Vegetation analysis of mangrove rehabilitation in the BeeJay Bakau Resort, Probolinggo City, East Java, Indonesia

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Abstract. Mangroves are plants that can live in ecosystems with high salinity and are affected by waves and tides of seawater. The unique adaptability of mangroves allows them to become one of the contributors to aquatic productivity. Mangroves are susceptible to growing in habitats contaminated with waste, especially solid waste. This study aims to investigate the rehabilitation of mangrove vegetation. The research was conducted at three research stations representing the rehabilitation mangrove ecosystem in the mangrove area of BeeJay Bakau Resort, Probolinggo City, East Java, Indonesia. The mangrove vegetation data were collected using a systematic sampling technique based on the transect plot. Analysis of mangrove vegetation includes species density, relative density, species frequency, species relative frequency, species cover, species relative cover, and index of importance. The analysis showed three mangrove species found at the research stations, namely *Rhizophora mucronata*, *Rhizophora stylosa*, and *Avicennia marina*. The Importance Value Index (IVI) of mangroves at the three research stations showed that *A. marina* had the highest IVI value in both the tree and sapling categories. The condition of the aquatic environment in the area is classified as good, where the values of temperature, salinity, and pH can support mangrove growth well.

Key Words: environmental characteristics, importance value index, mangrove vegetation, Probolinggo.

Introduction. The mangrove ecosystem is one of the most productive coastal ecosystems affected by tides in tropical and subtropical climates (Kathiresan & Bingham 2001; Ariana et al 2014). These ecosystems have complex functions, such as physical functions, biological functions (spawning grounds, nurseries, feeding areas, germplasm, and genetic sources), and socio-economic functions. As a coastal ecosystem with high biological productivity, mangroves provide a natural habitat for numerous fish species. Various mangroves species will support the diversity and abundance of animal resources, such as fishes and shrimps (Eddy et al 2016). Biotic processes consisting of succession and abiotic factors consisting of nutrient availability, physiochemical conditions, soil composition, tidal inundation affect the abundance of mangrove species in coastal forests (Strauch et al 2012).

Mangrove ecosystems are essential ecosystems that maintain coastal areas' balance (Baderan et al 2019). Apart from protecting the coast from physical processes such as tides, currents, and waves (Mullarney et al 2017), this ecosystem also acts as an organic matter producer. Mangrove litter is a source of organic matter that increases aquatic productivity (Rahman 2016). High litter production is an important factor because it is a valuable component of the food chain in mangrove ecosystems (Bengen 2001; Ashton et al 1999) and exports the resulting nutrients to the surrounding aquatic ecosystem through the interaction of tidal dynamics and river discharge (Harborne et al 2006).

As a coastal area, Probolinggo City has a mangrove area of 90 hectares, located close to the coastal fishing port (PPP) of Mangunharjo Village, Mayangan District, Probolinggo City. The mangrove ecosystem in this area was previously a waste disposal area with degraded conditions. This area is managed and rehabilitated into a tourist attraction named BeeJay Bakau Resort (BJBR). Rehabilitation activities can restore the function of damaged mangrove ecosystems (Pribadiningtyas 2013). Seeing the potential of the mangrove ecosystem and the lack of data on the mangrove ecosystem rehabilitation at BJBR, this research was conducted to investigate the contribution of the rehabilitation results to the restoration of the coastal environment in the mangrove area of BeeJay Bakau Resort through mangrove vegetation analysis.

Material and Method

Description of the study site. This research was conducted in the mangrove area of BeeJay Bakau Resort, Probolinggo City, in December 2020 (Figure 1). The environmental conditions of each station are shown in Figures 2, 3, and 4.

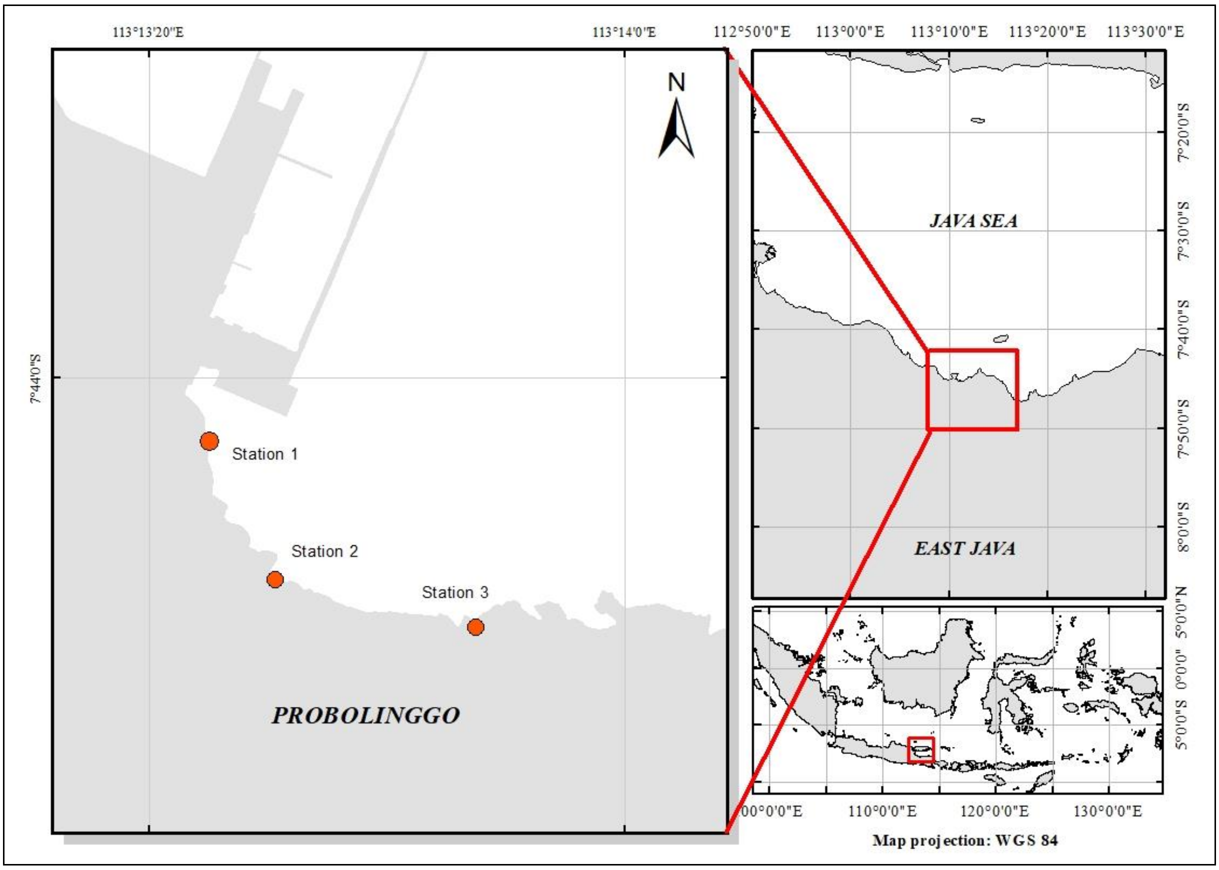

Figure 1. Research location in the mangrove ecosystem area of BeeJay Bakau Resort, Probolinggo (generated using QGIS Version 3.24).

Figure 2. Environmental conditions at station 1.

Figure 3. Environmental conditions at station 2.

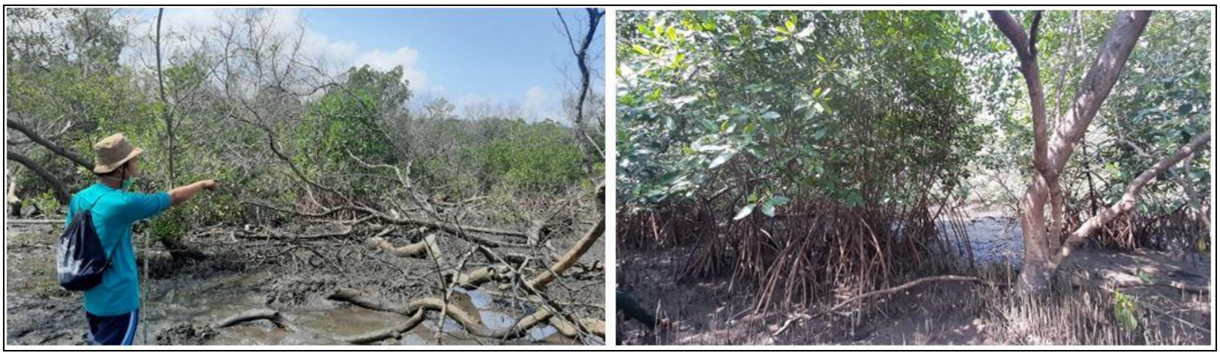

Figure 4. Environmental conditions at station 3.

In the research location, 3 (three) research stations were established, where at each station, 3 (three) line transects were stretched, and on each line, transect 3 (three) quadratic transects (plots) were placed as locations for the data collection on mangrove vegetation. The transect line is placed perpendicular to the coastline from the sea to each research station's land—placement of the transect line representing each mangrove zoning in the research location. The distance between research stations is as far as 300 meters, and the distance between line transects at each research station is as far as 50 meters.

Data collection. Mangrove data collection, which includes the species and number of mangroves stands, was carried out at each research station on each quadratic transect and systematically placed along the line transect. Mangrove vegetation is divided into three categories, namely trees, saplings, and seedlings (Figure 5). Data collection for mangrove tree categories was carried out on quadratic transects measuring 10 m × 10 m, seedling categories on quadratic transects measuring 5 m × 5 m placed in 10 m x 10 m transects, and seedling categories using quadratic transects measuring 1 m × 1 m placed in a 5 m x 5 m quadratic transect (Bengen 2001). The measurement of parameters of water environmental conditions at each research station including water temperature, salinity, and pH was repeated three times.

Data analysis. According to the calculation of mangrove vegetation starting from species density (Di), relative density (RDi), species frequency (Fi), the relative frequency of species (RFi), species cover (Ci), relative species cover (RCi), and Importance Value Index (IVI) (Hotden et al 2014; Ariyanto et al 2018).

Species density (Di) is the number of mangrove stands of species "i" in an area unit. The calculation of mangrove species density is used as a reference for planting locations that prioritize areas with the lowest density. The formula for determining the density of mangrove species is (Snedaker & Snedaker 1984):

$$Di = \frac{Ni}{A}$$

where: Di - density of species "i" (stands.m^{-2}); Ni - Total number of stands for species "i"; A - Total area of the quadratic transect (m^2)

The relative density of species (RDi) is the ratio between the number of stands for species "i" (Ni) and the total number of stands of all species (Ʃn) in percentage units. The relative density formula is:

$$RDi = \frac{Ni}{A} x\ 100\%$$

where: RDi = Relative Density (%); Ni - Number of stands for species "i"; ∑n - Number of all stands.

The species frequency (Fi) is the probability of finding an "i^{th}" species in all quadratic transects. This calculation is carried out to know the species of mangroves that are often found in quadratic transects of mangrove data collection so that the dominant mangrove species in the research location can be identified. The formula for species frequency is:

$$Fi = \frac{pi}{\sum p}$$

where: Fi - Frequency of the "i^{th}" species; pi - Number of quadratics transects found species i; ∑p - total number of quadratics transects for data collection.

The relative frequency (RFi) is the ratio between the frequency of species "i" (Fi) and the total frequency of all species (∑F). The formula for relative frequency is:

$$RFi = \frac{Fi}{\sum F} x\ 100\ \%$$

where: RFi - Relative frequency of species "i" (%); Fi - Frequency of the "i^{th}" species (stands); ∑F - Total frequency of all species (stands).

The species cover (Ci) is the area of the ith species cover in an area. This calculation is carried out to reference planting locations that prioritize areas with the lowest density and cover. The formula used for species cover is:

$$Ci = \frac{\sum BA}{A}$$

where: Ci - Area cover of species "i"; BA - 3.1416 x DBH (tree diameter) 2/4; A - The total area of the quadratic transect (plot).

Relative species cover (RCi) is the ratio between the cover area of species "i" (Ci) and the total cover area for all species (∑ C) in percentage units. The formula for determining relative cover is:

$$RCi = \frac{Ci}{\sum C} x\ 100\ \%$$

where: RCi - Relative cover of species "i" (%); Ci - Area cover of species "i"; ∑C - The total area covered by all species.

The Importance Value Index (IVI) is the sum of the values for species relative density (RDi), species relative frequency (RFi), and species relative cover (RCi). This calculation is carried out to determine the priority mangrove species for planting in future planting efforts. The formula for determining the importance value index is:

$$INP = RD_i + RF_i + RC_i$$

The importance of a species ranges from 0% - 300% for trees. This IVI value provides an overview of the role of a mangrove species in the mangrove community.

Results and Discussion. The results showed that there were 3 (three) species of mangrove vegetation at the research location, which belonged to two families. The overall identified species of mangrove vegetation can be seen in Table 1.

Table 1

Species of mangrove vegetation at each research station in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Station 1*	*Station 2*	*Station 3*
1	*Rhizophora mucronata*	Rhizophoraceae	√	√	√
2	*Rhizophora stylosa*	Rhizophoraceae	√	√	-
3	*Avicennia marina*	Avicenniaceae	√	√	√

Note: (√) = found, (-) = not found.

Table 1 shows that *Rhizophora stylosa* is only found at stations 1 and 2, while *R. mucronata* and *A. marina* are found at the three research stations. Of the three stations, station 3 gets the most significant tidal impact.

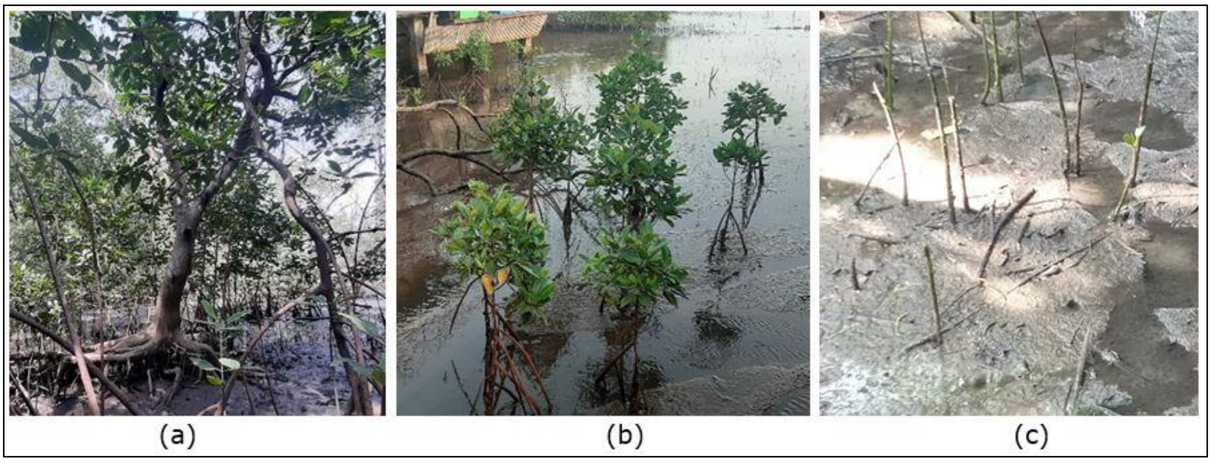

Figure 5. Trees (a), saplings (b), and seedlings (c) in research location Beejay Bakau Resort, Probolinggo.

The mangrove vegetation community structure can be seen from the importance value index and diversity index of the mangrove vegetation community constituents. The following is the percentage composition of mangrove vegetation with growth categories, as presented in Table 2.

Table 2

Percentage of mangrove vegetation composition in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Number of Stands*	*Composition (%)*
1	*Rhizophora mucronata*	Rhizophoraceae	78	30,58
2	*Rhizophora stylosa*	Rhizophoraceae	39	13,40
3	*Avicennia marina*	Avicenniaceae	161	56,01
	Total		278	100

Table 2 shows that *Avicennia marina* has the highest number of stands, than the other two mangrove species in the BeeJay Bakau Resort mangrove area, namely 163 stands with a percentage of 56.01%. *Rhizophora stylosa* species had the lowest number of stands, at 37 stands (13.40%).

The data from Table 3 found that the highest relative density was in the seedling category at 52.51%, dominated by *Rhizophora mucronata*. The highest relative density in the sapling category was occupied by *Avicennia marina*, with 53.42% in the middle zone, which supported *Avicennia marina* species' growth and density. The highest relative density was found in *Avicennia marina* in the tree category with a value of 64.96%.

Table 3

Relative density of mangrove growth categories in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Seedling (%)*	*Sapling (%)*	*Tree (%)*
1	*Rhizophora mucronata*	Rhizophoraceae	52.51	46.58	25.98
2	*Rhizophora stylosa*	Rhizophoraceae	25.93	0.00	9.06
3	*Avicennia marina*	Avicenniaceae	21.57	53.42	64.96
	Total		100	100	100

The relative cover value of each species at the research location is shown in Table 4. *Rhizophora mucronata* in the seedling category had the highest relative cover with a value of 75.07%. In contrast, in the category of saplings, *Avicennia marina*'s highest relative cover was occupied with a value of 60.85%, similarly for the tree category with a value of 76.35%.

Table 4

Relative cover of mangrove vegetation species in the tree, sapling, and seedling growth categories in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Seedling (%)*	*Sapling (%)*	*Tree (%)*
1	*Rhizophora mucronata*	Rhizophoraceae	75.07	39.15	17.10
2	*Rhizophora stylosa*	Rhizophoraceae	17.57	0.00	6.55
3	*Avicennia marina*	Avicenniaceae	7.36	60.85	76.35
	Total		100	100	100

Based on the analysis results, the relative frequency values of mangrove vegetation species at each research location can be seen in Table 5.

Table 5

Relative frequency of mangrove vegetation species in the tree, sapling, and seedling growth categories in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Seedling (%)*	*Sapling (%)*	*Tree (%)*
1	*Rhizophora mucronata*	Rhizophoraceae	66.67	33.33	33.33
2	*Rhizophora stylosa*	Rhizophoraceae	16.67	0.00	6.67
3	*Avicennia marina*	Avicenniaceae	16.67	66.67	60.00
	Total		100	100	100

Table 5 shows that the highest relative frequency value for the seedling category was dominated by *Rhizophora mucronata* with a relative frequency value of 66.67%. In the seedling growth category, *Avicennia marina* is occupied with a relative frequency value of 66.67%. *Avicennia marina* seeds can survive because they are supported by environmental factors such as substrate, water salinity, and water temperature compared to other species of mangroves. In the tree growth category, *the Avicennia marina* is also occupied with a relative frequency value of 60.00%.

The significance of IVI indicates the importance of a particular species of vegetation in the community and ecosystem (Diyah et al 2019). *Avicennia marina* occupied the highest percentage value than other species, with 201.31%. IVI for the sapling growth category with the highest value was *Avicennia marina* (180.94%). In the seedling category was *Rhizophora mucronata* with a value of 194.25% (Table 6). From the mangrove species above, the *Avicennia marina*, which has the highest value, indicates that this species can regenerate and adapt well to the mangrove environment conditions, such as salinity, temperature, and substrate factors.

Table 6

Importance value index for growth categories of tree, sapling, and seedling growth categories in the BeeJay Bakau Resort area, Probolinggo

No	*Species*	*Family*	*Seedling*	*Sapling*	*Tree*
1	*Rhizophora mucronata*	Rhizophoraceae	194.25	119.06	76.42
2	*Rhizophora stylosa*	Rhizophoraceae	60.16	0.00	22.27
3	*Avicennia marina*	Avicenniaceae	45.59	180.94	201.31
	Total		300	300	300

The results of the Importance Value Index (IVI) of mangroves showed that there were differences in the IVI values of each category, both categories of trees, saplings, and seedlings. It illustrates that the influence of a species in the mangrove community is different from each category. The tree category had the highest IVI value compared to the category of saplings and seedlings. It is influenced by the more excellent cover value of the species, resulting in a higher IVI. According to Raymond et al (2010), the effect of a population on communities and ecosystems depends not only on the species of organisms involved but also on the population's number or density. The aquatic environment's condition at the research location at each station can be seen in Table 7. At each research station, parameters were measured three times.

Table 7

Water environment parameters at each station in the BeeJay Bakau Resort area, Probolinggo

No	*Parameter*	*Station 1*			*Station 2*			*Station 3*		
1	Temperature (^{o}C)	30.9	29.4	30.0	31.7	30.2	30.5	31.1	32.9	32.3
2	Salinity ($^{o}/_{oo}$)	3.0	3.1	1.9	4.0	3.5	2.1	3.0	3.2	0
3	pH	8.1	8.4	8.5	8.83	8.34	7.89	7.25	7.72	7.93

The temperature at the study site ranged from 29.4^{o}C to 32.9^{o}C. Salinity values range from 0 to 3.2$^{o}/_{oo}$, while the pH ranges from 7.25 to 8.83. Environmental conditions at each research station are classified as suitable for mangrove growth, substrate conditions, temperature, pH, and salinity. This pH value range is still within the tolerance limit for mangrove growth. In general, mangroves can live at a pH ranging from 5.0–8.5. The existing substrate in the research location belongs to the class of silty clay or dusty clay substrate. The characteristic of clay soil is that when it is dry, it will be hard. The salinity value at each station tends to below. It is because the three stations are affected by the abundance of freshwater from the land. It is also due to rainy weather conditions that reduce salinity levels in the BeeJay Bakau Resort area. According to Su et al (2020), temperature and saltiness alter quickly day by day (high/low tide) and regularly in mangrove environments. The development of mangroves must involve versatile procedures to flourish in such a physiologically challenging environment.

Conclusions. The area of BeeJay Bakau Resort is dominated by three mangrove species, *Rhizophora mucronata*, *Rhizophora stylosa*, and *Avicennia marina*. The tree category had the highest IVI value compared to the category of saplings and seedlings. There is a difference in the IVI value between research stations, where *A. marina* has the highest IVI value in both the tree and sapling categories. The condition of the aquatic environment in the area is classified as good, where the values of temperature, salinity, and pH can support mangrove growth well.

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Conflict of Interest. The authors declare no conflict of interest.

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