

Research Article

Mangrove Vascular Flora Composition, Distribution, and Diversity in Selected Sites of the Coastal Areas of Surigao del Sur, Philippines

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ABSTRACT

Mangrove forests are vital components of coastal ecosystems, particularly in tropical and subtropical regions, where they act as natural barriers against environmental hazards. This study aimed to identify and classify mangrove vascular flora, plants adapted to coastal intertidal zones at the species level, analyze their composition and diversity, assess their zonal distribution, and evaluate their conservation status. The study focused on five municipalities: Hinatuan, Barobo, Lianga, San Agustin, and Cagwait, selected for their diverse mangrove ecosystems. Using a non-destructive belt-transect method, the study identified 32 mangrove species from 13 families, totaling 1,301 individuals. Among the most abundant species were *R. mucronata* (127) and *R. apiculata* (110). Several species were found to be near-threatened, including *C. decandra*, *H. littoralis*, and *A. floridum*, while those classified as vulnerable included *C. tagal*, *O. octodonta*, and *A. rumphiana*. Additionally, two species, *A. aureum* and *B. gymnorhiza*, are not yet assessed. While, *O. octodonta* is classified as endemic, emphasizing the need for conservation efforts. The overall species diversity index was calculated at 3.68, indicating a very high level of diversity. These findings are crucial for participatory resource management, enabling the development of conservation strategies that protect biodiversity while addressing the economic needs of vulnerable coastal communities. The study provides a baseline for future studies and assists local governments in developing effective mangrove preservation strategies while raising community awareness of these critical ecosystems.

Keywords: Mangroves, species diversity, coastal areas, distribution status, IUCN redlist

INTRODUCTION

Mangrove forests are a crucial component of coastal ecosystems, particularly in tropical and subtropical regions, where they serve as natural barriers against environmental hazards. Often referred to as "Coastal Woodland" or "Intertidal Forest" (Aksornkoae, 1995; Abejo et al., 2022), mangroves consist of diverse woody shrubs and trees adapted to the harsh conditions of intertidal zones. According to Joshi and Ghose (2014), these forests thrive in saline environments and play a key role in supporting coastal biodiversity. Typically found in tropical regions, mangrove forests are dominated by dicotyledonous woody plants, forming dense clusters along muddy shores and sometimes appearing in nearly monospecific stands (Hogarth, 2007; Buot, 2020). Their ecological importance is undeniable, as they provide protection from typhoons and storm surges, regulate floods, trap sediment, recycle nutrients, and create critical habitats for wildlife. Mangroves also serve as nurseries for many marine species, contributing to both biodiversity and the livelihoods of coastal communities (Sarmiento, 2018; Primavera et al., 2020).

Despite their significance, mangrove ecosystems face alarming rates of degradation due to human activities such as coastal development, aquaculture expansion, and land reclamation (Freiss et al., 2020; Guo et al., 2021). According to the Global Mangrove Alliance (2023), approximately 35% of the world's mangroves have been lost over the past century, with Southeast Asia experiencing the highest rates of deforestation. Hamilton and Casey (2020) reported that between 1996 and 2016, the region lost over 500,000 hectares of mangroves, primarily due to conversion for agriculture and urbanization. In the Philippines, where mangrove forests play a vital role in ecological balance and coastal protection, more than 50% of mangrove cover has been lost since the 1900s (Hati et al., 2021). The continued decline of mangrove ecosystems has far-reaching consequences, including increased coastal erosion, loss of biodiversity, and heightened vulnerability to climate change impacts.

In response to these threats, numerous conservation and restoration initiatives have been implemented globally, focusing on the rehabilitation of degraded

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areas and the adoption of sustainable management practices. In the Philippines, extensive efforts have been undertaken to map, classify, and protect mangrove species (Wang et al., 2022). These studies not only monitor the health and diversity of mangrove ecosystems but also provide critical data for conservation planning and climate change mitigation. However, gaps remain in the localized assessment of mangrove biodiversity, particularly in areas like Surigao del Sur, where coastal communities depend on these ecosystems for protection and livelihood.

Various government and non-government organizations have launched restoration and conservation programs to safeguard mangrove forests, yet site-specific data remain limited. In Surigao del Sur, where mangroves play a crucial role in coastal resilience, a deeper understanding of their composition, classification, distribution, and diversity is necessary. This study focused on five key localities, Hinatuan, Barobo, Lianga, Cagwait, and San Agustin where mangrove ecosystems are under threat. A comprehensive assessment of mangrove taxonomy is essential for tracking environmental changes, evaluating ecosystem degradation and regeneration, identifying early signs of climate change, and guiding government mitigation programs (Hati et al., 2021; Jumawan et al., 2023). Proper classification of mangroves at the species level is critical for their long-term conservation and sustainable management.

Several studies have examined mangrove forests in the Philippines, contributing to an expanding body of knowledge on their ecological significance. Quimpang et al. (1987) documented the structure of local mangrove forests, identifying eight distinct species. However, since then, research priorities have shifted toward other areas, such as the phytochemical remediation potential of mangroves (Toledo-Bruno et al., 2019; Saro et al., 2022a).

This shift has left gaps in understanding the current state of mangrove ecosystems in the region, particularly regarding species composition and distribution. Given the rapid environmental changes and increasing anthropogenic pressures, there is an urgent need for updated studies that assess mangrove biodiversity at the local level. This study aimed to address these knowledge gaps by providing recent insights into the diversity, zonal distribution, and ecological status of mangrove forests in Surigao del Sur. The primary objectives of this study were to identify and classify mangrove vascular flora at the species level, determine their zonal distribution and conservation status, and assess their species diversity index. These findings are crucial for informing participatory resource management efforts, enabling the design of conservation strategies that promote biodiversity protection while addressing the economic needs of vulnerable coastal communities. By providing baseline data on mangrove diversity, this research supports sustainable development initiatives and contributes to the long-term resilience of mangrove ecosystems in Surigao del Sur.

MATERIALS AND METHODS

Study Area

The study was conducted in Surigao del Sur, Philippines, focusing on five municipalities: Hinatuan, Barobo, Lianga, San Agustin, and Cagwait, in October 2024. These five municipalities were selected for their diverse mangrove ecosystems, as they are all located along coastal areas. The study primarily focused on ten sampling sites across the five municipalities. Specifically, the sampling sites were located at the following coordinates: Cagwait (126.295845°, 8.910506°), San Agustin (126.200487°, 8.727247°), Lianga (126.094944°, 8.631412°), Barobo (126.113912°, 8.540008°), and Hinatuan (126.335212°, 8.367750°) (Figure 1).

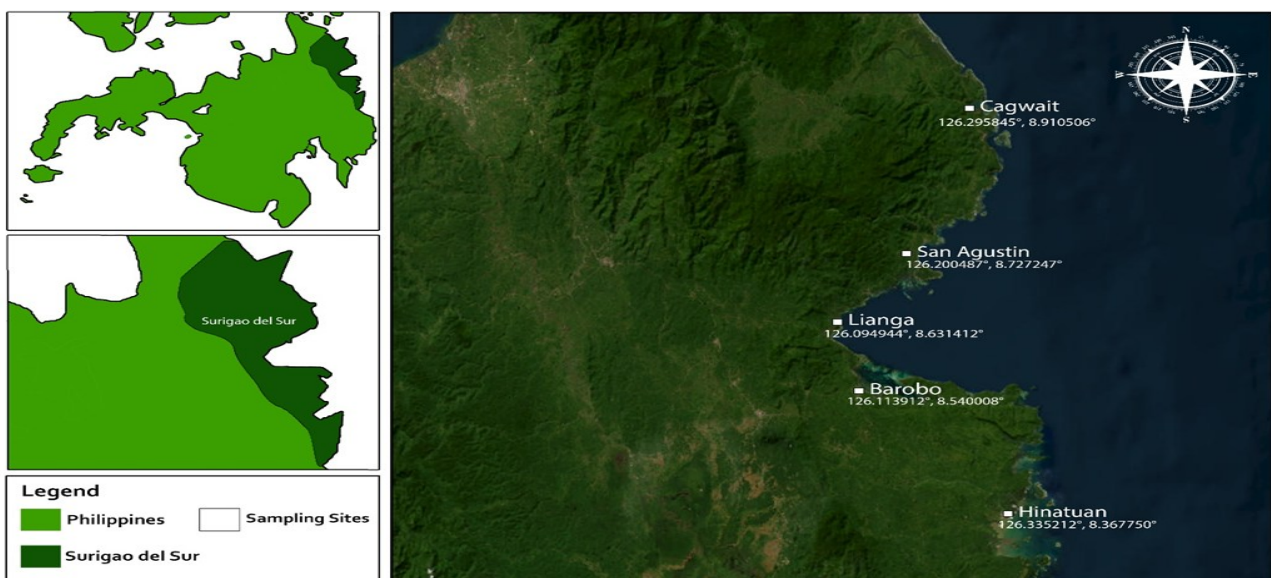


Figure 1. Map of the Location of the Study's Sampling Coastal Sites in the Province of Surigao del Sur, showing: Cagwait (126.295845°, 8.910506°), San Agustin (126.200487°, 8.727247°), Lianga (126.094944°, 8.631412°), Barobo (126.113912°, 8.540008°), and Hinatuan (126.335212°, 8.367750°) (Source: Adobe Photoshop CS6, ArcGIS Online, Google Maps)

Surigao del Sur was selected as the study location due to the lack of existing literature on the conservation status and distribution of mangrove vascular flora in the area. Additionally, this study aligns with Republic Act 9147, the Wildlife Resources Conservation and Protection Act, which mandates the conservation and protection of wildlife resources and their habitats. All necessary protocols for conducting the study were followed, including securing approval letters and permits from each municipality to conduct research in the selected areas.

species were manually identified, counted, and recorded. To enhance accuracy, a resident Forest Extension Officer guided species identification, ensuring precise classification and documentation. More so, to maintain consistency and minimize bias, each quadrat was marked with twine and posts at the start and end points of the transects. This delineation helped prevent overlap and ensured the integrity of data collection. The belt-transect approach facilitated an organized and repeatable method for evaluating species composition and

Table 1. Description of the Study Sites

Coastal Site	Main Locale	Transect (Sampling Sites)	Coordinates	Elevation (masl)
1	Hinatuan	Brgy. San Juan – Wharf	8° 25' 3" N, 126° 22' 24" E	20
		Brgy. Talisay	8° 27' 1"N, 126° 21' 3" E	23.9
2	Barobo	Brgy. Rizal, Sitio Pongpong	8° 31' 45" N, 126° 9' 33" E	10
		Brgy. Poblacion, Sitio Talisay	8° 32' 40" N, 126° 7' 22" E	10
3	Liangá	Brgy. Poblacion, Purok 1, Tagago	8° 37' 36" N, 126° 5' 36" E	20
		Brgy. St. Christine	8° 40' 2" N, 126° 8' 9" E	20
4	San Agustin	Brgy. Gata	8° 41' 57" N, 126° 0' 57" E	20
		Brgy. Hornasan	8° 45' 05" N, 126° 14' 10" E	20
5	Cagwait	Brgy. West Bitaugan	8° 52' 07" N, 126° 18' 58" E	20
		Brgy. Poblacion	8° 55' 06" N, 126° 18' 18" E	10

Sampling Design

The species composition, distribution, and diversity of mangrove vascular flora in the reforested mangrove forests along the coastal areas of Surigao del Sur were assessed using a belt-transect method, a widely used non-destructive technique for vegetation analysis (BMB, 2017). This method enables systematic sampling of plant species along a defined area, providing comprehensive insights into the structure and diversity of mangrove ecosystems. To ensure thorough coverage, ten (10) sampling sites were selected across five municipalities in Surigao del Sur. At each site, a 100-meter baseline transect was established parallel to the shoreline to serve as the main reference point. From this baseline, three perpendicular transects, each extending 150 meters inland, were laid out at 50-meter intervals. The length of these transects was adjusted as needed based on coastal characteristics such as tidal range, substrate composition, and vegetation density.

For species diversity analysis, five 100-square-meter quadrats were systematically placed along each transect line, leading to a total of 50 quadrats across all sites. Within each quadrat, mangrove vascular flora

distribution patterns, allowing for a more accurate assessment of the ecological status of mangrove forests in the province.

Species Identification, Composition, and Diversity Determination

The composition and diversity of mangrove vascular flora were determined through a comprehensive inventory of mangrove species, guided by literature and taxonomic identification field guides to Philippine mangroves by Primavera et al. (2004) and mangroves field guide (OCEANUS, 2024). Additionally, online identification resources were used to validate species encountered. Guidance from a resident Forest Extension Officer in Surigao del Sur was also obtained to ensure accurate species identification. The conservation status of identified species was assessed based on the National List of Threatened Philippine Plants (DENR Administrative Order 2017), the IUCN Red List of Threatened Species (IUCN 2021), and the Red List of Global Mangrove Ecosystems (2024). Photographs of each identified mangrove species were carefully taken during the study. Within each quadrant, individual mangrove

Ecosystems (2024). Photographs of each identified mangrove species were carefully taken during the study. Within each quadrant, individual mangrove species were identified, counted, and recorded. Paleontological Statistics (PAST) software by Hammer, Harper, and Ryan (2001) was used to calculate mangrove diversity indices. As shown in Table 2, Shannon–Weiner diversity values were classified using a scale established by Fernando (1998).

Table 2. Classification of Diversity Values (Fernando, 1998)

H' values	Relative Values
> 3.50	Very High
3.00 – 3.49	High
2.50 – 2.99	Moderate
2.00 – 2.49	Low
< 1.99	Very Low

Data Analysis

Descriptive statistics and visual graphs for the mangrove species data across sampling sites were generated using Microsoft Excel 2019, which allowed for the calculation of measures such as mean and variance to understand species distribution. The Paleontological Statistics (PAST) software by Hammer, Harper, and Ryan (2001) was utilized to calculate diversity indices, particularly the Shannon–Weiner index, which quantifies species richness and evenness. The diversity values obtained were then classified following Fernando's (1998) scale, categorizing sites into levels of low, moderate, or high diversity. This classification provides a clear understanding of biodiversity patterns across sampling locations, identifying areas of significant ecological interest.

RESULTS AND DISCUSSION

Species Composition

Table 3 presents the species composition, conservation status, and distribution of mangrove vascular flora across five municipalities, focusing on ten coastal sampling sites in Surigao del Sur, Philippines. A total of 32 mangrove vascular flora species from 13 families were identified. Among them, 31 species are categorized as Native, while one species, *Osbornia octodonta*, is classified as Endemic. The conservation status assessment shows that 24 species are classified as Least Concern (LC), 3 as Vulnerable (VU), 3 as Near Threatened (NT), and 2 as Not Yet Assessed (NYA). These findings highlight the ecological significance of mangrove biodiversity in the province and emphasize the need for targeted conservation efforts (Kumar et al., 2020; Mambo et al., 2023).

The dominance of species categorized as Least Concern suggests that the existing environmental conditions in Surigao del Sur such as stable hydrological patterns, moderate salinity levels, and sufficient nutrient availability, favor their growth and sustainability. However, the presence of Vulnerable and Near Threatened species, including *Ceriops decandra*, *Heritiera littoralis*, and *Aegiceras floridum*, indicates localized stressors such as coastal development, pollution, and rising sea levels. *Ceriops tagal*, *Osbornia octodonta*, and *Avicennia rumphiana* are specifically identified as vulnerable due to habitat fragmentation and increasing anthropogenic pressures (Purnamasari et al., 2021). Meanwhile, the classification of *Acanthus aureum* and *Bruuguiera gymnorrhiza* as Not Yet Assessed suggests gaps in conservation data that require further ecological monitoring.

Table 3. Species Composition, Conservation, and Distribution Status of Mangrove Vascular Flora in Surigao del Sur

Family	Species (Scientific Name)	Local Name	Conservation Status	Distribution Status
Acanthaceae	<i>Acanthus ebracteatus</i>	Lagiwliw/Ragoyroy	LC	Native
Acanthaceae	<i>Acanthus volubilis</i>	Lagiwliw/Ragoyroy	LC	Native
Acanthaceae	<i>Acanthus aureum</i>	Dila-dila	NYA	Native
Acanthaceae/ Rhizophoraceae	<i>Ceriops decandra</i>	Lapis-lapis	NT	Native
Acanthaceae/ Rhizophoraceae	<i>Ceriops tagal</i>	Tangal	VU	Native
Areaceae/Palmae	<i>Nypa fructicans</i>	Nipa	LC	Native
Avicenniaceae	<i>Avicennia rumphiana</i>	Bungalon	VU	Native
Avicenniaceae	<i>Avicennia officinalis</i>	Bungalon	LC	Native
Avicenniaceae	<i>Avicennia alba</i>	Bungalon puti	LC	Native
Avicenniaceae	<i>Avicennia marina</i>	Piapi	LC	Native
Combretaceae	<i>Lumnitzera racemosa</i>	Kulasi	LC	Native
Euphorbiaceae	<i>Excoecaria agallocha</i>	Alipata/Buta-Buta	LC	Native

Mangrove Vascular Flora Composition, Distribution

Lythraceae	<i>Pemphis acidula</i>	Maragomon	LC	Native
Lythraceae	<i>Sonneratia alba</i>	Pagatpat	LC	Native
Lythraceae	<i>Sonneratia ovata</i>	Pagatpat	LC	Native
Lythraceae	<i>Sonneratia caseolaris</i>	Pagatpat/Pedada	LC	Native
Malvaceae	<i>Heritiera littoralis</i>	Dungon	NT	Native
Meliaceae	<i>Xylocarpus granatum</i>	Tabigi	LC	Native
Meliaceae	<i>Xylocarpus moluccensis</i>	Piagao	LC	Native
Myrtaceae	<i>Osbornia octodonta</i>	Tawalis	VU	Endemic
Primulaceae	<i>Aegiceras corniculatum</i>	Saging-saging	LC	Native
Primulaceae	<i>Aegiceras floridum</i>	Tinduk-tindukan	NT	Native
Pteridaceae	<i>Acrostichum speciosum</i>	Palaypay	LC	Native
Pteridaceae	<i>Acrostichum aureum</i>	Palaypay	LC	Native
Rhizophoraceae	<i>Rhizophora apiculata</i>	Bakhaw lalaki	LC	Native
Rhizophoraceae	<i>Rhizophora mucronata</i>	Bakhaw babae	LC	Native
Rhizophoraceae	<i>Rhizophora stylosa</i>	Bakhaw bato	LC	Native
Rhizophoraceae	<i>Bruguiera parviflora</i>	Langarai	LC	Native
Rhizophoraceae	<i>Bruguiera cylindrica</i>	Pototan	LC	Native
Rhizophoraceae	<i>Bruguiera sexangular</i>	Pototan	LC	Native
Rhizophoraceae	<i>Bruguiera gymnorrhiza</i>	Pototan/Busain	NYA	Native
Rubiaceae	<i>Scyphiphora hydrophyllacea</i>	Nilad	LC	Native

Note: LC – Least Concern; VU – Vulnerable; NT – Near Threatened; NYA – Not Yet Assessed

To enhance mangrove conservation, local governments and conservation organizations should implement targeted strategies that address both ecological and socio-economic factors. Establishing protected zones in areas with high concentrations of Vulnerable and Near Threatened species can help mitigate habitat loss, while mangrove reforestation projects can restore degraded sites. Stricter regulations on land conversion and aquaculture expansion are necessary to promote sustainable coastal management and prevent further destruction of critical mangrove habitats. Community involvement in conservation programs is also crucial, as engaging local residents in mangrove monitoring, eco-tourism, and sustainable fishing practices can foster long-term stewardship. Additionally, conducting long-term ecological studies will provide data-driven insights into the impact of climate change and human activities on mangrove ecosystems, ensuring that conservation policies remain adaptive and effective. Raising awareness through educational campaigns will further strengthen public understanding of the importance of mangroves in coastal

protection, biodiversity conservation, and carbon sequestration. Thus, by integrating these conservation measures, this study provides a foundation for proactive environmental management that balances ecological sustainability with community development (Alpizar et al., 2022; Yao et al., 2023).

In addition, the conservation initiatives focusing on vulnerable and near-threatened species are critical to maintain ecosystem stability and resilience, as these species contribute to both ecological health and local livelihoods (Abejo et al., 2022; Mambo et al., 2023). Additionally, the identification of endemic species, *Osbornia octodonta*, emphasizes the unique ecological characteristics of Philippine mangroves and highlights the need for detailed and more conservation measures to address regional ecological nuances (Goloran et al., 2020; Yao et al., 2023). Consequently, understanding species composition, distribution, and conservation status not only aids local conservation efforts but also aligns with broader global initiatives to safeguard these vital coastal systems (Alpizar et al., 2022).

Table 4. Summary of Findings on Mangrove Vascular Flora in Coastal Areas

Main Locale	Coastal Sampling Sites	Family	Species	Individuals	Relative Frequency %
Hinatuan	Site 1 Brgy. San Juan – Wharf	2	4	48	3.69
	Site 2 Brgy. Talisay	5	7	83	6.38
Barobo	Site 3 Brgy. Rizal, Sitio Pongpong	3	5	67	5.15
	Site 4 Brgy. Poblacion, Sitio Talisay	6	10	112	8.61
Liangá	Site 5 Brgy. Poblacion, Purok 1, Tagago	9	15	228	17.52
	Site 6 Brgy. St. Christine	6	8	98	7.53
San Agustin	Site 7 Brgy. Gata	3	6	70	5.38
	Site 8 Brgy. Hornasan	8	12	129	9.92
Cagwait	Site 9 Brgy. West Bitaugan	8	11	147	11.30
	Site 10 Brgy. Poblacion	11	17	319	24.52

Note: Identified Species (32); Families (13); Total of Individuals (1,301)

Table 4 summarizes the findings on mangrove vascular flora across five coastal municipalities in Surigao del Sur, identifying 32 species from 13 families, with a total of 1,301 individual mangrove specimens. Site 10 in Cagwait exhibited the highest ecological diversity, hosting 17 species from 11 families and recording the highest individual count at 319, indicating a high population density. This density is likely influenced by favorable environmental factors such as nutrient-rich sediments, optimal tidal fluctuations, and minimal anthropogenic disturbances, which create ideal conditions for mangrove establishment and growth (Faridah-Hanum *et al.*, 2021). The differences in species diversity and individual counts across sites underscore the impact of environmental conditions on mangrove distribution. Sites with lower species abundance may be experiencing ecological stressors such as sediment erosion, salinity fluctuations, or human activities, which could limit mangrove regeneration and survival. Notably, Site 10 recorded the highest relative frequency at 24.52%, suggesting that its stable environmental parameters contribute to enhanced species recruitment and resilience. These findings highlight the need for conservation strategies designed to site-specific challenges.

Additionally, to sustain mangrove biodiversity, local governments and conservation organizations should prioritize habitat restoration in areas with declining populations by implementing reforestation programs and reinforcing protective regulations against coastal

encroachment. Establishing buffer zones can mitigate the impacts of human activities, while regular ecological monitoring can help detect environmental changes that may threaten mangrove health. Additionally, community-driven conservation initiatives, such as sustainable tourism and mangrove-friendly livelihood programs, can foster local engagement in preservation efforts. By integrating these measures, stakeholders can ensure the long-term sustainability of mangrove ecosystems while enhancing their ecological and socio-economic benefits (Santini *et al.*, 2020; Saro *et al.*, 2022b).

Table 5 presents the species composition and individual counts of mangrove vascular flora across ten sampling sites, revealing substantial diversity in mangrove vegetation. A total of 32 species from 13 families were documented, with the Rhizophoraceae family exhibiting the highest number of individuals, particularly *Rhizophora mucronata* (127) and *Rhizophora apiculata* (110). The dominance of Rhizophoraceae species suggests their ecological adaptability to varying tidal conditions and their crucial role in coastal stabilization. The Arecaceae/Palmae family is solely represented by *Nypa fruticans*, which recorded the highest individual count for a single species at 85. Other notable species include *Excoecaria agallocha* and *Sonneratia ovata* (63) from the Euphorbiaceae and Lythraceae families, respectively, as well as *Sonneratia alba* (81) from Lythraceae. In total, 1,301 individual mangrove plants were recorded, emphasizing the richness and resilience of mangrove ecosystems in these areas.

Mangrove Vascular Flora Composition, Distribution

Table 5. Count of Mangrove Vascular Flora Species in Ten Sampling Sites

Family	Species	Individuals
Acanthaceae	<i>Acanthus ebracteatus</i>	35
Acanthaceae	<i>Acanthus volubilis</i>	31
Acanthaceae	<i>Acanthus aureum</i>	23
Acanthaceae/ Rhizophoraceae	<i>Ceriops decandra</i>	10
Acanthaceae/ Rhizophoraceae	<i>Ceriops tagal</i>	17
Arecaceae/Palmae	<i>Nypa fruticans</i>	85
Avicenniaceae	<i>Avicennia rumphiana</i>	12
Avicenniaceae	<i>Avicennia officinalis</i>	60
Avicenniaceae	<i>Avicennia alba</i>	38
Avicenniaceae	<i>Avicennia marina</i>	30
Combretaceae	<i>Lumnitzera racemosa</i>	47
Euphorbiaceae	<i>Excoecaria agallocha</i>	63
Lythraceae	<i>Pemphis acidula</i>	32
Lythraceae	<i>Sonneratia alba</i>	81
Lythraceae	<u><i>Sonneratia ovata</i></u>	63
Lythraceae	<i>Sonneratia caseolaris</i>	32
Malvaceae	<i>Heritiera littoralis</i>	8
Meliaceae	<i>Xylocarpus granatum</i>	51
Meliaceae	<i>Xylocarpus moluccensis</i>	30
Myrtaceae	<i>Osbornia octodonta</i>	16
Primulaceae	<i>Aegiceras corniculatum</i>	40
Primulaceae	<i>Aegiceras floridum</i>	13
Pteridaceae	<i>Acrostichum speciosum</i>	37
Pteridaceae	<i>Acrostichum aureum</i>	33
Rhizophoraceae	<i>Rhizophora apiculata</i>	110
Rhizophoraceae	<i>Rhizophora mucronata</i>	127
Rhizophoraceae	<i>Rhizophora stylosa</i>	14
Rhizophoraceae	<i>Bruguiera parviflora</i>	36
Rhizophoraceae	<i>Bruguiera cylindrica</i>	25
Rhizophoraceae	<i>Bruguiera sexangula</i>	33
Rhizophoraceae	<i>Bruguiera gymnorrhiza</i>	27
Rubiaceae	<i>Scyphiphora hydrophyllacea</i>	42
TOTAL		1301

The variation in species abundance across sites can be attributed to environmental factors such as tidal range, substrate composition, and freshwater influx, which influence mangrove distribution and growth. The predominance of *Rhizophora* species, which are well-adapted to fluctuating salinity and soft sediments, suggests that many sites provide optimal conditions for seedling establishment and root development. In contrast, the presence of *Nypa fruticans* in specific areas may indicate freshwater influence or brackish water conditions that favor its growth. Sites with lower species counts may be affected by habitat degradation, coastal development, or limited seed dispersal, highlighting the need for targeted conservation efforts.

To ensure the sustainability of these mangrove ecosystems, local governments and conservation organizations should implement site-specific restoration programs, particularly in areas with low species diversity. Mangrove reforestation projects using native species, particularly from Rhizophoraceae, can enhance coastal resilience against erosion and storm surges. Additionally, community-based conservation initiatives, such as controlled harvesting of *Nypa fruticans* for livelihood purposes, can promote sustainable resource use. Regular monitoring and ecological assessments should also be conducted to track species population trends and detect environmental

changes that may threaten mangrove health. These strategic actions will contribute to the long-term preservation of mangrove biodiversity while supporting the ecological and socio-economic well-being of coastal communities.

Species Distribution

Table 6 displays the abundance, occurrence, and distribution of various mangrove species across ten sampling sites in five municipalities of Surigao del Sur. In total, 32 distinct species were recorded, with *R. mucronata* and *R. apiculata* displaying the highest numbers at 127 and 110 individuals, respectively, indicating their significant presence across the sites. Other prevalent species include *S. alba* and *N. fruticans*, with counts of 81 and 85, showing these mangroves' adaptability to diverse conditions within the area. In contrast, species like *H. littoralis* and *C. decandra* show limited distribution, being present at only a few sites and in smaller quantities, hinting at potentially specific environmental requirements. Sites 6 and 10 showed the highest abundance with 189 and 196 individuals, respectively, suggesting these sites may offer favorable conditions for mangrove growth. The "x" marking in the table for species not present in certain sites also emphasizes that species distribution is not uniform across all sites, indicating varied ecological factors influencing species' occurrences.

Table 6. Abundance, Occurrence, and Distribution of Mangroves Across Sampling Sites in Five Municipalities of Surigao del Sur

Species	Site	Sit	Sit	Site	Site	Site	Site	Site	Site	Site	Total Number of Individuals
	1	e 2	e 3	4							
<i>A. ebracteatus</i>	x	3	9	x	23	x	x	x	x	x	35
<i>A. volubilis</i>	x	x	5	x	11	x	15	x	x	x	31
<i>A. aureum</i>	x	x	x	3	x	3	x	9	x	8	23
<i>C. decandra</i>	x	x	x	x	x	x	x	10	x	x	10
<i>C. tagal</i>	x	x	x	x	x	4	x	8	5	x	17
<i>N. fruticans</i>	6	9	x	15	x	8	x	x	37	10	85
<i>A. rumphiana</i>	x	x	x	x	x	x	x	x	5	7	12
<i>A. officinalis</i>	x	x	13	x	x	17	x	x	10	20	60
<i>A. alba</i>	x	6	x	x	10	x	x	x	20	2	38
<i>A. marina</i>	x	x	x	16	x	7	x	3	x	4	30
<i>L. racemosa</i>	x	x	x	x	9	12	11	3	x	12	47
<i>E. agallocha</i>	x	3	12	x	x	15	5	8	9	11	63
<i>P. acidula</i>	2	4	x	7	4	x	x	x	8	7	32
<i>S. alba</i>	16	22	x	12	14	x	x	17	x	x	81
<i>S. ovata</i>	13	x	x	x	x	x	12	11	20	7	63

Mangrove Vascular Flora Composition, Distribution

<i>S. caseolaris</i>	x	x	x	x	2	7	6	8	5	4	32
<i>H. littoralis</i>	x	x	3	5	x	x	x	x	x	x	8
<i>X. granatum</i>	x	11	x	x	2	11	6	12	4	5	51
<i>X. moluccensis</i>	x	x	5	7	x	3	x	10	x	5	30
<i>O. octodonta</i>	x	x	x	x	6	10	x	x	x	x	16
<i>A. corniculatum</i>	x	x	x	x	x	9	x	x	x	31	40
<i>A. floridum</i>	x	x	x	x	3	7	x	x	x	3	13
<i>A. speciosum</i>	x	x	x	x	x	x	7	9	8	13	37
<i>A. aureum</i>	x	x	3	9	x	x	11	5	2	3	33
<i>R. apiculata</i>	9	x	20	26	13	17	13	3	1	8	110
<i>R. mucronata</i>	14	10	9	6	39	27	4	2	5	11	127
<i>R. stylosa</i>	x	x	x	x	x	x	x	14	x	x	14
<i>B. parviflora</i>	x	x	x	x	x	x	14	x	12	10	36
<i>B. cylindrica</i>	x	x	5	7	x	6	3	x	2	2	25
<i>B. sexangula</i>	x	2	x	4	x	6	7	3	x	11	33
<i>B. gymnorrhiza</i>	2	1	5	7	2	x	x	8	x	2	27
<i>S. hydrophyllacea</i>	x	x	x	x	x	20	22	x	x	x	42
TOTAL	62	71	89	124	138	189	136	143	153	196	1301

Note: x = Not Present (NP)

Species Diversity

Table 7 presents the Shannon-Wiener Diversity Index of mangrove flora in Surigao del Sur, Philippines, providing insights into species richness and abundance within this critical ecosystem. The table categorizes mangrove species by family, detailing the number of individuals recorded, their relative proportions within the total population, and their contributions to the diversity index calculation. Notably, *Rhizophora mucronata* and *Rhizophora apiculata* exhibit higher abundances, underscoring their ecological dominance in the mangrove community. This dominance suggests that these species thrive under the prevailing environmental conditions, including tidal fluctuations, sediment composition, and salinity levels, which favor their growth and propagation.

The calculated Shannon-Wiener Diversity Index of 3.68 indicates a high level of biodiversity, signifying a well-balanced ecosystem with diverse species contributing to ecological stability. The negative summation of the product of species proportions and their natural logarithms reflects the complexity and resilience of this

mangrove habitat. A higher diversity index is typically associated with greater ecosystem stability and adaptability, enabling mangrove forests to withstand environmental changes such as climate fluctuations, coastal erosion, and anthropogenic disturbances.

Given the ecological significance of mangroves, conservation efforts should prioritize habitat preservation, sustainable resource management, and community engagement. Local governments and environmental organizations can implement mangrove reforestation programs, particularly in areas where biodiversity is declining. Stronger enforcement of protective regulations can prevent habitat degradation caused by deforestation, aquaculture expansion, and pollution. Additionally, educational campaigns and participatory conservation programs can increase local awareness of the importance of mangrove biodiversity, promoting responsible stewardship of these ecosystems. By safeguarding the diversity of mangrove species, these initiatives will enhance coastal protection, sustain marine biodiversity, and support carbon sequestration efforts, contributing to long-term environmental sustainability.

Table 7. Shannon-Wiener Diversity Index of Mangrove Flora in Surigao del Sur, Philippines.

Family	Species	Number (<i>p</i>)	<i>p_i</i> (Proportion)	ln (<i>p_i</i>)	<i>p_i</i> ln (<i>p_i</i>)	- <i>p_i</i> ln (<i>p_i</i>)
Acanthaceae	<i>Acanthus ebracteatus</i>	35	0.0269	-	-	0.0974
Acanthaceae	<i>Acanthus volubilis</i>	31	0.0238	-	-	0.0889
Acanthaceae	<i>Acanthus aureum</i>	23	0.0177	-	-	0.0714
Acanthaceae/ Rhizophoraceae	<i>Ceriops decandra</i>	10	0.0077	-	-	0.0375
Acanthaceae/ Rhizophoraceae	<i>Ceriops tagal</i>	17	0.0131	-	-	0.0568
Areaceae/Palmae	<i>Nypa fruticans</i>	85	0.0653	-	-	0.1781
Avicenniaceae	<i>Avicennia rumphiana</i>	12	0.0092	-	-	0.0431
Avicenniaceae	<i>Avicennia officinalis</i>	60	0.0461	-	-	0.1419
Avicenniaceae	<i>Avicennia alba</i>	38	0.0292	-	-	0.1034
Avicenniaceae	<i>Avicennia marina</i>	30	0.0230	-	-	0.0868
Combretaceae	<i>Lumnitzera racemosa</i>	47	0.0361	-	-	0.1200
Euphorbiaceae	<i>Excoecaria agallocha</i>	63	0.0484	-	-	0.1465
Lythraceae	<i>Pemphis acidula</i>	32	0.0246	-	-	0.0912
Lythraceae	<i>Sonneratia alba</i>	81	0.0622	-	-	0.1725
Lythraceae	<i>Sonneratia ovata</i>	63	0.0484	-	-	0.1465
Lythraceae	<i>Sonneratia caseolaris</i>	32	0.0246	-	-	0.0912
Malvaceae	<i>Heritiera littoralis</i>	8	0.0062	-	-	0.0315
Meliaceae	<i>Xylocarpus granatum</i>	51	0.0392	-	-	0.1270
Meliaceae	<i>Xylocarpus moluccensis</i>	30	0.0230	-	-	0.0868
Myrtaceae	<i>Osbornia octodonta</i>	16	0.0123	-	-	0.0541
Primulaceae	<i>Aegiceras corniculatum</i>	40	0.0307	-	-	0.1069
Primulaceae	<i>Aegiceras floridum</i>	13	0.0100	-	-	0.0461
Pteridaceae	<i>Acrostichum speciosum</i>	37	0.0285	-	-	0.1014
Pteridaceae	<i>Acrostichum aureum</i>	33	0.0254	-	-	0.0933
Rhizophoraceae	<i>Rhizophora apiculata</i>	110	0.0845	-	-	0.2088

Mangrove Vascular Flora Composition, Distribution						
Rhizophoraceae	<i>Rhizophora mucronata</i>	127	0.0976	-	-	0.2271
Rhizophoraceae	<i>Rhizophora stylosa</i>	14	0.0108	2.3264	0.2271	0.0489
Rhizophoraceae	<i>Bruguiera parviflora</i>	36	0.0277	4.5243	0.0489	0.0992
Rhizophoraceae	<i>Bruguiera cylindrica</i>	25	0.0192	-	-	0.0758
Rhizophoraceae	<i>Bruguiera sexangula</i>	33	0.0254	3.5820	0.0992	0.0933
Rhizophoraceae	<i>Bruguiera gymnorrhiza</i>	27	0.0208	-	-	0.0806
Rubiaceae	<i>Scyphiphora hydrophyl- lacea</i>	42	0.0323	3.9502	0.0758	0.1109
TOTAL		1301		3.8754	0.0806	3.68
				3.4339	-3.68	3.68

Note: > 3.50 Very High; 3.00 – 3.49 High; 2.50 – 2.99 Moderate; 2.00 – 2.49 Low; < 1.99 Very Low (Fernando, 1998)

Recent studies emphasize the significance of maintaining mangrove biodiversity to enhance coastal resilience and mitigate climate change impacts. The study by Adams et al. (2021) and Dapar et al. (2023) emphasizes the role of diverse mangrove forests in supporting ecosystem services essential for human communities. In addition, Dahdouh-Guebas et al. (2019) highlight the

importance of biodiversity assessments in informing conservation policies and community-based protection guidelines. These findings align with the diversity index presented in Table 7, reinforcing the necessity for continued monitoring and conservation efforts in Surigao del Sur to ensure the health and sustainability of these critical ecosystems.

Table 8. Species Richness, Dominance, Equitability, and Diversity Index of Mangrove Species by Study Sites in Surigao del Sur

Index	Main Locale					Total	Mean
	Hinatuan	Barobo	Liangá	San Agustin	Cagwait		
Species Richness	11.0	15.0	23.0	18.0	28.0	95.0	19.0
Species Diversity	0.6570	0.6612	0.6114	0.6485	0.6234	3.2015	0.6403
Equitability	0.2740	0.2442	0.1950	0.2244	0.1871	1.1246	0.2249
Dominance	0.5357	0.5316	0.5795	0.5440	0.5681	2.7589	0.5518

Note: Species Richness (DMn), Dominance (D), Equitability (J), Diversity (H')

Table 8 provides an overview of Species Richness, Dominance, Equitability, and the Diversity Index of mangrove species across various study sites in Surigao del Sur, Philippines. The analysis reveals varying levels of species richness, with Hinatuan hosting 11 species, Barobo 15 species, Lianga 23 species, San Agustin 18 species, and Cagwait 28 species. This distribution suggests that each municipality contributes to the overall mangrove biodiversity within the province, with Cagwait exhibiting the highest richness, indicating a more diverse and ecologically complex mangrove habitat. The greater species richness in Cagwait may be attributed to favorable environmental conditions, such as nutrient-rich sediments, optimal salinity levels, and well-maintained hydrological processes. These findings align with previous studies highlighting that mangrove ecosystems with higher species richness tend to be more resilient, offering enhanced ecological services such as coastal stabilization, carbon sequestration, and

habitat provision for marine biodiversity (Barbier et al., 2018; Lee et al., 2020).

The total Shannon-Wiener Diversity Index of 3.2015 (mean = 0.6403) reflects a relatively high level of biodiversity, suggesting that the mangrove ecosystems in these municipalities are ecologically complex and functionally stable. Additionally, the Equitability Index of 1.1246 (mean = 0.2249) provides insight into the distribution of species across sites. Variations in equitability suggest that while some areas, such as Cagwait, support a wider range of species, others may exhibit species dominance, where a few species thrive more prominently. Species dominance can sometimes reduce overall ecosystem stability, as lower diversity may limit adaptability to environmental changes and disturbances (Murray et al., 2019).

Moreover, these indices provide critical insights for conservation and resource management strategies. The presence of high species richness in certain areas

underscores the importance of protecting these habitats from deforestation, pollution, and human encroachment. Conservation strategies should focus on restoring degraded mangrove areas, enforcing protective regulations, and promoting community-led reforestation initiatives. Additionally, understanding the equitability and dominance indices can help policymakers and environmental managers develop site-specific

conservation approaches that address ecological imbalances while enhancing the resilience of mangrove ecosystems (Cai et al., 2020). Thus, by integrating these findings into coastal management programs, local authorities can strengthen biodiversity conservation efforts while ensuring that mangrove ecosystems continue to provide essential services for both ecological sustainability and climate resilience.

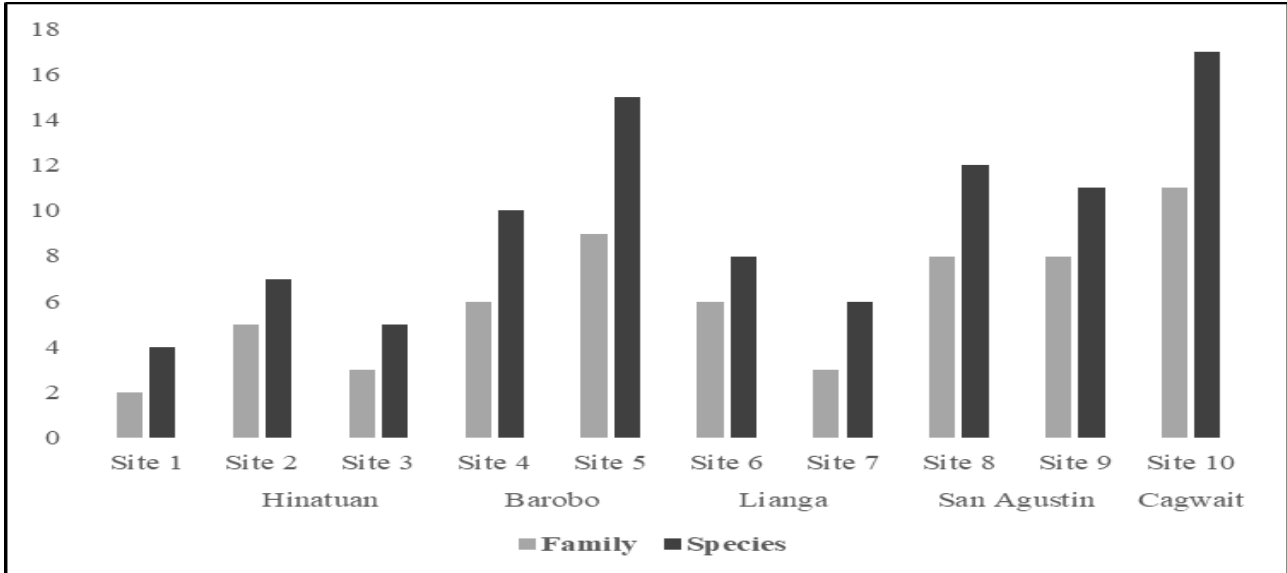


Figure 2. Composition and Average Levels of Mangrove Vascular Flora by Family and Species in Surigao del Sur Coastal

The graph illustrating the composition and average levels of mangrove vascular flora by family and species in Surigao del Sur’s coastal areas emphasizes the diversity and relative abundance of key mangrove species, essential to coastal ecosystem health. Mangrove ecosystems, particularly dominated by families like *Rhizophoraceae*, *Acanthaceae*, *Avicenniaceae*, and *Lythraceae*, play a crucial role in shoreline stabilization, providing habitats for diverse marine and bird life, and serving as natural buffers against coastal erosion and extreme weather events (Duke et al., 2020; Dapar et al., 2023). The high abundance of species such as *R. mucronata* and *R. apiculata*, could suggest favorable conditions for these spe

cies, reflecting the resilience and adaptive capacity of these flora in saline environments. On the other hand, lower levels of certain species could point to potential ecological stressors like deforestation, pollution, or climate change impacts (Giri et al., 2020; Saro et al., 2022). These patterns emphasize the importance of targeted conservation strategies, as maintaining species diversity and abundance in mangrove ecosystems is critical to sustaining biodiversity, supporting fisheries, and enhancing carbon storage capacities (Friess et al., 2020). Conservation efforts in mangrove-rich regions like Surigao del Sur are therefore integral to safeguarding these valuable ecosystems, especially as coastal development pressures increase.

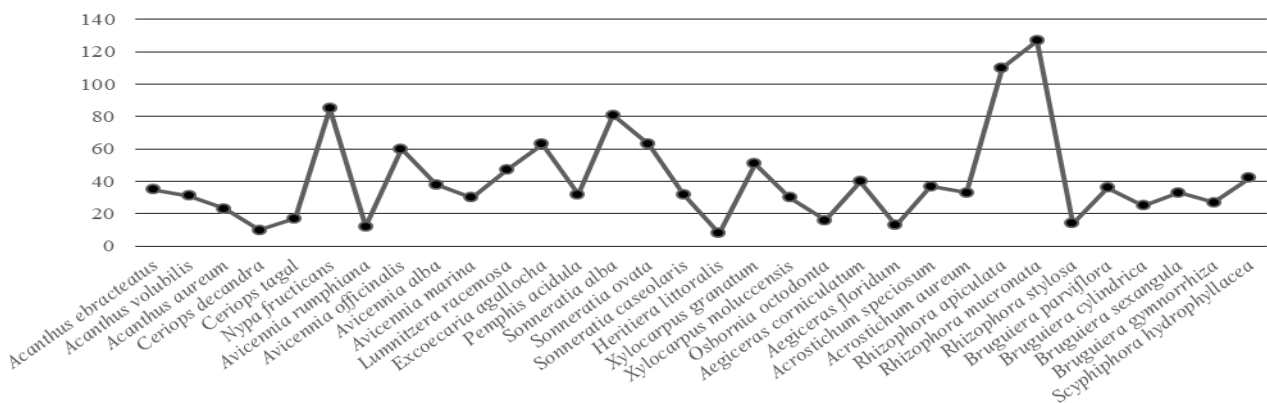


Figure 3. Overall Graph of Mangrove Species Counts in Five Municipalities along the Coastal Areas of Surigao del Sur, Philippines

Figure 3 presents an overview of mangrove species counts across five coastal municipalities in Surigao del Sur, Philippines, offering a visual representation of species abundance and distribution patterns. The graph illustrates variations in mangrove population density, reflecting differences in ecological conditions across the surveyed sites. The cumulative count of various mangrove species provides valuable insights into the health and stability of these ecosystems, with higher species counts potentially indicating favorable environmental factors such as optimal water salinity, nutrient-rich sediments, and minimal anthropogenic disturbances.

Conversely, municipalities with lower species counts may be experiencing ecological stressors that hinder mangrove growth and survival. These stressors could include coastal erosion, pollution, deforestation, or unsustainable land use practices that impact species diversity and overall ecosystem resilience. The distribution pattern observed in the graph serves as a critical tool for identifying priority areas for conservation, rehabilitation, and sustainable management. More so, by analyzing species abundance trends, policymakers and environmental stakeholders can develop targeted conservation strategies aimed at preserving biodiversity, restoring degraded mangrove habitats, and mitigating environmental threats. This visual representation not only enhances our understanding of mangrove ecosystem dynamics but also reinforces the need for localized and data-driven conservation efforts to ensure the long-term sustainability of mangrove forests in Surigao del Sur.

Species Diversity and Conservation Status

The study emphasizes the rich species composition of mangrove vascular flora in Surigao del Sur, Philippines, identifying a total of 32 species across 13 families. The predominance of native species (31 out of 32) is indicative of a healthy mangrove ecosystem, which plays a critical role in coastal stability and biodiversity (Kumar et al., 2020; Mambo et al., 2023; Amalo et al., 2024). Accordingly, *Osbornia octodonta* is recognized as an endemic species, emphasizing the unique ecological significance of Philippine mangroves. The conservation status reveals that while the majority of species (24) fall under the Least Concern category, the presence of Vulnerable (3 species) and Near Threatened species (3 species) raises important concerns regarding their sustainability amidst environmental changes and habitat degradation (Purnamasari et al., 2021; Taneja & Buisson, 2023).

The identification of vulnerable and near-threatened species, such as *Ceriops decandra* and *Heritiera littoralis*, necessitates targeted conservation strategies to prevent further decline. These species are crucial not only for their ecological roles but also for the local communities that rely on mangrove ecosystems for resources and livelihood (Abejo et al., 2022; Mambo et al., 2023; Hapsari et al., 2024). Moreover, two species categorized as Not Yet Assessed highlight the need for further research to determine their conservation status and potential vulnerabilities. Moreover, this understanding serves as a foundational step for developing conservation initiatives that align with both local and global biodiversity goals, advocating

for a collective effort in mangrove preservation (Alpizar et al., 2022; Yao et al., 2023; Gueta et al., 2023).

Nevertheless, the conservation initiatives focusing on the vulnerable and near-threatened species are paramount in maintaining ecosystem stability. These species contribute to ecological health and the livelihoods of local communities, thereby emphasizing the intertwined relationship between biodiversity and human well-being (Goloran et al., 2020; Sabai, 2023). The study serves as a critical baseline for future ecological assessments and assists local governments and conservation organizations in formulating effective strategies to preserve mangrove ecosystems, thereby enhancing community awareness about their ecological importance.

Distribution and Abundance of Mangrove Species

The distribution and abundance of mangrove species across the ten sampling sites reveal significant ecological patterns driven by environmental factors. The most frequently observed species, *Rhizophora mucronata* and *Rhizophora apiculata*, showcase high individual counts of 127 and 110, respectively, indicating their adaptability and resilience in the coastal ecosystems of Surigao del Sur. Additionally, the presence of other species such as *Sonneratia alba* and *Nypa fructicans* further emphasizes the region's biodiversity (Faridah-Hanum et al., 2021). The highest ecological diversity was recorded at Site 10 in Cagwait, which hosts 17 species and a total of 319 individuals, attributed to favorable environmental conditions such as nutrient-rich sediments and optimal tidal influences (Santini et al., 2020).

Moreover, the data indicates a correlation between the ecological characteristics of the sites and the diversity of mangrove species present. Sites with a higher abundance of species not only support greater individual counts but also reflect a broader range of family representation. The relative frequency of species at Site 10, which reached 24.52%, aligns with its significant ecological richness, suggesting that specific environmental conditions play a crucial role in shaping mangrove distribution patterns (Dapar et al., 2023). In contrast, species such as *Heritiera littoralis* and *Ceriops decandra* exhibit limited distributions across the sampling sites, indicating specific habitat requirements that may render them vulnerable to environmental changes.

This variability in species distribution emphasizes the importance of site-specific management strategies that consider the unique ecological characteristics of each location. The findings provide critical insights into the ecological dynamics and variations of mangrove forests in Surigao del Sur, emphasizing the need for continuous monitoring and conservation efforts to protect these vital ecosystems (Alpizar et al., 2022). As mangroves contribute to coastal protection, carbon sequestration, and habitat provision for diverse species, understanding their distribution patterns can significantly inform local conservation initiatives and policy-making efforts in the region (Febriana & Utary, 2024).

Implications for Conservation and Community Engagement

The study's findings indicate the urgent need for conservation efforts directed at vulnerable and endemic mangrove species in Surigao del Sur. The varied conservation statuses of the identified species reveal a critical scenario where proactive measures are required to safeguard these ecological resources. The classification of 24 species as Least Concern may give a sense of security; however, the identification of three Vulnerable and three Near Threatened species presents an important warning sign that cannot be overlooked. These vulnerable species are integral to maintaining ecological balance and their decline could have cascading effects on the overall health of the mangrove ecosystem and the livelihoods of local communities that depend on these resources (Ramírez-Ruiz *et al.*, 2024).

Additionally, the unique characteristics of endemic species, such as *Osbornia octodonta*, emphasize the necessity for detailed conservation strategies that address the specific ecological needs of these species. Effective conservation strategies must involve local communities in the decision-making process, cultivating a sense of ownership and responsibility for preserving their natural heritage (Abejo *et al.*, 2022; Lleno *et al.*, 2023). Initiatives that promote community awareness about the ecological and economic importance of mangroves can encourage sustainable practices, also contributing to the resilience of these vital ecosystems (Berame, Bulay, & Mercado, 2021; Saro *et al.*, 2022a). Overall, this study serves as an important resource for local governments, conservation organizations, and community stakeholders in Surigao del Sur, providing a framework for developing targeted strategies that enhance the conservation and management of mangrove ecosystems. Furthermore, it advocates for collaborative efforts that combine scientific research, community engagement, and effective policy frameworks to ensure the sustainability of mangrove habitats and their associated biodiversity for future generations.

CONCLUSION AND RECOMMENDATION

The study emphasizes the critical ecological significance and biodiversity of mangrove forests in Surigao del Sur, emphasizing the richness of species composition while also addressing the pressing conservation challenges associated with vulnerable and near-threatened species. These findings have direct implications for conservation policy, as they provide scientific evidence that can guide policymakers in strengthening existing environmental regulations and developing targeted conservation programs. Integrating local community participation in mangrove protection efforts is essential, as raising awareness of their ecological and economic value fosters greater commitment to sustainable management practices.

Moreover, continuous monitoring and research are necessary to track mangrove health, resilience, and species composition over time, allowing for adaptive management strategies that respond to evolving environmental conditions. Future research should explore the long-

term ecological impacts of human activities on mangrove ecosystems, assess the effectiveness of current conservation policies, and investigate innovative restoration techniques to enhance mangrove recovery efforts. Lastly, collaborative efforts among local governments, conservation organizations, researchers, and coastal communities are pivotal in formulating data-driven policies that ensure the long-term sustainability of these vital ecosystems for future generations.

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Declaration of Conflict of Interest

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Author Contributions

J. M. Saro: conceptualization of the study, methodology, data analysis and interpretation, original draft preparation, review, and editing. E. A. Litera: grammar checking, language formatting, review, and editing. D. R. C. Chua: review, preparation, and editing. M. L. Bulay: validation of the analysis, technical assistance, review, and editing.

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