

Biomonitoring application using macrozoobenthic assemblages at coastal area of Menjangan Besar Island, Kepulauan Karimunjawa, Indonesia

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Biomonitoring application using macrozoobenthic assemblages at coastal area of Menjangan Besar Island, Kepulauan Karimunjawa, Indonesia

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Abstract

The macrozoobenthic structure inhabiting marine ecosystem may be used as a bioindicator of changes in aquatic environmental disturbance. This study was aimed to assess environmental disturbance by application of biomonitoring using macrozoobenthic assemblages at coastal area of Menjangan Besar Island, Kepulauan Karimunjawa, Indonesia. The macrozoobenthic assemblages were assessed at two sampling locations, i.e. floating net cage of monoculture and reference areas. Each sampling location was consisted of three stations with three replicates for each station. The samples were taken in two sampling times, i.e. August and November 2018. Data of abiotic parameters included the composition of organic matter content, sediment substrates, DO, pH, salinity, temperature and water current. Sediments were sampled using Ekman grab from 15 m deep. The relationship between biotics (macrozoobenthos) and abiotics (physical-chemical factors) was assessed using a non-parametric multivariate procedure (BIO-ENV; Primer 6.1.5). Macrozoobenthic assemblages were consisted of 89 species with the total abundance of 1,135 individuals, 52 families and 4 classes of macrozoobenthos. The values of indices were ranging from 2,47-3,33 for diversity index (H'), 0,95-0,97 for Pielou's evenness index (e'), and 0,08-0,15 for dominance index (C). The most common classes were a member of Gastropods and bivalves. Diversity and evenness indices exhibited were differed by location (monoculture vs reference) and time sampling. Fluctuation of macrozoobenthic structure was considered as a result of environmental changes spatially and temporally, especially sediment composition and food availability as the form of organic matter. Nitrogen and silt were the most chemical and physical factors influencing the structure of macrozoobenthos ($r = 0,632$; BIO-ENV).

Keywords: biomonitoring, macrozoobenthic structure, Menjangan Besar Island, and Kepulauan Karimunjawa

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INTRODUCTION

Menjangan Besar Island is one of the islands located in Kepulauan Karimunjawa, Jepara Regency, Central Java, Indonesia. The area covers 61 ha, with coastal lines reach 5,026 m. Menjangan Besar Island is included as the Karimunjawa National Park area for fish farming and tourism utilization zones (DPPK, 2012). It has beautiful natural scenery, easy accessibility, and economic development activities in the aquaculture sector (Husain *et al.*, 2016). As ecotourism zone, mapping is considered to be useful for coastal management (Indarjo, 2014). The island is currently used as one of the aquaculture activities, mostly traditional fish farming. Such activity may potentially disturb surrounding water ecosystem. Syuja *et al.*, (2018) reported that changes in the quality of water caused by farming activity set up at Tembelas Island, Kepulauan Riau have affected organisms inhabiting sediment under the farm, especially on changes in structure of macrozoobenthic.

Macrozoobenthic animals are organisms that spend a part or all of their lifespans in the bottom of water sediments (sessile, crawling, digging holes, or building tubes) and they have an important role in decomposition and mineralization processes of organic material in the water, as well as occupying several trophic levels in the food chains (Putro *et al.*, 2018).

Their structure varies spatially and temporally, and are sensitive to environmental disturbance (Dauvin *et al.*, 2004), thus they are considered as an important part of biomonitoring procedures as a formal protocol in assessing the status of water (Putro *et al.*, 2015; Hernandez-Arana *et al.*, 2003). The use of indicator organisms to assess water quality is considerably useful for routine biomonitoring to assess the status of the water ecosystem. Thus, the taxa of indicators can be used as a complementary part or strengthened the assessment of water quality based on physical and chemical parameters (Husain *et al.*, 2016). Consequently, further research is urgently needed to determine the quality of aquaculture areas using macrozoobenthic assemblages

and to assess the level of environmental disturbance caused by fish farming activities.

RESEARCH METHODS

The sampling sites were located at Menjangan Besar Island, Kepulauan Karimunjawa, Central Java, Indonesia at the coordinates between 110°25'40"-110°25'50"E and 5°53'10"-5°53'0"S. Two sampling locations were assessed with three stations and three replicates for each location, i.e. floating net cage of monoculture and reference area.

The base sediments were taken from the two locations using Eckman Grab. Each sediment sample was put into a 2L plastic jar, containing 10% of formalin and 70% of ethanol solutions. The measurement of the physical-chemical water parameters was done three times for each location. The parameters measured in this study were pH, temperature (°C), dissolved oxygen (DO), water current and salinity. Sediment samples were further analysed for each sampling station for sediment composition (coarse sand, fine sand, silt, and clay) and organic contents (total carbon and nitrogen organics).

Data of biotic and abiotic parameters was presented in tables, pie diagrams, and histogram with a standard deviation. The samples were taken in two sampling times, i.e. August and November 2018. Macrozoobenthic identification was done at finest taxonomic resolution (species or genus) using identification books as references, followed by enumeration for total abundance, number of species, and tabulation.

The relationship between biotics (macrozoobenthic) and abiotics (physical-chemical factors) was assessed using a non-parametric multivariate procedure (BIO-ENV). The strength of correlation was expressed by the *r* value (Clarke and Gorley, 2006). The diversity of the macrozoobenthic assemblages was analyzed using Shanon-Wiener diversity index (*H'*), Evenness index (*e'*) to express similarity and dominance index (*C*) to assess level dominance by certain taxa. Diversity of macrozoobenthic assemblages was expressed by the diversity index of Shannon-Wiener (*H'*), using the following formula (Krebs, 1989):

$$H' = \sum_{n=i}^s \frac{1}{P_i \ln P_i} \tag{1}$$

Where, *H'* = the Shannon diversity index; *P_i* = fraction of the entire population made up of species *i*; *S* = numbers of species encountered; Σ = sum from species 1 to species *S*.

Pielou's Evenness index was used to express composition of a number of individuals in any genus within the community. It was gained by comparing index diversity with its maximum value and calculated by using formula (Brower, 1990):

$$e' = \frac{H'}{H'_{max}} \tag{2}$$

Where, *e'*: population index; *H'*: the diversity index of Shannon Weiner species; *H' max*: maximum the diversity index/*ln S*.

The community dominance index was used to calculate dominance index (Odum, 1994) with the formula:

$$C = \sum p_i^2 \tag{3}$$

Where, *C* = dominance index; *n_i*: number of individuals per species; *N*: the total number of individuals per species.

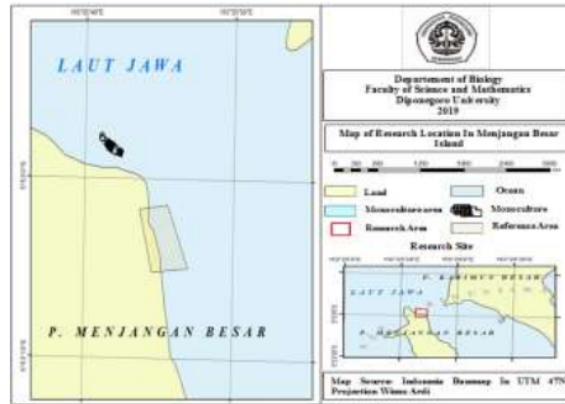


Fig. 1 Map of sampling sites at Menjangan Besar Island, Karimunjawa, Central Java, Indonesia as a study site.

RESULTS AND DISCUSSION

The amount of macrozoobenthos abundance

This study found that 89 species with the total abundance of 1,135 individuals, were consisted of 52 families and 4 classes of macrozoobenthic i.e Gastropoda class was 52 species from 31 families, Bivalvia class was 26 species from 12 families, Polychaeta class was 8 species from 7 families, and Crustacea class was 2 species from 2 families (Table 1).

No	Class of macrozoobenthos	Families	Species
1	Crustacea	2	2
2	Bivalvia	12	26
3	Gastropoda	31	52
4	Polychaeta	7	8

The results of identification, is a family of gastropoda and bivalva class with a fairly high distribution found in the two sampling locations. This is because Gastropoda and Bivalvia class can live and thrive on a wide variety of sedimentary structures and can adapt to waters dominated by silt and sand substrate types (Aufa et al., 2018).

Diversity index, evenness index, and dominance index

The value of diversity index (*H'*) in the first sampling time was highest in the monoculture with a value of 2.47 while the lowest was in the reference area with a value of 2.68. The value of diversity index (*H'*) in the second sampling time was highest in the reference area with a value of 3.33, while the lowest index value was at the monoculture with the value of 3.23 (Fig. 2). Sampling was based on different time and has a long enough pause, resulting the first sampling and the second sampling showed the high index value of diversity index (*H'*) of macrozoobenthic animals.

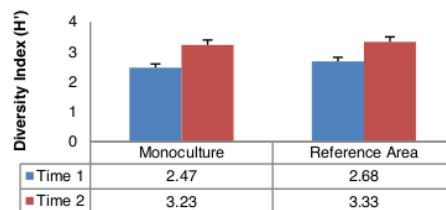


Fig. 2 Diversity index among sampling time sites

The high biodiversity values are thought to be related to the ability of a amount of genus to tolerate environmental parameters while the low value of the diversity index is thought to be due to an inability to compete for feeding with more adaptive biota (Odum, 1994). The fluctuation of macrobenthic structure is resulted from of environmental changes that responded spatially and temporally, especially food availability as the form of organic matter (Putro et al., 2018). The diversity of the genus in a community is judged to be low if its distribution is uneven, where certain species are found in abundant quantities but there are certain genus that found only slightly (Aufa et al., 2018).

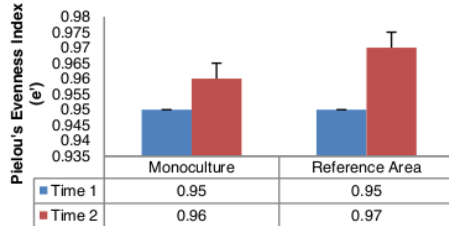


Fig. 3 Evenness index among sampling time sites.

Fig. 3, shows values of Pielou's evenness index, by comparing the first sampling time and the second sampling time ranged between 0,95-0,97. This indicated that the macrozoobenthic assemblages were relatively distributed among the sites and no indication of dominant taxa inhabiting the studied sites. The lowest value of the index was occurred at the reference site, compared to monoculture sites. This may be because of the ecological pressure from activities in the surrounding waters, not only can spread out of organic material generated from fish farming but also can be obtained from urban waste and industrial waste that is carried away by the waves (Putro et al., 2018).

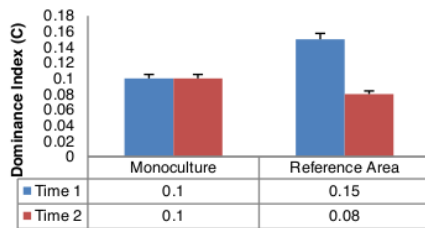


Fig. 4 Dominance index among sampling time sites.

The values of dominance index (C) were ranged between 0,08-0,015 at all sampling sites (Fig. 4). The two sampling locations have a dominance of close to 0 so that it could be interpreted that there was no or few species that dominated the location of the research. According to Putro et al., (2014), the tendency of dominance values to approach 0 means that there is no type that dominates in the waters, proving that each individual at the observation location has the same and maximum opportunity to utilize resources in the waters.

Physical-chemical water factors at Menjangan Besar Island

Physical-chemical water factors measured at the monoculture and reference area were dissolved oxygen, salinity, temperature, pH, water current, nitrogen, and carbon. The physical and chemical data obtained was pH (8,08-8,1), DO (5,03-8,05 mg/l), salinity (26,38-33,6‰), temperature (28,6-33,03°C), and water current (3,5-10 cm.s⁻¹). It could be concluded that factors values of physical-chemical water were recorded within normal range over the study period, as shown in Fig. 5.

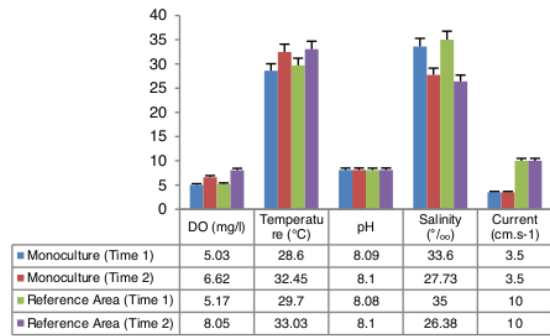


Fig. 5 Physical-chemical water factors at the Menjangan Besar Island.

Temperatures obtained at the study were 28,6-33,03°C. The temperature value at this study site was good for macrozoobenthic life and in the normal range, this was in accordance with the Izzah et al., (2016) statement that the ideal temperature for growth of macrozoobenthic was in the range of 25-35°C. The measurement of water current at the location of this study was ranged from 3.5 cm.s⁻¹ to 10 cm.s⁻¹. The water current between 3-39 cm/s belonged to the medium current category and still below the threshold for macrozoobenthic animal life (Zulfiandi, 2003). The water current is a factor that limits the spread of macrozoobenthic, where it will affect the types of macrozoobenthic. The water current will affect the distribution of sediments which will form a basic substrate that will become a habitat for macrozoobenthic animals in the waters (Irmawan et al., 2010).

Salinity at all sampling locations was still within limits of tolerance for farmed and macrozoobenthic organism life. According to Sharani et al., (2018), optimum salinity for gastropoda (26-32‰) and bivalva (24-36‰). Based on the Menteri Lingkungan Hidup (2004), standard of salinity for marine biota was 33-34 ppt. pH on the coast of Menjangan Besar island in the two sampling locations was still normal between 8,09 to 8,1, allowing for benthos animals to live. The pH range that can still be tolerated benthos animals is 6,5-8,5 (Aininur et al., 2015).

Sediment properties: Organic content and sediment grain size

Based on the analysis, the average carbon content was ranged from 0,493-2,07% and the nitrogen content was ranged from 0,025-1,74% (Fig. 6).

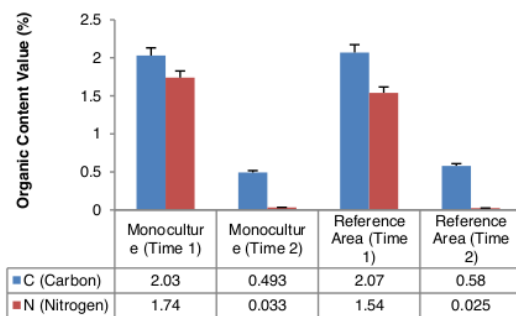


Fig. 6 Proportion of organic content of Carbon and Nitrogen at the Menjangan Besar Island.

Substrate organic content is a food source for a variety of organisms and for macrozoobenthic animals in particular (Putro, 2007). The source of nitrogen and carbon organic in the waters comes from the decay of living things that have died while the anthropogenic source is derived from fishery activities (Effendi, 2003). The nitrogen content in the first sampling time was averaged at 1,74-1,54, while the second sampling time was averaged at 0,025-0,033. The carbon content in the first sampling time was averaged at 2,03-2,07 and the second sampling time was averaged at 0,493-0,580.

Carbon and nitrogen levels during the first and second sampling time sessions at all two locations were considerably different due to the effect of the intervals between the first and second sampling time sessions which organic matter was influenced by aquacultural activities as well as by strong currents that could deliver organic matter, causing accumulation in the area (Syuja' et al., 2018).

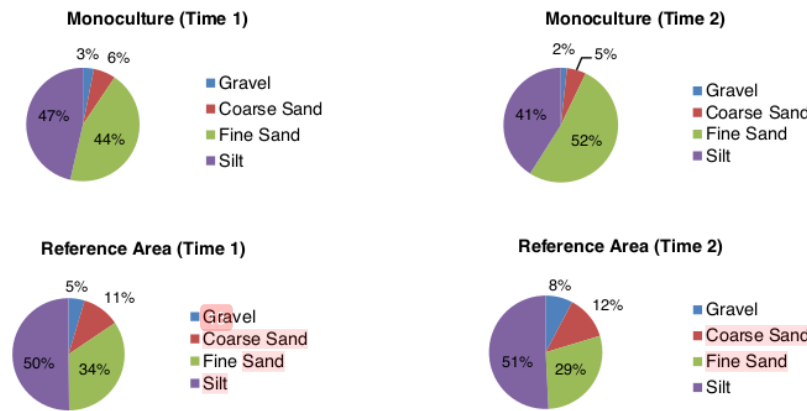


Figure 7. Composition of sediment grain size at the Menjangan Besar Island.

According to Borja et al., (2000) silt sediment can be affected by high suspended particles in waters, resulting in low oxygen levels in the sediment. Type of substrate in water is considerably important for the growth of the macrozoobenthic community. The sand substrate may make it easier for macrozoobenthic to move to another place than silty substrate that contains less oxygen. Therefore, the organisms live in silty substrate have to adapt under these circumstances. Macrozoobenthic of Bivalvia, Gastropoda, and Polychaeta were found in silty sampling sites. The Bivalvia and Gastropoda species have a wider spread because they were able to adapt to marine habitats with soft or hard sediment textures (Sharani et al., 2018).

macrobenthic organisms. Therefore, the sedimentary substrate greatly determines abundance and distribution of macrobenthic = community. The high organic matter (Nitrogen) at farmed sites, especially in first sampling time might be generated from accumulation of organic matter (nutrient enrichment) from the residual feed and residual feces during farming activities in sediments and water column. Sediments that have high organic matter can support an abundance of infauna dominated by deposit feeders (Putro et al., 2018). Furthermore, source of organic nitrogen in water column is mainly produced from decay process of living things that have died, while anthropogenic source is derived from fishery and industrial activities (Sharani et al., 2018).

Linking chemical and physical parameters to macrobenthic assemblages

The table 2 shows the correlations between physical-chemical factors, substrate granular composition and the carbon and nitrogen content with the abundance of macrozoobenthic that were analyzed using BI-OENV on PRIMER V.6.1.5 software. Nitrogen and silt were the most chemical and physical factors influencing the structure of macrozoobenthic (r = 0,632; BIO-ENV).

CONCLUSION

Macrozoobenthic assemblages were consisted of 89 species with the total abundance of 1,135 individuals, consisting of 52 families and 4 classes of macrozoobenthos. Diversity and evenness indices exhibited were differed by location (monoculture vs reference) and time sampling. Fluctuation of macrobenthic structure was considered as a result of environmental changes spatially and temporally, especially sediment composition and food availability as the form of organic matter. The values of indices were ranged from 2,47-3,33 for diversity index (H'), 0,95-0,97 for Pielou's evenness index (e'), and 0,08-0,15 for dominance index (C). The most common classes were a member of Gastropoda and Bivalvia. Nitrogen and silt were the most chemical and physical factors influencing the structure of macrozoobenthos (r = 0,632; BIO-ENV).

Table 2. Analysis of the correlation between biotic and abiotic component

No	Correlation Coefficient (r)	Variable*	Variable Amount
1	0,632	7,11	2
2	0,617	1,6,7,9,10	5
3	0,617	1,3,6,7,9	5
4	0,617	1,3,6,7,10	5
5	0,615	6,7,	2
6	0,615	6,7,11	3
7	0,614	1,6,9,10	4
8	0,614	1,6,9,10,11	5

*Variables: (1) pH; (2) Temperature; (3) Salinity; (4) DO; (5) Water urent; (6) Carbon; (7) Nitrogen; (8) Gravel; (9) Coarse Sand; (10) Fine Sand; (11) Silt.

This may imply that nitrogen in sediment of marine waters is a basic requirement that affects in growth and reproductive control of

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