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Community structure and regeneration capacity of mangrove forest

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Abstract

Mangrove forests play a vital role in the environment. They provide a number of ecosystem services for supporting marine biodiversity, humans, and other living organisms inhabiting the area. This study aimed to determine the community structure and regeneration capacity of mangrove forests in Lebak, Sultan Kudarat, Philippines. Community structure was determined through relative density, relative frequency, relative dominance, and importance value. Using the center point circular plot method, 13 plots with 40 m diameter were established in two sampling sites: natural stand and reforested. Shannon-Weiner diversity and evenness indexes were used to determine species diversity and distribution, respectively. This study recorded a total of 14 462 individuals within the 1256 m^2 sampling plots, having Rhizophoraceae as the most abundant family with seven species that cover about 71% of both mangrove ecosystems. The vegetation analysis revealed that *Ceriops tagal* (70.35%) and *Rhizophora mucronata* (96.51%) had the highest importance value in the natural stand and reforested mangrove forests, respectively. Furthermore, these two species were also accounted for having the highest regeneration contribution among all species in each site. Shannon-Weiner diversity index revealed that the natural stand was more diverse compared to the reforested mangrove forest. However, the Shannon-Weiner evenness index showed that species in the reforested mangrove forest are more evenly distributed than species in the natural stand. Natural mangrove stands in Lebak have complex community structure and have higher regeneration capacity than the reforested mangrove forest. With this, the study suggested continuing the best practices employed for mangrove conservation in the area and crafting a strategic plan for sustainable mangrove resource utilization.

Key words: diversity, mangrove juvenile, natural stand, reforested mangrove forest, vegetation analysis.
Abbreviations: MENRO, Municipal Environment and Natural Resource Office; RC, regeneration class.

Introduction

Mangrove forests are distributed along the intertidal region between the sea and land in tropical and subtropical areas around the world between approximately 30°N and 30°S geographical latitude (Giri et al. 2011). This type of vegetation consists of evergreen trees and shrubs dominated by mangroves that grow in intertidal zones. These forests also provide crucial habitats for rare and endangered faunal species including waterfowl, fish, mollusks, and crustaceans. Various research studies indicated that the core protected areas have increased, but most critical marine areas, including mangroves, remain under-protected. Conservation and protection strategies for mangrove forests depend on biodiversity information (Tregrot et al. 2021).

The mangrove forest ecosystem in Brgy, Taguisa, Lebak (Philippines) is known to be rich in different species (Cano-Mangaoang, Flores 2019). A total of 29 species of mangroves were identified including an endangered species *Camptostemon philippinensis* (IUCN 2010) and *Pemphis acidula* (DAO 2017). This count of mangrove species in Brgy, Taguisa is 78% of total species identified in the Philippines, which is 37 (Primavera 2004). The number of species identified in the area is higher compared with the mangrove forest in nearby coastal provinces such as the Saranggani Protected Seascape (22 species; Agduma 2023), Timaco Mangrove Swamp (12 species; Mangaoang et al. 2022), in the coastal municipalities of Davao del Norte-Carmen (12 species), Tagum (11 species), and Panabo (16 species; Pototan et al. 2017). These studies provide complete assessment of mangrove species of each site, but no attempts on characterizing community structure and regeneration capacity have been done.

With the initiative of the Local Government Unit in partnership with the Municipal Environment and Natural Resource Office (MENRO) tree planting activities were comprehensively implemented to restore cleared areas due to unregulated cutting of trees. In the protection of a certain ecosystem, initiatives like this must be accompanied with information to further support endeavors for preservation and conservation. However, few studies have been conducted about mangrove forest in Lebak. Data on its community structure together with its regeneration capacity are still unavailable. Determining and assessing mangrove community structure as well as its regeneration capacity would provide information that can be used as an instrument in evaluating the resiliency of the mangrove forest when natural and anthropogenic disturbances occur, as well as provide data as a basis for appropriate intervention on restoring mangrove ecosystems, conservation and crafting specific policy recommendations for ecotourism. Thus, this study was conducted to determine the community structure and regeneration capacity in two types of mangrove forest – natural stand and reforested – in Lebak, Sultan Kudarat.

Materials and methods

Entry protocol

A letter of request for permission was given to the Local Government Unit of Lebak both at municipal and barangay levels and a courtesy call was conducted to respective agencies for their awareness of the researcher's presence and purpose around the study area. Reconnaissance was also done for a general survey around the study area and to identify better sampling plot locations.

Study area

The study was conducted in the natural forest with coordinates of 6.709072N, 124.019074E and reforested mangrove forest situated at 6.679680N, 124.036270E of barangay Taguisa of the Municipality of Lebak (Fig. 1). An approximately 1000 ha of mangrove forest can be found in this barangay and 2 ha forms a community based managed eco-park with a 1.6 km boardwalk leading to the Taguisa Beach. The Lebak mangrove forest is also a home for tourists (Cano-Mangaoang, Flores 2019).

Establishment of sampling plots

Two mangrove forest types were considered in this study: (1) natural stand and (2) reforested mangrove forest. A 3-km transect was established in each forest type. Each transect was then divided into 13 sampling plots with a 250 m distance. The centre point circular plot method (Kent, Coker 1992) was used wherein a circular plot had a radius of 20 m, and was established in each sampling plot. Each circular plot was divided into four sections, which were used as replicates.

Species composition

Pre-identification of mangrove species was done in situ through reconnaissance by using a pictorial guide, key guides, and assistance from local experts. Identification depends on both vegetative features, such as leaf and bark characteristics, and reproductive components, such as flower and fruit characteristics. Confirmation of the pre-identified species was done by using the "Field Guide to Philippine Mangroves" by Primavera (2009) as well as knowledge and assistance from local experts.

Regeneration capacity

Regeneration capacity indicates the ability of the forest to regenerate based on the proportion of seedling, saplings and trees. It represents the capacity of the mangrove site to regenerate given the conditions during the sampling or assessment. All juveniles of different mangrove species with diameter at breast height equal to or less than 5 cm were measured and included in the regeneration capacity. Mangrove juvenile height was determined and categorized based on regeneration class (RC) categories established by Raganas et al. (2020). These include Regeneration Class I (RCI) with mangrove juveniles with height ≤ 40 cm considered as seedlings; Regeneration Class II (RCII) with mangrove juveniles with heights between 41 and 150 cm considered as saplings; and Regeneration Class III (RCIII) with mangrove juveniles with height from 151 to 300 cm considered as small trees.

Data and statistical analyses

Data that were collected for the determination of mangrove forest community structure included relative density, relative frequency, relative dominance, and importance value. Relative density was calculated using the number of individuals per mangrove species per area. Relative frequency was calculated using the number of times a species occurs in all sampled plots. Relative dominance represents the dominant mangrove species in all sample plots. The sum of relative density, relative frequency and relative dominance was determined for importance value. Diversity indices, including the Shannon-Weiner and Shannon Evenness Indexes were also calculated.

Similarity of the composition of mangrove species in the two study sites was determined using the Bray-Curtis Similarity Index, which was illustrated through a cluster

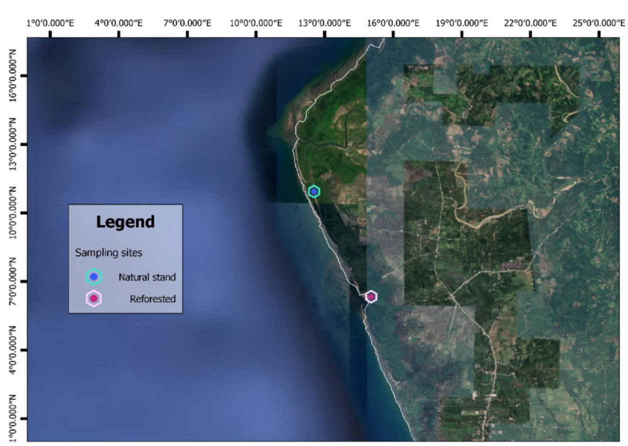

Fig. 1. Location of mangrove sampling sites in Lebak, Sultan Kudarat.

dendogram. After subjecting data to normality testing, the Mann-Whitney U test was used in comparing the regeneration capacity of mangrove species. The p value of significance was set at 0.05.

Results

Identified mangrove species

An estimated total of 14 462 true mangrove individuals were identified from the natural stand and reforested mangrove forest (Table 1). Nineteen mangrove species belonging to nine families were recorded in the two sampling sites. Mangrove families identified were: Acanthaceae, Arecaceae, Avicenniaceae, Combretaceae, Meliaceae, Myrsinaceae, Rhizophoraceae, Sonneratiaceae, and Sterculiaceae. There were nine families having 19 species with 7375 individuals present in the natural stand and four families having nine species with 7087 individuals present in the reforested mangrove forest.

Family Rhizophoraceae was the most abundant family having seven species with 10 233 individuals, which covers about 71% of both mangrove forests, followed by the family Avicenniaceae having four species and 2505 individuals, covering about 17% of both mangrove forests. The remaining families of mangroves identified were represented by only one or two species.

The most recorded species identified in the natural stand was *Ceriops tagal* with 2786 individuals, while the species recorded with the least number of individuals was *Heritiera littoralis* with only one individual seedling. In the reforested mangrove forest, the most abundant species recorded was the *Rhizophora mucronata* with 2722 individuals, while the least abundant species recorded was *Bruguiera gymnorrhiza* with only one individual.

Table 1. Species composition of mangroves in natural stand and reforested mangrove forest in Lebak, Sultan Kudarat

Family	Species	Number of individuals	
		Natural stand	Re-forested
Acanthaceae	*Acanthus volubilis*	5	0
Arecaceae	*Nypa fruticans*	10	0
Avicenniaceae	*Avicennia alba*	221	440
	Avicennia marina	158	1561
	Avicennia officinales	85	0
	Avicennia rumphiana	40	0
Combretaceae	*Lumnitzera littorea*	148	0
Meliaceae	*Xylocarpus granatum*	6	0
	Xylocarpus moluccensis	699	8
Myrsinaceae	*Aegiceras corniculatum*	26	0
Rhizophoraceae	*Bruguiera cylindrica*	9	0
	Bruguiera gymnorrhiza	70	1
	Bruguiera parviflora	811	32
	Bruguiera sexangula	326	0
	Ceriops tagal	2786	605
	Rhizophora apiculata	1196	1291
	Rhizophora mucronata	384	2722
Sonneratiaceae	*Sonneratia alba*	394	427
Sterculiaceae	*Heritiera littoralis*	1	0
	Total	7375	7087

Diversity indices

Table 2 shows the computed diversity indices in both natural and reforested mangrove forest. It revealed that natural mangrove forest was more diverse (H' = 2.0159) than the reforested mangrove forest (H' = 1.59615). However, reforested mangrove forest (E_H = 0.726439) was more evenly distributed than the natural stand (E_H = 0.684647), which might have been due to more evenly distributed species and lesser abundance value difference from each species.

Vegetation analysis

Table 3 shows the vegetation analysis of mangroves in both sampling sites. Species having the highest relative density was *C. tagal* (37.78%) in the natural stand, while *R. mucronata* (38.41%) in the reforested. The species with the highest relative frequency was *Sonneratia alba* (12.15%) in the natural stand, while in the reforested, *R. apiculata* (18.31%) has the highest relative frequency. Species with the highest relative dominance in the natural stand was *Sonneratia alba* (28.60%), while species *R. mucronata* (41.20%) had the highest relative dominance in the reforested mangrove forest. Overall, the highest importance value among the species recorded in the natural stand was *C. tagal* (70.35%), which had the highest relative density, followed by *S. alba* (44.09%) which had the highest relative frequency and relative dominance. In the reforested stand, *R. mucronata* (96.51%) had the highest importance value, the highest relative density and relative dominance, followed by *Rhizophora apiculata* (59.87%), which had the highest relative frequency. Furthermore, the Jaccard similarity coefficient between both sites had a value of 0.47, revealing that species composition and vegetation was distinct in each site.

Regeneration capacity

The juvenile abundance of mangrove species in both sites were compared to determine which among them highly contributed to the regeneration capacity of each mangrove

Table 2. Diversity indices of natural stand and reforested mangrove forest. DI, Diversity Index; EI, Evenness Index

Site	Shannon-Weiner DI	Shannon-Weiner EI
Natural stand	2.0159	0.684647
Reforested mangrove forest	1.59615	0.726439

Table 3. Vegetation analysis of natural stand and reforested mangrove forest. IV, importance value; RD, relative density; RDBA, relative dominance; RF, relative frequency. All values are in %

Species	Natural stand				Reforested			
	RD	RF	RDBA	IV	RD	RF	RDBA	IV
Acanthus volubilis	0.07	0.93	0.00	1.00	0.00	0.00	0.00	0.00
Nypa fruticans	0.14	4.67	0.00	4.81	0.00	0.00	0.00	0.00
Avicennia alba	3.00	9.35	4.38	16.73	6.21	14.08	9.33	29.62
Avicennia marina	2.14	7.48	3.37	12.99	22.03	16.90	13.37	52.30
Avicennia officinales	1.15	3.74	3.02	7.91	0.00	0.00	0.00	0.00
Avicennia rumphiana	0.54	1.87	1.18	3.59	0.00	0.00	0.00	0.00
Lumnitzera littorea	2.01	1.87	1.89	5.77	0.00	0.00	0.00	0.00
Xylocarpus granatum	0.08	1.87	0.14	2.09	0.00	0.00	0.00	0.00
Xylocarpus moluccensis	9.48	8.41	15.88	33.77	0.11	2.82	0.10	3.03
Aegiceras corniculatum	0.35	1.87	0.00	2.22	0.00	0.00	0.00	0.00
Bruguiera cylindrica	0.12	2.80	0.13	3.05	0.00	0.00	0.00	0.00
Bruguiera gymnorrhiza	0.95	5.61	0.84	7.40	0.01	1.41	0.00	1.42
Bruguiera parviflora	11.00	7.48	4.13	22.61	0.45	5.64	0.42	6.51
Bruguiera sexangula	4.42	0.93	2.62	7.97	0.00	0.00	0.00	0.00
Ceriops tagal	37.78	10.28	22.29	70.35	8.54	9.86	3.96	22.36
Rhizophora apiculata	16.22	11.22	12.44	39.88	18.22	18.31	23.34	59.87
Rhizophora mucronata	5.21	6.54	1.09	12.84	38.41	16.90	41.20	96.51
Sonneratia alba	5.34	12.15	26.60	44.09	6.02	14.08	8.28	28.38
Heritiera littoralis	0.01	0.93	0.00	0.94	0.00	0.00	0.00	0.00

ecosystem. Fig. 2 shows that the natural stand had more abundant juveniles compared to the reforested mangrove forest.

In the natural stand, *C. tagal* had the most abundant juveniles dominated three regeneration classes, followed by *Bruguiera parviflora* which also had abundant RCI and RCII. However, species *H. littoralis* was the least abundant juvenile, having only one individual seedling. Overall, the mangrove vegetation in the natural stand had abundant RCI for all mangrove species. Whereas in the reforested mangrove forest, *R. mucronata* juveniles dominated the mangrove forest with the most abundant RCII and RCIII followed by *Avicennia marina* which had the most abundant RCI juveniles. Species *B. gymnorrhiza* was the least abundant juvenile with only one individual sapling. Generally, reforested mangrove forest contained abundant RCII for all species.

Cluster analysis

Cluster analysis in Fig. 4 showed similarities of mangrove juvenile abundance in the natural stand and reforested mangrove forest sampling sites at about 41% similarity. Thus, mangrove juvenile abundance among the regeneration classes was 59% unique in each mangrove

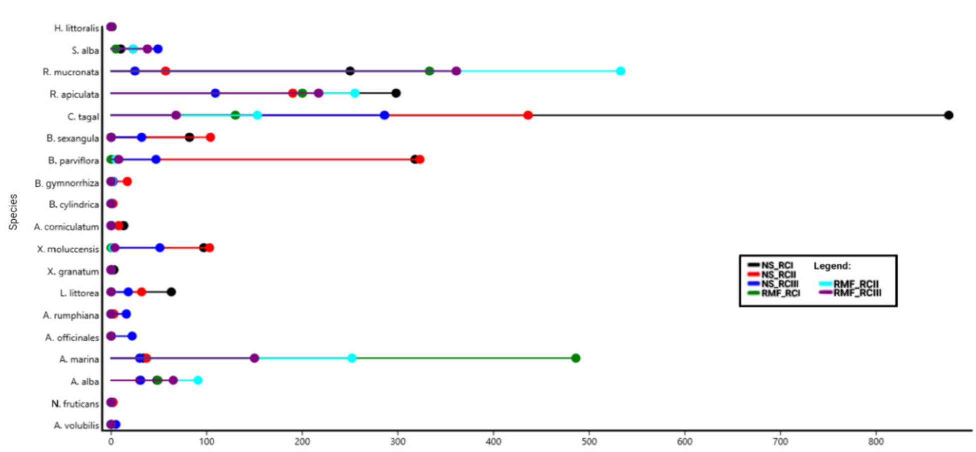

Fig. 2. Regeneration classes of different mangrove species in both sites. (NS) stands for natural stand and (RMF) stands for reforested mangrove forest.

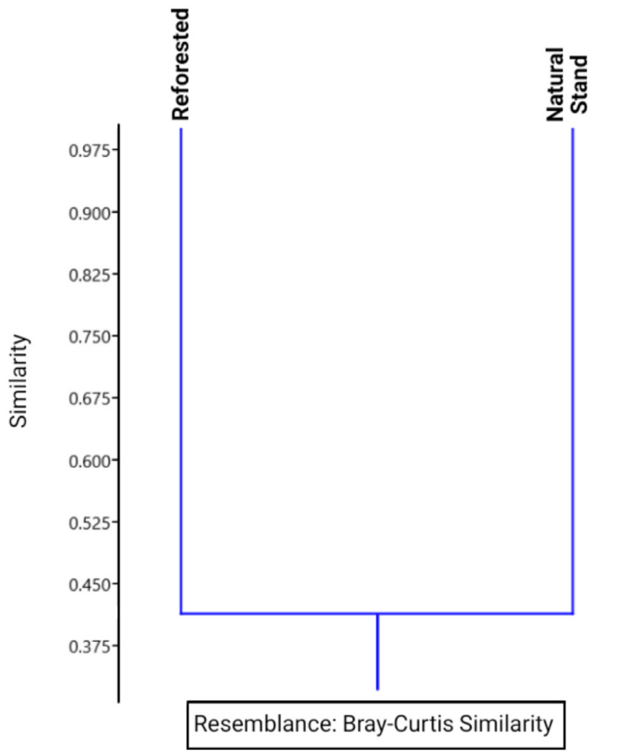

Fig. 3. Cluster analysis showing similarities of both sites using Bray-Curtis Similarity Index.

ecosystem. Statistical testing also revealed significant difference between the abundance of mangrove juveniles between the sites as indicated by a *p* value less than 0.05 ($p = 0.021$), therefore, supporting the results of the cluster analysis.

Discussion

The results of this study revealed that mangrove species in the family Rhizophoraceae can dominate both natural stand and reforested mangrove forests, specifically *C. tagal* which dominated the natural stand and *R. mucronata* which dominated the reforested mangrove forest in terms of species abundance and importance value. Moreover, species in the family Avicenniaceae and Sonneratiaceae also had a high number of individuals in both sites, specifically species *Avicennia alba, A. marina*, and *S. alba*. These species also had high importance value which implies that they contributed to the community structure and vegetation of both mangrove ecosystems. The dominance of *C. tagal* in the natural stand and *R. mucronata* in reforested mangrove forest is the result of rehabilitation activity of the Local Government Unit of Lebak and in partnership with MENRO. In addition, the selection of *C. tagal* in regeneration of cleared mangrove forest was based on the observation that they are not browsed on by wild animals and thus have a high survival rate (MENRO, personal communication). Similar results were obtained in the study of Raganas et al. (2020) in which species of *Rhizophora* and *Avicennia* dominated the mangrove stands in Oriental Mindoro. Bigsang et al. (2016) reported that in terms of abundance the three mangrove species that dominated mangrove forest of Maasim in Saranggani, Philippines were *R. mucronata, S. alba* and *R. apiculata*.

The results showed that the natural stand mangrove forest was more diverse with a diversity index value of 2.0159, compared to the reforested mangrove forest with a diversity index value of 1.59615. Higher H' value indicates higher species diversity in a community (Nolan, Callahan 2006). This study found that the natural stand had 19 species present, while the reforested stand had only nine species present. Thus, the natural stand had higher species richness than the reforested mangrove forest, which resulted in the higher diversity index value. Species diversity is a combination of both species richness and abundance which also influences community structure and productivity. Diversity is higher when all species present in the community are equally abundant. The high diversity of the natural stand compared with the reforested is further supported by various studies (Mariano et al. 2019; Osing et al. 2019; Raganas, Magcale-Macandog 2022). The low diversity and species richness of the reforested site can also be attributed to the selection of the species used for regeneration. *Rhizophora* species were chosen in the tree planting activities due to their high survival rate and availability of propagules in the area (MENRO, personal communication). *Rhizophora* species are popular in mangrove regeneration programmes because of their availability and fast growth of propagules (Primavera et al. 2005). The value of evenness in the two sites represented a high level. The computed value of evenness is related to species diversity. The higher the evenness value the more stable the species diversity (Mawazin 2013). Thus, both sites had a more or less stable species diversity, which is an important detail in developing conservation strategies.

The importance value of each species indicates how dominant these species are in a particular ecosystem or forest, greatly contributing to its community structure. Species *C. tagal* had the highest importance value in the natural stand while species *R. mucronata* had the highest importance value in the reforested mangrove forest, which indicates that these species were the most dominant in each site. Moreover, *R. mucronata* and *C. tagal* are from the same family Rhizophoraceae. Both species are widespread viviparous mangroves (Ge, Sun 2001), where seeds germinate and develop into seedlings while still attached to the parent tree, which they use for adaptation and dispersal, also allowing them to adapt to water with high saline conditions (Shamin-Shazwan et al. 2021). Community structure is at steady state when the species composition of the community and the densities of the species stays constant, which implies that species richness and evenness within a community does not change (Moore

2013). Thus, it is very infrequent to meet this state since species composition and densities between both mangrove forest changes through time.

The results showed higher regeneration in the natural stand than the reforested mangrove forest, as species richness was also higher in the natural stand. Species *C. tagal* had the most abundant juveniles among all species in the natural stand, and *R. mucronata* in the reforested mangrove forest, which indicated that these species had the highest regeneration contribution in both sites. Furthermore, vivipary was observed in both species, illustrating rapid dispersal and growth in both mangrove ecosystems. It is important that mangroves adapt so that they can survive any environmental conditions where they disperse and thrive. Mangrove species dominance in both sites is driven by the conditions of the mangrove environment, where they develop characteristics for adaptation (Srianth et al. 2015).

Internal factors such as type of propagules or fruits can also influence the success of regeneration endeavors (Van der Stocken et al. 2017). The stick like propagule of Rhizophora species might be helpful in its establishment on the substrate, while that of species with lesser abundance recorded such as *H. littoralis* and *Xylocarpus granatum* however, has different seed characteristics such as their ability to float, containment of seeds in a capsule or fruit (Van der Stocken et al. 2015), which might also be a reason why these species might be present only in seedling form and far from the parent tree.

The results were further supported by statistical testing which revealed significantly different regeneration between both sites. Cluster analysis also showed similarity at about 41%, thus, revealing that each mangrove ecosystem was different and unique both in species composition and abundance.

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