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Bat diversity in Sitio Guillan, Barangay Mansawan (Nueva Vista), Philippines

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Abstract. *Baterna RCB, Ramos AMB, Magsalay DD. 2025. Bat diversity in Sitio Guillan, Barangay Mansawan (Nueva Vista), Philippines. Biodiversitas 26: 4898-4907.* Bats are essential components of tropical ecosystems, functioning as pollinators, seed dispersers, and natural pest regulators. However, their populations are increasingly threatened by habitat loss, hunting, and human disturbance, particularly in regions where survey data remain scarce. The Philippines, recognized as a global biodiversity hotspot, harbors 73 bat species, including many endemics, yet localized assessments in Mindanao remain limited. This study assessed bat species diversity across an elevational gradient in Sitio Guillan, Barangay Nueva Vista, Don Victoriano Chiongbian, Misamis Occidental, Philippines, situated within the buffer zone of Mt. Malindang National Park. Sampling was conducted in January and April 2024 using mist-netting and the capture-mark-release method over 360 net-hours at three sites ranging from 1,042 to 1,241 m asl. A total of 134 individuals representing seven species from three families were documented. Five species were fruit bats (*Cynopterus brachyotis, Rousettus amplexicaudatus, Haplonycteris fischeri, Ptenochirus jagori, P. minor*) and two were insectivorous bats (*Hipposideros diadema, Rhinolophus subrufus*). Of these, three species were Philippine endemics and one was Mindanao-endemic. Conservation assessments indicated six species as Least Concern and one as Data Deficient. Site 1, located near a cave system, exhibited the highest species richness and diversity (H′: 1.642), while Site 3, dominated by vegetable plantations at higher elevation, showed reduced diversity. These findings provide critical baseline information on bat assemblages in Misamis Occidental, highlighting the ecological value of caves and surrounding forests as key habitats. Strengthening conservation measures in buffer zones is essential to mitigate habitat disturbance, safeguard endemic populations, and enhance sustainable biodiversity management in northern Mindanao.

Keywords: Chiroptera, conservation, disturbance, elevational gradient, endemism

INTRODUCTION

Deforestation and hunting pose significant threats to bat populations, particularly megachiropterans, with nearly half of these species currently endangered (Frick et al. 2019). The lack of survey data further complicates conservation efforts, leaving knowledge gaps on species distribution and ecological needs (Andriesse 2017). Bats play a crucial ecological role and are recognized as bioindicators due to their sensitivity to environmental changes. They contribute to ecosystem functioning through pest regulation, pollination, and seed dispersal, which support both natural ecosystems and agricultural systems (Kasso and Balakrishnan 2013). Moreover, bats aid forest regeneration by dispersing seeds over wide areas and maintaining the health of fruit trees, making them indispensable in sustaining tropical biodiversity (Del Socorro et al. 2018).

Despite their importance, protection strategies for bat habitats remain limited. Unlike birds or butterflies, whose habitats are well mapped, bats are elusive, and geographic methods often fail to capture their roosting and feeding sites (Razgour et al. 2016). Habitat fragmentation from human activities alters ecosystem structure and quality, affecting bats' morphology, prey availability, and foraging efficiency (Furey and Racey 2016; Jung and Threlfall 2016). Such conditions often favor bats with longer; thinner wings adapted for energy-efficient flight but reduced maneuverability and prey capture (Marinello and Bernard 2014). Insectivorous bats are especially at risk since their prey depends on intact canopies and stable microclimates. The global decline of insects caused by pesticides, habitat loss, and climate change worsens these threats (Sánchez and Wyckhuys 2019). Monitoring bat populations thus reflects habitat quality and broader ecosystem health.

The Philippines, a recognized biodiversity hotspot, supports exceptional bat diversity, with 25 megachiropteran and 48 microchiropteran species, many endemic to the archipelago (Achondo et al. 2014). Caves serve as critical roosting, breeding, and hibernation sites (Quibod et al. 2019) but face threats from vandalism, urban encroachment, pollution, and unregulated tourism (Furey and Racey 2016; Medellin et al. 2017). Globally, bats comprise about 20% of all mammals, with over 1,400 species (Ingala et al. 2018). Southeast Asia hosts 379 species (Kruskop 2021), while the Indian subcontinent supports 141 (Srinivasulu et al. 2021). Within the Philippines, Luzon harbors 57 species, the Visayas 16, and Mindanao 53, including three restricted to Mindanao (Del

Socorro et al. 2018; Sedlock et al. 2020; Bejec et al. 2021). This highlights the Philippines' global significance for bat diversity, with Mindanao as a center of endemism.

Within Mindanao, Mt. Malindang National Park in Misamis Occidental is recognized as a biodiversity hotspot harboring unique flora and fauna. However, surrounding buffer zones, such as Sitio Guillan in Barangay Mansawan, remain poorly studied compared to other more prominent sites like Mt. Kitanglad and Mt. Apo. Despite its ecological significance, Sitio Guillan faces pressures from agricultural expansion, hunting, and habitat conversion. Local-scale biodiversity assessments are urgently needed to address gaps. Without such studies, conservation planning risks overlooking key habitats and species that may already be vulnerable to extinction. Previous assessments across Mindanao emphasize the island's exceptional endemism, yet documentation of bat communities in Misamis Occidental remains scarce (Sedlock et al. 2020; Bejec et al. 2021).

This study addresses that gap by documenting bat diversity in Sitio Guillan, focusing on elevational gradients that influence species composition and abundance. Elevational surveys provide insights into how environmental variables such as temperature, humidity, and vegetation affect species distributions, especially in mountainous landscapes. Beyond ecological relevance, these assessments have practical applications in agriculture and forestry, as bats contribute to natural pest control and forest regeneration.

The objectives of this study are to: (i) determine bat species diversity across different elevations in Sitio Guillan, (ii) identify their habitats and ecological requirements, and (iii) assess their conservation status. The findings will establish a baseline for local biodiversity management within Mt. Malindang's buffer zones and guide sustainable land-use planning by the Department of Environment and Natural Resources (DENR) and other agencies. Additionally, the study emphasizes the need to raise public awareness about bats' ecological value, as they remain misunderstood and persecuted despite their essential roles. By integrating research, education, and community engagement, this study aims to promote long-term bat conservation in Misamis Occidental and strengthen the ecological resilience of Mindanao's montane ecosystems.

MATERIALS AND METHODS

Sampling area

Don Victoriano Chiongbian is situated on the island of Mindanao, formerly known as Don Mariano Marcos, and is a landlocked municipality in Misamis Occidental, Philippines (Figure 1). The city has a land area of 284.60 square kilometers or 109.88 square miles, constituting 14.18% of Misamis Occidental's total area (Philatlas 2023). The municipal center lies around 8°15'N, 123°34'E, on Mindanao Island, with an elevation of approximately 809.4 meters or 2,654.8 feet above sea level. This municipality comprises 11 barangays, namely: Barangay Nueva Vista, formerly Mansawan, Bagong Clarin, Gandawan, Lake Duminagat, Liboron, Napangan, Lalud, Maramara, Petianan, Tuno, and Lampasan.

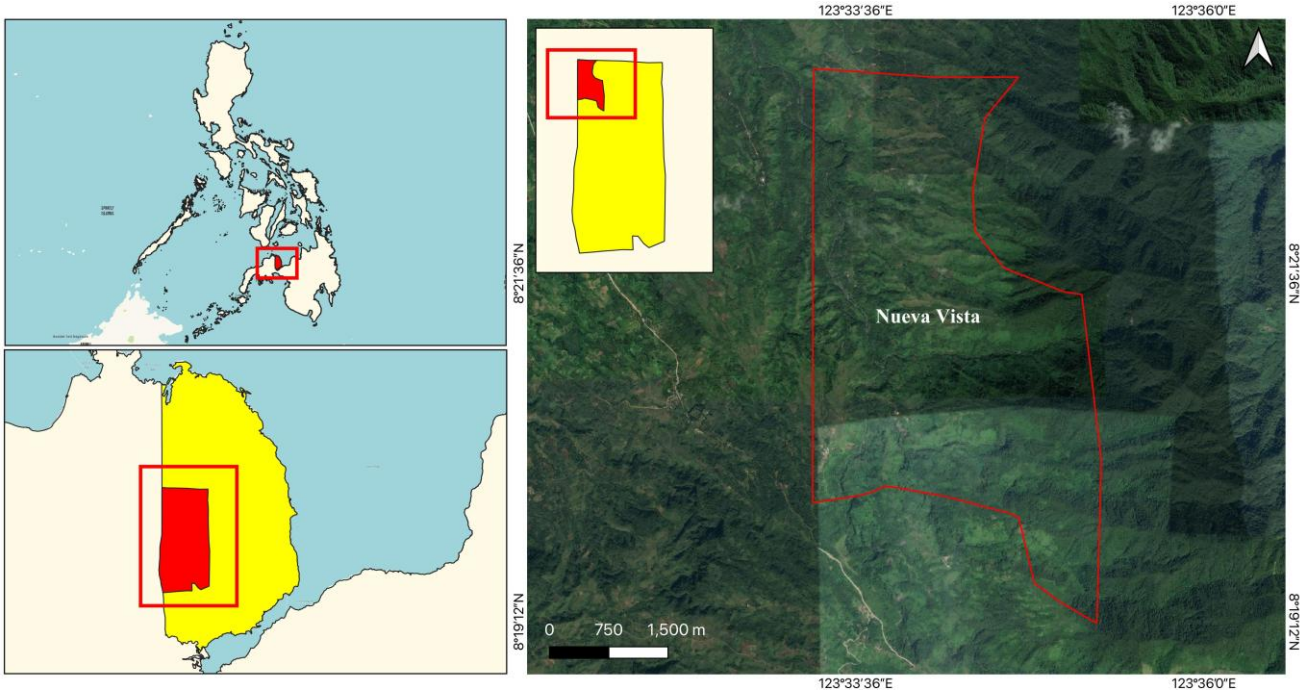

Figure 1. Map of the established study location in Barangay Nueva Vista, Don Victoriano Chiongbian, Misamis Occidental, Philippines

The study area is situated in one of the barangays of the Municipality of Don Victoriano Chiongbian, Misamis Occidental, Philippines, specifically in Barangay Nueva Vista, particularly in Sitio Guillan. Nueva Vista is situated at approximately (8°18'N, 123°35'E), on the island of Mindanao, with an elevation of 1,303.5 m asl (Philatlas 2023). Based on its elevation, the area is classified as lower montane forest, which typically occurs within the altitudinal range of 1,000-1,241 m asl. The study area was subdivided into three sampling sites situated along a continuous elevational gradient within the same vegetation type.

The first sampling site (Figure 2.A), located at a low elevation near the cave's entrance (1042 m asl), was characterized as a montane forest. The area was surrounded by diverse vegetation, including bamboo trees (*Bambusa vulgaris*), fishtail fern (*Nephrolepis biserrata*), *Trilepisium gymnandrum*, spiked pepper (*Piper aduncum*), majestic palm (*Ravenea rivularis*), *Christella parasitica*, and lumba rimba (*Molineria latifolia*). Additionally, abaca plants (*Musa textilis*) were also observed. Bryophytes (mosses) were predominantly present on trees and fallen logs, while numerous fallen leaves were scattered throughout the site.

The second sampling site (Figure 2.B) has an elevation of 1142 m asl. This area is a mixed secondary forest and agroforest. This site has a closed canopy, surrounded by plants and trees; however, the Spiked pepper (*P. aduncum*) dominated this area. Fruit plants were observed, such as cacao tree (*Theobroma cacao*) and langka tree (*Artocarpus heterophyllus*). Different kinds of ferns, such as *C. parasitica*, fishtail fern (*N. biserrata*), tree fern (*Dicksonia antarctica*), and golden chicken fern (*Cibotium barometz*), were also present in the area.

The third sampling site (Figure 2.C) is an open canopy near a vegetable plantation with an elevation of 1241.45 meters or 4073 feet above sea level (m asl). Crops mostly dominate the area: Spring onion (*Allium fistulosum*), cabbage (*Brassica oleracea*), lettuce (*Lactuca sativa*), Chinese pechay (*Brassica rapa*), sayote (*Sechium edule*), and bitter eggplant were present. Fruit plants, such as guava (*Psidium guajava*) and banana (*Musa* spp.), were also observed in the area. Grasses and bushes, as well as some ferns, were found to be present in the area.

Collection of samples

Field sampling was conducted from January 11-16, 2024, and April 9-14, 2024, with a total of 360 net-hours, corresponding to 120 hours per location. Mist netting was systematically conducted at three sampling sites, with each site sampled over four consecutive nights using three mist nets (mesh size: 20 mm; dimensions: 2 m × 10 m) per night to ensure consistent sampling effort across locations. Nets were opened at 1700 h and monitored at 1800 h to 2300 h, and 2400 h to 0500 h to ensure bat safety. Weather conditions, particularly rain and wind, occasionally affected bat activity and capture success (Gorrman et al. 2021). Captured bats were carefully removed and placed in cloth bags, measured for total body length, tail length, ear length, hindfoot length, and forearm length, identified using the Field Guide to Bats of the Philippines (Ingle et al. 1999), verified by an expert, and then released (Lama et al. 2023). Individuals were marked using non-toxic nail polish for recapture identification, a safe and effective Captured-Mark-Release (CMR) method (Ibouroi et al. 2021). Morphometric measurements, including forearm, hind foot, tail, ear, and body length, were taken using a vernier caliper (Del Socorro et al. 2018; Morgan et al. 2019).

Figure 2. Sampling sites included: A. Montane forest near the cave entrance at 1042 m asl with bamboo, ferns, abaca, and abundant bryophytes; B. A Mixed secondary forest/agroforest at 1142 m asl with a closed canopy dominated by *Piper aduncum*, along with cacao, jackfruit, and various ferns; C. Open canopy agricultural area at 1241 m asl near a vegetable plantation, characterized by crops, fruit trees, grasses, and scattered fern

Data analysis

Biodiversity indices used in this study included species richness (number of species and individuals), Shannon-Wiener diversity index (H′), evenness index, and the dominance index. These indices were calculated using Paleontological Statistics (PAST) software (Hammer et al. 2001). Shannon-Wiener index (H′) measures the uncertainty in predicting the species identity of an individual randomly selected from a sample, while evenness quantifies how evenly individuals are distributed among species, reaching a value of one when all species are equally abundant (Gregorius and Gillet 2021). The Dominance index indicates the extent to which a single or a few species dominate the community. Community-environment relationships were further analyzed through Canonical Correspondence Analysis (CCA) (Ter Braak 1987). The endemism and conservation status of bats were assessed based on the International Union for Conservation of Nature (IUCN 2018) criteria.

RESULTS AND DISCUSSION

Species composition, distribution, and conservation status

Seven bat species distributed across three families were documented in three sampling sites in Sitio Guillan, Barangay Mansawan, Don Victoriano Chiongbian, Misamis Occidental, Philippines, with 134 individuals belonging to three families (Pteropodidae, Rhinolophidae, and Hipposideridae). The most commonly observed family was Pteropodidae, comprising five fruit bat species: *Cynopterus brachyotis*, *Haplonycteris fischeri*, *Ptenochirus jagori*, *Ptenochirus minor*, and *Rousettus amplexicaudatus*. Two insectivorous species were recorded: *Hipposideros diadema* from the family Hipposideridae, and *Rhinolophus subrufus* from the family Rhinolophidae. This composition reflects the dominance of frugivorous species in the area, which are known to play key roles in pollination and seed dispersal (Aguiar and Marinho-Filho 2007), while insectivorous species contribute significantly to natural pest control, especially in forest and agroecosystem interfaces (Gong et al. 2025).

Of the seven species documented, three are non-endemic (*C. brachyotis* and *H. diadema, R. amplexicaudatus)*, three are Philippine endemics (*H. fischeri, P. jagori, R. subrufus*), and one is a Mindanao faunal region endemic (*P. minor*). Quibod et al. (2019) have reported that these bat species, being endemic, are recognized for their vulnerability to disruptions such as habitat loss due to deforestation, agricultural expansion, mining activities, and human disturbance in roosting sites, which can significantly impact their populations. According to IUCN (2024), six species are listed as the least concern species, while one species is classified as data deficient (Table 1). The presence of endemic and data-deficient species underlines the conservation value of the study area and highlights the importance of monitoring localized populations in habitats that may be experiencing increasing anthropogenic pressure.

The bat species recorded common across all sampling sites were *C. brachyotis*, along with the Philippine endemic species *P. jagori*, *H. fischeri*, and the Mindanao faunal region species *P. minor*. Lama et al. (2023) suggest that *P. jagori* and *C. brachyotis* are capable of adapting to a broad spectrum of habitats, which allows them to thrive in both forested and non-forested areas, thus explaining their presence across all sampling sites. *Cynopterus brachyotis,* also known as the lesser dog-faced fruit bat, is the most abundant bat species, with 35 individuals recorded with a relative abundance value of 26.12%. This high abundance is likely due to the availability of food resources in the area. Mubarok et al. (2023) identify *C. brachyotis* as a widely distributed and generalist fruit bat species that occupies a range of habitats across Southeast Asia. Its flexibility in foraging and roosting behavior allows it to survive in both disturbed and semi-natural areas, particularly where fruit-bearing plants like figs and bananas are abundant (Corlett 2017). This adaptability allows *C. brachyotis* to thrive in diverse environments, contributing to its widespread presence in all sampling sites. *Ptenochirus jagori*, *H. fischeri,* together with the Mindanao faunal region endemic species, *P. minor,* were found in all sampling sites. According to Monteclaro and Nuneza (2015), *P. jagori* and *P. minor* are known to roost in hollow trees and are known to rely heavily on figs and Musa plant species, which are found in the area, explaining their significant number in the study area.

The greater musky fruit bat, known scientifically as *P. jagori*, was the second most common species in the study, comprising 20.90% of the total with 28 individuals recorded (Table 2). As stated by Juganas et al. (2022), the presence or absence of such species can greatly affect the biodiversity of an area. They may serve as important sources of food for other species and act as indicators of habitat or ecosystem conditions (Gong et al. 2025). Thus, observing *P. jagori* helps determine the state of the habitat and the extent of disturbances experienced in the area. Its presence in disturbed zones further supports its adaptability and resilience to moderate environmental changes. As a widespread and adaptable species, *P. jagori* can also serve as a reliable habitat indicator because its distribution and abundance across varying environments reflect the degree of disturbance (Decena et al. 2023). This indicates that while the species can tolerate moderate ecological changes, significant shifts in its population dynamics, spatial distribution, or behavioral patterns may serve as early warning signs of habitat degradation. Therefore, monitoring this species is essential for assessing habitat quality and understanding the ecosystem's resilience to environmental stressors. Along with *P. minor*, *P. jagori* demonstrates ecological flexibility by thriving in disturbed habitats, particularly those altered by agricultural activities, where they exploit available foraging and roosting opportunities despite reduced habitat quality (Bacordo et al. 2019).

The Mindanao-endemic species, *P. minor*, was also found in all sampling sites, comprising 21 individuals with a relative abundance of 15.67% (Table 2). In a study by Aribal et al. (2016), *P. minor* frequently visited four *Ficus*

species, including *F. crassiramea, F. callosa, F. forstenii,* and *F. variegata*, demonstrating a strong preference for figs. Such a preference is ecologically significant, as the regular consumption of *Ficus* fruits enables *P. minor* to play an important role in pollination and seed dispersal. In turn, this interaction contributes to forest regeneration and the maintenance of ecosystem stability, highlighting the species' ecological importance within its natural habitat. According to Monteclaro and Nuneza (2015), this bat inhabits hollow trees. It prefers Musa plant species, as evidenced by the presence of *M. textilis* (abaca plant) at site 1, which aligns with observations in the area. The population growth of certain fruit bat species may rely on food availability, with bats potentially serving as pollinators for specific plant species (Bacordo et al. 2019). Therefore, preserving the food resources and the habitat is essential for maintaining existing bat populations, particularly endemic ones.

Rousettus amplexicaudatus, also known as the common roussette, is an old-world fruit bat species recognized for its excellent visual abilities, which are crucial for its foraging activities, as noted by Aziz et al. (2021). Relox et al. (2014) reported that the presence of non-endemic fruit bats like *R. amplexicaudatus* in small, disturbed forest patches reflects degradation and conversion of once-forested areas into agricultural landscapes. Unlike other fruit bats, *R. amplexicaudatus* is reported to be more adaptive to certain biogeographic barriers (Jahari et al. 2020). The species' wide-range dispersion and adaptation are supported by their adaptability to mesic and dry habitats, long-distance dispersal capabilities, and exceptionally accurate linguistic echolocation (Stribna et al. 2019; Hassanin et al. 2020).

This suggests that the environmental conditions and resource availability in site 3 were more favorable, allowing the species to exploit the habitat more effectively, whereas site 1 may have offered fewer foraging opportunities or less suitable roosting conditions. Its presence may serve as an indicator of habitat disturbance or conversion, suggesting a shift in bat community composition toward generalist species in degraded landscapes (Phelps et al. 2018). Although there is limited direct evidence from recent studies regarding its absence in true montane or mossy forests, recent surveys across elevational gradients indicate that generalist fruit bat species tend not to occupy high-elevation forest zones (Deligero et al. 2016). This distribution pattern is likely influenced by reduced fruit availability, colder climatic conditions, and the competitive advantage of specialist species at higher elevations, which collectively limit the ability of generalist bats to establish in montane habitats.

Rhinolophus subrufus accounted for 6.72% of total captures, with eight individuals recorded in Site 1, a single individual in Site 2, and a complete absence in Site 3. This distribution suggests that *R. subrufus* has a strong association with cave habitats (Labadie et al. 2025), as Site 1 contains a known roosting cave that provides the microclimatic conditions necessary for insectivorous bats. Its scarcity in Sites 2 and 3 may be attributed to reduced roost availability, limited insect prey, or greater habitat disturbance in those areas. Furthermore, the species' reliance on specialized echolocation for aerial insect capture may make it less susceptible to mist-net detection, which tends to favor frugivores flying along flight corridors (Estrada-Villegas et al. 2010).

Table 1. Bats species recorded in the cave of Sitio Guillan, Barangay Mansawan, Don Victoriano Chiongbian, Misamis Occidental, Philippines and their common name, local name, distribution, and conservation status

Family	Species	Common name	Local name	Distribution	Conservation status (IUCN 2024)
Pteropodidae	*Cynopterus brachyotis*	Lesser dog-faced fruit bat	Kwaknit	Non-endemic	Least concern
Pteropodidae	*Rousettus amplexicaudatus*	Common roussette	Kwaknit	Non-endemic	Least concern
Pteropodidae	*Haplonycteris fischeri*	Pgymy fruit bat	Kwaknit	Philippine-endemic	Least concern
Pteropodidae	*Ptenochirus minor*	Lesser musky fruit bat	Kwaknit	Mindanao-endemic	Least concern
Pteropodidae	*Ptenochirus jagori*	Greater musky fruit bat	Kwaknit	Philippine-endemic	Least concern
Rhinolophidae	*Rhinolophus subrufus*	Small rufous horshoe bat	Kwaknit	Philippine-endemic	Data deficient
Hipposideridae	*Hipposideros diadema*	Diadem leaf-nosed bat	Kwaknit	Non-endemic	Least concern

Table 2. Relative abundance of bat species in each sampling site of Sitio Guillan, Barangay Mansawan, Don Victoriano Chiongbian, Misamis Occidental, Philippines

Species	Site 1	Site 2	Site 3	Total
Cynopterus brachyotis	12 (23.53%)	13 (33.33%)	10 (22.73%)	35 (26.12%)
Rousettus amplexicaudatus	0	3 (7.69%)	7 (15.91%)	10 (7.46%)
Haplonycteris fischeri	3 (5.88%)	4 (10.26%)	5 (11.36%)	12 (8.96%)
Ptenochirus minor	4 (7.84%)	8 (20.51%)	9 (20.45%)	21 (15.67%)
Ptenochirus jagori	5 (9.80%)	10 (25.64%)	13 (29.55%)	28 (20.90%)
Rhinolophus subrufus	8 (15.69%)	1 (2.56%)	0	9 (6.72%)
Hipposideros diadema	19 (37.25%)	0	0	19 (14.18%)
Total no. of individuals	51 (38.06%)	39 (29.10%)	44 (33.83%)	134 (100%)

In contrast, frugivorous species such as *C. brachyotis*, *P. jagori*, and *P. minor* were consistently recorded across all three sites, reflecting their generalist feeding habits and adaptability to disturbed habitats where fruiting trees remain accessible. This highlights a clear ecological distinction: while generalist fruit bats thrive in a variety of habitats, including modified landscapes, *R. subrufus* appears more sensitive to habitat alterations and depends on the preservation of cave systems and intact foraging environments (Meyer et al. 2015). Such differences emphasize the importance of conserving diverse habitat types to protect both adaptable and habitat-restricted bat species.

In this study, fruit bats were found to be more numerous than insect bats, likely due to the fruit bats' ability to thrive in a wide range of habitats (Jose et al. 2021). Of the seven species observed, two were insectivorous bats: *Rhinolophus subrufus* and *H. diadema*. *H. diadema*, known as the diadem leaf-nosed bat and part of the Hipposideridae family, had the highest number of individuals captured in site 1, likely due to the presence of a cave. Similarly, Perez and Nuneza (2020) also reported the presence of *H. diadema* in Agusan Del Sur, finding it to be the most abundant bat species across the three caves studied. According to Domingo and Buenavista (2018), the cave is home to some species of cave-roosting bats, which are currently being hunted by locals for food. This observation supports the idea that caves and diverse vegetation are crucial in sustaining the diversity of insect bat populations.

The findings highlight the different ecological roles of the recorded bat species. Frugivorous bats such as *C. brachyotis*, *P. jagori*, and *P. minor* contribute to pollination and seed dispersal, supporting forest regeneration and plant diversity. In contrast, insectivorous species like *H. diadema* and *R. subrufus* play a vital role in controlling insect populations. These ecological functions are closely linked to the habitat types the bats occupy. Fruit bats were commonly found in both forested and disturbed areas with abundant fruit-bearing plants, while insectivorous bats were often associated with cave systems and dense vegetation (Cajaiba et al. 2020; Duco et al. 2023). The presence of both endemic and data-deficient species further underlines the conservation importance of Sitio Guillan. Maintaining habitat quality, protecting food resources, and reducing human disturbance are essential to preserving these valuable bat populations and their ecosystem services.

The species accumulation approached an asymptote after approximately twelve sampling days, indicating that the sampling effort was sufficient to document the majority of bat species in the area, with seven species recorded and minimal undetected diversity (Gotelli and Colwell 2001; Duco et al. 2023; Lama et al. 2023). Among the three sampling sites, site 1 observed the highest number of species diversity with a value of (H': 1.642) and the highest species dominance of (0.2227) since site 1 is located near the cave's entrance, where the abundance of montane forest and various vegetation was observed (Table 3). As stated by Medellin et al. (2017), caves play key biodiversity roles and provide important ecosystem functions. This suggests that the presence of abundant and diverse vegetation in the vicinity of the cave's entrance creates an ideal habitat for insect-eating bats, attracting a wide range of prey species. Consequently, this environment fosters a greater diversity of bat species. Despite having a diverse range of species, caves are also facing problems from both natural and human activities and disturbances (Furey and Racey 2016); this action poses comparable dangers to cave-dwelling bats, as they may be compelled to leave their caves and struggle to locate alternative habitats (Sedlock and Ingle 2010). The bat assemblage was dominated by frugivorous species such as *C. brachyotis*, *P. jagori*, and *P. minor*, while insectivorous bats were rarely encountered due to mist-netting limitations, emphasizing both the effectiveness of the sampling design and the ecological importance of these taxa (Rickart et al. 2011; Fidelino et al. 2020).

Meanwhile, observed sampling site 3 had the lowest species diversity of (H': 0.9557) and high dominance of (0.4286) due to its high elevation; the site has an open canopy where vegetable plantation and crops are mostly dominant. This discovery corresponds with McCain's (2007) meta-analysis, which determined that in consistently moist mountainous areas, there is a decrease in bat abundance and variety at greater elevations, and this change could be dangerous for bats, as they are sensitive to shifts in their environment (Voigt and Kingston 2016). The evenness of the three sampling sites, especially sites 1 and 2, showed close evenness values of 0.8607 and 0.8498, respectively, while sampling site 3 had a species evenness value of 0.9972. Results indicate that the species distribution in sampling sites 1 and 2 is relatively balanced, with similar abundances across different species, while sampling site 3 exhibits a slightly higher evenness value.

Similarity index of bat species

Figure 3 illustrates the differences in bat species composition across the sampling sites. Site 1 stands out as distinct, indicating the presence of unique bat species not found in Sites 2 and 3. Meanwhile, the illustration suggests a similarity between Sites 2 and 3 in terms of their bat species composition. Site 1, situated near a cave and surrounded by diverse vegetation, stands out for having all seven observed species and achieving the highest species diversity, with a count of 51 individual bats. Bat caves, recognized as unique roosting habitats hosting thousands of bats of various species (Labadie et al. 2025), play a crucial role in supporting the maintenance and survival of many bat species (Tanalgo and Tabora 2015). The significance of caves for bat populations is emphasized by Tanalgo and Tabora (2015), who highlight that in Southeast Asia, caves are highlighted as vital habitats for bats; however, due to various factors such as habitat destruction, disturbance, or other environmental changes, caves and other underground habitats are deemed threatened environments for bats.

This observation aligns with the understanding that caves and varied vegetation play a pivotal role in supporting the richness of bat populations (Labadie et al. 2025). Figure 3 effectively captures the ecological nuances and biodiversity patterns, offering valuable insights into the species distribution among the sampling sites.

Table 3. Biodiversity indices of bat species in each sampling site of Sitio Guillan, Barangay Mansawan, Don Victoriano Chiongbian, Misamis Occidental, Philippines

Biodiversity indices	Site 1	Site 2	Site 3
Species	7	6	4
Number of individuals	51	39	44
Shannon-Weiner (H')	1.642	1.629	0.1607
Evenness (EH')	0.8608	0.8498	0.9972
Dominance	0.2227	0.2159	0.2008

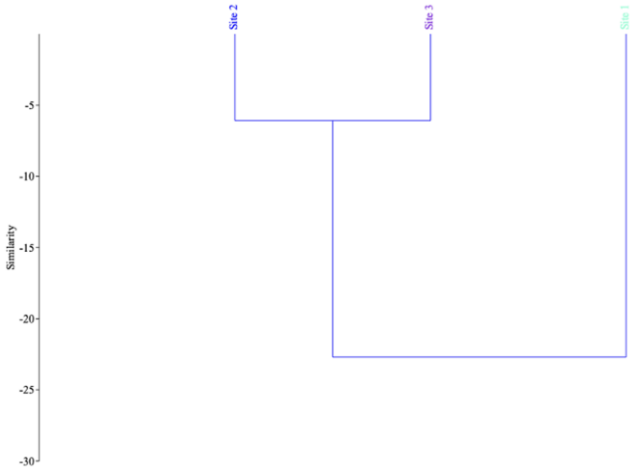

Figure 3. The figure shows clear differences in bat species composition across the three sites. Site 1, located near a cave and surrounded by diverse vegetation, is the most distinct, supporting a greater variety of species. In contrast, Site 2, near mixed agricultural areas, and Site 3, in an elevated area dominated by vegetable plantations, appear more similar to each other with fewer species overall

Canonical Correspondence Analysis (CCA)

Figure 4 illustrates the influence of environmental variables such as air temperature, elevation, and relative humidity on the distribution and abundance of bat species across various sampling sites, using Canonical Correspondence Analysis (CCA). The results indicate that seven (7) bat species, specifically, *C. brachyotis, R. amplexicaudatus, H. fischeri, P. minor, P. jagori, H. diadema,* and *R. subrufus,* are associated with tree-related environmental parameters like relative humidity, air temperature, and elevation. Specifically, *H. diadema* and *R. subrufus* are closely aligned with air temperature, suggesting these species are more abundant in warmer areas with temperatures ranging from 20-23°C, typically at lower elevation, as seen near site 1. Meanwhile, *R. amplexicaudatus* and *C. brachyotis* show associations with higher elevation and relative humidity and are found closer to site 2 and site 3, which represent slightly cooler and more humid environments with temperatures between 18-20°C. *Ptenochirus minor, H. fischeri,* and *P. jagori* are clustered near the center of the plot, positioned between site 2 and site 3, indicating they are less influenced by extreme values of air temperature, elevation, or humidity and may tolerate a range of environmental conditions, occurring across multiple sites. Similar findings were also reported by Relox and Florence (2018) in Mt. Kitanglad, where fruit bats showed positive associations with temperature but negative correlations with elevation and humidity, and by Lama et al. (2023), who documented shifts in bat community composition across elevation in Mt. Tuminungan. Comparable elevational and climatic influences on bat assemblages have also been observed outside the Philippines, such as in Mt. Kilimanjaro, Tanzania (Vogeler et al. 2021).

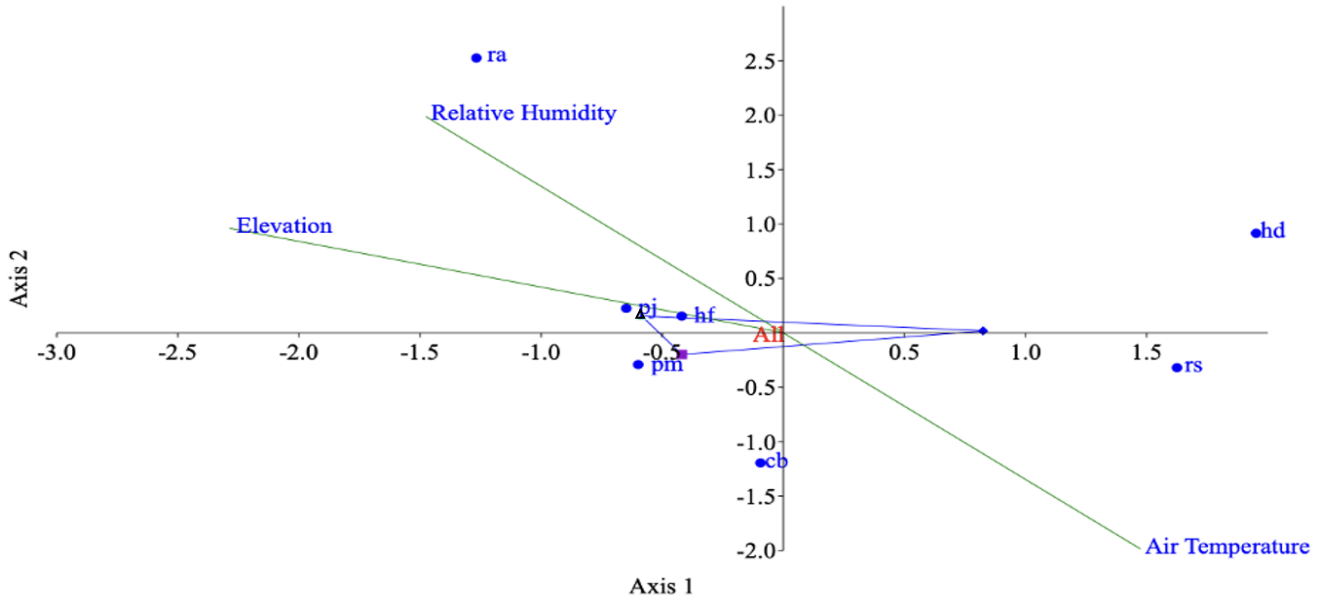

Figure 4. Canonical Correspondence Analysis (CCA) of environmental variables related to the bat species in 3 sampling sites of Sitio Guillan, Barangay Mansawan (Nueva Vista), Don Victoriano Misamis Occidental, Philippines. The variables used in this analysis are air temperature, relative humidity, and elevation. P.m: *Ptenochirus minor*, hd: *Hipposideros diadema,* rs: *Rhinolophus subrufus*, hf: *Haplonycteris fischeri,* pj: *Ptenochirus jagori*, cb: *Cynopterus brachyotis,* ra: *Rousettus amplexicaudatus*, ◆: Site 1, ■: Site 2, △: Site 3

This study documented seven bat species totaling 134 individuals, with Pteropodidae being the most common family observed. Site 1 exhibited the highest diversity (H': 1.642) and high dominance (0.2227) due to its proximity to a cave and montane forest, while Site 3 had the lowest diversity (H': 1.607) and low dominance (0.2008) in an elevated area dominated by vegetable plantations. Species included non-endemic (*C. brachyotis*, *H. diadema, R. amplexicaudatus),* Philippine endemic (*H. fischeri, P. jagori, R. subrufus*), and Mindanao-endemic bats (*P. minor*). Comparable patterns have been reported in other studies conducted in habitats with similar conditions.

For instance, Relox and Florence (2018) in Mt. Kitanglad documented higher bat diversity near forest-cave ecotones compared to cultivated upland areas, highlighting the importance of intact forest and roosting habitats in sustaining bat assemblages. Likewise, Lama et al. (2024) in Mt. Tuminungan observed reduced bat diversity and abundance in higher elevation zones dominated by agricultural landscapes, mirroring the low diversity recorded in Site 3 of the present study. Outside the Philippines, studies in montane ecosystems such as Mt. Kilimanjaro in Tanzania (Böhning-Gaese et al. 2021) and the Central Amazon (Willig et al. 2019) also revealed that bat richness declines in disturbed or agriculturally dominated sites compared to forested areas. These comparisons reinforce that cave proximity, forest cover, and elevation are key determinants of bat diversity across tropical landscapes. Forest conversion for agricultural purposes and other anthropogenic activities has been observed in the area. These activities can destroy habitats and threaten the diversity of bats. Since the cave where bats thrive is located at Site 1, there is a possibility it may be developed as a tourist attraction in the future, especially given that some areas of Mt. Malindang are already popular tourist spots. Therefore, conservation efforts should prioritize protecting biodiversity and addressing habitat loss, with particular focus on preserving caves and maintaining diverse vegetation. The study, however, may be affected by sampling bias, particularly in the capture of insectivorous bats, which are often underrepresented when using mist nets. To address this, future research should incorporate complementary methods, such as acoustic monitoring and extended sampling periods, to provide a more accurate assessment of bat diversity and ecological dynamics.

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