HASIL CEK_Etika Dyah Puspitasari

by Etika Dyah Puspitasari 60160956

Submission date: 24-Oct-2022 10:34AM (UTC+0700)
Submission ID: 1933547882
File name: ek_Plagiasi_Etika_Dyah_Puspitasari_60160956_Jurnal_Sustinere.pdf (1.31M)
Word count: 6917
Character count: 36397

Sustinere
Journal of Environment and Sustainability
Volume 6 Number 2 (2022) 157-173

Print ISSN: 2549-1245 Online ISSN: 2549-1253
Website: https://sustinerejes.com E-mail: sustinere.jes@iain-surakarta.ac.id

RESEARCH PAPER

Environmental analysis of mangrove ecosystems in the southern coast of Purwodadi Subdistrict, Purworejo Regency, Central Java

Ika Feni Setiyaningrum[1]*, Etika Dyah Puspitasari[2]
[1]*Center for Science and Technology UIN Raden Mas Said Surakarta, Indonesia*
[2]*Department of Biology Education, Universitas Ahmad Dahlan, Indonesia*

Article history:
Received 16 November 2021 | Accepted 11 November 2022 | Available online 31 August 2022

Abstract. The southern coast of Purwodadi Subdistrict, Purworejo Regency, Central Java, has a mangrove ecosystem which is a part of nature conservation area. Unfortunately, some of the mangrove areas have been converted into ponds by the local community. This study aims to examine the current condition of the mangrove ecosystem, especially following land conversion activities, in terms of physical and biotic aspects. The results of this study can later be used as evaluation material to determine the best approach in sustainably managing the mangrove ecosystem. The method used in this study was the transect line plot for vegetation observation and in situ measurements to obtain physical water data. Aerial photographs were used to determine the area of existing mangroves and the overall state of mangrove vegetation. Data analysis of this study used vegetation index calculations and compared them with the guidelines from the Minister of Environment and Forestry Decree No. 201/2004 and No. 51/2004. This study indicates that the mangrove ecosystem of Purwodadi Subdistrict is in the brackish stream mangroves zone, which is located along with the brackish water flow until the area where the water is almost fresh (barely salty). The dominant vegetations are *Rhizophora mucronata* and *Nypa fruticans*. Except for the dissolved oxygen (DO) parameter, the measurement of the physical elements of the waters fulfills the quality criteria. This is due to the presence of shrimp pond waste in the mangrove waters. The salinity level in this area has a value below 10%, unlike the salinity value found in mangrove waters in general.

Keywords: mangrove; south coast; Purworejo; shrimp pond; *Sonneratia caseolaris*

1. Introduction

Mangrove deforestation is one of the most critical environmental issues in Indonesia, which leads to global climate change. Mangrove ecosystems can absorb more carbon than other forest types (Writers, 2011; Donato et al., 2012; Hudaya et al., 2014; Purnobasuki, 2012). The existence of the mangrove ecosystem mut be preserved in order for it to be sustainable. In addition, the mangrove ecosystem provides a variety of other benefits, including physical, biological and economic benefits.

Mangrove area in Indonesia ranks first in Asia, with more than three million ha (FAO, 2007). The area of mangroves in Indonesia is equivalent to 23% of the world's mangrove area, from

*Corresponding author. E-mail: ife.hamasah@gmail.com
DOI: https://doi.org/10.22515/sustinere.jes.v6i2.222

16,530,000 hectares (KLHK, 2017). Currently, the area of mangroves in Indonesia has decreased compared to the previous decades. Indonesia has seen the most extensive mangrove destruction in the world since the 1980s (FAO, 2007). Anthropogenic activities that contribute to mangrove deforestation include the development of residential and industrial areas (FAO, 2007; Dale et al., 2014; Faridah-Hanum et al., 2014; KLHK, 2017), tourism, agriculture (FAO, 2007; Faridah-Hanum et al., 2014), shrimp ponds (FAO, 2007; KLHK, 2017), fisheries (Dale et al., 2014; Faridah-Hanum et al., 2014), as well as mining and salt pond activities (Faridah-Hanum et al., 2014).

Among these anthropogenic activities, the conversion of mangroves into shrimp ponds is the dominant factor in causing damage and loss of mangroves in Southeast Asia, including Indonesia (Valiela et al., 2001; Giesen et al., 2007; Walters et al., 2008). This pond activity resulted in 1.72% decrease in mangrove forests in Indonesia between 2000 and 2012 (Richards & Friess, 2016).

Several studies on the analysis of mangrove damage have been investigated. Among them is the analysis of mangrove damage at the Pekalongan restoration center (Ario et al., 2016). In addition, the analysis of damage and changes in mangrove forests has been investigated using Landsat imagery by Haryani (2013) which was conducted in Probolinggo Regency. Suwargana (2008) conducted research on changes in mangrove forests using remote sensing in Pantai Bahagia, Muara Gembong, Bekasi. Research on the mangrove environment in Purwodadi District, Purworejo Regency, Central Java has also been conducted only in Gedangan Village (Rahayu et al., 2018) and there has never been a thorough study of the environmental conditions of the mangrove forest in the district.

The conversion of mangroves into shrimp and fish ponds is found in the southern coastal area of Purwodadi District, Purworejo Regency, Central Java. The conversion of mangrove function in this area has resulted in a significant reduction in mangrove stands (Rahayu et al., 2017). The damage to mangroves in Purworejo Regency, Central Java for trees is classified as damaged which is rare (Rahayu, 2017). Purworejo's mangroves are included in the nature conservation area, which protects life support systems while also preserving the diversity of plant and animal species and biological natural resources and their ecosystems (RTRW Kabupaten Purworejo, 2011). Furthermore, based on BNPB data (2013), the southern coastal area of Purworejo is at high danger of a tsunami disaster. The southern coast of Purworejo is ranked third in Central Java for tsunami thread (Kurniawan et al., 2014).

The idealism to attain sustainable mangrove ecosystem management by transforming the function of mangroves into shrimp ponds is an attractive issue to analyze in order to become a policy recommendation for the local government. Based on the results of field observations, the use of mangrove land to become ponds is mostly no longer operational for various reasons, particularly now. In several villages of Purwodadi Subdistrict, mangrove resources have been managed into ecotourism whose existence is of great interest to the community. Therefore, it is necessary to analyze the condition of the mangrove ecosystem in this area, both physically and biologically, to determine the best strategy for managing the mangrove ecosystem in the long term. The goal is that an appropriate mangrove management strategy would be able to preserve mangroves' ecological, economic, socio-cultural and disaster mitigation values.

2. Methodology

2.1. Study area

This study was conducted on the south coast of Purwodadi Subdistrict, Purworejo Regency, Central Java, from September 2018-May 2019. Based on the existence of the mangrove ecosystem, three villages were chosen as the focus of the research: Gedangan, Jatikontal and Jatimalang. The mangrove ecosystems in these three villages grow on each side of Kali Pasir, which extends from the Bogowonto River (Pasir Mendit Village, Kulon Progo Regency) towards the Cokroyasan River (Keburuhan Village, Purworejo Regency). The map of the study area can be viewed in Figure 1.

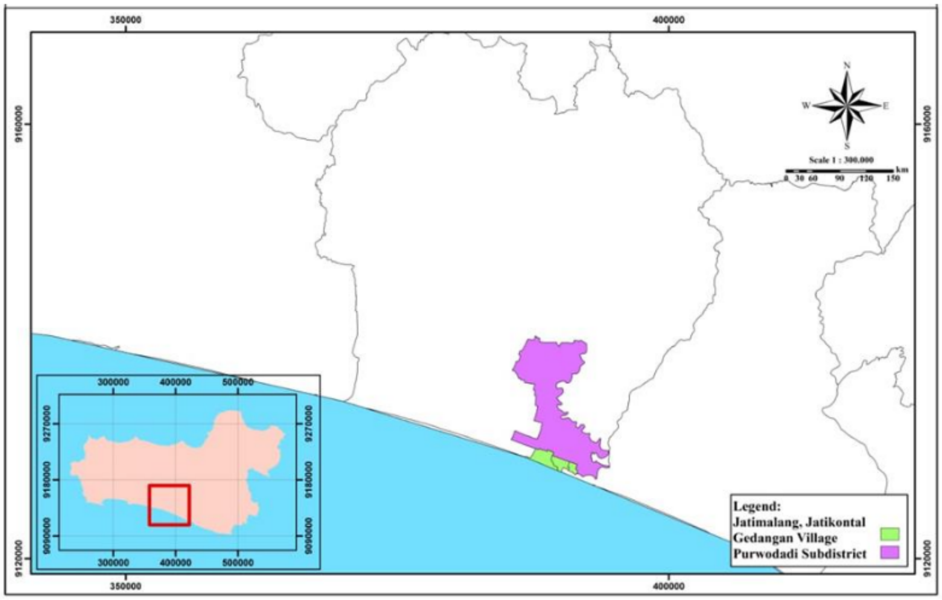

Figure 1. Map of the study area

2.2. Data collection technique

The condition of the mangrove ecosystem was examined from the physical and biotic aspects. Data on physical and biotic aspects of the mangrove ecosystem were collected through field observations. Measuring the physical parameters of water, including pH, temperature, dissolved oxygen (DO), and salinity, was carried out in situ. The physical parameters of the substrate were observed visually, and a literature review of prior investigations at this precise research location was conducted. The biotic aspect data collected includes identification of types, vegetation density and vegetation cover. The methods used were the transect line and plot sample (Transect Line Plot) following the Minister of Environment Decree No. 201 of 2004. Plot making was carried out at each research station in the three villages; station 1 was in Gedangan Village, station 2 in Jatikontal Village and station 3 in Jatimalang Village. The plot size was 10m x 10m with three plots in each station. There were three sub-plots of vegetation measurement in one plot along the transect line based on the regeneration rate of mangrove species, namely 2m x 2m for the seedling, 5m x 5m for the sapling and 10m x 10m for trees. Vegetation data were recorded after the plot was made by inventorying the species, including the names of the species, number and growth rate. Specifically for the tree and sapling, the diameter of the trunk was measured. The diameter of the stem was at a height of 1.3m above the ground or 10cm above the buttress or supporting roots if the tallest buttress or supporting root was located at the height of 1.3 m or more. The identification of mangrove vegetation refers to Noor et al. (2012). The aerial photography provides an accurate estimation of mangrove acreage and knowledge of mangrove health.

2.3. Data analysis technique

The results of the measurement of the physical condition of the mangrove ecosystem were compared with the quality standards of mangrove waters according to the Minister of

Environment Decree No.51/2004 on Sea Water Quality Standards. The biotic aspects were analyzed using specific indices in order to know the structure and composition of the stands, namely density, diversity index and evenness index (Onrizal, 2008; Rahayu et al., 2018).

Density

Density indicates the number of individuals of a species per unit area.
Density = (number of individuals of a species)/(area of sample plots/plots)

Diversity index

The diversity index is calculated using the Shannon-Wienner diversity index formula, which is as follows:

$$H' = -\sum \frac{ni}{N} \ln \frac{ni}{N}$$

H'= ShannonWiener's index of diversity
ni = the number of each *i*-th species
N = total number (overall) of individuals

Evenness index

The evenness index is calculated using the Evenness Index formula, which is as follows:

$$E = H'/(H\ max)$$

E = population evenness index
H '= diversity index
H max = maximum diversity index = ln S
S = number of individuals of all species

Biotic conditions were analyzed by comparing the measurement results obtained with the Minister of Environment Decree No.201/2004 on the Standard Criteria and Guidelines for Determining Mangrove Damage.

3. Result and discussion

3.1. Mangrove vegetation conditions

The mangrove ecosystems in these three villages were in the Brackish Stream Mangroves Zone. This zone was found along the brackish to almost freshwater flows (Giesen et al., 2007). The mangrove ecosystems in the three research locations in Purwodadi Subdistrict, Gedangan, Jatikontal, and Jatimalang, generally have different conditions. In Gedangan Village (station 1), the mangrove ecosystem was dominated by *Rhizophora mucronata* vegetation (Figure 2). In Jatikontal Village (station 2), the mangrove vegetation was dominated by *Nypa fruticans* species in the tree category and *Rhizophora mucronata* species in the sapling category. As for Jatimalang Village (station 3), the mangrove conditions were dominated by *Nypa fruticans* with greater density than in Jatikontal Village.

The distribution of mangroves in Purwodadi Subdistrict is mainly located on the riverbank, while a small portion was found in residential water bodies. The mangroves in these three villages were relatively thin, only around 9 meters (Figure 3).

According to the results of the calculation of mangrove area in the three villages, the largest area of mangroves is in Jatimalang Village, which has an area of 7.47 ha. In Jatikontal, the mangrove area was 4.72 ha. As for Gedangan Village, the mangrove area was only 1.02 ha. A mangrove area of 1.24 ha across the river in Gedangan Village, part of the Kulon Progo area, was also managed by the community.

Figure 2. Mangrove ecosystem in Gedangan Village, Purwodadi Sub-District

Table 1. Mangrove plant species found at the observation station

Species	Local name	Family	Mangrove type
Rhizophora mucronata	Bakau, bakung	Rhizophoraceae	Major mangroves
Sonneratia caseolaris	Bogem	Sonneratiaceae	Major mangroves
Nypa fruticans	Daon, ipah	Arecaceae	Major mangroves
Acrostichum aureum	Wrakas	Pteridaceae	Minor mangroves
Acanthus ilicifolius	Jeruju, drujon	Acanthaceae	Association mangroves
Derris trifoliata	Tali piting	Leguminosae	Association mangroves
Ipomoea pes-caprae	Kathang	Convolvulaceae	Association mangroves
Terminalia catappa.	Ketepeng	Combretaceae	Association mangroves

Purwodadi Subdistrict had eight mangrove species, based on observations and identification at the three stations (Table 1). There were eight mangrove species found in Purwodadi Subdistrict and three major mangroves *(Rhizophora mucronata, Sonneratia caseolaris*, and *Nypa fruticans*), one minor mangrove *(Acrostichum aureum*), and four related mangrove species *(Acanthus ilicifolius, Derris trifoliata, Ipomoea pes-caprae*, and *Terminalia catappa).* Figure 4 depicts morphological species discovered at the station.

3.2. Species Density

Density is one of the quantitative parameters used to determine the condition of mangrove vegetation. Density is the number of species per sample plot area (Onrizal, 2008). The density of mangrove vegetation in this study was calculated based on the level of trees, saplings and seedlings at each observation station.

In the tree category, the highest species' density value (Table 2) was *Nypa fruticans* at station 3. In the sapling category, the species *Rhizophora mucronata* has the highest density at station 1, and in the category of seedling and understorey, the highest density was *Derris trifoliata.*

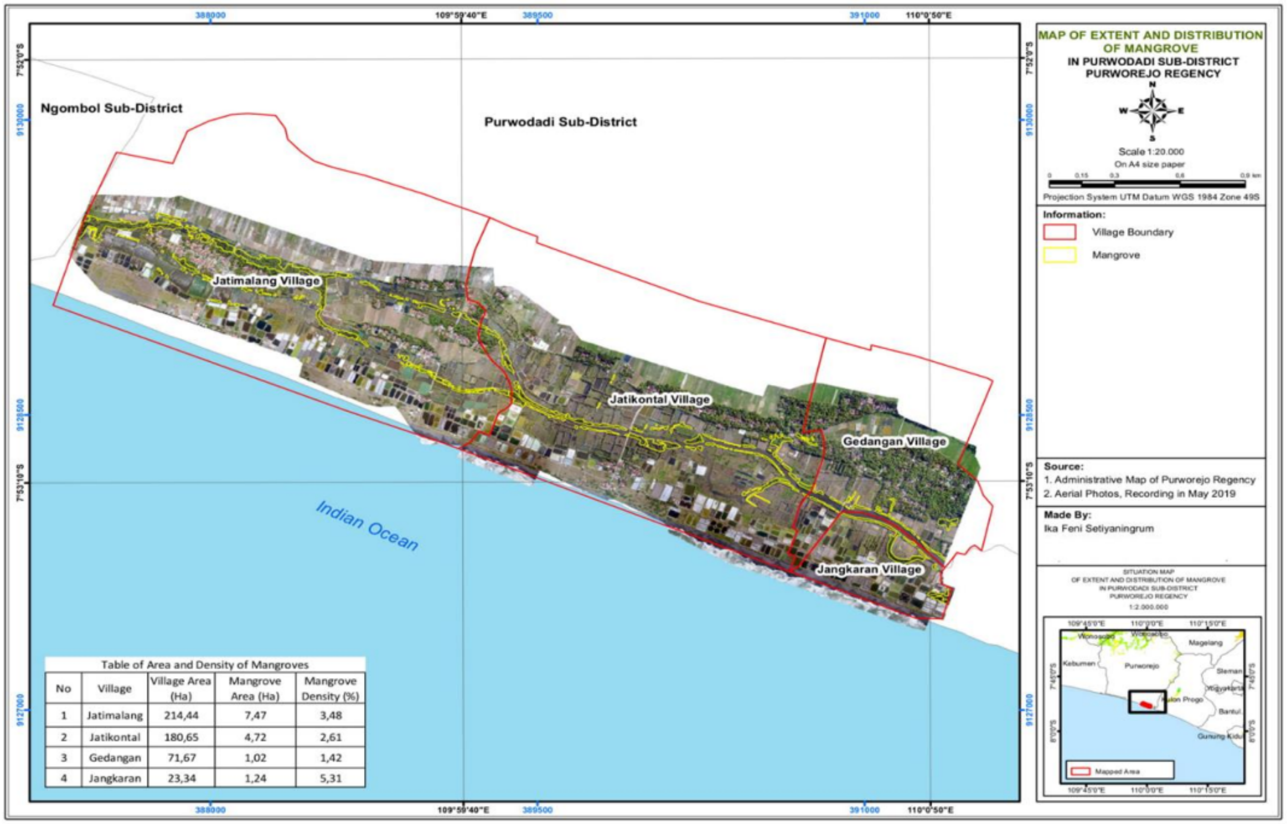

Figure 3. Map of the extent and distribution of mangrove in Purwodadi Sub-District

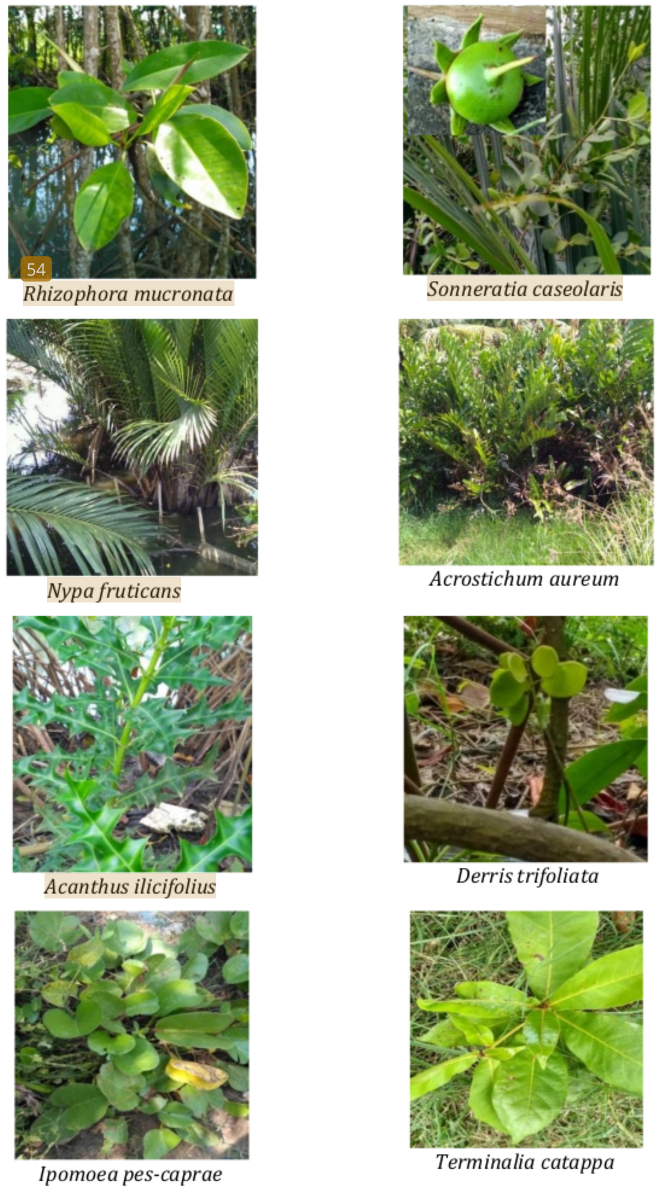

Figure 4. Species found at the observation stations

Table 2. The density of mangrove species in Purwodadi Sub-District

Species	Species Density (Ind/Ha)								
	Tree			Sapling			Seedling		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Rhizophora mucronata	533	333	275	4533	1633	0	0	167	250
Sonneratia caseolaris	33	67	300	0	0	125	0	0	0
Nypa fruticans	0	1667	3800	0	0	0	0	0	325
Acanthus ilicifolius	0	0	0	0	0	0	167	0	0
Derris trifoliata	0	0	0	0	0	0	500	567	175
Ipomoea pes-caprae	0	0	0	0	0	0	67	0	0
Terminalia catappa	0	0	0	0	0	0	33	0	50
Acrostichum aureum	0	0	0	0	0	0	0	0	50

When viewed per station (Figure 5), *Rhizophora mucronata* had the highest density in the sapling category at station one, Sonneratia caseolaris had the lowest density in the tree category, and *Terminalia catappa* had the highest density in the seedling category. The *Nypa fruticans* species had the largest density at station 2, whereas Sonneratia caseolaris species had the lowest. The species *Nypa fructicans* has the largest density at station 3, whereas *Acrostichum aureum* and *Terminalia catappa* have the lowest density.

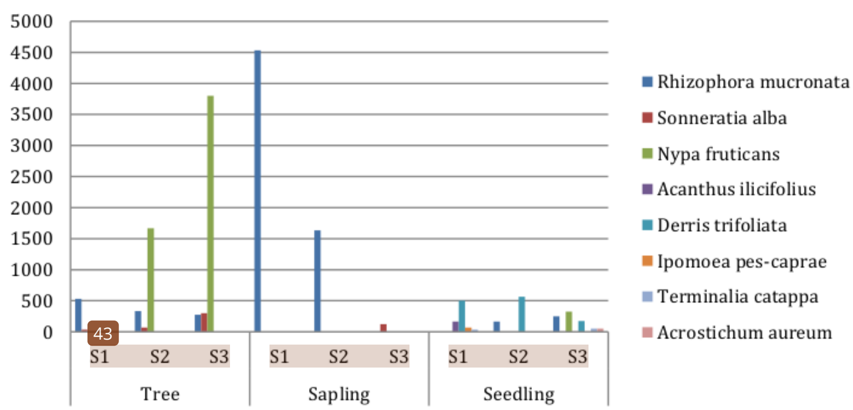

Figure 5. Density graph of mangrove species in Purwodadi Sub-District

Referring to the Minister of Environment Decree No. 201 of 2004, it can be seen that the sapling category at station 1 is classified as a dense category with the highest species density namely *Rhizophora mucronata* at 4,533 ind/ha. At station 2, *Nypa fruticans* species can be classified as dense, with the highest density of 1,667 ind/ha. Meanwhile, at station 3 is classified as dense, with the highest density value of *Nypa fruticans* species of 3,800 ind/ha.

The average vegetation density per observation station calculated was 1,955.4 ind/ha for station 1, 1,478.1 ind/ha for station 2 and 1,783.3 ind/ha for station 3. The vegetation at station 3 had the highest density compared to the other two observation stations. *Nypa fruticans* species contributed the highest density value compared to other species at this station because the salinity level of this station is the lowest compared to the other stations, even close to fresh condition, making *Nypa fruticans* the most suited species for life.

Furthermore, if the average density of mangrove vegetation at all stations is 783.7 ind/ha for seedlings and understorey, 2,097.2 ind/ha for spalings, and 2,336 ind/ha for trees. The high level of mangrove vegetation density in saplings indicates a good regeneration ability. However, seedlings were relatively rare due to the large number of seedlings that died. At station 1, where the majority of the vegetation was *Rhizophora mucronata*, 36 dead seedlings were found in a plot area of 10m x 10m. The high mortality rate related was caused by the presence of the turret shell, which ate the plants' roots and young stems, causing the plants to die. The same failure also happened to the mangrove rehabilitation program on the south coast of Kulon Progo, where many plants died because of turret shell (Sawitri et al., 2012). Turret shells are animals that eat mangroves (Sawitri et al., 2012, Haryatfrehni et al., 2015).

Based on the results of a research conducted by the Komangjo team from 2016-2018 in Kali Pasir, the number of turret shell pests found was 700-800/m^2. The high number of turret shells in Kali Pasir is triggered by the accumulation of shrimp pond waste, which is rich in organic materials and serves as its food source. In addition, turret shell predators, mud crabs, are regularly consumed by the surrounding community, implying that the presence of turret shells is becoming more common (interview with a Komangjo activist). It was combined with the annual floods caused by the estuary closing for about five months, leading to higher mortality in seedling mangroves. Stagnant water conditions due to the closure of the estuary by sand deposits endangers the growth of mangrove seedlings (Sawitri et al., 2012).


(a) Dead seedling


(b) Turret shell pests that eat mangrove roots


(c) Dead mangrove saplings


(d) Mangrove saplings that have collapsed in the wind and currents

Figure 6. Condition of mangroves at the observation stations

In addition to mangrove seedling deaths, mangrove saplings were damaged by turret shells eating root bark and being submerged by floods. When a puddle is flooded, the turret shell rises upwards to the higher stem to avoid water and then eats the bark, causing the mangrove stakes to collapse when blown by the wind or exposed to water currents. Figure 6 depicts the dying mangroves.

Mangrove damage was not only caused by the presence of turret shell or flooding. Anthropogenic factors are also the cause of mangrove damage, one of which is converting mangrove ecosystems into ponds (Figure 7). According to the observations of Setyawan et al. (2003), there was a limited number of activities to convert wet mangrove land into ponds at the mouths of the Lokulo, Cakrayasan, Bogowonto and Ijo rivers.

Figure 7. Photos of withered mangrove trees in Jatikontal Village

The results of aerial photographs can be used to map several locations where mangroves are damaged or believed to be unhealthy (Figure 8). Unhealthy mangroves comprising 0.04 ha in Gedangan, 0.32 ha in Jatikontal, and 0.39 ha in Jatimalang were discovered through these photographs.

3.3. Species Diversity Index

The species diversity index is calculated based on the Shannon index. The Shannon diversity index (Shannon's index) determines the diversity of species at the observation stations. The diversity index is calculated at each level of mangrove vegetation growth at each station. The calculation of the diversity index, as shown in Table 2, yielded the following results.

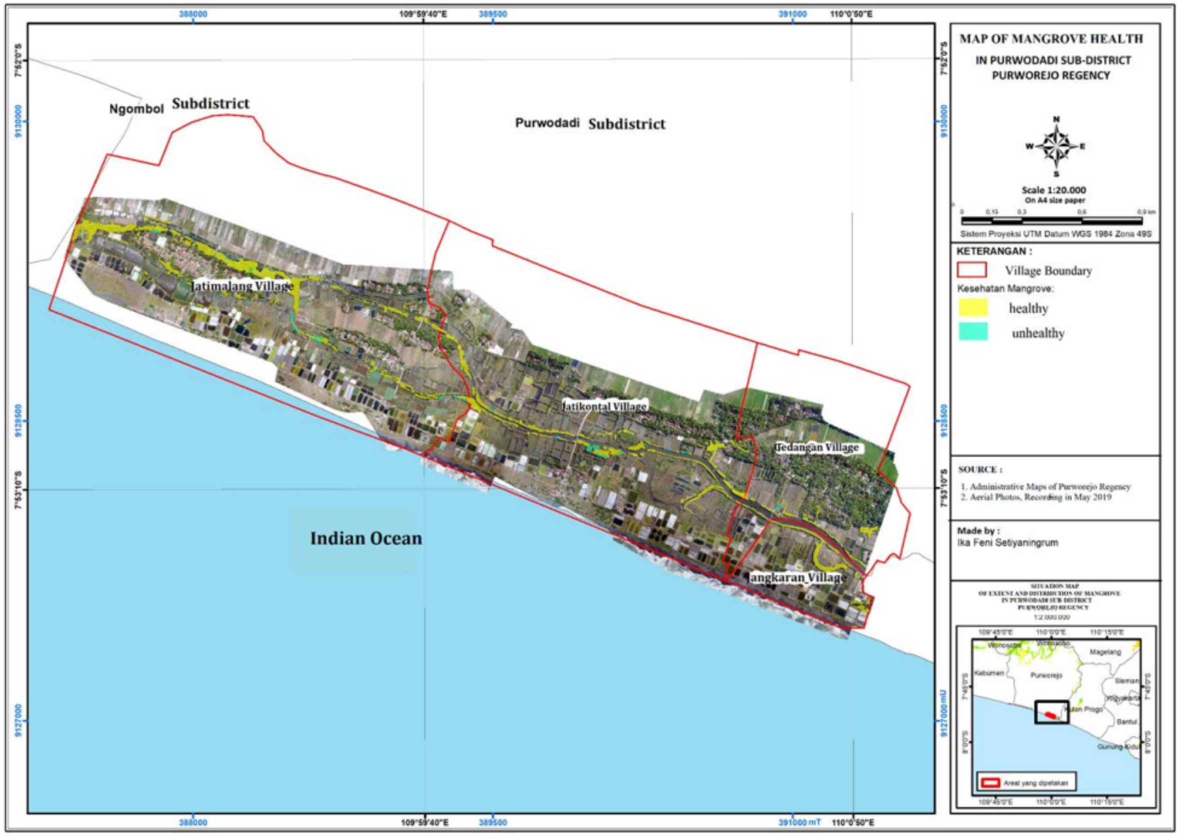

Figure 8. Map of mangrove's health in Purwodadi Sub-District

Table 2. Diversity index calculation results (H ')

Species Diversity Index	Station		
	Station 1 (Gedangan)	**Station 2 (Jatikontal)**	**Station 3 (Jatimalang)**
Tree	0,22	0,58	0,48
Sapling	0,00	0,00	0,00
Seedlings and understorey	0,96	0,54	1,39

Based on the calculation results, the highest diversity index value at station 1 was found in the category of seedlings and understorey, with a value of 0.96. At station 2, the highest diversity index value was found in the tree category, which was 0.58. As for station 3, the highest diversity index value was found in the seedlings and understorey category, which was 1.39.

From the calculation of the diversity index value (H'), it was found that the value is in the range of 0-2. According to Barbour et al. (1987) in Onrizal (2008), this value shows that vegetation diversity is low.

The value of H' at almost all stations, except for station 3 in seedlings and understorey, has a value of <1. According to Kent & Paddy (1992) in Mawazin & Subiakto (2013)), if the value of H' is <1, the vegetation is classified as poor. The H' value at station 3 is 1.39, which is in the range of 1-2, indicating that the vegetation community is in a stable environmental condition. The higher the value of the vegetation diversity index (H'), the greater the ecosystem's stability. Conversely, the lower the diversity index value, the lower the ecosystem's stability (Odum, 1996 in Mawazin & Subiakto, 2013).

The high number of one of mangrove species, *Rhizophora mucronata*, in the tree and sapling categories at stations 1 and 2, was due to the uniformity of the mangrove species planted during the rehabilitation program. This program has an influence on the current mangrove ecosystems' lack of stability. According to Setyawan et al. (2004), 12 species can be used for mangrove restoration, including *Rhizophora, Avicennia, Sonneratia, Bruguiera, Heritiera, Lumnitzera, Ceriops, Excoecaria, Xylocarpus, Nypa, Cassurina*, and *Hibiscus*. The selection of the species is determined by soil texture, salinity, duration of inundation and other micro-climates. Therefore, no single species should be dominant. The mangrove planting initiative should not rely solely on a single species.

The existence of *Rhizophora spp* species is the result of importation, hence they are not native to the south coast of Purwodadi District. According to the locals, the native mangrove vegetation in this area is Bogem (*Sonneratia caseolaris*) and Ipah (*Nypa fruticans*). This is consistent with the findings of Setyawan et al., (2008), who found that the Bogowonto area, a river mouth from mangrove vegetation in Purwodadi Subdistrict, has mangrove vegetation naturally dominated by *Sonneratia spp*. In addition, there were also *Nypa fruticans* that grow naturally. The large quantity of *Sonneratia spp* is due to the sandy-loamy texture of the soil on the south shore.

3.4. Species Evenness Index

The evenness index is used to determine the evenness level of species at the observation stations. Based on the calculation results (Table 3), the evenness index value at the three stations in the tree category has a value of> 0.3 and is in the range of 0.3-0.6. This value indicates that the level of stability of the diversity in the category is moderate. The evenness index value in the sapling category has a value of 0 (e '= <0.3), which means that the level of stability of the diversity of the species is low. The evenness index value in the seedlings and understorey category has a range of values of >0.6, which means that the level of stability of the species diversity is high (Magguran, 1988 in Mawazin & Subiakto, 2013).

Table 3.The Results of the Evenness Index Calculation

	The Evenness Index (e')		
	Station 1 (Gedangan)	Station 2 (Jatikontal)	Station 3 (Jatimalang)
Tree	0,32	0,83	0,44
Sapling	0,00	0,00	0,00
Seedlings and understorey	0,69	0,77	0,86

3.5. Abiotic Conditions

The physical condition of the waters directly influences the physical condition of the mangrove vegetation. Therefore, several parameters were measured using in situ techniques. Physical parameters measured include salinity, pH, temperature, DO and the type of substrate. The values in Table 4 below were derived based on the results of measurements of some of these parameters.

Table 4. Water environment parameters at the observation stations

Station	Plot	Parameters				
		Salinity (°/₀₀)	pH	Temperature (°C)	DO (mg/L)	Substrate
1	1	4,0	7,7	30,1	3,2	Sandy mud
	2	3,3	7,8	29,9	3,1	Sandy mud
	3	3,8	7,7	32,6	3,5	Sandy mud
2	1	2,8	7,7	31,8	3,1	Sandy mud
	2	3,0	7,7	32,6	2,6	Sandy mud
	3	2,1	7,7	31,9	2,1	Sandy mud
3	1	1,4	7,7	31,5	1,6	Sandy mud
	2	2,3	7,7	31,7	2,6	Sandy mud
	3	1,5	7,6	30,7	1,1	Sandy mud
	4	0,4	7,5	29	0,2	Sandy mud

3.6. Salinity

The salinity conditions at station 1 ranged from 3.3‰ to 4.0‰, those at station 2 from 2.1‰ to 3.0‰, and those at station 3 from 0.4‰ to 2,3‰ (Table 4). The salinity value of the waters in this area is classified as low and is not the same as the salinity value of mangrove waters in general. Mangroves are generally found in habitats with salinities ranging from 10-30‰ (Aksornkoae, 1993), with mangrove seedlings growing in salinities ranging from 5-30‰ (Hastuti & Budihastuti, 2016). Based on the results of previous studies that measured the salinity of mangrove waters at the mouth of the river Bogowonto, Kulon Progo, which is the estuary of Kali Pasir, low salinity values were around 4-5‰ during low tide in the rainy season, and had a salinity value of 0‰ during inundated conditions (Sawitri et al., 2012). Although *Acrostichum aureum* is a plant that grows well in areas of high salinity, it is also capable of growing in areas of low salinity (Medina et al., 1990). The adaptation of *Acrostichum aureum* plants with high salt content is to accumulate salt in the leaves. *Acrostichum aureum* plants were found in the form of seedlings at the location of this study. Salinity is important for seedling growth (Hastuti & Budihastuti, 2016). Tanjung et al. (2017) stated that the salinity value of the Kulon Progo coast ranged from <0.5 ppt to> 3.0 ppt. Djohan (2000) in Sawitri et al. (2012) also reported that the salinity conditions decreased to close to 0‰ when the Bogowonto River lagoon was inundated because it was dominated by freshwater. The lagoon waters have a salinity range of 4-14‰ during the rainy season. Because the Kali Pasir flow at the three observation stations emptied into Bogowonto, the salinity value was not much different from the measurement results in the waters of the

Bogowonto estuary. The three observation stations that are further away from the river mouth naturally have lower salinity values. Another study that also carried out salinity measurements in Gedangan Village found that the salinity values in mangrove waters were ranging from 6-7.6 ppt (Rahayu et al., 2018). Therefore, it can be concluded that the salinity of mangrove waters on the south coast of Purworejo is indeed low and is below the salinity value of mangroves in general, which are usually from 10-30 ppt.

In these conditions, the *Sonneratia caseolaris* vegetation can tolerate growth, even at a salinity of less than 0.1%. On Pulau Kaget and Pulau Kembang at the mouth of the Barito River in South Kalimantan or the mouth of the Singkil River in Aceh, *Sonneratia caseolaris* is more dominant, especially in the estuary, whose water is barely salty (Giesen et al., 2007). *Nypa fruticans* were also found at the observation stations, with a higher density away from the river mouth, which aligns with Noor et al. (2012)'s discovery that mangroves along brackish to almost fresh rivers are usually dominated by the *Nypa* or *Sonneratia* vegetations. *Nypa* plants can even live in inland areas far from river flows (Giesen et al., 2007). According to Watson (1928) in Friess (2017), *Nypa* can live in areas inundated by seawater twice a month. *Rhizophora* can survive in this area because it has adapted to its surroundings. However, with a low salinity value, the carrying capacity for the growth of this species is classified as moderate (Sawitri et al., 2012).

Referring to the Decree of the State Minister for the Environment Number 51 of 2004 on Sea Water Quality Standards for mangrove ecosystems, the salinity of mangrove waters in the three stations is still within a reasonable range for mangrove growth, which is up to 34‰. When comparing stations, station 3 has a lower average salinity than station 2; similarly, station 2 has a lower average salinity than station 1. This is due to the observation stations' distance from the river estuary bordering the sea. Station 3 is the furthest away from the river mouth, while station 1 has the closest distance to the river mouth. The farther from the sea, the lower the salinity value because the volume of seawater inflow decreases and freshwater inflow increases.

3.7. pH

Station 1 has an average pH value range of 7.7 - 7.8, station 2 has a pH value of 7.7 while station 3 has an average pH value range of 7.5 - 7.7 (Table 4). Referring to the Decree of the State Minister for the Environment Number 51 of 2004 on Sea Water Quality Standards for mangrove ecosystems, these numbers are within a reasonable range for mangrove growth (7.0 - 8.5). The pH range of 4.7-11 is ideal for the growth of *Rhizophora mucronata* seedling (Hastuti & Budihastuti, 2016). The pH value obtained from this test is also not significantly different from Rahayu et al.'s (2018) research on the mangrove ecosystem in Gedangan Village, which ranges from 7.30 - 7.90. The pH of the waters in the mangrove ecosystem of Dudepo Island, Gorontalo, fluctuates from 6.5 to 7.4 (Usman et al., 2013). When the pH is low, the absorption of N elements is impeded. The pH tolerance range for mangrove growth is between 6.0-9.0, with an optimal pH between 7.0-8.5 (Wantasen, 2013). *Sonneratia caseolaris* plants can thrive in a pH range of 7-8.5 (Ronavia et al., 2020).

3.8. Temperature

Surface temperature in the mangrove waters of Purwodadi District (Table 4) at observation station 1 has an average value range of 29.9°C-32.6°C, station 2 has an average value of 31.8°C-32.6°C, and station 3 has an average value averages range of 29^{0}C-31.7°C. The average temperature value of the three stations is acceptable for mangrove life because according to the Decree of the Minister of Environment Number 51 of 2004, mangroves should not grow in water temperatures less than 20°C. According to Aksornkoae (1993), mangroves can grow well in tropical areas with temperatures above 20^{0}C.

3.9. Dissolved Oxygen (DO)

Based on Table 4, the DO conditions at station 1 have an average value of 3.1 -3.5 mg/L, station 2 has an average DO value ranging from 2.1-3.1 mg/L, and station 3 has an average DO value ranging from 2.1 to 3.1 mg/L. DO levels varied from 0.2-2.6 mg/L. Compared to the quality standard, the DO value of the three stations was lower, which was less than 5 mg/L. Nonetheless, mangroves could still persist in that location. According to Aksornkoae (1993), DO levels in waters may vary depending on the time, season, the amount of plants and aquatic organisms that live in mangroves. In some locations with low DO levels of 1.0-2.0 mg/L, aquatic organisms can survive because they can adapt.

DO conditions at station 3 were lower compared to other stations because the waters at station 3 were polluted by shrimp waste accumulated over a long period of time. Furthermore, nipah leaves that had fallen from the trees and rotted were discovered in these streams. Because of the narrow river width factor which lowers the DO value, river water cannot flow in large volumes compared to rivers at the other two stations. According to Salmin (2005), the diffusion rate of oxygen from free air, which is a source of dissolved oxygen in the waters, depends on several factors, including water turbidity, temperature, salinity, movement of water and air masses, such as currents, waves and tides.

3.10. Substrate

The substrate found at the observation station was sandy mud (Table 4). This substrate is suitable for mangrove life. The mangrove substrate in sandy mud at the research locations is similar to that found by Rahayu et al., (2018), who also investigated Gedangan Village. In addition, based on the research results by Setyawan et al., (2008), the Bogowonto area, which is the mouth of a river in Purwodadi Subdistrict, has a sandy-loamy texture. This type of substrate is ideal for the growth of the species such as *Rhizophora spp.* and *Sonneratia spp.*, although *Sonneratia spp.* dominated more because the south coast's substrate was dominated by sand. According to Ronavia et al. (2020), *Sonneratia caseolaris* grows well on substrates with a sandy-clay texture. *Nypa fruticans* can also grow well in this area because the type of the substrate is sand and clay (Ng & Sivasothi, 2001).

4. Conclusion

The mangrove ecosystems in the three research locations in Purwodadi Subdistrict, namely in Gedangan, Jatikontal, and Jatimalang, generally have different conditions, both from the biotic and physical aspects. *Rhizophora mucronata* and *Nypa fruticans* make up the majority of the vegetation present in Purwodadi Subdistrict. The further away from the estuary, the greater the number of *Nypa fruticans* species such as those found in Jatimalang Village. *Rhizophora mucronata* species are abundant in villages along the estuary, particularly Gedangan Village. The high density of *Rhizophora mucronata* is attributed to the government's restoration initiative. The results of the measurement of physical factors in mangrove waters meet the quality standards for mangrove ecosystems, except for the dissolved oxygen (DO) parameter. The buildup of shrimp pond waste that enters the river waters causes the low DO value. In terms of salinity parameters, this area has a lower salinity value compared to mangrove ecosystems in general, which is less than 10‰. The existence of turret shell pests, the annual flooding due to the closure of river estuaries and anthropogenic factors all have an impact on the growth of mangroves in this area.

Acknowledgement

The authors would like to express their gratitude to LPDP or the Indonesian Endowment Fund for Education for their support and funding. We would like to thank Rizki Setiawan who served as our field assistant. We are also grateful to the informants who participated in the study.

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