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Abundance and Species Composition of Cave Bats (Mammalia: Chiroptera) in Selected Key Biodiversity Areas (KBAs) of Central Visayas, Philippines

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ABSTRACT

This study assessed the abundance and species richness of bats (Order Chiroptera) inhabiting caves in three KBAs (Key Biodiversity Areas) of Central Visayas: Mt. Bandilaan in Siquijor (13 caves), Mabinay, Negros Oriental (11 caves), and Rajah Sikatuna Protected Landscape(RSPL) in Bohol (31 caves). The study was conducted between February 14 to September 20, 2019. Of the 55 caves surveyed, 35 caves were inhabited by bats. Field survey methods included mist-netting at the cave entrances and direct observations of roosting sites in each cave. This study captured 754 individuals of bats belonging to 16 species, majority of which are insectivorous species (13 species) and only three species are fruitbats (Pteropodidae). Mabinay caves had the highest number of species (11) and captured bats (271 individuals) while RSPL had 9 species (221 individuals) while Mt. Bandilaan only had five species but relatively high captured bats (262 individuals). Five species are Philippine endemics (*Hipposideros obscurus*, *Hipposideros pygmaeus*, *Ptenochirus jagori*, *Rhinolophus inops*, and *R. rufus*) and three Near-threatened species (*H. lekaguli*, *M. schreibersii*, and *R. rufus*). The rare bat species (*Dobsonia chapmani*) may be locally extirpated in Mabinay, where it last documented at Mambajo cave in the 1960s. The survey also noted the absence of fruit bats (observed in 2011 study) in all of the caves in Mt. Bandilaan, probably due to on-going anthropogenic activities (treasure hunting, bat hunting, guano extraction, land conversion, locals illegal entry, graffiti, etc) in caves surveyed. Large colonies of fruitbats and insect bats in RSPL may have been affected by anthropogenic activities inside the caves. Most of the caves surveyed have been promoted for ecotourism activities.

Keywords: cave; chiropteran; extraction; karst; limestone

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INTRODUCTION

Bats (Order Chiroptera) are very important because of their diverse ecological functions (Kunz *et al*., 2011). Aside from being a source of food in some localities, they also serve as prey items for some vertebrate species (Mikula *et al*., 2016). Some bat species also feed on insects (Balete, 2010), thereby limiting insect pests in agroforestry system (Williams-Guillén *et al*., 2008). They are also well-known for their role as pollinators (Hodgkison *et al*., 2003) and therefore play a significant role in forest ecology and also in agroforestry. Bats may also roost in groups inside caves (Sedlock *et al*., 2014; Tanalgo & Tabora, 2015) and their guano deposits have been collected for use as fertilizers (Sothearen *et al*., 2014).

A number of studies have been done on the cave roosting bats in the Philipines. Tanalgo & Tabora (2015) documented 14 bat species in the South central Mindanao. In Panay Island, Mould (2012) found 12 bat species in 19 out of the 21 caves surveyed. Sedlock *et al*. (2014) surveyed the cave bats in Rajah Sikatuna Protected Landscape (RSPL) in Bohol Island, central Philippines. They documented 14 taxa in 23 out of 25 caves that they surveyed. In central Negros Island, Tababa *et al.* (2012) identified 15 bat species in four caves.

The study aims to assess the abundance and bat species composition in selected caves of Key Biodiversity Areas (KBAs) in Central Visayas, central Philippines. Such information is highly needed to develop appropriate conservation strategies for cave-dwelling bats.

MATERIALS AND METHODS

Study Areas

1. Mt. Bandilaan Natural Park, Siquijor

The Mt. Bandilaan Forest Ecosystem has 271 hectares of lowland forest under the management of the Provincial Environment & Natural Resources (PENRO) and the Protected Areas and Wildlife Bureau (PAWB). The caves in Bandilaan were surveyed from February 16-25, 2019. These caves are being promoted by the local government for eco-tourism. The research team surveyed 13 caves in Siquijor (Appendix 1). The highest cave ceiling height reaches to almost 20m and the lowest is at 1.866 m for Cang-anhao cave and Bung-aw cave, respectively.

2. Mabinay, Negros Oriental

The municipality of Mabinay in Negros Oriental is gaining popularity because of their more than four hundred caves. In fact, the said municipality is also known as "The Cave Capital of the Philippines". The area is a karst limestone and rolling landscape characterized by numerous caves and underground river systems (Alcala *et al*., 2007). The surveyed caves were located in the four barangays of said municipality, namely; Bulwang, Lamdas, Namangka and Paniabonan. A total of 11 caves were surveyed from April 23-May 03, 2019 (Appendix 1). The heights of the ceiling on these caves could reach to 10m and chambers measuring more than 15m in diameter. Mambajo has a perennial underground river that periodically floods during rainy seasons, while the rest of caves lack this feature. Many large caves in Mabinay (including the cave study sites) are presently used for cave eco-tourism activities by the local government of Mabinay Municipality.

3. Rajah Sikatuna Protected Landscape (RSPL), Bohol

RSPL covers an area of 10,452.6 hectares of lowland forested limestone hills with springs and caves. It is the largest of the remaining forests on Bohol Island. Our research team surveyed 31 caves within the RSPL as listed in Appendix 1. These caves are situated in five (5) municipalities out of seven (7) anchored municipalities within the premises of RSPL, namely; Batuan, Bilar, Carmen, Dimiao, Sierra Bullones and Valencia. The said cave survey started July 24 to September 20, 2019. Elevation of these caves ranges from 362.21 (Palabyo cave) to 571.51 (Bagacay 2 cave) meters above sea level (masl).

Data Gathering

Prior to fieldwork, the survey team coordinated with the corresponding local government units and the Department of Environment & Natural Resources (DENR) Offices in Siquijor, Negros Oriental, and Bohol provinces. Caves were surveyed based on standard spelunking safety protocols. To capture bats, two types of mist netting was being deployed (stationary and mobile mist netting) using 3m x 1m mist nets and then were set up near the cave entrance/s. Other team members also searched the inner chambers for the presence of roosting bats. When roost was present, the researchers counted the approximate number of individuals to species level, if possible. However, reconnaissance survey was made into each cave prior to sampling activity. Captured individuals were identified to species level based on Heaney *et al*. (2010) and Ingle & Heaney (1992) then marked adopting "marked – and – recapture technique" of C.J.G. Petersen and immediately released back into the wild right after taking all information like age, sex, morphometric, etc.

Data Analysis

Data were presented in terms of the number of captured bats per species in each cave. To compare counts of captured bats between islands (as groups), data were subjected to non-parametric Kruskall-Wallis test (significance level set at $p < 0.05$). To visualize similarity of bat species composition, data matrix was transformed into binary data, presence (coded as 1) or absence (coded 0) then subjected to cluster analysis (using the software PAST3 (Hammer *et al*., 2001). In this analysis, we used the Jaccard Similarity Index and paired group (UPGMA) as the algorithm. Clusters were visually determined based on the resulting dendrogram. To test the hypothesis that these

three clusters are distinct, One Way-Analysis of Similarity (ANOSIM) was used. Higher R values (from 0 to 1) and p values <0.05 suggest that this separation (between clusters) is statistically significant. To differentiate between the clusters, pair-wise comparisons were made. To determine which of the species contributed to any observed differences between clusters, the Similarity of Percentage (SIMPER) test was used.

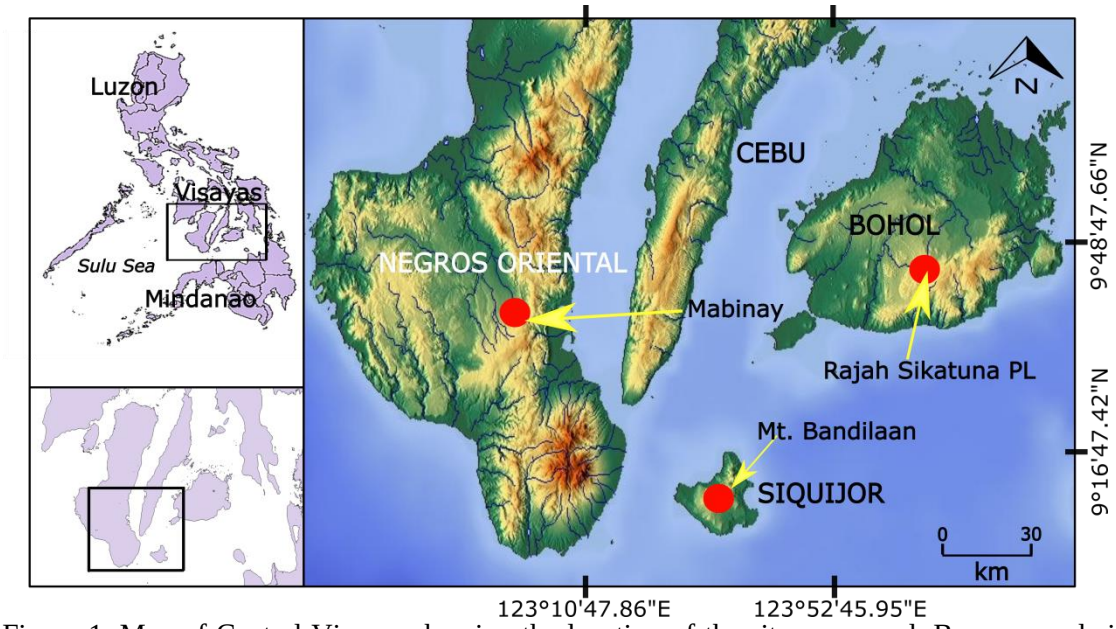

Figure 1. Map of Central Visayas showing the location of the sites surveyed. Base maps derived from PhilGIS (www.philgis.org) and https://maps-for-free.com/.

RESULTS AND DISCUSION

Results

This study conducted a more comprehensive survey on cave-dwelling bats in the three Key Biodiversity Areas (KBAs) in Central Visayas, namely Siquijor (13 caves), Negros Oriental (11 caves), and Bohol (31 caves). In all 53 caves surveyed, 754 individual bats were captured belonging to 16 species, 13 species are insectivorous and only three species of fruit bats (Pteropodidae: *Cynopterus brachyotis*, *Ptenochirus jagori* and *Eonycteris spelaea*). Five species are Philippine endemics (*Hipposideros obscurus, Hipposideros pygmaeus, Ptenochirus jagori, Rhinolophus inops,* and *R. rufus*) and three Near-threatened species (*H. lekaguli*, *M. schreibersii*, and *R. rufus*). Detailed accounts of abundance (expressed as number of individuals captured) and species richness for each province are provided in the succeeding sections.

Mt. Bandilaan Natural Park, Siquijor Island

This survey documented 262 individual bats belonging to five species in four families (Hipposideridae, Megadermatidae, Rhinolophidae, and Vespertilionidae) from 13 caves within the Bandilaan Natural Park (Fig. 2). All five species were present in Cang-anhao Cave, of which *Hipposideros diadema* dominated the mistnetted individuals (151 out of the estimated maximum count of around 1,000 individuals roosting in this cave). This was followed by Ambakag - baki nature spring cave with 57 individuals mistnetted, 44 of which belong to *Miniopterus australis* while 13 individuals belong to *Rhinolophus arcuatus*). In Tugok cave, 22 individuals of *Hipposideros obscurus* were documented. There were no bats observed inside the rest of the caves, probably due to anthropogenic activities (e.g. treasure hunting).

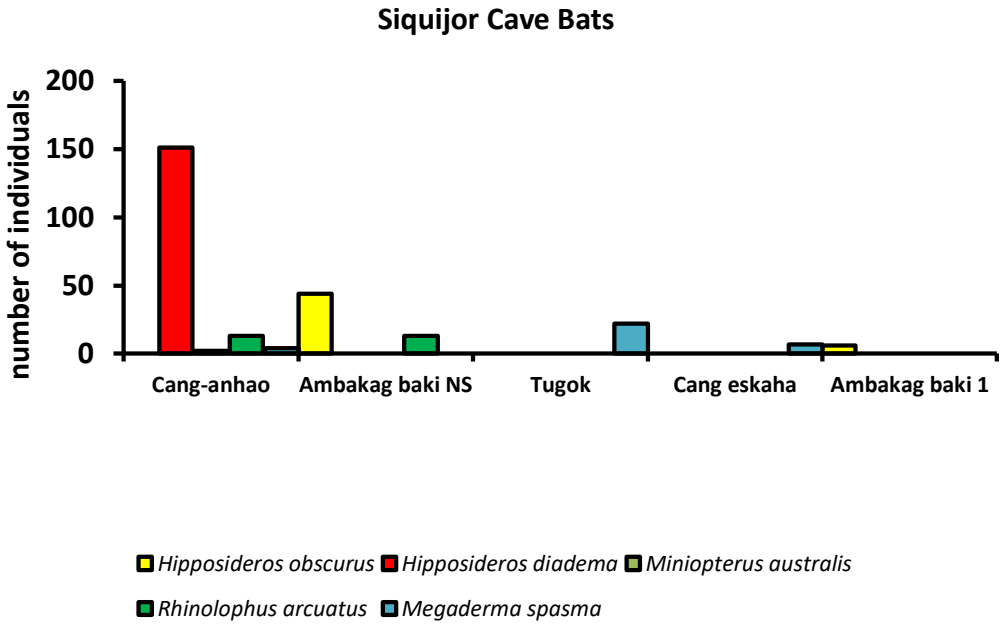

Figure 2. Abundance of cave dwelling bat species in Bandilaan Natural Park, Siquijor (the rest of the caves had no bats).

Mabinay, Negros Oriental

Between April 23-May 03, 2019, the survey team mistnetted a total of 271 individuals of bats belonging to 11 species in four families (Hipposideridae, Pteropodidae, Rhinolophidae, and Vespertilionidae) were observed in the Mabinay caves (Fig. 3). The highest number of mistnetted bats was in Mambajo cave with 116 individuals, dominated by the the fruit bat *Eonycteris spelaea* (Common Nectar Bat) with 107 individuals. In Kabugan cave 1, a total of 85 individuals belonging to *Miniopterus australis* were mistnetted while in an adjacent cave, no bat was observed. Other caves visited but not inhabited by bats include Crystal and Toto, probably due to anthropogenic activities.

Rajah Sikatuna National Park (RSPL), Bohol

In the caves of RSPL (Fig. 4), a total of 221 individual bats belonging to 9 species were recorded, the highest number of captured bats was in Canlusong cave 1 with 53 individuals followed by Cadabas cave with 29 individuals and Buhong Anghit cave with 23 individuals. The rest of the 31 caves in RSPL were represented by below 20 individuals while eight of the caves had no bat inhabitant. Of the 221 bats in these caves, the three species with the highest count were *Hipposideros obscurus* (55 individuals), *H. diadema* (44 individuals), and *Miniopterus australis* (33 individuals). The species with the least number of individuals were *Megaderma spasma* and *Rhinolophus arcuatus*, with only 7 and 2 individuals, respectively.

Cave Bats Abundance and Distribution Between Island Groups

Overall, median counts of captured bats did not differ significantly between island groups based on Kruskall-Wallis test ($p > 0.05$). However, the two roosting sites (1,000 individuals in Cang-anhao Cave in Mt. Bandilaan and Mambajo Cave with > 3,000 individuals in Mabinay, Negros Oriental) were not considered in the analysis owing to the difficulty in quantifying mixed-roosting bat species.

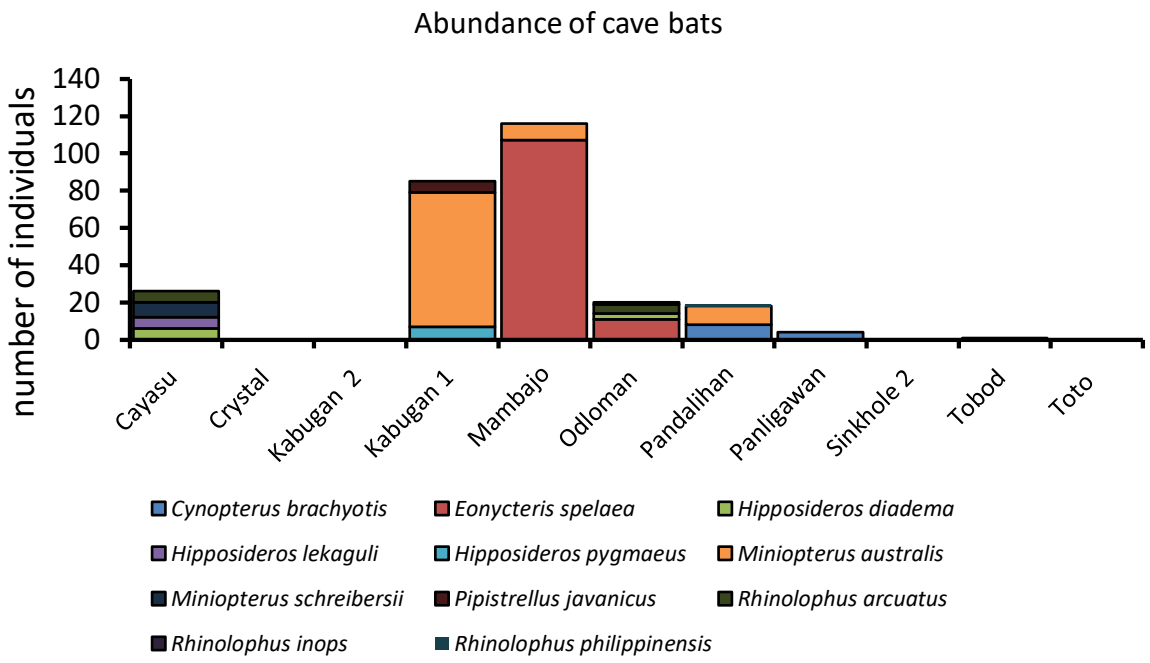

Figure 3. Abundance of cave-dwelling bat species in Mabinay, Negros Oriental.

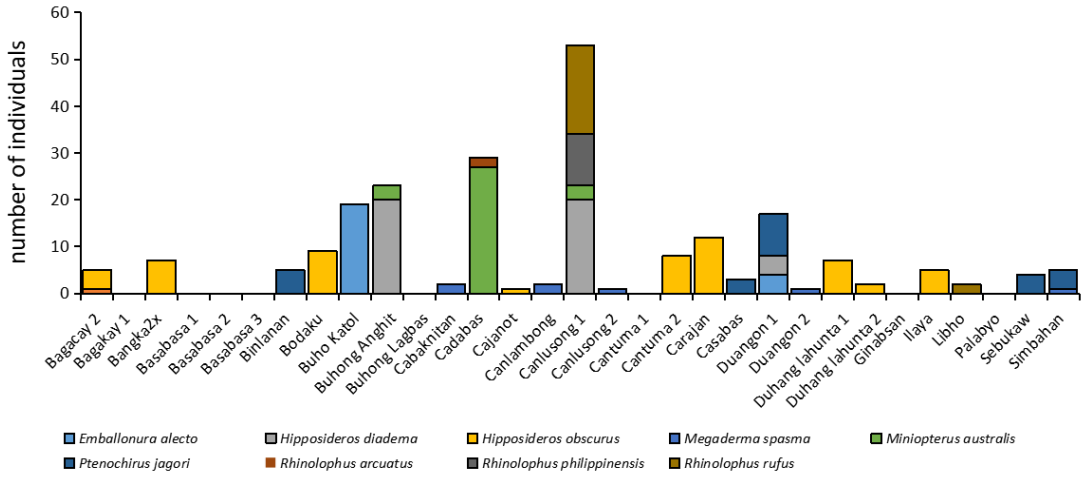

Figure 4. Abundance of cave-dwelling bat species in Rajah Sikatuna Protected Landscape (RSPL), Bohol.

As shown in Fig. 5, three clusters can be shown with strong support (R = 0.7059; p value = 0.0001) based on ANOSIM (using Jaccard Similarity Index). Pairwise comparisons of these clusters were also statistically significant (p = 0.0001) and shows high R values (> 0.5). Clusters 1 and 3 were mainly attributed to Bohol caves with one and two caves from Siquijor, respectively, while Cluster 2 shows an overlap of sites from the three major KBA sites. Subsequent Similarity of Percentage (SIMPER) Analysis revealed that pairwise comparisons between clusters 1 and 3 (R = 0.7364) and between 2 and 3 (R = 0.8321) were mainly driven by *Hiposiderus obscurus*, with 42.31% and 26.72%, respectively. Pairwise comparison between clusters 1 and 2 was of moderate R value (0.5328) but still statistically significant (p = 0.0001) was mainly driven by another insect bat species *Miniopterus australis* with 17.74% contribution (Table 1).

The fruitbat species *E. spelaea* and *C. brachyotis* were found only inside caves on Negros while *P. jagori* was encountered only in five caves in Rajah Sikatuna Protected

Landscape (RSPL). Six insectivorous bat species (*Hipposideros lekaguli*, *Hipposideros pygmaeus*, *Miniopterus schreibersiiii*, *Pipistrellus javanicus*, and *Rhinolophus inops*) were found only in Negros caves and absent in Siquijor or Bohol. Meanwhile, *Emballonura allecto* and *Rhinolophus rufus* were found only in RSPL. All of the five species found in Siquijor are also found either in Bohol or Negros sites.

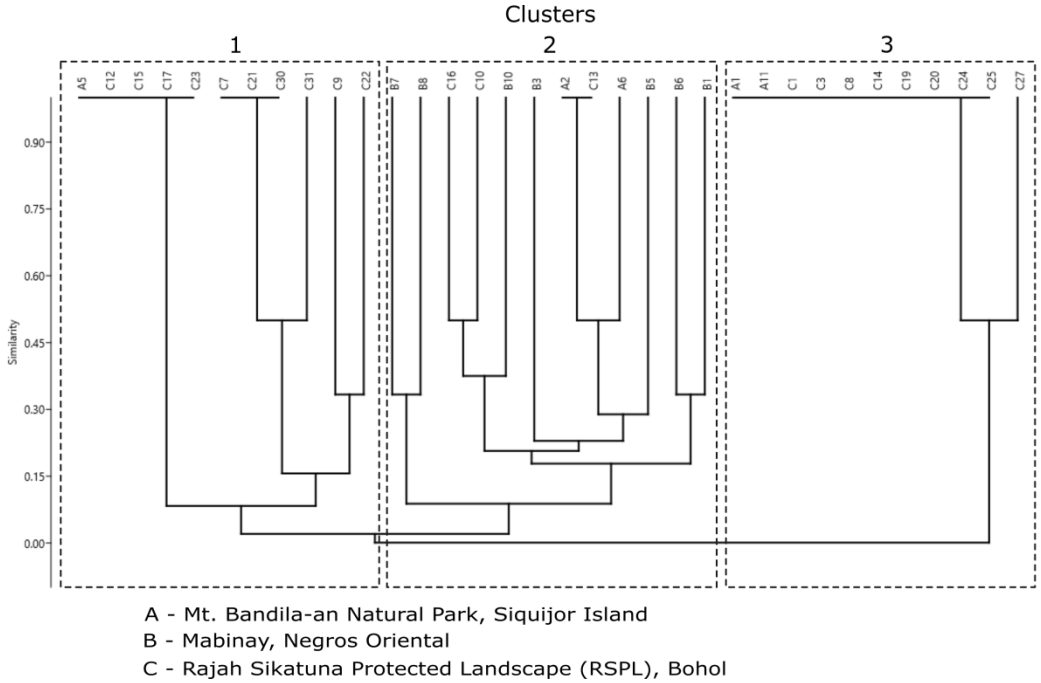

Figure 5. Cluster plot to demonstrate similarity in presence/absence of species cave bats species in selected caves from three KBA sites.

Table 1. Summary of SIMPER and ANOSIM results.

	SIMPER			One-Way ANOSIM		
Groups	Average Dissimilarity (%)	Discriminating Species	Contribution (%)	R value	p value	significance
Cluster 1 vs. 2	23	*Miniopterus australis*	17.74	0.5328	0.0001	***
Cluster 1 vs. 3	15	*Hipposideros obscurus*	42.31	0.7364	0.0001	***
Cluster 2 vs. 3	24	*Hipposideros obscurus*	26.72	0.8321	0.0001	***

significance: *** <0.001
Cluster 1 (A5, C7, C9, C12-17, C21-C23, C30-31)
Cluster 2 (A2, A6, B1, B3, B5-B8, B10)
Cluster 3 (A1, A11, C1, C3, C8, C14, C19-C20, C24-C25, C27)

In all of the caves surveyed (n = 55) in three provinces (Bohol, Negros and Siquijor), the caves in Mabinay had the highest number of bats species with eleven (11) species followed by the caves in RSPL with ten (10) bats species and while Mt. Bandilaan Nature Park in Siquijor only had five (5) species. However, in terms of number in bats family, RSPL had the highest followed Mabinay and Mt. Bandilaan Nature Park at 6 and 4, respectively. Photographs of bats when captured on site are shown in Fig. 6.

Discussion

This study assessed the cave-dependent bats in three provinces of Central Visayas. This study documented 16 species of bats, majority of which are insectivorous bats with 13 species while fruitbats (Pteropodidae) were represented only by three species (*Cynopterus brachyotis*, *Eonysteris spelaea* and *Ptenochirus jagori*).

The number of species of cave-dwelling bats documented in each study site appears

lower compared to previous studies done on the cave bats in the Philipines. For example, only five species were observed in Rajah Sikatuna Protected Landscape (RSPL) versus 14 taxa reported by Sedlock *et al*. (2014) and Phelps *et al*. (2016) reported 21 species in 56 caves in Bohol. Only 5 species were recorded in 13 caves in Siquijor while Sedlock & Gomez (2010) recorded 11 species from 20 caves. In Mabinay, this study reported 11 species despite in 11 caves surveyed. Tababa *et al*. (2012) identified 15 bat species in just four caves. Interestingly, all fruitbats observed in the caves of Mt. Bandilaan by MLR Alcala *et al*. (2011) were no longer encountered by this study, probably due to continued human disturbance such as guano harvesting and treasure hunting. Tanalgo & Tabora (2015) documented 14 bat species in the South central Mindanao. In Panay Island, Mould (2012) found 12 bat species in 19 out of the 21 caves surveyed. Alviola *et al*. (2015) recorded 13 species in 11 caves. Quibod *et al*. (2019) listed 15 species in 30 caves in Samal Island, Mindanao.

Our survey further confirmed the absence of any rare bat species. Based on IUCN (2019), no threatened species were recorded during the surveys. However, two insectivorous species are considered Near-Threatened: 1) *Hipposideros lekaguli*; and 2) *Miniopterus schreibersiii*. *Hipposideros lekaguli* has a very limited distribution in the Philippines (Mindoro and Luzon).

The fruitbat *Eonycteris spelaea* was observed overlapping roost sites with *Eonycteris robusta* in one large chamber in 2010 (Tababa *et al*., 2012) but not observed by this study. Earlier counts made by Alcala *et al*. (2007) of these species combined in Mambajo cave were placed close to 4,000 individuals, a figure significantly lower than the count estimates (~7,000) in the earlier survey in May 2010. Tababa *et al*. (2012), however, reported a total bat population of 3,000 in Mambajo Cave. In October 2010, M.L.R. Alcala *et al*. (2011) showed a significant increase in bat populations with estimates reaching about 50,000 individuals. The increase in the number of bats in Mambajo prior to management interventions by the local government unit has been attributed to the relocation of bat populations coming from other caves. Quarrying, hunting and guano extraction have recently increased in other caves resulting to the transfer cave bats in Mambajo (Alcala *et al.*, 2011). Alcala *et al*. (2007) noted the absence of the rare, Negros Bare-backed Fruit Bat (*Dobsonia chapmani*) which used to inhabit Mambajo cave in the 1960s, probably due to prolonged period of anthropogenic activities leading to the extirpation of this rare bat species. Interestingly, the large roosts of fruitbats (either *Rousettus amplexicaudatus* or *Eonycteris* spp.) and thousands of insect bats in caves surveyed by Sedlock *et al*. (2014) declined during our survey at RSPL. This suggests a negative impact of anthropogenic activities (e.g. guano harvesting and extensive digging) in the past few years.

CONCLUSION

This study assessed for the first time the abundance and species richness of bats (Order Chiroptera) inhabiting caves in the three KBAs (Key Biodiversity Areas) of Central Visayas: Mt. Bandilaan in Siquijor (13 caves), Mabinay, Negros Oriental (11 caves), and Rajah Sikatuna Protected Landscape in Bohol (31 caves). Of the 55 caves surveyed, between February 14 to September 20, 2019, only 35 caves were inhabited by bats. Using mist-netting at the cave entrances and direct observations of roosting sites in each cave, this study captured 754 individuals of bats belonging to 16 species, majority of which are insectivorous species (13 species) and only three species are fruitbats (Pteropodidae). The caves in Mabinay, Negros Island had the highest number of species (11) and captured bats (271 individuals) while RSPL had 9 species (221 individuals) while Mt. Bandilaan only had five species but relatively high captured bats (262 individuals). The rare bat species (*Dobsonia chapmani*) may be locally extirpated in Mabinay, where it last documented at Mambajo cave in the 1960s and the lowland forests near caves have been lost already. The survey also noted the absence of fruit bats (observed in 2011 study) in all of the caves in Mt. Bandilaan, probably due to on-going anthropogenic activities (treasure hunting, bat hunting, guano extraction, land conversion, locals illegal entry, graffiti, etc) in caves surveyed. Large colonies of fruitbats and insect bats in RSPL may have been affected by anthropogenic activities inside the

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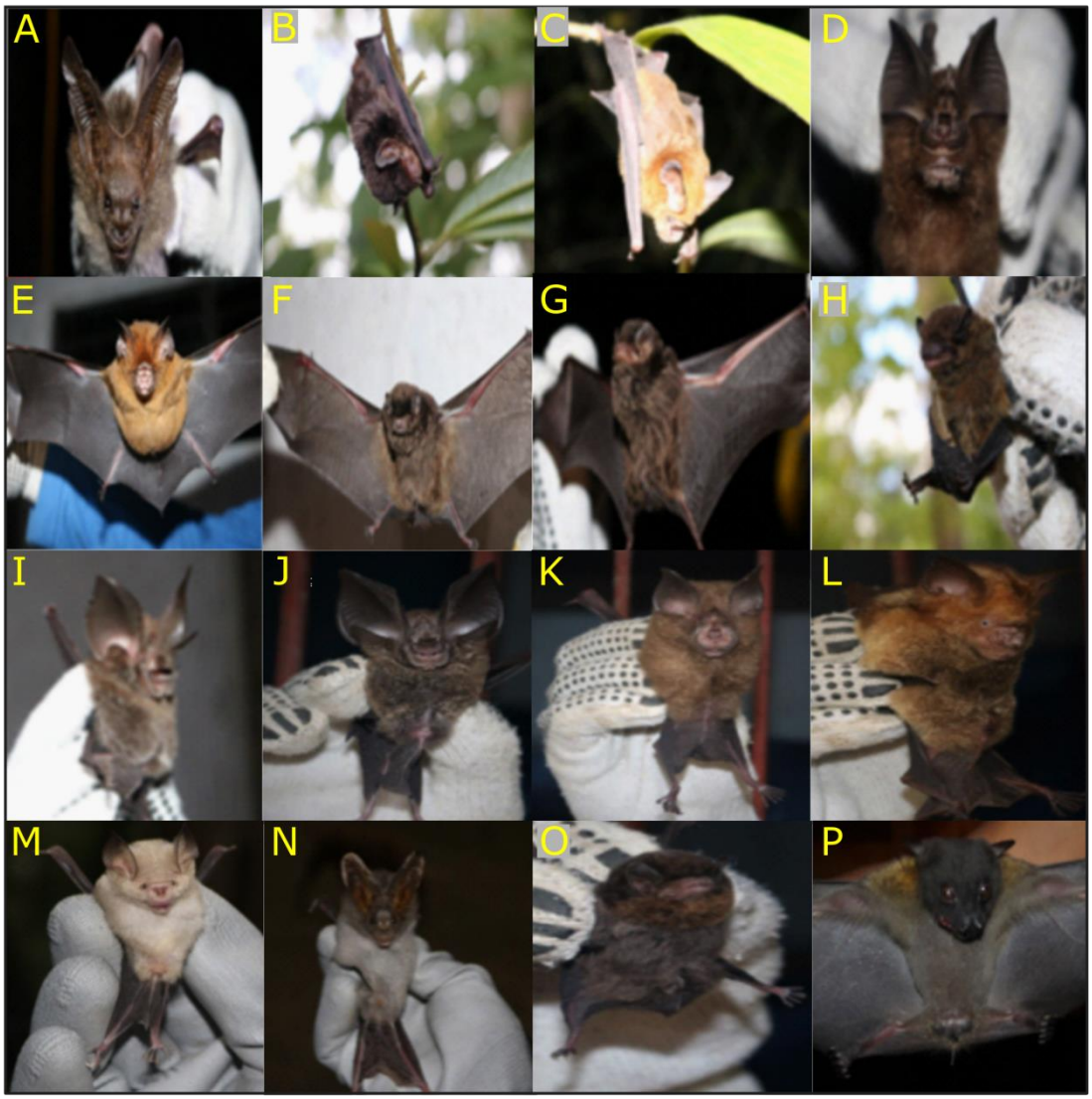

Figure 6. Representative bats photographed *in situ* during the cave survey in the three key biodiversity areas. From Mt. Bandilaan (A-*Megaderma spasma*, B-*Miniopterus australis*, C-*Hipposideros obscurus*, D-*Rhinolophus arcuatus*), Mabinay (E-*Hipposideros lekaguli*, F-*Miniopterus schreibersiiii*, G-*Miniopterus australis*, H-*Hipposideros diadema*, I-*Rhinolophus philippinensis*), and Rajah Sikatuna Protected Landscape (J-*Rhinolophus philippinensis*, K-*Rhinolophus rufus*, L-*Hipposideros diadema*, M-*Hipposideros obscurus*, N-*Megaderma spasma*, O-*Miniopterus australis*, P-*Ptenochirus jagori*).

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Appendix 1. List of caves surveyed in three Key Biodiversity Areas (KBAs) in Central Visayas, Philippines.

Code	Name of Cave/ Site	Remarks
A	**Bandilaan Natural Park, Siquijor**	
1	Ambak baki	frequented by tourists
2	Ambak baki nature spring	frequented by tourists
3	Campbulawan	No bat observed; treasure hunting activities observed
4	Campong karaan	No bat observed; treasure hunting activities observed
5	Cang-skaha	
6	Cang-anhao	
7	Dakanay	No bat observed; treasure hunting activities observed
8	Lunas	No bat observed; treasure hunting activities observed
9	Tinamnag gabi	No bat observed; treasure hunting activities observed
10	Toronio	No bat observed; treasure hunting activities observed
11	Tugok	
B	**Mabinay, Negros Oriental**	
	Cayasu	frequented by tourists
13	Crystal	No bat observed; frequented by tourists
14	Kabugan 2	
15	Kabugan 1	No bat observed
16	Mambajo	Known habitat of rare species (*Dobsonia chapmani*); large colonies of fruit bats (*Eonycteris* spp) observed
17	Odloman	
18	Pandalihan	frequented by tourists
19	Panligawan	frequented by tourists
20	Sinkhole 2	
21	Tobod	No bat observed
22	Toto	No bat observed
	Rajah Sikatuna Protected Landscape, Bohol	
23	Bagacay 2	
24	Bagakay 1	No bat observed
25	Bangka2x	
26	Basabasa 1	No bat observed
27	Basabasa 2	No bat observed
28	Basabasa 3	No bat observed
29	Binlanan	
30	Bodaku	
31	Buho Katol	
32	Buhong Anghit	Guano extraction observed
33	Buhong Lagbas	No bat observed
34	Cabaknitan	

35	Cadabas	Treasure hunting activities observed
36	Cajanot	
37	Canlambong	
38	Canlusong 1	Guano extraction observed
39	Canlusong 2	Guano extraction observed
40	Cantuma 1	No bat observed
41	Cantuma 2	
42	Carajan	
43	Casabas	
44	Duangon 1	
45	Duangon 2	
46	Duhang lahunta 1	
47	Duhang lahunta 2	
48	Ginabsan	No bat observed
49	Ilaya	
50	Libho	Guano extraction observed
51	Palabyo	No bat observed
52	Sebukaw	
53	Simbahan	