

# Species Richness and Conservation Status of Cave Bats in Agusan Del Sur, Philippines

Ian Carlmichael J. Perez<sup>1</sup> and Olga M. Nuñez<sup>1,\*</sup>

<sup>1</sup>Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, Iligan City, Philippines

(Received: November 27, 2019; Revised: February 24, 2020; Accepted: April 05, 2020)

## ABSTRACT

Cave bats are constantly threatened by human encroachment in caves. Species richness of cave bats and conservation issues in caves in Agusan del Sur, in particular, are still poorly known. In this study, conservation status and species richness of cave bats were determined using a combination of mist netting, abundance estimates, and key informant interview methods. Seven species of bats were recorded with low endemism of 29%. The most abundant species was *Hipposideros diadema* which was documented in three caves. Agpan cave was the most species-rich with four species of bats. All the documented bats have “Least Concern” status, however, *H. diadema*, *Ptenochirus jagori* and *Rousettus amplexicaudatus* appear to be locally threatened due to bat hunting pressure and human encroachment inside the caves. All caves were found to be moderately to highly disturbed. Thirteen signs of cave disturbances were recorded where vandalism, treasure hunting, and bird’s nest collection showed high prevalence. Wildemess/Epheso Cave, Magdaguhong Cave, Agpan (Paraiso 2) Cave, and Sampyagit Cave were found to be the most impacted. Results indicate a need to strengthen conservation efforts and mitigate the identified local threats.

**Key words:** conservation, disturbances, endemism, hunting, threats.

## INTRODUCTION

The Cave Management and Conservation Program was established in the Philippines to ensure the sustainable use, protection, development, management, and conservation as well as equitable access to the benefits offered by caves and cave resources. Moreover, Republic Act 9072, also known as the National Cave and Cave Resources Management and Protection Act mandates the formulation, development, and implementation of a national program for the management, protection, and conservation of caves and cave resources (DENR-PAWB, 2008). Caves are biodiversity hotspots as measured by endemism and threat, being characterized by lack of light, cave-specific conditions of humidity, airflow, and source of energy (Whitten, 2009). The subterranean environment harbors a unique fauna of unexpectedly high diversity (Gibert *et al.*, 2009). Organisms found in caves often show high degree of specialised physiological, behavioral adjustments, and often morphological alteration (Biswas, 2010). Obligate cave-dwelling species are known throughout the world but in spite of various taxonomic and biogeographic studies, large scale patterns of diversity have remained obscure (Culver *et al.*, 2006). Caves are non-renewable resources that hold socio-economic and biological importance (DENR-PAWB, 2009).

Tropical caves of Southeast Asia are often home to a wide range of cave fauna, ranging from microscopic invertebrates to snakes and bats at the top of the food

chain (Price, 2004). The Philippine archipelago itself hosts several interesting karst areas such as caves (De Vivo *et al.*, 2009). The Philippine caves exhibit amazing and beautiful formations, thriving ecology, and unique fauna (Wagner, 2013).

The mammalian fauna of the Philippines is quite remarkable due to its high overall species richness and endemism (Heaney *et al.*, 1998; Balete *et al.*, 2009). The Mindanao biogeographic region (including Mindanao, Basilan, Bohol, Leyte, Samar, and other small islands) in particular is noted for its rich mammal fauna (Heaney & Rabor, 1982). Among these mammals, bats are the only group of vertebrates that are able to successfully exploit caves (Kunz, 1982). Over 1,100 species of bats represent almost a quarter of all mammal species where they serve as primary predators of night-flying insects worldwide (Taylor, 2006). They serve as biological pest control and are important in plant pollination, seed dispersal, guano mining, and in education and research (Kasso & Balakrishnan, 2013). Over 1500 caves have been recorded in the Philippines by the Department of Environment and Natural Resources since the implementation of the Cave Management and Conservation Program in 1994. Forty-four species of vertebrates are recorded to dwell in Philippine caves where 34 of these identified species are represented by bats (DENR-PAWB, 2009). Moreover, over 40 species of Philippine bats roost in caves (Heaney *et al.*, 2010). Despite significant natural heritage values of caves and their vulnerability to anthropogenic activities, caves are

\*Corresponding Author's E-mail: [olgamnuneza@yahoo.com](mailto:olgamnuneza@yahoo.com)



**Figure 1.** Geographical location of Agusan del Sur and the caves that were assessed.

Legend: ★ Wildemess Cave, Magdaguhong Cave, Ararat Cave, and Katam-isan Cave;  
 ★ Taonaga Cave; ★ Sampyagit Cave, and Simbahan Cave; ★ Agpan (Paraiso 2)

seldom given attention in environmental management and planning (Smith & Burns, 2011). Caves are essential in maintaining various fauna, however, caves in the Philippines have been continuously subjected to too much destruction and disturbance (Esselstyn *et al.*, 2004). Lack of understanding by the general public as well as policy makers on the ecological importance of caves and associated wildemess values may play a role in the lack of designation of caves as an important resource that requires management and protection (Seiser & Schuett, 2006). Caves in the Philippines, particularly in Mindanao, are threatened due to illegal collection of cave resources, treasure hunting, vandalism, pollution, urbanization, and recreational utilization (Abantas & Nuñez, 2014; Belleza & Nuñez, 2014; Nuñez *et al.*, 2015; Tanalgo & Tabora, 2015).

About 37% of the caves in the Philippines are distributed across the Mindanao biogeographic region (DENR-PAWB, 2009). There are existing several studies on cave fauna in different areas in Mindanao such as those of Takeda & Ng (2001), Balete *et al.* (2009), Warguez *et al.* (2013a), Warguez *et al.* (2013b), Lagare & Nuñez (2013), Abantas & Nuñez (2014), Enriquez & Nuñez (2014), Mag-usara & Nuñez (2014), Novises & Nuñez (2014), Nuñez & Galorio (2014), Sobrepena & Nuñez (2014), Nuñez & Galorio (2015), and Nuñez *et al.* (2015). These studies, however, are mostly focused on invertebrate fauna and herpetofauna in Agusan del Norte, Siargao Island, Bukidnon, Davao, Sarangani, Lanao del Sur, and Lanao del Norte. As far as existing publications are concerned, there are no records regarding cave bats in Agusan del Sur. This study aimed to determine the species richness and conservation status of cave bats in Agusan del Sur.

## MATERIALS AND METHODS

### Study area

The study was conducted in Agusan del Sur (8°30' N 125°50' E). The province has an elongated basin formation with mountain ranges in both the western and eastern sides forming a valley. It is bounded by Compostela Valley from the South, Agusan del Norte from the North, Surigao del Sur from the east, and Bukidnon Province from the west. The southern half of the province is an area filled with swamps and lakes. It has a Type II climate which means that there is no dry season with very pronounced wet season of heavy precipitation. It has an average monthly rainfall of 355 mm and an average temperature of 27.15°C (Agusandelsur.gov.ph, 2009). Eight caves were assessed which are located in three municipalities (Loreto, Trento, and Prosperidad) and one city, Bayugan City. The caves surveyed were the Sampyagit Cave and Simbahan Cave in Loreto, Agusan del Sur; Agpan (Paraiso 2) Cave in Trento, Agusan del Sur; Taonaga Cave in Prosperidad, Agusan del Sur; and Wildemess Cave, Magdaguhong Cave, Ararat Cave, and Katam-isan Cave in Bayugan City. Figure 1 shows the location of the caves assessed.

The coordinates of each cave were recorded using a GPS device. The number of entrances for each cave, the temperature, and humidity of the different zones of each cave, and the presence of bodies of water were recorded. The light intensity was noted (Warguez *et al.*, 2013b). All necessary parameters specified by the DENR-PAWB (2009) cave handbook were documented.

### Description of the caves studied

Cave A, Wildemess/Epheso Cave is located at Sitio Wildemess, Barangay Mt. Carmel Bayugan City. The cave

has three floors with separate entrances. The entrance of the first and second floor has geographical coordinates of 8°48'22.7" N and 125°50'58.7" E with an elevation of 687 meters above sea level (masl) and 8°28'20.38" N and 125°50'51.4" E with an elevation of 733 masl, respectively. The cave is about 200m away from a small patch of comfields and about 1 kilometer (km) away from the nearest community settlements. The first entrance of the cave has a vertical orientation with a slope of about 60° with a height of 1.5 m and a width of 0.5 m. The second entrance has a slight slope of 10° and is 0.61 m high and 1 m wide. The third entrance also has a vertical orientation with a slope of about 60° with a height of 2 m and a width of 1.5 m. The longest and largest chamber of the cave lies on the second floor having an approximate length of 50-80m. A small and shallow stream was found running through the first floor of the cave with a flood depth marking of 0.5 m. Patches of bird and bat guano were present with a depth of 3-5cm. Stalactites were present but were more abundant on the second floor. Few stalagmites were also present but were mostly found on the second floor of the cave. Twilight zone has an ambient temperature of 24°C with light intensity of 218 lux. The deep zone ambient temperature on the other hand was 23°C with 92% relative humidity.

Cave B, Magdaguhong Cave is located at Barangay Mt. Carmel, Bayugan City. The cave lies at the geographic coordinates of 8°47'42.9" N and 125°50'26.4" E with an elevation of 569masl. The surface right above the cave was utilized for com and falcata tree farms. The cave has one entrance which also serves as the exit. The mouth of the cave is 3 m high and 8 m wide. On the left of the cave mouth is a smaller opening, 1 m high and 1 m wide, which leads to the inner portion of the cave. The entire cave floor has a loamy and muddy substrate. Body of water was absent inside the cave, however, a small stream runs in front of the cave mouth. Banana and moss density around the cave premises was low. Guano deposits were absent. Stalactites were abundant especially on the cave mouth and the main chamber. Twilight zone ambient temperature was 24.5°C with a light intensity of 262 lux. The deep zone ambient temperature was 23°C with 92% relative humidity.

Cave C, Ararat Cave is situated at the peak of Barangay Mt. Ararat, Baguayan City, Agusan del Sur. It has geographical coordinates of 8°49'43.1" N and 125°50'15.3" E with an elevation of 693 masl. The cave is approximately 1.5-2 km away from Barangay Mt. Ararat settlements. The area around the cave was planted with a few falcata trees. The cave mouth lies at the bottom of a 10m wide and 15m deep sinkhole. The cave mouth is 10m high and 12m wide with a very steep slope of 75-80°. On the left side of the cave mouth is a smaller and more passable opening with a height of 0.75 m and a width of 1m. Six meters away from the entrance is a muddy portion with a depth of 4-6 inches. This is the only flat portion of the cave. The cave is a single large chamber with a descending orientation. Body of water and guano deposits were absent. Banana and moss density near the cave had moderate abundance. Stalactites were abundant and covered almost the entire cave ceiling whereas stalagmites were moderately abundant. Crystal

linings were also moderately abundant. Twilight zone ambient temperature was 23°C with a light intensity of 9 lux. The deep zone ambient temperature was 22°C with 92% relative humidity.

Cave D, Katam-isan Cave is situated at Barangay Mt. Ararat, Baguayan City, Agusan del Sur. It has geographical coordinates of 8°49'43.1" N and 125°50'15.3" E with an elevation of 598 masl. It was surrounded by a secondary growth forest in the middle part of the hillside of Barangay Mt. Ararat. It is approximately 50 m away from the nearest household. The cave has only one entrance which also serves as the exit with a height of 0.5 m and a width of 1 m. The entrance has a descending slope of approximately 30°. Steel bars were installed at the cave mouth by the landowner to prevent outsiders from entering the cave. The cave has two distinct areas, the dry portion which comprises the first 30 m of the cave and a wet portion which comprises the remaining area beyond the first 30 m. These two portions were divided by a narrow and sandy area that can only be accessed by crawling. A shallow stream runs through the entire length of the wet portion of the cave which possibly drains to a larger stream 50m away from the cave. Guano deposits were absent. Stalactites were moderately abundant while stalagmites were only few. Flowstones and crystal linings were abundant on the wet portion of the cave. Twilight zone ambient temperature was 25°C with a light intensity of 125 lux. Deep zone ambient temperature was 24°C with 92% relative humidity.

Cave E, Agpan (Paraiso 2) Cave is located within the midst of oil palm (*Elaeis guineensis*) plantation in Barangay Manat, Trento, Agusan del Sur. It lies within the geographic coordinates of 8°07'17.5" N, 126°06'08.5" E with an elevation of 83 masl. The cave is 5 km away from Barangay Manat community. It is a very large cave complex with multiple entrance and exit points. The largest opening is about 10m high and 15m wide. It is vertical in orientation with a slope of about 45°. This serves as the main entrance of the main chamber and can be reached by passing through the first chamber of the cave complex. On the opposite end of the main chamber is another opening. It has a height of about 10m and a width of 5m. The third entrance was located at about 600m away from the main entrance. This entrance was only 0.75m wide and 2m high. Aside from the major opening of the cave complex, a number of smaller openings were also present. The main chamber of the cave complex has four major branches which lead to other smaller chambers. Signs of flooding were present inside the main chamber. This was indicated by the presence of oil palm seedlings scattered almost all throughout the cave floor, presence of large logs on one area of the cave, the collapse of some areas on the cave ceiling forming portals, and presence of stagnant water along the main passage and on one of the smaller chambers. There were also indications of deterioration on some areas of the cave complex such as the exposure and drying out of large flowstones. Moreover, a large portion of the cave complex could possibly have collapsed as indicated by the rocky composition of the ground around the cave perimeter. Vast bat guano deposit was present on the entire cave floor of the chambers and passages. The

depth of the deposits ranges from 6 inches to 1 ft. Banana and moss density around the cave complex was moderate. Stalactites were abundant while stalagmites have moderate abundance. Flow stones were also abundant on one of the collapsed areas of the cave complex, however, such flowstones were already dry because of exposure to sunlight, dust particles, and air. Twilight zone ambient temperature was 25.5°C with 92% relative humidity and light intensity of 220 lux. Deep zone ambient temperature was 24°C with 85% relative humidity.

Cave F, Taonaga Cave is located in Barangay Magsaysay at the Municipality of Prosperidad, Agusan del Sur. It lies on the geographic coordinates of 8°2'33.4" N and 126°3'45.7" E with an elevation of 63 masl. It is surrounded by a secondary growth forest and lies within the watershed of Barangay Magsaysay. The cave is 3 km away uphill from the nearest household which lies 8-10 km away from the Barangay Magsaysay community. The mouth of the cave was 2 m high and 5 m wide. On the right side of the cave mouth is a smaller opening that leads inside the cave with a height of 0.75 m and a width of 1.5 m. The first 5-10 m of the cave consists of smooth granite rocks possibly carved by the movement of water within the cave. Only 25-30 m of the cave was explored because the areas beyond it were flooded with water. A small stream also runs along the cave which drains to one of the tributaries of the Barangay Magsaysay watershed. Guano deposits were absent. Stalactites and flow stones were abundant due to the hydrology of the cave. Stalagmites were moderately abundant because of the movement of water inside the cave that hinders the formation of some stalagmites. The twilight zone ambient temperature was 25.5°C with a light intensity of 3 lux. The deep zone temperature was 24.5°C with 92% relative humidity.

Cave G, Simbahan Cave is located near the boundary between barangays Waloe and Kasapa in the Municipality of Loreto, Agusan del Sur. Its location is inside the jurisdiction of Barangay Wabe. It is surrounded by secondary growth forest and lies approximately 70m on the left side of the Umayam River within the geographic coordinates of 8°9'25.3" N and 125°40'26.3" E with an elevation of 63 masl. It is approximately 2.5 km away upstream of the Umayam River from the nearest household. Traversing through the river could be hazardous especially to non-swimmers because of the strong water current and some deep parts of the river. The cave mouth is 4 m high and 6 m wide with a slight descending slope of 30°. On the right side of the cave mouth is a smaller opening with a height of 2 m and a width of 1.5 m. The entire cave floor has loamy and muddy substrate with a depth of 2-4 inches. No water body was present inside the cave. Bat guano deposits were present on the main chamber of the cave with a depth of 2-6 inches. Stalactites were moderately abundant while stalagmites were only few. The twilight zone ambient temperature was 27°C with a light intensity of 3 lux. The deep zone ambient temperature was 26°C with 78% relative humidity.

Cave H, Sampyagit Cave is located near the boundary between barangays Waloe and Kasapa in the Municipality of Loreto, Agusan del Sur. Its location is inside the jurisdiction of Barangay Wabe. It lies about

100m on the right side of the Umayam River within the geographic coordinates of 8°9'16.7" N and 125°41'26.6" E with an elevation of 99 masl. It is surrounded by secondary growth forest and is approximately 2 km away downstream of the Umayam River from the nearest household. Traversing through the river could be hazardous especially to non-swimmers because of the strong water current and some deep parts of the river. The cave has one opening, 4m high and 1.5m wide, which serves both as the entrance and exit. The cave has two main passages which branch 5 m away from the entrance. The passage that branches to the right has muddy substrate with a depth of 6-12 inches. The passage that branches to the left has a loamy substrate with few bat guano deposits. Two small pools were present on the left passage of Sampyagit cave. The first pool was approximately 50m away from the entrance. This pool is about 1m long and 0.5m wide with a depth of about 4 inches. The second pool is about 110m away from the entrance. This pool is located in a chamber that branches from the left passage of Sampyagit Cave. It is about 1.5 long and 0.75m wide with a depth of about 6 inches. Stalactites were abundant while stalagmites were very few. Large dome-shaped flowstones were also present along the left passage of the cave. Twilight ambient temperature was 26°C with a light intensity of 2 lux. The deep zone ambient temperature was 25°C with 78% relative humidity.

#### **Sampling Method**

Mist nets were placed across the mouth of the cave and inside whenever possible, to capture and determine the species richness of the cave-dwelling bats. Sweep nets were also used to collect bats from reachable roosting sites within the caves. Captured bats were placed in cloth bags and were examined immediately for identification after collection. The roosting preferences of the bats were also assessed by adopting the methods used by Warguez *et al.* (2013b). Roosting preference surveys were done from 900hours to 1700 hours. The type of relief as well as the species composition of a particular relief occupied by bats at daytime was assessed for every roosting site. To estimate the bat population, evening emergence surveys outside the cave entrances were done (Mould, 2012). The methods described by Churchill (2008) were followed where at least two observers positioned at suitable vantage points outside the cave entrances before dusk. The number of bats flying out was tallied until emergence activity ceased. Two counting methods were observed: 1) full counts of all bats seen emerging, and 2) establishment of bat emergence rates by using sample one-minute count, multiplying it by the total colony emergence time to provide an overall number estimates. Moreover, estimates were done by counting the number of bats in a 1mX1m area and multiplying it to the estimated total area occupied as roosts. After the identification of the collected and observed bats, their conservation status was checked through the IUCN Red List. Local conservation status was determined according to actual observations and key informant interviews.

#### **Statistical Analysis**

Data analysis was done using Paleontological Statistics (PAST) software version 3. Cave bat species diversity

**Table 1.** Species richness and conservation status of bats in the eight cave sites in Agusan del Sur.

Species	Conservation Status	A	B	C	D	E	F	G	H	Population
<b>Microchiroptera</b>										
<i>Emballonura alecto</i> <sup>1</sup> (Philippine Sheath-tailed Bat)	LC	+	+	-	-	-	-	-	-	M
<i>Hipposideros cervinus</i> <sup>2</sup> (Fawn-colored Leaf-nosed Bat)	LC	-	-	+	-	-	+	-	-	M
<i>Hipposideros diadema</i> <sup>2</sup> (Diadem Leaf-nosed Bat)	LC (LT)	-	-	-	-	+	-	+	+	H
<i>Rhinolophus arcuatus</i> <sup>3</sup> (Arcuate Horseshoe Bat)	LC	-	-	-	-	+	+	-	-	M
<b>Megachiroptera</b>										
* <i>Ptenochirus jagori</i> <sup>4</sup> (Greater Musky Fruit Bat)	LC (LT)	-	+	-	-	+	-	-	-	M
* <i>Ptenochirus minor</i> <sup>4</sup> (Lesser Musky Fruit Bat)	LC	+	-	-	-	-	-	-	-	L
<i>Rousettus amplexicaudatus</i> <sup>4</sup> (Common Rousette Bat)	LC (LT)	-	-	-	-	+	-	-	-	H
<b>Species richness</b>		2	2	1	0	4	2	1	1	
<b>Shannon-Weiner Index</b>		0.45	0.30	0	0	0.70	0.68	0	0	
<b>Evenness</b>		0.78	0.68	1	0	0.50	0.98	1	1	

Legend: <sup>1</sup>Family Emballonuridae, <sup>2</sup>Family Hipposideridae, <sup>3</sup>Family Rhinolophidae, <sup>4</sup>Family Pteropodidae; (A) Wilderness/Epheso Cave, (B) Magdaguhong Cave, (C) Ararat (Nameless) Cave, (D) Katam-isan Cave, (E) Agpan (Paraiso 2) Cave, (F) Taonaga Cave, (G) Simbahan Cave, (H) Sampyagit Cave; Population Estimate: L(Low) - <100 individuals M(Medium) - 100-10,000 individuals H(High) - >10,000 individuals (Arita 1993); (+) Present, (-) Absent; (\*) Philippine Endemic; (LC) Least Concern, (LT) Locally Threatened

and evenness for each cave site were determined. Cluster Analysis was done to determine the similarities of the sampled caves in terms of bat species present. Seriation was used to present the presence or absence of bats in the cave zones utilized as roosting site.

#### **Cave Conservation and Cave Conservation Issues**

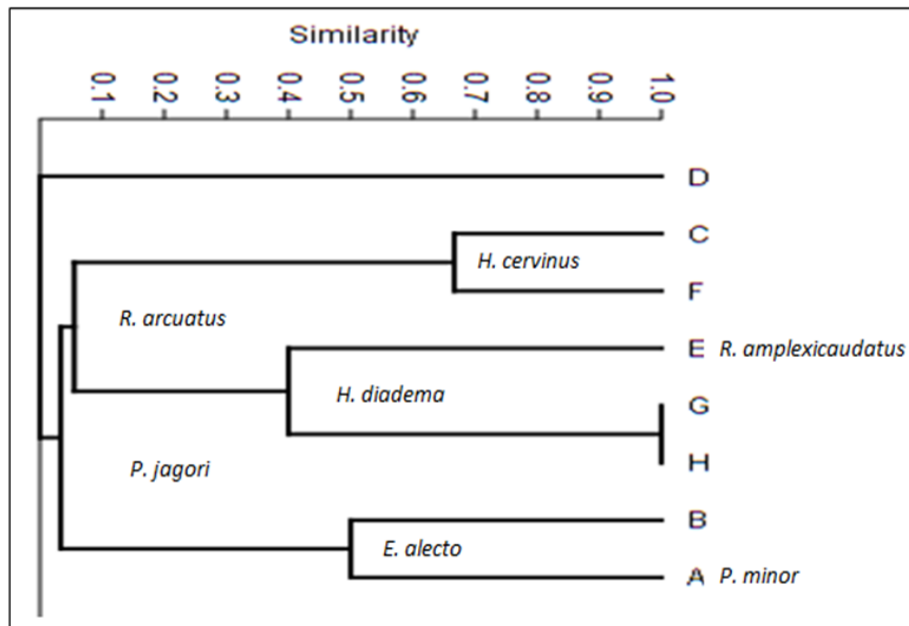
Indicators of anthropogenic disturbances were taken into account. These disturbance indicators were divided into three main categories: 1) External Indicators: quarrying, vegetation alteration, human settlements and infrastructure (pipelines, roads, etc.); 2) Internal Indicators: debris/garbage, vandalism, tourism/visitation, treasure hunting, mineral mining, guano mining, swiftlet nest collection and construction inside cave (cave gating, installation of lighting systems, etc.); and 3) Indications of Bat Hunting: presence of bamboo poles, remnants of bonfire, torches, nets and mud balls. Key informant interviews were conducted in the community adjacent to the cave sampling site to gather information regarding the knowledge of the locals about the bats as well as the threats towards the bat population within the area. Information regarding the local uses of the bats was also gathered during the interviews.

## **RESULTS AND DISCUSSION**

Seven of the eight surveyed cave sites were found to host bats. Seven species of bats from four different families were positively identified within the surveyed caves. These bat species were the Philippine Sheath-tailed Bat (*Emballonura alecto*), Fawn-colored Leaf-nosed Bat (*Hipposideros cervinus*), Diadem Leaf-nosed Bat

(*Hipposideros diadema*), the Philippine endemic Greater Musky Fruit Bat (*Ptenochirus jagori*), the Lesser Musky Fruit bat (*Ptenochirus minor*), the Common Rousette Bat (*Rousettus amplexicaudatus*), and the Arcuate Horseshoe Bat (*Rhinolophus arcuatus*) (Table 1).

Compared to the number of recorded bat species from other areas in the Philippines, these results were higher than in Agusan del Norte (Warguez *et al.*, 2013b) and Tagoloan, Lanao del Sur (Abantas & Nuñez, 2014) but lower than in North Cotabato (Gomez *et al.*, 2005; Achondo *et al.*, 2014; Tanalgo & Tabora, 2015), Cagayan de Oro (Lobite *et al.*, 2013), Siargao Island (Nuñez & Galorio, 2014), Panay Island (Mould, 2012), Pollilo Island (Alviola, 2000), Marinduque Island (Alviola *et al.*, 2015), Danjungan Island Negros Occidental (O'malley *et al.*, 2006), and Bukidnon and Davao Oriental (Galorio & Nuñez, 2014). Endemism was low at 29%. Due to the limitations during the sampling, the number of bat species recorded in this study is still a gross underestimate as a reflection of the low number of caves surveyed whereby the encountered species only accounts 13% out of the 53 species found in Mindanao (Ingle *et al.*, 1999). Moreover, the survey time for each cave was limited where the survey for each cave was done only once. Furthermore, the sampling methods implemented in capturing bat samples were limited to the use of mist-netting techniques and utilization of sweep nets. This provides an emphasis on the need of adequate survey time per cave and other supplemental novel sampling technique such as acoustic sampling with the use of bat detectors (Petrov *et al.*, 2014; Alviola *et al.*, 2015). Moreover, the presence of multiple openings in the cave, especially smaller undetected holes in the cave wall/



**Figure 2.** Dendrogram of the similarities of the eight caves sites on Agusan del Sur. (A) Wilderness/Epheso Cave, (B) Magdaguhong Cave, (C) Ararat (Nameless) Cave, (D) Katam-isian Cave, (E) Agpan (Paraiso 2) Cave, (F) Taonaga Cave, (G) Simbahan Cave, (H) Sampyagit Cave.

ceiling makes the probability of capturing bat specimens lower. Such was the case in Wilderness/Epheso Cave and Agpan (Paraiso 2) Cave where the multiple openings of the cave provided bats more exit points thus lowering the capture efficiency.

The conservation status of all of the bats encountered was classified as Least Concern by IUCN. However, some of the recorded bat species such as *H. diadema*, *P. jagori* and *R. amplexicaudatus* could be locally threatened due to the pressures of bat hunting activities and encroachment of humans inside the caves. Bat hunting activities have been shown to threaten bats in South Central Mindanao where larger bat species such *H. diadema* and *R. amplexicaudatus* are being hunted for food (Tanalgo & Tabora, 2015). The same observation was recorded in Panay Island where large colonies of *R. amplexicaudatus* were recorded to experience decline in its population due to continuous hunting activities (Mould, 2012). Bat hunting has also been identified as a major threat to bats on Marinduque Island (Alviola *et al.*, 2015), Cebu (Paguntalan & Jakosalem, 2008), and Mt. Matutum Protected Landscape (Nuñez *et al.*, 2015). Bats from families Pteropodidae, Hipposideridae, Rhinolophidae, and Emballonuridae are among the most threatened in insular Southeast Asia. Regional threats to bats mostly stem from the expanding human populations and their increasing pressure on natural ecosystems (Wiles & Brooke, 2009). Guano mining is also another threat to the bats especially in Agpan (Paraiso 2) Cave, Simbahan Cave, and Sampyagit Cave, where guano harvesting was reported. Mining the guano of cave-dwelling bats often results to overharvesting of guano which leads to the disturbance of cave roosting bats (Furey & Racey, 2016). Juvenile *R. amplexicaudatus* and *P. jagori* were recorded in Agpan (Paraiso 2) Cave which is an indication of a potential maternity roost in the cave that could be disturbed by noise and people entering the cave during guano mining.

Cave-dwelling bats are very sensitive to roost disturbance (Malotaux, 2012) which is intensified by the availability of electric torches that enable people to venture deeper into the cave (Palmeirim *et al.*, 2007). Roosting bats are most disturbed by light intensity of flashlights and noise from frequent cave visitations which force female bats in maternity roost to expend more energy by transferring from one roost site to another (Mann *et al.*, 2002). Disturbances at maternity sites often lead to females abandoning their young (Taylor, 2006). In addition to the current threats to bat populations, the low reproductive rate of bats places them at risk because of their inability to quickly recover from population declines (Mickleburgh *et al.*, 2002).

Cluster analysis was done to draw out the similarities of the caves in terms of the species of bat present. The dendrogram for the cave similarities is shown in Figure 2. Caves G and H both have one species, *H. diadema*, thus having 100% similarity. This species was also present in Cave E, making it 40% similar to caves G and H. Caves C and F have 65% similarity by sharing *H. cervinus*. Caves A and B have 50% similarity where *E. alecto* was the species common to both caves. Cave D has 0% similarity to other caves because of the absence of any bat species.

All the caves studied have low species diversity although comparing all cave sites, Agpan (Paraiso 2) Cave was the most diverse and species-rich with a Shannon-Weiner index of 0.70 and four species of bats present. However, it has the least uniform pattern of distribution of cave bat species. Taonaga Cave, Wilderness/Epheso Cave, and Magdaguhong Cave had Shannon-Weiner Indices of 0.68, 0.45, and 0.30, respectively. These caves also have the same species richness with two species of bats present that are more evenly distributed compared to Agpan (Paraiso 2) Cave. Ararat Cave, Simbahan Cave, and Sampyagit Cave only have one bat species each thus having zero diversity. Wynne &

CAVES	A			B			C			D			E			F			G			H		
CAVE ZONES	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
<b>Microchiroptera</b>																								
<i>E. alecto</i>			■			■												■						
<i>H. cervinus</i>									■											■				■
<i>H. diadema</i>																								
<i>R. arcuatus</i>																								
<b>Megachiroptera</b>																								
<i>P. jagori</i>						■																		
<i>P. minor</i>		■																						
<i>R. amplexicaudatus</i>																								

**Figure 3.** Figure showing the distribution of bats in the eight caves in Agusan del Sur and the cave zones they occupy.

Legend: (A)Wilderness/Epheso Cave, (B)Magdaguhong Cave, (C)Ararat (Nameless) Cave, (D)Katam-isan Cave, (E)Agpan (Paraiso 2) Cave, (F)Taonaga Cave, (G)Simbahan Cave, (H)Sampyagit Cave; 1-T wilight Zone, 2- Transition Zone, 3- Dark Zone

Pleytez (2005) in their study, used the modified bat diversity rank system where less than 2 species is considered low diversity, 3-5 species as medium diversity, 6 or more species is regarded as high diversity. In this study, we refer to species richness where Agpan (Paraiso 2) Cave with four species is considered moderately species-rich while other cave sites with only 1-2 species are of low species richness.

No bats were captured and there were no signs of presence (e.g. bat droppings and bat stains) observed at Katam-isan Cave. This could be due to the cave's proximity to household settlements and easy accessibility. Nuñez & Galorio (2014) recorded the same observation at Siargao Island protected landscape and seascape where bats were not documented in caves near human settlements. Increased human populations and facilitated access to caves lead to increased disturbance in caves which in turn causes a decline in cave-dwelling species (Malotaux, 2012). Lower bat activity and richness are associated with high-density residential areas (Gaisler *et al.*, 1998; Threlfall *et al.*, 2012) due to the sensitivity of bats to the effects of changing urban forms (Kunz & Reynolds, 2003; Kunz *et al.*, 2008; Jones, 2009; Hale *et al.*, 2012).

The recorded fruit and insectivorous bats were observed to occupy different zones in the caves. Figure 3 shows the absence or presence of bats in the different caves and the cave zones they occupy.

All insectivorous bat species were observed in the dark zone of the cave. *E. alecto* was observed to occupy the innermost part of both Wilderness/Epheso Cave and Magdaguhong Cave. The same was true for *H. cervinus* at Ararat Cave and Taonaga Cave. *R. arcuatus* was observed to roost in a chamber opposite to the one utilized by *H. cervinus* in Taonaga Cave. *H. diadema* was also observed to roost in the inner chambers in Agpan (Paraiso 2), Simbahan, and Sampyagit caves. Notably, the caves where *H. diadema* was recorded were large caves with high ceiling and multiple chambers. Most bats prefer to roost in caves with high ceiling to avoid disturbance and threats inside the caves (Warguez *et al.*, 2013b). Fruit bats on the other hand, except for *R. amplexicaudatus*, roosted near the transition zones of the caves with partial illumination. Among the members of

family Pteropodidae, only those from the genus *Rousetus* has the capability to echolocate (Kunz, 1982). *R. amplexicaudatus* was observed even in the innermost area of Agpan (Paraiso 2) Cave with total darkness. Unlike *R. amplexicaudatus*, the Philippine endemic *P. jagori* and *P. minor* were both roosting in the transition zone a few meters away from the entrance of Wilderness/Epheso cave and Agpan (Paraiso 2) cave, and Magdaguhong cave, respectively. Such preference could be due to the easier accessibility and escape route from the cave when threatened or disturbed (Warguez *et al.*, 2013b). The same roosting zonation patterns for both insectivorous and frugivorous bats were observed on Panay Island (Mould, 2012), Tagoloan, Lanao del Norte (Abantas & Nuneza, 2014), and Marinduque Island (Alviola *et al.*, 2015) where insectivorous bats generally roost in the inner cave zones while frugivorous bats roost in partially illuminated transition zones of the cave.

#### Cave Conservation and Conservation Issues

The fine balance of tropical cave ecosystems is being upset by a variety of ways through unregulated caving activities and unsustainable cave resource exploitation (Price, 2014). Such disturbances are identified by assessing the physical evidences of anthropogenic disturbances for each cave based on the classified indicators. The following disturbance indicators were designated into three general categories: external signs, internal signs, and indications of bat hunting. External signs include quarrying, vegetation alteration (changing natural vegetation with plantation and mono cropping), human settlement and infrastructures (pipelines, roads, etc.), within 50m radius. Internal indicators were debris/garbage dumping, vandalisms/graffiti, visitation/tourism use, treasure hunting, mineral mining, guano harvesting, swiftlet nest collection, and constructions inside caves. Presence of bamboo poles, remnants of bonfire, torches, net and other indicators were noted for bat hunting activities. The presence of the different physical evidences of disturbance is summarized in Table 2.

Thirteen physical evidences of disturbance were recorded for all the caves surveyed in Agusan del Sur. All the caves surveyed showed signs of disturbances. The highest number of disturbances was recorded in

**Table 2.** Observed physical evidences of disturbance in each surveyed cave in Agusan del Sur.

Disturbance Indicator	Cave								Total	% Occurrence
	A	B	C	D	E	F	G	H		
<b>External Signs</b>										
1.Quarrying	-	-	-	-	-	-	-	-	0	0
2.Vegetation alteration	-	+	-	-	+	-	-	-	2	25
3.Human settlement	-	-	-	+	-	-	-	-	1	12.5
4.Infrastructure	-	-	-	-	-	-	-	-	0	0
<b>Internal Signs</b>										
1.Debris/Garbage	+	-	-	-	+	-	-	+	3	37.5
2.Vandalism	+	+	-	+	-	-	-	+	4	50
3.Tourism/Visitation	+	-	-	-	+	-	-	-	2	25
4.Treasure hunting	+	-	-	-	-	+	+	+	4	50
5.Mineral mining	-	-	-	-	-	-	-	-	0	0
6.Guano mining	-	-	-	-	+	-	+	+	3	37.5
7.Swiftlet nest collection	+	+	+	-	-	-	-	+	4	50
8.Construction inside cave	+	-	-	+	-	-	-	-	2	25
<b>Indications of Bat Hunting</b>										
1.Presence of bamboo poles	-	-	-	-	-	-	+	+	2	25
2.Remnants of bonfire	-	+	-	-	-	-	-	-	1	12.5
3.Torches	-	-	-	-	-	-	-	-	0	0
4.Nets	-	-	-	-	-	-	-	+	1	12.5
5.Use of mud balls	-	-	-	-	-	-	-	+	1	12.5
<b>% Incidence</b>	<b>35.3</b>	<b>23.5</b>	<b>5.9</b>	<b>17.6</b>	<b>23.5</b>	<b>5.9</b>	<b>17.6</b>	<b>47.1</b>		

Legend: (A) Wilderness/Epheso Cave, (B) Magdaguhong Cave, (C) Ararat (Nameless) Cave, (D) Katam-isan Cave, (E) Aggan (Paraiso 2) Cave, (F) Taonaga Cave, (G) Simbahan Cave, (H) Sampyagit Cave; (+)– Present/Observed, (-)– Absent.

Sampyagit Cave with eight indicators. Six indicators were noted in Wilderness/Epheso Cave. On the other hand, two caves, the Ararat Cave and Taonaga Cave with only one observed indicator showed the least disturbance. The most common signs of disturbance present were internal indicators. Vandalism/graffiti (Figure 4A), swiftlet nest collection, bat hunting (Figure 4C), and treasure hunting (Figure 4D) were the most prevalent with 50% occurrence. Pristine caves were not observed in this study.

Sampyagit Cave had the highest percentage of disturbance incidence that showed extensive internal disturbances and evidences of bat hunting activities. Treasure hunting excavations (Figure 5F) were very prominent and were observed from the twilight zone of the cave to the farthest area explored. Moreover, the locals also destroyed some of the rocks (Figure 5E) inside the cave in hopes of finding treasure beneath the rocks. According to the locals, the Japanese soldiers once used the area around Sampyagit Cave as a camp during their occupation of the Philippines which made the local people believe that Japanese treasures could also be hidden inside the cave. Furthermore, the locals also reported that some of them were actually able to find treasure such as gold within the area around the cave. Due to the historical background of the area, treasure hunting activities in Sampyagit Cave were more evident and on a greater extent compared to other caves that showed signs of treasure hunting activities. The locals also reported that they covered the mouth of Sampyagit Cave with logs at one time in order to prevent other people to conduct treasure hunting inside Sampyagit Cave. Guano mining was also evident in Sampyagit Cave as indicated by the empty

sacks (Figure 5D) in one of the main passages of the cave. The locals use the harvested guano from the cave as fertilizer for their corn farms. Bat hunting activity was also prevalent in Sampyagit Cave and was reportedly done by both adults and children. Fresh bamboo poles (Figure 5B) were scattered along the passages of cave indicating recent bat hunting activities. These poles were also used by the locals to collect swiftlet nests. A few mosquito nets (Figure 5C) which were used as improvised mist nets to capture bats were also found. As a consequence of the frequent entry of some locals due to treasure hunting, bat hunting, nest collection, and guano mining, debris such as used sacks, cans, and plastics bags were scattered along the passages of Sampyagit Cave. Simbahan Cave, which belongs to the same locality with Sampyagit Cave, also showed signs of treasure hunting, guano mining, and bat hunting activities but on a lesser extent, compared to Sampyagit Cave.

The high extent of disturbances in Sampyagit and Simbahan caves could be attributed to the lack of local cave resource conservation ordinances and regulations in the Municipality of Loreto that led to the unregulated and unsustainable use of Sampyagit Cave and Simbahan Cave. Both Sampyagit Cave and Simbahan Cave belong to an Ancestral Domain of the Manobos in the Municipality of Loreto. Under Section 9(a) of Republic Act 8371 or the Indigenous Peoples' Rights Act of 1997 (IPRA), it is the responsibility of the Manobos in Loreto to maintain the ecological balance in their ancestral domain by protecting its flora and fauna and its natural resources including caves. To achieve this purpose, a collaboration between the National Commission on Indigenous Peoples (NCIP), DENR and the Local Government



**Figure 4.** Some of the prevalent disturbances found in caves in Agusan del Sur: (A) Vandalism/Graffiti, (B) remnants of the living quarters in Wilderness/Epheso Cave, (C) Fresh Bamboo pole used for stunning bats and harvesting nests in Wilderness/Epheso Cave, (D) Treasure hunting hole.



**Figure 5.** Documented Disturbance in Sampyagit Cave A) Log used to cover the entrance, B) Bamboo pole used for bat hunting and nest collection, C) Mosquito net used as improvised mist net, D) Sack used for guano harvesting, E) Broken rocks due to treasure hunting, F) Treasure hunting excavation, G and H) Mudballs used to stun roosting bats



**Figure 6.** Internal disturbance indicators at Wilderness/Epheso Cave and Magdaguhong Cave – (A) Vandalism/Graffiti at Wilderness Cave and (B) Magdaguhong Cave, (C) Treasure hunting hole at Wilderness Cave and remnants of the utilization of Wilderness Cave as a refuge shelter (D) Logs and posts, (E) Plastic sheet and (F) cloth.

Unit of Loreto is highly essential in order to formulate management plans and programs as well as to educate and empower the Manobo community for cave resource conservation and protection. Section 57 of R.A. 8371 (IPRA) states that the Indigenous Peoples/Indigenous Cultural Communities have the priority rights in the harvesting, extraction, development or exploitation of any natural resources within their ancestral domain, however, it is very important to take into consideration the provisions of DENR Administrative Order No. 04- Cave Management and Conservation Program and Republic Act 9072 – National Caves and Cave Resources Management and Protection Act that mandates the sustainable use and conservation of cave resources. Both Sampyagit Cave and Simbahan Cave could be considered as “significant caves” as defined by Section 3(f) and Section 6 of R.A. 9072 due to their historical, cultural, and ecological values. Sampyagit Cave and Simbahan Cave also serve as roosting sites for a large population of *H. diadema* that is threatened by the activities of the locals inside the caves. Caves with large bat populations should be given adequate importance to be designated or included in a protected area (Mould, 2012). This further emphasizes the need for both Simbahan Cave and Sampyagit Cave to be given due consideration to protect the large population of *H. diadema* in these caves from the negative impacts caused primarily by bat hunting and treasure hunting activities.

Internal signs of disturbance were recorded to be most prominent in the Wilderness/Epheso Cave. The aggregation of these internal signs of disturbance in caves is a direct effect of the unregulated entry of humans in caves. Debris/garbage and vandalism were found to be more persistent in Wilderness/Epheso Cave compared to other surveyed caves. Debris such as plastics (Figure 6E), bottles, used clothes/textiles (Figure 6F), and wood posts (Figure 6E) were found scattered

all throughout the second floor of the cave. According to the locals, they utilized Wilderness/Epheso Cave as a refuge shelter from December of 1999 to January of 2000. They believed that the world was about to end in the year 2000 and only those who can hide inside the cave will survive. More than 40 families took shelter inside the cave where each family built a small quarters made of wood inside the cave. Moreover, they also installed lighting systems and generator inside the cave. After more than a decade, the remnants of the materials used by the locals inside the cave were still present. Bats are highly disturbed by the light intensity from the installation of lighting system and from the noise caused by human activities inside caves (Mann *et al.*, 2002). According to Sobrepeña & Nuñez (2014), cave ecosystems become more threatened with higher incidence of anthropogenic activities inside caves. Indication of treasure hunting was also observed at Wilderness/Epheso Cave and was positively confirmed by the locals. Its most notable sign was a 2m deep hole (Figure 6C) near the entrance of the second floor of the caves. According to the locals, treasure hunting activities in the cave were also done on the first floor of the cave but its indicators were not observed. Bat hunting was absent because majority of the locals that reside in Sitio Wilderness practice vegetarian diet as part of their religious belief. In Tagoloan Lanao del Sur, the installation of lighting system inside caves, noise from cave visitations, nest harvesting, and vandalism have been shown to assert negative impacts on bats and other cave-dwelling organisms. Magdaguhong Cave showed the highest degree of vegetation alteration. The surface directly above the cave was converted into falcata tree plantation, which was recently harvested during the study. A small hole on the ceiling of the terminal end of the cave was observed which could possibly be caused by the conversion of the surface to agroforest monoculture. The area adjacent to the cave was also

converted into corn farms. The farmers working in the adjacent corn farm also utilized the cave as a resting area. Despite the distance to the human settlements, both Wildemess/Epheso Cave and Magdaguhong Cave have relatively easier accessibility compared to other caves surveyed in this study. Because of this, vandalism and graffiti were more extensive in Wildemess/Epheso Cave (Figure 6A) and Magdaguhong Cave (Figure 6B) among the caves studied.

Among the localities studied, only Barangay Mt. Carmel in Bayugan City made some efforts to protect its cave resources. The office of Brgy. Mt. Carmel issued an ordinance that prohibits the collection of swiftlet nests in Wildemess Cave. However, there still seems to be a lack in implementing and enforcing such ordinances as evidenced by reports on nest collection and treasure hunting activities in the cave. The lack of the enforcing capability of the barangay could be attributed to the distance of the cave from the community and the lack of manpower to monitor the entry of locals in the cave. Like Sampyagit Cave and Simbahan Cave, caves in Brgy. Mt. Carmel particularly Wildness/Epheso Cave could also be considered as significant caves under R.A. 9072 because of their local historical significance and ecological values. Caves with vulnerable, fragile, threatened, endangered or endemic species should be given adequate management (Arita, 1993). Moreover, under Article II Section 25 of R.A. 9147 – Wildlife Resources Conservation and Protection Act, which states that areas outside protected areas with species endemism and/or richness that are facing anthropogenic pressures/threats can be designated as critical habitats. Both Wildemess/Epheso Cave and Magdaguhong Cave harbor the Mindanao endemic *P. minor* and the Philippine endemic *P. jagori*, respectively. Hence, management plans and impact mitigation is needed for the protection of these endemic species as well as the cave resources in Barangay Mt. Carmel, Bayugan City.

The largest scale of guano harvesting was reported in Agpan (Paraiso 2) Cave in the Municipality of Trento. The locals as well as the guides confirmed the regular harvesting of guano in the cave. In Borneo, the unregulated guano mining and other cave resource exploitation have been related to the potential decline in species richness and abundance of bats (Rahman *et al.*, 2011).

Signs of heavy flooding were also documented in Agpan (Paraiso 2) Cave. These were indicated by the presence of large logs and other debris (Figure 7A) in one part of the cave complex. Another notable sign of flooding in Agpan (Paraiso 2) Cave was the presence of oil palm seedlings (Figure 7B) scattered along the main passage of the cave. Because of the rich guano content of Agpan (Paraiso 2) Cave, the oil palm seedlings were still able to germinate even in total darkness. Bat hunting activities were also reported but its indicators were not observed in Agpan (Paraiso 2) Cave. An area directly above Agpan (Paraiso 2) Cave complex was also converted into falcata tree plantation. Among the caves studied, only Agpan (Paraiso 2) cave showed multiple species assemblage with four species of bats recorded. Moreover, two of these species, *H. diadema* and *R. amplexicaudatus*, were observed to have large populations. Agpan (Paraiso 2) Cave also serves as a roosting site of the Philippine endemic *P. jagori*. Juvenile *R. amplexicaudatus* was also observed roosting in holes at the ceiling of the cave which could be an indication of a potential maternity roost. Hence, it can be inferred that Agpan (Paraiso 2) Cave has relatively high ecological significance and socioeconomic value.

According to Arita (1993), an effective plan for conservation of cave bats would require a double strategy. First is the protection of caves with unusually high diversity and multiple species population and secondly, the management of caves utilized by bats with special concern (fragile, vulnerable, and endemic species). Considering the results in the present study, it is imperative to implement immediate action to mitigate and reduce the impacts of anthropogenic disturbances in Agpan (Paraiso 2) Cave which harbors large populations of four different bat species.

Katam-isan Cave and Ararat Cave in Barangay Mt. Ararat Bayugan City were both found on a land owned by the Brgy. Captain. Notably, no bats were documented at Katam-isan Cave. This could be due to its proximity to the local community. Furthermore, compared to other caves surveyed, Katam-isan Cave also had the easiest accessibility and easy entrance. Increasing development in areas around cave had been considered as one of the main pressures to bats and other cave inhabitants (Price, 2014). The same observation was noted by



**Figure 7.** Signs of heavy flooding at Agpan (Paraiso 2) Cave indicated by A) logs and other debris and B) oil palm seedlings.

Nuñez & Galorio (2014) on Siargao Island where bats were absent in a cave near residential areas. Ordinances and cave management programs were absent, however, the land owner took the initiative of installing a gate at the mouth of Katam-isán Cave to prevent the entry of treasure hunters and nest collectors. The installation of the gate seems to have helped in minimizing cave disturbance as reflected by the minimal presence of disturbance indicators inside the cave. However, gating the mouth of Katam-isán Cave is a violation of Section 7(a) of Philippine Republic Act 9072 that prohibits any alteration of the free movement of any animal or plant life into or out of cave. However, there were reports of nest collection, especially in Ararat cave.

Both Ararat Cave and Taonaga Cave only have one sign of disturbance noted. This could be due to the remoteness of both caves. Ararat Cave can only be accessed by experienced nest collectors because of its difficult entrance and slippery and sloping terrain. On the other hand, the disturbance noted in Taonaga Cave was a 1m deep hole at the cave mouth which indicates treasure hunting activity.

Taonaga Cave is hidden within a secondary growth forest and is within a locally protected watershed. This could be one of the major contributing factors that minimized anthropogenic disturbance in the cave despite the lack of specific regulations and ordinances that would protect Taonaga Cave. Moreover, the Municipal office of Prosperidad was also actively conducting assessments of natural resources, including cave ecosystems, to formulate proper and comprehensive management program.

Disturbances such as human settlements near caves, vandalism/graffiti, treasure hunting, nest collection, and bat hunting were found to have negative effects on cave bat species richness but significant relationships were not found. Nonetheless, tropical caves which are rich in cave fauna appear to have declining number of some of their inhabitants, particularly bats (Kock *et al.*, 2000; Biswas, 2009; Price, 2014). According to Sedlock *et al.* (2014) most of the surveyed caves in the country have been subjected to either current or historical human disturbance, primarily by nest collectors, bat hunting, guano harvesting for fertilizer use, habitat alteration (Hutson *et al.*, 2001; Jones *et al.*, 2009), vandalism, treasure hunting (Esselstyn *et al.*, 2004), tourism, and unregulated entry (Tanalgo & Tabora, 2015). The unregulated entry of people in caves which brought about vandalism and improper waste disposal, is considered as a major threat to cave-dwelling bats (Bucs *et al.*, 2012; Petrov *et al.*, 2014). Stress from anthropogenic disturbances in cave could be a key limiting factor for most cave-dwelling species (Figueroa & Nuñez, 2013). Habitat alteration such as logging activities around karst areas such as caves has been known to reduce shade and humidity, drive away cave-dwelling organisms that supply organic matter to guano communities (Culver *et al.*, 2000), and diminish bat populations that rely heavily on surrounding forests for foraging (Clements *et al.*, 2006). Tropical bats depend most of all on forests. The conversion of habitats into agricultural sites is considered as a probable cause of declining bat populations (Rahman

*et al.*, 2011). According to Jones *et al.* (2009), the conversion of land into agricultural purposes prompts the increase usage of pesticides which greatly reduces the food availability for insectivorous bats and removes valuable foraging and commuting habitats. Hunting bats for food is also considered as one of the common threats to bats where larger bat species are preferred by bat hunters (Tanalgo & Tabora, 2015). Notably, caves in this study that showed signs of bat hunting activities were those utilized by larger species of bats such as *P. jagori*, *R. amplexicaudatus*, and *H. diadema*. Decline in bat populations is presumably an effect to human-induced stress such as cave disturbances and bat overhunting (Kasso & Balakrishnan, 2013). Bats and other small game species are exploited regularly on a subsistence basis due to the greater hunting success that they provide (Wiles & Brooke, 2009). Several cave studies in the Philippines such as on Siargao Island (Nuñez & Galorio, 2015), Sarangani Province and Lanao del Sur (Belleza & Nuñez, 2014), Wao (Sobrepeña & Nuñez, 2014), Tagoban Lanao del Norte (Abantas & Nuñez, 2014), Cagayan de Oro City (Lobite *et al.*, 2013), Davao Oriental and Northern Mindanao (Lagare & Nuñez, 2013, Nuñez *et al.*, 2015), North Cotabato (Tanalgo & Tabora, 2015), Marinduque Island (Alviola *et al.*, 2015), Pollilo Island (Alviola, 2000), Panay Island (Mould, 2012), Central Philippines (Sedlock *et al.*, 2014), Danjungan Island, Cauayan, Negros Occidental (O'malley *et al.*, 2006), and Palawan (Esselstyn *et al.*, 2004) also reported persistent disturbances such as bat hunting, nest collection, treasure hunting, habitat alteration, guano mining, vandalism, and unregulated cave visitations. Thus, it can be inferred that the cave disturbances observed in this study are not only a problem in Agusan del Sur but are present in other caves in the country.

One of the general cave conservation issues in Agusan del Sur is that almost all of the barangay leaders were not aware of Republic Act 9072 –National Caves and Cave Resources Management and Protection Act, hence failed to issue and implement regulations that would protect the cave ecosystem and its fauna in their respective barangays. Moreover, most of the locals, especially the guides who frequently enter the caves, were not aware of the ecological importance of bats and their habitat. Most of them view bats as source of food along with other cave fauna such as snakes. They also see caves as a source of revenue generation without considering the impacts of unsustainable exploitation of cave resources. The need for the establishment of an environmental education program in local communities seems to be imperative (O'malley *et al.*, 2006) especially in highly-impacted caves such as Wildemess/Epheso Cave, Magdaguhong Cave, Agpan (Paraiso 2) Cave, and Sampyagit Cave. Nonetheless, other cave sites also need to have immediate mitigation and management programs. Upon the declaration of a karst landscape such as caves as protected areas, it is also important to establish buffer zones between the protected area and the neighboring land to reduce the influence and consequences of environmental damage to the adjacent lands (Barany-kevie, 1999; Simoes *et al.*, 2014). Issuance of Protected Area Community Based Resource Management Agreements

(PACBRMA) can be granted by the Department of Environment and Natural Resources (DENR) with recommendation from the Protected Area Management Board (PAMB) to provide rights to tenure to qualified communities and indigenous peoples (IPs) within protected areas. Through this, communities in the protected areas are given the rights to manage, develop, utilize, conserve, and protect the resources along multiple use zones of protected area and buffer zones parallel with the protected area management plans (Naz, 2012).

The caves studied showed potential to be established as ecotourism sites. Establishing the caves as ecotourism sites could help protect the caves by providing alternative economic benefits but should be implemented sensitively (Mould, 2012). The management of caves for tourism needs to be more protective of the cave through the control of visitors and applying strategies that would mitigate impacts where only already impacted caves should be restored and developed for tourism rather than opening new caves for tourism purposes (Hutacharem, 2004).

## CONCLUSION

Seven species of bats were documented with two endemic species recorded, which could still be a gross underestimate due to sampling limitations. All recorded bat species are categorized as of Least Concern status, but could be locally threatened especially the larger bat species. All microchiropterans were encountered at the dark zone of caves while megachiropterans were observed at the transition zone. The most distributed bat species was *H. diadema* which was documented in three cave sites. Internal indicators of disturbance on the surveyed caves were predominantly observed. Wildemess/Epheso Cave, Magdaguhong Cave, Agpan (Paraiso 2) Cave, and Sampyagit Cave were found to be the most impacted.

## ACKNOWLEDGMENT

We acknowledge the LGU-PENRO of Agusan del Sur for the logistical support.

## REFERENCES

- Abantas, A. D. and Nuñez, O. M. 2014. Species diversity of terrestrial vertebrates in Mighty Cave. *Journal of Biodiversity and Environmental Sciences* 5(6): 122–132.
- Achondo, M. J. M. M., Casim, L. F., Tanalgo, K. C., Agduma, A. R., Bretaña, B. L. P., Supremo, J. P., Mancao, L. S., Salem, J. G. S. and Bello, V. P. 2014. Occurrence and abundance of fruit bats in selected conservation areas of North Cotabato, Philippines. *Asian Journal of Conservation Biology* 3(1): 3-7.
- Agusandelsur.gov.ph. 2009. Geography. <http://agusandelsur.gov.ph/assets/geography.html>. Cited 29 June 2019.
- Alviola, P. A. 2000. The distribution and ecology of bats in the Pollilo Islands, Philippines. In Bennett, D. (ed): *Wildlife of Pollilo Island, Philippines*. Viper Press, pp. 105-124.
- Alviola, P. A., Macasact, J. P. A., Afuang, L. E., Cosico, E. A. and Eres, E. G. 2015. Cave-dwelling bats of Marinduque Island, Philippines. *Mus Pub Nat His* 4: 1-17.
- Arita, H. T. 1993. Conservation biology of the cave bats of Mexico. *Journal of Mammalogy* 74: 693-702.
- Balete, D. S., Heaney, L. R., Veluz, M. J. and Rickart, E. A. 2009. Diversity patterns of small mammals in the Zambales Mts., Luzon, Philippines. *Mammalian Biology* 74(6): pp.456–466.
- Barany-Kevei, I. 1999. Impacts of agricultural land use on some Hungarian karst regions. *International Journal of Speleology* 28: 89-98.
- Belleza, G. D. and Nuñez, O. M. 2014. Herpetofaunal Diversity and Endemism in Selected Caves of Sarangani Province and Lanao del Sur, Philippines. *Advances in Environmental Biology* 8(21): 411–418.
- Biswas J. 2009. The Biodiversity of Krem Mawkhyrdop of Meghalaya, India, on the verge of extinction. *Current Science* 96(1): 275-289.
- Biswas, J. 2010. Kotumsar Cave biodiversity: A review of cavernicoles and their troglobiotic traits. *Biodiversity and Conservation* 19(1): 275–289.
- Bucs, S., Jere, C., Csosz, I., Barti, L. and Szodoray-Paradi, F. 2012. Distribution and conservation status of cave-dwelling bats in Romanian Western Carpathians. *Vespertilio* 16:97-113.
- Chokkalingam, U., Carandang, A. P., Pulhin, J. M., Lasco, R. D., Peras, R. J. J. and Toma, T. 2006. One Century of Forest Rehabilitation in the Philippines: Approaches, Outcomes and Lessons. Center for International Forestry Research (CIFOR), Bogor, Indonesia, p 132.
- Churchill, S. K. 2008. *Australian Bats*. Second Edition. Crows Nest, N.S.W.: Allen and Unwin, Sydney, p 255.
- Clements, R., Sodhi, N. S., Schilthuizen, M. and Ng, P. K. L. 2006. Limestone Karsts of Southeast Asia: Imperiled Arks of Biodiversity. *BioScience* 56(9): 733-742.
- Culver, D. C., Master, L. L., Christman, M. C. and Hobbs, H. H. 2000. Obligate cave fauna of the 48 contiguous United States. *Conservation Biology* 14: 368-401.
- Culver, D. C., Deharveng, L., Bedos, A., Lewis, J. J., Madden, M., Reddell, J. R., Sket, B., Trontelj, P. and White, D. 2006. The mid-latitude biodiversity ridge in terrestrial cave fauna. *Ecography* 29(1): 120–128.
- Day, M. and Urich, P. 2000. An Assessment of Protected Karst Landscapes in Southeast Asia. *Cave and Karst Science* 27(1): 61-70.
- DENR-BMB and Ateneo School of Government. 2014. The Fifth National Report to the Convention on Biological Survey, Republic of the Philippines, p 1-68.
- Department of Environment and Natural Resources-Protected Areas and Wildlife Bureau (DENR-PAWB). 2009. *Cave Classification Handbook*. Quezon City, Philippines, p 62. <http://www.bmb.gov.ph/downloads/References/CAVEHandbookFinal.pdf>. Cited 30 June 2019.

- De Vivo, A., Piccini, L. and Mecchia, M. 2009. Recent explorations in the Saint Paul Karst (Palawan, Philippines). Proceedings 15th International Congress of Speleology, Kerville, Texas (USA) 3: 1786-1792.
- Enriquez, C. M. D. and Nuñez, O.M. 2014. Cave spiders in Mindanao, Philippines. ELBA Bioflux 6 (1): 46–55.
- Esselstyn, J. A., Widmann, P. and Heaney, L. R. 2004. The mammals of Palawan Island, Philippines. Proceedings of the Biological Society of Washington 117(3): 271–302.
- Figueras, G. S. and Nuñez, O. M. 2013. Species Diversity of ants in karst limestone habitats in Bukidnon and Davao Oriental, Mindanao, Philippines. AES Bioflux 5(3): 306-315.
- Furey, N. M. and Racey, P. A. 2016. Conservation Ecology of Bats in the Anthropocene: Conservation of Bats in the Changing World. Springer, Cham, p 463-500.
- Gaisler, J., Zukal, J., Rehak, Z. and Homolka, M. 1998. Habitat preference and flight activity of bats in a city. Journal of Zoology, 244: 439-445.
- Galorio, A. H. N. and Nuñez, O. M. 2014. Diet of cave-dwelling bats in Bukidnon and Davao Oriental, Philippines. ABAH Bioflux 6(2): 148-157.
- Gibert, J., Culver, D. C., Dole-Olivier, M.-J., Malard, F., Christman, M. C. and Deharveng, L. 2009. Assessing and conserving groundwater biodiversity: Synthesis and perspectives. Freshwater Biology 54(4): 930–941.
- Gomez, R. K. S. C., Ibañez, J.C. and Bastian, Jr. S.T. 2005. Diversity and community similarity of pteropodids and notes on insectivorous bats in the Arakan Valley Conservation Area, Mindanao. Sylvatrop 15(1-2): 87-102.
- Hale, J. D., Fairbrass, A. J., Matthews, T. J., Sadler, J. P. 2012. Habitat composition and connectivity predicts bat presence and activity at foraging sites in a large UK conurbation. PLoS One 7(3): e 3330.
- Heaney, L. R. and Rabor, D. S. 1982. Mammals of Dinagat and Siargao Islands, Philippines. Occasional Papers of the Museum of Zoology University of Michigan 699: 1-30.
- Heaney, L. R., Balete, D. S., Dolar, M. L., Alcala, A. C., Dans, A. T. L., Gonzales, P. C., Lepiten, M. V., Oliver, W. L. R., Ong, P. S., Rickart, E. A., Tabaranza, B. R. and Uzzurum, R. C. B. 1998. A synopsis of the mammalian fauna of the Philippine Islands. Fieldiana:Zoology 88: 1-61.
- Heaney, L. R., Dolar, M. L., Balete, D. S., Esselstyn, J.A., Rickart, E. A and Sedlock, J. L. 2010. Synopsis of Philippine Mammals The Field Museum of Natural History in co-operation with the Philippine Department of Environment and Natural Resources - Protected Areas and Wildlife Bureau. [http://archive.fieldmuseum.org/philippine\\_mammals](http://archive.fieldmuseum.org/philippine_mammals). Cited June 30, 2019.
- Hutachareem, C. 2004. The effects of Human Impacts on Cave and Karst Biodiversity:Thailand Component:Final Report. ASEAN Regional Centre for Biodiversity Conservation, p. 1-148.
- Hutson, A. M., Mickleburgh, S. P. and Racey, P. A. 2001. Microchiropteran Bats: Global Status Survey and Conservation Plan. Gland (Switzerland): Species Survival Commission Chiroptera Specialist Group, IUCN, p 256.
- Ingle, N. R., Sedlock, J. L., and Heaney, L. R. 1999. Bats of Mindanao Island, Philippines. Environmental & Conservation Programs, The Field Museum, Chicago, IL 60605, USA, p 1-2.
- Jones, G., Jacobs, D. S., Kunz, T. H., Willig, M. R. and Racey, P. A. 2009. Carpe Noctem: the importance of bats as bioindicators. Endangered Species Research 8(1-2): 93-115.
- Kasso, M. and Balakrishnan, M. 2013. Ecological and Economic Importance of Bats (Order Chiroptera). ISRN Biodiversity, 2013: 1-9.
- Kock, D., Altmann, J. and Price, L. 2000. A fruit bat new to West Malaysia: *Rousettus leschenaultia* (Desmarest 1820) in Batu Caves. Malaysian Nature Journal 54(1): 63-67.
- Kunz, T. H., 1982. Roosting Ecology of Bats. In Kunz, T. H. (ed.): Ecology of Bats. Plenum Press, New York, p 1-55.
- Kunz, T. H. and Reynolds, D. S. 2003. Bat colonies in buildings. In O’Shea, T. J. and Bogan, M. A. (eds): Monitoring trends in bat population of the United States and territories: problems and prospects. US Geological Survey, Biological Resources Division, Information and Technology Report, Washington D.C., p 91-102.
- Kunz, T. H., Gauthreaux, Jr. S. A., Hristov, N. I. and Horn, J. W. 2008. Aeroecology: probing and modelling the atmosphere. Integr Comp Biol 48: 1-11.
- Lagare, N. J. S. and Nuñez, O. M. 2013. The cavernicolous crickets in selected caves in Davao Oriental and northern Mindanao, Philippines. Elba Bioflux 5(2): 130–140.
- Lobite, N. J. S., Lubos, L. C. and Japos, G. V. 2013. A preliminary assessment of the chiropteran fauna of the Oro River, Cagayan de Oro City, Philippines. Asian Journal of Biodiversity 4: 119-134.
- Mag-Usara, V. R. P. and Nuñez, O. M. 2010. Diversity and relative abundance of cockroaches in cave habitats of Siargao Island, Surigao del Norte, Philippines. ELBA Bioflux, 2(2): 39–44.
- Malotaux, J. 2012. Bat Caves in Fiji. NatureFiji-MareqetiViti, Suva, Fiji, p 1-40. [https://www.cepf.net/sites/default/files/annex9\\_nfmv2012\\_15batcavesfiji\\_joannemalotaux.pdf](https://www.cepf.net/sites/default/files/annex9_nfmv2012_15batcavesfiji_joannemalotaux.pdf). Cited 30 June 2019.
- Mann, S. L., Steidl, R. J. and Dalton, V. M. 2002. Effects of cave tours on breeding *Myotis velifer*. Journal of Wildlife Management 66(3): 618-624.
- Mickleburgh, S. P., Hutson, A. M. and Racey, P. A. 2002. A review of the global conservation status of bats. Oryx 36: 18-34.
- Mould, A. 2012. Cave bats of the central west coast and southern section of the Northwest Panay Peninsula, Panay Island, the Philippines. Journal of Threatened Taxa 4(11): 2993–3028.

- Naz, A. C. 2012. The State of the Philippine Environment: An update on Chapter 4 of the 1994 Philippine Human Development Report, Philippines, p 1-48.
- Novises, I. and Nuñez, O. M. 2014. Species richness and abundance of cave-dwelling crickets on Siargao Island, Surigao Del Norte, Philippines. *Elba Bioflux*, 6(1): 10-21.
- Nuñez, O. M. and Galorio, A. H. N. 2014. Cave bat fauna of Siargao Island protected landscape and seascape, Philippines. *AES Bioflux* 6(3): 243-255.
- Nuñez, O.M. and Galorio, A. H. N. 2015. Cave Herpetofauna of Siargao Island Protected Landscape and Seascape, Philippines: *World Journal of Environmental Biosciences* 4(1): 26-35.
- Nuñez, O. M., Calizo-Enguito, M. R., Labajo-Villantes, Y. and Ponce, A. G. 2015. Species richness and endemism of cave herpetofauna in Northern Mindanao, Philippines. *ELBA Bioflux* 7(1): 10-24.
- O'malley, R., King R. A., Turner, C. S., Tyler, S., Cummings, M. and Raines, P. 2006. The diversity and distribution of the bat fauna (Mammalia, Chiroptera) of Danjungan Island Cauayan, Negros Occidental, Philippines. *Biodiversity and Conservation*, 15: 43-56.
- Paguntalan, L. M. J. and Jakosalem, P. G. C. 2008. Conserving Threatened and Endemic Fruit Bats in Isolated Forest Patches in Cebu with notes on new records and rediscoveries. *Silliman Journal* 48(2). pp. 81-94.
- Palmeirim, J. M., Champion, A., Naikatini, A., Niukala, J., Tuiwawa, M., Fisher, M., Fisher, M., Yabaki, M., Thorsteinsdottir, S., Qalovaki, S. and Dunn, T. 2007. Distribution, status and conservation of the bats of Fiji Islands. *Oryx* 41: 509-519.
- Parise, M. and Gunn, J. 2007. Natural and anthropogenic hazards in karsts areas: an introduction. *Geological Society of London: Special Publications*, 278: 1-3.
- Petrov, B., Alexandrova, I., Karadakov, V., Georgieva, T., Toshkova, N. and Zhelyazkova, V. 2014. Bats (Mammalia: Chiroptera) in Ponor Special Protection Area (Natura 2000), Western Bulgaria: Species Diversity and Distribution. *Acta zoologica bulgarica* 65 (Suppl. 5): 117-128.
- Posa, M. R. C., Diesmos, A. C., Sodhi, N.S. and Brooks, T. M. 2008. Hope for Threatened Tropical Biodiversity: Lessons from the Philippines. *BioScience* 58(3): 231-240.
- Price, L. 2004. An Introduction to Some Cave Fauna of Malaysia and Thailand. *Acta Carsologica* 33(1): 311-317.
- Price, L. 2014. Species Diversity and Food-web Complexity in the Caves of Malaysia. *Ambient Science* 1 (12): 1-8.
- Rahman, M. R. A. B. D., Tingga, R. C. T., Azhar M. I., Hasan, N.H. and Abdullah, M. T. 2011. Bats of the Wind Cave Nature Reserve, Sarawak, Malaysian Borneo. *Tropical Natural History* 11(2): 159-175.
- Restificar, S. D. F., Day, M. J. and Ulrich, P. B. 2006. Protection of Karsts in the Philippines. *Acta Carsologica* 35(1): 121-130.
- Sedlock, J. L., Jose, R. P., Vogt, J. M., Paguntalan, L. M. J. and Cariño, A. B. 2014. A Survey of Bats in Karst Landscape in the Central Philippines. *BioOne* 16(1):197-211.
- Seiser, B. Y. P. E. and Schuett, M. A. 2006. Defining the Concept of Cave Wilderness and Its Designation Values 12(2): 8-16.
- Simoës, M. H., Souza-Silva, M. and Ferreira, R. L. 2014. Cave Invertebrates in Northwestern Minas Gerais State, Brazil: Endemism, Threats and Conservation Priorities. *Acta Carsologica* 43(1): 159-174.
- Smith, M. J. and Burns, G. L. 2011. Australia's crystalline heritage: Issues in cave management at Jenolan Caves. *Helictite* 40(2): 27-34.
- Sobrepena, J. M. M. and Nuñez, O. M. 2014. Cave macro-invertebrates of Wao, Lanao Del Sur, Philippines. *Journal of Applied Ecology* 5(6): 107-121.
- Takeda, M. and Ng, P. K. L. 2001. The Freshwater Crab Fauna (Crustacea, Brachyura) of the Philippines: VI. A New Cavernicolous Crab from Mindanao. *Zoological Science* 18(8): 1123-1127.
- Tanalgo, K. C. and Tabora, J. A. 2015. Cave-dwelling bats (Mammalia: Chiroptera) and conservation concerns in South Central Mindanao, Philippines. *Journal of Threatened Taxa* 7(15): 8185-8194.
- Taylor, D. A. R. 2006. Forest Management and Bats. *Bat Conservation International*, p 1-14. <http://www.batcon.org/pdfs/ForestMgmtandBats.pdf>. Cited 30 June 2019.
- Threlfall, C.G., Law, B. and Banks, P. B. 2012. Sensitivity of Insectivorous bats to urbanization: implications for suburban conservation planning. *Biological Conservation* 146(1): 41-52.
- Wagner, J. 2013. Karst landscapes and karst features in the Philippines. *Stuttgart*, p 1-165.
- Warguez, D., Mondejar, E. P. and Demayo, C. G. 2013a. Frogs and their Microhabitat Preferences in the Agricultural and Secondary Forest areas in the Vicinity of Mt. Kalatungan Mountain, Bukidnon, Philippines. *International Research Journal of Biological Sciences* 2(10): 51-63.
- Warguez, D., Tagarda, P. M. M. and Demayo, C. G. 2013b. Bats in Northeastern Agusan Del Norte, Mindanao. *Elba Bioflux* 5(2): 103-116.
- Wiles, G. J. and Brooke, A. P. 2009. Conservation Threats to Bats in the Tropical Pacific Islands and Insular Southeast Asia. *Island Bats: Evolution, Ecology, and Conservation*. University of Chicago Press, p 405-459.
- Whitten, T. 2009. Applying ecology for cave management in China and neighbouring countries. *Journal of Applied Ecology* 46(3): 520-523.
- Wynne, J. J. and Pleytey, W. 2005. Sensitive ecological areas and species inventory of Actun Chapat Cave, Vaca Plateau, Belize. *Journal of Cave and Karst Studies* 67(3):148-157.

