Tides of renewal: tracking the progress of mangrove rehabilitation in Sitio Fuentes, Iligan City, Philippines

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Abstract. Mangrove habitats are essential for maintaining biodiversity, protecting coastlines, and sequestering carbon, yet they are nevertheless subject to deterioration from human activity and natural disturbances. This study assessed the current ecological status and rehabilitation progress of the rehabilitated mangrove forest in Sitio Fuentes, Barangay Maria Cristina, Iligan City, Philippines. Monthly field assessments were conducted from March to December 2023 during spring low tides using ten 50-meter transect lines with systematically placed plots. Species identification and structural measurements were performed to evaluate species composition, density, and importance value. A total of 218 mangrove individuals were recorded, belonging to one family, one genus, and two species — *Rhizophora apiculata* and *Rhizophora mucronata*. Results revealed that *R. apiculata* was the dominant species, reflecting the typical composition of rehabilitated mangrove areas in the Philippines. The Shannon–Wiener diversity index (H′ = 0.68) indicated low species diversity, while the high density of seedlings and saplings (0.87 individuals m^{-2}) suggested active regeneration and favorable recruitment conditions. However, the dominance of a single genus implies limited ecological resilience and restricted habitat complexity. The findings classify the mangrove area as having low biodiversity but with strong potential for recovery. Continuous monitoring and the inclusion of more diverse native species are recommended to enhance ecological balance, ensure long-term sustainability, and strengthen the mangrove's protective and productive functions.
Keywords: coastal restoration, ecological status, biodiversity.

Introduction. Coastal locations with shallow water and tidal mudflats are home to mangrove forests, which also grow inland along rivers, streams, and tributaries where the water is typically brackish. They thrive in tropical climates, such as those found in the Philippines, and are crucial to the health of the coral reefs and seagrass that comprise the coastal and marine ecosystems. Around the world, more than 70 mangrove species are known to exist in various regions (Melana et al., 2000; Hogarth, 2015). Being a type of wooded wetland habitat, mangroves offer a variety of ecosystem services, such as reducing beach and soil erosion and carbon sequestration, as well as protecting beaches and coastlines from storms, waves, and floods (Millennium Ecosystem Assessment, 2005; Barbier, 2007; Siikamäki et al., 2012). Plants called mangroves live and thrive in intertidal zones. These have a variety of plant life, including palms, ferns, trees, and vines (Tomlinson, 1986).

The Philippines is home to one of the world's most diverse mangrove ecosystems. But these ecosystems are threatened by environmental peril and human activities, which can lead to significant ecological degradation and biodiversity loss (Long & Giri, 2011; Sinfuego & Buot Jr., 2008). These ecosystems provide essential ecological and economic benefits but are increasingly threatened by both natural hazards and human-induced disturbances, including coastal development, pollution, and deforestation (Van Lavieren et al., 2012). Being one of the most productive and biodiverse wetlands on earth, mangrove forests are regarded as important coastal resources that significantly contribute to the nation's economy and the maintenance of ecological balance. These are significant ecosystems that offer wood, food, fodder, and medicine. These coastal woodlands are essential for a vast variety of fish and shellfish. Moreover, mangroves offer shoreline protection from storm surges and typhoons and aid in preventing coral reef siltation caused by upland erosion. Despite the significance of mangrove forests, they are nonetheless threatened by things like rapid aquaculture development and deforestation. Additional dangers include pollution, siltation, and sea level rise (Cañizares & Seronay, 2016; Amir, 2018).

As a result of the significant and distinctive ecosystem products and services they offer to human society, coastal ecosystems, marine systems, and mangrove forests rank among the world's most productive and biologically significant ecosystems (Macintosh et al., 2011). The successful restoration of tens of thousands of mangroves has been accomplished through community-based efforts in mangrove woods and acres of abandoned ponds. The ecologically suitable locations for such ponds include they were once mangrove woods and hence needed repair. The issues with mudflat afforestation and more involved restoration procedures are avoided by restoring previous ponds (Primavera & Esteban, 2008; Primavera et al., 2012, 2014). The main purpose of this study is to determine the species composition, importance value, and ecological status of the mangroves in Sitio Fuentes, Barangay Maria Cristina, Iligan City, Lanao del Norte, Philippines. The outcome of this study will give an updated status of mangrove rehabilitation in Barangay Maria Cristina concerning the present number of mangroves, and it will also help the locals and local government in managing and monitoring the mangrove areas for their sustainability, as they are a big help in protecting in shores and nursery ground for aquatic animals in the area.

Material and Method

Description of the sampling area. The study was conducted at Barangay Maria Cristina, a small administrative division (barangay) in the city of Iligan, Philippines. It is situated at approximately 8°11'56.0"N and 124°11'37.0"E, on the island of Mindanao. The study site was identified as Marcelo Private Property, and the Mangrove Rehabilitation is located at 8°12'20.1"N, 124°11'59.5"E (Figure 1).

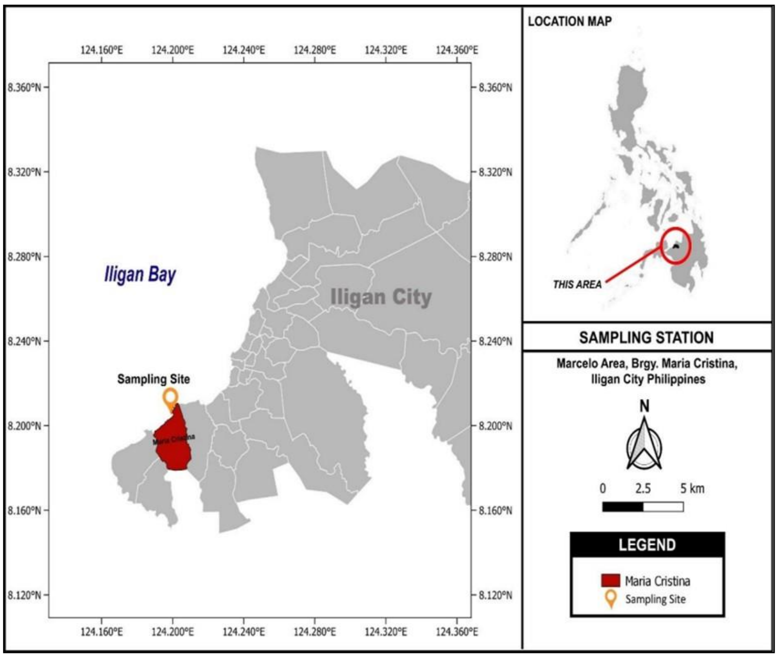

Figure 1. Research location map of Marcelo Area, Barangay Maria Cristina, Iligan City, Philippines.

Field sampling. The assessment and monitoring of mangroves were conducted monthly from March to December 2023 during low tides, between 6:00 and 9:00 in the morning. Ten transect lines measuring fifty meters were established parallel to the coastline to ensure systematic sampling. A 5 m x 5 m plot was placed beside each transect tape with a 5-meter interval. Mangroves within the plot were measured for height using a tape measure for smaller trees and a steel tape for the taller ones. Identification of mangrove species was carried out using specific characteristics such as leaf morphology, arrangement (phyllotaxy), and the structure and colour of the stem. Each mangrove species was classified up to species levels, utilizing taxonomic keys from Calumpong and Meñez (1997), Melana and Gonzales (1996), with species descriptions further verified against Duke (2006). Species nomenclature and conservation status were verified using the IUCN Red List of Threatened Species (Duke et al., 2010a, 2010b).

Data analysis. Data were analysed to describe the mangrove stand in terms of density (stems ha^{-1}), basal area (m^2 ha^{-1}), relative density, relative frequency, and relative dominance. Species diversity was evaluated using the Shannon–Wiener diversity index (H'), which accounts for both species richness and the relative abundance of each species. The index was calculated using the formula:

$$H' = -\sum_{i=1}^{s} p_i \ \ln p_i$$

Where p_i is the proportion of individuals belonging to the i^{th} species. Higher H' values indicate greater species diversity within the mangrove community.

Species evenness was assessed using Pielou's evenness index (J'), which measures how evenly individuals are distributed among the recorded species. The index was calculated using the formula:

$$J' = \frac{H'}{\ln(S)}$$

Where H' is the Shannon–Wiener diversity index and S is the total number of species. Pielou's evenness index ranges from 0 to 1, with values approaching 1 indicating that individuals are distributed more evenly among species, whereas values closer to 0 indicate that the community is dominated by one or a few species. Both indices were calculated using PAST (Paleontological Statistics) version 4.01 (Hammer et al., 2001). The importance value of each mangrove species was also determined. They were calculated using the formulas presented by English et al. (1997), and these are as follows. Basal area per tree (cm^2) = $\pi DBH^2/4$ (where DBH is the diameter at breast height), stand basal area (m^2 ha^{-1}) = sum of basal areas/area of the plot, density (stems ha^{-1}) = (no. of living stems in a plot x 10,000)/area of the plot, relative density = (density of a species/total density of all species) x 100, relative frequency = (frequency of a species/total frequency of all species) x 100, relative density = (total basal area of a species/total basal area of all species) x 100, importance value = relative density + relative frequency + relative dominance.

Results and Discussion

Mangrove species composition. A total of two hundred eighteen mangrove individuals were recorded in the sampling site. Two mangrove species were identified in the sampling area, namely: *Rhizophora apiculata* and *Rhizophora mucronata.* The species identified in the study site are categorized as Least Concern (LC) according to the IUCN Red List of Threatened Species (Duke et al., 2010a, 2010b). This means that the chance of these species going extinct is low, although mangrove species globally continue to experience varying levels of extinction risk depending on habitat degradation and geographic distribution (Polidoro et al., 2010). According to Primavera and Esteban (2008), *Rhizophora* species are commonly found in reforested mangrove forests, as they are widely utilized in mangrove restoration efforts in the Philippines and Southeast Asia. A total of 218 mangrove individuals were recorded in the sampling site, comprising of 109 mature trees, 61 saplings, and 48 seedlings. The Sitio Fuentes mangrove rehabilitation project was initiated in 2022, and according to the locals, the plantation is experiencing disturbances, including animal intrusions.

The Shannon–Wiener diversity index (H' = 0.68) indicates low species diversity, reflecting the limited number of mangrove species established within the rehabilitated site. In contrast, the Pielou's evenness index (J' = 0.98) indicates that individuals were distributed almost equally between the two recorded species (Table 1). This suggests that although species richness was low, neither species overwhelmingly dominated the community in terms of abundance. Such a pattern is common in rehabilitated mangrove stands established using a limited number of planted species. Mangroves generally have lower plant diversity than other ecosystems because of their unique environmental conditions — such as high salinity, regular tidal flooding, and oxygen-poor soils — restrict the variety of plant species able to survive there (Kathiresan & Bingham, 2001).

Table 1

Mangrove diversity analysis in Sitio Fuentes, Iligan City, Philippines

Diversity analysis	
Shannon-Wiener diversity index (H')	0.68
Pielou's evenness index (J')	0.98

Mangrove community structure. Importance value (IVI) was examined more closely in relation to the variations of mangrove forests based on the significance of a species to the overall community structure (Rotaquio et al., 2007). The mangrove stand in the rehabilitation site was represented by only two true mangrove species, *Rhizophora apiculata* and *Rhizophora mucronata*. Among these, *R. apiculata* dominated the restored forest, as evidenced by the highest importance value index (IVI). With 205.40 in transect 1, 203.53 in transect 2, 191.23 in transect 3, and 300 in both transect 4 and 5 (Table 2). Transect 2 shows the highest percentage value compared to the other transects, with 61.70% of relative density, 71.43% of relative frequency, and with relative dominance of 70.40%. This trend aligns with rehabilitation techniques throughout the Philippines, where *Rhizophora* species are frequently chosen because of their greater survival rate in reforestation areas and ease of propagule collection (Primavera & Esteban, 2008). Previous studies have likewise highlighted the potential of mangrove revegetation as an effective approach for restoring degraded mangrove habitats in the Philippines (Samson & Rollon, 2011). Although it indicates good planting efforts, the monospecific stand shown by the abundance of *Rhizophora* also shows minimal diversity. Rehabilitated mangrove stands typically exhibit this low diversity since natural regeneration processes typically prefer a larger variety of taxa, such as *Sonneratia* and *Avicennia* (Bosire et al., 2008). This limited species composition may limit the amount of habitat available to faunal communities and lower the long-term sustainability of the ecosystem.

Table 2

Analysis of the importance value of a mature tree in Sitio Fuentes, Iligan City, Philippines

Species	*Transect*	*Basal area*	*Relative density*	*Relative frequency*	*Relative dominance*	*IVI*
Rhizophora mucronata	1	0.08	74.42	53.85	77.13	205.40
Rhizophora apiculata	1	0.02	25.58	46.15	22.87	94.60
Rhizophora mucronata	2	0.05	61.70	71.43	70.40	203.53
Rhizophora apiculata	2	0.02	38.30	28.57	29.60	96.47
Rhizophora mucronata	3	0.02	64.29	66.67	60.27	191.23
Rhizophora apiculata	3	0.01	35.71	33.33	39.73	108.77
Rhizophora mucronata	4	0.01	100	100	100	300
Rhizophora apiculata	4	-	-	-	-	-
Rhizophora mucronata	5	0.003	100	100	100	300
Rhizophora apiculata	5	-	-	-	-	-

Note: The (-) sign means that there is no species found in the transect.

Ecological status. The mangrove habitat assessment revealed that the average height of mature trees was 0.69 m, while the regeneration density was 0.87 m^{-2} (Figure 2). The results suggest that the site is characterized by relatively short mature trees but a relatively high regeneration rate. Seedlings and saplings were abundant across transects, with an average regeneration density of 0.87 individuals m^{-2}. This high density suggests favorable recruitment conditions, likely facilitated by canopy gaps and tidal dispersal of propagules. Amir and Duke (2009) reported that disturbances within mangrove stands often enhance light penetration and space availability, thereby stimulating seedling establishment. The profuse regeneration observed in this study is a positive indicator of ecological recovery. However, high seedling density does not guarantee stand persistence, as seedling and sapling mortality in monoculture plantations can be substantial without active management (Samson & Rollon, 2008). The low average height of mature mangroves may indicate that the stand is still undergoing recovery following disturbance. Alternatively, site-specific environmental stressors, including salinity fluctuations, prolonged tidal inundation, and anthropogenic disturbances, may constrain tree growth (Watson, 1928; Ball, 1988; Friess et al., 2012). Sharma et al. (2017) noted, citing Salmo III and Juanico (2015), *Rhizophora* spp. that are planted in seaward, low-elevation zones show poor growth rates and substantial mortality. On the other hand, the high regeneration density reflects active recruitment within the site. A strong presence of seedlings and saplings is often associated with canopy gaps or disturbances that create space and light availability, thereby facilitating regeneration. Consistent with this finding, mangrove regeneration is more successful at greater distances from urban settlements in the Gulf Cooperation Council (GCC) (Mohan et al., 2024). This aligns with previous studies demonstrating that canopy disturbances create light gaps that promote seedling recruitment and natural regeneration in mangrove forests (Amir & Duke, 2009). Continuous monitoring is therefore necessary to assess whether these recruits successfully transition into mature trees.

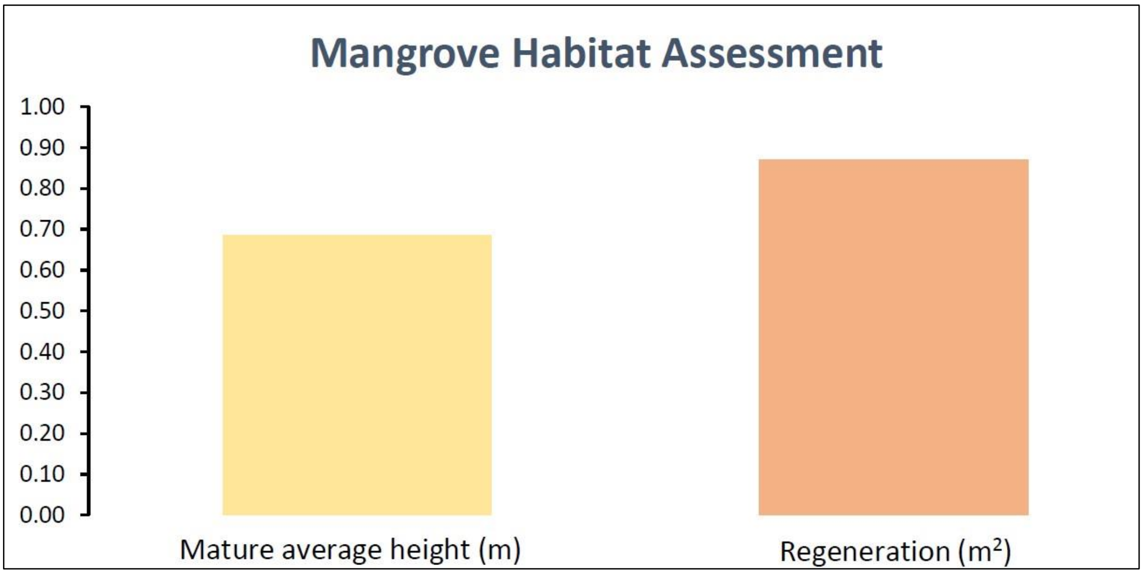

Figure 2. Habitat assessment within the mangrove forest of Sitio Fuentes, Iligan City, Philippines

Conclusions. The assessment of the rehabilitated mangrove stand revealed a community dominated by *Rhizophora* species, reflecting the common planting practices in restoration projects. While the stand exhibited low species diversity and relatively small structural development in terms of height, DBH, and basal area, the high density of seedlings and saplings indicates active regeneration and promising potential for long-term recovery. These findings suggest that the rehabilitation efforts have been partially successful in re-establishing mangrove cover and initiating natural recruitment, although the limited species composition may constrain the ecological resilience and biodiversity benefits of the forest. Overall, the rehabilitated site can be considered at an early successional stage, where continued monitoring and management interventions will be critical to ensure its progression toward a mature, structurally complex, and ecologically functional mangrove ecosystem.

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Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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