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Species composition of cave-dwelling reptiles and their micro-habitats in Agusan del Sur, Philippines

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ABSTRACT There are more than 1500 caves known in the Philippines which provide refuge, shelter, and food to many vertebrates including reptiles. The microhabitats inside and around the caves are essential in the survival of these cave-dwelling reptiles. In this work, we provide the checklist and microhabitat utilized by different lizards and snakes occupying cave habitats in Agusan del Sur. We used modified cruising method and visual encounter search to survey reptiles in eight selected caves from Agusan del Sur. A total of ten species belonging to three different families of which seven are Philippine endemic (70%) species were documented. Most of the species were recorded in Agpan cave, Municipality of Trento. Scincid lizards were the most diverse family of reptiles documented to inhabit rotten logs, leaf piles, rocks, and wall crevices of the cave entrances. The presence of these endemic lizards and snakes validates the importance of this natural ecosystem for its conservation and protection.

KEY WORDS Agpan Cave; Colubridae; Endemic; Gekkonidae; Scincidae.

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INTRODUCTION

Caves are home to specialized and unique fauna and flora, hosting unique ecological niches (Pipan & Culver, 2013), and provide important ecosystem functions (Medellin et al., 2017; Quibod et al., 2019). They are home to peculiar reptilian fauna that adapts to subterranean environments which can survive despite total darkness, relatively lower air and water temperature, relative humidity approaching saturation, and a relatively poor supply of nutrients (Culver et al., 2004; Engel, 2007). These caves essentially provide inhabitation, nesting ground, maternal sites, water sources, foraging sites, and shelter (Strong & Goodbar, 2005).

Reptiles play a critical role in ecological food webs as predators. Several studies in karst cave habitat accounted numerous cave-dwelling reptiles (Abantas & Nuñeza, 2014; Belleza & Nuñeza, 2014) and found to have low-moderate diversity. They provide significant benefits to agriculture (Pough et al., 2004; Natural Resources Conservation Service, 2006) as control agents for pest, useful in monitoring biodiversity (Ngilangil et al., 2014), and serve as good environmental indicators due to their sensitivity to habitat alteration. A major factor considered behind the possibility of the reptiles living inside caves is the presence of their micro-habitats that enables them to reduce their exposure to extreme environmental conditions (Goode et al., 1995).

Southeast Asia is one of the ecoregion of the Earth that is considered as a biodiversity hotspot (Hughes, 2017), containing a high proportion of threatened reptile species (Heath, 2017) due to a high level of deforestation and habitat loss (Sodhi et al., 2010; Hughes, 2017; Estoque et al., 2019), which includes the Philippines. The Philippine archipelago is the world's second-largest archipelago (Alip & Amenomori, 2011), that is collectively known, among other countries, as one of the vital centers for herpetofaunal diversity throughout South East Asia, with about 477 reptilian (lizards and snakes) species thought to be present in the country of which 363 species (76%) are endemic and 105 species (22%) are native in the Philippines (Mittermeier et al., 1999; Diesmos et al., 2002; Ambal et al., 2012; Sanguila et al., 2016; Leviton et al., 2018; Barley et al., 2020; Weinell et al., 2020; Eliades et al. 2021; Maglangit et al., 2021). Reptiles are scattered within the different regions of the archipelago of which 58 species of these reptiles inhabit the cave ecosystem in the country (Diesmos et al., 2002; Brown et al., 2013).

The Mindanao island holds more or less 40% of the known caves in the Philippines (Delima et al., 2007; Department of Environment and Natural Resources-Protected Areas and Wildlife Bureau, 2008). However, there are only a few cave-related studies on reptiles conducted in Mindanao. This includes Mighty Cave, Tagoloan, Lanao Del Norte (Abantas & Nuñeza, 2014), Sarangani Province, and Lanao del Norte (Belleza & Nuñeza, 2014), and Northern Mindanao (Nuñeza et al., 2015). Nevertheless, there were no published report on reptiles in caves and their microhabitats in Agusan del Sur. In this study, we surveyed eight caves within the three municipalities and one city of Agusan del Sur to determine the species composition of reptiles dwelling on different cave zonation, their microhabitats, and anthropogenic disturbances present in the caves.

MATERIAL AND METHODS

Sampling area

The sampling was conducted in Agusan del Sur of CARAGA Region 13 on Mindanao island, Philippines (Fig. 1) with coordinates 08°30'N 125° 50'E. It has a land area of 8966 km^2 which is divided into 13 municipalities. We sampled lizards and snakes in selected cave habitats in the municipalities of Prosperidad, Loreto, Trento and city of Bayugan. Sampling site and cave descriptions are shown in Table 1.

Sampling methods and data analysis

We employed modified cruising sampling method to survey and document reptiles (lizards and snakes) in the proximity of the cave habitat

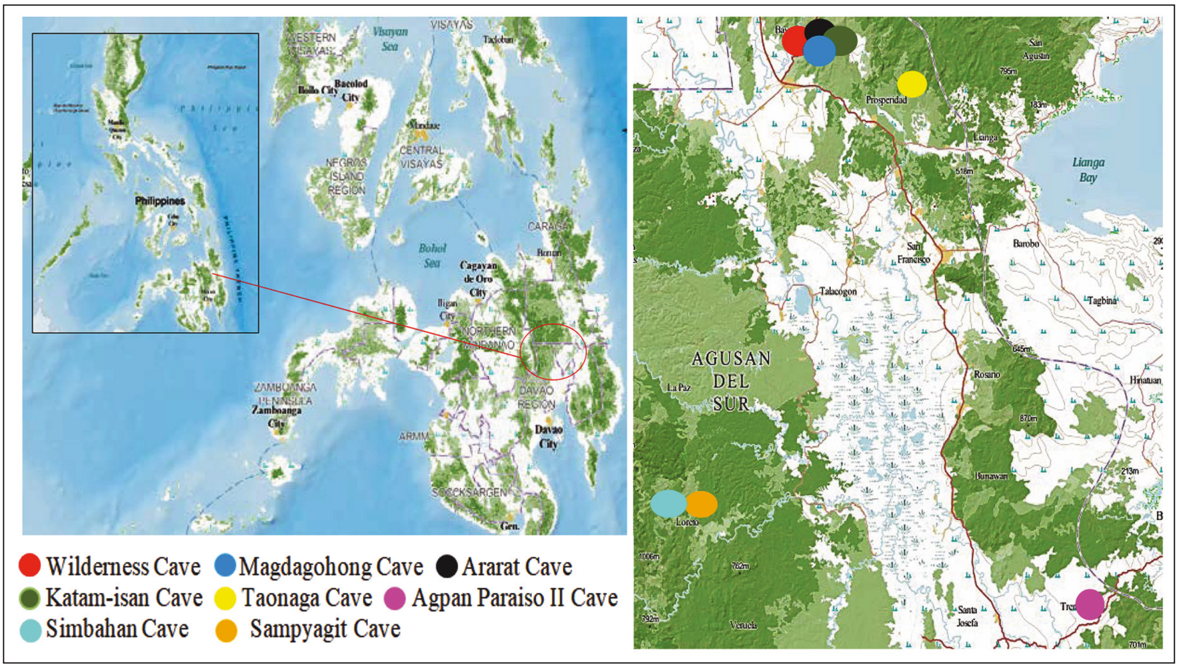

Figure 1. Map showing the geographical location of Agusan del Sur (encircled in red) from the inset map of the Philippine archipelago. The cave sites sampled with reptiles are represented with colored dots.

Cave	Coordinates and Elevation	Number of openings	Speleothems	Water bodies	Signs of Human Disturbance
A	8°28’20.38’’ N 125°50’51.4’’ E, 733 masl (1st floor); 8048’22.7’’ N 125050’58.7’’ E, 687 m asl (2nd floor)	3	few stalactites and stalagmites	present (stream)	vandalism, treasure hunting activity, and cutting of stalactites
B	8°47’42.9’’ N 125°50’26.4’’ E, 569 m asl	3	abundant stalactites and few stalagmites	absent but temporary stagnant water is present	Vandalism and cutting of stalactites
C	8°49’43.1’’ N 125°50’15.3’’ E, 693 m asl	1	abundant stalactites and stalagmites	absent	cutting of stalactites and soil erosion
D	8°49’38.2’’ N 125°50’9.2’’ E, 598 m asl	1	abundant stalactites and moderate stalagmites	present	cutting of stalactites
E	8°07’17.5’’ N 126°06’08.5’’ E, 83 m asl	5	abundant stalactites and a few stalagmites	present	harvesting of guano, and soil erosion due to typhoon Senyang
F	8°2’33.4’’ N 126°3’45.7’’ E, 63 m asl	2	abundant stalactites and moderate stalagmites	present (stream)	treasure hunting activity
G	8°9’25.3’’ N 125°40’26.3’’ E, 63 m asl	2	moderate stalactites and few stalagmites	absent	treasure hunting activity
H	8°9’16.7’’ N 125°41’26.6’’ E, 99 m asl	1	abundant stalactites and few stalagmites	absent	treasure hunting activity

Table 1. Description of the cave sites. Legend: (A) Wilderness Cave (Bayugan City), (B) Magdagohong Cave (Bayugan City), (C) Ararat Cave (Bayugan City), (D) Katam-isan Cave (Bayugan City), (E) Agpan Cave (Trento), (F) Taonaga Cave (Prosperidad), (G) Simbahan Cave (Loreto), and (H) Sampyagit Cave (Loreto).

and different cave zonation. We used a digital camera to document and specimens taken from the field were placed in our sample bags. We measured the snout-vent-length (SVL) and body length (BD) using a measuring tape and the body weight using a Pesola spring balance. Voucher specimens were fixed in 10% formalin solution and later washed with tap water and preserved in a 70% ethanol solution (Heyer et al. 1994, Simmons, 2002).

The air and soil temperature in the cave was measured using a glass thermometer while relative humidity was measured with the use of an improvised sling psychrometer. We examined the presence of stalactites and stalagmites in all cave sites. Human-induced disturbances were also noted.

The works of Alcala (1986) and the photographic guide by Nuñeza (2012) were used for species identification and further verified by Dr. Rafe Brown (Herpetologist) from Kansas University. The distribution and conservation status of the reptile species was based on the IUCN (2021) Red List of Threatened Species (Version 2021-1). The microhabitats of reptiles were documented and categorized as rotten logs, leaf piles, wall crevices, leaf litter, and cave ground. The number of species observed per habitat were all noted. The Paleontological Statistics Software (PAST) version 2.17c (Hammer et al., 2001) was used to perform seriation analysis to show the presence and absence of reptiles along different cave zonation and microhabitats.

RESULTS AND DISCUSSION

Species composition and microhabitat

This work accounted 10 species of reptiles (8 lizards, 2 snakes) belonging to three different families (Table 2) of which seven are Philippine endemic species (70%). Two species belong to the family Gekkonidae, six species are from the family Scincidae, and only two species belong to the family Colubridae. This notable account is slightly higher than the number of species of reptiles recorded in the caves of Sarangani and Lanao del Sur (Belleza & Nuñeza 2014), Lanao Del Norte (Abantas & Nuñeza 2014), Northern Cagayan Valley (Cabauatan et al., 2014), Siargao Island Protected Landscape and Seascape (Nuñeza & Galorio, 2015), and Northern Mindanao (Nuñeza et al., 2015). According to the study of Stevens and O'Connor (2006), differences in species richness in caves are greatly affected by several ecological factors such as food availability, vegetation type, and abiotic factors such as habitat area, temperature, humidity, rainfall, latitude, and altitude.

The highest number of species (S = 6, *n* = 17 individuals) was recorded in Agpan cave potentially due to the size of the cave, the vegetation around cave entrances, and unnoticeable anthropogenic activities within this cave. This cave consists of numerous cave entrances with relatively wide openings allowing snakes and lizards to freely come and go and select a variety of microhabitats around the cave for refuging and site for foraging. The information gathered concur with the study of Heinen (1992) that less disturbed areas contain higher species richness and diversity. Although Agpan cave is utilized as a source of guano material, six out of 10 reptile (60%) species including the Philippine endemic and near threatened *Stegonotus muelleri* (Fig. 2) were all found and observed in Agpan cave.

There were two species (*n* = 1 individual) found in Wilderness cave (A), Ararat cave (C), Katamisan Cave (D), and Simbahan Cave (G). The Taonaga (F) cave recorded three species whereas Sampyagit cave (H) recorded only one individual (N = 1 species). Based on observations, several anthropogenic disturbances detected in caves may be one factor for few individuals and species recorded as was seen in Wilderness cave, Magdagohong cave, and Taonaga cave. Threats include vandalism, treas-

Figure 2. *Stegonotus muelleri* (Muller's Wolf Snake).

Species	Common Name	Distri-bution	Distribution Record	Conser-vation	Cave Sites							
					A	B	C	D	E	F	G	H
Family Colubridae												
Psammodynastes pulverulentus (Boie, 1827)	Common Mock Viper	NE	Global: Bangladesh, Bhutan, Burma, Cambodia, China, Hong Kong Indonesia Laos, Malaysia, Nepal, Taiwan Thailand, Vietnam Philippines: Balabac, Basilan, Bohol, Bongao, Busuanga, Cebu, Dinagat, Jolo, Leyte, Luzon, Mindanao, Negros, Palawan, Panay, Polillo, Samar		0	0	0	0	0	1	0	0
Stegonotus muelleri Duméril, Bibron et Duméril, 1854	Müller's Wolf Snake	PE	Philippines: Dinagat, Leyte, Mindanao, Samar	NT	1	0	0	0	1	0	0	1
Family Gekkonidae												
Cyrtodactylus agusanensis (Taylor, 1915)	Agusan Bent-toed Gecko	PE	Philippines: Camiguin, Dinagat, Leyte, Mindanao, Samar, Siargao	LC	1	0	0	0	0	0	0	0
Cyrtodactylus annulatus (Taylor, 1915)	Annulated Bow-fingered Gecko	PE	Philippines: Basilan, Bohol, Cebu, Jolo, Leyte, Mindanao, Negros, Pacijan, Tawi Tawi	LC	0	0	0	1	0	0	1	0
Family Scincidae												
Eutropis caraga (Barley, Diesmos, Siler, Martinez er Brown, 2020)	Caraga Sun Skinks	PE	Philippines: Bohol, Dinagat, Mindanao, Samar, Siargao Islands		0	1	0	0	5	0	1	0
Eutropis multicarinata (Gray, 1845)	Many-keeled Mabuya	NE	Global: Indonesia, Malaysia (Borneo), Micronesia, Palau Island (Belau), Talaud Archipelago, Sulawesi, Taiwan (Lanyu), Philippines: Bohol, Mindanao		0	0	0	0	5	2	0	0
Otosaurus cumingi Gray, 1845	Cuming's Sphenomorphus	PE	Philippines: Bohol, Calotcot, Dinagat, Leyte, Lubang, Luzon, Mindanao, Mindoro, Samar, Sibuyan, Sicogon Island	LC	0	0	0	0	1	0	0	0
*Sphenomorphus Acutus (*Peters, 1864)	Pointed-headed Sphenomorphus	PE	Philippines: Bohol, Dinagat, Leyte, Mindanao, Samar	LC	0	2	0	0	4	0	0	0
Sphenomorphus fasciatus (Gray, 1845)	Banded Sphenomorphus	PE	Philippines: Basilan, Camiguin, Leyte, Mindanao, Samar, Sulu Archipelago	LC	0	0	0	0	1	0	0	0
Sphenomorphus variegatus (Peters, 1867)	Black-spotted Sphenomorphus	NE	Global: Malaysia (Borneo) Indonesia (Sulawesi) Philippines: Bohol, Camiguin, Dinagat, Leyte, Mindanao, Sulu Archipelago		0	2	2	1	0	0	0	0

Table 2. Reptile species composition in the eight sampled caves of Agusan del Sur. Legend: NT = Near Threatened, NPE = Non Philippine Endemic, PE = Philippine endemic, A = Wilderness Cave, B = Magdagohong Cave, C = Ararat Cave, D = Katam-isan Cave, E = Agpan Cave, F = Taonaga Cave, G = Simbahan Cave, and H = Sampyagit Cave.

ure hunting, while cutting of stalactites, soil erosion, and improper garbage disposal were all detected. According to the study of Soldatini et al. (2015), human disturbance is a stress factor which potentially has a strong impact on the distribution and abundance of faunal vertebrates (Ruddock & Whitfield, 2007). In addition, rapid and irreversible shifts in the integrity and function of an ecosystem such as cave and wildlife it supports may be in peril due to human disturbances (Groffman et al., 2006; Phelps et al., 2018).

The Ararat cave is situated above 600 meters elevation while Katam-isan cave is known to be placed above 500 m elevation, which are all higher in comparison to other caves. Based on the study of Custodio (1986), the higher the elevation, the fewer reptile species may be recorded. This observation corresponds to the insights wherein this present study exemplifies and recorded only two species of reptiles whereas in Agpan cave we recorded numerous snakes and lizards at 83 meters elevation. Although these results are not conclusive, present survey depicts that habitats and other forms of ecosystem provide a suitable habitat for unique and karst-cave dwelling reptiles in low elevation.

Table 3 shows the distribution of the snake and lizard species along different cave zonation wherein skinks of the Family Scincidae (*E. caraga, E. multicarinata, O. cumingi, S. acutus,* and *S. variegatus*) were mostly found abundant in the cave entrances along with *P. pulverulentus* from the family Colubridae. The study of Belleza & Nuneza (2014) and Nuñeza & Galorio (2015) also found most of the documented reptiles dwelling on cave entrances and in the twilight zone where a variable amount of light can still penetrate the area. In addition, the recorded skinks in this study are subtroglopilic species and are not true caved-dwelling reptiles for they were found only occupying the cave entrances.

However, the deepest zone of most caves has a relatively constant temperature and high relative humidity that is devoid of light compared to cave entrances (Frushour, 2012). In this case, since reptilian species are ectothermic, they are unable to produce their body heat so they rely on external or environmental sources including the heat from sunlight which passes through the cave entrance (Raske et al., 2012) allowing them to regulate their body temperature.

On the other hand, *P. pulverulentus* was found in the cave entrance of Taonaga cave near a small stream. Based on literature, this snake preys and feeds on hard-bodied prey such as skinks (Jackson & Fritts, 1996; Miller & Zug, 2016), which were observed to be abundant around cave entrances.

The only two Philippine endemic species of gekkonid found in this study were *C. agusanensis* (Fig. 3) and *C. annulatus* (Fig. 4) which were all encountered in the twilight zone. According to the study of Bauer et al. (2002) and Ellis & Pauwels (2012), these two species are considered as substrate specialists rather than true cave specialist species. Hence, a great variety of gekkonid lizards are

Species	Cave Entrance	Twilight Zone	Deep Zone
Cyrtodactylus agusanensis (Taylor, 1915)		■	
Cyrtodactylus annulatus (Taylor, 1915)		■	
Eutropis caraga (Barley, Diesmos, Siler, Martinez et Brown, 2020)	■		
Eutropis multicarinata (Gray, 1845)	■		
Otosaurus cumingi Gray, 1845	■		
Sphenomorphus acutus (Peters, 1864)	■		
Sphenomorphus variegatus (Peters, 1867)	■		
Psammodynastes pulverulentus (Boie, 1827)	■		
Sphenomorphus fasciatus (Gray, 1845)			■
Stegonotus muelleri Duméril, Bibron et Duméril, 1854			■

Table 3. Distribution of reptiles along different cave zonation.

Figure 3. *Cyrtodactylus agusanensis* (Agusan Bent-toed Gecko) and its microhabitat.

Figure 4. *Cyrtodactylus annulatus* (Annulated Bow-fingered Gecko) and its microhabitat.

adapted to inhabitat karst ecosystem and cave habitat given their adeptnesss on climbing rock walls and use cave habitat as foraging or refuging site (Bauer et al., 2002; Esmaeili-Rineh et al., 2016). The colubrid snake *S. mueller,* and skink lizard *S. fasciatus* were both found in the deep zones of the caves. The *S. muelleri* was also reported to occupy cave habitat (Barnes & Knierim, 2018) whereas *S. fasciatus* is uncommon and no previous reports documenting this species to occur on cave habitats. These species are referred to as troglophilic reptiles which utilize cave habitat for shelter and source of food. In the study of Hobbs (2005), it was reported that reptiles occasionally utilize cave habitats for shelter due to unfavorable environmental conditions such as summer drought or winter frost. In general, reptiles are terrestrial, arboreal, or burrowing and primarily hide in rotting logs, humus, leaf litter, tree holes, underneath stones, and bark of trees, where these microhabitat sites are almost always moist or near a body of water (Alcala, 1986).

Based on results, there were several microhabitats (Table 4) along cave ecosystem that were utilized by snakes and lizards. These microhabitats

Species	MICROHABITAT				
	H1	H2	H3	H4	H5
Cyrtodactylus agusanensis (Taylor, 1915)					■
Cyrtodactylus annulatus (Taylor, 1915)					■
Eutropis caraga (Barley, Diesmos, Siler, Martinez et Brown, 2020)			■	■	
Eutropis multicarinata (Gray, 1845)	■		■	■	
Otosaurus cumingi Gray, 1845		■			
Sphenomorphus acutus (Peters, 1864)	■		■		
Sphenomorphus fasciatus (Gray, 1845)	■				
Sphenomorphus variegatus (Peters, 1867)		■	■		
Psammodynastes pulverulentus (Boie, 1827)			■		
Stegonotus muelleri Duméril, Bibron et Duméril, 1854		■			■

Table 4. Distribution of reptiles according to microhabitat. Legend: H1 = Rock pile, H2 = Wall Crevices, H3 = Leaf litter, H4 = Rotten Log, H5 = Cave Ground.

were categorized as rock piles, wall crevices, leaf litter, rotten logs, and cave ground. The *E. multicarinata* and *E. caraga* (Fig. 5) of the family Scincidae had the most number of individuals observed at the entrance zone of Magdagohong cave, Agpan cave, Simbahan cave, and Taonaga cave. Species of the genera *Sphenomorphus, Eutropis,* and *Otosaurus* occupy the same microhabitat such as rotten logs, rock piles, wall crevices, and leaf litter.

The scincid lizard, *E. caraga* was found inhabiting rotten logs and leaf litter microhabitat whereas *E. multicarinata, S. acutus,* and *S. variegatus* were found inhabiting a pile of rocks, rotten logs, wall crevices, and leaf litter microhabitat. In the study of Barley et al. (2020), *E. caraga* was primarily collected on leaf litter and under logs in forest floors. They also added that this species appears to be able to tolerate some disturbance, as it has been found in disturbed, agricultural areas, coconut groves, and residential areas near the forest.

In the same manner, *Otosaurus cumingi* was found inhabiting the wall crevices of Agpan cave while *S. fasciatus* was found in the deep zone of Agpan inhabiting in a pile of rock. This result mainly attributed to the food preference of skinks as they are mainly insectivorous (Pope, 1955; Berkovitz & Shellis, 2017). They feed on insects and spiders that are found roaming around rotten logs, ground, and leaf litter inside and around cave entrances.

Figure 5. *Eutropis caraga* (Caraga Sun Skinks) and its microhabitat.

In the case of *S. fasciatus*, it was found to occupy the deep zone. Unlike the genus *Eutropis* and the other two *Sphenomorphus* species, *S. fasciatus* is a species that keeps away from direct sunlight. In the study of Belleza & Nuñeza (2014) observed that this insectivorous species is active on the forest floor in the twilight zone where a small amount of sunlight penetrates along the cavern. The *S. fasciatus* is not a cave-dwelling species and potentially use cave habitat for foraging food.

The Philippine endemic *Cyrtodactylus agusanensis* of the family Gekkonidae was also recorded inhabiting the cave substrate of the Wilderness cave along the twilight zone. The same is the case with *C. annulatus* found in Katam-isan cave. This occourence may possibly be associated with the availability of food resources (Ibrahim, 2005).

According to the study of Belleza & Nuñeza (2014), geckkonid lizards demonstrate thermoregulatory behavior allowing them to adapt and utilize different microhabitats to maintain a preferred body temperature. This is why most of the species were only seen in the entrance and twilight zones wherein sunlight potentially influences the behavioral thermoregulation of reptiles (Sievert and Hutchison 1988). In addition, the study of Gleed-Owen & Price (2012) noticed that reptiles are generally diurnal and need to thermoregulate via direct insolation or lying beneath warm objects which is potentially the reason why some reptiles were observed in cave entrances and twilight zones.

The snakes of the family Colubridae, *S. muelleri* and *P. pulverulentus,* were found in separate zones of the cave. The *S. muelleri* was encountered in the deepest zone of the Wilderness cave, Agpan cave, and Sampyagit cave inhabiting the cave ground (H5) and wall crevices (H2) of the caves. *P. pulverulentus* was found in the cave entrance of Taonaga cave inhabiting leaf litter. This result may be associated with the snakes' diet since *S. muelleri* is a carnivorous species which feeds on small mammals and potentially also consumes bats in caves while *P. pulverulentus* feeds on small lizards such as skinks which were found abundant in the cave entrance. This observation indicates that the recorded reptile species mostly prefers ground litter microhabitats. This observation coincides with the records of Fernandez & Nuńeza (2007) on *P. pulverulentes* that reptiles are found in various microhabitats which enable them to survive depending on the availability of food resources and their utilization of these microhabitats.

Recorded Threats to the reptilian fauna

The caves surveyed in Agusan del Sur provide a habitat for a diverse species of snakes and lizard. However, due to several athropogenic disturbances observed in all these cave sites such as treasure hunting by digging holes inside the cavern, human activities and spelunking, extraction of stalagmites and stalactites, vandalism on cave walls, evidence of fragments by people utilizing the cave as refuge from natural hazards, and improper waste disposal posed as severe threats and negatively affect the population of reptilian species that utilize cave habitat for their survival and shelter.

CONCLUSIONS

In this work, we documented ten species of reptiles and notably accounted 70% endemic snakes and lizards. They were all observed in the proximity of various types of microhabitats and cave zonations wherein they utilize the cave habitats as refuging and foraging site. The skinks lizards were the most abundant reptiles and mostly found inhabiting rotten logs and leaf piles around cave entrances.

Natural hazards and human-made disturbances such as vandalism, stalactite extraction, and treasure hunting that were observed in most of the caves are considered threats to the existence of the reptilian fauna of these caves. The considerable number of endemic species recorded in the all caves sampled reveals the significance of each cave as home to unique and diverse reptiles which indicates the need to support protection of these cave ecosystems.

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