Assessment of environmental status of coastal mangrove area using macrobenthic assemblages: a study case at Tapak Mangrove area, Semarang, Central Java

S P Putro¹, S Adhy², H Safrijal³ and F Muhammad³

¹Centre of Marine Ecology and Biomonitoring for Sustainable Aquaculture (Ce-MEBSA), Diponegoro University, Semarang, Indonesia
²Department of Informatics, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
³Department of Biology, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia

Corresponding Author: saptoputro@live.undip.ac.id ; saptoputro@gmail.com

Abstract. Macrobenthic structure can be used as a bioindicator in determining the level of disturbance in water ecosystem through their composition, presence or absence spatially and temporally as apart of ecological management. Tapak is a coastal area of Semarang City, Central Java, Indonesia that has potency as an ecotourism area for integrated aquaculture at mangrove area. On the other hand, industrial activity around Tapak coastal area may lead to a degradation of the ecological function of that area. This study aims to assess environmental status at Tapak Mangrove Area through the macrobenthic structure in space and time. Purposive random sampling method was applied, consisting five sampling stations with 3 replicates between March to May 2018. Sediment samples were taken by using Ekman grab and were analyzed through the stages of fixation, rinsing, sieving, preservation, sorting, identification, and enumeration. The biotic parameters observed were the macrobenthic community structure, including species composition, abundance, and diversity, evenness, and dominance indices. Physico-chemical parameters of the water and sediment were measured every month. The Early Warning System (EWS-3SWJ) software was used to assess the level of environmental disturbance at each station. The total of 15 species of macrobenthic assemblages were found. The most common species were Telescopium telescopium, Cerithidea cingulata, and Metapenaeus sp.. The diversity of macrobenthos was considered low at all sampling stations (H= 0.56 – 1.52), with marked variability in dominant taxa (D= 0.21 – 0.71). Further analysis using the EWS-3SWJ showed that the environmental status of the Tapak Mangrove Area is categorized as slightly disturbed areas.

1. Introduction

Semarang as the capital city of Central Java has parts of coastal areas, bordered by the Java Sea. Utilization of coastal areas of the city includes fishing activities, ports, industry, agriculture, settlement and tourism. One of the coastal areas in Semarang City that has potential is Tapak, a coastal area in Tugurejo sub-district where pond and mangroves areas are integrated. Tapak River supplies fresh water to the Mangrove Tapak area, including for aquaculture ponds. Unfortunately, this potential natural
resources are being threatened by industrial activities in the surrounding area. Industrial activities may cause a decrease in the quality of the aquatic environment as a result of the disposal of industrial waste into body column of the Tapak River. Furthermore, aquaculture activities can also cause environmental disturbances through enrichment of organic material derived from fish faeces and unfed pellets. Organic material can be spread outside the fish farm area, especially during the rainy season [1]. Environmental status of aquatic environment can be carried out by physical, chemical, and biological assessment. Biological assessment can be done by examining the structure of aquatic biota communities, one of which is macrobenthos [2];[3]. Macrobenthos are organisms that live at the bottom of the water ecosystem, sedentary at least a part of their life cycle, so they can respond to environmental disturbance. Macrobenthos as a bioindicator is an important part in determining water quality through the presence or absence, comparison of the amount of density between types or groups of macrobenthos between space and time, and the dominance of certain taxa. The taxa indicator macrobenthos can complement or strengthen the assessment of water quality based on physics and chemistry [4];[5];[6].

Response of macrobenthic communities (biotic) to the environmental disturbance are dependent upon various abiotic factors, including season, water quality, hydrodynamical condition of water column, sediment properties, food availability, organic matter, amount of other pollutants [7]. This relationship between abiotic and biotic components is dynamical, owing to presence or absence of environmental disturbance. Members of macrobenthic community response variously against the disturbance. Some species are tolerant namely opportunistic taxa [8] some others are sensitive to the disturbance. Whether natural or anthropogenic disturbance, environmental disturbance will influence structure of macrobenthic assemblage, especially in taxa richness, abundance, and biomass. The changes may be used as an indicator of community disturbance and provide an assessment of the levels of disturbance [9]. In this study, their abundance, diversity, evenness, and taxa richness among sampling stations are compared. The changes in the pattern of their abundance, opportunistic taxa, physico-chemical parameters, sediment characterstic are analysed. Environmental status at Tapak Mangrove Area are assessed through their structure in space and time.

2. Experimental

2.1. Sampling method
This research was conducted at the Mangrove Tapak Area, Semarang, Central Java. The study was conducted in March - May 2018. Sampling was carried out using a purposive sampling method, which is based on certain considerations that can represent the overall research area. Sediment samples were taken using Ekman grab at 5 stations for three times with a time interval of 1 month. The samples were then put into plastic jars with 10% formalin for fixation. Rinsing, sieving, and sorting were carried out to collect macrobenthic animals into plastic bottles with 70% ethanol solution for identification and enumeration. The physical-chemical factors of the waters were measured, i.e DO, temperature, pH, salinity, and turbidity. Sediments analysis included sediment grain size and organic matter content.
Figure 1. Map of sampling station at Tapak mangrove area, Semarang. Note: Station I: Rear Estuary, Station II: Rear Pond, Station III: Middle Section Muara, Station IV: Middle Pond, and Station V: Front Estuary River.

2.2. Environmental status analysis of mangrove tread

Determination of the status of the aquatic environment was determined using the EWS-3SWJ software [10], which is an ecological assessment for water ecosystems using macrobenthic assemblage. This application paid attention to biotic and abiotic components and diversity indices, evenness indices, and dominance indices. The main output of this application is to show the level of disturbance at the location being observed and is complemented by conclusions and recommendations needed to be done. The system architecture and flowchart of EWS-3SWJ are described as Figure 2.

Figure 2. Schematic diagram of system architecture (A) and Flowchart of EWS-3SWJ (B).

Other capabilities of this application including having user settings features along with password management, counting water quality by adding taxa indicators, and managing the calculation of each calculation process can be utilized together as a data bank for further analysis related to water quality in various places/regions. The analysis was conducted by inputting biotic data, namely abundance of macrobenthos, abiotic data, diversity index (H'), evenness index (E), and dominance index (D). After the data is inputted, it is run, so the analysis results appear.
3. Results and discussion

3.1. Spatial and temporal patterns of macrobenthic assemblages
Based on sampling data collected from all stations in three sampling times, there were 15 species of macrobenthos from 11 families. The composition of macrobenthos at the study site consisted of 4 classes, i.e. Gastropods (5 species), Bivalvia (4 species), Crustaceans (5 species), and Polychaeta (1 species), with various proportion of each species for each sampling station. Total abundance of macrobenthos at Station I and Station II were considerably low, i.e. 57 ind/m² and 91 ind/m², respectively. These stations are located closest to the industrial estate and residential areas so that the level of disturbance is likely to be higher than other sampling stations. Meanwhile, total abundance of macrobenthos at Station III and Station IV were noticeably higher than the former two stations, i.e. 119 ind/m² and 215 ind/m², respectively. Station III and Station IV are stations where mangrove vegetation exhibited high density, considering that mangrove forests are favorable habitat for various marine life, including macrobenthos. According to [11], mangrove ecosystems have high productivity, provide abundant food for various types of marine animals, and provide a breeding ground, spawn for various types of fish, shellfish, crabs and shrimp. The station which has the highest abundance is Station V, i.e. 238 ind/m². This may be related to the location, which is the front of the river mouth. River mouth is an rich area of organic matter deposited from upstream to downstream, also because of the strength of the ocean waves that deposited organic material in the region. According to ref. [12], the front of the river estuary is an area that is rich in organic material derived from plant vegetation along the river flow or from organic waste. Therefore, factors suggested to influence the variability of their abundance of macrobenthos were sampling station, water quality, food availability and sediment characteristics.

| Table 1. Macrobenthic abundance and composition based on sampling stations. |
|-----------------------------------------------|
| Class       | Family               | Species                  | Abundance (ind/m²) | Station |
|             |                      |                          | I   | II   | III  | IV   | V   |
| Gastropoda  | Potamididae          | Telescopium              | 17  | 23   | 34   | 17   | 0   |
|             |                      | cingulata                | 17  | 11   | 17   | 102  | 0   |
|             | Nassariidae          | Nassarius sp.            | 0   | 28   | 0    | 0    | 0   |
|             | Potamididae          | Terebralia sp.           | 11  | 0    | 0    | 11   | 0   |
|             | Cerithiidae          | Corallium                | 0   | 0    | 0    | 34   | 85  |
| Bivalvia    | Arcidae              | Anadara sp.              | 0   | 0    | 0    | 6    | 17  |
|             | Corbiculidae         | Batina violacea          | 6   | 0    | 0    | 0    | 0   |
|             | Pharidae             | Pharus legumen           | 0   | 0    | 6    | 0    | 0   |
|             | Mytilidae            | Septifer bilocularis     | 0   | 6    | 0    | 0    | 0   |
| Crustacea   | Penaeidae            | Penaeidae (larva)        | 0   | 0    | 11   | 0    | 23  |
|             | Penaeidae            | Metapenaeus sp.          | 0   | 6    | 28   | 28   | 45  |
|             | Penaeidae            | Penaeus sp.              | 6   | 17   | 23   | 11   | 45  |
|             | Grapsidae            | Metopograpsus sp.        | 0   | 0    | 0    | 6    | 6   |
|             | Alpheidae            | Alpheus sp.              | 0   | 0    | 0    | 0    | 6   |
| Polychaeta  | Nereidae             | Nereis sp.               | 0   | 0    | 0    | 0    | 11  |
|             | Total abundance      | (TA)                     | 57  | 91   | 119  | 215  | 238 |
|             | No. of Species (s)   |                          | 5   | 6    | 6    | 8    | 8   |
The composition of macrobenthic assemblages at 5 stations was generally dominated by fam. Potamididae (Class Gastropoda) and fam. Penaeidae (Class Crustacea). Gastropods were the most abundant, with total of 408 individuals. Gastropods are considered as biota easily adaptable in the various environment and can live on a variety of sediments, both muddy, rocky substrates and sandy [13]. The most common species found at the study site were Telescopium telescopium, Cerithidea cingulata, Metapenaeus sp., and Penaeus sp.. T. telescopium is a cosmopolitan species found in almost all research stations. This can be attributed to the habitat of T. telescopium which lives at ponds integrated with mangrove forests. According to [14], the species is a mangrove snail inhabiting mangrove areas and is mostly detritus-feeder. The existence of this species at ponds can be a biofilter for aquaculture activities, as reported by [15].

This species is able to reduce levels of waste from the maintenance of milkfish on a laboratory scale. According to ref.[16] the tissue in leg organs, antennas, mantles, gill of T. telescopium are able to absorb heavy metals, i.e. Pb, Zn, and Cu substances, so that it can be used as a bioindicator of water quality. Another species found almost at all stations is Cerithidea cingulata. This species is the species most abundant at Station IV. This can be related to the habitat that lives in the mangrove area, both at ponds, rivers, and attach on the mangrove vegetation. In addition, C. cingulata is an organism that can survive in a disturbed environment. According to ref. [17] C. cingulata is an indicator organism in a polluted environment, because it can survive in environmental conditions that change suddenly, has a low dissolved oxygen level, and high hydrogen sulfide (H2S). Furthermore, [18] explained that C. cingulata is macrobenthic species relatively resistant to high levels of water pollution. Furthermore, Penaeus sp. (Crustacea) was found in all sampling stations, while Metapenaeus sp. (Crustacea) was found at 4 sampling stations. Penaidae family is a member of crustaceans commonly found in mangrove habitats. According to ref. [19] mangrove forests that have mud bottom waters are the most preferred habitat by shrimp species, as the ecosystem is considered an excellent niche for protection, laying eggs, and a place to find food. In particular, species Nereis sp. (Class Polychaeta) was found at Station V, as it is a part of a river estuary which usually high organic matter deposited on the sediment. According to ref. [20], some members of polychaeta are marine organisms most tolerant to stress due to organic content and oxygen depletion, thus they can be used as an environmental indicator. In addition, Sanusi et al. (2005) stated that Nereis sp. plays an important role in the process of sediment diagenesis and has a high adaptability. Other species considered as bioindicator are Terebralia sp., and Anadara sp. Terebralia sp. is native species of molluscs inhabiting mangrove forests. According to ref. [16], this species found in the sediment under the roots of mangrove plants in the middle to the back of the mangrove forest. Terebralia sp. has a role as litter degradation that plays a role in the nutrient cycle. According to ref. [21] Terebralia sp. has a wide distribution as it has a range of adaptations to environmental conditions, and is able to multiply rapidly. Anadara sp. is a bivalve that lives in sediments of estuarine areas and has a role as pollutant biofilter. According to ref. [22]. A. granosa is a bioindicator of water quality because it has the ability to accumulate metals better than other aquatic faunas. A. granosa is a filter feeder and has slow movement so it cannot avoid the effects of pollutants.
Figure 3. The comparison of proportion (%) of macrobenthic abundance by sampling station.

3.2. Diversity and evenness of macrobenthic assemblages

The values of diversity index (H’) at all sampling stations by three times the data collection ranged from 0.56 - 1.52. The highest diversity index value was found at Station IV (middle part of the pond) in the third sampling with a value of 1.52, while the lowest diversity index value was found in Station I (back of the river estuary) in the third sampling, with a value of 0.56. In general, the diversity index values (H’) at the study site showed low to moderate level of diversity. According to ref. [23], if the value of Shanon Wiener diversity index (H’) <1 includes low species diversity, if H’ = 1-3 includes moderate diversity, and if H’ > 3 is included high species diversity. Based on diversity index values (H’) indicate low to moderate community diversity. This may be attributed to environmental disruption as a result of industrial and household activities around the sampling sites. In addition, several studies stated that the level of heavy metal pollution in the Tapak Mangrove area has exceeded the threshold. Research conducted [24] showed that the average concentration of copper (Cu) in pond water in the Mangrove Tapak Region ranged from 0.02 ± 0.007 to 0.05 ± 0.008 mg.L⁻¹. The content of heavy metal Cu has exceeded the threshold determined by the Government. In accordance with the Decree of the Minister of Environment No. 51 of 2004 concerning Sea Water Quality Standards, Cu content for seawater biota is 0.008 mg.L⁻¹. The content of heavy metal Cu in pond sediments was also high, namely 15.20 ± 1.77 - 25.03 ± 4.77 mg.kg⁻¹ [24]. Furthermore, concentration of Pb in Tapak river water was 0.462 mg / L (Raharjo et al, 2018) and cadmium (Cd) content ranges from 0.015-0.016 mg.L⁻¹ with an average of 0.015 mg.L⁻¹ [25].
Figure 3. Values of Shanon-Wiener Index (H’) for each sampling station and sampling time.

3.3. Sediment properties: grain size and organic content

The contents of organic matter were varied, ranging from 8.19 to 13.37%. The highest organic matter content was found at Station IV, especially at the middle part of the pond with an average of 12.01%. The lowest organic matter content occurred at Station II, particularly at the rear pond with an average of 9.37%. That may be because Station IV has more mangrove vegetation compared to Station II. Mangrove leaves are considered as one of the largest sources of organic matter in the mangrove area. Organic matter in aquatic sediments will support macrobenthic life, as it is a food source. As the highest organic matter content occurred at Station IV, there were 8 species of macrobenthos with 215 individuals. This number is considered most abundant compared to other stations. In contrast to Station IV, Station II has the lowest organic matter content, macrobenthos found was also relatively low in number of species and abundance. Consisting 6 species with 91 individuals.

Meanwhile, sediment grain size was various in their composition but dominated by silt (42.3-77.4%) for all sampling stations. The type of substrate is closely related to the content of organic matter. Silt type substrate has the property to hold organic material. According to ref.[12], substrate with silt or mud fraction has denser pores than sand type substrate, so silt type substrate can hold organic material. The nature of this type of silt supports the life of macrobenthos because it provides organic material as a source of food for macrobenthic life.

Table 2. Material organic content of sediment for each sampling station

| Period/ Month | Station I (%) | Station II (%) | Station III (%) | Station IV (%) | Station V (%)|
|---------------|---------------|---------------|----------------|---------------|--------------|
| 1             | 9,25          | 9,7           | 11,1           | 10,72         | 8,19         |
| 2             | 11,85         | 8,81          | 10,82          | 11,94         | 10,77        |
| 3             | 10,02         | 9,6           | 11,34          | 13,37         | 12,04        |
| Averages      | 10,37         | 9,37          | 11,09          | 12,01         | 10,33        |

Table 3. Sediment grain size analysis for each sampling station.

| Station | Gravel (%) | Coarse sand (%) | Fine sand (%) | Silt (%) | Clay (%) |
|---------|------------|-----------------|---------------|----------|----------|
| 1       | 4,3        | 25,16           | 12,82         | 45,72    | 12       |
| 2       | 3,82       | 3,62            | 6,46          | 76,1     | 10       |
Environmental status assessed using the EWS-3SWJ software is based on biotic and abiotic factors in its analysis. Biotic factors are total abundance and number of species of macrobenthic community from studied sites, whereas abiotic factors are the result of measurements of physical-chemical factors in water and sediment properties. Additional weighing to assess the status is used by inputting the series of indices, including similarity (J), dominance (C), and diversity (H’) indices. Furthermore, opportunistic taxa or bioindicator are also calculated as additional information in assessing the status. By inputting all biotic and abiotic data, the environmental status and value will be revealed. Based on the EWS-3SWJ software, it was found that the environmental status of all stations are classified as Lightly Disturbed Areas. This status may be due to human and industrial activities, such as agriculture, tourism, port, and industry close to the sampling sites. Some of macrobenthic infauna found at studied sites were also considered as tolerant taxa (C. cingulata, T. telecopium) and sensitive taxa (Nassarius sp, B. violacea, S. bolocularis), thus may be used as indicator taxa.

### 3.4. Assessment of environmental status

**Table 4.** The status of environment for each sampling station based on EWS-3SWJ.

| Sampling Location | Environmental status          |
|-------------------|-------------------------------|
| Station I         | Lightly Disturbed Areas       |
| Station II        | Lightly Disturbed Areas       |
| Station III       | Lightly Disturbed Areas       |
| Station IV        | Lightly Disturbed Areas       |
| Station V         | Lightly Disturbed Areas       |

Environmental status assessed using the EWS-3SWJ software is based on biotic and abiotic factors in its analysis. Biotic factors are total abundance and number of species of macrobenthic community from studied sites, whereas abiotic factors are the result of measurements of physical-chemical factors in water and sediment properties. Additional weighing to assess the status is used by inputting the series of indices, including similarity (J), dominance (C), and diversity (H’) indices. Furthermore, opportunistic taxa or bioindicator are also calculated as additional information in assessing the status. By inputting all biotic and abiotic data, the environmental status and value will be revealed. Based on the EWS-3SWJ software, it was found that the environmental status of all stations are classified as Lightly Disturbed Areas. This status may be due to human and industrial activities, such as agriculture, tourism, port, and industry close to the sampling sites. Some of macrobenthic infauna found at studied sites were also considered as tolerant taxa (C. cingulata, T. telecopium) and sensitive taxa (Nassarius sp, B. violacea, S. bolocularis), thus may be used as indicator taxa.

### 4. Conclusion

Based on sampling data collected from all stations in three sampling times, there were 15 species of macrobenthos from 11 families. The composition of macrobenthos at the study site consisted of 4 classes, i.e. Gastropods (5 species), Bivalvia (4 species), Crustaceans (5 species), and Polychaeta (1 species), with various proportion of each species for each sampling station. The highest abundance is Station V, owing to the organic matter deposited from upstream to downstream of the river and tidal wave. The most common species found are Telescopium telescopium, Cerithidea cingulata, Metapenaeus sp. and Penaeus sp. In general, the physical chemistry of water is still in the normal range, except the dissolved oxygen (DO) which is classified as low and turbidity is classified as high. Assessed using the EWS-3SWJ software, all the sampling stations are classified as lightly disturbed areas, owing to human and industrial activities.

### Acknowledgement

The authors would like to thank Faculty of Science and Mathematics Diponegoro University. The study was supported by Center of Marine Ecology and Biomonitoring for Sustainable Aquaculture (CE-MEBSA), and Laboratory of Ecology and Biosystematics, Biology Department, Faculty of Science and Mathematics, Diponegoro University.

### References

[1] Putro S P 2014 *Metode Sampling Penelitian Makrobenthos dan Aplikasinya* [Research Sampling Method of Macroblenthos and Its Application] (Yogyakarta: Graha Ilmu)

[2] Ambariyanto 2011 *Biomonitoring Pencemaran Perairan* (Semarang: Badan Penerbit Undip)
[3] Pearson T H and R Rosenberg 1978 *Oceanography and Marine Biology Annual Review* 16: 229-311

[4] Putro S P 2010 *Environmental Quality Assessment of Fish Farming: Solutions Toward Sustainable Aquaculture* (Saarbrucken, Germany: Lambert Academic Publishing)

[5] Putro S P, Widowati and Anthony C 2018 *Malaysian Journal of Fundamental and Applied Sciences* 14(1) 78-82

[6] Clarke K R and R N Gorley 2006 *Primer v6: User manual/tutorial* (Plymouth: PRIMER-E Ltd)

[7] Putro S P 2016 *Konsep Aplikasi Budidaya Sistem Polikultur Terintegrasi Biomonitoring; Menuju Akuakultur Produktif Berkelanjutan* [Application Concepts of Polyculture Farming System Integrated with Biomonitoring: Towards Sustainable Productive Aquaculture] (Yogyakarta: Plantaxia)

[8] Weston D P 1988 *Continental Shelf Research* 8: 267-286

[9] Putro S P 2007 *Journal of Coastal Development* 10(3) 15-22

[10] Putro S P, Adhy S, Hariyati R, Prohastanti E, Hastuti E D, Koneri R, and Prabuwono S 2019 *Detecting Level of Environmental Disturbance Caused by Fish Farming Using Multivariate Analysis: Introducing EWS-3SWJ software.* IOP Conf. Ser.: Mater. Sci. Eng. xxxx *In Press.*

[11] Kariada N and Irsadi A 2014 *Jurnal Manusia dan Lingkungan* 21(2) 188-94

[12] Taqwa R N, Muskananfola M R and Ruswahyuni 2014 *Diponegoro Journal of Maquares* 3(1) 125-33

[13] Putro S P, Muhammad F, Aininnur A, Widowati and Suhartana 2017 *IOP Conf. Series: Earth and Environmental Science* 55 012-022

[14] Hamsiah, Djoko setiyanto D, Adiwilaga E M and Nirmala K 2002 *Jurnal Akuakultur Indonesia* 1(2) 57-63

[15] Khalil M, Ezraneti R, Jannatiah and Hajar S 2016 *Omni-Akuatika* 12(3) 88-97

[16] Isnaningsih R and Patria M P 2018 *Jurnal Biotropika* 6 (2) 35-44

[17] Salehi H, Pazira A R and Noorbakhsh H Z 2015 *AES Bioflux* 7(1) 70-81

[18] Ramakritinan C M, Chanduvelan R and Kumaraguru A K 2012 *Indian Journal of* 41(2) 141-45

[19] Pratiwi R 2008 *Oseana,* 33(2) 15-14

[20] Levin 1992 *Ecology* 73 1943-1967

[21] Saptarini D, Trisnawati I and Hadiputra M A 2010 *Struktur Komunitas Gastropoda (Moluska) Hutang Mangrove Sendang* [Structure of Gastropod Community (Mollusk) Sendang Mangrove Forest] Digilib ITS

[22] Halwany W and Andriani S 2015 *Indonesian Journal of Forestry Research* 2(2) 131-40

[23] Nangin S R, Langoy M L and Katili D Y 2015 *Jurnal MIPA UNSRAT Online* 4(2) 165-68

[24] Martuti N K T, Widianarko B and Yulianto B 2016 *Jurnal Kesehatan Lingkungan Indonesia* 17(1) 9-15

[25] Saputro J A, Hidayat J W and Hariyati R 2018 *Kandungan Kadmium (Cd) Pada Perairan Sungai Tapak Semarang* [The content of cadmium (Cd) in the waters of the Tapak River Semarang]. *Seminar Nasional Biologi Dan Pendidikan Biologi UKSW 2018*