INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 25, No. 4, p. 111-121, 2024
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Plant community structure and diversity assessment of selected mangrove forest ecosystems along Hinatuan passage, Surigao Del Norte, Philippines

Jerry B. Acero*, **Jr. Ruben F. Amparado, Peter D. Suson, Jose Patrcio H. Hermis, Jay Rey G. Alovera, Sulpecia L. Ponce**

Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines

Article published on October 08, 2024

Key words: Community structure, Conservation status, Diversity, Hinatuan passage, Mangrove forest, Species composition

Abstract

Community structure and diversity assessment of mangrove forests play a critical role in biodiversity conservation and protection of this valuable resource. The study was conducted primarily to assess the plant community structure and species diversity of the three selected mangrove forests along Hinatuan passage, Surigao del Norte, Philippines. Line-quadrat method was used with three established transect lines per sampling station. Each transect line was composed of five-100m² quadrats with one 1m² sub-plot for regeneration capacity. Plant species were carefully identified using taxonomic knowledge and Field identification manuals for mangroves. Height, diameter at breast height (dbh) and frequencies of plant occurrences were recorded and analyzed. Findings showed that the 4,880 sampled mangrove plants, 22 species of true mangroves and associates were identified, grouped into 11 families and 14 genera. All species are classified by IUCN as Least Concern. Biggest dbh was obtained by *Sonneratia alba* with 32cm and *Rhizophora apiculata* was the tallest at 14m. Bakauan-lalaki is the most frequent, densest, most dominant, and highest species relative important value at 56.98%. The overall Diversity Index is Very Low at 1.45, with regeneration capacity of 0.56, classified as *Fair Condition*. Mangrove forest in Opong sampling site is the most disturbed among the three sites due to unabated anthropogenic activities. Mangrove forests in Hinatuan passage are economically and ecologically functional but needing stakeholders' holistic management conservation efforts to improve and sustain the ecosystem's biodiversity, goods and services offered.

***Corresponding Author:** Jerry B. Acero ✉ jerry.acero@g.msuiit.edu.ph

Introduction

Philippines is an archipelagic country with longer coastlines. Thriving well along these coastlines are mangroves species known for their numerous tangible and intangible benefits such as source of livelihood among fisherfolks, a haven for perpetuation and habitat of various marine species, coastline tidal belt, carbon sequestration, filtering water, and among others. Good quality timber of mangrove species benefited many people in terms of shelter, fuel and fishing materials and tannin (Arfan *et al.*, 2021; Sadeer and Mahomoodally, 2022).

Mangrove is the general name for several species of plants which can survive in saline environment with large trees and shrubs that grow within the intertidal zone tropical and subtropical regions and have special adoption to survive in this type of environment. Mangroves are classified in 16 different families in 24 genera which encompasses 84 species with only 70 species are considered true mangroves (Nabeelah Bibi *et al.*, 2019). In the Philippines there are about35- 40 mangrove species (Buot *et al.*, 2022; Primavera, 1013).

In terms of perpetuating the various types of marine life, mangrove forests are vital as they serve as the natural hatchery and nursery habitats for juveniles of fish and different organisms like insects, reptiles, amphibians, birds, and animals (Bharmal *et al.*, 2020). Their proximity to the coastline makes them efficient water filter in improving water quality and protecting habitat such as coral reefs, at the same time protecting coastline from erosion, providing grounds to a rich and complex array of species (Das, 2023).

Despite of the many benefits that communities and people derived from mangrove resources, these valuable resources have been on the verge of losing significantly its vegetation at an alarming pace. According to Hance (2021*)* more than 35% of the world's mangroves are already gone from 1980s to 2000. In Philippines, the various anthropogenic activities impose serious threat to mangroves leading to faster rate of mangrove forests destruction (Goloran *et al.*, 2020). There is an estimated total of 2,091 square kilometers of mangroves area in the Philippines in year 2000 but this area was reduced by 0.11% per year until 2012 (Primavera *et al.*, 2019). Generally, the human-induced pressures have paved for illegal cutting of mangrove plants and trees mainly cut for making charcoal, house, or even firewood or livelihood to the people near the sea (Hamza, 2022). There is also rapid conversion of land-use transforming mangrove forest from small to large scale commercial fishponds (Mariano *et al.*, 2022), residential, industrial, and other types of special economic zonation which led to massive reclamation of mangrove forests.

Biodiversity index is a quantitative measure that reveals the totality of the different individual species seen on the area of interest. To determine the biodiversity status of any vegetation, the following measures are commonly determined such as: Species Richness, Density, Abundance, Dominance, Important value, Evenness and Shannon's Diversity Index (Prasanna *et al.*, 2019). To determine the Biodiversity status of an ecosystem in a scientific approach is key to gain a better understanding of environmental conservation because this will help identify the diversity and abundance of environmental resources at the same time can identify areas, issues and challenges that are needing immediate concerns necessary to maintain ecological balance. The regeneration condition of any mangrove forest is one of the salient biodiversity parameters because this explains the potential of the vegetation to return its vegetative cover and its dynamics would change over time (Azman *et al.*, 2021). Mullet *et al.* (2014) explains that the regeneration value on a per square meter basis is the ratio between the total counted or observed young plants and categorized either *Excellent, good, fair, and poor conditions*.

Since nowadays biodiversity is always challenged by exploitive anthropogenic activities and natural calamities, evaluating forest vegetation and diversity could provide timely inputs any biodiversity initiatives and to the scientific community, particularly those studies that link to the natural forests and the human–induced phenomena (Premlata *et al.*, 2024). Decision makers, planners, line agencies, local legislators, and chief executives along Hinatuan Passage will be provided with relevant and valid data and information on the biodiversity status of the forest resources that are found in their areas of jurisdiction. For this reason, this study was conducted with the primary view of assessing the community structure and diversity status of the selected mangrove forests along Hinatuan Passage, Surigao del Norte, Philippines.

Materials and methods

The study area

Hinatuan Passage in a sea channel located adjacent to Surigao Strait clustering the mainland municipalities of Surigao del Norte namely: Malimono, San Francisco, Taganaan, Placer, Bacuag, Gigaquit and Claver, including the City of Surigao (HIPADA, 2020).

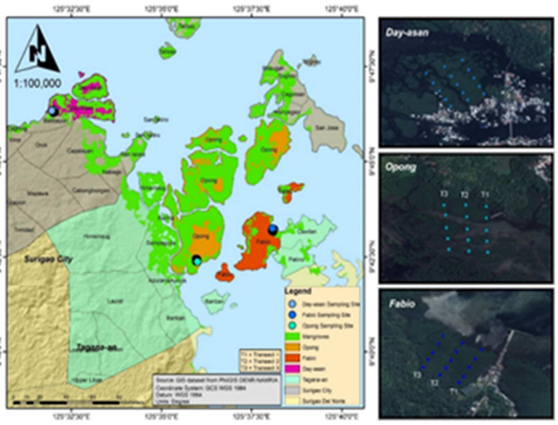

Fig. 1. Location map of Hinatuan passage in Surigao del Norte Philippines

Mangrove is the major theme in the coastal areas of Surigao del Norte. The province of Surigao del Norte is endowed with 14,730 hectares of mangrove forest. Hinatuan Passage has a total 5,281 hectares of mangrove forest (ENR- Profile, 2015). However, NAMRIA (2020) data show that Surigao del Norte province has 13,936 hectares of mangrove forest of which 1,916 hectares are in Surigao City and 2,117 hectares are in the municipality of Taganaan, Surigao del Norte. Fig. 1 shows the three barangays along Hinatuan Passage as selected sampling sites of this study based on having endowed with mangrove forest vegetation approximately 132 hectares for Fabio, 337 hectares for Day-asan and 1,680 hectares for Opong (NAMRIA, 2020).

The proper entry protocol was highly observed prior to the collection of data needed in this study. Series of contacts were observed to obtain informed consent from appropriate agencies such as DENR and BFAR as well as needed coordination with Local Government Units from City down to Municipal and Barangay councils of concerned LGUs. Upon issuance of informed consent, the field reconnaissance to study sites was conducted for familiarization and paying courtesy calls to local leaders.

Data collection was conducted during low tidal condition to facilitate the easy access to the mangrove vegetation. Using the Non-destructive Line Quadrat sampling method (Apriyanto and Nugroho, 2021), three transect lines were then established per sampling site where each transect line, laid out 150 meters long perpendicular to the shoreline composed of five sampling quadrats of 10mx10m dimension set at 25 meters apart. The coordinates of transect lines and quadrats were determined using Global Positioning System (GPS). Mangroves species found within the quadrats were counted and trees with at least 5cm Diameter at Breast Height (DBH) were measured using the diameter tapes and the total height was measured using calibrated bamboo poles. The 1m × 1m sub-plot was also established per quadrat for the counting of propagules or saplings of mangroves for computing the regeneration capacity. The mangrove species were identified using reliable assessment guides, particularly the field guide manual to Philippine Mangroves by Primavera (2013). Local names were also considered for appropriate identification of the spotted species. Species observed outside the sampling quadrats were also recorded and included in the counting of total number of species of the study sites (Zhao *et al,* 2023).

In evaluating the vegetation analysis and community structure metrics, the species frequency, density, dominance and importance value and their relative values were evaluated using the formulae (Maua *et al.*, 2020):

Population density = (Number of individuals)/(Total area sampled)

Relative density = {(Density of a species)/(Total density of all species)} ×100

Frequency = (Number of plots in a species occurs)/(Total number of plots sampled)

Relative Frequency (RF) = {(Frequency value for a species)/(Total of frequency value for all species)}×100

Dominance = (Total Basal Area of each tree species from all plots)/(Total area sampled)

The Basal Area per tree is the cross- sectional area of a tree at breast height and was calculated based from DBH measurement (Apriyanto and Nugroho, 2021).

$BA = D^2 \times 0.7854$

Relative Dominance (RDO) = {(Dominance of a species)/(Total dominance for all species)}×100

Species Important Value (SIV)

SIV = Relative Density + Relative Dominance + Relative Frequency

Determination of species diversity

The mangrove community's species diversity was calculated using Shannon-Wiener's Diversity Index (Abba and Timothy, 2021), which indicates a quantitative description of mangrove habitat in terms of species distribution and evenness.

Shannon-Wiener Diversity (H'):

$$H' = -\sum_{i=1}^{s}(i \times \ln pi)$$

Where S is the total number of species, p_i is the proportion of individuals to the i^{th} species expressed as a portion of the total cover and ln is the log base n.

The Paleontological Statistics Software (PAST) developed by Hammer *et al.* (2024) was used to determine the corresponding diversity indexes (Abba and Timothy, 2021). The Diversity values for Shannon-Wiener were classified based on the scale developed by Fernando in 1998 (Dimalen and Rojo, 2019).

Results and discussion

Species composition and community structure

The inventory of mangrove species in the three sampling sites of this study along Hinatuan passage, Surigao del Norte, Philippines included species that are considered True Mangrove and those that are known as mangrove associate species. True mangroves are those mangrove species that are exclusively restricted to tropical intertidal habitats and do not extend into terrestrial plant community and are morphologically, physiologically, and reproductively adapted to saline, waterlogged and anaerobic condition (Lugo and Medina, 2020).

Table 1. Inventory of mangrove Species observed in all sampling stations along Hinatuan Passage, Surigao del Norte, Philippines

Family	Species	Classification	Common Name	IUCN Status
Rhizophoraceae	*Rhizophora apiculata*	True Mangrove^	Bakhaw- Lalaki	LC
Rhizophoraceae	*Rhizophora mucronata*	True Mangrove^	Bakhaw- Babae	LC
Rhizophoraceae	*Rhizophora stylosa*	True Mangrove^	Bakhaw- Bato	LC
Lythraceace	*Sonneratia alba*	True Mangrove^	Pagatpat	LC
Avicenniaceace	*Avicennia Marina*	True Mangrove^	Bungalon	LC
Avicenniaceace	*Avicennia rumphiana*	True Mangrove^	Miapi	LC
Myrsinaceace	*Aegiceras corniculatum*	True Mangrove^	Saging-saging	LC
Rhizophoraceae	*Ceriops decandra*	True Mangrove^	Baras-baras	NT
Rhizophoraceae	*Ceriops tagal*	True Mangrove^	Tungog	LC
Rhizophoraceae	*Bruguiera gymnorrhiza*	True Mangrove^	Busain	LC
Rhizophoraceae	*Bruguiera sexangola*	True Mangrove^	Pototan	LC
Bombacaceae	*Camptostemon philippinense*	True Mangrove^	Gapas-gapas	EN
Arecaceace	*Nypa fruticans*	True Mangrove^	Nipa	LC
Sterculiaceace	*Heritiera littoralis*	Mangrove Associate^	Dungon	LC
Rubiaceace	*Scyphiphora hydrophyllacea* *	True Mangrove^	Nilad	LC
Lythraceace	*Pemphis acidula* *	Mangrove Associate^	Bantigi	LC
Acanthaceace	*Acanthus ebracteatus**	True Mangrove	Lagiwliw	LC
	*Acanthus ilicifolius**	True Mangrove#	Ragoyroy	LC
Combretaceace	*Lumnitzera littorea**	True Mangrove#	Tabau	LC
	*Lumnitzera racemosa**	True Mangrove#	Culasi	LC
Meliaceace	*Xylocapus granatum**	True Mangrove^	Tabigui	LC
	*Xylocarpus moluccensis**	True Mangrove^	Piag-ao	LC

* - Species observed outside the sampling plots

LC - Least Concern; EN – Endangered; Nearly Threatened

Classification Sources: (^) - Replan & Malabrigo, 2017); # - (Vaigan & Joseph, 2016)

A total of 22 mangrove species in the three study sites were identified taxonomically up to species level as presented in Table 1. Of the 22 species, 20 were classified as true mangroves and two as associates representing 11 families and 14 genera. However, 8 of the 22 species were observed outside the sampling stations. In Day-asan sampling site, there were 12 mangrove species identified, 9 in Opong and 8 in

Fabio, Taganaan, Surigao del Norte all of which are considered True mangroves.

IUCN red list of species for 2022 identified all species as Least Concern in terms of conservation status, except Baras-baras (*Ceriops decandra)* which is categorized as Nearly Threatened. However, Bantigi (*Phemphis acidula*) which is considered as Least Concern by IUCN belongs to critically endangered category, while Gapas-gapas (*Camptostemon philippinense*) and Baras-baras (*C. decandra)* are endangered classification based on DAO 2017-11. The study of Goloran *et al.* (2020) disclosed that there are 9 mangrove trees species in Claver, Surigao del Norte and 12 species of mangrove in Butuan Bay, in Agusan del Norte, an adjacent province of Surigao del Norte.

Likewise, the study of Villanueva *et al.* (2021) reported the 17 mangrove species observed in Panguil Bay, Ozamiz City, Philippines, while Cano-Mangaoang *et al.* (2022) identified 15 true mangrove species in Cotabato City. This comparison of results as to mangroves species from various parts of Mindanao, Philippines shows that the mangrove diversity status in Hinatuan passage is relatively more diverse compared to other mangrove forests in the country, and likewise gives us the wider perspective of the notable current species richness condition of the mangrove forest in the study area.

Table 2. Species Composition and Community Structure of Three Natural Mangrove forests along Hinatuan Passage, Surigao del Norte, Philippines

Site	No. of Trees/Plants	Species	DBH (cm) Mean	DBH (cm) Min	DBH (cm) Max	Height (m) Mean	Height (m) Min	Height (m) Max
Day-asan	134 Trees **1,263** plants	*R. apiculata, R. mucronata A. corniculatum, C. decandra, B. gymnorrhiza, C. philippinense, S. alba, A. marina, N. fruticans, H. littoralis*	9.5	5	25	5.12	3.20	12.5
Opong	179 Trees **1,447** Plants	*R. piculata, R. mucronata R. stylosa S. alba, A. rumphiana, A. corniculatum*	6.48	5	27	3.92	2.5	12.0
Fabio	386 Trees 2,170 Plants	*R. apiculata, R. mucronata B. gymnorrhiza B. sexangola C. tagal, N. fruticans, A. corniculatum*	10.58	5	32	8.51	2.7	14
TOTAL	**669** **4,880**	**Trees** **Plants**						

Table 2 shows the DBH and height measurements of the mangrove species in Hinatuan passage, Surigao del Norte. Generally, the DBH of the sampled trees ranges 5-32cm with a mean of 8.85cm. Day-asan station has a mean of 9.5cm with lowest diameter at 5cm and the highest at 25cm. Opong site ranges 5-27cm with a mean of 6.48cm, while Barangay Fabio ranges 5-32cm with a mean DBH of 10.58cm. The biggest DBH was measured at 32cm from *S. alba* in Fabio site. For height measurement, it was revealed that Opong has the shortest among the three stations with a mean of 2.5 meters from *A. corniculatum*, while the tallest was measured from *R. apiculata* in Fabio site at 14 meters. Findings reveal further that mangrove size in Barangay Opong is relatively smaller and shorter in heights than those in Day-asan and Fabio stations. This finding can be attributed to the conservation efforts of Barangay Fabio which has strict law enforcement program to mangrove forest within its areas of concern. The Municipality of Taganaan passed the Municipal Ordinance No. 05 Series of 2016 declaring portions of mangrove and marine ecosystems in Barangay Fabio as protected areas locally known as Tagana-an Marine Sanctuary (TMS).

Fabio sampling station as presented in Table 2 obtained the highest number of trees recorded and measured in all quadrats with a total of 2,170 plants, followed by Opong at 1,447 and the least was in Day-asan with 1,263 plants. Observations reveal that of all the mangrove forest included in the study, Opong sampling site is the most disturbed due to frequent and less regulated fishery activities, particularly in the Asinan areas where the sampling site was located. As a result of human constant disturbance to mangroves in Opong area, trees became smaller and shorter (Zanvo *et al.,* 2021).

Species important value

The Species Important Value (SIV) indicates the structural importance of each mangrove species in the community (Raganas *et al.*, 2022). It also provides overall estimate of the influence of these species in the community (Liu *et al*., 2021).

Table 3 presents the community metrics and the most the dominant species found in Hinatuan passage. It was observed that *R. apiculata,* is the most frequent, the densest, most dominant, and obtained also the highest species important relative value. It explains the degree of influence of Bakauan-lalaki in terms of distribution, number, and space utilization in the area with a relative species value of 56.98%. This is followed by *R. mucronata at 12.91%* while the least is *C. decandra at 0.50%.* In high salinity areas, Rhizophora species could tolerate because of their nature to ecologically adapt coupled with their stress response mechanisms to salinity stress in the early developing propagules (Nizam *et al.*, 2024) which could enable them to thrive in wide range of salinity level across the brackish ecosystem (Purwanto *et al.*, 2022).

Table 3. Species Importance Value and Rank of Mangrove Trees in the Selected Mangrove Forests Along Hinatuan Passage

Species	Freq	Den	Dom	SIV	RIV (%)	Rank
R. apiculata	0.3333	0.8331	0.001057	170.93	56.98	1
R. mocrunata	0.2889	0.1511	0.000094	38.738	12.91	2
S. alba	0.1556	0.0331	0.000085	18.771	6.26	3
A. corniculatum	0.2000	0.0300	0.000008	16.014	5.34	4
N. fruticans	0.0889	0.0216	0.000089	13.778	4.59	5
R. stylosa	0.1556	0.0036	0.000004	10.215	3.41	6
C. tagal	0.0667	0.0018	0.000025	6.142	2.05	7
A. marina	0.0444	0.0022	0.000028	4.951	1.65	8
B. sexangola	0.0444	0.0027	0.000019	4.399	1.47	9
A. rumphiana	0.0444	0.0013	0.000000	2.970	0.99	10
B. gymnorrhiza	0.0222	0.0007	0.000014	2.434	0.81	11
C. Philippinense	0.0222	0.0004	0.000014	2.414	0.80	12
H. littoralis	0.0222	0.0004	0.000007	1.932	0.64	13
C. decandra	0.0222	0.0004	0.000001	1.509	0.50	14

- *Freq = Frequency; Den = Density; Dom = Dominance; SIV=Species Important. Value*

The distribution of the number of mangrove trees with DBH of at least 5cm is shown in Fig. 2, which shows that out of 699 mangrove trees measured and recorded, 377 trees (56%) fall within 5-10 cm range. There were five *S. alba* trees measured more than 30cm DBH. The highest mean diameter is 10.58cm obtained from Fabio site (see Table 2) which can be attributed however to the fact that all three transect lines were in pure natural stand of mangrove vegetation. This result is supported by the case of Lanao del Norte where human disturbance to mangroves is minimal, mangroves have evidently seen by old strands of trees with large basal area (Barbanera, 2020). The overall distribution of recorded plants regardless of DBH measurement is presented in Fig. 3 which depicts that most of the plants observed in the three sampling stations are smaller in size with less than 5cm DBH.

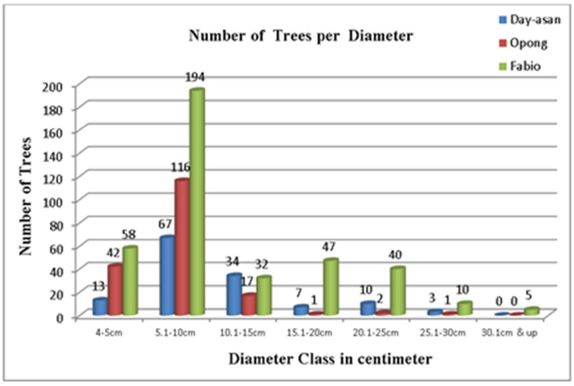

Fig. 2. Distribution of mangrove species with at least 5cm diameter

Out of the 4,880 plants recorded, 4,294 or 87.99% measured less than 5cm DBH, while 377 or 7.73% fall within 5-10cm range, 83 or 1.7% within 10-15cm and only 5 trees or 0.1% have 30cm and above DBH.

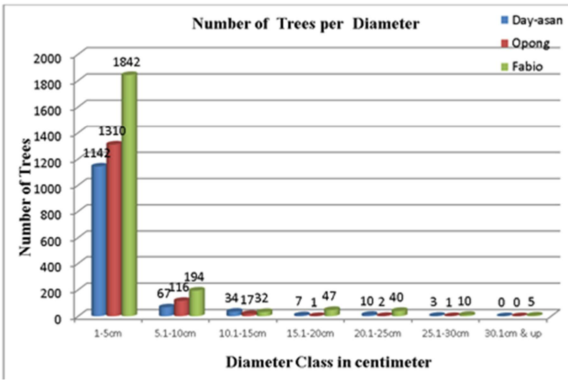

Fig. 3. Distribution of mangrove species by 5cm diameter interval

The species density is the ratio of the number of individuals recorded and the total area sampled (Zulhalifah *et al.*, 2021). The species density and other community metrics of mangrove forest in Hinatuan passage in is shown in Table 4 which shows that there are 8,418 trees per hectare in Day-asan, Surigao City and Opong is at 9,647 trees/ha. However, the densest among the three sampling sites is Barangay Fabio with 14,667 trees per hectare. It is because the natural stand of mangrove trees tends to have higher density during pioneer growth stage (Ahmed *et al.*, 2022).

Table 4. Vegetation Analysis and Shannon-Weiner Index of Mangrove Species found in sampling stations along Hinatuan Passage, Surigao del Norte, Philippines

Sampling Sites	Species	Tree Density (Trees/ha)	SIV (%)	H'
Day-asan	*R. apiculata,*	0.4153	116.44	1.769
	R. mucronata	0.3866	81.12	
	A. corniculatum,	0.0093	9.63	
	C. decandra,	0.0013	3.14	
	B. gymnorrhiza,	0.0020	7.44	
	C. philippinensis,	0.0013	7.37	
	S. alba,	0.0060	42.27	
	A. marina,	0.0127	12.23	
	N. fruticans,	0.0060	31.60	
	H. littoralis	0.0013	5.11	
	Total	**0.8418**		
Opong	*R. apiculata,*	0.8473	218.24	0.982
	R. mucronata	0.0080	11.12	
	R. stylosa	0.01067	26.21	
	S. alba,	0.0880	30.03	
	A. rumphiana,	0.0040	7.98	
	A. corniculatum	0.0067	7.10	
	Total	**0.9647**		
Fabio	*R. apiculata,*	1.2367	224.81	1.091
	R. mucronata	0.0587	19.32	
	S. alba	0.0053	14.21	
	B. sexangola	0.0080	9.57	
	C. tagal,	0.0053	13.49	
	N. fruticans,	0.0587	12.06	
	A. corniculatum	0.0740	19.66	
	Total	**1.4467**		

Note: SIV, Species Important Value; H' Diversity Index

The species density and Species Important Value (SIV) were used to determine the Diversity Index of the study sites using Shannon-Weiner Diversity Index with the aid of Paleontological Statistical Software (PAST) developed by Hammer and Harper (2024). The result of the analysis as shown in Table 4 which reveals that the Diversity Indexes of the three sampling stations in Hinatuan passage, Surigao del Norte are 1.769 for Day-asan, 0.982 for Opong and 1.091 for Fabio. Based on the scale developed by Fernando (1998), all study sites are interpreted as Very Low. The low diversity index value explains the dominance of few species (Fernando, 1998). In the case of Hinatuan passage it is the species of Rhizophora family that is observed as the most widely distributed species in all areas, particularly the *R. apiculata* characterized having the ability to adapt and tolerate to high salinity (Lomoljo-Bantayan *et al.,* 2023). This finding shows similar scenario along with other studies on mangroves in some parts of Caraga region such as that of the study of Goloran *et al.* (2020) and Lillo *et al.* (2019) where Rhizophora genera were reported as most abundant and dominant species in their respective studies.

Regeneration condition of mangrove species

Mangrove seedlings and saplings were also evaluated to gain insight on the regeneration capacity of the mangrove forest ecosystems in Hinatuan passage. In a 1m × 1m subplot, the number of saplings and propagules were counted and recorded. The ratio between the matured mangrove plants (5cm DBH and above) and the young (saplings and propagules with DBH of < 5cm) was counted as presented in Fig. 4.

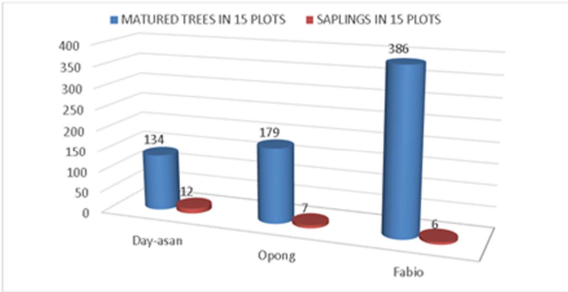

Fig. 4. The ratio of matured and young mangrove plants in selected mangrove forests of Hinatuan passage, Surigao del Norte

The Highest number of matured individuals was observed in Fabio station at 386 individuals, followed by Day-asan station with 134 and Opong site with 179. However, the number of young plants observed in 15 plots per station was highest in Day-asan with 12, followed by Opong with 7 and the lowest was in Fabio at 6 individuals. Based on the criteria set by Mullet *et al.* (2014) the regeneration condition Day-asan at 0.80 is categorized as in *Good Condition*, while that of Opong (0.47) and Fabio (0.40) are both in *Poor Conditions*. The poor condition in Fabio can be attributed to the stage of the stand which is already matured, particularly the middle sampling quadrats (2-3 quadrats) having generally taller and bigger plants compared to Opong and Day-asan. This situation provides a condition that could not allow the young mangrove plants to survive due to closer canopies (Amir and Duke, 2019). The fewer number of young plants in Opong station can be attributed most likely to the disturbance due to unregulated anthropogenic activities. This sampling station is situated nearby the seaport where daily fishery activities of the community caused disturbance to the growth and development of mangroves as emphasized by (Ellison, 2021) that stress leads to decreasing structural complexity in black mangroves. The overall regeneration condition of the selected mangrove forests in Hinatuan Passage is 0.56 which is generally interpreted as *Fair Condition*.

Conclusion

Based on the findings of this study, it hereby concluded that the community structure of the 3 selected mangrove forests in Hinatuan Passage is structurally functional having composed of 22 mangrove species, though dominated by *Rhizophora* family. Its overall diversity is *Very Low* due to the dominance of few *Rhizophora* species, particularly the Bakawan lalaki and Bakauan-babae which provide the widest extent of influence among the mangrove species found in the study site. The overall regeneration condition of the selected mangrove forest of this mangrove ecosystem is in fair which indicates its ability to self-regenerate amid disturbances. Its current condition in terms of forest protection has been affected with the presence of illegal cutting of mangrove trees as evidenced by the presence of freshly cut stumps during assessment which shows the prevalence of unregulated extraction of mangrove resources. Indeed, Hinatuan mangrove forest ecosystem is needing a holistic approach to management and protection of mangrove resources for the sustainability of its role in providing various economic and ecological services for the benefit of the people along Hinatuan passage who are mostly dependent to mangrove resources.

Recommendations

In the light of the foregoing findings and for the conservation of the mangrove forest resources in Hinatuan Passage, it is highly recommended to undertake the following courses of action:

1. Regularly conduct Coastal Resource Management seminar in all coastal communities within Hinatuan passage to disseminate to the people the Importance of Mangroves in their community and the ways to conserve the mangrove resources,
2. Strengthen the initiatives within the LGU Barangay and municipal levels in conserving mangrove resources by strengthening the coastal reforestation and strict enforcement of environmental laws to regulate cuttings of mangrove trees an throwing of solid wastes to mangrove areas. In barangay Opong, the enrichment planting along Asinan area is highly recommended since there are patches of mangrove forest ideal for reforestation thereby preventing the total loss of mangrove vegetation in the area soon.
3. Conduct a periodic (every 5 years) mangrove community structure and diversity assessment to monitor the condition mangrove forest area as vital inputs to community planning and coastal program prioritization among Local Government Units.

References

Abba HM, **Timothy H**. 2021. Assessment of Herbaceous Species Diversity in Lede and Galumji, Wawa-Zange Forest Reserve, Gombe State, Nigeria. American Journal of Plant Sciences **12**(11), 1741-1753. https://doi.org/10.4236/ajps.2021.1211120

Ahmed S, **Kamruzzaman M**, **Rahman MS**, **Sakib N**, **Azad MS**, **Dey T**. 2022. Stand structure and carbon storage of a young mangrove plantation forest in coastal area of Bangladesh: the promise of a natural solution. Nature-Based Solutions **2**, 100025. https://doi.org/10.1016/j.nbsj.2022.100025

Amir AA, **Duke NC**. 2019. Distinct characteristics of canopy gaps in the subtropical mangroves of Moreton Bay, Australia. Estuarine, Coastal and Shelf Science **222**, 66-80. https://doi.org/10.1016/j.ecss.2019.04.007

Apriyanto E, **Nugroho PB**. 2021. Species composition, diversity and biomass of mangroves forest in Pulau Bai-Pantai Panjang Natural Conservation Park of Bengkulu, Indonesia. Aquaculture, Aquarium, Conservation & Legislation **14**(4), 2012-2020.

Arfan A, **Side S**, **Maru R**, **Juanda MF**. 2021. Mangrove forest management model as sustainable production forest of post COVID-19 in South Sulawesi, Indonesia. Asian Journal of Conservation Biology **10**(2), 234-239.

Azman MS, **Sharma S**, **Shaharudin MAM**, **Hamzah ML**, **Adibah SN**, **Zakaria RM**, **MacKenzie RA**. 2021. Stand structure, biomass and dynamics of naturally regenerated and restored mangroves in Malaysia. Forest Ecology and Management **482**, 118852. https://doi.org/10.1016/j.foreco.2020.118852

Barbanera A. 2021. Determining the consequences of forest degradation on mangrove epifauna in South-East Kenya (Master's thesis, Bangor University, United Kingdom).

Bharmal DL, **Dethe UL**, **Desai NM**, **Pawar UR**, **Aparadh VT**. 2020. Climate Change, Mangrove & Sustainable. Bhumi Publishing.
ISBN: 978-93-88901-10-9

Buot Jr IE, **Origenes MG**, **Obeña RDR**. 2022. Conservation status of native mangrove species in the Philippines. Journal Wetlands Biodiversity **12**, 51-65.

Cano-Mangaoang C, **Amino ZC**, **Mastur BB**. 2022. Status of mangrove forest in Timaco Mangrove Swamp, Cotabato City, Philippines. Journal of Threatened Taxa **14**(11), 22080-22085. https://doi.org/10.11609/jott.7826.14.11.22080-22085

DAO 2017-11. Updated National List of Threatened Philippine Plants and Their Categories. Department of Environment and Natural Resources. https://elibrary.bmb.gov.ph/elibrary/wp-content/uploads/2023/05/dao2017-1.pdf

Das S. 2020. Does mangrove plantation reduce coastal erosion? Assessment from the west coast of India. Regional Environmental Change **20**(2), 58. https://doi.org/10.1007/s10113-020-01637-2

Dimalen FK, **Rojo MJ**. 2019. Floral diversity of a mangrove forest in Cotabato City, Philippines. Journal of Biodiversity and Environmental Science.

Ellison JC. 2021. Factors influencing mangrove ecosystems. Mangroves: Ecology, Biodiversity and Management, 97-115.

ENR Profile. 2015. Environment and Natural Resources Profile of DENR-Provincial Environment and Natural Resources Office. DENR-PENRO-Surigao del Norte.

Fernando ES. 1998. Forest Formations and Flora of the Philippines Handout in FBS 21. (Unpublished).

Goloran AB, **Demetillo MT**, **Betco GL**. 2020. Mangroves assessment and diversity in coastal area of Barangay Cagdianao, Claver, Surigao del Norte, Philippines. International Journal of Environmental Sciences and Natural Resources **26**(3), 82-90. http://dx.doi.org/10.19080/IJESNR.2020.26.556188

Goloran AB, **Laurence C**, **Glenn B**, **Tricia MA**. 2020. Species composition, diversity and habitat assessment of mangroves in the selected area along Butuan Bay, Agusan Del Norte, Philippines. Open Access Library Journal **7**(4), 1-11. https://doi.org/10.4236/oalib.1106249

Hammer Ø, **Harper DA**. 2024. Paleontological data analysis, 2nd Ed. John Wiley & Sons.
ISBN: 9781119933939

Hamza A. 2022. Understanding changes in mangrove forests and the implications to community livelihood and resource management in Kenya. Doctoral dissertation. Department of Life and Environmental Science, Faculty of Science and Technology, Bournemouth University.

Hance J. 2021. Vanishing mangroves are carbon sequestration powerhouses. Accessed on 26

HIPADA. 2020. Hinatuan Passage Development Alliance Profile. https://surigaofocas.wordpress.com/hipada/retrieved March 16, 2020.

IUCN. 2022. IUCN Red List of Threatened Species. Available at: http://www.iucnredlist.org. Accessed: January 15, 2022.

Lillo EP, **Fernando ES**, **Lillo MJR**. 2019. Plant diversity and structure of forest habitat types on Dinagat Island, Philippines. Journal of Asia-Pacific Biodiversity **12**(1), 83-105. https://doi.org/10.1016/j.japb.2018.07.003

Liu M, **Li X**, **Zhu R**, **Chen N**, **Ding L**, **Chen C**. 2021. Vegetation richness, species identity, and soil nutrients drive the shifts in soil bacterial communities during restoration process. Environmental Microbiology Reports **13**(4), 411-424. https://doi.org/10.1111/1758-2229.12913

Lugo AE, **Medina E**. 2020. Mangrove forests. In Coastal and Marine Environments, pp. 117-133. CRC Press. eBook ISBN: 9780429441004. https://www.taylorfrancis.com/books/mono/10.1201/9780429441004/coastal-marine-environments?refId=9bac6fe5-c558-436f-ba35-7ff2e7a543b6&context=ubx

Malabrigo P, **Tobias A**, **Eduarte G**, **Terbio L**, **Hernandez J**, **Umali AG**. 2022. Tree diversity and stand structure of a 2-hectare Permanent Biodiversity Monitoring Area (PBMA) in Mts. Iglit-Baco National Park, Mindoro Island, Philippines. Ecosystems and Development Journal **12**(1), 83-94. https://ovcre.uplb.edu.ph/journals-uplb/index.php/EDJ/issue/view/87

Mariano H, **Aguilos M**, **Dagoc FL**, **Sumalinab B**, **Amparado Jr R**. 2022. Abandoned Fishpond Reversal to Mangrove Forest: Will the Carbon Storage Potential Match the Natural Stand 30 Years after Reforestation? Forests **13**(6), 847. https://doi.org/10.3390/f13060847

Maua JO, **Mugatsia-Tsingalia H**, **Cheboiwo J**, **Odee D**. 2020. Population structure and regeneration status of woody species in a remnant tropical forest: A case study of South Nandi Forest, Kenya. Global Ecology and Conservation **21**, e00820. https://doi.org/10.1016/j.gecco.2019.e00820

Nabeelah Bibi S, **Fawzi MM**, **Gokhan Z**, **Rajesh J**, **Nadeem N**, **RR RK**, **Pandian SK**. 2019. Ethnopharmacology, phytochemistry, and global distribution of mangroves—A comprehensive review. Marine Drugs **17**(4), 231.

Nizam A, **Rawoof A**, **Adot V**, **Madhavan C**, **Ramchiary N**, **Kumar A**. 2024. Comparative root transcriptome analysis of *Kandelia candel* Druce and *Rhizophora mucronata* Lam. germinating propagules under salinity gradients reveal their tolerance mechanisms and ecological adaptations. Plant Growth Regulation **103**, 539–563. https://doi.org/10.1007/s10725-024-01210-3

Prasanna MM, **Ranawana KB**, **Jayasuriya KG**. 2019. Species composition, abundance and diversity of mangroves in selected sites in Amprara District in the east coast of Sri Lanka. Ceylon Journal of Science **48**(2). https://doi.org/10.4038/cjs.v48i2.7621

Premlata, **Kumar R**, **Hajam YA**, **Giri A**. 2024. Threats, Challenges, and Conservation Strategies of Himalayan Faunal Biodiversity. In Role of Science and Technology for Sustainable Future: Volume 1: Sustainable Development: A Primary Goal, pp. 321-344. Singapore: Springer Nature Singapore. DOI: 10.1007/978-981-97-0710-2_19

Primavera JH, **Friess DA**, **Van Lavieren H**, **Lee SY**. 2019. The mangrove ecosystem. World Seas: An Environmental Evaluation, pp. 1-34. https://doi.org/10.1016/B978-0-12-805052-1.00001-2

Primavera JH. 2013. Field Guide to Philippine Mangroves. Journal of Chemical Information and Modeling **53**(9), 1689–1699. https://doi.org/10.1017/CBO9781107415324.004

Purwanto RH, **Mulyana B**, **Satria RA**, **Elawad Yasin EH**, **Raditya Putra IS**, **Putra AD**. 2022. Spatial distribution of mangrove vegetation species, salinity, and mud thickness in mangrove forest in Pangarengan, Cirebon, Indonesia. Biodiversitas: Journal of Biological Diversity **23**(3). DOI: 10.13057/biodiv/d230324

Raganas AFM, **Magcale-Macandog DB**. 2022. Diversity and Structural Characteristics of Mangrove Forests in the Southern District of Oriental Mindoro, Philippines. In Assessing, Mapping and Modelling of Mangrove Ecosystem Services in the Asia-Pacific Region, pp. 219-237. Singapore: Springer Nature Singapore. https://www.springer.com/series/11884

Sadeer NB, **Mahomoodally MF**. 2022. Mangroves with Therapeutic Potential for Human Health: Global Distribution, Ethnopharmacology, Phytochemistry, and Biopharmaceutical Application. Academic Press.

Vaiga M, **Joseph S**. 2016. Identification of mangrove and mangrove associates in Kannur district of Kerala including their economic–ecological linkages. International Journal of Botany Studies **1**(5), 22-31.

Villanueva GV, **Alaman BB**, **Calago JC**, **Genon AM**, **Pangilinan P**. 2021. Diversity of mangrove species along Panguil Bay, Ozamiz City, Mindanao Island, Philippines. Intl J Bot Stud **6**(3), 580-586. ISSN: 2455-541X

Zanvo MS, **Salako KV**, **Gnanglè C**, **Mensah S**, **Assogbadjo AE**, **Glèlè Kakaï R**. 2021. Impacts of harvesting intensity on tree taxonomic diversity, structural diversity, population structure, and stability in a West African mangrove forest. Wetlands Ecology and Management **29**, 433-450.

Zhao J, **Chen J**, **Chen C**, **Lu S**, **Song C**, **Liu S**, et al. 2023. Is it sufficient. Assessment of two sampling methods for urban plant species richness investigations. Urban Forestry & Urban Greening **79**, 127824. https://doi.org/10.1080/01431161.2020.1800123

Zulhalifah Z, **Syukur A**, **Santoso D**, **Karnan K**. 2021. Species diversity and composition, and above-ground carbon of mangrove vegetation in Jor Bay, East Lombok, Indonesia. Biodiversitas Journal of Biological Diversity **22**(4). https://doi.org/10.13057/biodiv/d220455