

Research Article

An Inventory of Bats (Chiroptera) in Mount Musuan, Maramag, Bukidnon, Philippines Conducted Between 2013 and 2023

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ABSTRACT

Bats play a crucial role in the ecosystem. However, their richness and abundance is declining, especially in tropical countries like the Philippines. This study was conducted to monitor and compare the species richness, abundance and status of bats in Mount Musuan, Maramag Bukidnon over 3 sampling periods between 2013 and 2023. Three sampling sites were established in the study area. Only the mist netting strategy was applied to capture bats, which were identified through morphometric measurements and field guide. The IUCN Red List was referred to determine the conservation statuses of the recorded bats. A total of 11 species belonging to 4 families were recorded: Megadermatidae, Pteropodidae, Rhinolophidae and Vespertilionidae. The highest number of individuals captured were *Ptenochirus jagori* (186), *Cynopterus brachyotis* (113) and *Miniopterus schreibersi* (53). Of the bats collected, 82% (9) were classified as Least Concern, 9% (1) as Endangered and 9% (1) as Near Threatened. Out of 11 species, 7 (64%) species were Philippine endemic species. This study contributes important information to the existing knowledge of bats in the region, highlighting their abundance and significance in local wildlife. The results can be used to inform conservation strategies of these species.

Keywords: Bats; endemism; Mindanao; Mount Musuan; monitoring.

INTRODUCTION

The Philippines is home to a rich variety of unique flora and fauna, with many species endemic to the archipelago (Cabras et al., 2017). Among these diverse fauna groups are bats. Bat diversity and richness in the Philippines has been well-documented and studied (Tanalgo and Hughes, 2018). Heaney et al. (2010) conducted comprehensive surveys of bat species in Luzon, identifying over 70 species, including several endemics, such as the Philippine pygmy fruit bat (*Haplonycteris fischeri*) and the endangered giant golden-crowned flying fox (*Acerodon jubatus*). Mildenstein et al. (2005) explored the habitat preferences of flying foxes in Subic Bay and found that these bats heavily rely on primary and secondary forest habitats for roosting and feeding, highlighting the impact of deforestation on their populations. Insectivorous species, such as those documented by Wiles et al. (2011), have been found to play a crucial role in controlling agricultural pests, yet the broader implications of this ecosystem service remain underexplored. However, some remote areas in the Philippines particularly in Southern Mindanao have yet to be explored and studied in detail (Tanalgo and Hughes, 2018).

Bats are essential to the ecosystem because they perform critical ecological functions such as insect pest control, pollination, and seed dispersal (Costa et al., 2018). Species of fruit bats, particularly those in the genus *Pteropus*, help pollinate native plants and crops such as durian (*Durio zibethinus*), bananas (*Musa* spp.) and the kapok tree (*Ceiba pentandra*) (Heaney et al., 2010). Many tropical fruits, including economically valuable crops, rely on bat pollination. These functions are vital for maintaining and restoring forests and promoting the growth of fruit trees that rely on bats. Additionally, bats act as bioindicators for ecosystem health, providing insights into environmental quality (Stahlschmidt and Bruhl, 2012). Because bats are sensitive to changes in habitat quality, pollution levels, and climate conditions, they are often among the first species to show signs of ecological stress (Heaney et al., 2010), particularly the Philippine cave-dwelling bat species like *Eonycteris robusta* that are vulnerable to habitat disturbances.

The major threats to bat populations in the Philippines include habitat loss and fragmentation, agricultural land conversion, hunting, cave exploitation, extractive industries, climate change, and logging (Tanalgo and Hughes, 2019). These threats have led to significant declines in bat populations, particularly for species that depend on intact forest habitats (Voigt and Kingston, 2016).

Mount Musuan, also known as Mount Kalayo, is a stratovolcano located in the province of Bukidnon on the island of Mindanao in the Philippines. With an elevation of 646 meters above sea level, this majestic mountain offers stunning views of the surrounding landscape, along with a unique blend of cultural and natural attractions. The mountain is renowned for its diverse flora and fauna, and provides a suitable habitat for various species of bats. It has also been identified as one of the Long-Term Ecological Research (LTER) sites in the Philippines. Due to its accessibility, Mount Musuan is a popular tourist destination, especially during Holy week. However, reports of small-scale logging in the lowlands raises concern about the potential impact on the richness and abundance of bat species. The bat population in Musuan, Bukidnon has been extensively studied and documented by Mohagan et al., (2009) and Mohagan and Baguhin (2011). However, no additional data on bats has been published since 2011. Their work highlighted significant differences in bat species richness between intact forest habitats and areas disturbed by human activities, underscoring the detrimental effects of deforestation and land conversion.

While these studies provided critical insights into bat diversity and the impacts of habitat degradation, the studies were conducted over a decade ago, during a time when the rate of deforestation and urban expansion in the Philippines was accelerating but not at its current pace. Since then, increased agricultural intensification, and climate shifts have likely affected bat populations in ways that were not fully captured by these earlier studies. This study which conducted over three samplings between 2013 and 2023, provides a comprehensive assessment of bat species present in Mount Musuan, a critical biodiversity site. The long-term nature of this study is essential for understanding the population trends of bats in response to ongoing environmental changes such as deforestation, agricultural expansion and climate change. Long term monitoring is necessary to detect gradual shifts in species richness and abundance that may not be apparent in shorter studies. The study hypothesises that bat species richness and abundance have decreased between 2013 and 2023, likely due to habitat loss, human disturbance, and climate-related changes.

MATERIALS AND METHODS

Sampling area

The study was conducted in Mount Musuan (7.87699°N , $125.06966^{\circ}\text{E}$), Maramag Bukidnon (Fig. 1). The site features a wet forest environment with ferns-dominated ground cover, and the soil is of mixed muddy and loamy textures. Sampling took place in 2013, 2015 and 2023. The significant gap between 2015 to 2023 was due to restrictions, particularly during the Covid-19 pandemic. In addition, these years were chosen to capture potential medium- and long-term changes in bat populations while accounting for logistical constraints. Specifically, 2013 and 2015 were selected as initial and intermediate assessment points to establish early trends, while the final sampling in 2023 aimed to capture the cumulative effects of environmental changes over the decade. Three sampling locations were selected: the base (forested area), middle (grassland) and peak (mixed grassland and pine tree plantation).

Sampling was done from March to November to collect data in the dry and wet seasons. The area experiences temperatures ranging from $27\text{--}29^{\circ}\text{C}$ with relative humidity of 80–100%. Mount Musuan experiences an average annual rainfall of approximately 2,500 mm, with the dry season from March to May and the wet season from June to November. The wet season typically brings typhoons and heavy rainfall, which can lead to temporary reductions in bat foraging activity due to adverse weather conditions. Conversely, the dry season offers more favourable weather, making it an ideal time for sampling.



Figure 1: Study site map. A) Philippines and Mindanao Island, Mount Musuan (red spot). B) Mount Musuan, Maramag, Bukidnon (©2023 Google, image).

Collection and identification of bats

Bats were collected using mist nets set at different levels: 0-5 meters for ground nets, 5-10 meters for subcanopy and above 10 meters for canopy nets. Bats were collected during both the dry and wet seasons. Captured bats were placed in a cloth bags and their morphometric measurements were recorded including head length, ear length, tail length, forearm length, tarsus length, and total body length. The bats were identified using the taxonomic guides by Ingle and Heaney (1992) and Ingle et al., (1999). Voucher specimens were collected and deposited at the Central Mindanao University Museum. Bats released were marked by clipping fur on the head following the standard protocol by Gannon et al, (2009). Bats were

photographed by handling them within the shortest time possible as prolonged handling can induce stress, affecting their health and behaviour (Murray et al., 2016). They were also fed sugar syrup before release to help them regain energy and reduce stress.

The conservation statuses and distribution ranges of the identified bats were recorded following the IUCN Red List of Threatened Species (IUCN, 2023). This list was referenced to provide up-to-date information on the global conservation statuses of the species, including classifications such as Least Concern, Vulnerable, Endangered, and Critically Endangered. However, no formal IUCN assessment was conducted as part of this study. Instead, the IUCN Red List served as a reference point for reporting the conservation statuses of the species encountered during the sampling period.

RESULTS AND DISCUSSION

Species richness and abundance of bats

During the ten-year monitoring period from 2013 to 2023, a total of 11 bat species were recorded in Mount Musuan. These species belong to 4 families, with the majority from Pteropodidae (8), followed by Megadermatidae (1), Vespertilionidae (1) and Rhinolopidae (1) (Table 1). The 11 species collected during the sampling in Mount Musuan are *Megaderma spasma*, *Cynopterus brachyotis*, *Haplonycteris fischeri*, *Macroglossus minimus*, *Ptenochirus jagori*, *Ptenochirus minor*, *Acerodon jubatus*, *Miniopterus schreibersii*, *Eonycteris robusta*, *Eonycteris spelaea* and *Rhinolophus subrufus* (Fig. 2).

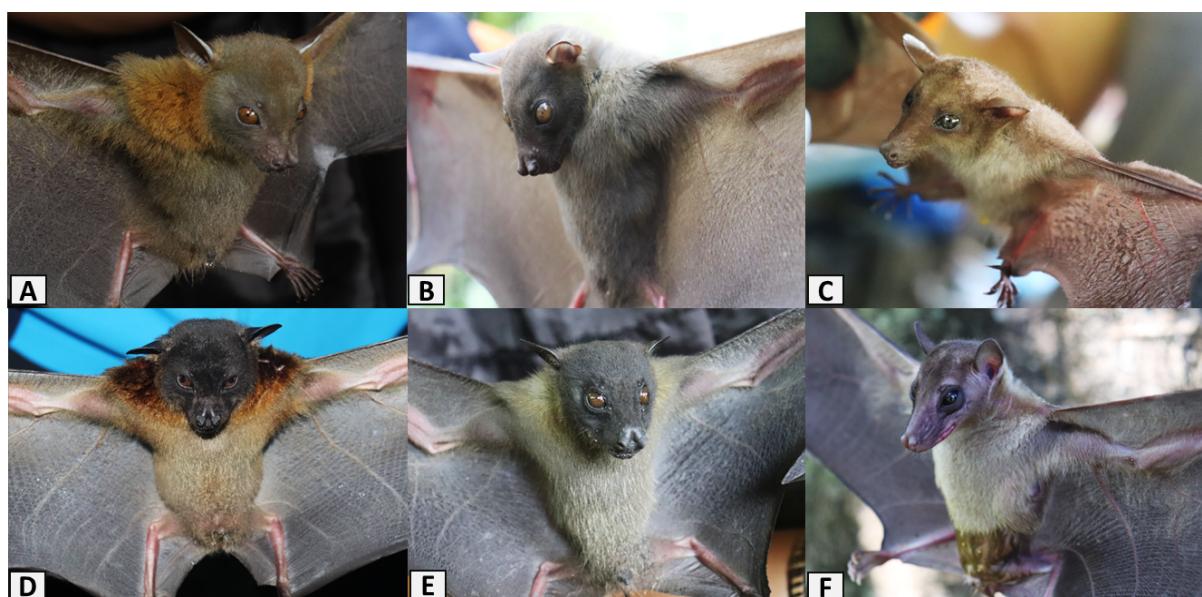


Figure 2: Bats species collected in Mount Musuan (a) *Cynopterus brachyotis* (b) *Macroglossus minimus* (c) *Haplonycteris fischeri* (d) *Ptenochirus jagori* (e) *Ptenochirus minor* and (f) *Eonycteris spelaea*.

In 2013, only 5 bat species were collected, with *Ptenochirus jagori* having the highest number of individuals (186) followed by *Cynopterus brachyotis* (98) (Table 1). A decline in species was observed in 2015 with only 4 species recorded. Additionally, the number of individuals also decreased with *Cynopterus brachyotis* being the most abundant (113 individuals) followed by *Ptenochirus jagori* (42). The most recent study, conducted in 2023, recorded 10 bat species,

but it also showed a decline in the number of individuals for species collected in previous years. *Miniopterus schreibersi* had the highest number of individuals (53) followed by *Cynopterus brachyotis* (48). These results align with findings from previous studies conducted in other parts of Mindanao and across the Philippines, which have also reported *Ptenochirus jagori* and *Cynopterus brachyotis* as common fruit bats in disturbed or secondary habitats. For instance, Achondo et al. (2014) recorded *Cynopterus brachyotis* as the dominant species in Mount Apo, while Salmoy et al. (2017) found *Ptenochirus jagori* to be highly abundant in Mount Hilong-hilong, which may suggest these species are particularly resilient to habitat disturbances in both lowland and montane forest areas.

This study recorded higher number of bat species per unit area compared to the previous studies. In comparison to the study by Achondo et al., (2014), which reported only 8 bat species collected in portions of Mount Apo Natural Park with an elevation of 2,954 meters and an area of approximately 54,000 hectares, and Kidapawan Cotabato City Ecotourism Park. Salmoy et al., (2017) collected 11 species in the mossy forest of Mount Hilong-hilong, (elevation of 2,367 meters and 24,500 hectares) located in Agusan del Sur. Additionally, Amoroso et al., (2019) collected 10 species in Mount Hamguitan (elevation: 1,620 meters, area: 1,942 hectares), and Relox et al., (2017) collected 9 species in Mount Kitanglad (elevation: 2,899 meters, area: 30,000 hectares). However, it is important to note that Mount Musuan with an elevation of 646 meters and a smaller area of approximately 1,600 hectares, exhibits lower elevations and size relative to the other study areas. As cited by Relox et al., (2017) the forest area is positively correlated with the species abundance and richness, as well as the diversity of endemic foliage inhabitants. Furthermore, the quality of the area, vegetation and the size of forest fragments are important factors in the distribution and abundance of bats (Relox et al., 2017). Despite its smaller surveyed area, the relatively high species richness observed in Mount Musuan suggests this habitat still supports diverse bat populations, likely due to the availability of food resources and suitable roosting sites.

According to Mildenstein et al., (2005), a decline in bat populations can indicate habitat destruction, particularly deforestation, and the degradation of cave ecosystems where many bats roost. Monitoring bat populations in agricultural landscapes can also provide insights into the impact of pesticide use and landscape changes on biodiversity (Lunney and Mathews, 2005). Conversely, thriving bat populations can indicate healthy ecosystems with abundant food sources, suitable roosting sites, and balanced predator-prey relationships (Heaney et al., 2010). The restoration of bat populations in areas where they had declined can often coincide with the recovery of overall biodiversity, as bats help rebuild plant communities through seed dispersal and pollination (Mildenstein et al., 2005).

Table 1: Bat species collected in Mount Musuan from 2013–2023

Classification	Species	Common Name	2013	2015	2023
			Number of Individuals		
Chiroptera					
Megadermatidae	1. <i>Megaderma spasma</i>	Lesser false vampire bat			1
Pteropodidae	2. <i>Acerodon jubatus</i>	Giant golden-crowned flying fox			2
	3. <i>Cynopterus brachyotis</i>	Common Short-eared-nosed Fruit Bat	98	113	48
	4. <i>Eonycteris robusta</i>	Philippine Dawn bat	2	3	
	5. <i>Eonycteris spelaea</i>	Lesser Dawn Bat	1		1
	6. <i>Haplonycteris fischeri</i>	Philippine Pygmy Fruit Bat			3
	7. <i>Macroglossus minimus</i>	Dagger-toothed Long-nose Fruit Bat	7	2	5
	8. <i>Ptenochirus jagori</i>	Greater Musky Fruit Bat	186	42	36
	9. <i>Ptenochirus minor</i>	Lesser Musky Fruit Bat			17
Vespertilionidae	10. <i>Miniopterus schreibersii</i>	Schreiber's Bent wing Bat			53
Rhinolophidae	11. <i>Rhinolophus subrufus</i>	Philippine horseshoe Bat			3

Statuses of bats

According to the IUCN Red List (2024), 9 species (82%) are classified as Least Concern, 1 species (9%) as Near Threatened and 1 species (9%) as Endangered (Table 2). Seven (64%) of the bat species are endemic to the Philippines, while 4 (36%) are more widely distributed (IUCN, 2024). In comparison, the study by Nuñez et al. (2015) recorded a total of 7 endemic species. Achondo et al. (2014) and Escarlos et al. (2019) both recorded 3 endemic species while Salmoy et al., (2017) recorded 4 endemic species. Large forest patches serve as habitats of more endemic species of fruit bats which exhibit strong site fidelity (Relox et al., 2017). Endemic species are particularly important for Philippine biodiversity conservation because they have adapted to specific ecological niches and contribute uniquely to their ecosystems (Mackie and Smith, 2016). Furthermore, as anthropogenic disturbances increase, endemic species may decline while non-endemic species may increase. This is consistent with the findings of Amoroso et al. (2019), who reported that endemism is affected by human activities such as hunting, logging, shifting cultivation and mining. In addition, many endemic bats rely on specific types of vegetation for foraging and roosting, making them less able to adapt to changing environmental conditions (Achondo et al., 2014).

A recent study showed that most of the bats collected were dominated by non-endemic and widespread species *Cynopterus brachyotis*. This may suggest that *C. brachyotis* can tolerate slightly disturbed areas, such as Mount Musuan. However, it was also observed that most endemic species were found in the more forested areas of Mount Musuan. These findings are consistent with the studies of Amoroso et al. (2019) and Salmoy et al. (2017). According to Relox et al. (2017), fragmented habitats support a diverse range of fruit bats including species that are highly tolerant of anthropogenic disturbances, unlike large, continuous forest, which harbour more endemic species that are sensitive to such disturbances.

Table 2: Conservation and Ecological Status of Bats in Mount Musuan, Maramag, Bukidnon.

Classification	Species	Conservation Status	Ecological Status
Chiroptera			
Megadermatidae	1. <i>Megaderma spasma</i>	LC	Widespread
Pteropodidae	2. <i>Acerodon jubatus</i>	EN	PE
	3. <i>Cynopterus brachyotis</i>	LC	Widespread
	4. <i>Eonycteris robusta</i>	NT	PE
	5. <i>Eonycteris spelaea</i>	LC	PE
	6. <i>Haplonycteris fischeri</i>	LC	PE
	7. <i>Macroglossus minimus</i>	LC	Widespread
	8. <i>Ptenochirus jagori</i>	LC	PE
	9. <i>Ptenochirus minor</i>	LC	PE
Vesperilionidae	10. <i>Miniopterus schreibersi</i>	LC	Widespread
Rhinolophidae	11. <i>Rhinolophus subrufus</i>	LC	PE

Legend: PE-Philippine Endemic, LC-Least Concern, NT- Near Threatened, EN-endangered

CONCLUSION

The study revealed that Mount Musuan is home to 11 species of bats, of which 9 (82%) are Least Concern, 1 (9%) Endangered and 1 (9%) Near Threatened. Additionally, 7 (64%) species are Philippine endemic species. The increasing number of bats species suggests that suitable food sources and habitats are still present in Mount Musuan. However, anthropogenic disturbances are contributing to the decline in species abundance. While this study provides valuable insights, it is important to acknowledge its limitations, including the uneven dataset across the three sampling years and potential biases in sampling methods that may affect the interpretation of bat populations. This study recommends conducting a diversity analysis and employing additional collection methods such as harp traps, to enhance bat sampling. Furthermore, the use of bioacoustics in monitoring studies is highly recommended. In addition, future research should focus on investigating the habitat preferences of endemic bat species in Mount Musuan and assessing the impact of specific anthropogenic activities, such as agricultural expansion and urban development, on bat populations. Longitudinal studies could provide a clearer understanding of these dynamics and inform conservation management practices.

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