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Diversity of macro-detritivores associated with guano piles in Magsupit Cave, Canapnapan, Corella, Bohol, Philippines

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Key words: Guano pile, Macro-diversity, Species abundance, Species diversity, Species richness

Abstract

The study was conducted to determine the relationship diversity of the guano pile to the diversity of macro-detritivores in the cave ecosystem. Specifically, this study aimed to determine the diversity of macro-detritivores associated with guano pile in terms of the guano pile area, pH, and distance from the cave entrance. Moreover, it also aimed to determine the effects of light intensity to the diversity of macro- detritivores in the cave ecosystem. The distance from the entrance of the cave to each guano pile was measured using a tape measure. A light meter was used to measure the amount of light for the identification of the cave zones: entrance zone, twilight zone, and dark zone. The pH was measured with a manual p Hmeter in a sample solution with deionized water, from the middle of the pile. The area of each pile was calculated using Simpson's formula, which integrates the measures of the lengths of parallel segments along longitudinal axis of each pile. Results showed that guano pile distance versus species richness demonstrated a positive correlation, while the species diversity demonstrated no significant correlation to the guano pile distance from the cave entrance. Moreover, the analyses of species abundance showed varied results. Analyses of guano pile area versus species richness, species diversity, and species abundance demonstrated positive correlations, while the analyses of guano pile pH versus species richness, species diversity, and species abundance demonstrated no significant correlations. Analyses of light intensity versus species richness, abundance, and diversity showed varied results.

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Introduction

Extensive guano deposits in caves by birds, invertebrates or most commonly by bats represent the main food resource of cave-dwelling organisms. Guano deposits have a strong influence on the distribution pattern of certain cave – dwelling populations sometimes hosting large communities at different successional stages. These communities include such diversed organisms as bacteria, fungi, nematodes, mites, coleopterans, dipterans, lepidopterans and spiders. In a particular case, a deposited guano pile has something to do with the decomposition process of detritivores such as macro-invertebrates, bacteria and fungi (Mc Faulane *et al.*, 1995; Miyutami *et al.*, 1992). Macro-invertebrates have important influence as decomposition process for generating of nutrients and translocation of materials (Wallace & Webster, 1996).

Bohol Island is made up of extensive karst (limestone) formations, such as sinkholes, ravines, the curious Chocolate Hills, and a large number of caves, many of them unexplored. In fact, it is considered by most as a cave country.

To date, there have been no reports on the macro-detritivores diversity in guano piles from Philippine caves. Studies on guano deposits have been made but these studies made a focus on bacterial diversity. Moreover, there have been no ecological studies done on macro-detritivores that live in guano in Bohol area, despite the potential importance of detritivores on the structure of bat guano communities. In addition, understanding the role that each species plays within cave communities is a key for the proper management and protection of detritivores, other organisms inhabiting the cave, and the cave as a whole. Thus, this study aimed to determine the relationship of the guano pile to the diversity of macro-detritivores in the cave ecosystem. Guano deposition appears to be significant in the diversity of macro-invertebrate species in caves. In relation to guano deposition, there have been no further studies made on the diversity of macro-detritivores in relation to bat guano piles taking into consideration the variations in the physicochemical parameters of the cave and of the guano pile, such as the guano pile area, guano pile pH, distance of guano pile from the entrance, and the light intensity or amount of light that enters the inner part of the cave. These parameters will be taken into account as to how they affect macro-detritivores diversity in a cave ecosystem.

Statement of the Problem

This study aimed to determine the diversity of macro-detritivores associated with guano pile. Specifically, it sought to investigate the following:

1. Is there a relationship between the guano pile, and the diversity of macro-detritivores in terms of:
   a. Guano pile area,
   b. Guano pile pH, and
   c. Guano pile distance from the cave entrance?
2. What are the effects of light intensity to the diversity of macro- detritivores?

3. *Significance of the Study*

Detritivores play a very important role in the cycle as they are the consumers of the dead leaves, old skin, carcasses and manure. It helps translocate materials from the environment to be used as essential components in the element cycle. The study is important as it assesses the diversity of macro-detritivores in caves especially that it is unusual environment for the organisms. The results of the study would be used as the inputs for the future researchers to conduct another study to triangulate results that will validate the results of the present study. For the scientific community, the study would be used as a useful baseline information as to what types of organisms are present in the cave of Bohol and its abundance and diversity associated with large deposits of guano pile. Moreover, this study would encourage biologists to study cave food chains to understand the whole cave ecosystem, and to better understand the more complicated food webs of the surface. They would be encouraged also to study cave organisms to see how they survive with so little food and no light. The results of this study would help improve the local government's ecotourism by making caves totally part of nature tourism that could increase the popularity of the place, thus, attracting local and foreign tourists. In addition, this would push the local government to formulate ordinances to further strengthen proper management and protection of the whole cave ecosystem and other ecosystems in the place.

Materials and methods

Study Area

The Municipality of Corella (Fig. 1) is located in the interior part in the island of Province of Bohol. It is the first town northeast of the City of Tagbilaran with a distance of 10 kilometers. It is bounded on the northeast by the Municipality of Balilihan; in the east by the Municipality of Sikatuna; in the west by the City of Tagbilaran; in the southwest Municipality of Baclayon; and in the southeast by the Municipality of Alburquerque; and in the northwest by the Municipality of Cortes. It has a total land area of 3,722.14 hectares. It has 8 barangays, namely: Sambog, Anislag, Tanday, Poblacion, Pandol, Cancatac, Canapnapan and Canangcaan. The climate is tropical, with wet and dry seasons. Precipitation is at maximum during February and November (Comprehensive Land Use Plan of Corella 2002-2011 in Abucay and Guillen, 2007).

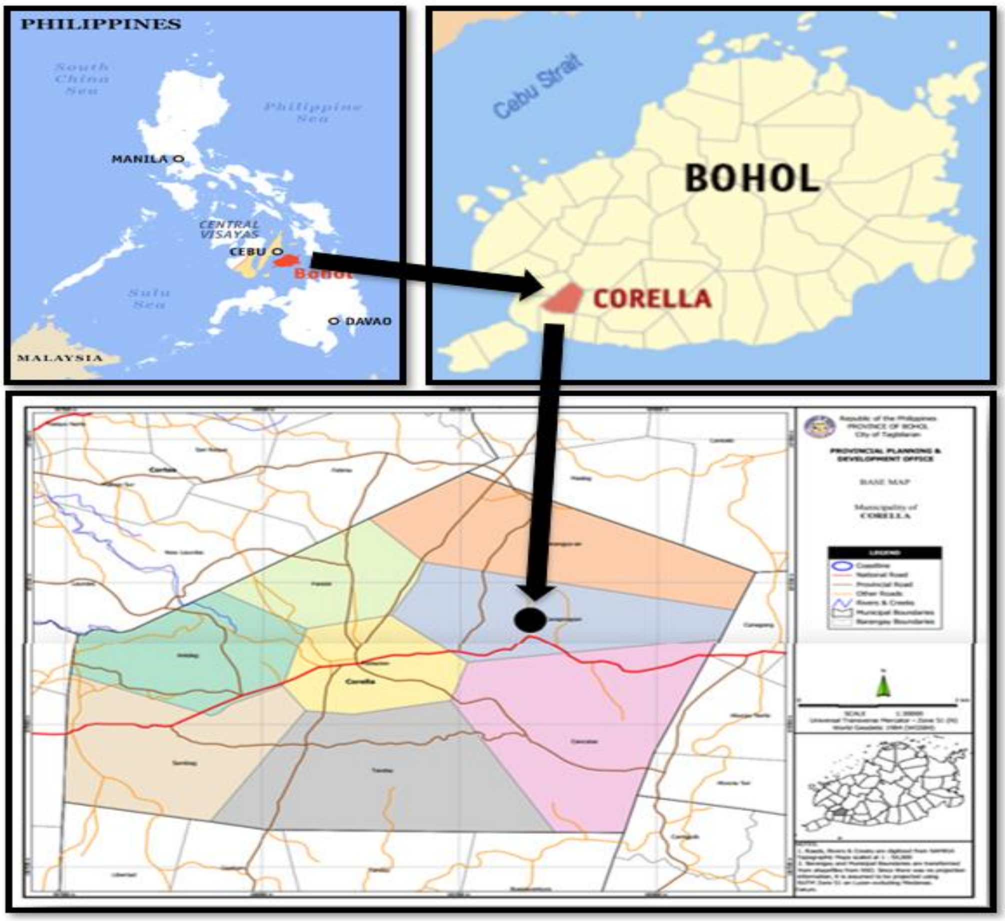

Fig. 1. Map of the Philippines, Bohol and Corella, with a black dot indicating the barangay where the cave can be found.

The study was conducted in Magsupit Cave (Fig. 2), which is situated at 9°41’ 22” North, and 123°56’34” East at an elevation of 92 meters above sea level in Barangay Canapnapan, Corella, Bohol, Philippines (Fig. 1). The large depression on the side of a hill that the locals refer to as “cave” actually consists of two separate cave systems, each with its own passageway, with the two openings separated by piles of rock and leaf litter. Both caves are surrounded by plants such as ferns, palms, and trees with big buttress roots. Magsupit Cave is a close-ended cave that has a wide opening and a large area of roost stains. There are large rocks on the floor of the cave's entrance, and it has a high ceiling filled with roost stains. As you go deeper, the cave changes orientation as it narrows into a small chamber leading to the right.

Fig. 2. Entrance of the Magsupit Cave.

Sampling Method

Macro-detritivores associated with each guano pile was collected in the 3rd week of February, from February 19-22, 2018, spending 30 minutes per pile on manual collection with tweezers, brushers and magnifying glass. All specimens were placed in plastic containers upon collection, counted individually, and were taken photos for the purpose of identification. Each photo was properly labeled with the corresponding numbers in the data sheet. Photos of the specimens were sent to Mr. Fidel Bendanillo, University of San Carlos Entomological Collection Curator, for identification. All organisms were identified and grouped by their morphospecies.

The distance from the entrance of the cave to each guano pile was measured using a tape measure. A light meter was used to measure the amount of light for the identification of the cave zones: entrance zone, twilight zone, and dark zone (Fig. 3). According to the Riverina Environmental Education Centre (2013), the entrance zone of a cave has a light intensity of more than 625 lux, twilight zone has a light intensity ranges from 1 lux to 625 lux, and dark zone has 0 lux due to total absence of light. Moreover, in a cave a reference level is sometimes useful when comparing caves and their biota, and a zone where <1% of the external surface light intensity occurs is suggested for the limit of the cave entrance habitat (Gunn, 2014). The pH was measured with a manual pHmeter in a sample solution with deionized water, from the middle of the pile.

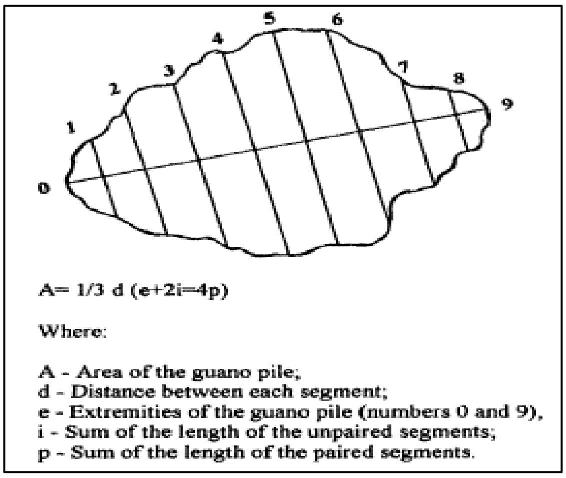

Fig. 3. A cave showing the different zones.

Sample sizes are dependent on guano area. The area of each pile was calculated using Simpson's formula (Fig. 4), which integrates the measures of the lengths of parallel segments along longitudinal axis of each pile. The perimeters of each guano pile were taken with a string (mark inmm) place around its circumference (Bernarth, 1981; Ferreira, 1999).

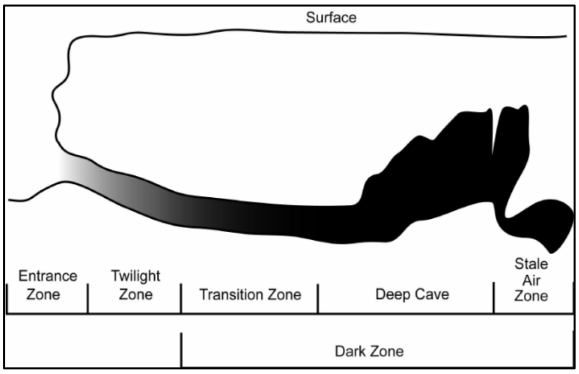

Fig. 4. Schematic drawing illustrating Simpson's formula in measuring guano pile area.

Analysis of Data

In the statistical analysis, the diversity of macro-detritivores was calculated using the Shannon-Weiner index (Ferreira & Martins, 1998). The correlations between the macro-detritivores richness and guano pile pH was tested using the Spearman rank correlation test. The same with the correlations between macro-detritivores richness and guano pile pH, the correlations between guano pile area and macro-detritivores richness, guano pile distance from cave entrance and macro-detritivores richness, and the amount of light and macro-detritivores richness were also tested using Spearman rank correlation test. Moreover, the correlations between the variables (guano pile area, distance from the cave entrance, pH, and light intensity), and species abundance and diversity were calculated using Spearman rank correlation test.

Results and discussion

Results

All guano piles were found in the twilight and dark zones of the cave. There were no guano deposits in the entrance zone. The thirty guano piles were located between 14.3 m to 41.69 m from the entrance of the cave. The area of the guano piles was variable, not related to the distance from the cave entrance, and did not show any pattern of distribution with respect to the location in the cave. The pH of the guano piles ranged from 4.60 to 7.29. Species richness, abundance and diversity were variable in the guano piles (Table 1).

Table 1. Measured variables for each guano pile in Magsupit Cave, Canapnapan, Corella, Bohol.

Guano Pile	pH	Distance (m)	Area (m^2)	Species richness	Species abundance *Pheidologeton* sp. (Formicidae)	*Scaphidium* sp. (Scaphidiidae)	*Gonocephalum* sp. (Tenebrionidae)	*Blatta* sp. (Blattidae)	Species diversity
1	6.26	14.3	8.19	2	120	0	0	6	0.19
2	7.29	18.6	3.10	2	0	29	17	0	0.66
3	4.66	18.9	6.01	2	0	18	24	0	0.68
4	4.74	18.2	6.09	2	0	57	94	0	0.66
5	4.95	17.4	26.45	4	89	137	185	53	1.29
6	5.93	14.7	15.07	3	0	102	126	68	1.07
7	5.70	14.7	19.05	3	0	105	122	121	1.10
8	5.28	14.3	19.70	4	36	100	127	101	1.31
9	5.38	14.7	22.10	4	64	132	139	112	1.07
10	5.64	15.2	18.49	3	0	155	132	141	1.10
11	5.65	15.65	10.14	3	29	132	165	0	0.93
12	4.82	23.11	5.75	2	0	54	42	0	0.69
13	5.29	23.51	7.25	2	0	24	31	0	0.69
14	4.60	21.60	47.61	4	104	139	148	135	1.38
15	4.73	25.76	20.72	4	29	128	125	111	1.28
16	5.84	33.60	12.73	3	0	201	211	286	1.09
17	6.01	33.65	7.52	2	0	152	134	0	0.69
18	5.99	33.67	10.91	3	0	178	163	143	1.09
19	5.87	34.42	14.37	3	0	243	202	301	1.09
20	5.69	36.42	10.05	3	0	254	268	285	1.10
21	5.81	38.47	27.75	4	88	372	375	385	1.09
22	6.02	39.37	49.89	4	206	426	438	321	1.35

Guano Pile	pH	Distance (m)	Area (m^2)	Species richness	Species abundance *Pheidologeton* sp. (Formicidae)	*Scaphidium* sp. (Scaphidiidae)	*Gonocephalum* sp. (Tenebrionidae)	*Blatta* sp. (Blattidae)	Species diversity
23	6.37	40.75	24.45	4	14	368	401	327	1.14
24	5.83	40.38	39.32	4	23	346	421	206	1.07
25	5.72	40.05	59.93	4	97	310	462	506	1.07
26	5.82	38.47	31.27	4	72	320	401	234	1.07
27	5.86	37.82	30.48	4	115	285	321	403	1.31
28	5.87	40.83	23.78	4	67	432	412	317	1.08
29	5.75	40.38	22.57	4	123	349	424	214	1.29
30	5.51	41.69	30.22	4	118	432	423	308	1.29

A total of 1,394 individuals were caught belonging to the *Pheidologeton* sp. (Family Formicidae), 5,980 individuals belonging to the *Scaphidium* sp. (Family Scaphidiidae), 6,533 individuals belonging to *Gonocephalum* sp. (Family Tenebrionidae), and 5,084 belonging to *Blatta* sp. (Family Blattidae) (Table 1). The cave has a total measure of 46 meters from the entrance or mouth to the end part of the cave. The light intensity of the cave ranges from 0 lux to 104.9 lux. Using light intensity, the zones, entrance, twilight and dark zones, were identified.

The entrance zone has the light intensity of 104.9 lux. The twilight zone has the light intensity ranges from 0.1 lux to 85.5 lux. The dark zone is completely dark, with the light intensity of zero (0) lux (Table 2).

Table 2. Light intensity in lux per one meter from the cave entrance with its corresponding cave zone.

Distance (m)	Light Intensity (lux)	Cave Zone	Distance (m)	Light Intensity (lux)	Cave Zone
0	104.9	entrance	12	5.4	twilight
1	85.5	twilight	13	4.9	twilight
2	60.4	twilight	14	1.8	twilight
3	46.4	twilight	15	1.5	twilight
4	30.9	twilight	16	1.0	twilight
5	27.0	twilight	17	0.7	twilight
6	19.4	twilight	18	0.3	twilight
7	17.0	twilight	19	0.1	twilight
8	15.9	twilight	20	0.1	twilight
9	9.6	twilight	21	0.6	twilight
10	9.0	twilight	22	0.1	twilight
11	6.2	twilight	23-46	0	dark

Guano pile distance from the cave entrance versus species richness, species abundance, and species diversity

Analyses of guano pile distance versus species richness (R=0.471, P=.009).

demonstrated a positive correlation, while the species diversity demonstrated no significant correlation to the guano pile distance from the cave entrance (R=0.272). Moreover, the analyses of species abundance showed that *Scaphidium* sp. (R=0.848, P=.000), *Gonocephalum* sp. (R=0.806, P=.000), and Blatta sp. (R=0.708, P=.000) were positively correlated to the guano pile distance from the cave entrance, while *Pheidologeton* sp. demonstrated no significant correlation to the guano pile distance (R=0.322) (Table 3).

Guano pile area versus species richness, species abundance, and species diversity

Analyses of guano pile area versus species richness (R=0.919, P=.000), guano pile area versus species diversity (R=0.652, P=.000), and the species abundances: guano pile area versus *Pheidologeton* sp. (R=0.729, P=.000), guano pile area versus *Scaphidium* sp. (R=0.721, P=.000), guano pile area versus *Gonocephalum* sp. (R=0.777, P=.000), and guano pile area versus *Blatta* sp. (R=0.740, P=.000), demonstrated positive correlations (Table 3).

Guano pile pH versus species richness, species abundance, and species diversity

Analyses of guano pile pH versus species richness (R= - 0.047), guano pile pH versus species diversity (R= -

0.117), guano pile pH versus *Pheidologeton* sp. (R=0.027), guano pile pH versus *Scaphidium* sp. (R=0.336), guano pile pH versus *Gonocephalum* sp. (R=0.258), and guano pile pH versus *Blatta* sp. (R=0.340), demonstrated no significant correlations (Table 3).

Light intensity versus species richness, species abundance, and species diversity

Analyses of light intensity versus species richness (R= -0.602, P=.000) demonstrated a negative correlation, while the species diversity demonstrated no significant correlation to the light intensity (R= -0.390). Moreover, the analyses of species abundance showed that *Scaphidium* sp. (R= -0.880, P=.000), *Gonocephalum* sp. (R= -0.866, P=.000), and *Blatta* sp. (R= -0.787, P=.000).

were negatively correlated to the light intensity in the cave, while *Pheidologeton* sp. demonstrated no significant correlation to the guano pile distance (R= -0.381) (Table 3).

Table 3. Correlations (Spearman) between all tested variables. The values below are R values (except for the ones in the gray columns). The numbers in boldface are significant at $P<0.01$.

	Distance	p-value	Area	p-value	pH	p-value	Light intensity	p-value
Species richness	0.471	.009	0.919	.000	-0.047	.806	-0.602	.000
Species abundance								
Pheidologeton sp. Family Formicidae	0.322	.083	0.729	.000	0.027	.887	-0.381	.038
Scaphidium sp. Family Scaphidiidae	0.848	.000	0.721	.000	0.336	.069	-0.880	.000
Gonocephalum sp. Family Tenebrionidae	0.806	.000	0.777	.000	0.258	.168	-0.866	.000
Blatta sp. Family Blattidae	0.708	.000	0.740	.000	0.340	.066	-0.787	.000
Species diversity	0.272	.146	0.652	.000	-0.117	.537	-0.390	.033

Discussion

Cave has different characteristic from other cave due to its unique formation and other variables such weather condition, type of biomes, geological location and even disturbance affecting its ecological and environmental activities (Bella *et al.*, 2008).

Guano pile distance from the cave entrance and light intensity versus species richness, species abundance, and species diversity

The pile distance from the cave entrance is inversely proportional to the light intensity. As the pile distance increases, the light intensity gradually diminishes to zero lux as the results suggest. In terms of correlation, the pile distance from the cave entrance is positively correlated, while light intensity is negatively correlated to species richness, abundance of *Scaphidium* sp., *Gonocephalum* sp., and *Blatta* sp,. On the other hand, species diversity and abundance of *Pheidologeton* sp. have no significant correlations to guano pile distance from the cave entrance and light intensity. These results are supported by the study conducted by Ferreira & Pompeu (1997) that the patterns of variation of richness and diversity of the guano communities in relation to distance from the cave entrance are similar which is decreasing. The same result was obtained by Ferreira & Martins (1998). A reduction in richness and diversity with increasing distance in the Taboa Cave (Sete Lagoas, Minas Gerais State) and also a reduction in richness and diversity of spiders associated with guano in Morrinho Cave.

However, the increase of *Blatta* sp. *Scaphidium* sp. and *Gonocephalum* sp., with increasing distance and diminishing light intensity, are ubiquitous in almost all imaginable environments (Schal *et al.*, 1984) from temperate to tropical regions (Bell *et al.*, 2007) and prefer to inhabit dark, humid, poorly ventilated, and cramped or crowded area (Capinera, 2008). These species were more abundant in cave zones with temperatures between 27°C to 28°C and relative humidity of 85% and above. This result coincides with the findings obtained by Jones (2008), and Gunn

(1934) that the preferred temperature of cockroaches and beetles is around 20-29°C depending on the type of species. Clay (1999) reported a preferred relative humidity of about 80%. Relative humidities of 80% and above may provide these species with a predictable source of water (Schal *et al.*, 1984). However, *Pheidologeton* sp. stay in any part of the cave regardless of the distance and light intensity as long as there could be sources of food, but most them would prefer to stay in the entrance zone due to their food preference, which varies from plant seeds, nectar and honey dew secreted by sap-sucking insects (LaSalle and Gauld, 1993). In the study conducted by Ferreira & Martins (1998), their analysis of distance versus diversity, guano pile type versus diversity, and guano pile pH demonstrated no significant correlations. On the other hand, diversity is positively correlated to the area of the guano piles (Macud & Nuneza, 2014; Perez & Nuneza, 2016; Ferreira & Martins, 1998). Moreover, increasing light intensity drives species loss in the cave community (Li, Zheng, Xie, Zhao, & Gao, 2017).

Guano pile area versus species richness, species abundance, and species diversity

Analyses of guano pile area versus species richness, guano pile area versus species diversity, and guano pile area versus species abundances demonstrated positive correlations. The species richness, species abundance and species diversity are dependent on the area of the guano. Bigger area of guano means the larger amount of organic matter that these macro-detritivores would decompose for them to thrive. In other words, bigger area of guano piles could support more species in terms of richness, abundance and diversity. In fact, these results were supported by other studies. Iskali (2011), in his study on Macroinvertebrate Diversity and Food Web Dynamics in a Guano Subsidized Cave Ecosystem in Bracken Bat Cave, located near Garden Ridge, Texas, observed that macro-invertebrate abundance, richness and diversity are significantly correlated with guano depth and area. Moreover, Pape (2014), in his study on Biology And Ecology Of Bat Cave, Grand Canyon National Park, Arizona, he concluded that most of the invertebrates present in Bat Cave are associated directly with the active guano deposit, and that guano serves as the foundation of the cave invertebrates and the diversity of invertebrates in caves is actually dependent on the guano microenvironment (Ferreira, Prous & Martins, 2007). Lagare & Nuñeza (2013), Cabili & Nuñeza (2014), Novises & Nuñeza (2014) and Mag-Usara & Nuñeza (2014) added that a major factor why caves harbored more number of macro-invertebrates could be the high amount of guano deposition which serves as food sources for macro-invertebrates and that the presence of more guano deposit contributes to higher number of macro-invertebrates. Further, thick and large size guano deposits support large number of macro-invertebrates and diversity in a cave ecosystem and that macro-invertebrate populations did fluctuate with respect to guano depth and area (Iskali & Zhang, 2015).

Guano piles with large areas probably embrace a higher diversity of microhabitats, which can support a higher number of associated taxa (or individuals) in these biotopes, as in other ephemeral ones (Doube, 1986). Guano plays a very important role in the food web of cave ecosystem (Cabili and Nuñeza, 2014) which supports most invertebrates (Clements, Sodhi & Schilthuizen, 2006). Caves with a higher source of vertebrate guano support different and higher number of macro-invertebrate than cave that lack such support (Bell *et al.*, 2007).

Guano pile pH versus species richness, species abundance, and species diversity

Analyses of guano pile pH versus species richness, guano pile pH versus species diversity, and guano pile pH versus species abundances demonstrated no significant correlations. The reason for the insignificant correlations is that guano become acidic when the deposited organic matter is decomposed by the macro-detritivores, they produce hydrogen ions which are responsible for soil acidity. The increasing amount of organic matter may make the soil more acid (Schroder, Zhang, Girma, Raun, Penn & Payton, 2011). Thus, this means that guano pH is dependent on the richness and abundance of species in a guano pile. In other words, the pH of the guano does not affect the diversity of macro-detritivores, but the macro-detritivores are the ones affecting the guano pH as they decompose organic matter, resulting to insignificant correlations. As Ferreira, Martins & Yanega (2000) showed, pH does not reflect species richness and abundance in a guano pile. Except for some rich alkaline piles from Morrinho Cave, the relationship between guano pH and richness is quite similar to that found in Lavoura Cave, which is no significant correlation (Ferreira *et al.*, 2000).

Caves are stable environments when compared with epigean habitats, with permanent lack of light far from entrances (Ferreira & Martins, 1998). Cave ecosystems are recognized as among the world's most fragile ecosystems (Wynne *et al.*, 2007; Nuneza & Sobrepena, 2014; Nuneza & Macud, 2014) that are usually characterized by the absence of natural light, stable temperature, geophysical structure, high relative humidity, low energy input (Biswas, 2010), and poor and sporadic food source (Bernabo *et al.*, 2011). In spite of these characteristics, caves harbor a variety of unique and sensitive organisms (Martin *et al.*, 2003), making them as wildlife sanctuaries for many organisms that need protection from predators and adverse conditions in the outside environment (Nuneza & Macud, 2014). It has long been recognized that caves and other subterranean habitats are likely to be food-limited because of the absence of photoautotrophic organisms (Simon *et al.*, 2007). In the absence of photoautotrophic organisms, these heterotrophic organisms must rely on other resources that usually are scarce in caves. These resources are mainly organic matter imported to caves by water, or animal excreta and carcasses of animals that has fallen into pit entrances or get lost within the cave (Poulson, 2005; Schneider *et al.*, 2011; Iskali & Zhang, 2015). In some dry caves, the main resource is guano of bats or birds which can form large piles (Ferreira & Martins, 1998). Bat fauna in the neotropics is characterized by the high richness of species and feeding habits: insectivory, carnivory, piscivory, frugivory, nectarivory, omnivory, and hematophagy (Gnaspini & Trajano, 1999). This diversity of bat feeding habits allows the comparison among the communities that use different types of bat guano.

The guano of hematophagous bats generally is inhabited by large numbers of fly larvae, in addition to nematodes, springtails and beetles. The guano of insectivorous bats possesses mainly mites, pseudoscorpions, beetles, thrips, moths, and flies. The guano of frugivorous bats is most diversified, containing mainly pseudoscorpions, harvestmen, spiders, mites, isopods, millipedes, centipedes, springtails, barklice, true bugs, and beetles (Ferreira & Martins, 1998).

Guano is a variable biotope that can be considered a mosaic of microhabitats, with animal communities in various successional stages because they show alteration in physiochemical parameters over time (Harris, 1970; Ferreira & Martins, 1998). Bat guano has a wide range of differences in the nutrient content and characteristics of various guano and guano-derived materials (Bird *et al.*, 2007; Emerson and Roark, 2007; Mizutani *et al.*, 1992a; Studier *et al.*, 1994). A variety of factors influence the nutrient content of guano, including species, feeding strategy (fruit, insects, blood, fish, omnivory), seasonal variations in diet, maternity status, and location (Bird *et al.*, 2007; Emerson and Roark, 2007; Goveas *et al.*, 2006; Mizutani *et al.*, 1992a; Studier *et al.*, 1994; Wurster *et al.*, 2007). As an example, a study comparing the guano of the fruit-eating Rodrigues flying fox (Pteropus rodricensis), the insect-eating Mexican free-tailed bat (Tadarida brasiliensis), and the blood-feeding common vampire bat (Desmodus rotundus) found those diets higher in nitrogen, with similar correlations between diet and phosphorus and carbon content (Emerson and Roark, 2007).

Once bat guano is deposited, macro-invertebrates, bacteria, and fungi begin the decomposition process. This breaks down organic matter, releasing carbon dioxide (CO_2) and ammonia (NH_3) (McFarlane *et al.*, 1995; Mizutani, *et al.*, 1992a). In a guano deposit, the topmost inches will have the highest organic matter content, as it is incompletely decomposed. The organic matter content declines with depth, and is generally completely consumed within the top few feet (Shahack-Gross *et al.*, 2004; Bird *et al.*, 2007; Wurster *et al.*, 2007).

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).

Macro-invertebrates, which have extremely restricted distribution, are largely located in areas with sufficient amount of nutrients and food source (Hunt and Millar, 2001). 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). They 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). In the process of decomposition of cave detritus, macro-detritivores are involved, such as ants, cockroaches, crickets and millipedes. Ants are ubiquitous, diverse, abundant, and fairly well-described. They constitute 10% of the tropical rainforest's total animal biomass (Wilson, 2000) and are good indicators of diversity (Lawton *et al.*, 1998). They are able to respond to a variety of disturbances and have served as bio-indicators to assess effects of forest clearing, road construction, mining, and agriculture (Uno *et al.*, 2010). They can positively affect physical and chemical soil properties, plant and animal distribution, and forest health (Lindgren & MacIsaac, 2002). The number of species still remaining to be discovered and described is incredibly high and studies on arthropod biodiversity are relatively limited (Uno *et al.*, 2010).

The Philippines has an estimated ant species diversity of 1,000 with only 394 species currently known. The presence of ants, an invertebrate arthropod, in cave environments is interesting as few species have been recorded from cave habitats, with only one ant exhibiting troglomorphic characters: Leptogenys khammouanensis (Roncin & Deharveng, 2003; Batucan & Nuneza, 2013). Certain physical and biological factors could affect species richness and abundance of ant communities inhabiting particular environments. Solar radiation, temperature, and water are examples of factors that play an important role in determining ant diversity (Rios-Casanova *et al.*, 2006). Caves have different zones (entrance, twilight, and deep zones) which make them an interesting study area since they have varying intensities of solar radiation, vegetation, temperature, substrate, and moisture.

The cockroaches have been on Earth for about 350 million years with nearly 4,000 species, of which only 1% are considered domestic pests. However, with their diversity, cockroaches remain widely uninvestigated (Bell *et al.*, 2007; Mag-usara & Nuneza, 2014). They are not generally considered as charismatic, and have not been commonly utilized in biodiversity studies. Nevertheless, they are an integral part of a stable and productive ecosystem. They contribute by breaking down organic matter and aiding in release of nutrients. They recycle dead animals, plants, and excrement, a process that is critical to a balanced environment. They also provide waste elimination services because they feed on the fecal matter of animals in all trophic levels; hence they are considered garbage collectors in terrestrial ecosystems (Mag-usara & Nuneza, 2014).

Cockroaches are ubiquitous in almost all imaginable environments from temperate to tropical regions (Bell *et al.*, 2007) and prefer to inhabit dark, humid, poorly ventilated, and cramped or crowded area. However, they are largely distributed and considered to be most diverse in the tropics (Mag-usara & Nuneza, 2014).

Crickets are hemimetabolous and oviparous insects and an important component of forest litter macro-fauna (Perez & Nuneza, 2016). In the field, most of the crickets are omnivorous feeding on organic materials as well as decaying plant material, fungi, and seedling plants. Crickets are also known to eat other dead crickets and become predator to weak members of their own species when there is no available food (Jones, 2013).

Cave crickets, also known as camel crickets and spider crickets because the back is humped up with the head bent down (Lavoie *et al.*, 2007) belong to the Family Rhaphidophoridae. All Rhaphidophoridae species are nocturnal and wingless with a preference for humid habitats. Rhaphidophoridae has nine subfamilies that are mainly distributed in the temperate regions of the northern and southern hemispheres and in the Southeast Asian tropics (Allegrucci *et al.*, 2010). Cave crickets that feed outside and roost in caves are important in the food budgets of cave ecosystems (Studier *et al.*, 2002).

Cave crickets gather around entrances as roosts and in staging areas where they can evaluate surface conditions before leaving the cave to forage but in accordance with the time of day and season. They can also be found in stable deep cave areas away from human-sized entrances, but close to cricket-sized entrances (Lavoie *et al.*, 2007). Cave crickets are also extremely sensitive to temperatures above cave temperatures, and show markedly greater metabolic demands with modest increases in ambient temperature compared to camel crickets (Studier & Lavoie, 1990). When the environment of cave crickets becomes too hot or dry, they may move inside. They are not usually capable of reproducing outside of their outdoor habitats and rarely find indoor locations that are dark and damp enough to suit them (Perez & Nuneza, 2016).

Millipedes are among the most abundant macro-decomposers in temperate forests, and have been found to play a significant role in decomposition and nitrogen release (Zuo *et al.*, 2014). They are most commonly found in the cooler, damper and darker places within their environment. They inhabit areas under rocks, in the leaf litter, in rotting logs and occasionally in burrows which are all known as micro-habitats. The millipede is an omnivorous animal but primarily feeds on dead plant material and decaying matter on the forest floor and caves. Millipedes are also known to eat some species of plants (that are alive) and the larger species of millipede also hunt insects. They are important members of the soil and litter fauna in temperate and tropical parts of the world, where they and other invertebrates aid in the breakdown of plant organic matter. Their general role in this process has been recognized since the early decades of this century; more recent studies have emphasized the interactions of these animals with microorganisms directly responsible for decomposition (Crawford, 1990). Globally, among macro-detritivores in mesic woodlands and regions characterized by calcareous soils, millipedes now rank somewhat behind earthworms and termites — but probably ahead of other groups — in terms of their contribution to litter breakdown (Edwards, 1974).

Beetles are the first agent of wood degradation arriving on a dead tree and animal wastes. This is not as apparent in the temperate zones, especially in dry ecosystems. However, in the tropics or in a healthy temperate conifer forest, beetles colonize dead trees and other ecosystems that contain animal wastes, and by drilling through the deep into the wood or waste, they open up the tree tissues and inner part of wastes for symbiotic as well as general degrading fungi (Hulcr &mccoy, 2013). Moreover, in agroecosystems, beetles have an added importance as biological control agents of pests. Some ground beetles are useful representatives of farm production, such as organic or conventional systems, as well as of specific farming practices. For example, ground beetles have been used as gauges of soil and weed management practices, insecticide use, and fertilizer application, to name a few of the farming practices (Lundgren, 2005). Beetles are also fed on both plant and animal material and scavenging (Lövei & Sunderland, 1996).

Guano deposition, temperature, and the amount of light are environmental factors which appear to be significant to the distribution of the macro-invertebrate species in the caves (Sobrepena & Nuneza, 2014). In addition, the interactions between energy availability and habitat characteristics create unique microhabitats and ecological niches within a cave. Organisms in a guano-subsidy cave were more dependent upon their microhabitat than the overall cave conditions (Iskali & Zhang, 2015). Thus, the variability of energy input and habitat conditions and their interactions must be taken into consideration to gain an understanding of the factors that influence cave communities.

Conclusion

Magsupit Cave in Bohol Island has found to have four species of macro-detritivores that aid in the decomposition process of bat guano deposited in the cave. These species include *Pheidologeton* sp., *Scaphidium* sp., *Gonocephalum* sp. and *Blatta* sp. Area of the guano pile is positively correlated to the species richness, abundance, and diversity because the larger the area of a guano pile, the bigger its ability to support macro-detritivores species to thrive. Distance of the guano pile from the cave entrance is positively correlated, while light intensity is negatively correlated to the species richness and to three of the four identified species of macro-detritivores: *Scaphidium* sp., *Gonocephalum* sp. and *Blatta* sp. However, species diversity and the abundance of *Pheidologeton* sp. do not have significant correlations to the distance of the guano pile from the cave entrance and light intensity.

Guano pile pH does not have any significant correlation to species richness, abundance and diversity at all due to the fact that macro-detritivores are the ones affecting the guano pH as they decompose organic matter present in the guano pile. The results suggest that the guano pile distance from the cave entrance is not positively related to all dependent variables. Moreover, pH level of the guano pile did not at all affect or no significant correlations to the diversity of macro-detritivores. However, the results showed that guano pile area is positively correlated to the diversity of macro-detritivores in the cave.

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