Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 6, p. 122-132, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Species diversity of terrestrial vertebrates in Mighty Cave, Tagoloan, Lanao Del Norte, Philippines

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Article published on December 06, 2014

Key words: Cave-dwelling, birds, herpetofauna, mammals, Mindanao.

Abstract

Cave is a known habitat for a variety of vertebrates and out of 1500 caves in the Philippines, about 37% are found in Mindanao. The Mighty Cave in Tagoloan was found to have no available records on vertebrate diversity because no previous studies were conducted in the area. To determine the species composition of cave- dwelling vertebrates in Mighty Cave, Tagoloan, Lanao del Norte, field sampling was done in four sampling subsites using the modified cruising method. Five species of mammals, one species of birds, and two species of herpetofauna were documented. Two Philippine endemic species, *Rhinolophus inops and Cyrtodactylus annulatus* were present in the Deep Zone. Moderate diversity was observed. Major threat observed for the birds was nest gathering. The cave was observed to be disturbed as seen from vandalism and installation of lights and concrete pathways inside the cave. The presence of endemic species indicates the need to conserve the Mighty Cave in Tagoloan.

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Introduction

The Philippines is the world's second largest archipelago with more than 7,100 distinct islands (Ambal *et al.,* 2012) that holds a concentration of species diversity and endemism of global importance (Peterson *et al.,* 2000). It is also home to about 1,500 caves all throughout, and 37% of these are in Mindanao. These caves are also home to specialized mineral formations, as well as unique and diverse flora and fauna (DENR-PAWB, 2008). For vertebrate fauna, the country consists of 102 amphibian species (Alcala *et al.,* 2006) of which 78 are endemic (Diesmos *et al.,* 2002), 179 species of mammals of which 111 are endemic (Stuart *et al.,* 2008) and 58 species of reptiles of which 170 species (66%) are endemic (Diesmos *et al.,* 2002). Some, if not most of these species are tropical rain forest-associated and are highly dependent on forest microhabitats (Alcala *et al.,* 2006). Caves are used by vertebrate fauna for a variety of reasons such as to provide den sites, nest substrates, roost sites, maternity sites, water sources, predation or foraging sites, and hibernation sites (Strong and Goodbar, 2005).

A cave is characterized by total darkness, almost constant air and water temperature, relative humidity approaching saturation and a relatively poor supply of nutrients (Engel, 2007). However, despite these characteristics, cave harbors a rich fauna unique to subterranean environments (Culver *et al.,* 2004) that are also worth analyzing because all of these species have successfully invaded one of the harshest environments (Christman and Culver, 2001) and are generally overlooked because they are uncharismatic and difficult to study (Percival, 2006). It is less well known that caves, and particularly cave entrance areas, can provide an important resource for a wide variety of species. Especially in arid regions, caves may provide temporary relief from extreme temperature or low-humidity conditions (Strong and Goodbar, 2005). A study conducted in Naih Great Cave of Sarawak shows 26 species of birds inhabiting the cave (Khan *et al.,* 2008). Moreover, over 40 species of Philippine bats roost in caves (Heaney *et al.,* 2010). Thus, caves are very crucial for the conservation of biodiversity and provide habitat to some of the country's endangered animals which are yet to be protected by existing network of protected areas (DENR-PAWB, 2008).

Most of the caves in the Philippines are in peril due to lack of specific statutory protection, increased demand for recreational sites, treasure hunting, mining, pollution, illegal collection of cave resources and rapid urbanization (DENR-PAWB, 2008). Thus, most of the Philippine caves where vertebrates can be found are unprotected, and many are seriously threatened (Bat Conservation International, 2010). Only seven caves are presently with protected area status, representing less than 1% while the other caves in the country were initially assessed for the purpose of cave management plan preparation (DENR-PAWB, 2008). Several reports on recent discoveries of vertebrate species are documented in the country (Diesmos *et al.,* 2002; Alcala, 2002; Siler *et al.,* 2007; Siler *et al.,* 2009; Rosler *et al.,* 2006; Sedlock *et al.,* 2008; Linkem *et al.,* 2010; Lobite *et al.,* 2013). However, studies on cave fauna are lacking except for some recent reports by Brown and Alcala (2000); Novises and Nuñeza (2014); Lagare and Nuñeza (2013); Batucan and Nuñeza (2013); Figueras and Nuñeza (2013); Enriquez and Nuñeza (2014); Cabili and Nuñeza (2014); and Mag-usara and Nuñeza (2014).

No studies on faunal diversity have been conducted earlier in the Mighty Cave in Tagoloan, Lanao del Norte, Philippines, but the cave has already been transformed into an ecotourism site. In earlier times, it was utilized as hideout of rebels that hindered the conduct of faunal inventories. This study determined the species diversity of vertebrate fauna found in Mighty Cave of Barangay Kiazar, Tagoloan, Lanao del Norte and identified the existing threats to the cave fauna.

Materials and methods

Sampling area

Mighty Cave is located at coordinates N 08° 19'18.5" and E 124° 17'38.5" east at 246 meters above sea level

(Fig. 1). Boulders were observed in this limestone habitat. The greater part of the cave is in total darkness and a small part is highly illuminated. The cave has one twilight zone, two transition zones and one deep zone. The cave consists of many chambers. The top external cave surface was thickly covered with trees. Small amount of flowing water was present inside the cave especially during heavy rains. Presence of breakdown or rockfall was observed. Stalactites, stalagmites and natural cave formations were present in moderate number.

Fig. 1. Map of the Philippines and Lanao del Norte (A) (www.zamboanga.com, 2013) showing the location of Tagoloan (B) (www.en.wikipedia.org, 2014).

Four subsites were established according to the degree of illumination inside the cave. Subsite 1 or the Twilight Zone was the highly illuminated area which was the point at the main entrance of the cave. Subsite 2 or the Transition Zone 1 was the partially illuminated part which was immediately next to sampling site 1. Subsite 3 or Deep Zone was the portion with total darkness and where guano was thickest. Subsite 4 or the Transition Zone 2 was the second partially illuminated portion which was located at the back side of the cave immediately after the deep zone.

In each subsite, air temperature was taken by holding up a laboratory thermometer at least one meter above the ground for 2 minutes. Humidity was taken by using a sling psychrometer. Degree of disturbance was noted through visual observation and personal communication with the local guides.

Cave sites

Subsite 1 or the Twilight Zone was at the 1st mouth of the cave and is considered as the main entrance. A boulder in the opening divided the opening into two; small and large openings which can both be penetrated by an average person. It had an air temperature of 26°C. Presence of cave development was apparent because of concrete structures in the area

Subsite 2 or the Transition Zone 1 is the area of the cave which had little amount of sunlight and had an air temperature of 25°C. The substrate on the floor was made up of guano which measured a depth of 18 inches.

Subsite 3 or the Deep Zone of the cave is an area of absolute darkness. Substrate was made up of guano. Water body was present near to this area. This subsite consists of many chambers and had an air temperature of 20°C.

Subsite 4 or the Transition Zone 2 is an area of the cave which had an air temperature of 24°C. This is the portion situated at the back side of the cave. There was no guano and mud deposits but boulders and rocks were present. Cave development was apparent such as cemented structures and steps.

Sampling, Processing of Samples, Identification and Analysis of Data

Sampling was done using the modified cruising method. The cave was surveyed at 0900-1200 hours and 1500-1700 hours during the day and 1900-2200 hours at night for eight days from May 16-17, 22-24 and July 3-5, 2010. Birds and bats were captured by mist nets placed across the mouth of the caves in the Twilight Zone in the front side, Transition Zone 2 at the backside, and inside the cave in the Transition and Deep Zones. Nets were fastened to poles at least

1-2 meters above the ground and were checked at an interval of three to four hours throughout day and night. Captured bats and birds were retrieved immediately and were placed in separate cloth bags for identification. Visual or actual counting was employed to determine the abundance of vertebrates. Photographs were taken for documentation. Morphometric data and weight were taken. Voucher specimens were fixed in 10% formalin solution and later washed and transferred to 70% ethanol. Brown and Alcala (1978), Alcala (1986), Kennedy *et al.,* (2000), and Ingle and Heaney (1992) were used as references for identification. Biodive Pro software was used to measure the biodiversity indices. SPSS version 17 was used in principal component analysis to determine the similarities and differences in abundance of vertebrates. Conservation status of the species captured was noted using the IUCN Red List of Threatened Species (2014).

Results and discussion

Eight vertebrate species were collected from the four subsites explored within the Mighty Cave of Tagoloan, Lanao del Norte (Table 1). The same number of cave-dwelling vertebrate species was also recorded by Wynne and Voyles (2014) in the caves of North Rim, Grand Canyon, Arizona but a higher number of bat species was recorded in Mighty Cave. The Mighty cave was dominated by mammals which was the same observation of Strong and Goodbar (2005) in a cave in Chihuahuan Desert in Mexico. Five of the eight species recorded are mammals under the order Chiroptera. This finding concurs with the statement of Hutson *et al.,* (2001) that the order Chiroptera is the second most diverse and abundant order of mammals, and the only group of vertebrates that have successfully exploited caves for permanent shelter (Kunz, 1982). The bat, *Pipistrellus javanicus* was only captured in the Deep Zone. This species was found roosting in caves (Francis, 2008) and was recorded in the caves of Andaman Islands (Aul *et al.,* 2014). Most of the bat species were not found in transition zone 1 except for *E. spelaea*. According to Kryštufek (2004), bats are present and are able to survive only in places providing suitable microclimate condition (constant low ambient temperature and high humidity to compensate water losses through evaporation) and safety from predation and disturbance which could be the reason for the absence of bats in the mouths of the cave. During the day, bats prefer to roost in a cave where it is cooler and darker. They are also more protected by surrounding boulders and vegetation and so they are less exposed to predators and changes in the weather (Burgess and Lee, 2004). Individuals appeared to have their own specific position within the roost forming clusters. Microchiropteran bats or the insectivorous bats were found in the deep zone of the cave most commonly and abundantly. The eyes of Microchiroptera work well under low ambient illumination (Eklöf, 2005). According to Betts (1997) and Kryštufek (2004), microchiropterans select sites within caves suited to their microclimatic preferences and accordingly from time to time alter their positions. Moreover, variation in latitude, altitude, depth and volume as well as the presence of blow-holes inside the caves collectively provides them the hospitable microclimatic conditions suitable for roosting (Murray and Kunz, 2005) and this explains why these bat species were abundant in the deep zone. *Rousettus amplexicaudatus* which was found in twilight zone, the mouth of the cave and transition zone 2 had the highest number of individuals (44) and relative abundance (25.88%). *R. amplexicaudatus* is a locally abundant species in the Philippines and is colonial which forms cave roosts of several thousand animals (Csorba *et al.,* 2008). In the study of Kim and Diong (2012) it was observed that this species is also one of the most abundant fruit bats recorded in all their study sites. Warguez *et al.,* (2013) found that this species roosts near the mouth of the cave in Davao del Norte and prefers to roost in small cavities where there is partial illumination. This species has wide distribution, large population, and occurs in a number of protected areas (Csorba *et al.,* 2008).

Of the birds, only *Collocalia esculenta* was captured and found only in the Twilight Zone. Day and Mueller

(2004) reported that some species of the genus *Collocalia* are particularly adapted to the interior of the cave and these birds often venture deep into the cave beyond the threshold or twilight zone for nesting sites and feeding. Only one species of reptiles, *Cyrtodactylus annulatus,* was captured and found in the Deep Zone. Only one species of amphibian, *Limnonectes magnus* was captured and found in two subsites, Transition Zone 1 and Deep Zone. Of the vertebrate species documented in the cave, only *Rhinolophus inops* and *Cyrtodactylus annulatus* are endemic.

Geckos, spiders, and crabs were observed in the cave particularly in the transition zone 1 and deep zone. Manchi (2009) reported that these organisms are known predators to swiftlets. This could be the reason why swiftlets were found only in the twilight zone where these predators were not found. Another reason that made possible the existence of swiftlet in the cave opening is that it does not echolocate and therefore builds its nests near cave openings in the dim-lit zones (Sheshnarayan, 2009). *C. annulatus* was observed only in the deep zone where a body of water is present. According to Brown and Rico (2009) this species seems to congregate in suitable habitat close to rivers and streams which may be the reason for the presence of this species in the area. Moreover, *C. annulatus,* is present in the deep zone mainly because like other geckos, this species feeds on the usual invertebrates of appropriate size like crickets, spiders, bugs, flies and roaches (Barts and Schneider, 2009) which were present in the area. *L. magnus* was found in the transition zone 1 and in the deep zone probably due to the presence of their preys such as mosquitoes and other invertebrates.

Table 1. Species List and Relative Abundance of Vertebrates captured in Mighty Cave, Tagoloan.

Species	Common Name	Sampling Subsites									
		1 (Twilight Zone)		2 (Transition Zone 1)		3 (Deep Zone)		4 (Transition Zone 2)		Total	
		No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
CLASS AMPHIBIA											
Order Anura											
Family Dicroglossidae											
Limnonectes magnus +	Giant Philippine Frog	0	0	4	66.67	7	23.33	0	0	11	6.47
CLASS AVES											
Order Apodiformes											
Family Apodidae											
Collocalia esculenta	Glossy swiftlet	29	25.66	0	0	0	0	0	0	29	17.06
CLASS MAMMALIA											
Order Chiroptera											
Family Pteropodidae											
Eonycteris spelaea	Dawn Bat	31	27.43	2	33.33	0	0	2	9.52	35	20.59
Rousettus amplexicaudatus	Common Rousette	40	35.40	0	0	0	0	4	19.05	44	25.88
Family Rhinolophidae											
Hipposideros diadema	Diadem Leaf-nosed Bat	8	7.07	0	0	11	36.67	10	47.62	29	17.06

Species	Common Name	Sampling Subsites									
		1 (Twilight Zone)		2 (Transition Zone 1)		3 (Deep Zone)		4 (Transition Zone 2)		Total	
		No.	RA	No.	RA	No.	RA	No.	RA	No.	RA
*Rhinolophus inops**	Philippine Forest Horseshoe Bats	5	4.42	0	0	9	30	5	23.81	19	11.18
Family Vespertilionidae											
Pipistrellus javanicus	Javan Pipistrelle	0	0	0	0	1	3.33	0	0	1	0.59
CLASS REPTILIA											
Order Squamata											
Family Gekkonidae											
Cyrtodactylus annulatus *	Small Bented-toed gecko	0	0	0	0	2	6.67	0	0	2	1.18
Total Number of Individuals		**113**		**6**		**30**		**21**		**170**	
Total Number of Species		**5**		**2**		**5**		**4**		**8**	

Legend: *Philippine endemic, +Near Threatened, RA – Relative Abundance, No. – Number of Individuals

Table 2 shows the biodiversity indices of vertebrates in Mighty Cave. Lowest diversity was recorded in transition zone 1 because it is near the mouth of the cave that has few roosting sites. Other zones like transition zone 2, twilight and deep zones had moderate diversity. Transition zone 2 is another mouth of the cave which enables the bats to pass through to search for food. The twilight zone is where outside organisms and some cave dwellers share as roosting site (Hajenga, 2005). Most of the species captured in the twilight zone were bats which are flying mammals that go in and out of the cave to search for food. There was a more or less even distribution of vertebrates captured. More individuals of vertebrates were captured in twilight zone because it is the main opening of the cave. It is where the bats exit when they search for food particularly for the fruit bats which may also explain why there is higher species richness in the twilight zone. Species is abundant throughout the cave where there is the greatest absence of light (McClure *et al.*, 1967). .

Table 2. Biodiversity Indices of Vertebrates captured in Mighty Cave.

	1 Twilight Zone	2 Transition Zone 1	3 Deep Zone	4 Transition Zone 2	Total
Species	5	2	5	4	8
Individuals	113	6	30	21	169
Dominance	0.2734	0.5556	0.2844	0.3288	0.1842
Shannon	1.3970	0.6365	1.3630	1.235	1.784
Evenness	0.8085	0.9449	0.7812	0.8594	0.7444

Fig. 2 shows the Principal Component Analysis of the captured vertebrates. It shows the similarities in abundance of vertebrate species. *L. magnus, C. annulatus,* and *P. javanicus* were of the same abundance which grouped these species together. Boulders which were some of the microhabitats of *C. annulatus* and *L. magnus* were present only in small quantity which may explain the small population of these species. Francis *et al.,* (2007) reported that the Vespertilionidae family in which *P. javanicus* belongs has small size and has the tendency to roost alone. This might explain why *P. javanicus* was rarely

captured. *E. spelaea, C. esculenta*, and *R. amplexicaudatus* were grouped in one cluster. *R. inops* and *H. diadem*a also formed one group for they have almost the same abundance. The fig. showed that there is significant difference on the distribution and abundance of the vertebrates found in the cave. One of the most important factors determining the presence of bats in caves is suitable microclimate (Speakman and Thomas, 2003) and safety from predation and disturbance (Kryštufek, 2007).Thus, bat abundance was positively correlated to the type of habitat. Bat abundance is positively correlated to areas near bodies of water (Walsh and Hariss, 1996) on where a stream about 200 meters away from the cave was observed. Fruit bats, *R. amplexicaudatus* and *E. spelaea*, were of the same abundance because they have the same diet, the reason why *H. diadema* and *R. inops* which are insectivorous bats were of the same abundance also. *C. esculenta* was observed to be abundant in the mouth of the cave because its most abundant prey are insects of Orders Hymenoptera and Diptera which include flies, bees, and wasps. The habitats of Hymenopterans and Dipterans are soil, trees and shrubs (Lourie and Tompkins, 2000). These habitats were observed about 5-10 meters away from the cave indicating the presence of food for *C. esculenta* and its abundance in the mouth of the cave.

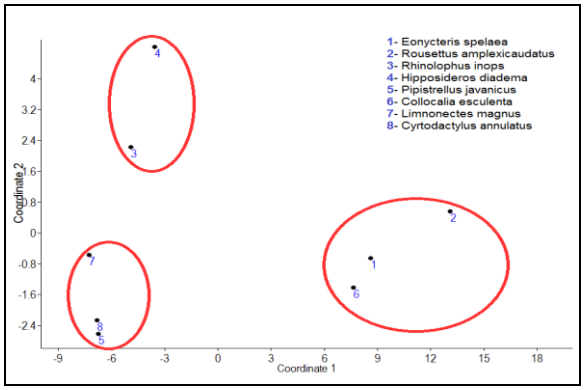

Fig. 2. Principal Component Analysis of captured species.

Existing threats to Vertebrates in Mighty Cave

Persistent human disturbance is a major cause for the decline in population of many cave-dwelling bats and other sensitive cave-dwelling organism (Martin *et al.,* 2003). Disturbance and destruction of caves is one of the major causes for the bat population decline across the world (Pocora *et al.,* 2012). According to an interview with the nearby inhabitants of the area, some threats to the cave were the noise, lighting system which was installed inside the cave, harvesting of guano and bird's nest, and vandalism. It is the lighting and not the noise which causes most disturbances to bats. Human activities in caves can affect bats adversely especially bats that assemble in maternity colonies (Mann *et al.,* 2002).

Conclusion and recommendations

Mighty Cave is an area of moderate vertebrate diversity. Species richness was higher in the Deep and Twilight zones. The major threats to the vertebrates in the Mighty Cave were vandalism, installation of lights and concrete pathways inside the cave. The presence of endemic species indicates that Mighty cave is an important cave for conservation.

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