Environment and Ecology 43 (2) : 522—529, April—June 2025
Article DOI: https://doi.org/10.60151/envec/UIQJ7175
ISSN 0970-0420

Diversity and Structure of Natural Mangrove Forest in Nabago, Surigao City, Philippines

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Received 24 March 2025, Accepted 15 May 2025, Published on 14 June 2025

ABSTRACT

Mangroves are among the most productive ecosystems on earth, yet they face growing threats from human activities. Mangroves are unique ecosystems that play an important role in maintaining ecological balance, protecting coastlines from erosion and serving as habitats for diverse marine life. This study aims to assess the diversity of a natural mangrove forest in Surigao City, Philippines. Three sampling stations were selected, and three 150-meter transects were laid in each station in which five 10 m^2 quadrats with 20-meter intervals were established per transect. A total of 45 sampling quadrats were assessed in this study employing the standard methods for mangrove inventory. A total of six mangrove species and one mangrove associate were recorded. The area falls into a very low diversity category (H′=0.9179) and is dominated by *Rhizophora apiculata* (Relative Dominance=67.17). *R. apiculata* also obtained the highest species importance value (SIV=199.38). Given the vital ecosystem services that mangroves provide to the local community, it is essential to reinforce community-based mangrove management strategies along side conservation initiatives and follow-up research programs. Strengthening these efforts will support the long-term protection and restoration of the mangrove ecosystem in the area.

Keywords Diversity, Mangrove conservation, *Rhizophora apiculata.*

INTRODUCTION

Coastal ecosystems are among the most productive and significant ecosystems on earth. They play critical roles in maintaining ecosystem well-being and global biodiversity. One of these coastal ecosystems is the mangrove ecosystem. Aside from being essential habitats for many invertebrate and vertebrate species, and other aquatic and terrestrial animals, mangroves also provide a wide array of services to humankind, including food provision, shoreline stabilization, protection from floods and soil erosion, among others (Beck *et al.* 2001, Cullen-Unsworth & Unsworth 2013, Food and Agriculture Organization 2007, United Nations Environment Program 2006). By far, its role in storing carbon and relevance in mitigating the

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impact of climate change is paramount (Mills 2011).

Despite their value, mangroves are exposed to threats of over-exploitation and degradation. They face strong pressure from coastal development and land-use change (Waycott *et al.* 2009), resulting in the reduction of around half of the world's mangrove forests in the last 50 years. According to Giri *et al.* (2010), the mangrove disappears at a rate of 2.1% per year, or 2,834 km^2 per year (United Nation Environmental Program 2006). In the Philippines, mangrove cover in 1918 was estimated to be between 400,000 and 500,000 hectares (Brown & Fischer 1920). However, based on 2001-2003 satellite imagery, the country's mangrove forest cover has decreased by about 50% (Forest Management Bureau 2010). The recent data of 247,362 hectares (Garcia *et al.* 2013) indicates that nearly half of the estimated mangrove cover has already been lost. This implies that more than half of the estimated mangrove cover was already lost within a century and is continually degrading. Declining mangrove forests are mainly due to over-exploitation and land-use conversion (Primavera 2000). Both catastrophic events such as hurricane and anthropogenic activities (Alongi 2008) lead to the decline of the mangrove diversity especially those endemic species.

In the Philippines, Surigao is one of the cities with vast mangrove forests covering 2,757 hectares (Surigao City Ecological Profile 2016). While many communities depend on the services provided by coastal areas and mangrove forests in the city, mangrove forests were degraded as the population encroached the majority of the city's coastal areas. To date, no studies have been published about the mangrove forests of Surigao City, particularly in Barangay Nabago. Thus, this study was conducted to establish reliable information about its diversity and structure, which is relevant for a better understanding of its importance and science-based management of mangrove forests in the area.

MATERIALS AND METHODS

Study site and establishment of sampling stations

The study was conducted in the natural mangrove forest of Barangay Nabago, Surigao City, Philippines. Based on the 2016 Surigao City Ecological Profile, Barangay Nabago is classified as a mainland coastal barangay with a human population of 1,143. It is located at 9.734761 N and 125.564056 E. The barangay has a total land area of 375.38 hectares with an average elevation of seven meters above sea level. The mangrove forests of Nabago belong to the Cagniog-Balibayon-Day-asan-Orok-San Isidro-Capalayan-Nabago mangrove belt, which serves as the spawning ground for various marine organisms. In 2008, a 500-hectare mariculture park was established in Barangays Nabago, Day-asan, Capalayan, Cabongbongan, and San Isidro (Roa *et al.* 2017) to support the fishing community in the area. The park later became a recipient of the city's Mobile Mariculture Platforms (MPPs) program (Crismundo 2016). However, the mangrove forests in the area are threatened by domestic activities, industry, marine transportation, human settlement, development of infrastructure, and timber extraction.

Three sampling stations were established in the mangrove forest of Barangay Nabago (Fig. 1). The first station lies geographically at 125.57212 N and 9.73483 E. It is situated along the riverine system of the barangay, with silt-clay substrate. The second station is situated at 125.5785 N and 9.744194 E and is 1,246 meters away from the first station. The substrate of the second station is sandy clay. The third station is situated at125.5952 N and 9.740633 E with a distance of 1,876 meters from the second station and 2,613 meters from the first station. Its soil substrate is mostly sandy.

Sampling design, mangrove inventory and identification

A non-destructive transect-quadrat sampling technique was employed to determine the mangrove species composition. In each station, a 100-meter baseline parallel to the shoreline served as the starting point. Three 150-meter transects were established perpendicular to the baseline at 50-meter intervals. In each transect line, five 10 m^2 quadrats were established. The first quadrat was set at 10-meter distance from the baseline, with the succeeding quadrats established at 20-meter intervals.

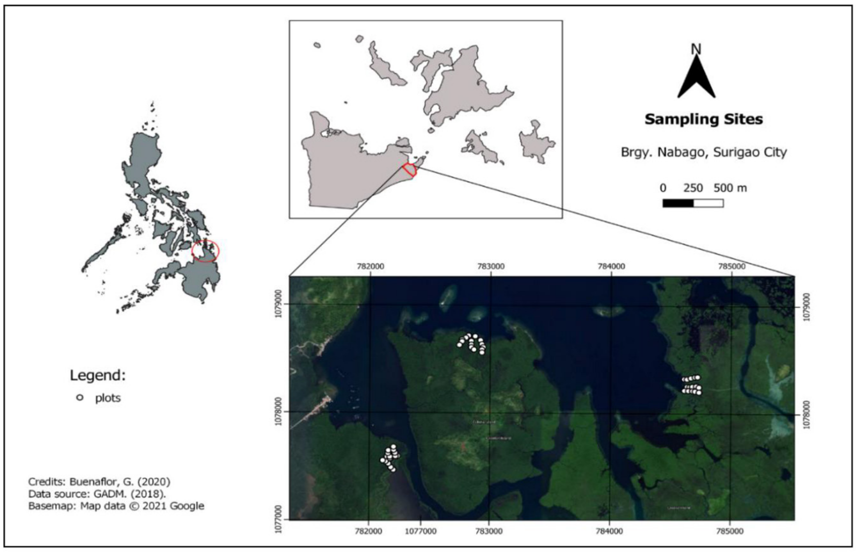

Fig. 1. The philippine map showing the geographic location of Surigaodel Norte in Mindanao and the three sampling stations in Barangay Nabago, Surigao City. Data sources: Database of Global Administrative Areas (GADM 2011) and Google (2015).

A 100% inventory of mangrove species inside each quadrat was conducted. Trees with at least 50% of the main stem rooted inside the quadrat and with at least 4 cm girth were included in the inventory. The diameter at breast height (DBH) of the mangrove tree's main stem was measured at 1.3 meters from the highest stilt root (Forest Management Bureau 2014). The mangrove species were identified *in situ* and were classified taxonomically down to the species level using a Field Guide by Primavera *et al.* (2004). The conservation status of the identified mangrove species was determined using the list of threatened species of the International Union for the Conservation of Nature (iucnredlist org).

Data analysis

Biodiversity indices

The Paleontological Statistical Software Package (PAST) developed by Hammer *et al.* (2001) was used to calculate biodiversity indices such as species dominance, evenness, and the Shannon-Weiner diversity index. To give a descriptive analysis of the level of diversity in the area, the Shannon-Weiner values were classified according to the scale used in the study of Fernando (1998).

Table 1. Formula used in calculating parameters for vegetation analysis.

Parameters	Formula	Where
Population Density (PD)	$PD = \frac{N}{Area}$	PD = Population density N = Number of individuals per species Area = Total area sampled
Relative Density (RDi)	$RDi = \frac{PD}{TDi} \times 100$	RDi = Relative density PD = Density of a species TDi = Total density of all species
Frequency (F)	$F = \frac{SO}{Area}$	F = Frequency SO = Species occurence Area = Total area sampled
Relative Frequency (RFi)	$RFi = \frac{F}{TF_i} \times 100$	RFi = Relative frequency F = Frequency value for a species TF_i = Total of frequency value for all species
Dominance (D)	$D = \frac{BA}{Area}$	D= Dominance BA = Total basal area of a species Area = Total area sampled
Relative Dominance (RDo)	$RDo = \frac{D}{TD_o} \times 100$	RDo= Relative dominance D= Dominance of a species TD_o = Total dominance for all species
Species Importance Value (SVI)	$SIV = RDi + RDo + RFi$	SIV = Species importance value RDi = Relative density RDo= Relative dominance RFi = Relative frequency

Table 2. Species composition and conservation status of mangrove species in Barangay Nabago, Surigao del Norte, Philippines.

Family	Species	Conservation status	Station 1	Station 2	Station 3	Total
Mrysinaceae	*Aegiceras corniculatum*	Least Concern	7	0	0	7
Rhizophoraceae	*Ceriops tagal*	Least Concern	0	0	7	7
	Rhizophora apiculata	Least Concern	708	228	154	1,090
	Rhizophora mucronata	Least Concern	58	10	34	102
	Rhizophora stylosa	Least Concern	0	5	1	6
	Bruguiera gymnorrhiza	Least Concern	4	0	37	41
Aracaceae	*Nypa fruticans*	Least Concern	281	34	0	315
		Total	**1,058**	**277**	**233**	**1,568**

Vegetation analysis

Vegetation analysis utilized the following parameters: Population density, frequency, dominance, relative density, relative dominance, and importance value index using equations based on the study of Ali and Sulistiono (2018) which are shown in Table 1. Compared to using density alone, this analysis is more helpful in determining the importance or function of different species in their habitat. It also provides information on the rank of a specific species within a forest community (Cañizares & Seronay 2016). The Species Importance Value (SIV) was computed by adding relative density, relative dominance, and relative frequency to determine the species composition of the mangrove forest.

RESULTS

Species composition and conservation status of mangrove species in nabago

A total of 1,568 individuals were recorded across three sampling stations in the barangay, representing six true mangrove species which include *Aegiceras corniculatum, Ceriops tagal, Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa,* and *Bruguiera gymnorrhiza,* as well as one mangrove associate, *Nypa fruticans.* These species belong to three families, with the Rhizophoraceae being the most dominant, comprising five of the recorded species (Table 2). Among the recorded species, *R. apiculata* had the highest abundance, with 1,090 individuals, accounting for 69.5% of the total relative abundance across all sampling stations (Fig. 2). In contrast, *C. tagal, A. corniculatum,* and *R. stylosa* had the lowest recorded abundances, each contributing only 0.4% to the total.

All mangrove species recorded in the area were of Least Concern Status based on the International Union for the Conservation of Nature's Red List of Threatened Species (IUCN 2021). Nonetheless, mangroves are disappearing three to five times faster than overall global forest losses which have serious ecological and socio-economic impacts (IUCN 2021). With this declining trend of mangrove species population, the continuous and strict implementation of local ordinances specific for protecting the mangrove ecosystems is crucial.

Among the three sampling stations, Station 2 exhibited the lowest diversity index (H′ = 0.6101), while Station 3 had the highest species diversity, with a Shannon diversity index (H′ = 0.9754) and an evenness value of 0.5305, as it was represented by six species (Table 3). However, the overall diversity

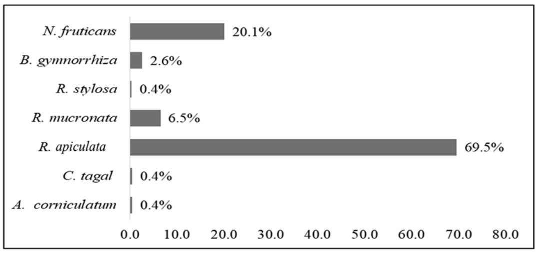

Fig. 2. Relative abundance of mangrove species in Brgy. Nabago, Surigao City.

Table 3. Diversity indices of the sampling area.

	Station 1	Station 2	Station 3
Taxa	5	4	5
Individuals	1,058	277	233
Dominance	0.5214	0.6942	0.4843
Shannon-Weiner (H′)	0.8344	0.6101	0.9754
Evenness	0.4607	0.4601	0.5305

Table 4. Vegetation analysis and importance value.

Species	DBH (Mean ± STDEV)	Relative density	Relative frequency	Relative dominance	Importance value
R. apiculata	5.54 ± 4.28	79.91	52.30	67.17	199.38
R. mucronata	5.32 ± 1.35	11.16	20.30	21.30	52.76
B. gymnorrhiza	7.00 ± 3.31	5.85	14.10	8.56	28.50
A. corniculatum	2.66 ± 0.98	2.41	6.25	0.40	9.06
R. stylosa	9.31 ± 4.51	0.59	4.88	0.69	6.16
C. tagal	13.05 ± 8.52	1.00	4.26	2.28	7.53

across all sampling stations remained low, with a Shannon-Weiner index of H′ = 0.9179, an evenness value of 0.3577, and a high dominance index of 0.5286. These values indicate that mangrove species in the area are unevenly distributed, with *Rhizophora apiculata* being the dominant species.

Species vegetation analysis

The structural variables of the mangrove community, such as relative density, relative frequency, and relative dominance are summarized in Table 4. The DBH of *C. tagal* (13.05 ± 8.52) was generally the largest, though these mangrove species were relatively few across sampling stations. Among the recorded species, *Rhizophora apiculata* has the highest value in terms of relative density (79.91), relative frequency (52.30), and relative dominance (67.17), followed by *Rhizophora mucronata* with values of 11.16 for relative density, 21.30 for relative frequency, and 21.17 for relative dominance. Both *R. apiculata* and *R. mucronata* species have the highest SIV of 199.38 and 52.76 respectively. These species were also frequently observed in all sampling stations in the area.

DISCUSSION

Mangroves provide a range of ecosystem services that benefit human societies. They act as natural barriers against coastal erosion, storm surges, and tsunamis, protecting communities from extreme weather events (Alongi 2014). Additionally, they serve as breeding and nursery grounds for many commercially important fish and crustaceans, directly supporting the livelihoods of fisherfolk (Walters *et al.* 2008). Many indigenous and local communities also rely on mangroves for firewood, timber, and medicinal resources (Primavera 2005). Sustainable management of mangroves is essential to balance resource extraction and conservation. Overharvesting of mangrove wood for fuel, charcoal, and construction has led to widespread deforestation in many coastal areas (Polidoro *et al.* 2010).

The data recorded in this study concerning the mangrove species in Barangay Nabago is less than the recorded mangrove species in other places situated in the northeast part of the Caraga Region such as Pilar, Surigao del Norte with a diversity of 1.63 (Padilla *et al.* 2021), Brgy. Cagdianao, Claver Surigao del Norte with 1.79 diversity (Goloran *et al.* 2020), and Condona Island, Taganaan, Surigao del Norte with diversity values ranging from 0.56 to 1.20 (Gamboa *et al.* 2019), and Barangay Imelda, Dinagat Island (Cañizares & Seronay 2016). These small number of species in Barangay Nabago might be attributed to the past human activities of the residents in the area, where coastal development, massive and extensive cutting of trees in the mangrove forest for household and commercial use were common practices before the implementation of a cutting ban in accordance with Section 4 of RA 7161 and Section 43 of PD 705 of 1975.

Coastal communities such as in Nabago, Surigao del Norte, Philippines are among the most dependent on mangrove ecosystems, as these provide essential breeding and nursery habitats for fish and shellfish species, a commodity in the area. Degradation of mangroves often leads to reduced fish stocks and increased vulnerability of coastal communities to climate change and natural disasters (Duke *et al.* 2007). Sustainable practices, such as community-led conservation initiatives like mangrove reforestation and habitat restoration, along with integrated mangrove-aquaculture systems can be implemented in the area, as these practices have already demonstrated their effectiveness in boosting fishery productivity and strengthening the resilience of coastal communities. These strategies offer the potential to rehabilitate degraded mangrove ecosystems while simultaneously preserving and sustaining economic benefits (Samson & Rollon 2008, López-Angarita *et al.* 2016).

Species from family *Rhizophoraceae* were found to be abundant in the three sampling stations. Cerón-Souza *et al.* (2010) highlighted that these species are the most notable genus in tropical, coastal mangrove ecosystems. In addition, *R. apiculata* dominated in all three sampling stations, suggesting that the environmental conditions in the area favor their growth and proliferation. Members of this family, especially *Rhizophora* species, are known for their adaptability to varying salinity levels, strong root structures that provide stability in coastal environments, and efficient reproductive strategies such as vivipary, which enhance seedling survival in dynamic intertidal zones.

Despite the presence of multiple mangrove species, the low Shannon-Weiner diversity index (H) and high dominance index suggest that the ecosystem is not highly diverse and is instead characterized by a single-species dominance pattern. The dominance of a single species highlights the need for conservation and restoration efforts to promote the species' richness and evenness, ensuring long-term ecological stability and resilience of the mangrove ecosystem. Moreover, the classification of all recorded species under the "Least Concern" category by the IUCN indicates that, on a global scale, these species are not currently facing significant threats of extinction. However, localized pressures, such as habitat degradation, pollution, and even climate change, could still impact their populations over time. Although the local government of Nabago strictly implemented laws that prohibit anthropogenic activities in the area, cuttings were still evident in the sampling stations, indicating ongoing human disturbances. These cuttings are primarily associated with the collection of clam shells and other economically important organisms, as well as timber harvesting for house construction by encroachers from neighboring communities.

On the other hand, the high Species Importance Value (SIV) of *R. apiculata* (199.38) and *R. mucronata* (52.76) indicates their ecological dominance and significant role in the mangrove forest structure. Their frequent occurrence across all sampling stations suggests that these species are well-adapted to the environmental conditions of the study area, such as tidal fluctuations, salinity levels, and soil composition. As observed in the study stations, *R. apiculata* generally thrives in the seaward zones, while *R. mucronata* is often found in slightly more inland areas with stable substrate conditions. Moreover, the high SIV of these species may also be attributed to their efficient reproductive strategies, such as propagule dispersal and high seedling survival rates, which allow them to establish and dominate the mangrove community. Additionally, their structural adaptations, including strong prop roots that provide stability against tidal forces, contribute to their widespread distribution. The dominance of these species plays a crucial role in coastal protection, carbon sequestration, and biodiversity support, further emphasizing their ecological significance in maintaining the health and resilience of the mangrove ecosystem. According to Eisenbarth *et al*. (2018), these co-dominant species are also among the most widespread species in Southeast Asia. They can quickly grow in any substratum type and have the potential to be invasive (Duke *et al*. 2007).

Despite global efforts, mangrove restoration faces challenges such as poor seedling survival, illegal logging, and conflicts between conservation goals and economic development. In some areas, large-scale reforestation projects have failed due to poor site selection and lack of community involvement (Salmo *et al*. 2013). In the Philippines, community-based coastal resource management has been instrumental in restoring mangrove forests. In the locality of Nabago, Project Mangrove Rehabilitation and Conservation (MaReCon) have been started and extended by the authors in collaboration with various institutions and stakeholders from government agencies, industries, people's organization, non-government organizations, and local government unit. As part of MaReCon, a mangrove nursery has been established to ensure a continuous supply of propagules for reforestation efforts, alongside training on mangrove restoration and rehabilitation, mangrove planting in degraded areas, and providing alternative livelihoods to the community. Successful restoration requires careful ecological planning, enforcement of environmental laws, and above all community engagement.

CONCLUSION

This study presents the diversity and structure of mangrove forests in Brgy. Nabago, Surigao City, Philippines. A total of six (6) true mangrove species and one (1) mangrove associate were recorded in the area. The mangrove forest of Brgy. Nabago exhibited a very low diversity index (H'=0.9179), evenness (e^H/S=0.3577), and dominance index (D=0.5286). Across sampling stations, *Rhizophora apiculata* is the densest (79.91), most frequent (52.30), and dominant (67.17) among the recorded species. Thus, proper management of the mangrove forest, conservation programs extending beyond the mangrove ecosystem (e.g., solid waste management in nearby communities), and involvement of communities in restoration initiatives are highly encouraged.

ACKNOWLEDGMENT

This study was made possible through the financial and administrative support of Surigao del Norte State University. The local government unit of Barangay Nabago is also acknowledged for the logistical support extended during the conduct of the study.

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