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Species diversity, forest structure and composition of the Mangrove forest in the Sangalang locality, Biliran Island, Philippines

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Abstract

Mangrove forests contribute to the diversity, richness and productivity of coastal ecosystems. Unfortunately, these forest types are vulnerable to both human-caused and natural disturbances. In order to learn more about their diversity, structure and composition, and disturbance impact, nine permanent plots were established across three transect lines in Sangalang mangrove forest. The results showed a low species diversity using Shannon index (2.15), with five identified *Rhizophora* species within the study area. Additionally, the disturbance had no significant effect on the forest's structure ($p < 0.05$). Our research will serve as baseline for understanding the status of the mangrove forest and provides valuable insight for potential forest policies that could help protect and preserve these ecologically essential habitats in the island.

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Introduction

Mangroves contribute to the richness, diversity, and productivity of coastal ecosystems and exhibit resilience in challenging environmental conditions (Abino *et al.*, 2014; Pan *et al.*, 2013; Alimbon and Manseguiao, 2021). Mangrove forests, as highly productive ecosystems, offer numerous benefits to local communities, such as livelihood sustenance and opportunities, coastal erosion regulation, tourism promotion, spiritual practices, and diverse species habitats (Primavera, 2000; Spalding and Parrett, 2019). However, mangrove ecosystems face ongoing threats from unsustainable human activities, resulting in their degradation alongside their susceptibility to climate change impacts, such as rising sea levels (Abino *et al.*, 2014).

On the other hand, recent global interest in the ability of mangrove forests to capture and store carbon dioxide (CO^2) has led to the term "blue carbon sinks" to describe their significance (Rosen and Olsson, 2013). The amount of carbon stored in forest biomass varies due to factors like location, species composition, and disturbance history (Chapin *et al.*, 2006), underscoring the importance of understanding the factors influencing forest biomass variation to assess its future capacity as a carbon sink (Pan *et al.*, 2013).

Similarly, species diversity plays a crucial role in influencing aboveground biomass within a stand or community through various ecological processes, including niche complementarity, mass ratio selection, and competitive exclusion effects (Ali & Yan, 2017). According to Yachi and Loreau (2007), multilayered stands can enhance light availability, facilitating niche differentiation and mechanisms of species facilitation. The relationship between species diversity, stand structural complexity, and aboveground biomass is instrumental in driving significant carbon storage over time (Ali & Yan, 2017). While both species diversity and stand structural complexity are predictors of aboveground biomass, the latter emerges as a more robust predictor (Walters *et al.*, 2008). These indicators provide valuable insights for estimating forest carbon content and identifying areas with exceptional significance for carbon sequestration and storage.

This study aims to evaluate the present species diversity, species composition, and the influence of disturbance on the forest structure (measured by diameter at breast height and height) in the significant mangrove forest of Biliran Island, Philippines. Specifically, it seeks to answer the following research questions: (a) What is the level of species diversity observed in the Sangalang mangrove forest? (b) Are there variations in forest structure and composition across different transect lines? (c) Is there any similarity in structure and species composition among the plots? By addressing these research questions, this study aims to enhance our understanding of the current state of the mangrove forest.

Material and methods

Study area

Biliran Province, situated in Region VIII, is an volcanic island comprising of eight municipalities (Fig. 1). Given its susceptibility to natural disasters like storm surges, floods, and earthquakes, Biliran Island presents a distinct opportunity to establish permanent plots for monitoring the productivity of mangrove forests under these recurrent natural disturbances, which are more prevalent in island locations within the Philippines.

The research was conducted in the mangrove forests of the Sangalang locality, located in Biliran Island, Philippines (Fig. 1). The selection of this study site was based on factors such as availability and accessibility to the mangrove forest. Moreover, the choice of study sites in Biliran Province was guided by existing Memoranda of Agreement (MOAs), facilitating effective collaboration with local communities in the conservation and management of crucial mangrove forests. The frequent occurrence of natural disturbances in the area also presented a unique opportunity to observe and monitor the productivity of mangrove forests under such conditions.

Fig. 1. (a) Displays a map of the Philippines, highlighting the location of Biliran Island. Fig. (b) Illustrates a detailed map of Biliran Island, pinpointing the study site in Sangalang locality. The maps were sourced from Google Maps (Terrain) and provided a valuable visual reference for understanding the study's geographic location.

Sampling and data collection

A random sampling approach was employed in this study to establish nine permanent sampling plots within the mangrove areas. Each station had a transect line spanning 100 to 200 meters perpendicular to the shoreline. A total of nine plots were distributed evenly across the three transect lines, with a distance interval of 30 meters (Ogawa *et al.*, 2022; Abino *et al.*, 2014). To measure the diameter at breast height (dbh), a 10-meter diameter tape was used, while the height (m) of the trees was measured using a calibrated pole. All mangrove tree species encountered were taxonomically identified and classified using the field guide manual "Philippines Mangroves" by Primavera *et al.* (2016) and Primavera (1995). The identification and classification of mangrove tree species in this study were based on the field guide manual provided by Primavera *et al.* (2016).

Disturbance parameters

Our disturbance parameters are limited only from observation in the study area and was severely affected by tropical Urduja last 2017 (ADRC, 2017). Much of the forest were impacted and caused havoc to the locality. In this case, we refer the following disturbance parameters as follows: Moderate disturbance-less cutting of mangrove trees for fuel wood and low regeneration capacity after the tropical storm Urduja. On the other hand, high disturbance-presence of road construction for boats, cutting of mangrove trees for fuel wood, presence of garbage from the other locality, and flooded area (ADRC, 2017).

Data analysis

This study used descriptive statistics for both diameter at breast height (dbh) and height such as mean, minimum, maximum, and standard deviation (sd) coefficient of variation (cv) to identify differences among plots and by species. We used the library vegan (Dixon, 2003) to compute the Shannon Diversity Index in each transect lines and all plots in Sangalang locality. Additionally, we performed a two Sample T-test in R Core Team to verify the significant differences of mean dbh and height (to represent forest structure) among the locality. We performed all analyses using (R Core Team, 2021) and utilized the libraries ggplot2, tidyverse, and dplyr (Wickham, 2016).

Results and discussion

A total of five species were documented and identified in the Sangalang mangrove forest (Table 1). This species count was relatively low compared to a previous study conducted by Goloran *et al.* (2020) in Agusan Del Norte, Philippines. Among the 169 individuals recorded, only one individual of Sonneratia alba was found. The dominant species in the area were the red mangroves, specifically *Rhizophora* (*apiculata* and *mucronata*), with *Rhizophora mucronata* being the most dominant. Additionally, the *avicennia* species, known as black mangroves (*alba* and *rumphiana*), were present. The largest trees belonged to the *Avicennia* group (*alba* 24 cm and *rumphiana* 16 cm), although *Avicennia rumphiana* exhibited a higher standard deviation (11), with a minimum diameter at breast height (dbh) of 1.3 cm. Ecologically, only *A. rumphiana* was categorized as Vulnerable (V) according to the International Union for

Conservation of Nature (IUCN) classification, while the remaining species were classified as Least Concern (LC) (IUCN, 2020).

The recorded number of species, amounting to only five, indicates a low level of diversity. This is further supported by the modified diversity scale developed by Fernando (1988 *unpublished*). The diversity scale yielded a value of 2.15, which is considered very low across all plots (Table 2), as well as values ranging from 1.02 to 1.09 along the transect lines, also signifying very low diversity.

Table 1. Descriptive statistics of the five identified species in sangalang mangrove forest. sd - standard deviation, cv - coefficient of variation. (-) indicates the presence of only one species.

SN	Abundance	meandbh	mindbh	maxdbh	sd_dbh	cv_dbh	meanh	minh	maxh	sd_h	cv_h
Avicennia alba	3	23.87	22.70	25.70	1.61	0.07	5.23	1.10	7.60	3.59	0.69
Avicennia rumphiana	7	16.27	1.30	30.90	11.23	0.69	5.54	2.20	8.20	2.22	0.40
Rhizophora apiculata	20	8.62	2.00	16.60	3.50	0.41	6.17	0.04	10.70	2.16	0.35
Rhizophora mucrunata	25	5.73	0.80	16.90	3.50	0.61	4.11	1.10	7.43	1.49	0.36
Sonneratia alba	1	14.6	14.6	14.6	-	-	13.2	13.2	13.2	-	-

Table 2. Species diversity in all plots and by transect lines.

Sample plots	Abundance	Richness	Shannon Diversity Index	Diversity scale*
Transect 1 (3 plots)	49	3	1.02	very low
Transect 2 (3 plots)	51	3	1.09	very low
Transect 3 (3 plot)	69	5	1.09	very low
All plots (9 plots)	169	5	2.15	low

* Relative values modified Fernando (1998, *unpublished*)

In contrast, the analysis of plot-level descriptive statistics revealed no discernible pattern regarding the impact of disturbance parameters on forest structure, as represented by diameter at breast height (dbh) and height. Although high disturbance levels appeared to be associated with lower species abundance, the mean dbh values of 7 cm and 11 cm were comparable to those observed under moderate disturbance conditions. A similar pattern was observed for species richness, with plot 3 in transect 1 showing only one species, while moderate disturbance also exhibited lower richness. These results indicate that our disturbance parameters do not exhibit a clear influence on species abundance and richness. Additionally, the results of the two-sample t-test showed no significant differences in dbh (p-value 0.97) and height (p-value 0.75). However, it is important to acknowledge that our disturbance parameters were solely based on accessibility and distance from the community, and the study was conducted in a single locality. Therefore, we cannot fully ascertain the significant impact of disturbance, particularly because the transect lines were in close proximity to each other. Consequently, we only expect minimal variations among the plots. Nevertheless, our findings clearly demonstrate that both species abundance and richness were low in the study area, potentially influenced by both anthropogenic and natural disturbances.

Table 3. Descriptive statistics of dbh and height at the plot level.

Plot_id	Plot size	Disturbance	Abundance	Richness	meandbh	mindbh	maxdbh	cv_dbh	meanh	minh	maxh	cv_h
Plot_1_1	100	high	19	2	7.42	1.30	14.50	0.57	4.30	0.04	7.40	0.51
plot_1_2	100	moderate	22	3	11.16	2.20	30.90	0.57	6.03	2.80	8.20	0.21
plot_1_3	100	high	8	1	7.31	4.20	10.00	0.28	4.18	3.00	5.30	0.19
plot_2_1	100	high	16	2	7.98	2.00	15.80	0.45	5.91	3.10	9.10	0.30
plot_2_2	100	moderate	19	3	7.62	2.70	26.70	0.75	4.81	1.50	7.80	0.41
plot_2_3	100	moderate	16	1	5.01	2.00	12.30	0.55	4.14	3.20	5.00	0.10
plot_3_1	100	moderate	25	4	7.45	0.80	25.70	0.92	5.38	2.00	8.21	0.32
plot_3_2	100	moderate	19	4	8.64	2.50	23.20	0.57	7.72	1.10	13.20	0.35
plot_3_3	100	moderate	25	1	5.82	1.90	12.40	0.60	2.80	1.10	5.00	0.29

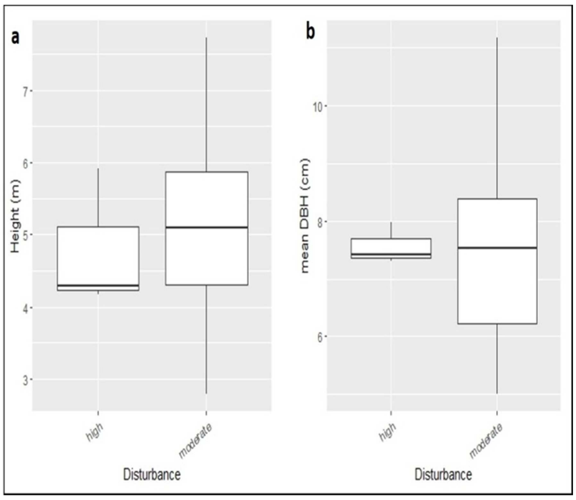

Fig. 2. Variation in forest structure (mean dbh and mean height) in response to disturbance (moderate and high). No significant difference based on the 2-sample t-test ($p < 0.05$). (a) p-value = 0.75 (b) p-value = 0.97.

Conclusion and recommendations

Our study conducted in the Sangalang mangrove forest on Biliran Island, Philippines, revealed a low level of diversity compared to other mangrove studies conducted in the country. Additionally, the abundance of species was found to be low. However, we did not observe any discernible patterns regarding the impact of our disturbance parameters on the structure and composition of the forest. These findings serve as an important baseline in understanding the current status of the mangrove forest and informing future forest policies aimed at protecting and conserving these essential ecosystems on the island. Nevertheless, we acknowledge the limitations of our study, including the limited number of plots. Therefore, we recommend expanding the study sites across the entire island and increasing the number of samples to obtain a more comprehensive understanding of the forest status. Lastly, we emphasize the urgent need for policymakers and stakeholders to take concrete actions to protect and conserve mangrove ecosystems. This can be achieved by establishing a more concrete and implementing stricter policies that aim to conserve and safeguard the mangrove forests on Biliran Island, Philippines. By fostering collective action, we can ensure the long-term sustainability of these crucial ecosystems and the services they provide to both humans and wildlife.

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