, namely 6±2 and 6±1 species, respectively. Moreover, number of macrozoobenthos at Station 3 was 8±3 species (Figure 4B). This finding illustrates that macrozoobenthos abundance in the waters of Labuange Bay has a
similar characteristic. [15] revealed that different sediment characteristics might lead to a difference of individual abundance in an ecosystem.

![Figure 4](image-url)

**Figure 4.** Average abundance (±SD) of macrozoobenthos (A) and an average number of (±SD) macrozoobenthos species (B) at each Station of observation. Value with the same letters are not significantly different (p<0.05).

Composition of macrozoobenthos by species shows that nine species were found at Station 1, around 11 species were found at Station 2, about nine species were found at Station 3, approximately 11 species were found at Station 4, a total of 9 species were found at Station 5, and 9 species were found at Station 6. Moreover, several species were found to be the most abundant species in each station, namely *Nassarius* sp. (40%) at Station 1, *Vexillum* sp., and *Portunus pelagicus* (15% of each) at Station 2, *Nassarius* sp. (27%) at Station 3, *Vexillum* sp. (28%) at Station 4, *Nassarius* sp. (29%) at Station 5 and *Nassarius* sp. (32%) at Station 6 (Table 4).

Macrozoobenthos successfully identified in the waters of Labuaneg Bay consisted of 7 classes. The class Gastropoda was mostly found (69%), followed by Bivalvia (16%), Echinoida, Scapopoda, and Malacostraca (4% of each), Polychaeta and Ophiuroidea (2% of each). The high composition of Gastropoda is closely related to the biological and ecological characteristics of Gastropoda that prefer muddy habitat with high organic matter content [11]. Bivalvia is widely distributed in the coastal area of Indonesia, particularly in many water aquatic ecosystems [12]. Bivalvia has a hard shell, allowing great adaptation to an extreme environment [13]. Benthos from the group Polychaeta, Bivalvia, Gastropoda, Crustacea, and Echinodermata are easily found in areas with a substrate of mud and sand, it is also said that Polychaeta, Bivalvia, and Gastropoda are better to adapt to the extreme environment than Crustacea [14]. Different species of macrozoobenthic bioindicator were found in all observation stations at different abundance. It was also confirmed by the value of a diversity index of 0.74 – 1.05, where the lowest value was obtained at Station 1, and the highest one was at Station 2. According to [8], compared to the index value, Station 1, 3, 4, 5, and 6 were categorized as heavily polluted, while Station 2 was moderately polluted (Figure 5).
Table 4. Composition of macrozoobenthos species as a bioindicator for organic pollution by the station.

| Station/Species | Composition of macrozoobenthos species (%) |
|-----------------|--------------------------------------------|
|                 | St 1 | St 2 | St 3 | St 4 | St 5 | St 6 |
| Nassarius absconditus | 6    | 0    | 11   | 0    | 0    | 3    |
| Nassarius sp.     | 40   | 13   | 27   | 3    | 29   | 32   |
| Pinna sp.         | 3    | 6    | 0    | 0    | 0    | 0    |
| Tenagodus sp.     | 4    | 4    | 11   | 4    | 11   | 0    |
| Vexillum sp.      | 27   | 15   | 0    | 28   | 16   | 11   |
| Tellina sp.       | 7    | 9    | 0    | 0    | 0    | 0    |
| Tellina radiata   | 4    | 6    | 0    | 0    | 0    | 0    |
| Arenicola sp.     | 2    | 9    | 9    | 1    | 3    | 4    |
| Portunus pelagicus| 7    | 15   | 0    | 1    | 0    | 4    |
| Aliculastrum solida| 0   | 9    | 12   | 17   | 5    | 14   |
| Cerithium sp.     | 0    | 6    | 0    | 0    | 6    | 6    |
| Stomatella sp.    | 0    | 9    | 0    | 9    | 0    | 0    |
| Ary sp.           | 0    | 0    | 7    | 5    | 17   | 15   |
| Olivia sp.        | 0    | 0    | 5    | 26   | 6    | 0    |
| Dentalium bisexangulatum | 0  | 0    | 9    | 2    | 0    | 0    |
| Dentalium sp.     | 0    | 0    | 9    | 3    | 6    | 10   |

Figure 5. Diversity Index (H') of macrozoobenthos at each sampling Station in Labuange Bay.

Based on the analysis of the correlation between the existence of macrozoobenthos and sediment characteristics, out of 16 potent bioindicator species of macrozoobenthos, there were only ten species directly related to sediment characteristics. It was found that sediment characteristics of organic carbon, organic matter, phosphate, and pHf affected the existence of *Nassarius absconditus*, *Tenagodus sp.*, *Nassarius sp.*, *Tellina radiata*, *Tellina sp.*, *Pinna sp.*, *Vexillum sp.*, and *Arenicola sp.* Moreover, redox potential influenced the existence of *Cerithium sp.*, and N-total contributed to the existence of *Cerithium salebrosum*. (Table 5). [15] mentioned that organic matter richness had triggered the difference in the spatial distribution of benthic in an ecosystem.
**Table 5.** Summary of CCA between sediment and macrozoobenthos characteristics in Labuange Bay of Barru Regency.

| Station | Characteristics of sediment | Characteristics of Macrozoobenthos |
|---------|-----------------------------|-----------------------------------|
| 1       | Organic carbon              | *Nassarius absconditus*          |
|         | Organic matter              | *Tenagodus* sp.                  |
|         | Phosphate                   | *Nassarius* sp.                  |
|         | pHf                          | *Tellina radiata*               |
|         |                              | *Tellina* sp.                    |
|         |                              | *Pinna* sp.                      |
|         |                              | *Vexillum* sp.                   |
|         |                              | *Arebicola* sp.                  |
| 2       | Redox potential             | *Aliculastrum solida*            |
| 3 & 4   | No anomaly in sediment      | *Dentalium* sp.                  |
|         | characteristic              | *Portunus pelagicus*             |
|         |                              | *Olivia* sp.                     |
|         |                              | *Dentalium bisexangulatum*       |
|         |                              | *Stomatella* sp.                 |
| 5 & 6   | N-total                     | *Cerithium salebrosum*           |

**4. Conclusion**

Organic waste contamination accumulated in the sediment resulted in the existence of 10 macrozoobenthos species as potent bioindicators directly related to the sediment characteristics of organic carbon, organic matter, phosphate, pHf, redox potential, and N-total, namely *Nassarius absconditus*, *Tenagodus* sp., *Nassarius* sp., *Tellina radiata*, *Tellina* sp., *Pinna* sp., *Vexillum* sp., *Arebicola* sp., and *Cerithium salebrosum*. The value of diversity index shows that bottom waters in Station 1, 3, 4, 5, and 6 were heavily polluted while Station 2 was still categorized as moderately polluted.

**References**

[1] Ferrando A, Esteves J L, Elías R, and Méndez N 2010 Intertidal macrozoobenthos in sandy beaches of Bahía Nueva (Patagonia, Argentina) and their use as bioindicators of environmental impact. *Scientia Marina* 74(2) 345-352

[2] Arimoro F O, Odume N, Uhnoma S I, and Edegbene A O 2015 Anthropogenic impact on water chemistry and benthic macroinvertebrate associated changes in a southern Nigeria stream. *Environmental Monitoring and Assessment* 187(2) 1-14

[3] Kanaya G, Nakamura Y, Koizumi T, and Yamada K 2015 Seasonal changes in infaunal community structure in a hypertrophic brackish canal: Effects of hypoxia, sulfide, and predator–prey interaction. *Marine Environmental Research* 108 14-23

[4] Patra A, Santra K B and Manna C K 2011 Ecology and diversity of zooplankton in relation to physico-chemical characteristics of water of Santragachi Jheel, West Bengal, India. *Journal of Wetlands Ecology* 5 20-39

[5] Woodward F 1993 Identifying Shells: The New Compact Study Guide and Identifier. Chartwell Books Incorporated

[6] Jones D S and Morgan G J 1994 A Field Guide to Crustaceans of Australian Waters. Reed, Chatsworth. New South Wales, Australia
[7] Efrizal T 2008 The structure of the macrozoobenthos community of Sail River waters in Pekanbaru City. *Journal of Environmental Sciences* 2 (02)
[8] Wilhm J L and Dorris T C 1968 Biological parameters for water quality criteria. *Bioscience* 477-481
[9] Krebs C J 1989 Ecological Methodology Harper Collins Publisher New York
[10] Brower J E, Zar J H and van Ende C N 1990 Field and Laboratory Methods for General Ecology. Third edition. WMC. Brown Publisher Dubuque Indiana USA 237 pp
[11] Wells F E and Slack-Smith S M 1981 Zonation of molluscs in a mangrove swamp in the Kimberley, Western Australia. *Proc. of Malacology. Departmen of Malacology* 9: 265-274
[12] Dame R F 1996 Ecology Marine Bivalves an Ecosystem Approach. CRC Press. New York 240 pp
[13] Tomascik T, Mah A J, Nontji A, and Moosa M K 1997 The Ecology of Indonesian Seas, part 1. Periplus Edition, Ltd Singapore 642p
[14] Ardi 2002 Utilization of Macrozoobenthos as an Indicator of Coastal Waters Quality. Undergraduate Program (S3), Bogor Agricultural University, Bogor. http://rudycl.tripod.com/sem2012/ardi.htm
[15] Kodama K, Lee J H, Oyama M, Shiraishi H, and Horiguchi H 2012 Disturbance of benthic macrofauna in relation to hypoxia and organic enrichment in a eutrophic coastal bay. *J. of Marine Environmental Research* 76:80-89