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ENVIRONMENTAL ASSESSMENT OF POLYCULTURE FARMING PRACTICE BASED ON MACROBENTHIC ASSEMBLAGES: A STUDY CASE AT COASTAL AREA OF KALIWUNGU, KENDAL (CENTRAL JAVA, INDONESIA)

Sapto Purnomo Putro[a*], Widowati[b], Ibni Jeudi Febria[a], Fuad Muhammad[a], Suhartana[c], Suminto[d], Agung Sudaryono[d], Sunshuke Koshio[e]

[a]Center of Marine Ecology and Biomonitoring for Sustainable Aquaculture (Ce-MEBSA), Diponegoro University, Tembalang, Semarang – 50275, Indonesia
[b]Department of Mathematics, Faculty of Sciences and Mathematics, Diponegoro University, Tembalang, Semarang – 50275, Indonesia
[c]Department of Chemistry, Faculty of Sciences and Mathematics, Diponegoro University, Tembalang, Semarang – 50275, Indonesia
[d]Department of Fishery, Faculty of Fishery and Marine Science, Diponegoro University, Tembalang, Semarang – 50275, Indonesia
[e]Department of Fisheries, Faculty of Fisheries, Kagoshima University, 1–21–24 Korimoto Kagoshima, Kagoshima Prefecture 890–8580, Japan

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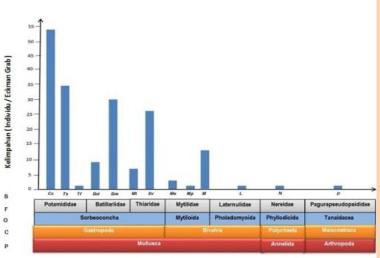
*Corresponding author
saptoputro@gmail.com

Graphical abstract



Abstract

The purpose of this study was to determine environmental quality parameters using number of species, diversity and similarity of macrobenthic communities. This study was conducted at two locations, the Location I was a polyculture farming area, farming milkfish (*Chanos Chanos*) and black tiger shrimp (*Penaeus monodon*) and seaweed *Gracilaria* sp. in the coastal area of Mororejo, Kendal District, Central Java. Location II was the coastal area of PT. Plywood Indonesia, which is located adjacent to industrial activities as well as directly affected the tide. Systematic random sampling was employed, measuring physical-chemical parameters of water and sediment. Samples of macrobenthos were taken from the sediment. Data was analysed using diversity and evenness indices approach. Samples of macrobenthos were taken from the sediment using Eckman grab, then was analysed using diversity and evenness indices approach. Results showed that the Location I was dominated by *Cerithidea cingulata* and *Terebralia sulcata* (Potamididae), *Minima batillaria* (Batillaridae). The Location II was dominated by *Cirratulus* sp., *Cirriformia* sp. and *Aphelochaeta* (Cirratulidae) and *Prionospio* sp. (Spionidae), which are considered as indicators of disturbed area. This results implied that the use of area for both polyculture and industrial activities may lead to environmental disturbance, thus environmental coastal management need to be applied in regular basis, both temporally and spatially.

Keywords: Environmental disturbance, macrobenthos, moderately disturbed area, polychaete, polyculture

1.0 INTRODUCTION

Aquaculture practices can not be separated from the various targets and challenges to be faced, among others are efforts to increase production capacity, maintaining the quality of fishery products, and environmental issues that could threaten the sustainability of farming activity itself, especially on the intensive fish farming. One of problems of aquaculture sector in Indonesia is tendency to disregard aspects of environmental carrying capacity by simply give priority mainly to the production capacity. This may result in the enrichment of organic matter in water ecosystem. Furthermore, sedimented organic matter in the bottom waters of the farms may affect the ecosystem in sedimentary habitat surrounding the area of fish farming. Industrial activity which is closed to the coastal areas can also have an impact on water quality and ecosystem. This activity may cause environmental pollution that may disturb living organisms, substances, energy flow and other components into the environment. Its quality decreases to a certain level which causes the environment no longer has optimum function [1]. According to reference [2] the quality of the water can be determined effectively by analyzing structure of macrobenthic assemblages. These animals have relatively sedentary life strategy and are less likely to inhibited away from environmental changes that may endanger his life, so it can be used as an indicator of organic pollution of the water ecosystem. Organisms that are not tolerant to water environment will no longer survive from the aquatic environment. Organisms that are sensitive to the change of the environment can be used as bio-indicators, because his absence indicates a change or environmental stress. Conversely, when the organisms are able to survive and the population is likely to increase in aquatic environments polluted by organic matter, the organisms may also be used as an indicator of contamination of organic materials, because of its abundance indicates the presence of organic enrichment in the area [3]

Polyculture is farming activities that farm more than one species in the same cage. In the long term, without adequate environmental management, the activity may lead to decreased water quality and lead to ecological imbalance in the region. Further impact of the decline in water quality can disrupt and harm aquatic organisms, including macrobenthos. Accordingly, this research determined how far polyculture and industrial activities operated close to the coastal areas impact on the waters and sediments, by analysing of structural changes of macrobenthos (biotic) and abiotic environmental changes (physical-chemical). The purpose of this study is to determine water environment quality through the number of species, diversity and similarity of macrobenthic communities and determine the status of the environmental conditions adjacent the area of polyculture and coastal areas.

2.0 MATERIAL AND METHOD

This study was conducted at two locations, the location I was a fish farm areas of polyculture system for milkfish (*Chanos chanos* Forsskal, 1775) and black tiger shrimp (*Penaeus monodon* Fabricius, 1798), farmed together with seaweed *Gracilaria* sp. in the coastal areas of Mororejo Village, Kendal District, Central Java. Location II is the coastal area of PT. Kayu Lapis Indonesia (KLI), Mororejo village, Kendal district, Central Java, which is located adjacent to industrial activities directly affected the tide.

Sediment samples taken using the Eckman grab were fixed in 4 % formalin solution and stored in 2 L plastic jars. The samples were then sieved through a 1.0 mm mesh. The macrobenthic animals from the sediment retained by the sieve were sorted under a binocular microscope. The fauna was preserved in 70 % ethanol for further analyses. Enumeration and identification of benthic animals were carried out at genus level for polychaetes and bivalves. Other animals were identified to higher taxa. The diversity of the macrobenthic assemblages was analysed using Shanon-Wiener index (*H*') using formula as follow:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \qquad (1)$$

Where : p_i = the proportion of individuals found in the *i*- species (n_i/N)

Pielou's evenness index (J') was used to express equitability using formula as follow:

$$J' = H'/H_{max} = H'/\ln S \qquad (2)$$

Where: H'= Shanon-Wiener diversity index; S= total number of species (4)

t-test analysis of the value of diversity index was carried out to compare the difference in macrobenthic abundances between the two sites using formula as follow:

$$\mathrm{Var}(H') = \frac{\sum_{i=1}^{S} p_i(\ln p_i)^2 - \left(\sum_{i=1}^{S} p_i \ln p_i\right)^2}{N} + \frac{S-1}{2N^2} \qquad (3)$$

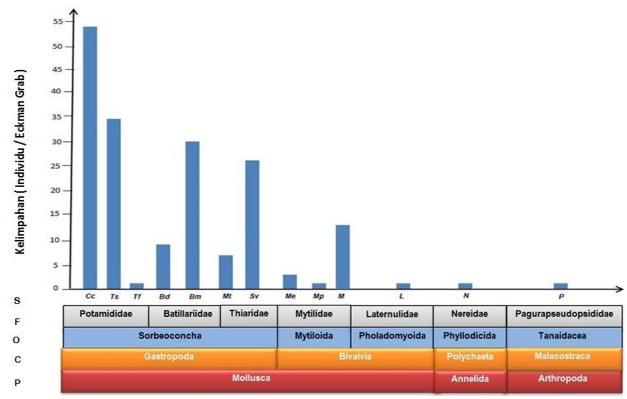
where S = number of species and N = total number of individuals (5).

3.0 RESULTS AND DISCUSSION

3.1. Macrobenthic Structure: Spatial and Temporal Distribution

Based on the first and second sampling at the all sampling location, there were 18 species of macrobenthos, belong to 10 families of four classes which include as many as seven species of *Gatropodaie, Cerithidea cingulata, Terebralia sulcata, Tympanotonos fuscatus, Batillaria diemenensis, Batillaria minima, Melanoides tuberculata, and Syrmylasma venustula.* Class Bivalvia was represented by four species namely, *Mytilusedulis, Mytilusperna, Modiolussp and Laternula* sp. Class Polychaeta was as many as six species, *Cirratulus* sp., *Cirriformia* sp., *Aphelochaeta* sp., *Prionospio* sp., *Capitella* sp. *and Nereis* sp. Class Malacostraca was represented by one species, namely *Pagura pseudopsis.* The fourth class that has the highest frequency of occurrence was the class Gastropoda. Class Gastropoda was represented by family Potamididae with large numbers of 91 individuals. This could be due to the types of gastropods can grow and develop in a variety of soil structure and have specific physiological to be able to adapt to the aquatic environment that has particularly muddy or sandy substrate. Their abundance may be related to the presence of litter of mangrove trees, resulting in the area is rich in organic matter accumulation. At the Location II, the macrobenthos were largely dominated by member of the class Polychaeta with the highest number of families Cirratulidae (three species), Spionidae and Capitellidae (one species) with individual number as many as 20 individuals. Their high abundance at Location II is presumably because these animals have high adaptability to environmental changes. Their roles in colonizing disturbed areas have been well documented [3] as some groups of polychaetes are associated with early stages of successions in organically enriched areas.

Meanwhile, at the Location I, where farming practice has been operating since 2006, there were 13 species of macrobenthos. As can be seen in Figure 1, it was dominated by species of the class Gastropoda *Cerithidea cingulata* (54 individuals/grab), followed by *Terebralia sulcata* species (34 individuals/grab) from the family Potamididae. Besides that has a large enough number that *Batillaria minima* (30 individuals/grab) from family Batillaridae and *Srymilasma venustula* (26 individuals/grab) from the family Thiaridae. The smallest amount of macrobenthos found in the location I is derived from the class Bivalvia (18 individuals/grab), the class Polychaeta (1 individual/grab) and class Malacostraca (1 individual/grab). According reference [6] the class Gastropoda is common in many types of environments and forms usually have to adjust to the environment. Most of gastropods inhabit in mangrove areas. Some live on the land that is muddy or wetland, some are attached to the roots or stems, and some are climbing. There are also living in tidal areas [7]. Gastropods generally live on the soil surface and tend to move downward at low tide and rise again at high tide [8]. The observation (Figure 1) shows that there are two dominant species found, i.e. *Cerithidea cingulata* (54 individuals/grab) and *Terebralia sulcata* (34 individuals/grab). The type of gastropods *C. cingulata* and *T. sulcata* are a native gastropods inhabiting mangrove ecosystems. These species prefer to live on the surface of the muddy puddles or areas with a fairly broad. Thus, the presence of class Gastropoda at many research sites are more likely related to the condition of the substrate and live strategy of the species. The existence of dietary factors such as detritus and also very supportive environment for their life will affect changes in the number and species of gastropods [9].

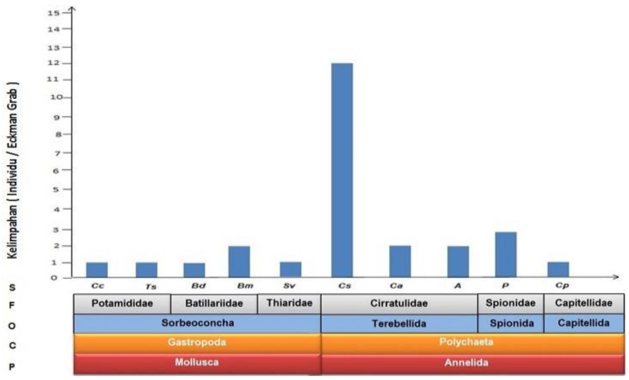


Information : S: spesies; F: famili; O: ordo; C: class; P: phylum. Cc: *Cerithidea cingulata*;Ts: *Terebralia sulcata*; Tf: *Typanotonos fuscatus*; Bd: *Batillaria diemenensis*; Bm: *Batillaria minima*; Mt: *Melanoides tuberculata*; Sv: *Syrmylasma venustula*; Me: *Mytilus edulis*; Mp: *Mytilus perna*; M: *Modiolus* sp.; L; *Laternula* sp.; N: *Nereis* sp.; P: *Pagurapseudopsis* sp.

Figure 1 Graph macrobenthos species abundance at the location I: Raising poly

Based on the sediment grain size analysis, the type of substrates at Location I generally are dominated by silt and clay, i.e. 71.70 % and 16.71 % respectively. According to reference [2], the presence of silty clay (mud) showed at the studied areas may be an indication of high rate of sedimentation. Furthermore, sedimentation can be affected by the current speed; when the speed is low, there will be calm waters that will undergo deposition of suspended material. Sedimentation is determined by several factors, such as current speed, riverbeds and other conditions including the diameter of the sediment itself [10].

Reference [2] stated that the substrate type may determine the abundance and distribution of macrobenthos. The above criteria are common for some macrobenthic habitat, especially class Gastropoda, Bivalvia and Polychaeta. The high composition of muddy substrates tend to accumulate organic matter, result in an sufficient supply of potential food for macrobenthic organisms [11]. According to reference [12] in a certain concentration of the organic content of the substrate is needed as a source of food for certain organisms, particularly macrobenthos so that the number and rate of its accumulation in sediments have a considerable influence on a population of organisms.



Information : S: Spesies; F:famili; O:ordo; C:class; P:phylum. Cc: *Cerithidea cingulata*;Ts: *Terebralia sulcata*; Bd: *Batillaria diemenensis*; Bm: *Batillaria minima*; Sv: *Syrmylasma venustula;* Cs: *Cirratulus* sp.; Ca: *Cirriformia* sp.; A: *Aphelochaeta* sp.; P: *Prionospio* sp.; Cp: *Capitella* sp.

Figure 2 Graph abundance of macrobenthos at location II: coastal PT. Plywood Indonesia

Organic matter content can be derived from a variety of sources of degradation of water plant litter, sedimentation of dissolved organic particle, feces or the excess of metabolism of aquatic biotas, and unfed fish pellets. Based on the results for carbon and nitrogen analysis at Location I, the concentration of carbon (C) and nitrogen (N) were ranged from 3.20 to 10.35 % and 0.72 to 1.16 %, respectively. The C content at Location I is more likely because of the accumulation of litter, nutrient enrichment during litter decomposition.

In contrast to the Location II, which are located near the sea, the number of species found fewer than the number of species in the Location I, i.e. 10 species of macrobenthos, originating from class Gastropoda (5 species) and class Polychaeta (5 species), as shown in Figure 2. The animals most commonly found belong to the class Polychaeta are *Cirratulus* sp. (12 individuals/grab) and *Prionospio* sp. (3 individuals/grab), followed by *Cirriformia* sp. and *Aphelochaeta* sp. (2 individual species/grab). Species that have the fewest number of class Polychaeta are *Capitella* sp. (1 individual/grab). Species of the class Gastropoda are *Batillaria minima* (2 individuals/grab), *Cerithidea cingulata*, *Terebralia sulcata*, *Batillaria diemenensis* and *Srymilasma venustula* (1 individual/grab).

Polychaetes are considered as the first marine invertebrate organisms colonize polluted areas. The highest number of abundance of macrobenthos at Location (Figure 2) belongs to the class Polychaeta, especially from Family Cirratulidae (16 individuals/grab), Spionidae (3 individuals/grab) and Capitellidae (1 individual/grab). Species or group of taxa associated with the early stages of succession in organic-rich sediments, among others, are from families Cirratulidae, Capitellidae and Spionidae [13, 14, 2]. Associated with opportunistic species, Ref [15] stated that in the conditions of disturbed areas, macrobenthos assemblages are dominated by organisms that have *r*-selection strategy in his life, or so-called opportunistic species. This species has the characteristics of a relatively small body size, short life span dominant in number of species but low in biomass, have a high level of potential reproductive and early maturation [16] Based on Figure 2, the species *Cirratulus* sp.*,* *Cirriformia* sp.*,* *Aphelochaeta* sp., which are member of the family Cirratulidae and *Prionospio* sp. which is Spionidae, a community dominated macrobenthos at location II. The existence of *Capitella* sp. at the Location II may indicate the presence of environmental disturbance [14, 17]. Three dominant families found at Location II are all from the class Polychaeta, some of them known as opportunistic species. [18] observed that opportunistic species have life history characteristics that allow them to respond quickly to disturbances aquatic environment.

3.2 Proportion of Macrobenthic Assemblages

The proportion of macrobenthos in the first sampling at Location I and Location II showed the difference between the two locations (Figure 3).

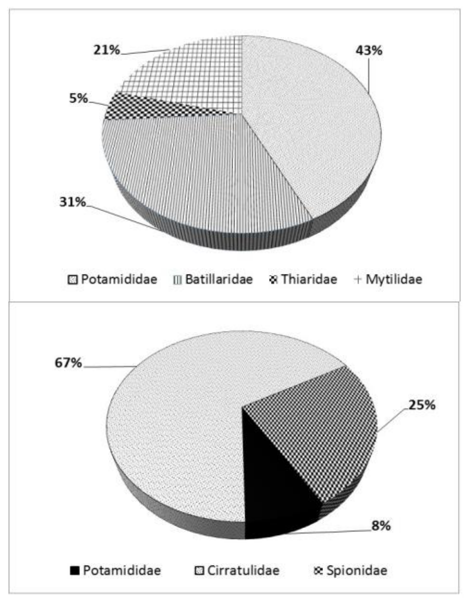


Figure 3 A. Proportion of macrobenthic abundance in the first sampling at Location I.; B. Proportion of macrobenthic abundance in the first sampling at Location II

At Location I, the percentage composition was dominated by the family Potamididae and families Batillaridae, i.e. 43 % and 31 % in their proportion respectively. Potamididae and Batillaridae which dominates at this location is not recommended as opportunistic taxa in the aquatic environment [19]. Both of these families inhabit mangrove environments. At the Location II, as shown in Figure 3B, the macrobenthic animals were dominated by family Cirratulidae (67 %) and family Spionidae (25 %) from the class Polychaeta. Reference [20] stated that these taxa belonged opportunistic taxa. This opportunistic taxa respond quickly to environmental disturbance by increasing the rate of the population, but are generally smaller per individual than a normal size [2].

In the second sampling time (Figure 4A), the percentage composition macrobenthos abundance at Location I was dominated by family Potamididae, Thiaridae, i.e. 52 %, 24 %, and 17.60 % resepectively. Batillaridae exhibited higher in abundance in the second sampling time compared to those in the first sampling time. This could be due to the amount of organic matter contained in the study area higher in the second sampling time. Dominance of taxa found in the second sampling time at Location I is still the same as that found in the first sampling time. Location I which is polyculture pond farming is surrounded by mangrove trees, so that the indicated amount of litter that falls in the pool was a suitable habitat for native mangrove animals, including member of phylum Mollusca i.e. family Potamididae, Thiaridae and Batillaridae [20]. Meanwhile, The number of species and abundance of macrobenthos at Location II which is located at the coastal areas surrounding industrial activities (PT. KLI) increased compared to the first sampling in the second sampling (Figure 4B). Yet, their structure was still dominated by the family Cirratulidae (58 %) in both sampling time. The results imply an indication of environmentally disturbed areas at this location, owing to the industrial activities of the PT. KLI.

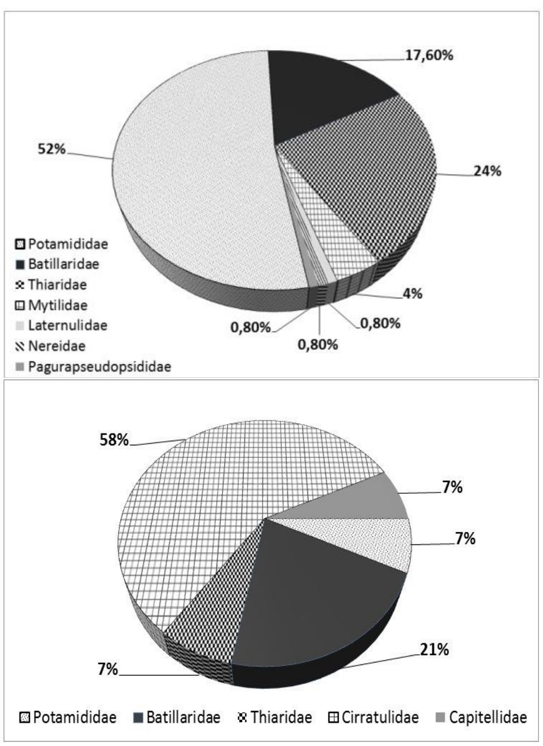


Figure 4 A. Proportion of macrobenthic abundance in the second sampling at Location I. B. Proportion of macrobenthic abundance in the second sampling at Location II

Based on macrobenthic proportion in the first and second sampling times, they were dominated by taxa that can respond rapidly to environmental disturbances. This condition influence low score of Shanon-Wiener diversity index (H ') and Similarity Pielou's index (E), as can be seen in Table 1. Table 1 shows that the average value of H' diversity index during the first sampling and second sampling times at both sampling location ranged from 1.07 to 1.70 and 0.72 to 1.86, respectively.

In the second sampling time, the H' diversity index at has the same value at both sampling, i.e. 1.86, which is categorized as moor a species. Table 1 shows the value of the similarity of the first sampling at both locations is 0.77. In the second sampling values between Location I and II are 0.72 and 0.86 respectively. Overall the level of similarity of macrobenthos location research is considerably high. According to reference [21], the water quality criteria based on diversity index is experiencing light pollution at Location 1, whilst those at Location II is experiencing moderate pollution. Similarity index value types Pielou's evenness shows the magnitude of the composition and the number of individuals possessed by each genus. Ref [4] and [17] stated that the similarity index determines how much an individual is distributed evenly within a sample caused by the dominance of a few species, especially opportunistic species. This implies that the composition of macrobenthic structure is equally distributed in the area. Based on the t-test analysis of the value of diversity index [5] showed that the differences in species diversity at the Location I and Location II were not significantly different ($t = 0.495 < table = 1.694$; $\alpha = 0.05$) between the locations, and the sampling time ($t = 0.317 < table = 1.645$; $\alpha = 0.05$).

Many species macrobenthos have complex relationships with sedimentary environments. The complexity is due to the interaction between multiple abiotic factors (particle size, organic content and microbial, hydrodynamic and chemical conditions) and biotic factors (competition and other biological interactions) can affect the occurrence of a species in their habitat. The results of multiple regression analysis showed that the size of the sediment, especially silt and organic matter content in the form of carbon are the most influential abiotic variables. This could be due to the link between the substrate with the availability of food contained in the sediments that affect the macrobenthic structures. Availability of organic matter in sediments is varied; these variations can be influenced by strong currents and distance source /discharge of organic material to the region. Reference [22] stated that the most important environmental factors in the distribution and structure of macrobenthos are the availability of food, dissolved organic particles, salinity and sediment grain sizes. Availability of food affects the number of species, abundance and biomass of the animals. Furthermore, refererence [23] stated that availability of food both in quality (the ratio of carbon and nitrogen) and the quantity effects on the metabolism and growth of macrobenthos.

Table 1 Values diversity index (H ') and similarity index type pielous's evenness (E')

Values diversity index (H ') and similarity index type (E)	First sampling time (1)		Second sampling time (2)	
	Location I	Location II	Location I	Location II
Diversity Index	1.70	1.07	1.86	1.86
Similarity Index Type	0.77	0.77	0.72	0.86

4.0 CONCLUSION

The polyculture areas (Location I) was dominated by *Cerithidea cingulata* and *Terebralia sulcata* (Potamididae), *Minima batillaria* (Batillaridae). Whilst the coastal area of PT. Plywood Indonesia (Location II) was dominated by *Cirratulus* sp., *Cirriformia* sp. and *Aphelochaeta* (Cirratulidae) and *Prionospio* sp. (Spionidae), which are considered as indicators of disturbed area.

Although similarity index indicated no dominance taxa accounted at both locations, however based on diversity index, both locations were occurring environmental pressures by farming activities (Location I) and industrial activities (Location II). These results imply that the use of area for both polyculture and industrial activities may lead to environmental disturbance, thus environmental coastal management need to be applied in regular basis, both temporally and spatially.

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