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Impact of Revegetation of *Rhizophora apiculata* and *Rhizophora stylosa* on The Development of Mangrove Vegetation in Teluk Jor, East Lombok

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Abstract. Mangrove degradation has become a source of awareness, especially the government, such as the Indonesian government. This study aims to assess the effect of planting *Rhizophora apiculata* and *Rhizophora stylosa* on the growth and development of mangrove species diversity that grows naturally in Teluk Jor, East Lombok. Methods of data collection using the method of observation and transects. Furthermore, the first data were analyzed using descriptive statistics, and the second was the importance of value index analysis and Shannon-Wiener (H') analysis. In this study, five new species were found besides *Rhizophora apiculata* and *Rhizophora stylosa*. The new species are *Avicennia marina*, *Ceriops tagal*, *Lumnitzera racemosa*, *Sonneratia alba*, and *Sonneratia casidaris*. Furthermore, the highest index of importance was *Sonneratia alba* (tree 239.26, sapling 136.57, and seedling 66.89), and the lowest was *Lumnitzera racemosa*. Meanwhile, the diversity index is in the medium category, namely 1.451. In this case, the revegetation of two mangrove species in the study location significantly impacts mangrove vegetation growth and development. Therefore, the mangrove revegetation model in Teluk Jor can reference mangrove conservation in other areas.

Keywords: Mangroves, Revegetation, Mangrove Species Richness, and Conservation.

1. Introduction

Indonesia has 3,244,018 ha of mangrove forests and a potential area for planting mangroves of 7,758,411 ha, with 30.7% mangrove forests in good condition, 27.4% moderately damaged, and 41.9% heavily damaged [1]. The term "mangrove" refers to ecosystems or individual plants [2,3]. Mangrove forest zoning is strongly influenced by substrate, salinity, and letter pairs [4,5,6]. Degradation of mangrove forests, especially in Indonesia, is due to the development of brackishwater ponds and exploitation of wood that has significantly contributed to the destruction of mangrove ecosystems [7]. The loss of mangroves is associated with anthropogenic and natural causes [8,9].

The leading causes of loss of mangrove forests due to urban development, over-harvesting, and shrimp farming have resulted in the loss of 20 to 50% of mangroves worldwide [10]. Also, the rate of mangrove deforestation is the highest in Indonesia (52,000 ha yr⁻¹) [11], which has resulted in the loss of nearly 800,000 ha of forest in just 30 years. So far, mangrove revegetation in Indonesia has only been carried



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out using one type of mangrove, namely from the genus *Rhizophora* spp [12,13]. Naturally, mangroves have specific zoning based on plant types suitable for living in the mangrove ecosystem [14,15]. The natural zoning of mangroves from sea to land generally consists of the *Avicennia* and *Sonneratia* zones, the *Rhizophora*, and *Bruguiera* zones, the *Lumnitzera* zone, and the *Nypa* zone [16,13]. Mangrove zoning significantly affects both physically and ecologically, especially on the survival of the mangrove association biota [17]. This can be demonstrated by evaluating the structure of mangrove vegetation in areas that have been rehabilitated [18].

Naturally, two mangrove ecosystems with similar environmental conditions will have similar mangrove vegetation structures [13,14]. Mangroves that a planted need at least 50 years to grow and develop to function like natural mangrove forests [19]. The success of replanting mangroves on the South Coast of East Lombok has a positive impact on environmental restoration, as seen from the diversity of fauna [20]. In this regard, of the study's objectively to assess the impact of planting *Rhizophora apiculata* and *Rhizophora stylosa* on the growth and development of natural mangrove species in Teluk Jor, East Lombok. The results of this research can be used as a benchmark in assessing previous mangrove revegetation programs' success and conducting conservation activities in various areas that have degraded mangrove ecosystems, especially on the islands of Lombok, Sumbawa, and mangrove in Indonesia.

2. Methods

The research location is Teluk Jor, East Lombok (Figure 1). The research was conducted for 5 months from January to May 2020 in Teluk Jor, East Lombok. The research used is descriptive research with an explorative orientation. The research location has two seasons. The eastern season in the local tradition is called summer or dry season (April-November) and the west season is called the rainy season (December-March). The total area of mangrove areas in the southern part of the coast of Lombok Island is 596.03 ha [21], and the area of mangrove vegetation in the study location is 61.52 ha.

The research sample was determined by using the purposive sampling method; this method is based on certain considerations. The study population was all mangrove communities, and the research samples were all types of mangrove categories in the research plot. The research sample was taken as many as 5 points with different location conditions, where T1 and T5 are near the sea, T2 and T4 are near ponds and densely populated settlements, and T3 is close rivers.

Mangrove vegetation data were collected using the transect method. The research location is divided into 5 points; at each observation point, a line transect is drawn perpendicular to the 100 m long coastline. Then, for each transect, sample plots (squares) were made. Next, identify all mangrove species in the square, count the number of tree stands, the number of saplings, and the number of seedlings/tillers. Measure the stem's circumference, where the measurement is taken at the chest height of an adult (DBH = 1.3 m from ground level). Each rod was measured using a sewing meter and then recorded for each type.

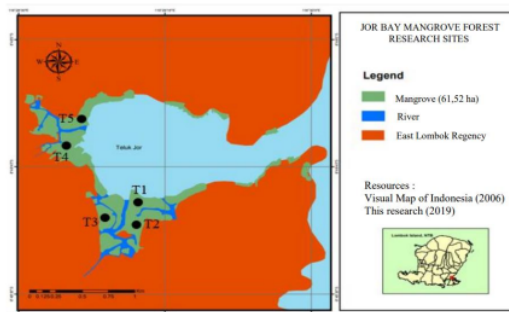


Figure 1. Map of Teluk Jor.

The line transect method is a method to determine the types of natural forest vegetation. The transect is drawn perpendicular to the 100 m long coastline. Then, from the data obtained, analysis and importance value index and diversity index (H') were carried out. The Shannon-Wiener diversity index (H') is calculated by the formula [22], as follows:

$$H' = -\sum P_i \ln P_i, \text{ when } P_i = \frac{n_i}{N}$$

The importance value index is used to determine the types that have the most important role. The significance value of a species ranges from 0-300. The formula is as follows [23]:

$$INP = KR + DR + FR$$

3. Results and Discussion

3.1. Composition of Mangrove Plant Types

The mangroves in Teluk Jor were identified as many as four families Aviceniaceae, Sonneratiaceae, Rhizophoraceae, Combretaceae from seven species *Avicennia marina*, *Sonneratia alba*, *Sonneratia casidaris*, *Rhizophora stylosa*, *Rhizophora apiculata*, *Ceriops tagal*, and *Lumnitzera racemosa*. Sonneratiaceae is the most dominant of all other individuals by life stage (tree 29%, sapling 60%, and seedling 11%). The composition of mangrove species is dominated by members of the Sonneratiaceae family, which constitute 54% of the study location's total species. Three families of natural mangrove species were found (Aviceniaceae, Combretaceae, and Sonneratiaceae). In comparison, one family Rhizophoraceae is a species planted when the mangrove forest is damaged. The number of mangrove species in the research location is higher than that in Maitara Island, North Maluku, which consists of four species (*Rhizophora apiculata*, *Rhizophora mucronata*, *Rhizophora stylosa*, and *Sonneratia alba*) [24]. The same research reports natural mangrove forests Pemongkong is dominated by *Sonneratia alba* [25]. This supports that the mangroves in Teluk Jor have been thriving in revegetation to become natural mangroves after being damaged.

Table 1. Composition of mangrove species (trees, saplings, and seedlings) on each transect.

Species	Category														
	Tree (10x10)					Sapling (5x5)					Seedling (2 x 2)				
	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5	T1	T2	T3	T4	T5
<i>S. alba</i>	25	9	14	17	5	14	1	91	16	12	-	-	11	12	5
<i>S. casidaris</i>	-	-	3	-	-	-	-	19	-	-	-	-	-	-	-
<i>R. apiculata</i>	-	4	-	1	-	10	58	-	1	7	-	33	-	-	4
<i>R. stylosa</i>	2	-	-	-	-	10	-	-	-	-	10	-	13	-	-
<i>C. tagal</i>	-	-	-	-	2	-	-	17	-	13	-	-	-	-	2
<i>L. racemosa</i>	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-
<i>A. marina</i>	-	-	-	-	2	-	10	-	-	2	-	-	10	-	-
Total Number	84				291					100					

Information : T (Transect)

3.2. Mangrove community structure

The results showed that *Sonneratia alba* species had the highest index of importance for all stages of mangrove growth (Figure 2). Furthermore, the lowest importance value index was *Lumnitzera racemosa*. It can be seen that the vegetation structure in the Teluk Jor mangrove ecosystem is also composed of *Ceriops tagal* species, even though the area is the result of revegetation with the species *Rhizophora* spp. The presence of *Ceriops tagal* indicates that naturally, this species can overgrow in the area. This shows that *Ceriops tagal* is a very suitable species for living with environmental conditions in Teluk Jor.

Related to the mangrove community structure is the value of the Importance Value Index (INP). The importance value index shows how vital a plant species is to its ecosystem [14]. Also, the heterogeneity of the type, size, or diameter of the tree trunks and the distance between trees is marker natural ecosystems [11]. Meanwhile, the *Sonneratia alba* species can reach a climax community [26]. Apart from the index of importance, the diversity index is an essential parameter in a vegetation study. The diversity value of a community depends on the number of species and the number of individuals. In this case, the general diversity index will be high on the community composed of many types, and no species dominate.

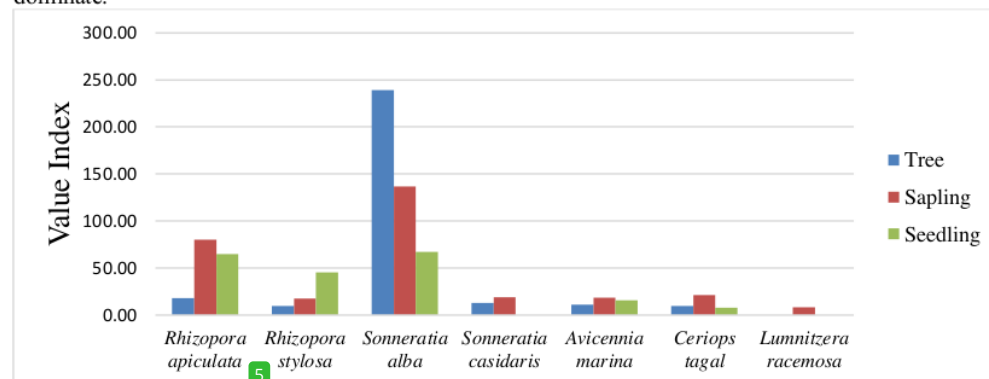


Figure 2. Important value index of mangrove species at the study location

Conversely, species diversity will be low if the community comprises few species and dominant species [27]. The mangrove vegetation diversity index in Teluk Jor is classified as moderate at 1.451 (table 2). Compared with the diversity index in Gili Sulat, which is 2.246, the mangrove vegetation index in Teluk Jor has a smaller value [28]. The high diversity index in Gili Sulat is due to the high uniformity of species in that location, and none of them dominate. In contrast, the Teluk Jor area has less species uniformity, meaning that the number of individuals for each species is not the same, so certain species tend to be dominated.

Table 2. Mangrove diversity index value.

No	Species	Number of Individuals	Pi	In Pi	Pi . In Pi
1	<i>Rhizophora apiculata</i>	118	0.251	-1.382	-0.347
2	<i>Rhizophora stylosa</i>	35	0.074	-2.597	-0.193
3	<i>Sonneratia alba</i>	232	0.494	-0.706	-0.348
4	<i>Sonneratia casidaris</i>	22	0.047	-3.062	-0.143
5	<i>Avicennia marina</i>	24	0.051	-2.975	-0.152
6	<i>Ceriops tagal</i>	34	0.0672	-2.637	-0.189
7	<i>Lumnitzera racemosa</i>	10	0.021	-3.850	-0.082
Number Total		475			-1.451
		H'			1.451

The vegetation of an ecosystem always gets influence from the environment. The physical and chemical characteristics of the environment are listed in table 3. Overall, the five transects did not differ significantly in environmental factors, except for salinity and substrate depth. The difference in depth and into the substrate causes the dominant vegetation to grow at various growth rates in the area to be different. As though the *Rhizophora* spp is suitable for living in areas with muddy to sandy mud substrates [13,14]. Therefore, in this study, it can be assumed that mangroves' environmental conditions

are suitable for the growth of natural species and revegetated species (*Rhizophora apiculata*, and *Rhizophora stylosa*).

Table 3. Physical and chemical characteristics of the mangrove ecosystem in Teluk Jor.

No	Environmental Parameters	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5	Average
1	pH	7	7	6	6.6	6.8	6.6
2	Salinity (%)	33	33	30	25	25	29.2
3	Temperature (°C)	29	29	28	28	28	28.4
4	Substrate depth (cm)	35	33	30	25	20	28.6
5	Substrate type	Muddy					

On the other hand, the dominance of each mangrove species indicates the substrate condition and the success of planting *Rhizophora* spp. For example, *Sonneratia alba* is one of the dominant from the Sonneratiaceae family. This shows that the species is capable of breeding in the Teluk Jor area. The dominance of this type of mangrove is related to the substrate conditions suitable for the growth and development of two families (Aviceniaceae, Combretaceae). This indicates revegetation activities' success mangrove revegetation is fauna diversity [29]. Also, several elements need to be considered in conservation management, including the surrounding community's involvement. Replanting must involve mangrove species that are locally available according to the zone where they grow naturally.

4. Conclusion

The Indonesian government has done a lot of mangrove revegetation through replanting, especially in Lombok island. This study shows that the Rhizophoraceae family can increase the growth and stability of the mangrove ecosystem on the south coast of East Lombok. Further research on the suitability of an area for planting with the Rhizophoraceae family needs to be carried out for the replanting program.

5. Acknowledgments

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