

## Short communication: Diversity of cave-dwelling bats in Cebu Island, Philippines

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**Abstract.** *Alcazar SMT, Lit Jr IL, Rebancos CM, Barrion-Dupo ALA, De Guia APO, Bantayan NC, Alvarez JDV. 2020. Short communication: Diversity of cave-dwelling bats in Cebu Island, Philippines. Biodiversitas 21: 3249-3254.* The species composition and richness of cave-dwelling bats in 16 caves of Cebu Island were studied to provide resource managers and local government units in Cebu baseline information that may be used toward conservation and sustainable utilization and management of local cave resources. Stationary and mobile mist-netting were employed at the entrance and dark zones of the caves to maximize the capture of bats. The study accounts for 15 species of cave bats, of which two were unidentified but are believed to be potentially new species, namely *Rhinolophus* sp. and *Myotis* sp., and three are new distribution records to Cebu, namely *Rhinolophus philippinensis*, *Eonycteris robusta*, and *Megaderma spasma*. In terms of richness values, Balay'g Agta holds six species and the remaining caves have less than five species. The presence of endemic, potentially new species and new distribution records of bats presents high conservation value and raises concern and calls for urgent action to protect the caves and the resources therein.

**Keywords:** Cebu, new distribution record, potential new species, richness, species composition

### INTRODUCTION

Biodiversity, particularly in caves, can be analyzed on a larger scale (Dumbrell et al. 2008; Zimmermann et al. 2010; McGlenn and Hurlbert 2012; Morueta-Holme et al. 2013; Alviola et al. 2015). For example, Cebu as a larger landscape contains karst areas where there are sinkholes, gaps (water nests), underground rivers, and caves (Gutiérrez et al. 2014). This study presents a diversity analysis of cave-dwelling bats in Cebu Island. Bats are among the most important organisms in caves because their abundance therein will provide guano that supports and activates the function of energy transfer. Many ecological services are facilitated by bats and in agricultural and natural ecosystems, they deliver some regulating services such as pest suppression, seed dispersal, and pollination that economically benefit humans (Kunz et al. 2011). Some cave roosting bats pollinate economically important plants. For example, the lesser dawn bat, *Eonycteris spelaea*, is one of the primary pollinators of durian, *Durio zibethinus* (Kunz et al. 2011). The study of Arrizabalaga et al. (2015) in Karrantza Valley, northern Iberian Peninsula proved that insectivorous bats need the forest and agricultural vegetation to search for their prey throughout the season. Bat and plant interactions play key and complementary

roles in forest dynamics, regeneration, and biodiversity conservation (Fleming and Kress 2011; Bueno et al. 2013). For instance, bats impact forest regeneration by feeding on a number of fruits, ingesting a large range of seed sizes, dispersing, and carrying them over long distances (Bueno et al. 2013; Gonzalez and Stevenson 2014; Fuzessy et al. 2017). The stable environment in caves is preferred by bats to other habitable ecosystems. Kingston (2010) reported that because of their size and stable microclimatic conditions, caves make excellent roost sites by at least 40% of Southeast Asia's bat species. A report by Wiantoro (2012) who conducted a study in the caves in Buni Ayu, Sukabumi, West Java, Indonesia proved that the morphological and physical factors of caves are important factors that influence bat diversity. The said study showed that the average air temperature of caves usually favored by bats ranged between 26.67°C and 28.46°C, with relative humidity from 81.5 to 84.48 %. The excellent dimensionality of Gombong Karst caves such as cave length, width, and height of cave passages was significantly correlated with the abundance, diversity, and evenness of bat species (Wijayanti and Maryanti 2017).

The changes in our natural landscapes are due mainly to anthropogenic activities that affect biodiversity mosaics or patterns around the world (Tschantke et al. 2012),

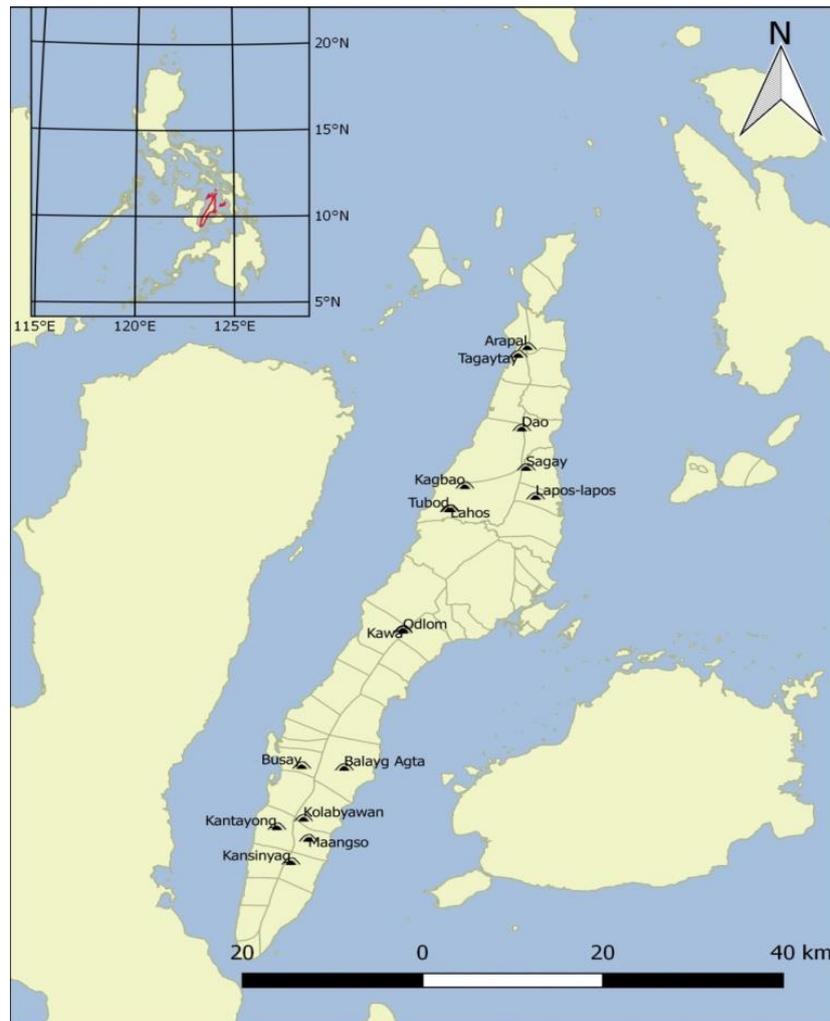
particularly karst areas in the Philippines. All these activities have resulted in pollution, cave destruction, and biodiversity loss (Beynen et al. 2012). The country has a unique landscape forming many caves that host many bats that are facing emerging threats. Over a quarter of known bat species are endemic (Heaney et al. 2010). Its more than 7640 islands harbor over 70 bat species belonging to seven families (Heaney et al. 2010).

There is a relaxed implementation of Republic Act No. 9072 (National Caves and Cave Resources Management and Protection Act) in the Philippines, particularly in Cebu, due to the inadequacy of information, particularly on the diversity and distribution of bats on the island. Understanding subsurface biodiversity is essential in establishing measures from human-induced changes (Reboleira et al. 2011; Christman and Zagamajster 2012). Hence, this study was conducted to determine the richness and composition of bats from the different caves in Cebu to generate information that will help provide scientific bases for the protection, conservation, and management of caves and the resources therein.

## MATERIALS AND METHODS

### Study site: Cebu Island

Cebu province is a narrow strip of land stretching about 220 kilometers from north to south and about 41 kilometers at its widest, located at its central part. The province is mountainous with several hills, as a rugged mountain range traverses the entire length of the island, although flatlands can also be found along the coastline (NWRB-CEST Consultant 2004). The slopes of the hills represent 75% of the landscape whereas the coastal area consists of 15% with maximum ground elevation of 600 masl. Karstic topography exists under most limestone/carbonated rock types. Metamorphic and tertiary rocks tend to be more resistant to weathering, developing rugged terrain and slopes. Box pattern river drainage forms on old limestone areas while dendritic and irregular patterns develop on younger limestone outcrops and older basement rocks (NWRB-CEST Consultant 2004).



**Figure 1.** Location map of surveyed caves in Cebu Island, Philippines (Source: GADM 2016)

Two types of climatic conditions affect Cebu Province. Northern Cebu falls under Type IV, which is characterized by evenly distributed rainfall throughout the year. It also receives the moderate effects of northeast monsoon, easterly waves, and typhoons from November to June. The central and southern part of Cebu falls under Type III climate.

Bat caves in municipalities were top priority for study, with consideration of their ecology, levels of disturbance, distance, and accessibility, based on the information and recommendation from the office of the Municipal Planning and Development Council (MPDC), Tourism Office, the Municipal Environment and Natural Resources Office (MENRO), or whichever office is concerned about caves in each municipality.

### Field sampling techniques

To assess cave bats, two types of mist netting were employed. First, standard (stationary) mist nets (monofilament 36 mm x 6 mm) of different sizes were used depending on the size of cave passages. These nets were set on strategic areas (stationary sampling) usually in dark zones to maximize the rate of capture. The second type, mobile mist-netting, was also employed depending upon the size of caves. Mist nets 3m x 1m and 6m x 1m were used for this purpose. These mist nets (with poles on both ends to hold the nets) were used to capture especially insectivorous bats. This is a sampling method where the equipment is held while walking along cave passages to efficiently capture bats. Sampling was carried out usually during daytime. Sampling effort hours were extended particularly for larger caves. The mist-net was left for 30 minutes in strategic locations, such as cave entrance/s, opening of roosting sites, and chambers, to maximize sampling. Effort hours were obtained only for large caves. Caves less than 50 m in total length were considered small and sampled only twice (sweep the mist-net back and forth); medium-sized caves (50-100 m in total length) were sampled four times (sweep the mist-net back and forth twice), and caves longer than 100 m (total length) were considered large and sampled more than four times. For small and medium-sized caves, the effort hours were not determined anymore since it was assumed that all species were counted, captured, and identified. For larger caves, 30 minutes was spent in each strategic location (cave entrance/s, roosting site openings, and chambers) to ensure that all bat species were obtained. The total time spent in strategic locations were summed up and used as the denominator for the formula:

$$\text{Effort hours: } \frac{\text{Number of cave bat species captured}}{\text{Total time (spent in mist-netting)}}$$

Mist nets were also set up at cave entrances at locations believed to be potential flyways of bats as they go out from caves at night. Net lines were also mounted for the purpose of extending the net barriers across flight paths at cave entrances. Captured bats were placed in cloth bags and brought to the campsite for identification/confirmation and morphometric measurements.

### Bat identification and measurements

Collected bats were identified up to species level using the key published by Ingle and Heaney (1992), still the only available key used by bat researchers in the Philippines. Standard measurements were taken for all captured bats. Total length as well as lengths of the tail, hindfoot, forearm, and ears were obtained using a calibrated ruler and noted on the datasheets. The weight was obtained using a Pesola® 30-100 g spring balance. The approximate age categories (juvenile, sub-adult, young adult, and adult) and sex of the specimens were also determined. A method used in estimating the age category of live bats is applied by passing light through the wing specifically on the dorsal surface of the extended wing and examining the epiphyseal-diaphyseal fusion of the fourth metacarpal-phalangeal joint on the ventral surface. The measurements of their size, body mass, and color oftentimes overlap with each other and that makes it difficult in identifying sub-adult, young adult, and adult samples. Thus, it is important to examine their reproductive organs to determine their age category. For female bats, adults have medium to large nipples, which may be lactating, and moderate to well-developed throat patches. Young adults have tiny to small nipples and poor to moderately developed throat patches, while sub-adults have very tiny nipples and poorly developed throat patches. On the other hand, adult male bats have moderate to well-developed throat patches and palpably large or scrotal testes. Young adult males have poor to moderately developed throat patches and moderately palpable or scrotal testes, while sub-adults have poorly developed throat patches and testes are unpalpable. The body pelage of sub-adult bats retains immature tones (i.e., lighter color). Sexes of bats were examined through their external genitalia.

### Data analysis and management

To assess the biological variability of bats per cave, species richness and composition were used and for which quantitative estimates were obtained. Species richness is a measure of the total number of species in the community whereas species composition provides taxonomic information of the samples collected.

## RESULTS AND DISCUSSION

Balay'g Agta Cave has the highest species richness with a total of six species (Table 1). Four caves in Cebu; namely, Busay, Sagay, Tagaytay, and Kantayong host four bat species while three caves in Northern Cebu such as Kagbao, Lapos-lapos, and Tubod have three each. The remaining caves only have one or two species recorded. The identification of the caves and the bats are essential so that priorities could be set for caves with high biodiversity conservation value. Prioritization of caves for conservation and management is a widely accepted approach considering the limited financial resources available. This set of data, therefore, is useful for Local Government Units (LGUs) as a base for the formulation of cave management plans, especially if the LGUs plan to open caves within their respective localities for ecotourism.

**Table 1.** Number of individuals captured and species richness from each cave surveyed on Cebu Island, Philippines

Name of cave	Municipality	No. of ind.	Species richness
Balay'g Agta	Argao	53	6
Busay	Moalboal	11	4
Kantayong	Alegria	6	4
Sagay	Catmon	11	4
Tagaytay	San Remegio	12	4
Kagbao	Tuburan	19	3
Lapos-Lapos	Carmen	10	3
Tubod	Asturias	7	3
Kansenyag	Boljoon	5	2
Dao	Sogod	12	2
Maangso	Alcoy	9	2
Kolabyawan	Dalaguete	1	1
Lahos	Asturias	1	1
Kawa	Pinamungajan	0	0
Udlom	Pinamungajan	0	0
Arapal	Bogo	0	0
Total no. of caves:		16	
Total no. of individuals:		157	

**Table 2.** Observed species of cave bats and the location of their roosts

Family/ Species	Roost cave
Pteropodidae	
<i>Eonycteris robusta</i> **	Lapos-lapos
<i>Eonycteris spelaea</i>	Balay'g Agta, Dao, Lapos-lapos, and Maangso
<i>Rousettus amplexicaudatus</i>	Dao, Kansenyag, Lapos-lapos, and Maangso
Hipposideridae	
<i>Hipposideros ater</i>	Kagbao
<i>Hipposideros diadema</i>	Balay'g Agta and Kagbao, Kansenyag, Sagay, Tagaytay, and Kantayong
Rhinolophidae	
<i>Rhinolophus arcuatus</i>	Balay'g Agta, Busay, Tubod, and Tagaytay
<i>Rhinolophus inops</i>	Balay'g Agta, Sagay, Tubod, and Kantayong
<i>Rhinolophus philippinensis</i> **	Sagay
<i>Rhinolophus virgo</i> +	Busay, Kagbao, and Lahos
<i>Rhinolophus</i> sp.*	Tagaytay
Vespertilionidae	
<i>Miniopterus australis</i>	Balay'g Agta, Busay, Sagay, and Kantayong
<i>Miniopterus schreibersii</i> <sup>b</sup>	Busay and Kantayong
<i>Myotis</i> sp.*	Tubod
Megadermatidae	
<i>Megaderma spasma</i> **	Tagaytay
Molossidae	
<i>Chaerophon plicata</i>	Balay'g Agta
Total no. of species:	15

Note: \*Potential new species, \*\*New distribution record, +Philippine endemic

This study accounts for 15 species of bats (Table 2) from 16 caves surveyed on Cebu Island (Table 1). Three species of frugivorous bats and 12 of insectivorous bats were recorded. The frugivorous and insectivorous bats belong to the family Pteropodidae, and the families Hipposideridae, Rhinolophidae, Megadermatidae, Vespertilionidae, and Molossidae, respectively. Interestingly, in documenting caves and their resident bats, potential new species and new distribution records to Cebu were encountered. Such species include, *Rhinolophus* sp. and *Myotis* sp. On account of new distribution records, this study has recorded three species, namely: *Eonycteris robusta*, *Rhinolophus philippinensis*, and *Megaderma spasma*.

We pioneered the assessment in Tagaytay cave and this is also based on our interview with local residents near the area. From this cave, *Rhinolophus* sp. was documented. There were 12 bat roosts determined but not all roosts were occupied. Majority of the roosts were abandoned probably due to human disturbance. The morphometric measurements of *R.* sp. fall within those of *Rhinolophus virgo*. However, closer examination revealed that they are different from each other and that *R.* sp. has characteristics distinct from *R. virgo*. *Rhinolophus* sp. from Tagaytay Cave has a copper brown pelage both on ventral and dorsal sides while that of *R. virgo* is usually medium brown and paler ventrally. Although there are individuals of *R. virgo* recorded to have no yellow tint on the face, this species is mostly distinguished by this obvious and distinct characteristic (Heaney et al. 2010), which is absent in the *Rhinolophus* sp. captured in Tagaytay Cave. Aside from the yellow tint on the face, the two species vary greatly in the character of the noseleaf, connecting process, and sella. Likewise, their ears also appear different. These two potential species are now the subject of further examination at the University of the Philippines (UPLB) Museum of Natural History.

**Figure 2.** *Rhinolophus* sp., a potentially new species of insectivorous bat from Cebu Island



A



B

**Figure 3.** *Megaderma spasma* (A) and *Rhinolophus philippinensis* (B), new distribution records for Cebu Island, Philippines

All studied caves have mean air temperature and relative humidity ranging from 28 to 30°C, and 90-95%, respectively. Specifically, Lapos-lapos cave where *E. robusta* was captured has two known entrances with the main entrance measuring 574 m<sup>2</sup>. It has passages and chambers with maximum ceiling height reaching 50 m. Water was absent in the cave and it is dry throughout the year. The Sagay cave which harbors *R. philippinensis* was a wet cave with a single entrance measuring 261 m<sup>2</sup> and with passages that run parallel to the surface and have a maximum ceiling height of 16 m. The Tagaytay cave that harbors *M. spasma* was described as a horizontal cave with an entrance measuring 19 m<sup>2</sup>. It has passages and is also a dry cave.

The presence of endemic, potentially new species, as well as new distribution records of bats to Cebu Island, renders high conservation importance particularly to these caves where there are emerging threats from various sources. Such threats or disturbances common to these caves include removal of speleothems (stalagmites and stalactites), rock phosphate extraction, collection of swiftlets' nests, vandalism/graffiti, and floor sediment compaction due to frequency of human visits. We observed that if disturbance in cave habitats are unabated, bats abandon their roost sites. Hence, the most difficult problem would be the lack of other suitable habitats for bats after they abandon their roosts. With more bat species listed, site-specific conservation becomes clearly an important and potentially successful strategy to reduce further biodiversity loss in caves, particularly the communities of bats therein. Government efforts and commitments to protect priority conservation areas such as those caves surveyed in this study should be afforded appropriate governance mechanisms and institutionalization because these approaches vary from every place.

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#### REFERENCES

- Alviola PA, Macasaet JPA, Afuang LE, Cosico EA, Eres EG. 2015. Cave-dwelling bats of Marinduque Island, Philippines. UPLB Mus Pub Nat His 4: 1-17.
- Arrizabalaga-Escudero A, Garin I, García-Mudarra JL, Alberdi A, Aihartza J, Goiti U. 2015. Trophic requirements beyond foraging habitats: The importance of prey source habitats in bat conservation. Biol Conserv 191: 512-519.
- Beynen PV, Brinkmann R, Beynen VK. 2012. A sustainability index for karst environments. J Cave Karst Stud 74 (2): 221-234.
- Bueno RS, Guevara R, Ribeiro MC, Culot L, Bufalo FS, Galetti M. 2013. Functional redundancy and complementarities of seed dispersal by the last Neotropical megafrugivores. PLoS One. DOI: 10.1371/journal.pone.0056252
- Christman MC, Zagamajster M. 2012. Mapping subterranean biodiversity. In: White WB, Culver DC (eds.). Encyclopedia of Caves. Elsevier, Amsterdam.
- Dumbrell AJ, Clark EJ, Frost GA. 2008. Changes in species diversity following habitat disturbance are dependent on spatial scale: theoretical and empirical evidence. J Appl Ecol 45 (5): 1531-1539. DOI: 10.1111/j.1365-2664.2008.01533.x

- Fleming TK, Kress WJ. 2011. A brief history of fruits and frugivores. *Acta Oecol* 37: 521-530.
- Fuzessy LF, Janson CH, Silveira FAO. 2017. How far do Neotropical primates disperse seeds? *Am J Primatol*. DOI:10.1002/ajp.22659.
- Gonzalez M, Stevenson PR. 2014. Seed dispersal by woolly primates (*Lagothrix lagothericha*) at Caparú Biological Station (Colombia): quantitative description and qualitative analysis. In: Defler T, Stevenson PR (eds). *The Woolly Primate: Behavior, Ecology, Systematics and Captive Research*. Springer, New York.
- Gutiérrez F, Parise M, Waele JD, Jourde H. 2014. Earth-Science reviews a review on natural and human-induced geohazards and impacts in karst. *Earth Sci Rev* 138: 61-88.
- Heaney LR, Dolar ML, Balette DS, Esselstyn JA, Rickart EA, Sedlock JL. 2010. A synopsis of the mammalian fauna of the Philippine Islands. [www.archive.fieldmuseum.org](http://www.archive.fieldmuseum.org).
- Ingle NR, Heaney LR. 1992. A key to the bats of the Philippine Islands. *Fieldiana Zool* 69: 1-44.
- Kingston T. 2010. Research priorities for bat conservation in Southeast Asia: A consensus approach. *Biodiv Conserv* 19: 471-484.
- Kunz TH, Braun TE, Bauer D, Lobo T, Fleming TH. 2011. Ecosystem services provided by bats. *Ann N Y Acad Sci* 1223: 1-38.
- McGlenn DJ, Hurlbert AH. 2012. Scale dependence in species turnover reflects variance in species occupancy. *Ecology* 93 (2): 294-302.
- Morueta-Holme N, Enquist BJ, McGill BJ, Boyle B, Jørgensen PM, Ott JE, Peet RK, Šimová I, Sloat LL, Thiers B, Violle C, Wiser SK, Dolins S, Donoghue II JC, Kraft NJB, Regetz J, Schildhauer M, Spencer N, Svenning JC. 2013. Habitat area and climate stability determine geographical variation in plant species range sizes. *Ecol Lett* 16: 1446-1454.
- NWRB CEST Consultant 2004. Cebu Island Morphology. NWRB CEST Consultant, Philippines.
- Reboleira AS, Borges PS, Gonçalves P, Serrano ARM, Oromi P. 2011. The subterranean fauna of a biodiversity hotspot region-Portugal: An overview and its conservation. *Intl J Speleol* 40 (1): 23-37.
- Tscharntke T, Tylianakis JM, Rand TA. 2012. Landscape moderation of biodiversity patterns and processes-eight hypotheses. *Biol Rev* 87 (3): 661-685.
- Wiantoro S. 2012. Diversity and roosting characteristic of bats in Buni Ayu Cave, Sukabumi Limestone Area, West Java. *Jurnal Fauna Tropika* 21 (1): 32-36.
- Wijayanti F, Maryanto I. 2017. Diversity and pattern of nest preference of bat species at bat-dwelling caves in Gombong Karst, Central Java, Indonesia. *Biodiversitas* 18 (3): 864-874.
- Zimmermann P, Tasser E, Leitinger G, Tappeiner U. 2010. Effects of land-use and land-cover pattern on landscape-scale biodiversity in the European Alps. *Agric Ecosyst Environ* 139 (1-2): 13-22.