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Assessment of Mangrove Species Diversity in the Municipality of Nasipit, Agusan del Norte, Philippines

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ABSTRACT

Mangrove habitats are the most productive and biologically diverse ecosystems in the world. This study assessed the community structure of mangrove species in the two villages of Nasipit, Agusan del Norte, Philippines. There were 10 sampling quadrats with a size of 20 m × 20 m in Barangay (Village) Ata-atahon and Camagong. The data collected include taxonomic names, species diversity, and vegetation analysis. The results of the study revealed that Ata-atahon and Camagong fell under low diversity, as indicated by their Shannon-Wiener Index values of 1.091 and 0.873, respectively. The evenness index showed that Camagong has high evenness compared to Ata-atahon. Moreover, all species found in the two areas were listed as least concern based on the IUCN Red List for its conservation status. Both barangays being studied located at Nasipit, Agusan del Norte, fell under the low category due to anthropogenic activities. These results suggest the need for the rehabilitation and enrichment of the mangrove forest in Nasipit, Agusan del Norte, which could be led by the Department of Environment and Natural Resources in collaboration with the local government and non-governmental organizations. It is also strongly recommended to adopt preventive measures to prevent habitat loss.

1. Introduction

Mangroves are halophytic woody plants that inhabit intertidal zones along tropical and subtropical coastlines. They produce hydrochorous propagules with high dispersal capacity, enabling them to colonize dynamic coastal environments (Van der Stocken et al. 2019). They play a crucial role in supporting commercial fisheries by serving as nursery, breeding, and spawning grounds for various marine species. Several studies showed that areas with intact mangroves experience significantly less cyclone damage than those with degraded forests (Hochard et al. 2019; Ihinegbu et al. 2023). In addition, mangroves offer cultural ecosystem services that support sustainable ecotourism, providing spiritual, recreational, educational, and aesthetic benefits (Moussa et al. 2024).

The Philippines harbors a rich diversity of mangrove forests, comprising approximately 50% of the world's known mangrove species. Despite this, the country has experienced a significant decline in mangrove cover, losing nearly half of its original extent over the past century (Buitre et al. 2018). Both natural and anthropogenic factors drive this degradation. Natural disasters, particularly typhoons—which frequently strike the archipelago—have caused extensive damage, economic losses, environmental degradation, and loss of life. For instance, the storm surge from Super Typhoon Haiyan in 2013 resulted in widespread destruction, including the uprooting of numerous mangrove trees (Villamayor et al. 2016). In addition, long-term human activities such as the harvesting of mangrove trees for charcoal production, construction materials, and the conversion of mangrove areas into fishponds pose persistent and cumulative threats to these ecosystems (Buitre et al. 2018).

Mangroves provide a wide array of goods and services to local communities, including firewood, fisheries resources, building poles, honey and traditional medicine (Duryat et al. 2024). Moreover, they provide other services such as coastal protection. Certain mangrove species help prevent flooding and erosion of unconsolidated coastlines by breaking the force of waves (Asari et al. 2021). Mangroves are suitable homes for epibenthic, infaunal, and meiofaunal invertebrates and can support diverse communities of phytoplankton, zooplankton, and fish due to the unique environment they create (Cañizares and Seronay 2016). Mangroves serve as a critical nursery area for fish and crustaceans, which in turn provide rich feeding grounds for aquatic birds. It has been evident that preserving a larger extension of mangrove cover favors the increase of taxonomic and functional diversity of waterbird communities (Santos-Tovar et al. 2024). Similar findings have also been reported, indicating that expanded mangrove areas correlate with higher bird diversity, emphasizing mangroves as essential habitats for nesting, feeding, and roosting (Yang et al. 2024). In a study conducted by Arfan et al. (2024), they reported that mangrove density is correlated with macrobenthos diversity in Ampekale Ecotourism Village, Indonesia.

Mangrove ecosystems are rapidly disappearing due to increasing anthropogenic pressures, highlighting the urgent need for updated assessments of their current state. This study aims to evaluate the diversity, composition, and community structure of mangrove species in Barangay Ata-atahon and Barangay Camagong, located in Nasipit, a third-class municipality in Agusan del Norte with a population exceeding 2,047. Nasipit is one of the Agri-industrial Growth Centers in the region designated by the Caraga Regional Development Council. There is a need to conduct a mangrove diversity assessment in this municipality due to man-made and development pressures, such as ports, aquaculture, and salt farming. The data on mangrove diversity can be used for environmental impact assessment, zoning for industry, aquaculture, and conservation, as well as the protection of threatened species and ecologically sensitive zones.

2. Materials and Methods

2.1. Study Site

This study was conducted in Barangay Ata-atahon and Barangay Camagong, Nasipit, Agusan del Norte Province (**Fig. 1**). It is geographically located at 8°59' North, 125°23' East, within the Caraga Region. Nasipit is a third-class municipality in the Province of Agusan del Norte, Philippines. The Ata-atahon is one of the barangays with a total population percentage of 2.73% (2,047) as of 2020. Mangrove fish and mud crabs were their sources of economic income. The area also serves as the fishing ground for the individuals. Barangay Camagong Nasipit, however, was located at the mouth of the Agusan River, several kilometers distant. *Sonneratia alba* and

Avicennia spp. predominate mostly in the Camagong mangrove wetland (Elvira and Jumawan 2017).

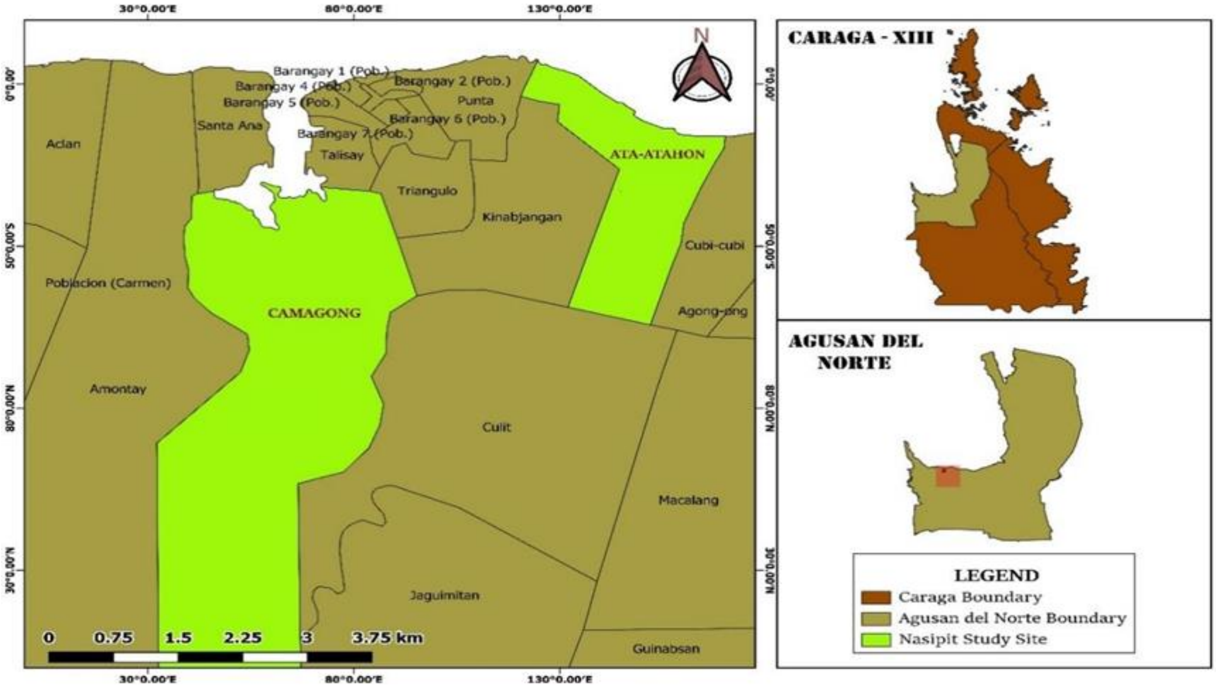

Fig. 1. Map showing the locale of the study.

2.2. Sampling Design and Layout

This study employed a quadrat sampling technique to achieve the highest possible representation of the entire area. The researchers randomly established five 20 m × 20 m sampling plots with a distance ranging from 200 m, which also depends on the structure of the mangrove community. All mangrove species with a diameter of ≥ 5cm were recorded. The diameter was measured using a diameter tape, and the total height was measured with a meter stick. The mangrove in every plot was identified and counted; the diameter at breast height (DBH) in cm, basal area in square meters (m^2) and the density of the mangrove species were also measured.

2.3. *Mangrove Species Identification*

The mangroves within the plots were taxonomically identified and classified using the field guide and taxonomic key manual to the Philippines Mangroves developed by Primavera et al. (2004).

2.4. Determination of Species Diversity

The Mangrove community's species diversity was calculated using Shannon-Wiener's Diversity Index by Shannon and Wiener (1963) (Equation 1), which indicates a quantitative description of mangrove habitat in terms of species distribution and evenness, with the aid of Paleontological Statistics Software (PAST) developed by Hammer et al. (2001).

$$\text{Shannon-Wiener Diversity } (H'):\ H' = \sum[pi \times (\ln pi)] \quad (1)$$

where *pi* is the proportion of individuals of the i-th species expressed as a portion of the total cover and *ln* is the log base n.

The diversity values for Shannon-Wiener were classified based on the scale developed by Fernando (1998), as presented in **Table 1**.

Table 1. Interpretation of the biodiversity index based on the scale provided by Fernando (1998)

Relative Interpretation	Shannon's (H') Index	Evenness Index
Very high	≥ 3.5	0.75–1.00
High	3.00–3.49	0.50–0.74
Moderate	2.50–2.99	0.25–0.49
Low	2.00–2.49	0.15–0.24
Very low	≤ 1.99	0.05–0.14

2.5. Vegetation Analysis

For the analysis of vegetation, the following parameters were used: population density, frequency, dominance, relative density, relative frequency, relative dominance and importance value. Species composition and community structure of a plant community can be studied using vegetation analysis. Identifying community types and understanding their diversity can help guide the planning and prioritization of conservation efforts, especially in response to the uncertain effects of climate change on forest dynamics (Latt et al. 2022).

The dominance of the plant species was determined using the importance value index (IVI). Vegetation composition was evaluated by analyzing the frequency, density, abundance, and IVI, using the formulas in Equations 2–6, as given by Curtis and McIntosh (1951) and Mishra (1968).

$$Population\ Density = \frac{Number\ of\ Individuals}{Total\ Area\ Sampled} \tag{2}$$

$$Relative\ Population\ Density = \frac{Density\ for\ a\ Species}{Total\ Density\ for\ All\ Species} \times 100 \tag{3}$$

$$Frequency = \frac{Number\ of\ Plots\ wherein\ Species\ Occurs}{Total\ Number\ of\ Plots} \tag{4}$$

$$Relative\ Frequency = \frac{Frequency\ Value\ of\ a\ Species}{Total\ Frequency\ Value\ for\ All\ Species} \times 100 \tag{5}$$

$$Dominance = \frac{Total\ Basal\ Area\ of\ Each\ Tree\ Species\ in\ All\ Plots}{Total\ Area\ Sampled} \tag{6}$$

$$Relative\ Dominance = \frac{Dominance\ of\ a\ Species}{Total\ Dominance\ of\ All\ Species} \times 100 \tag{7}$$

$$Importance\ Value = Relative\ Density + Relative\ Frequency + Relative\ Dominance \tag{8}$$

3. Results and Discussion

3.1. Species Composition at Barangay Ata-atahon

Table 2 shows the species composition of mangrove species in Barangay Ata-atahon. Results revealed that there are only 7 species of mangrove in the area, which are identified as *Lumnitzera racemosa*, *Sonneratia alba*, *Avicennia officinalis*, *Pongamia pinnata*, *Terminalia* *catappa*, *Rhizophora mucronata* Lam, and *Rhizophora apiculata* Blume. Among the 7 species, *Lumnitzera racemosa* has the highest total number of counts in all quadrats followed by *Sonneratia alba* with 209 and 155 counts, respectively. The number of counts of each species is correlated with its ecological preferences. In Sri Lanka, it was observed that *L. racemosa* is abundant in seaward zones, indicating high tolerance to saline conditions (Arulnayagam 2020). It is found in open residual mangrove forests along seashores, estuaries, lagoon sides, saltwater swamps, and marshy meadows on sandy soils, according to later research by Aluri (2022). On the other hand, the lowest number of counts was recorded on species identified as *T. catappa and R. mucronata*. Moreover, the following species belonged to the families Combretaceae, Lythraceae, Acanthaceae, Rhizophoraceae, and Fabaceae.

Table 2. Species composition and conservation status of mangroves in Barangay Ata-atahon

Local Name	Scientific Name	Family Name	No. of Counts
Kulasi	*Lumnitzera racemosa*	Combretaceae	209
Pagatpat	*Sonneratia alba*	Lythraceae	155
Bani	*Pongamia pinnata*	Fabaceae	7
Api-api	*Avicennia officinalis*	Acanthaceae	3
Bakauan lalaki	*Rhizophora apiculata*	Rhizophoracea	2
Bakauan babae	*Rhizophora mucronata*	Rhizophoracea	1
Talisai-dagat	*Terminalia catappa*	Combretaceae	1

3.2. Species Composition at Barangay Camagong

Table 3 shows the species composition of the mangrove in Barangay Camagong. There are only 3 species of mangrove recorded in the area, composed of *L. racemosa*, *S. alba* and *A. officinalis* with a total of 185 counts. Among the 3 species, *L. racemosa* has the highest number of counts, followed by *S. alba* with 74 and 61 counts, respectively. On the other hand, the lowest number of counts is recorded on *A. officinalis*. These species belong to the families Combretaceae, Lythraceae, and Acanthaceae. The density of the species is affected by their ecological preferences. In a zonation study conducted by Chowdhury et al. (2023), they found that *A. officinalis* is typically found along riverbanks with clayey soils and is more prevalent in inland intertidal zones rather than near the open sea. It thrives in soils with moderate salinity and a pH range between 7.07 and 7.65. This suggests a preference for slightly alkaline, less saline environments, which are characteristics of inland riverbanks with clayey substrates. Moreover, the results show that Barangay Camagong has a lower species composition compared to Barangay Ata-atahon. Some mangrove species are so close to the shore that when the tide comes in and submerges their roots, they are swamped with saltwater every day. All mangroves have developed unique adaptations that enable them to survive in soils that are both saline and oxygen-deficient. Moreover, both areas have been found to exhibit low biodiversity, as indicated by the Biodiversity Scale (Fernando 1998) (**Fig. 2**). A significant contributing factor to this major problem is the alarming rate at which mangroves are being destroyed. The woods are at risk from a variety of factors, including land development, pollution, fuel deforestation, and climate change. Long-term human activities, such as harvesting mangrove trees for charcoal production, construction materials, and converting mangrove areas into fishponds, pose persistent and cumulative threats to these ecosystems (Buitre et al. 2018).

Table 3. Species composition of mangroves in Barangay Camagong

Local Name	Scientific Name	Family Name	No. of Counts
Kulasi	*Lumnitzera racemosa*	Combretaceae	74
Pagatpat	*Sonneratia alba*	Lythraceae	61
Api-api	*Avicennia officinalis*	Acanthaceae	50

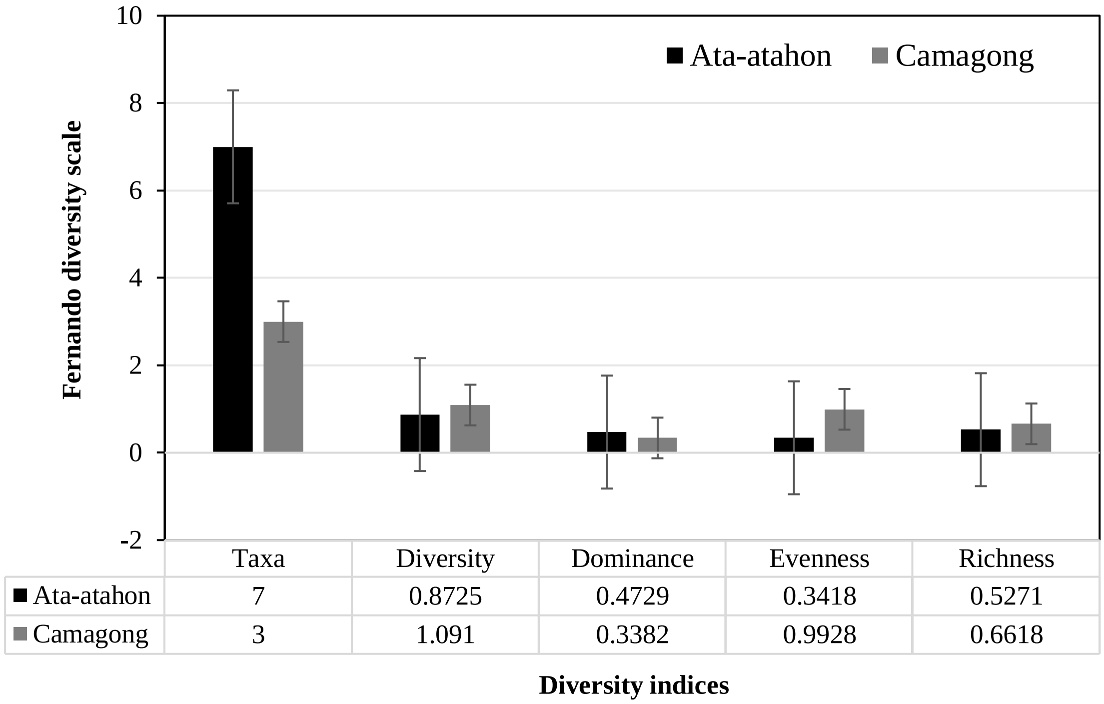

Fig. 2. Diversity indices.

3.3. Diversity Indices

Based on the results exhibited through the PAST analysis, comparing the two locations, Camagong has greater species diversity than Ata-atahon, with 1.091 and 0.8725, respectively. The species diversity of both locations fell into the very low category according to the Biodiversity Scale by Fernando (1998). These ideas are supported by reality in the selected sampling locations, which have witnessed significant land conversion for various economic reasons, such as aquaculture and fuelwood production. The massive decline of mangrove areas in the Philippines continues to occur due to the clearing of land for the creation of shrimp and fish culture ponds (Cabuga et al. 2022). Barangay Ata-atahon has a low mangrove species diversity because people in the vicinity rely on the mangrove forest for their daily needs. In a study conducted by Goldberg et al. (2020), they suggested that human activity has been a primary cause of mangrove forest loss. They also estimated that 62% of global losses between 2000 and 2016 resulted from land-use change, primarily brought about by the conversion to aquaculture and agriculture. Similarly, previous studies also pointed out that mangrove forest clearing and exploitation for timber production, as well as rapid population growth and urban expansion, have been a constant threat to the rapid decline of mangrove forests (Thomas et al. 2017). The dominance of the two locations also varied, with Camagong having a dominance value of 0.3382 and Ata-atahon having a dominance value of 0.4729. The significance of these mangrove species in the area cannot be overstated, as evidenced by their strong dominance value. The predominance demonstrates that type species have a good capacity to use solar energy. The capacity to compete with other species, energy, nutrients/minerals, and water (Irsadi et al. 2019). Based on the conducted site assessment, both locations of interest, Barangay Camagong and Barangay Ata-atahon, exhibited a dominant species of *A. officinalis* (**Fig. 3**). *A. officinalis* is a salt-secreting mangrove tree, characterized by an underlying framework of pneumatophores and specialized salt glands in its aboveground tissues, which secrete excess salt. The existence of this tissue serves as a tool to aid adaptation to unfavorable environments, such as land with a high salt content (Somssich 2020). Under the evenness index, Camagong showed a high category with a value of 0.9928, while Ata-atahon had a value of 0.3418, which falls into the low category. The diversity of species in a region is determined by both the number of species seen (species richness) and their total number, whereas evenness refers to the relative abundance of species. Evenness is high when all species have a similar distribution (i.e., a similar population density) (Munoz et al. 2018). Increasing species evenness may enhance complementarity while reducing the impact of selection. Wang et al. (2021) found that species evenness can alter the associations between species richness and community tolerance to disturbance by modifying the complementary effects between species. Therefore, evenness is important because it defines the stability of an ecosystem.

Fig. 3. Mangrove species identified in Barangay Ata-atahon and Camagong, Nasipit, Agusan del Norte, Philippines, namely: (A) *Rhizophora apiculata*; (B) *Sonneratia alba*; (C) *Pongamia pinnata*; (D) *Avicennia officinalis*; (E) *Lumnitzera racemosa*; (F) *Rhizophora apiculata*.

3.4. Vegetation Structure Analysis

3.4.1. Barangay Ata-atahon

The result of Barangay Ata-atahon has shown 7 species composition, with the highest density being the same as that of the other region of interest, which is *L. racemosa* at 55.58%, followed by *S. alba* at 41.22%. The dominant species, based on the analysis conducted, are both the same species with the highest density, at 34.615%, and the highest importance value is *L. racemosa*, at 90.67% (**Table 4**). In a previous study conducted by Cabuga et al. (2022), a total of 19 mangrove species were documented in Barangay Ata-atahon. In contrast, the present study recorded fewer species, suggesting a possible decline in mangrove species composition in the area.

However, this apparent decrease may also be influenced by the different methodologies used by the researchers. Cabuga et al. (2022) employed the transect line method, whereas the present study utilized the quadrat sampling method, which may have resulted in a lower number of species recorded. The high importance value (SIV) of *L. racemosa* and *S. alba* is attributed to their ecological and physiological adaptations in the mangrove ecosystem. *L. racemosa* can be found in open remnant mangrove forests along sea shores, estuaries, lagoon sides, saltwater swamps, and swampy meadows on sandy soils (Shu 2007). Previous studies have reported that *L. racemosa* grows well in harsh conditions, often in association with other mangrove species and associates (Tomlinson et al. 1978). The pollination ecology of *L. racemosa* was previously investigated by Solomon et al. (2014), who found that the flowers are bisexual, self-compatible, self-pollinating, and exhibit a mixed breeding system. Fruit set is approximately 90% due to self and cross-pollination, and the pollinators include bees, wasps, and butterflies.

Table 4. Species importance value (SIV) of Barangay Ata-atahon

Scientific Name	Relative Density	Relative Frequency	Relative Dominance	SIV
Lumnitzera racemosa	55.59	0.47	34.62	90.67
Sonneratia alba	41.22	0.63	34.62	76.47
Pongamia pinnata	1.33	6.52	3.85	11.70
Avicennia officinalis	0.80	10.87	3.85	15.51
Rhizophora apiculata	0.53	16.30	15.38	32.22
Rhizophora mucronata	0.27	32.60	3.85	36.72
Terminalia catappa	0.27	32.60	3.85	36.72
Total	100	100	100	300

3.4.2. Barangay Camagong

Results revealed that most of the species found in Barangay Camagong are *L. racemosa*, with a relative density of 40%, compared to *S. alba* and *A. officinalis*. Among the sampled plots taken by the researchers, the species that occurs relatively frequently is *A. officinallis*, with 40.07%, which is much higher compared to the other two. All the species found in the area are dominant, with a percentage result of 33.33% based on the analysis conducted. The species with the highest importance value is *L. racemosa*, with a value of 100.45 (**Table 5**).

Table 5. Species Importance Value (SIV) of Barangay Camagong

Name of Species	Relative Density	Relative Frequency	Relative Dominance	SIV
Lumnitzera racemosa	40.00	27.08	33.33	100.45
Sonneratia alba	32.97	32.85	33.33	99.15
Avicenia officinalis	27.03	40.07	33.33	100.43
Total	100	100	100	300

Based on the analysis conducted on both areas, *L. racemosa* is the species with the highest density. This is due to its adaptability to local conditions. According to McArdle (2008), population density is often used as a simple relative measure of how an organism responds to local conditions. If conditions are not good for the species, the density will be low (organisms will have died or moved out of the sampled area). In contrast, if conditions are good, the density will be high (organisms will have reproduced and/or immigrated into the area). In this way, changes in density can provide insight into the natural history of the preferences and tolerances of individual species members. Moreover, the most dominant species were both the *L. racemosa* and *S. alba*. This species' highest relative dominance is also attributed to its ability to obtain more nutrients, ensuring that the stem volume is large enough and the canopy is wide enough, which contributes to its dominance over other types. Additionally, it prefers muddy substrates and tolerates high salt levels (Nurdin et al. 2015).

3.5. Conservation Status

Based on the IUCN conservation status, all the mangrove species that exist in the regions of interest are classified as of least concern. This means that these species were not the least priority for conservation because there are still plenty of them in existence. According to the IUCN Red List, although least concern species have a lower risk of extinction, they are still important in terms of global biodiversity (**Table 6**).

Table 6. Species composition and conservation status of mangroves found in both areas

Local Name	Scientific Name	Family Name	Conservation Status (IUCN 2022)
Kulasi	*Lumnitzera racemosa*	Combretaceae	Least Concern
Pagatpat	*Sonneratia alba*	Lythraceae	Least Concern
Api-api	*Avicennia officinalis*	Acanthaceae	Least Concern
Talisai-dagat	*Terminalia catappa*	Combretaceae	Least Concern
Bakauan babae	*Rhizophora mucronata*	Rhizophoracea	Least Concern
Bakauan lalaki	*Rhizophora apiculata*	Rhizophoracea	Least Concern
Bani	*Pongamia pinnata*	Fabaceae	Least Concern

3.6. Mangrove composition in the Municipality of Nasipit

Principal Component Analysis (PCA) revealed that PC1 accounts for the most variation, at 50.57%, while PC2 accounts for 32.77%, totaling 83.34%. Despite the high explanatory power of these components, the PCA biplot (**Fig. 4**) shows that there are no discernible differences or distinct clustering between the two sites—Barangay Ata-athon and Barangay Camagong in the Municipality of Nasipit, Agusan del Norte—in terms of the composition of mangrove species.

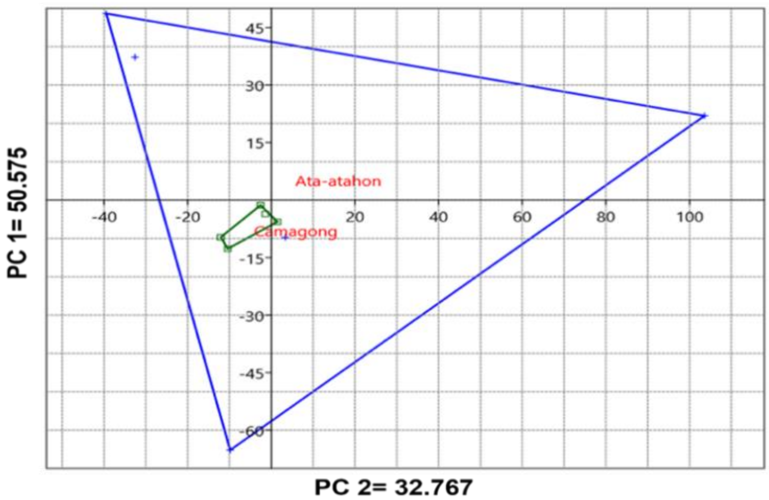

Fig. 4. The correlation of mangrove composition in the Municipality of Nasipit, Agusan del Norte.

These sites showed similarities in the composition of mangrove species. This suggests that the presence, abundance, or dominance of species between the two sites do not vary significantly, as indicated by the overlapping positions of the sample points on the PCA plot. The similarity may be attributed to their geographical proximity, which resulted in the narrow genetic composition of mangrove species in both areas, and was also influenced by seed pollination and dispersal. Other ecological considerations include shared tidal and substrate conditions, as well as exposure to the same man-made pressures, which are also contributing to the homogenization of species assemblages across these two coastal areas of Nasipit, Agusan del Norte. These factors resulted in no ecological difference in mangrove species structure.

4. Conclusions

Generally, 7 species were found in Barangay Ata-atahon and 3 species in Barangay Camagong, all of which belong to the Acanthaceae, Combretaceae, Rhizophoraceae, and Fabaceae families. The two sites of interest fell under the low category for species diversity. The evenness of both areas differed from each other. Ata-atahon fell under the low category, while Camagong has high species evenness. The mangrove composition of both areas shows no difference, as indicated by the results of the principal component analysis (PCA), due to the influence of seed pollination and seed dispersal from the two neighboring areas. Since the two locations fell under the low category of diversity, which is the basis for a healthy ecosystem, the researchers proposed incorporating mangrove forest rehabilitation in a specific area, to be led by the Department of Environment and Natural Resources in partnership with the local government, and to adopt preventative measures to prevent habitat loss. These findings could be included in the government's comprehensive land use plan (CLUP) and forest land use plan (FLUP). To restore the mangrove, a tree-planting activity should be conducted, and regular monitoring, education, and awareness programs should be implemented throughout the region.

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Author Contributions

R.L.P.: Conceptualization, Methodology, Data Curation, Writing – Original Draft Preparation, Review and Editing; E.F.C.: Conceptualization, Methodology, Data Analysis, Writing – Original Draft Preparation, Review and Editing; M.J.R.: Methodology, Data Curation, Writing – Original Draft Preparation; C.J.: Methodology, Data Curation, Writing – Review and Editing; L.O.: Methodology, Data Curation, Review and Editing; J.M.S.: Methodology, Data Curation, Review and Editing; M.E.: Methodology, Data Curation, Statistical Analysis, Review and Editing; V.C.: Conceptualization, Methodology, Supervision, Data Curation, Writing – Original Draft Preparation, Review and Editing.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Generative AI And AI-Assisted Technologies in the Manuscript Preparation

During the preparation of this work, the authors utilized Quillbot.com, a paraphrasing tool, to enhance the clarity of the writing, making it easier for readers to understand and avoid plagiarism. After using this tool/service the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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