The Evidence of Rhizophora as a Potential Species to Improve Mangrove Recovery on the Southern Coast of East Lombok, Indonesia

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The Evidence of *Rhizophora* as a Potential Species to Improve Mangrove Recovery on the Southern Coast of East Lombok, Indonesia

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Mangroves are essential for coastal protection and as the habitats of marine organisms. The present study aims to evaluate the potential of some mangrove species of Rhizophoraceae in supporting the recovery and development of mangrove ecosystem on the southern coast of East Lombok, by assessing the mangrove species diversity at several locations where planting activities had been carried out 28 years ago. Primary data collected from quadrat sampling along line transects were further analyzed to determine the diversity and distribution indices of the mangrove species. The results showed that the mangrove species belonged to five families, namely Rhizophoraceae, Acanthaceae, Lythraceae, Meliaceae and Combretaceae. Rhizophoraceae, the most dominant family in the mangrove community with individuals of all life stages inclusive, encompassed 2.39% of the trees, 15.90% of the saplings, and 15.30% of the seedlings sampled. Jor Bay had the highest diversity index at 1.5, and Lungkak recorded the lowest value of diversity index (0.9). The values of these parameters indicated mangrove recovery on the southern coast of East Lombok. The development of mangrove communities dominated by members of Rhizophoraceae on the southern coast of East Lombok indicated the success of mangrove replanting activities that have been carried out more than 25 years ago. It also explained the potential of Rhizophoraceae for the recovery of coastal ecosystems.

Keywords: mangrove community; potential recovery; environment and conservation

I. INTRODUCTION

The term "mangrove" can refer to either the ecosystem or individual plants (Tomlinson, 2016). Mangroves are a taxonomically diverse group of salt-tolerant plants which normally grow above mean sea level in the intertidal zones of marine coastal environments (Ellison & Stoddart, 1991). The distribution of mangrove species is affected by temperature, protected coastlines, currents, substrate types, shallow shores, water salinity and tidal range (Chapman, 1977). In addition, the mangrove ecosystem provides environmental services for biodiversity sustainability (Ellison, 2008; Nagelkerken *et al.*, 2008).

The degradation of mangrove forests, especially in Indonesia, is caused by the development of brackish water ponds since 1800. In addition, timber exploitation has contributed greatly to the destruction of mangrove ecosystems (Ilman *et al.*, 2016). On a global scale, mangrove loss is attributed to anthropogenic and natural causes (Vannucci, 2004). The problems faced in protecting the mangrove ecosystem from degradation include population growth in coastal area, global climate change, sea-level rise, drought, freshwater flooding, erosion/shoreline abrasion, and conversion of mangrove forests into shrimp ponds (Brown, 2007; Ellison, 2008). The major causes of mangrove loss, such as conversion to

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agriculture, urban development, over harvesting and shrimp aquaculture accounted for the loss of 20 to 50% of mangroves worldwide (McLeod & Salm, 2006). It was estimated that in Indonesia, the existing mangrove forest area was 3,244,018 ha and the potential area to be planted with mangroves was 7,758,411 ha, with 30.7% of the mangroves in good condition, 27.4% moderately destroyed and 41.9% heavily destroyed (Faridah-Hanum *et al.*, 2012). Besides that, the highest mangrove deforestation rate in Indonesia (52,000 ha yr^{-1}) could be closely associated with shrimp pond expansion and shrimp production trends over the past three decades (Murdiyarso *et al.*, 2015), which has caused the loss of nearly 800,000 ha of forest in only 30 years. Most of the mangrove lands were converted into ponds, of which many are now in the form of low productivity or abandoned ponds (Ilman *et al.*, 2016).

The mangroves were shown to be very adaptive to extreme conditions in the coastal area (Rajapati *et al.*, 2017). In view of the importance of mangroves in the coastal area, mangrove replantation efforts had been attempted in Indonesia, including Lombok. However, planted mangrove requires at least 50 years to develop for it to perform similarly as the natural mangrove forests in stand structure, spatial arrangement of selected stand characteristics and species associations (Luo *et al.*, 2010). Although the mangrove plantations in Lombok are only less than 30 years old, local communities have been using the ecological services from the mangrove ecosystem as a source of livelihood (Al Idrus *et al.*, 2018). Preliminary observations indicated that one of the dominant species in the mangrove forests on the southern coast of Lombok was *Rhizophora stylosa*. The dominance of *R. stylosa* was thought to be related to the mangrove planting activities carried out in the early 1990s.

In this regard, this study was carried out with the aim of evaluating the potential of *Rhizophora* in improving mangrove ecosystem recovery, by assessing the mangrove species diversity at several locations on the southern coast of Lombok where replanting activities had been carried out 28 years ago. The findings could be a benchmark in assessing the success of previous mangrove rehabilitation programmes and conducting conservation activities in various regions that suffer a high level of mangrove ecosystem degradation, especially in Lombok and Sumbawa Islands of the West Nusa Tenggara.

II. MATERIALS AND METHODS

The study was conducted from April 2017 to October 2018 at six study sites of three locations spanning 116°27'0"–116°30'0" S and 8°48'0"–8°51'0" E on the southern coast of East Lombok, namely location I (Tanjung Luar, Kedome, and Lungkak), location II (Poton Bako and Jor Bay), and location III (Ekas Bay) (Figure 1). These study sites were where mangrove planting activities had been carried out in the early 1990s.

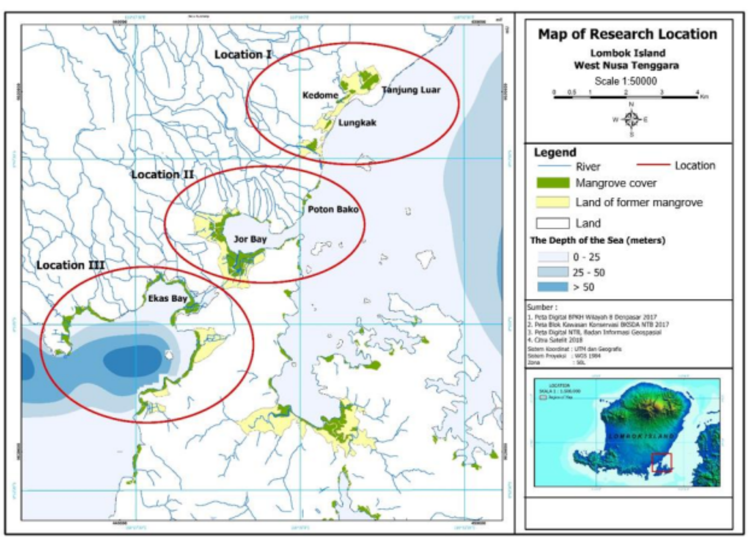

Figure 1. Map showing research locations

The study was carried out in two stages: (1) the documentation of information on the causes for declining mangrove areas, the mangrove replantation, and the proportion of planted mangrove species and, (2) the assessment of the impact of mangrove planting. In the first stage, data were obtained through a survey with 100 participants from May 2017 to September 2017, using a questionnaire in the form of semi-structured and open questions, direct interviews, and in-depth interviews to obtain qualitative and quantitative information (Guba & Lincoln, 1994). Respondents were chosen based on the following criteria: (1) having a residence close to the locations of mangrove replantation areas, i.e. villagers around the study sites, (2) the age of respondents were over 45 years old and, (3) have knowledge on mangroves. Data obtained were analyzed descriptively.

The second stage of the study involved the assessment of the impact of mangrove planting activities. The area of sampling plot at each site was 2 ha per site, with 6 ha at location I, 4 ha at location II, and 2 ha at location III. These sampling areas were long-standing permanent plots allocated for the research and educational purposes of Mataram University. The line transect method with quadrat sampling technique was used to obtain data at each site (Mueller-Dombois & Ellenberg, 1974). Observation of each sampling unit on permanent transect was made with three quadrats of different sizes: 20 m × 20 m for trees, 10 m × 10 m for saplings, and 5 m × 5 m for seedlings. There were three sampling units per site, giving a total of nine quadrats at each site. The mangrove species diversity at all sites was assessed from the number of species present (species richness) and their relative abundance (dominance or evenness). The number of individuals at different life stages (tree, sapling and seedling) of each mangrove species at each study site was assessed. In addition, environmental conditions such as substrate depth, soil pH, water pH, dissolved oxygen and salinity at each study site were assessed. The analysis of mangrove community data included analysis of diversity index (H′) and distribution index (ID).

The Shannon-Wiener diversity index (H′) was calculated with the following formula:

$$H' = -\sum (p_i \ln p_i) \quad (1)$$

where p_i is the proportion of individuals belonging to the ith species in the dataset (Odum, 1983).

The Morisita distribution index (ID) was calculated with the following formula:

$$\text{ID} = \frac{n(\sum x^2 - N)}{N(N-1)} \quad (2)$$

where n = number of sampling plots, N = number of individuals in n plots, and x = number of individuals in each plot. A distribution index of 1.0 indicates random distribution of individuals, while that less than 1.0 indicates individuals are evenly distributed and that greater than 1.0 indicates clustered distribution of individuals (Brower *et al*., 1990).

III. RESULTS AND DISCUSSION

A. History of Mangrove Planting

According to the respondents, mangroves in the study locations were damaged due to the conversion of land into ponds and salt fields. In addition, natural factors such as abrasion also caused the decline in mangrove areas. The most dominant factor in accelerating mangrove area damage according to respondents was land conversion to salt fields (Figure 2). Land conversion took place between 1970 and the late 1980s. However, after the conversion of mangrove forests into fishponds and salt fields, most of the fields were unproductive. Such land conditions became the reason for the implementation of mangrove planting in the early 1990s by the East Lombok Regency government and NGOs together with the local community.

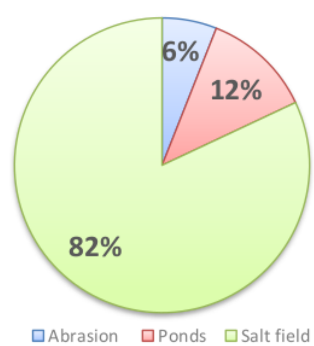

Figure 2. Causes of mangrove damage in the study area based on survey

The total area where mangrove planting was carried out at each study site was shown in Table 1. According to the respondents, *Rhizhophora stylosa* and *R. mucronata* were the mangrove species planted at that time. The planted seedlings comprised 92% of *R. stylosa* and 8% of *R. mucronata* at each site. The re-establishment of mangrove areas in the study locations since the planting activities were carried out in the early 1990s until now was quite significant, especially in the former salt fields and ponds. Based on the results of the assessment using satellite imagery and field observations, the current coverage area of mangrove was 30.01 ha at location I, 61.52 ha at location II and 110.04 ha at location III. The total coverage area of the three study locations made up 33.81% of the total mangrove area on the southern coast of Lombok Island, which covered an area of 596.03 ha.

Table 1. Total area of mangrove plantation at each study site based on survey

Study site	Mangrove plantation area (ha)
Location I	
Tanjung Luar	6
Kedome	4
Lungkak	4
Location II	
Poton Bako	4
Jor Bay	4
Location III	
Ekas Bay	8

B. Composition of Mangrove Species

Ten mangrove species of the families Rhizophoraceae, Acanthaceae, Lythraceae, Meliaceae and Combretaceae were identified at all study sites, with five from Rhizophoraceae (*Rhizophora stylosa*, *R. mucronata*, *R. apiculata*, *Ceriops decandra* and *Bruguiera cylindrica*), two from Acanthaceae (*Avicennia marina* and *A. lanata*), and one each from Lythraceae (*Sonneratia alba*), Meliaceae (*Xylocarpus moluccensis*) and Combretaceae (*Lumnitzera racemosa*). Based on Table 2, Rhizophoraceaae which consisted of five species was most dominant with individuals of all life stages inclusive (2.39% of trees, 15.90% of saplings, and 15.30% of seedlings), followed by Acanthaceae (34.48% of trees, 13.79% of saplings, and 12.17% of seedlings) and Lythraceae (61.62% of trees, 30.03% of saplings, and 16.86% of seedlings). The remaining two families were less dominant, with Meliaceae represented 1.87% of trees, 25.26% of saplings and 13.92% of seedlings, and Combretaceae only found as a small fraction of seedlings (1.85%) in Jor Bay. Of the present study sites, Jor Bay was most species-rich with eight mangrove species, and Tanjung Luar was the least speciose with three species recorded (Table 2). The composition of mangrove species was dominated by members of the family Rhizophoraceaae which constituted 50% of the total number of species in the study locations.

The study area in East Lombok showed the same number of mangrove species as that in Barangay Imelda, Dinagat Island, Philippines (Cañizares & Seronay, 2016). Both study sites were similar in having five mangrove species in the most speciose family, Rhizophoraceae. However, the mangrove species found in this study were included in five families, while those in Barangay Imelda, Philippines were included in six families. These numbers were lower than the number of mangrove species found in Thailand's Welu Estuary which consisted of 26 species, with 15 of them considered as true mangroves (Suk-ueng *et al.*, 2013).

When comparing the mangrove species diversity in different parts of Indonesia, a higher species diversity was reported at Segara Anakan mangrove forest in Cilacap, Central Java compared to the present study site by having 24 mangrove species in 19 families (Widyastuti *et al.*, 2018). However, the number of mangrove species in the present study site was higher than that in Maitara Island, North Maluku, which consisted of four species namely, *R. apiculata*, *R. mucronata*, *R. stylosa* and *Soneratia alba* (Subur & Sarni, 2018).

C. Diversity and Distribution of Mangrove Species

Diversity and distribution of mangrove species at each sampling site was shown in Figure 3. The highest diversity index value was found in Jor Bay at 1.5, followed by Poton Bako and Kedome, both recorded the same value of 1.4. Meanwhile, Lungkak showed the lowest diversity index value of 0.9. The distribution index values at the study sites ranged from 1.0 to 1.8, with the highest value found in Lungkak and the lowest in both Poton Bako and Jor Bay. The differing values of the vegetation parameters, diversity and distribution index, could be caused by various factors including differences in the characteristics of habitat at each site. One of the most important factors in determining the level of distribution of mangroves is the movement of water, especially that originating from the mainland (Duke *et al.*, 1998). In line with this, as shown in Figure 3, the highest mangrove distribution index was in Lungkak compared to other study sites. The clustered distribution of mangrove species in Lungkak may be due to the existence of two river mouths in the area. Most mangrove species are dispersed by water-buoyant propagules, allowing them to take advantage of the estuarine, coastal and ocean currents both to replenish the existing stands and to establish the new ones. Each species will also differ in the establishment success and growth development rate, with tolerance limits and growth responses which are apparently unique. Such attributes are presumably responsible for the characteristic distributional ranges of each species, in response to the physical and biotic environmental settings (Duke *et al.*, 1998).

Table 2. The composition of mangrove species based on the number of individuals of different life stages (tree, sapling and seedling) at each sampling site.

Mangrove species	**Location I**									**Location II**						**Location III**		
	Tanjung Luar			**Kedome**			**Lungkak**			**Poton Bako**			**Jor Bay**			**Ekas Bay**		
	Tree	**Sapling**	**Seedling**	**Tree**	**Sapling**	**Seedling**	**Tree**	**Sapling**	**Seedling**	**Tree**	**Sapling**	**Seedling**	**Tree**	**Sapling**	**Seedling**	**Tree**	**Sapling**	**Seedling**
Rhizophora apiculata						600						133		66	800		150	1800
Rhizophora mucronata								25			200	1066			533			
Rhizophora stylosa	8	33	133	2	50	400		25	200		300	266		66	800	3	46	400
Bruguiera cylindrica					50	200												
Ceriops decandra									133						266			200
Avicennia marina	10	11	23	20		4	51	25	34	2			15	15	20		50	200
Avicennia lanata				25	350				1466									
Sonneratia alba							150	100	556	100	166	533	58	266	933	87	450	400
Xylocarpus moluccensis		500	1066	12	100	400		226				133			400			
Lumnitzera racemosa															266			

D. Rhizophora *as Potential Species for Mangrove Resilience and Conservation*

The dominance of each mangrove family explained the conditions of the mangrove substrate, as well as the success of mangrove planting. For example, *R. stylosa* which is a member of the dominant mangrove family of Rhizophoraceae, was observed at all study sites. This indicated the species was able to thrive in the environment with relatively variable physical conditions at all sites (Table 3). The higher average number of seedlings than saplings and trees representing *R. stylosa* at each site (Table 2) suggested that this species would continue to grow and become dominant in the future. The dominance of Acanthaceae and Lythraceae was attributed to the substrate conditions which are suitable for the growth and development of members of the two families. In this case, species from both families grow well in sandy-muddy habitats near the sea (Al Idrus, 2014; Bengen, 2002).

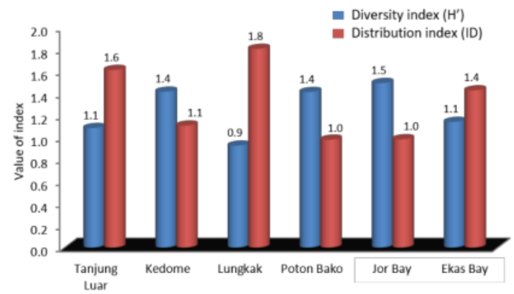

Figure 3. Diversity and distribution index values of mangrove at each study site

Table 3. Characteristics of the mangrove environment at the study sites

Environmental parameter	Location I			Location II		Location III
	Tanjung Luar	Kedome	Lungkak	Poton Bako	Jor Bay	Ekas Bay
Substrate depth (cm)	48–137	43–49	22–102	13–28	65–108	69–109
Soil pH	6–8.5	4.5–5.5	6	6–8.5	5.5–6.5	6.5
Water pH	7.56-7.7	7.39	7.45	6.88–7.88	6.8–7.6	6.79–7.63
Dissolved oxygen (ppm)	4–5	5.5	6–6.5	6.5	5–6	6.5
Salinity (°\oo)	3.5	4.3	4.2–5	4.2	5	4.2

Therefore, *Avicennia* and *Sonneratia* are better candidates for planting activity on the sandy substrates of open coastlines compared to *Rhizophora* (Primavera & Esteban, 2008).

Species diversity of the mangrove vegetation at the study sites are indicative of the success of planting activity. Mangrove rehabilitation by planting *R. stylosa* and *R. mucronata* more than twenty years ago was considered successful with the record of *R. stylosa* at all study sites (Table 2). *Avicennia marina* was also commonly found at all study sites. In-depth discussions with respondents revealed that *A. marina*, locally referred to as "api-api", is found in the habitat naturally and develops faster than other mangrove species. The relatively high diversity and distribution index values for fauna associated with mangroves are other ecological and social indicators of the success of mangrove planting at the study locations (Idrus *et al.*, 2019a; 2019b). These observations suggested that plantation of *Rhizophora* species might have contributed to the development towards a stable mangrove community that maintain a steady ecological state (Gunderson *et. al.*, 1997; Oliver *et al.*, 2015) by aiding in recruitment for recolonization in order to absorb perturbations in the ecosystem (Holling *et al.*, 1995).

As the mangrove ecosystem offers an excellent tool for monitoring coastal change (Blasco *et al.*, 1996), mangrove replantation is an important ecological aspect for inclusion in mangrove conservation. In order to maximize the effort in mangrove conservation, there are several aspects that should be taken into consideration in the conservation management, including the involvement of local community. Replanting should involve locally available mangrove species appropriate to the zone where it occurs naturally as suggested by Gilman *et al.* (2006), and the success of mangrove replanting can be improved by preselecting sites and restricting planting to *Rhizophora* species (Arihafa, 2016). Mangroves recover quickly from disturbances to some more or less persistent state (Gunderson *et. al.*, 2002; Quinn *et al.*, 2017) when given the opportunity, if there are no changes to the geomorphological and hydrological features of the habitat (Martinuzzi *et al.*, 2009).

IV. CONCLUSION

The Indonesian government has initiated many mangrove rehabilitation programmes through replanting, especially on the island of Lombok. This study showed that members of the genus *Rhizophora* have the potential to increase the growth and stability of mangrove ecosystems on the southern coast of East Lombok. Further study on the suitability of a region to be planted with the selected *Rhizophora* species is necessary for replanting programme.

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