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Species-Habitat Relationship of Bats and Mangroves in the Selected Coastal Areas in Northern Mindanao, Philippines

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ABSTRACT In the Philippines, mangrove coverage has been declining in Misamis Oriental, impacting bat populations due to coastal and aquaculture development. This study evaluated the relationship between bats and mangroves. Mist netting was used to capture bat species, while quadrat sampling was used to sample mangrove species. Six different bat species have been identified and classified as least concern (LC) by the International Union for Conservation of Nature (IUCN). *Cynopterus brachyotis* was the most common bat species in all sampling locations, while *Ptenochirus jagori, Eonycteris spelaea,* and *Harpyionycteris whiteheadi* were first recorded in mangrove forests, adding to existing bat fauna literature in Mindanao. *Cynopterus brachyotis* is strongly associated with taller mangroves with larger diameter at breast height (DBH) and denser canopy cover based on canonical correspondence analysis (CCA). All the mangrove species found were classified as 'Least Concern' by the IUCN, except for *Ceriops decandra*, which were classified as 'Near Threatened.'

KEY WORDS Bats; conservation; diversity; mangroves; population.

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INTRODUCTION

The Philippines is home to 180 mammals, with a significant proportion of this number consisting of bats (Order Chiroptera), specifically 78 species from six families (Dela Cruz et al., 2023; Reginaldo & de Guia, 2014). Bats are found in diverse habitats such as lowland forests, mangrove forests, urban areas, and riparian areas (Aguiar et al., 2021; Akasaka et al., 2010; Latinne et al., 2020). In tropical countries, mangrove forests provide wood for construction and fuel, are a habitat for coastal fauna, a nursery for juvenile marine organisms, act as stores of carbon in biomass and soil, provide protection from strong winds during typhoons, and mitigate coastal erosion (Alongi, 2009; Castillo et al., 2017; Donato et al., 2011). Moreover, mangrove ecosystems provide critical habitat for bat species, including spaces for feeding, roosting, and shelter (Arceo-Carranza et al., 2021; Luther & Greenberg, 2009; McConville et al., 2013; Reef et al., 2014; Stewart & Dudash, 2018). Although mangrove forests are of considerable importance to the ecosystem, their habitability for bats has declined. In the Philippines, mangrove forest coverage decreased from an estimated 500,000 hectares in 1918 to 256,185 hectares in 2000, with 341.19 hectares in Northern Mindanao, notably in Misamis Oriental (Long & Giri, 2011). This decline has been observed across Macajalar Bay in Misamis Oriental, for instance, El Salvador City and Alubijid in Barangay Baybay. This decline has been attributed to urbanization and the clearing of land for aquaculture, deforestation, and firewood use (Cagas, 2014; Lomoljo-Bantayan et al., 2023; Primavera, 2000; Salvaña et al., 2024). The deforestation of mangrove forests has substantial consequences for biodiversity. According to the International Union for Conservation of Nature (IUCN), at least 40% of species living in mangroves have a heightened red-list status (Polidoro et al., 2010). Among these species are bats, vulnerable to habitat disturbance and landscape changes caused by human activities (Kingston, 2010; Struebig et al., 2008; Zubaid, 1993). In Malaysia and Indonesia, numerous species have lost crucial roosting areas, particularly those inhabiting mangrove wetlands, such as *Pteropus vampyrus* (Linnaeus, 1758), and lowland forests. The timber industry is destroying mangrove wetlands for aquaculture, firewood, and coastal development, while lowland forests are being cut down for agricultural purposes and timber (Mickleburgh et al., 1992). As reported by Jones et al. (2009): "*The response of bats to various stressors associated with environmental change may serve as valuable indicators of biodiversity and ecosystem health*". However, most studies on bats in the Philippines, notably on Mindanao Island, have focused on distinct habitat types. These include primary, lowland forest, urban, and agricultural regions (Achondo et al., 2014; Heany et al., 1989; Rickart, 1993). Bats in caves have been the subject of other studies (Quibod et al., 2019; Tanalgo & Tabora, 2015). Research has been conducted on cultivated areas, secondary forests, forest edges, and montane forests on Mt. Apo (Achondo et al., 2014; Relox et al., 2014) and on lowland mixed dipterocarp forests (Amoroso et al., 2019). However, no published data on mangrove forests in the Philippines focusing on bat species' afforestation and reforestation habitats are available. Due to the scarcity of data on bat faunal composition in the

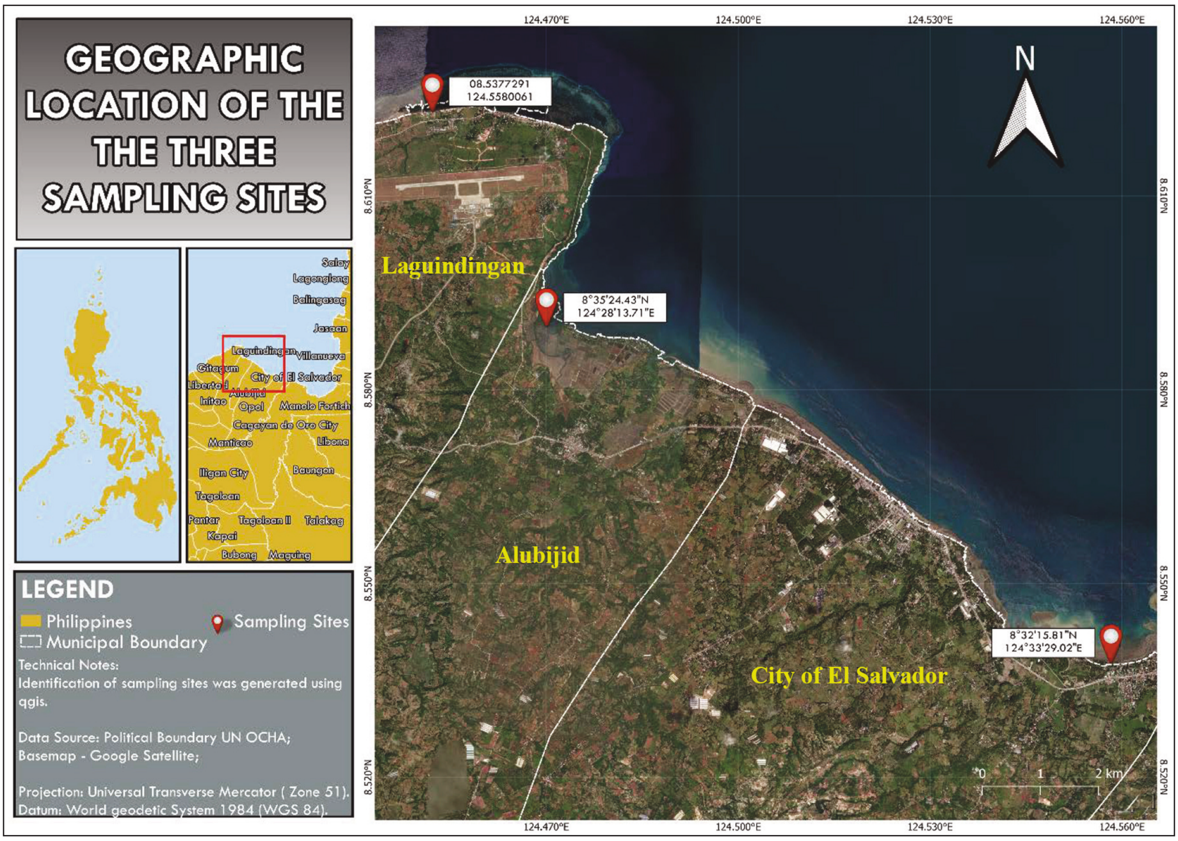
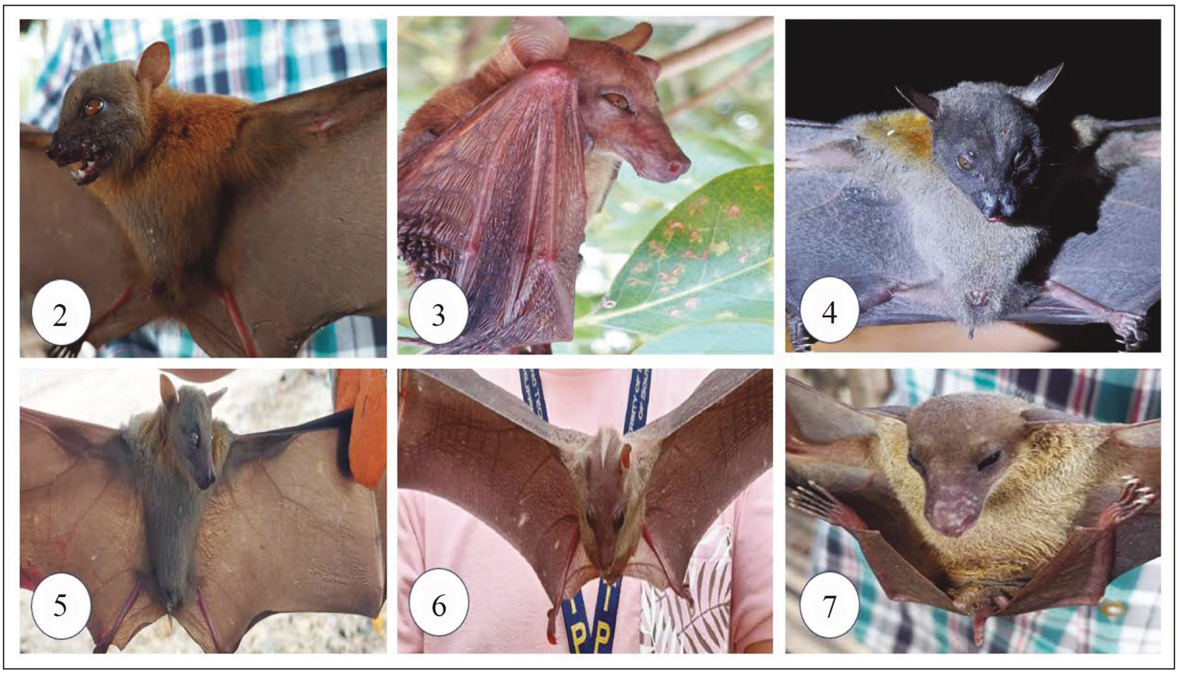
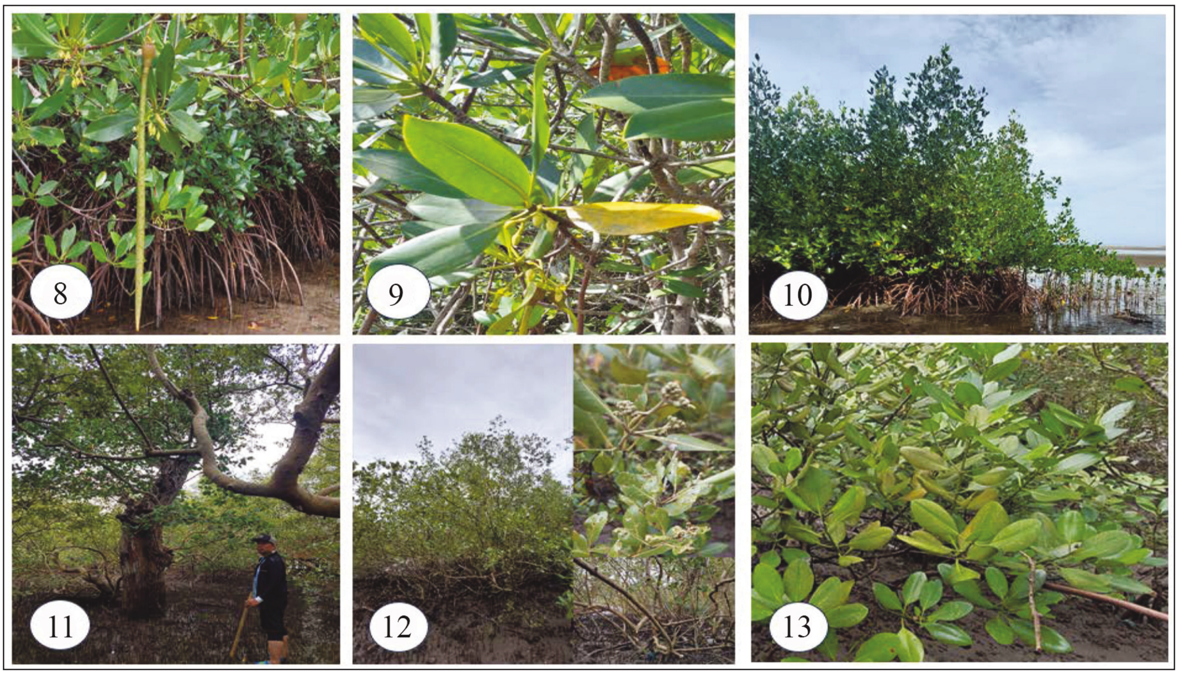


Figure 1. The study area: three selected barangays in coastal mangrove forest areas in Misamis Oriental, Northern Mindanao, Philippines.



Figures 2-7. Different kinds of bats captured in mist nets in Misamis Oriental mangrove forests in different barangays. Tubajon in Laguindingan, Baybay in Alubijid, and Barangay Molugan, El Salvador City, Philippines. Fig. 2: *Cynopterus brachyotis*. Fig. 3: *Macroglossus minimus*. Fig. 4: *Ptenochirus jagori*. Fig. 5: *Ptenochirus minor*. Fig. 6: *Harpyionycteris whiteheadi*. Fig. 7: *Eonycteris spelaea*.



Figures 8-13. Different types of mangrove species identified in Misamis Oriental mangrove forests in different barangays. Tubajon in Laguindingan, Baybay in Alubijid, and Barangay Molugan, El Salvador City, Philippines. Fig. 8: Rhizophora mucronata. Fig. 9: *Rhizophora stylosa*. Fig. 10: *Rhizophora apiculata*. Fig. 11: *Sonneratia alba*. Fig. 12: *Avicennia marina*. Fig. 13: *Ceriops decandra*.

three selected mangrove forests at the village level or barangays, the smallest administrative unit in the Philippines (Quevedo et al., 2020) specifically, Tubajon in Laguindingan, Baybay in Alubijid, and Molugan in El Salvador City in Northern Mindanao; an assessment to evaluate the status of bats inhabiting these selected mangrove forests in Misamis Oriental is required. Specifically, this study aimed to determine and compare bat species composition to fill this knowledge gap and provide foundational scientific data on the Misamis Oriental mangrove ecosystem for research, monitoring, and conservation strategies concerning relative abundance, conservation status, and ecological diversity and assess the relationship between bat species and mangrove structure in terms of diameter at breast height (DBH), height, and canopy cover using canonical-correlation analysis (CCA).

MATERIAL AND METHODS

Study area

The study was conducted in December 2022 in three selected barangays in coastal mangrove forest areas in Misamis Oriental, Northern Mindanao, Philippines (Fig. 1).

The first study site is in Barangay Tubajon, located at a latitude of 08˚53.77291"N and a longitude of 124˚5580061"E. This is not a naturally occurring mangrove area. Based on the record of the local government of Laguindingan, there were 74 ha planted in 1991, and Municipal Ordinance No. 94 was passed, preserving 22 hectares of mangrove as a Marine Protected Area (MPA), while 24 ha were designated as non-protected areas.

The second study site was Barangay Baybay in Alubijid, located at a latitude of 8˚35'24.43"N and longitude of 124˚33'28.13.71"E. Data from 1991 show that the Department of Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources (BFAR) facilitated the planting of 20 hectares of mangroves.

The third study site was in Barangay Molugan, El Salvador City, located at a latitude of 8˚32'15.81"N and longitude of 124˚33'59.29.02"E. Local government units have played a significant role in this area by overseeing the planting and maintenance of a 17-hectare mangrove forest.

Data gathering of mangrove and bat species

Before the research, a site visit and reconnaissance of the area were done to establish rapport among the locals and ask permission through formal letters from Barangay officials in each sampling site. Each Barangay Captain of the sampling site issued a clearance permit to conduct the study. Those clearance permits acquired by the researchers were attached to the research paper as required by the Department of Environment and Natural Resources Biodiversity Management Bureau (DENR-BMB) for applying for a gratuitous permit (GP) under Wildlife GP No. R10 2022–59 for collecting bat and mangrove species in Misamis Oriental. After granting the permit, it was hand-carried and submitted to every sampling site to the office of the Barangay Captains, informing them to gather the data stipulated in the permit. Various researchers have implemented and utilized this methodological approach (Obeña et al., 2021; Roño et al., 2021). At every sampling site, a handheld Global Positioning System (Garmin eTrex) was used to locate sampling locations along a 1 km transect line perpendicular to the shoreline in each barangay. This transect line was divided into five stations with an interval of 250 meters. At each station, three 10 m × 10 m plots were established at intervals of 20 m, in a protocol adapted and modified from previous studies (Hamilton et al., 2017; Hoque et al., 2015; Wang et al., 2003; Fils et al., 2014). All mangrove species in the plot were taxonomically classified using the Field Guide to Philippine Mangroves (Primavera et al., 2004). Mangrove tree parameters such as DBH, tree height, and canopy cover were measured inside the plot using a measuring tape and densiometer. These measurements were carried out according to the guidelines (Pace et al., 2022; Schofield, 2014; Sreelekshmi et al., 2020). Bat species were captured using mist nests at the three sampling sites (Duya et al., 2020). Mist nets tended to be continuous during the activity peak from early dusk to dawn (6:00 PM–10:00 PM and 4:00–6:00 AM). Bat species were identified using the taxonomic guidelines prescribed by Ingle & Heaney (1992). After identification, the species were photographed, their claws were marked with nail polish, and released (Nasir et al., 2021).

Data analysis

The bat species' conservation status and geographic distribution were based on the International Union for Conservation of Nature (IUCN) 2023 and Heaney et al. (2010). The relative abundance (%) was computed using the formula described by Tanalgo & Tabora (2015):

Relative Abundance = N/n,

where N is the total number of individuals of a species that have been captured, and n is the total number of species.

Ecological diversity was used for the Shannon–Wiener index (H') of bats based on research conducted by Cavalcanti & Larrazabal (2004), Atsbhaet et al. (2019), and Gevaña & Pampolina (2009). Canonical correlation analysis (CCA) was computed for ordination analysis to examine the correlation between bat species abundance and mangrove species' estimated average canopy cover, height, and DBH using PAST version 4.03 (Hammer et al., 2001).

RESULTS

A total of 4 bat species were recorded at the first site, with 31 specimens captured, as shown in (Table 1). *Cynopterus brachyotis* (Müller, 1838) had the highest relative abundance (54.83%) of the 17 specimens collected, followed by *Ptenochirus minor* (Yoshiyuki, 1979) with seven specimens, *Macroglossus minimus* (E. Geoffroy, 1810) with six specimens, and *Ptenochirus jagori* (Peters, 1861) with one specimen captured, with the least of relative abundance of 3.22 %.

The results in Table 2 show that *Cynopterus brachyotis* had the highest relative abundance (42.8%) of the nine (9) specimens collected, followed by *Harpyionycteris whiteheadi* Thomas, 1896 with six specimens. In comparison, *Macroglossus minimus* and *Ptenochirus minor* Yoshiyuki, 1979 were found in the mangrove forest with the same low relative abundance of 14.28%. In Barangay Baybay Alubijid Misamis Oriental, where the mangrove reforestation is located, four specimens and twenty-one specimens were recorded.

The results in Table 3 show that *Cynopterus brachyotis* had the highest relative abundance (58.33%) of the seven specimens collected, followed by *Eonycteris spelaea* (Dobson, 1871) with three specimens with a relative abundance of (25%) and the rest of the bat species representing one specimen namely: *Macroglossus mininus* and *Ptenochirus minor* with relative abundance of (8.33%).

Table 4 shows the conservation status and geographic distribution of fruit bat species found in selected mangrove forest locations in Misamis Oriental. The bat species identified are *Cynopterus brachyotis, Ptenochirus minor, Macroglossus min-*

Species	Number of specimens	Relative abundance %
Cynopterus brachyotis	17	54.83
Ptenochirus minor	7	22.58
Macroglossus minimus	6	19.35
Ptenochirus jagori	1	3.22
Total	31	100%

Table 1. Species composition and relative abundance of bat species in a mangrove forest area of Barangay Tubajon, Laguindingan, Misamis Oriental.

Species	Number of specimens	Relative abundance %
Ptenochirus minor	3	14.28
Cynopterus brachyotis	9	42.85
Macroglossus minimus	3	14.28
Harpyionycteris whiteheadi	6	28.57
Total	21	100%

Table 2. Species composition and relative abundance of bat species in a mangrove forest area of Barangay Baybay Alubijid, Misamis Oriental.

Species	Number of specimens	Relative abundance %
Ptenochirus minor	1	8.33
Cynopterus brachyotis	7	58.33
Macroglossus minimus	1	8.33
Eonycteris spelaea	3	25
Total	12	100%

Table 3. Species composition and Relative abundance of bat species in a mangrove forest area of Barangay Molugan El Salvador City, Misamis Oriental.

Scientific Name	Common name	Local Name	Conservation Status (IUCN, 2023-1)	Geographic Distribution (Heaney et al., 2010)
Cynopterus brachyotis	Lesser Dog-Faced Fruit Bat	Kwaknit	Least Concern	Southeast Asia
Ptenochirus minor	Lesser Musky-Fruit Bat	Kwaknit	Least Concern	Mindanao Endemic
Macroglossus minimus	Lesser Long, Tongued-Fruit Bat	Kwaknit	Least Concern	Southeast Asia
Harpyionycteris whiteheadi	Harpy Fruit Bat	Kwaknit	Least Concern	Philippine Endemic
Ptenochirus jagori	Musky Fruit Bat	Kwaknit	Least Concern	Philippine Endemic
Eonycteris spelaea	Dawn Bat	Kwaknit	Least Concern	Southeast Asia

Table 4. Conservation status and geographic distribution of fruit bat species found in selected mangrove forests in Misamis Oriental, namely Tubajon, Laguindingan, Baybay, Alubijid, and Molugan, El Salvador City.

Statistical Analysis	Brgy. Tubajon	Brgy. Baybay
Shannon's diversity index	1.094	1.277

Table 5. Summary of Shannon's diversity index and evenness of bats in a mangrove ecosystem in Tubajon, Laguindingan; Baybay, Alubijid, Misamis Oriental and Molugan, El Salvador City.

imus, Harpyionycteris whiteheadi, Ptenochirus jagori, and *Eonycteris spelaea.*

Table 5 shows that the diversity index of bat species varies with the sampling locations. The highest index is at Barangay Baybay (H = 1.277), followed by Barangay Tubajon, Shannon's diversity index of (H = 1.094), and Barangay Molugan (H = 1.075).

The taxonomic classification of mangrove species identified in Tubajon, Baybay, and Molugan Misamis Oriental is shown in Table 6. Six mangrove species of mangroves were found, including *Rhizophora mucronata* Poir., *Rhizophora stylosa* Griff., *Rhizophora apiculata* Blume, *Sonneratia alba* Sm., *Avicennia marina* (Forssk.) Vierh., and *Ceriops decandra* (Griff.) W. Theob.

Figure 4 shows the overall Canonical Correspondence Analysis (CCA) habitat vectors, specifically height, DBH, and canopy cover, which have been identified as environmental variables influencing the bat species-habitat relationship in the three (3) sites barangays in Tubajon, Baybay, and Molugan in Misamis Oriental. Arrows based on mangrove factors and species ordination show the distribution of bats. Moreover, it shows that *Cynopterus brachyotis* is

Family	Scientific name	Local Name	Conservation	Tubajon	Baybay	Molugan
Rhizophoraceae	*Rhizophora mucronata*	Bakhaw babae	Least Concern	–	–	–
Rhizophoraceae	*Rhizophora stylosa*	Bakhaw Bato	Least Concern	–	–	–
Rhizophoraceae	*Rhizophora apiculata*	Bakhaw Lalaki	Least Concern	–	–	–
Rhizophoraceae	*Ceriops decandra*	baras-baras, lapis-lapis, malatangal	Near Threatened	x	–	x
Sonneratiaceae	*Sonneratia alba*	Pagatpat	Least Concern	x	–	x
Avicenniaceae	*Avicennia marina*	bungalon, api-api, miapi, bayabason	Least Concern	x	–	–

Table 6. Mangrove species found in Tubajon, Baybay and Molugan Misamis Oriental (x = absent).

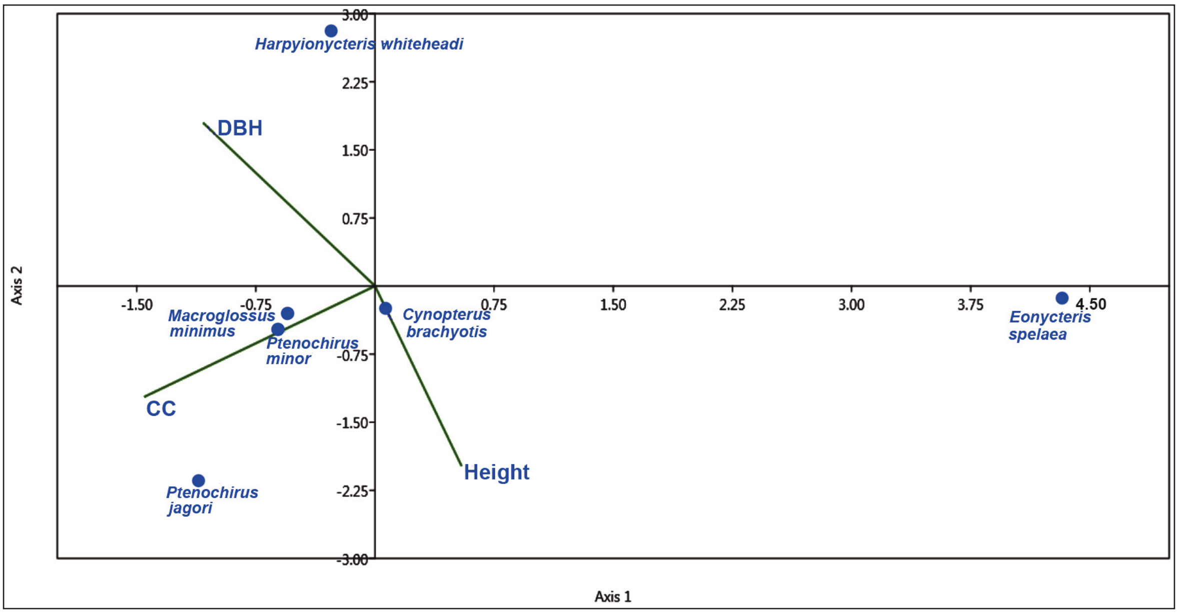


Figure 4. Shows height, DBH, and canopy cover in three (3) sites in mangrove forests, which are environmental factors that affect the bat species-habitat relationship.

strongly associated with taller mangrove trees with larger DBH and denser canopy cover. At the same time, there is a negative correlation between *Ptenochirus minor* and *Macroglossus minimus* and the canopy cover of the mangrove trees. It indicates that their abundance is lower in areas with shorter canopy cover. On the other hand, there are bat species (*Ptenochirus jagori*, *Eonycteris splaea*, and *Harpyionycteris whiteheadi*) not associated with environmental factors that affect the bat species-habitat relationship.

DISCUSSION

The bat species captured in Barangay Tubajon (Table 1) were similar to those reported by Lobite et al. (2013) in the riparian region of the Cagayan de Oro River, ranging from mixed secondary and agricultural habitats to mangrove habitats. *C. brachyotis*, in a true testament to its adaptability, was the dominant species in this study. This species is commonly found in all habitats because it is a generalist that can adapt to various environments. It can feed on various fruits, nectar, and pollen and survive in disturbed and fragmented habitats (Clements & Racey, 2005; Huang et al., 2014; Tan et al., 2000). However, *P. jagori* was collected only once, and its relative abundance was the lowest among the four bat species observed in mangrove afforestation projects in Barangay Tubajon. According to Ong et al. (2008), this species is endemic to the Philippines, forages in agricultural areas, and tolerates degraded habitats, such as urban environments (Mickleburgh et al., 1992). In Barangay, Baybay in Alubijid (Table 2), *Cynopterus brachyotis* was the most prevalent bat species at the sampling sites, like Barangay Tubajon. This species is a common frugivorous species in Southeast Asia. *Macroglossus minimus*, which is distributed throughout Asian countries, has a specialization for *Sonneratia* and has never been recorded away from mangrove areas; it was caught in very few numbers, underlining the critical importance of these habitats for their survival (Macintosh & Ashton, 2002). The most common bat species captured in Barangay Molugan in (Table 3) was *C. brachyotis*, like other bat species identified in Tubajon and Baybay in Alubijid. The occurrence of this species has also been documented in other studies conducted in South Asian countries, such as Vietnam, where mangroves provide roosting sites and foraging habitats (Thong et al., 2022). According to Francis & Barrett (2008), this species is found in all environments, including gardens, mangroves, strand vegetation, lower montane forests, and dipterocarp forests. The second-most frequently captured individual was *E. spelaea*, which feeds on *Sonneratia alba*, commonly known as the mangrove apple (Stewart & Dudash, 2017; Zalipah et al., 2016). Table 4 shows the conservation status and geographic distribution of fruit bat species found in the selected mangrove forest locations in Misamis Oriental. Three endemic bat species have been identified: *P. minor*, *H. whiteheadi*, and P. *jagori*. *Harpyionycteris whiteheadi* is generally found in the secondary forest in the Puhagan site in the Palinpinon Geothermal Reservation on Negros Island, Visayas region (Fidelino et al., 2020); however, this bat species was captured in mangrove forests. By contrast, two bat species, *C. brachyotis* and *M. minimus*, are commonly found and distributed across habitats in Southeast Asian countries. In contrast, *E. spelaea* can be found in roosting caves in south-central Mindanao and throughout much of South Asia, from Southern China to the islands of Indonesia and southwestern India (Tanalgo & Tabora, 2015). The IUCN Red List classifies all species as Least Concern (LC). Furthermore, as shown in Table 5, the diversity index of bat species varied with the sampling location, with the highest index at Barangay Baybay (H = 1.277), followed by Barangay Tubajon (H = 1.094) and Barangay Molugan (H = 1.075). However, these indices were relatively low. For instance, the diversity in Barangay Baybay is less than that found in a study of bat species in a mangrove forest in Southern Brazil, where the Shannon diversity index was H' = 2.19 (Soares et al., 2016). This indicated a higher diversity of bats in the mangrove forests of Brazil. Lower diversity indices in other barangays can be attributed to anthropogenic disturbances, which resulted in reduced species diversity and uneven distribution patterns. Urbanization near mangrove areas, as observed in Barangay Molugan, surrounded by residential and commercial areas, affects the diversity index (Dangan-Galon et al., 2015). This supports the notion that bat abundance and diversity are lower in urban environments than non-urban environments (Moretto & Francis, 2017). The mangrove species common to the three selected areas are *R. mucronata*, *R. stylosa*, and *R. apiculata*. The family *Rhizophoraceae* thrives in estuaries, tidal streams, and flat coastal locations that experience daily tidal flooding (Katriesan & Bingham, 2001; Setyawan et al., 2019). These three mangrove species are also found on Samar Island in the Visayas region (Abino et al., 2014). The IUCN Red List conservation status of these mangrove species is Least Concern. Conversely, *S. alba* was not identified at the Molugan and Barangay Tubajon sampling locations, whereas *A. marina* was detected at Barangay Baybay and Molugan. Raganas et al. (2020), Primavera et al. (2016), and Manual et al. (2022) documented the presence of this mangrove species on the southern coast of Oriental Mindoro, Eastern Samar in Visayas and Mabini, Davao de Oro, and Mindanao coastal areas. These two mangrove species are classified as Least Concern regarding their conservation status. *C. decandra* was found only in Barangay Baybay. This mangrove species is also found in Argao and Cebu and has a rare and restricted distribution of less than 4,500 km^2. It is threatened by habitat loss from coastal development throughout its range, and its conservation status is Near Threatened (Buot et al., 2022; Lillo & Buot, 2016). Moreover, canonical correspondence analysis (CCA) using the Paleontological Statistics tool version 4.03 (Hammer et al., 2001) showed that *C. brachyotis* was closely related to all the mangrove factors. This suggests that this bat species is more frequently found in areas with higher DBH, height, and canopy cover of mangrove trees, a finding that aligns with the findings of several studies (Law et al. 2000; Shigo 1984; Webala et al. 2010) which conclude that bat species in the Australian forest region prefer trees with large DBH.

CONCLUSIONS

This study provides benchmark data on bat species diversity in reforested and afforested coastal mangrove forests in Misamis Oriental in Northern Mindanao Philippines. Sixty-four individuals representing six species were captured at three sites, including cave bats like *E. spelaea* and the agricultural and urban bat *P. jagori*. Species such as *H. whiteheadi*, typically found in secondary forests, were also present. These findings add to the literature on bat faunas in the mangrove habitat since they have not been recorded in previous Mindanao studies. *C. brachyotis*, a generalist species, dominated all three sites. Shannon's diversity index indicated low diversity, suggesting limited bat species in these mangroves. CCA demonstrated that tree height, DBH, and canopy cover significantly influenced bat species' habitat associations, with *C. brachyotis* strongly preferring taller trees and denser canopies. Conversely, *P. minor* and *M. minimus* were negatively associated with canopy cover, while *P. jagori*, *E. spelaea*, and *H. whiteheadi* showed no correlation with these environmental factors. The mangrove species *Rhizophora mucronata*, *Rhizophora stylosa*, and *Rhizophora apiculata* were present at all sites, whereas *Ceriops decandra* showed localized distribution and conservation concerns, classified as Near Threatened.

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