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Bat diversity and its distribution in Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines

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Abstract. *Lama JMN, Caballero EB, Mondejar EP. 2023. Bat diversity and its distribution in Mount Gutom Protected Landscape, Zamboanga del Norte, Philippines. Biodiversitas 24: 5495-5502.* Bats play an indispensable role in the balance of the ecosystem in their habitats, which range from the seaside to mountains, caves, and rivers. This study surveyed the flying mammals of Mt. Gutom Protected Landscape, Zamboanga del Norte, Philippines, on April 12-23 and December 7-20, 2022. Mist netting was used to sample bats at the four sampling sites, with a total sampling effort of 126 net-nights. A total of eight species (n=330 individuals) representing two families was recorded. This includes Lesser Dog-faced fruit bat (*Cynopterus brachyotis*), Philippine Dawn bat (*Eonycteris robusta*), Philippine Pygmy fruit bat (*Haplonycteris fischeri*), Harpy fruit bat (*Harpyionycteris whiteheadi*), Dagger-toothed long-nosed fruit bat (*Macroglossus minimus*), Greater Musky fruit bat (*Ptenochirus jagori*), Lesser Musky fruit bat (*P. minor*), and Horsfield's myotis (*Myotis horsfieldii*). The Lesser Dog-faced fruit bat (*Cynopterus brachyotis*) was the most abundant species in Mt. Gutom, with relative abundance of 40.91% (n=135 individuals). Mt. Gutom also supports endemic species, with 62.5% endemicity, and a Vulnerable species (*Eonycteris robusta*) was documented only in Site 2 (a mixed secondary dipterocarp forest). Moreover, sampling site 3 (secondary dipterocarp forest) recorded the highest abundance (RA=44.24%) and species diversity index (H'=1.376) among the four sampling sites. The results suggest that Mt. Gutom supports a diverse species of bats and conservation measures are needed to protect the remaining habitats in the area.

Keywords: Conservation, diversification, endemic, threatened, Western Mindanao

INTRODUCTION

Bats are one of the most diverse and widely distributed groups of mammals that greatly depend on natural forests (Soliman and Emam 2022). In the Philippines, the bat fauna is very diverse, with 78 species, 53 of which are known in Mindanao (Heaney et al. 2010). A large percentage of Philippine bats occur in forest ecosystems, where 25% of the species are forest-dependent (Heaney et al. 2010). However, illegal logging and kaingin (slash and burn) are among the most common anthropogenic activities that cause habitat fragmentation due to agricultural, residential, and industrial expansion in forested areas. These anthropogenic activities have been associated with affecting a large proportion of bats, particularly those roosting and foraging in intact and primary forests (Heaney et al. 2006; Nuñeza et al. 2015). In Mindanao, only a few studies on bats have been conducted, and the rate of tree cover loss is higher (Tanalgo and Hughes 2019); thus, bat assessment is vital to our understanding of the impacts of deforestation on bat biodiversity.

Moreover, hunting, cave exploitation, and extractive industries also pose a great threat to the bat population. Nearly 50% of species are threatened by hunting (Mildenstein et al. 2016), primarily driven by poverty in remote areas where agriculture and livelihood are poorly established. Previous studies found that there is a drastic bat population decline due to hunting, unregulated eco-tourism activities, and limestone mining (Sedlock et al. 2014; Tanalgo and Tabora 2015; Phelps et al. 2016; Quibod et al. 2019). For instance, in 2001, an estimated 500,000 bat individuals in Canlunsong Cave (Southern Mindanao) drastically declined to only 200 bats during the surveys conducted by Sedlock et al. (2014). In addition, extractive industries like mining and quarrying threaten at least 22 species (27%) of Philippine bats (Tanalgo and Hughes 2019). Consequently, island habitats in the Philippines and elsewhere have been identified as particularly important for bats and a priority for conservation efforts on a global scale (Tanalgo and Hughes 2018).

Mindanao Island has one of the highest levels of megachiropteran diversity in the world (Mickleburgh et al. 1992). However, it remains a priority area for faunal surveys because little work has focused on the diversity and distribution of bat species on the island. The lack of baseline information on bats is one of the identified constraints to bat conservation efforts because it has not been possible to estimate the number of bats in the Philippines that are extinct or endangered, and several species are now threatened and possibly facing extinction in the wild (Frick et al. 2019) due to anthropogenic activities. The study by Tanalgo and Hughes (2018) reported that the island of Mindanao is second in the greatest number of research studies conducted on bats in the Philippines, following Luzon Island. However, only a few studies have been conducted in the westernmost region of the Southern Philippines, such as in Sulu, Tawi-Tawi, and Zamboanga. Also, comparative studies on the diversity of bats in various types of habitats are very scarce in published literature, which is vital to our understanding of how land use and environmental changes affect bat populations (Tanalgo and Hughes 2018). Thus, bat surveys in unexplored or data-deficient areas of Mindanao are highly relevant to bat conservation.

Mount Gutom Protected Landscape is one of the most important watersheds in Zamboanga del Norte Province that still holds natural habitats for bats (CENRO-Manukan 2018), but there is no study conducted on bats in this area, which is located within the key biodiversity area yet poorly studied and is threatened by anthropogenic activities that could lead to habitat degradation. Thus, the present study was conducted to determine the diversity and distribution of bats in the Mt. Gutom Protected Landscape, Zamboanga del Norte.

MATERIALS AND METHODS

Study area

Mt. Gutom Protected Landscape is located on the southern tip of the municipality of Pres. Manuel A. Roxas, Zamboanga del Norte, Philippines (Figure 1). It has a maximum elevation of 1,199 meters above sea level (masl) and is dominated by dipterocarp forest, which includes old and secondary growth forest, mossy forest, and pine forest at the peak. It has a total land area of 5,464 hectares (ha), with the biggest portion encompassing the two barangays of President Manuel A. Roxas (Barangay Panampalay and Barangay Tantingon) and a small portion in the municipalities of Katipunan and Siayan (CENRO-Manukan 2018). Each sampling site was selected through ocular inspection. Considering the presence of fruit trees, the existence of water systems such as creeks and canals, caves, and other areas known to be foraging and roosting sites of bats.

Site 1 is within the buffer zone located at 08°21'53.04" N, 123°09'09" E on Mount Gutom, with a maximum elevation of 859 masl. The area is a secondary lowland dipterocarp forest where fruit trees, Palms, and *Ficus* spp. (Moraceae) and epiphytic *Freycinetia* sp. (Pandanaceae) were documented. This site has flat to mountainous terrain and is a transition zone from agroecosystem to secondary forest. On this site, a temporary pond was documented. Also, the presence of illegal logging, resin extraction, and man-made trails indicates anthropogenic activities in the area.

Site 2 is a secondary lowland dipterocarp forest along the Sikitan River of Mount Gutom, located at 08°20'40.62" N, 123°10'9.12" E, and has a maximum elevation of 633 masl and a steep slope greater than 50% vertical rise. This site is part of the buffer zone with vegetation dominated by dipterocarp species, and the presence of *Musa* sp., Palms, fruit trees, and fig trees (*Ficus* sp.) were documented. Also, coconuts (*Cocos nucifera*) were commonly planted along the slopes adjacent to this site. Moreover, a landslide, fallen logs, and a man-made trail were observed.

Site 3 is a secondary lowland dipterocarp forest, situated at 08°20'49.68" N, 123°09'57.06" E, and has a maximum elevation of 718 masl. It is a proposed reserved zone, where *Ficus* spp., *Casuarina equisetifolia* and *Palaquium philippinensis* are abundant, and several ferns, aroids, and orchids. *Freycinetia javanica* and *Musa* spp. (wild banana and abaca) were also observed. On the other hand, streams and waterfalls were found in the vicinity of the sampling site. The presence of decomposing fallen logs and a man-made trail were also documented. This site has the most accessible terrain from Sitio Malikas towards Lower Gutom because this area had been heavily logged during the 1970s. In fact, the road used to transport heavy logs in the forest was still evident, and heavy equipment used for logging was still in the area.

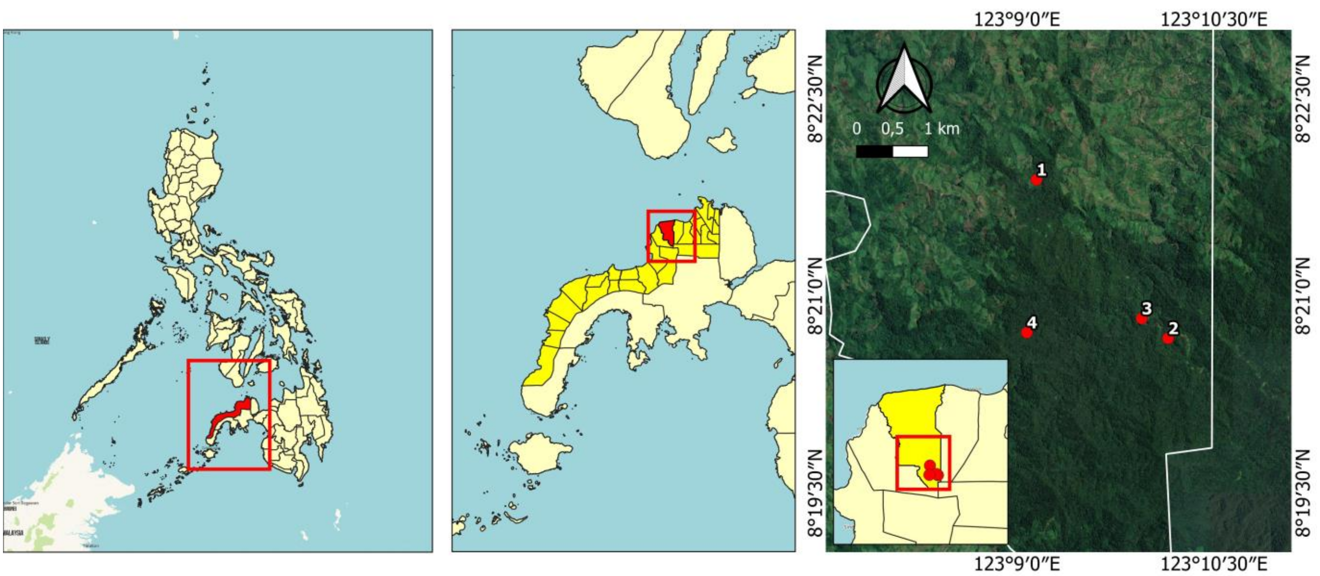

Figure 1. Map of Zamboanga del Norte Province located in the Mindanao Island, Philippines

Site 4 is a secondary dipterocarp forest located at 08°20.325' N and 123°09.458' E, with an 818 masl maximum elevation. It has a river and riparian ecosystem. The emergent tree, *Palaquium* sp., was common in the area. Trees were covered with thick mosses, epiphytic orchids and ferns, and climbing shrubs like *Freycinetia* sp. Fruit trees and figs, palms, *Musa* spp. were present in the area. A small community was also observed in this area.

Field survey and collection

A 6-meter mist net was used to sample bats. The mist nets were set at 1-1.5m above the ground (lower portion of the net) along possible flyways, left open from 1800 H to 2200 H, and checked regularly at least every half-hour interval. Then, the mist nets were checked the following morning (0530 H) to prevent the bats from stress from being held too long in the nets. The mist nets were then closed during the day. One net night is equivalent to one 6-m net open from dusk to early the next morning (Sedlock et al. 2008). Bats were carefully removed from the net and placed in a separate cloth bag, which was large enough for a bat to move freely and hang upside down. Mist netting was done separately on each site. Site 1 was sampled during the first visit to the area on April 12-23, 2022, and the remaining sites were surveyed on December 7-20, 2022, with 3-5 days sampling days. Overall, the sampling effort accounted for a total of 126 net-nights across four sampling sites. The adequacy of sampling efforts was evaluated through the examination of a species accumulation curve (Figure 4). A plateau in the species accumulation curve signifies that the majority of bat species have been documented, and further sampling endeavors are unlikely to yield additional bat records.

Measurement and identification

Captured bats were identified up to the species level using the Key to the Bats of the Philippines by Ingle and Heaney (1992). The sex, age, reproductive condition, and biometrics such as body weight, length of forearm, hindfoot, ear, tail vent, and total length were recorded. Bat species identified and examined were marked using indelible ink on their wing membranes, after which they were released back into the forest.

Determination of conservation status and endemicity

The species' conservation status and endemicity were determined using the most present database from the International Union for Conservation of Nature Red List version 2022-2(IUCN 2022).

Data analysis

Relative Abundance (RA%) was computed by dividing the number of individuals captured for each species by the total number of individuals for all species multiplied by 100. The species diversity index of each sampling site was calculated using the Paleontological Statistics software (Hammer et al. 2001). Furthermore, the data were grouped into clusters and measured for resemblance (similarity) using PRIMER 7 software with 999 permutations in all cases at a significance level of 5%. Similarity matrices were constructed from capture rate data using the Bray-Curtis index and performed a log+1 transformation on capture rates prior to the construction of similarity matrices to minimize the bias of this index on species with large differences in abundance (Avila-Cabadilla et al. 2012).

RESULTS AND DISCUSSION

Species composition and relative abundance of species

A total of 330 individuals representing two families, seven genera, and eight species were found in 126 net-nights (Table 1, Figure 2). Eight species have been identified, seven of which belong to the family Pteropodidae (fruit bats), namely: Lesser Dog-faced fruit bat *(Cynopterus brachyotis),* Philippine Dawn bat *(Eonycteris robusta),* Philippine Pygmy fruit bat *(Haplonycteris fischeri),* Harpy fruit bat *(Harpyionycteris whiteheadi),* Dagger-toothed long-nosed fruit bat *(Macroglossus minimus),* Greater Musky fruit bat *(Ptenochirus jagori),* Lesser Musky fruit bat *(P. minor), and* Horsfield's myotis *(Myotis horsfieldii).* The endemism of bat assemblage in the area scores 62.5%, with 4 Philippine endemic species and one species restricted in Mindanao Island.

Table 1. Species composition, abundance, distribution and conservation status of bats in Mt. Gutom Protected Landscape, Brgy. Panampalay, Manuel A. Roxas, Zamboanga del Norte, Philippines

Taxa	Conservation status	Distribution status	Sampling sites								Total	(RA%)
			S1	(RA%)	S2	(RA%)	S3	(RA%)	S4	(RA%)		
Pteropodidae												
Cynopterus brachyotis	LC	NE	39	(41.49)	16	(57.14)	64	(43.84)	16	(25.81)	135	40.91
Eonycteris robusta	VU	PE	-	(0.00)	1	(3.57)	-	(0.00)	-	(0.00)	1	0.30
Haplonycteris fischeri	LC	PE	27	(28.72)	2	(7.14)	6	(4.11)	9	(14.52)	44	13.33
Harpyionycteris whiteheadi	LC	PE	-	(0.00)	-	(0.00)	6	(4.11)	-	(0.00)	6	1.82
Macroglossus minimus	LC	NE	7	(7.45)	1	(3.57)	7	(4.79)	-	(0.00)	15	4.55
Ptenochirus jagori	LC	PE	20	(21.28)	5	(17.86)	50	(34.25)	37	(59.68)	112	33.94
Ptenochirus minor	LC	ME	-	(0.00)	3	(10.71)	12	(8.22)	-	(0.00)	15	4.55
Vespertilionidae												
Myotis horsfieldii	LC	NE	1	(1.06)	-	(0.00)	1	(0.68)	-	(0.00)	2	0.61
Total			94	(28.48)	28	(8.48)	146	(44.24)	62	(18.79)	330	100

Note: S1: Buffer zone; S2: Mixed Secondary Lowland Forest; S3 & S4: Secondary Lowland Forest; LC: Least Concern; VU: Vulnerable; NE: Non-endemic; PE: Philippine Endemic; ME: Mindanao Endemic

Figure 3 shows the rank-abundance curve of Bats in Mt. Gutom Protected Landscape. Results show that sampling site 3 recorded the most number of individuals (n=146, RA=44.24%) and *C. brachyotis* was the most abundant species in sites 1, 2, and 3, RA=41.49%, 57.14%, and 43.84%, respectively. Moreover, *P. jagori*, a Philippine endemic species, was the most abundant species in Site 4, with relative abundance of 59.68%. The said two species (*C. brachyotis* and *P. jagori*) can tolerate a wide range of habitats, making them exist in both non-forest and forest areas (Heideman and Heaney 1989; Mickleburgh et al. 1992), hence explains their presence in all sampling sites. Moreover, *H. fischeri* was also recorded in all sites of Mt. Gutom. This species primarily feeds on the fruit of *Ficus* and may depend on flowers during certain parts of the year (Heidemann 1989). Also, this species prefers secondary-growth forests (Heideman and Heaney 1989). This might explain the observed wide distribution of *H. fischeri* in Mt. Gutom since all sampling sites are secondary lowland dipterocarp forests and fruit trees and figs are also abundant.

Furthermore, *E. robusta* and *H. whiteheadi* were only recorded at site 2 and site 3, respectively. The Philippine endemic, *E. robusta*, primarily roosts in caves but is probably dependent on primary forests to forage (Heideman and Heaney 1989). The presence of this species in the area could be attributed to the good condition of the forest and potential habitats of this species in the site, such as rock crevices or nearby caves that were possibly undocumented. The presence of the large Philippine endemic *H. whiteheadi* in Site 3, could be attributed to the abundance of *F. javanica* in the area, its primary food plant, and might also be because this species has a moderately large home range, occurring at maximum density in a lower montane forest (Heaney et al. 1989; Heideman and Heaney 1989; Mickleburgh et al. 1992).

On the other hand, the Mindanao endemic *Ptenochirus minor* was found in Site 2 and Site 3. These endemic species are threatened by forest clearing and fragmentation due to their limited distribution and highly specialized food item preferences (Relox et al. 2014). In a study by Relox et al. (2014), *P. minor* exhibited a high preference for *Ficus* species, aiding in their successful pollination and seed dispersal. Depletion of preferred food resources could lead to bats having shorter residence times in the area (Restif et al. 2018). Hence, it is important to conserve these food resources and the area to sustain the existing bat populations, especially the endemic species.

In this study, fruit bats were more abundant than insect bats. This may be attributed to the capacity of these fruit bats to thrive successfully in almost all types of habitats (Jose et al. 2021). The presence of large numbers of fruit trees and the structural complexity of the forest would also contribute to their success in invading all the sites sampled. The low number of captures of insect bats is probably due to their ability to echolocate, thus enabling them to evade the mist nets (Sedlock et al. 2011). Furthermore, in the event that these bats are captured in mist nets, they have the ability to cut the nets using their sharp teeth, thereby freeing themselves (Jose et al. 2021). The greater amount and wide variety of food resources in the area is probably a factor that makes it a favorable foraging site for the bats. The absence of caves in the area could be the reason for the low catch of insect bats. The sites had little differences in their elevation and vegetation. Hence, bats being mobile can easily move from one area to another. The higher or lower number of individuals and number of species in the four sampling stations could be attributed to the availability of suitable places to forage and the presence of food (e.g., fruit trees and insects) in the area.

Figure 2. Bats recorded in Mt. Gutom Protected Landscape, Philippines in which: A. *Cynopterus brachyotis*; B. *Eonycteris robusta*; C. *Haplonycteris fischeri*; D. *Harpyionycteris whiteheadi*; E. *Macroglossus minimus*; F. *Ptenochirus jagori*; G. *Ptenochirus minor*; H. *Myotis horsfieldii*. Photos by J. M. Lama

Diversity and similarity

Of the four sampling sites, site 3 recorded the highest diversity index *H'* = 1.376, while Site 4 had the lowest *H'* = 0.938 (Table 2). All sampling sites show an even distribution of samples. However, the low number of species (S=3) and the presence of dominant species (*P. jagori*, R.A=59.68%*)* in site 4 influence the overall diversity index value. Hence, the computed diversity index of sampling site 4 is low due to the presence of dominant species.

On the other hand, the high diversity in Site 3 could be due to the variety of vegetation, specifically indigenous tree species, fruiting trees, and other food plants for some bats, like the climbing shrub *F. javanica*. On the other hand, the low species diversity observed in Site 4 can be due to the low number of food plants available and the elevation of the area. Katunzi et al. (2021) documented that bat activity and abundance are highest in the lowlands and decrease with increasing elevation. Also, the presence of several fruit trees in the area may have contributed to the abundance of these pteropodid groups. According to Reis et al. (2000), as cited by Tanalgo et al. (2017), the distribution and abundance of bats are affected by the diversity of vegetation, forest structure, the size of remaining forest patches and the overall quality of the area. In contrast, the reduced count of insectivorous bats may be explained by their ability in avoiding mist nets through the use of echolocation (Jose et al. 2021). Fruit bats lack this ability except for *Rousettus* groups (Grinnell et al. 2009). Research undertaken by Dai et al. (2001) in the boreal broad-leaved forest in Japan demonstrated that employing harp traps enhances the effectiveness of capturing bats, especially echolocating species, compared to the use of mist nets in sampling. Conversely, a low diversity of bats was recorded in the area.

Moreover, the results of Bray-Curtis similarity showed site 1 and site 3 had the highest similarity at 78.905%, whereas Site 3 and Site 4 had the lowest similarity at 63.868% (Figure 3). Moreover, two species contributed to the similarity of the sampling sites. The *C. brachyotis* accounted for 34.02% of the similarity, with an average species abundance of 1.47%, and *P. jagori* accounted for 30.39%, with an average species abundance of 1.39%. The high abundance of these two fruit bats, the *C. brachyotis* and *P. jagori*, influenced the similarity value at four sampling sites. These two fruit bats are generally common in secondary-growth forests and forage in agricultural habitats (Duya et al. 2020), and figs (Moraceae: *Ficus* spp.) appear to comprise a major part of their diet (Relox et al. 2014), which are abundant in both areas where they are most abundant. This may confirm that differences in vegetation and disturbance affect the number and abundance of species in a specific area.

Conservation status and threats

Seven species are of Least Concern and *E. robusta* was the only species recorded under the Vulnerable category of the International Union for the Conservation of Nature (IUCN) because of the rapid decline of its population (Waldien and Carino 2020). The study by Heideman and Heaney (1989) reported that no *E. robusta* was captured in caves on Negros, despite extensive sampling between 1981 and 1989. Its current rarity in caves and its strong association with primary forest suggest that it has declined sharply in parallel with the deforestation of lowland Negros. It might be threatened throughout its range, but it is apparently so rare that the seriousness of the threat is difficult to assess (Roño et al. 2021). Although most of the species assessed are of Least Concern, impending habitat changes in the area caused by anthropogenic activities have the potential to cause declines in species of conservation significance.

Mt. Gutom Protected Landscape experiences threats and anthropogenic pressures. Conversion of forest land into agricultural areas was the most prevalent disturbance observed in the sampling sites, specifically in Site 1 and Site 2. Small-scale timber extraction and forest clearing for small-scale timber production were both documented in these sites. These activities greatly affect obligate forest species such as bats and other forest-dwelling terrestrial vertebrates, leaving the area fragmented and exploited. Similarly, invasive alien species pose additional threats to the biodiversity in the area, which could outcompete or relocate other indigenous species. In the community adjacent to the site surveyed, poaching of wildlife threatens the survival of the bat fauna and other wildlife on Mt. Gutom.

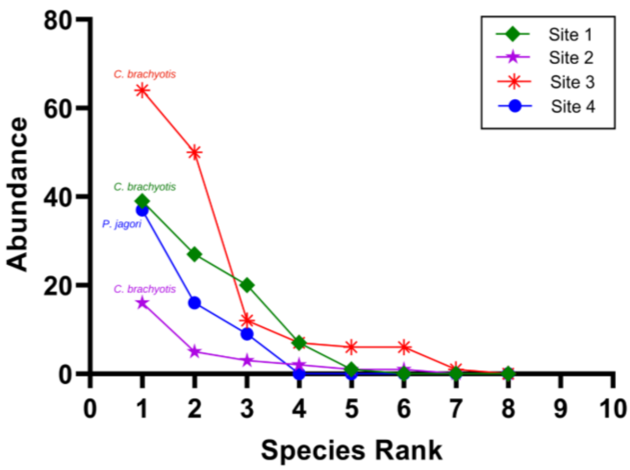

Figure 3. Rank-abundance curve of bat species in each sampling sites

Table 2. Biodiversity indices recorded in Mt. Gutom, Zamboanga del Norte

Sampling Sites	No. of Species	Diversity (Shannon_H')	Evenness (eH'/S)	Dominance (D)
Site 1	5	1.294	0.7297	0.3056
Site 2	6	1.293	0.6074	0.3776
Site 3	7	1.376	0.5656	0.3219
Site 4	3	0.9528	0.8514	0.4438

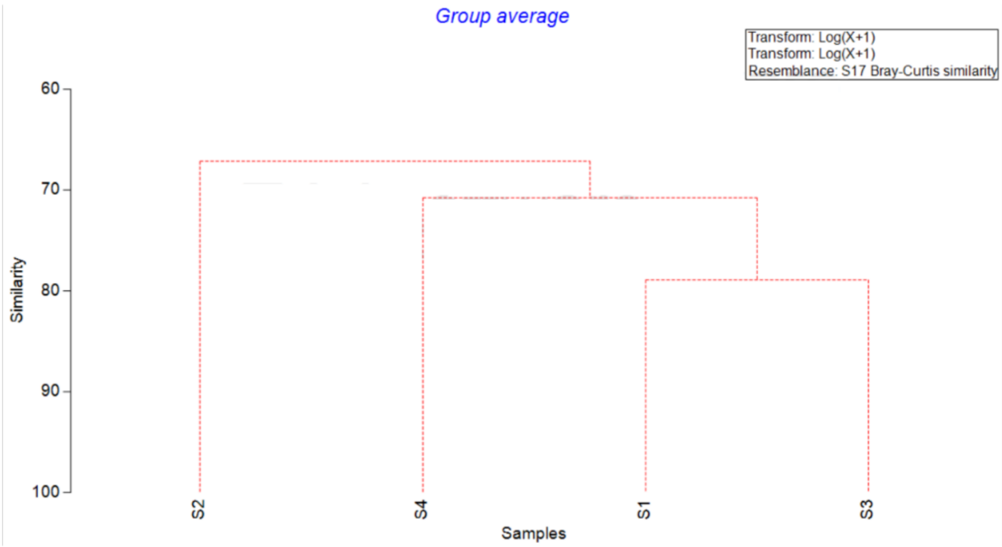

Figure 3. Bray-Curtis similarity of bat species in 4 sampled sites

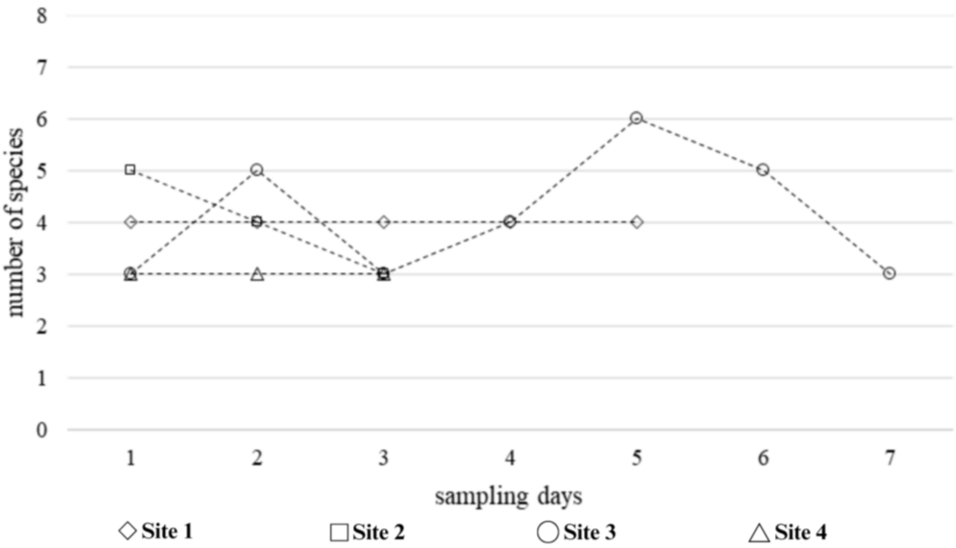

Figure 4. Species accumulation curve in 4 sampled sites. Furthermore, the results also demonstrate the resilience of these bats to tolerate various habitat gradients, and the high levels of richness and abundance of bats in small forest patches found in our study suggest that small-sized forest remnants are of conservation value not only for bats but also contribute substantially to the preservation of fauna in fragmented landscapes. However, in order to sustain forest-dependent bat populations and the long-term operation of the ecological services these bats provide, a significant level of forest integrity and structural connectivity is shown to be crucial. Nonetheless, the conservation of small and isolated remnants should be tightly linked with the preservation of larger tracts of forest to ensure the long-term persistence of an intact bat assemblage at the landscape level. Each species has a level of similarity with other species, possibly because they share the same habitat and food preference. For instance, the similarly-sized endemic species, *P. jagori* and *H. fischeri*, are potential competitors for food in several forest types in the country, where they mostly feed on plants from the family Moraceae and Musaceae (Mickleburgh et al. 1992)

Despite the anthropogenic activities on Mt. Gutom, three sampling sites show a moderately diverse species diversity index and only Site 4 has shown low diversity. Moreover, Site 3 recorded the highest abundance among the four sampling sites. This indicates that different sites on Mt. Gutom harbor diverse bat species, so conservation of the remaining habitats vital for the survival of these species must be protected. This study suggests that regular monitoring (dry and wet seasons) of bat populations in the area and dissemination of research data to the local communities through Information, Education and Communication (IEC) is important. Surveys can also be enhanced by utilizing ultrasonic detectors to assess the possible undocumented echolocating bats.

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