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Diversity of cave macro-invertebrates in mighty cave, tagoloan, lanao del norte, Philippines

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Abstract

Macro-invertebrates help maintain the stability of the wide niches of faunal assemblage of caves. This study was conducted to determine the diversity and relative abundance of macro-invertebrates in the recently-explored Mighty Cave in Tagoloan, Lanao del Norte. Sampling was conducted using hand-searching, direct counting and pitfall trap methods in four cave zones. Ten species of macro-invertebrates belonging to six orders were recorded. *Pachyrrhynchus* sp. and *Aceraius* sp. under Order Coleoptera were found only in the twilight zone. The highest species richness and abundance were found in the deep zone where guano deposit was thickest. *Macropathus* sp. was the most abundant. Of the four cave zones, the transition zone 2 had the highest diversity while the twilight zone had the lowest diversity. Distribution in each of the site was more or less even. Temperature and relative humidity were significantly correlated to the presence and number of macro-invertebrate species. Cave development for ecotourism was identified as the major threat to the cave biodiversity.

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Introduction

Caves are recognized as the world's most remote and fragile wildernesses (Jones, 2009). Cave ecosystems are usually characterized by the absence of natural light, stable temperature, geophysical structure, high relative humidity (Biswas, 2010) and poor and sporadic food sources (Bernabo *et al.,* 2011). Cave environments are usually inaccessible with a number of physical and psychological barriers aggravated by the lack of light (Kambesis, 2007). Inspite of these characteristics, caves harbor a variety of unique and sensitive organisms, many of which are cave obligates (Martin *et al.,* 2003). Due to the kind of ecosystems caves have, cave-dwelling organisms show some structural modification, behavioral changes, and specialized function (Pan *et al.,* 2010).

Caves are considered as wildlife sanctuaries for many organisms that need protection from predators and adverse conditions in the outside environment. Cave fauna are unique and constitute one of the important components of biodiversity (Biswas, 2010) and have good potential value to humans as "indicator species" (Elliot, 2000). Cavernicolous organisms inhabit certain areas inside the cave depending on their degree of adaptation to the cave ecosystems. The mouth of the cave is termed as the twilight zone which is highly illuminated and where humidity and temperature vary. The adjacent zone which is partially illuminated is the transition zone. The deep zone is the area where natural light is completely absent, humidity is near 100%, and temperature is constant (Biswas, 2010).

Most cavernicoles that occupy the subterranean environment are invertebrates, which comprise the bulk of animal species diversity in all terrestrial habitats and are vital components of the functioning ecosystem (Patrick, 1994). Cave species, are usually categorized into different ecological classifications. Troglobites are obligated to live inside the cave because they cannot survive on the surface environment. They are cave-limited species and well-adapted to the cave environment. Some are facultative cavernicoles which are able to complete their life cycle inside the cave (subtroglophile) or could be the future troglobites (eutroglophiles) but could also survive outside the cave. Others may be temporary visitors (trogloxene) which exploit cave resources but cannot complete their life cycle inside the caves (Biswas, 2010). Lewis (1983) reported that in Southeastern Indiana all invertebrate species in subterranean environment are troglobites and phreatobites in classification. Holsinger and Peck (1971) have recorded a hundred species of invertebrates from the caves of Georgia which include snails, pseudoscorpions, spiders and beetles, large numbers of which are troglobites and troglophiles. Macro-invertebrates not only serve as food for fish, amphibians, and water birds; but they are also involved in the breakdown of organic matter and nutrients (Georgia Envirothon, 2010). They also have important influence on nutrient cycles, primary productivity, decomposition, and translocation of materials (Wallace and Webster, 1996). Moreover, macro-invertebrates are found to be sensitive to changes in their environment, a feature that has been proven useful in the quest to find indicators of environmental conditions (Flores and Zarafalla, 2012).

There are a number of studies in caves of Mindanao that account for the species richness of macro-invertebrates. Recent published reports on cave diversity of macro-invertebrates in Mindanao were on crickets (Novises and Nuñeza, 2014; Lagare and Nuñeza, 2013), ants (Batucan and Nuñeza, 2013; Figueras and Nuñeza, 2013), spiders (Enriquez and Nuñeza, 2014; Cabili and Nuñeza, 2014), and cockroaches (Mag-usara and Nuñeza, 2014). However, Mighty Cave, a newly explored subterranean environment in Mindanao has no known studies that have been done or published regarding the diversity of cave fauna. This cave has been developed into an ecotourism site and is named as Mighty Cave Park in honor of the mayor who owns the land where the cave is located. This cave has attracted a number of visitors and/or adventurers across Mindanao especially during “Tagoloan Day” where some activities are held few meters away from the cave. The cave is artificially lighted using generator whenever very important visitors are present.

In this study, Mighty Cave was assessed to determine the species richness, relative abundance and diversity as well as to determine the existing threats to the cave fauna.

Materials and methods

Study area

Mighty Cave is located in the Municipality of Tagoloan, Lanao del Norte in the Philippines (Fig. 1). It is located at 08° 19’ 18.5’’ north and 124° 17’ 38.5’’ east and has an elevation of 246 meters above sea level (masl). The cave has two openings. The first cave entrance is further divided into two more openings; a wider opening and a narrower one. The narrower one is the main access to the cave with an opening of about 1.2 meter wide. The wider opening has an opening of 8 meters wide. The second mouth of the cave located on the other end has a small opening. Access is not easy due to its narrow passageway. The cave is approximately 215 meters long and with irregular small chambers. Inside the cave are concrete steps which are used as pathways to avoid stepping on the thick guano deposits. In the first opening of the cave a chair was observed and the area around the cave is constructed with concrete pathways and railings. Although the cave is located on an elevated area, water can still enter. Whenever rain falls, water enters the cave and forms pools inside. Local people said that when heavy rain falls, a pool of water about two-feet in height is formed inside the cave.

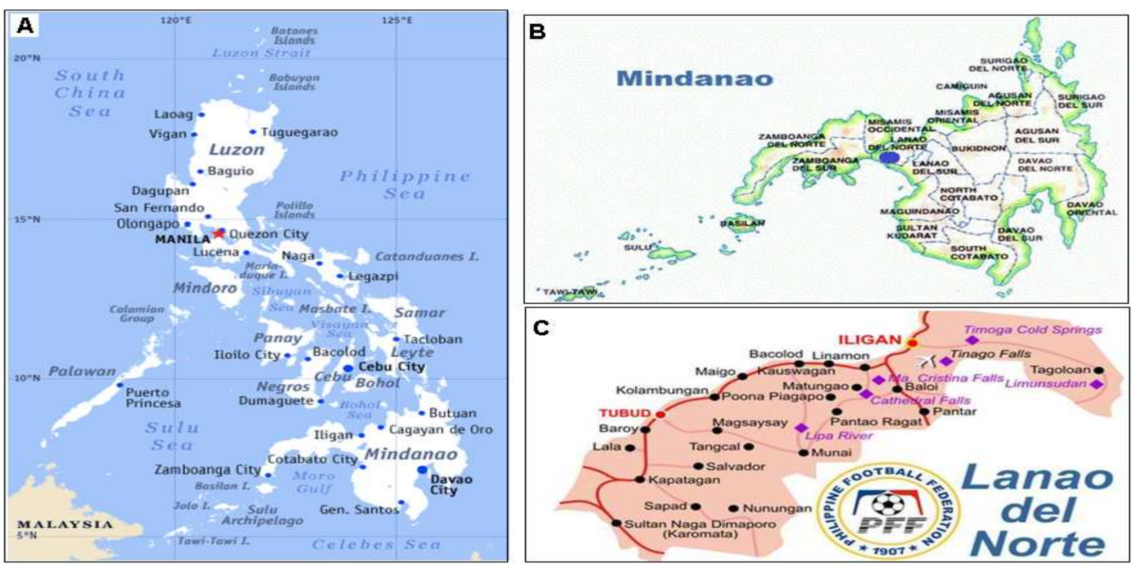

Fig. 1. Map of the Philippines (A) (www.mapsof.net, 2014) and Mindanao (B) (www.mcministries1.tripod.com) showing location of the sampling area in Lanao del Norte (C) (www.9news.ph, 2014).

Description of Subsites

The twilight zone was the area around the cave’s mouth which received the greatest amount of light among the zones thus, highly illuminated. Its opening measures approximately 8 meters wide and 10 meters high. The distance of light which determines the degree of illumination was 5 meters from the opening. The substrate of the first half of this zone was hard with cement due to the concrete steps while the rest was filled with guano deposits. No stalactites and gigantic columns were found; only roosting sites of bats and swifts were observed on the ceiling.

The transition zone 1 was the area adjacent to the twilight zone where the degree of light was apparently decreasing thus, partially illuminated. This zone was

15 meters long and 20 meters wide right after the highly illuminated area. This site had a mud and guano substrate where insects and other arthropods dwell. A relatively few stalactites and columns were observed. Roosting sites of bats were found 10 meters above the ground. Concrete steps and huge limestone's were also present in this site.

The deep zone was totally dark. This zone is right after the transition zone from the second branch of the cave and up to its end. It is 165 meters long. Its height and width ranged from 10 – 25 meters and 8 – 30 meters, respectively. This site was muddy and had a thick guano substrate where most macro-invertebrates dwell. Stalactites and few columns were observed. Numerous roosting sites of bats were found on the ceiling. Concrete steps were present.

The transition zone 2 was right after a very short second opening of the cave. Because of the small mouth of the second opening of the cave, the twilight zone in this area is very short which is about half a meter, thereby reducing the entrance of the light causing partial illumination. This site is considered as the second transition zone. Its opening measured approximately 5 meters wide and 1.5 meters high. This zone had hard substrate and no guano deposits were observed since no roosting sites of bats were found on its ceiling. Few stalactites and columns were observed.

Collection and processing of samples

Sampling was done on May 6-7, May 22-24 and July 10-12, 2010. Sampling was done every morning from 900 hours to 1200 hours and in late afternoon from 1400 hours to 1800 hours. Samples were collected from the different zones inside the cave. Different kinds of macro-invertebrates from the cave's floor, walls, holes and crevices were collected through hand searching. Collection of other macro-invertebrates was done by setting live-capture pitfall traps. Direct counting method, on the other hand, was employed to determine abundance of cave invertebrates found on walls, crevices, holes, and on the floor of the caves.

The captured specimens were transferred into plastic vials and preserved in 70% ethanol for later identification. All captured macro-invertebrates were identified by experts at the Philippine National Museum.

Collection of related data and analysis

Physico-chemical factors of the cave like temperature and relative humidity were measured. The temperature of each subsite was measured using field thermometer while relative humidity was measured using a sling psychrometer. Cave structures were examined for the presence of stalactites and stalagmites. The size of the cave and cave entrances (length, width, and height) was measured.

Biodiversity indices were determined using the program Biodive Pro. To determine the correlation of the number of macro-invertebrates with temperature and relative humidity, SPSS version 17 was used in ordination analysis.

Results and discussion

Species richness

Ten species of macro-invertebrates belonging to six orders were documented in the different zones in Mighty Cave in Tagoloan, Lanao del Norte (Table 1). These include one species of whip spider (Amblypygi), one species of tarantula (Aranea), three species of cockroaches (Blattodea), one species of weevil (Coleoptera), one species of beetle (Coleoptera), one species of crab (Decapoda), and one species of snail (Gastropoda), one species of cave cricket (Orthoptera). However, this result was lower than the recorded number of macro-invertebrates by Pape (2014) and Wynne *et al.,* (2007) in Grand Canyon National Park, Arizona which include spiders, beetles, flies, amphipods, harvestmen mites, springtails and diplurans. Moreover, a study in Mindanao caves recorded 18 species of spiders (Enriquez and Nuñeza, 2014). Low species richness on crickets (Novises and Nuñeza, 2014) and cockroaches (Mag-Usara and Nuñeza, 2014) was also recorded in some caves in Mindanao.

Table 1. Species richness and abundance of macro-invertebrates in Mighty Cave in Tagoloan.

Distribution in Mighty Cave Park	Subsite 1 (Twilight Zone)	Subsite 2 (Transition Zone 1)	Subsite 3 (Deep Zone)	Subsite 4 (Transition Zone 2)	Total
Order Amblypygi					
Family Phrynichidae					
Damon medius (Whip Spider)	0 (0)	14(8.18)	695(14.23)	9(19.14)	718(14)
Order Aranea					
Family Theraphosidae					
Phlogiellus sp. (Tarantula)	0(0)	2(1.169)	22(0.45)	3(6.38)	27(0.53)
Order Blattodea					
Family Blaberidae					
Blaberus giganteus (Giant Cave Cockroach)	0(0)	18(10.52)	468(9.58)	6(12.76)	492(9.59)
Laxta granicollis (Bark Cockroach)	8(25.8)	37(21.63)	891(18.24)	10(21.27)	946(18.4)
Family Blattidae					
Polyzosteria sp. (Sand Cockroach)	12(38.7)	49(28.65)	743(15.21)	8(17.02)	812(15.8)
Order Coleoptera					
Family Curculionidae					
Pachyrrhynchus sp. (Weevil)	1(3.23)	0(0)	0(0)	0(0)	1(0.02)
Family Passalidae					
Aceraius sp. (Bess Beetle)	1(3.23)	0(0)	0(0)	0(0)	1(0.02)
Order Decapoda					
Family Gecarcinucidae					
Sundathelphusa sp. (Crab)	0(0)	0(0)	3(0.061)	0(0)	3(0.06)
Order Gastropoda					
Family Thiaridae					
Melanoides granifera (spike tail trumper snail)	9(29)	19(11.11)	108(2.21)	4(8.51)	140(2.73)
Order Orthoptera					
Family Rhaphidophoridae					
Macropathus sp. (Cave-Weta)	0(0)	32(18.71)	1953(39.99)	7(14.89)	1992(38.8)
Total Number of Individuals	31	171	4883	47	5132
Total Number of Species	5	7	8	7	10

Legend: () – Relative Abundance.

Species abundance and distribution in the different subsites/cave zones

The ten species of macro-invertebrates recorded in this study, were found to be abundant in the deep zone except for two species, *Pachyrrhynchus* sp. and *Aceraius* sp. under the order Coleoptera. This indicates that species present in the deep zone are cave-adapted organisms since they are abundant in the area where natural light is absent which is characteristic of the deep zone. According to Hadley *et al.,* (1981), most deep cave zones are characterized by perpetual darkness, stable temperatures, and constant high humidity. It has often been assumed that species restricted to these zones (troglobites) exhibit physiological responses that mirror the physical environment. *Melanoides granifera, Laxta granicollis* and *Polyzosteria* sp. were found to be present in all zones. Bell *et al.,* (2007) stated that the distribution of cockroaches is often associated with the appropriate food sources and this could explain the presence of *Laxta granicollis and Polyzosteria* sp. in all zones. Twilight zone had the least number of macro-invertebrate species. Species under orders Coleoptera and Decapoda are considered trogloxene or temporary visitors of the cave since they were only observed once during the sampling period. Shaw and Davis (1999) reported that beetles in caves of Vancouver Island are commonly found in damp and dark places of forest habitats. Terrestrial beetles and weevils use the twilight zone. Twilight zone is dominated by surface animals and trogloxene species (SWCA Environmental Consultant, 2006). Cave crickets are mostly found in the deep zone associated with guano deposits. According to Marshall and Beehler (2007), cave crickets are abundant in the deep zone areas in caves particularly in areas where there are guano deposits. Relative to the result, twilight zone had the thinnest guano deposits (< 1cm deep) and was directly illuminated with light. This could be the reason why cave crickets in this area were absent. This result coincides with the observation of Novises and Nuñeza (2014) that caves with rich guano materials could also have abundant crickets. Crabs were obviously absent in the twilight zone since water body was absent in this area. They were only found in the deep zone of the cave where water body was present having an estimated depth of not less than two inches.

Table 2. Biodiversity indices of macro-invertebrates in Mighty Cave in Tagoloan, Lanao del Norte.

	Subsite 1 (Twilight Zone)	Subsite 2 (Transition Zone 1)	Subsite3 (Deep Zone)	Subsite 4 (Transition Zone 2)	Total
Species	5	7	8	7	10
Individuals	31	171	4883	47	5132
Dominance	0.3028	0.1942	0.2464	0.1607	0.2260
Shannon	1.298	1.741	1.579	1.879	1.6243
Evenness	0.7321	0.8147	0.6062	0.9352	0.7721

The cockroach *Blaberus giganteus* was found only in the three zones and not in the twilight zone. This may be due to the concrete substrate and less guano deposit in the twilight zone brought about by the absence of roosting sites of bats in this part of the cave. Guano deposition supports most invertebrates including cockroach communities (Clements *et al.,* 2006) and thus caves with guano deposits typically contain large numbers of few cockroach species (Darlington, 1970). Moreover, decomposing bat guano accumulations support macro-invertebrates which in turn support macro-invertebrates such as cockroaches (McFarlane, 2004). This may explain the fewer number of macro-invertebrates seen in this site. Biswas (2010) claims that searching for food; escaping unfavorable surface conditions and temporary shelter are possible reasons of the presence of beetle and weevil in the twilight zone. Thereby they are considered trogloxene or temporary visitors of the cave. He further reported that on a number of occasions, various trogloxenes have been recorded closely associated with the entrance and twilight zone of the cave.

Subsite 2 (transition zone 1) had a greater number of macro-invertebrates compared to subsite 1 (twilight zone). It had 171 individuals from seven species. The cockroaches dominated the area because of a rather thick guano deposit all over this subsite. These cockroaches were observed dwelling in the guano deposits looking for food. Welbourn (1999) explains that these guano accumulations are the primary food source for most invertebrates. Bell *et al.,* (2007) reported that cockroaches dwell in the guano and scavenge on dead micro-invertebrates. Mag-Usara and Nuñeza (2014) also found that microhabitat preferences of cockroaches were the dense desiccated guano deposits and boulder. Cave crickets were also observed in this zone due to the guano deposits. According to Hamilton-Smith (2004), guano deposits provide rich food resource for organisms particularly invertebrates. Thus, abundant food (guano) in caves supports high population densities (Ladle *et al.,* 2012).

Table 3. Correlation of temperature and relative humidity with the number of macro-invertebrates.

	Twilight Zone	Transition zone 1	Deep Zone	Transition Zone 2	Pearson Correlation value	p- value	Decision
Temperature (°C)	27	25	22	27	-.309	0.05	Significant
Relative Humidity %	78	80	92	82	.459	0.003	Significant
Species	5	7	8	7	None	none	None
Individuals	31	171	4883	47	None	none	None

In subsite 3 (deep zone), *Macropathus* sp. was the most abundant. Lagare and Nuñeza (2013) also found *Macropathus* sp. to be the most abundant cricket species on floors with thick guano deposit in the caves of Davao del Norte and Northern Mindanao. The cockroach *Laxta granicollis* and the spider, *Damon medius* were also abundant. *D. medius* was also recorded by Enriquez and Nuñeza (2014) in the caves of Mindanao and was observed as one of the most abundant species that was widely distributed at the twilight and inner zones. Cave crickets were found on the wall and on the floor of the cave. Marshall and Beehler (2007) reported that cave crickets feed on guano and many macro-invertebrates stay on or near the guano while others like the predators such as whip spiders tend to stay on cave walls frequently foraging near the pile of guano. Welbourn (1999) stated that the movements of the bats significantly affect the number of invertebrates living in the guano while Iskali (2010) reported that abundance of macro-invertebrates is related to guano availability. Whip spiders were observed on the wall while cockroaches were found on the ground. In this zone, guano was thickest compared to other zones. In the study of Santer and Hebets (2009), it was found that a whip spider was eating ground dwelling invertebrates such as cockroaches and crickets indicating the presence of available food contributing to the existence of spiders in the area. The same observation was also obtained by Enriquez and Nuñeza (2014) in the caves of Mindanao. A crab species, *Sundathelphusa* sp*.,* was also observed in the pools of water inside the cave. This crab may be considered a trogloxene species which was only observed on a sampling day when there was rain. The genus *Sundathelphusa* is a group of riverine freshwater crabs (Mendoza and Naruse, 2010).

The spike tail trumpet snail, *Melanoides granifera* was found to be scattered in all zones but were abundant in the muddy substrate of the deep zone where the level of water of a nearby water body ranged from two inches to one foot in depth. Based on information from the local guide, it had rained in the area on the last week of April, a week before the sampling period. The local people said that whenever there is heavy rain, rain water is deposited in the cave repository particularly in the deep zone. Michael (1966) in a study conducted in tropical freshwater fish pond found that samples of gastropods which included *M. granifera* have comparative high population peaks from the months of January to April and on the same time their breeding activities were also evident to have occurred on the same period due to the presence of younger length groups. It was found that differences in the number of these gastropods have been attributed to the inflow of water resulting in sudden alteration of the nutrient condition of the bottom mud. The inflow of water due to the heavy rain could be the reason for the abundance of *M. granifera* in Mighty Cave, a direct biotic-abiotic relationship.

Biodiversity indices

Table 2 shows the biodiversity indices of the cave zones. The four subsites were found to have moderate diversity with highest diversity in the transition zone 1.The most number of cave macro-invertebrates was recorded in the deep zone where light is absent with a total of eight species and least in the twilight zone where only five species of macro-invertebrates were observed. In the study conducted on Siargao Island, Surigao del Norte, almost all species of cockroaches (Mag-Usara and Nuñeza, 2014), spiders (Cabili and Nuñeza, 2014), and crickets (Novises and Nuñeza, 2014) were abundant in a zone where natural light was totally absent. The number of species found in each zone in this study appears to be related to the amount of guano deposit. Thick guano deposits support large number of macro-invertebrates and diversity can also be correlated with substrate heterogeneity (Chapman, 1983). Species were more or less evenly distributed in the four zones of the cave.

Correlation of species abundance with temperature and relative humidity

Table 3 shows the correlation of species abundance with temperature and relative humidity. In twilight zone and transition zone 2 where temperature is high, lesser number of macro-invertebrates was observed while in transition zone 1 and deep zone with lower temperature; more macro-invertebrates were observed. Deep zone had the highest degree of relative humidity wherein more number of species and individuals were observed. Most macro-invertebrates species were found in the zones where temperature was low and relative humidity was high. This indicates that macro-invertebrates prefer to inhabit the zone of the cave where it is more humid. According to Lavoie *et al.,* (2007), temperature and relative humidity affect the distribution of cave crickets and their foraging for food. Cave crickets in order to forage for food outside, surface temperature must be close to cave temperature and relative humidity must be close to saturated. Typically, cave crickets exit a cave to forage when the ambient surface temperature is close to 15º C and the relative humidity is close to 100%. Accordingly, species of cave crickets such as *Hadenoecus subterraneus* and *Ceuthophilus stygius* rapidly lose water and die even at mild temperature. In the study of Mag-Usara and Nuñeza (2014) it was observed that cave-dwelling cockroaches were more abundant in cave zones with temperatures between 27°C to 28°C and relative humidity of 85% and above. This indicates that relative humidities of 80% and above may provide cockroaches with a predictable source of water (Schal *et al.,* 1984) which concurs with the findings observed in this study. The cave spiders on Siargao Island were observed to be abundant in a zone where there are high humidity, cooler temperature and the presence of guano materials (Cabili and Nuñeza, 2014) indicating that some species of spiders can adapt to arid conditions, keep their activity and hunt slow-moving prey (Piterkina, 2005). Furthermore, macro-invertebrates are ectotherms which mean that their body temperatures respond to changes in the temperature of the environment. Macro-invertebrates depend on high humidity, stable temperatures, and surface nutrients such as animal droppings (U.S. Fish and Wildlife Service, 2008).

Existing threats to Mighty Cave

Mighty Cave was observed to be moderately disturbed. Concrete steps inside the cave, concrete railings, and pathways outside the cave were observed. Twilight zone was very prone to human disturbance. Electric wires and bulbs were observed inside the cave indicating that the entire cave is provided with artificial light. Eberhard (2001) stated that entry of man might directly affect the cave fauna leading to the disturbance of species populations. He also added that tourism development such as infrastructures around the cave might affect the cave micro-climate, nutrient inputs and migration of cave fauna. According to the residents near the cave, lighting system installed in the cave is used whenever the foundation day of Tagoloan is celebrated.

Based on information from local guides, another threat to the cave is the collection of guano for agricultural purposes where guano is used as fertilizer in the farms. Collection of guano is however, not regular and only minimal amount is collected. Graening *et al.,* (2006) reported that invertebrate number is abundant when guano deposit is also abundant.

Conclusion

Mighty Cave is an area of high macro-invertebrate abundance with moderate diversity. Guano deposits, temperature, and relative humidity are factors affecting the presence of macro-invertebrates in the different zones of the cave.

References

Batucan Jr LS, Nuñeza OM. 2013. Ant species richness in caves of Siargao Island Protected Landscape and Seascape, Philippines. ELBA Bioflux **5(2),** 83-92.

Bell WJ, Roth LM, Nalepa CA. 2007. Cockroaches: Ecology, Behavior, and Natural History. The Johns Hopkins University Press. Baltimore, Maryland, 1-230 p.

Bernabo P, Latella L, Jousson O, Lencioni V. 2011. Cold stenothermal cave-dwelling beetles do have an HSP70 heat shock response. Journal of Thermal Biology **36,** 206–208.

Biswas J. 2010. Kotumsar Cave Biodiversity: A Review of Cavernicoles and their Troglobitic Traits. Biodiversity and Conservation **19(1),** 275-289.

Cabili MHD, Nuñeza OM. 2014. Species Diversity of Cave-Dwelling Spiders on Siargao Island, Philippines. International Journal of Plant, Animal and Environmental Sciences **4(2),** 392-399.

Chapman PRJ. 1983. Species Diversity in a Tropical Cave Ecosystem. Proc.Univ. Bristol Spelaeol Soc. **16(3),** 201-213.

Clements R, Sodhi NS, Schilthuizen M, Ng PKL. 2006. Limestone Karsts of Southeast Asia; Imperiled Arks of Biodiversity. BioScience **56(9),** 733-742.

Darlington JPEC. 1970 Studies on the ecology of the Tamana Caves with special reference to cave dwelling cockroaches. Ph.D. Thesis. University of the West Indies, Trinidad, 224 P.

Eberhard S. 2001. Cave Fauna Monitoring and Management at Ida Bay, Tasmania. Records of the Western Australian Museum Supplement **64,** 97-104.

Elliott WR. 2000. Conservation of the North American cave and karst biota.Chap. 34. In: Wilkens H, Culver DC, Humphreys WF, eds. Subterranean Ecosystems. Ecosystems of the World, 30. Elsevier, Amsterdam, the Netherlands, 665-689 p.

Enriquez CMD, Nuñeza OM. 2014. Cave spiders in Mindanao, Philippines. ELBA Bioflux **6(1),** 46-55.

Figueras GS, Nuñeza OM. 2013. Species diversity of ants in karst limestone habitats in Bukidnon and Davao Oriental, Mindanao, Philippines. AES Bioflux **5(3),** 306-315.

Flores MJL, Zafaralla MT. 2012. Macroinvertebrate Composition, Diversity and Richness in Relation to the Water Quality Status of Mananga River, Cebu, Philippines. Philippine Science Letters **5(2),** 103-113.

Georgia Envirothon. 2010. Water Study Materials, 33-39 p. Retrieved August 31, 2014 from http://www.web.jasper.k12.ga.us/.../WATER/_REFERENCE%...

Graening GO, Slay ME, Bitting C. 2006. Cave Fauna of the Buffalo National River. Journal of Cave and Karst Studies **68(3),** 153-163.

Hadley NF, Ahearn GA, Howarth FG. 1981. Water and metabolic relations of cave-adapted and epigeanlycosid spiders in Hawaii. J. Arachnol **9,** 215-222.

Hamilton-Smith E. 2004. Organic Resources in Caves. In Gunn J, ed. Encyclopedia of Caves and Karst Science. Fitzroy Dearborn An imprint of Taylor and Francis Group, New York, 1169-1170 p.

Holsinger JR, Peck SB. 1971. The Invertebrate Fauna of Georgia.National Speleological Society Bulletin .**33(1),** 23-44.

Iskali G. 2010. Invertebrate diversity in Bracken Bat Cave: Effects of bat guano subsidy. The 95th ESA Annual Meeting (August 1-6, 2010), 81-124 p. Retrieved on August 30, 2014. from https://eco.confex.com/eco/2010/techprogram/P25727HTM.

Jones C. 2009. A Guide to Responsible Caving. 4th Edition. National Speleological Society, 2813 Cave Avenue Huntsville, AL **35810,** 1-24 p.

Kambesis P. 2007. The Importance of Cave Exploration to Scientific Research. Journal of Cave and Karst Studies **69(1),** 46-58.

Ladle RJ, Firmino JVL, Malhado ACM, Rodríguez-Durán A. 2012. Unexplored Diversity and Conservation Potential of Neotropical Hot Caves. Conservation Biology **26(6),** 978-82.

Lagare NJS, Nuneza OM. 2013. The Cavernicolous Crickets in Selected Caves in Davao Oriental and Northern Mindanao, Philippines. ELBA Bioflux **5(2),** 130-140.

Lavoie K, Helf KL, Poulson TL. 2007. The biology and ecology of North American cave crickets. Journal of Cave and Karst Studies **69(1),** 114-134.

Lewis JJ. 1983. The Obligatory Subterranean Invertebrates in Glaciated Southeastern Indiana. National Speleological Society Bulletin **45,** 34-40

Mag-Usara VRP, Nuñeza OM. 2014. Diversity and relative abundance of cockroaches in cave habitats of Siargao Island, Surigao del Norte, Philippines. ELBA Bioflux **6(2),** 72-79**.**

Marshall AJ, Beehler BM. 2007. The Ecology of Papua: Part Two. Tuttle Publishing, Hongkong, p. 1072.

Martin KW, Leslie DM, Payton ME, Puckette WL, Hensley SL. 2003. Internal Cave Gating for Protection of Colonies of the Endangered Gray Bats (*Myotis grisescens*). Acta Chiropterologica **5(1),** 1-8.

McFarlane DA. 2004. Guano. In: Gunn J, ed. Encyclopedia of Caves and Karst Science. Fitzroy Deaborn An imprint of Taylor and Francis Group, New York, 848-850 p.

Mendoza JE, Naruse T. 2010. A New Species of Riverine Crab of the Genus *Sundathelphusa* Bott, 1969 (Crustacea: Brachyura: Gecarcinucidae) from Northeastern Luzon, Philippines. Philippine Journal of Science **139(1),** 61-70.

Micheal GR. 1966**.** Studies on the bottom fauna in a tropical freshwater fish pond. Hydrobiologia **31(2),** 203-230.

Novises I, Nuñeza OM. 2014. Species richness and abundance of cave-dwelling crickets on Siargao Island, Surigao Del Norte, Philippines. ELBA Bioflux **6(1),** 10-21.

Pan Y, Hou, Z, Li S. 2010. Description of a new Macrobrachium species (Crustacea: Decapoda: Caridea: Palaemonidae) from a cave in Guangxi, with a synopsis of the Stygobiotic Decapoda in China. Journal of Cave and Karst Studies **72(2),** 86–93.

Pape RB. 2014. Biology and Ecology Of Bat Cave, Grand Canyon National Park, Arizona. Biology and ecology of Bat Cave, Grand Canyon National Park, Arizona. Journal of Cave and Karst Studies **76(1),** 1-13.

Patrick B. 1994.The importance of invertebrate biodiversity: an Otago Conservancy review. Conservation Advisory Science Notes No. 53, Department of Conservation, Wellington, 13 p.

Piterkina T. 2005. The diel vertical migrations of herbage-dwelling spiders in clayey semi-desert of the northern Caspian Sea basin, West Kazakhstan (Araneae). In Deltshev C, Stoev P, eds. European Arachnology Acta zoologicabulgarica **1,** 151-159.

Santer RD, Hebets E. 2009. Prey Capture by the Whip Spider *Phrynus marginemaculatus* C.L. Koch. The Journal of Arachnology **37,** 109–112.

Schal C, Gautier J-Y, Bell WJ. 1984. Behavioural ecology of cockroaches. Biological Reviews **59,** 209–254.

Shaw P, Davis M. 1999. Invertebrates from Caves on Vancouver Island. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk, Kamloops, B.C., **1,** 212-214.

SWCA Environmental Consultant. 2006. Draft Results of an Endangered Karst Invertebrate Presence/Absence Survey in an Un-Named Cave located West of U.S, 218 South of Overlook Pathway, Bexar Country Texas. Texas Department of Transportation environmental Affairs Division, p. A20951-A20965. Retrieved August 31, 2014 from Interchange_Appendi.

U.S. Fish, Wildlife Service. 2008. Bexar County Karst Invertebrates Draft Recovery Plan.U.S.Fish and Wildlife Service, Albuquerque, NM.Retrieved August 31, 2014 from

Wallace JB, Webster JR. 1996. The role of microinvertebrates in stream ecosystem. Annu Rev Entomol **41,** 115-139.

Welbourn CW. 1999. Invertebrate Cave Fauna of Kartchner Caverns, Arizona. Journal of Cave and Karts Studies **61(2),** 93-101.

Wynne JJ, Drost CA, Cobb NS, Rihs JR. 2007. Cave-dwelling Invertebrate Fauna of Grand Canyon National Park, Arizona. In van Riper C, Sogge M, eds. Proceedings of the 8th Biennial Conference of Research on the Colorado Plateau University of Arizona Press, Tucson, 235-246 p.

www.9news.ph. 2014. Lanao del Norte hosts football try outs. Retrieved August 31, 2014 from

www.cministries1.tripod.com. Map of Mindanao. Retrieved August 31, 2014 from

www.mapsof.net. 2014. Philippines General Map-Philipines Maps. Retrieved August 31, 2014 from