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Ant species richness in caves of Siargao Island Protected Landscape and Seascape, Philippines

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Abstract. The Philippines has a huge karst landscape with plenty of caves. These caves harbor many types of organisms, including invertebrates like ants. This study was conducted to determine the species richness of cave ants in Siargao Island Protected Landscape and Seascape. Rapid sampling of nine caves from four municipalities of the island yielded 14 species from ten genera. Million-bat Cave of del Carmen had the highest species richness. *Pheidologeton* sp. and *Odontomachus* sp. were the most common in caves around the island. Canonical correspondence analysis showed that temperature and humidity are the main factors which affect the presence of ants in caves. Guano deposits and the size of caves also appear to influence the presence of ants.

Key Words: guano, invertebrates, karst, organisms.

Introduction. 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 bioindicators 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 a karst landscape of approximately 35,000 km^2 with only about 29% declared as protected areas (Restificar et al 2006). According to Clements et al (2006), limestone habitats are rich in biodiversity and are good areas for ant sampling. The Philippines has an estimated ant species diversity of 1,000 with only 394 species currently known (Alpert & General 2012). Karst limestone areas have caves which harbor a rich fauna unique to subterranean environments. Although extensive records of cave animals are available, only a small fraction of known caves in any region have been biologically assessed. In spite of this, European and North American studies found that most cave dwellers are invertebrates with an average of 20 newly described species per year (Culver et al 2004). 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 (Roncin & Deharveng 2003).

Jeanne (1979) documented that species richness increases from the poles to the tropics so it is expected that there will be more ant species richness in tropical caves. But so far, there are only few studies on tropical cave ants and there has only been one truly troglobitic ant (*Leptogenys khammouanensis*) that was discovered and it can only be found deep in the caves of Laos (Roncin & Deharveng 2003). Dunn et al (2009, 2010) stated that ants usually do not follow the trend of increasing species richness with increasing precipitation (from the poles to the tropics) for which the opposite is true for a large majority of taxa. In fact, arid regions in Australia harbor similar or even higher numbers of ant species than tropical wet regions (Delsinne et al 2010).

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.

Many cave-dwelling and guano-collecting ants have been sampled throughout Southeast Asia (Roncin & Deharveng 2003) but there is a huge shortage of cave ant studies in the Philippines especially in Mindanao and its accompanying islands. This study assessed the species richness of ants in the caves of Siargao Island and determined whether or not physicochemical factors inside the caves affect the presence of ants in these caves.

Materials and Methods. The study was conducted in Siargao Island Protected Landscape and Seascape (SIPLAS) located in the northeastern portion of Mindanao (Figure 1) under the geographic and political jurisdiction of the province of Surigao del Norte. The island is identified as one of the Philippine Key Biodiversity Areas (KBA). It has three lithologic units, namely: limestone, volcanic, and alluvium covering a total of 62,796 hectares (PCHMB 2009). SIPLAS falls under climatic type II characterized as having no dry season with a maximum rainy season particularly from November to January (PAGASA 2009; PCHMB 2009). Nine caves in the municipalities of General Luna, Sta. Monica, del Carmen, and Burgos on Siargaoo Island were sampled. Physicochemical factors were determined in the three zones of each cave.

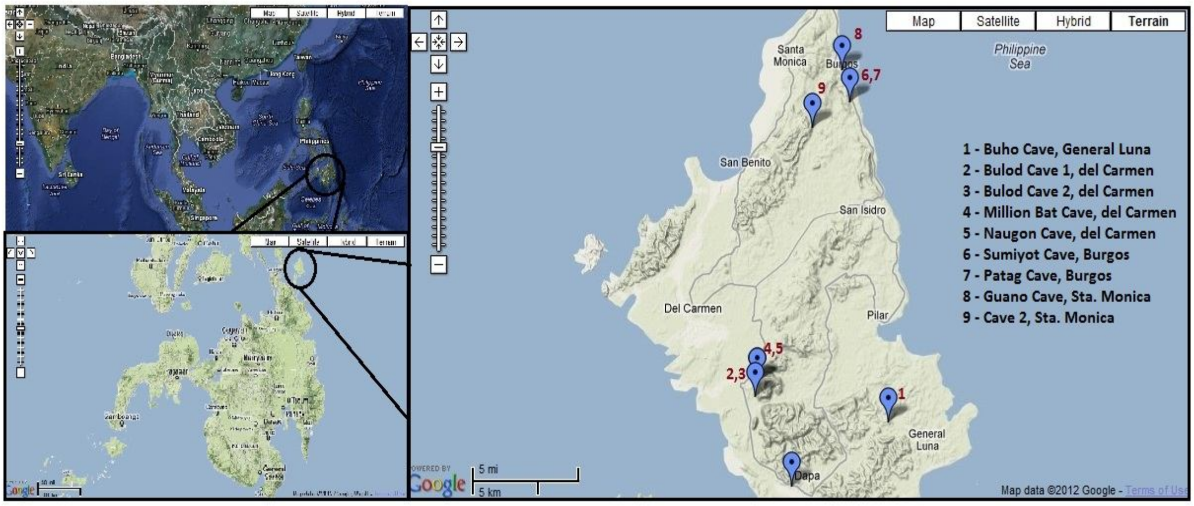

Figure 1. Map of Siargao Island relative to Southeast Asia and the locations of the sampling sites (Google Maps 2012).

Assessment of caves was conducted from October 28 to 31, 2011 for a total of 168 man-hours. Hand searching was the method employed in the study as it is more applicable to cave environments and avoids certain problems (time consumption, type of substrate, effort) and is efficient in yielding collections (Gotelli et al 2011).

At most three voucher specimens were collected per morphospecies as stated in the Wildlife Gratuitous Permit issued by the Department of Environment and Natural Resources (DENR) Region XIII. Samples were preserved in 70% ethanol. Collections were sent to the Philippine National Museum for identification by an expert. Canonical correspondence analysis was employed to determine the environmental factors that affect the presence of ants in caves and similarities in their distribution.

Results and Discussion. Fourteen species of ants were collected in nine separate caves of Siargao Island (Table 1 and Figure 2). The Million-bat cave yielded the highest species richness (5) while the three other caves (Bulod 2, Naugon, and Cave 2) only had one species each. Million-bat Cave is a dry cave with guano deposits. Guano deposits have been known as food source for certain species of ants (Moulds 2006). In contrast, the three species-poor caves were also the three smallest caves with shorter cave length (20-30m), smaller surface area, and without guano deposits.

Table 1

Ants collected in caves of SIPLAS and the sites where each species can be found

Subfamily	**Species Name**	**Buho Cave**	**Bulod Cave 1**	**Bulod Cave 2**	**Million-bat Cave**	**Naugon Cave**	**Sumiyot Cave**	**Patag Cave**	**Guano Cave**	**Cave Two**	**TOTAL**
Dolichoderinae	*Dolichoderus thoracicus*	+			+						2
	Dolichoderus sp2.			+							1
Myrmicinae	*Pheidologeton* sp.	+			+	+					3
	Crematogaster sp.				+						1
	Myrmicaria brunnea						+	+			2
	Pheidole sp.									+	1
Formicinae	*Polyrhachis* sp.1		+								1
	Polyrhachis sp.2		+								1
	Polyrhachis sp.3							+			1
	Polyrhachis sp.4								+		1
	Nylanderia sp.								+		1
	Camponotus sp.				+						1
Ponerinae	*Odontomachus* sp.				+			+	+		3
	Pachycondyla sp.						+				1
TOTAL 4	**14**	2	2	1	5	1	2	3	3	1	

Pheidologeton sp. and *Odontomachus* sp. were found in three caves wherein two of the caves where each was found are adjacent to each other. *Myrmicaria brunnea* and *Dolichoderus thoracicus* were both found in two caves, all the rest can only be found in one cave. Species found in Caves 6 to 9 (northern Siargao) are unique and cannot be found in the southern caves (Caves 1 to 5), and vice versa. In the middle of the island are forests, farmlands, and swamplands. These barriers are probable reason for the apparent difference of species composition between the northern and southern areas. Natural barriers prevent ants from colonizing new areas because it is hard for them to cross water bodies aside from desiccation due to the heat of the sun.

Figure 2. Digital images of the 14 species of ants found in the caves of SIPLAS.

Of the nine caves, three were wet caves (Naugon, Sumiyot, and Patag) and had flood marks. Only Patag cave had guano deposits (Table 2). Species richness of wet caves ranged from one to three. The wet cave with highest species richness was the cave with guano deposit while the other two were depauperate. In comparison, dry caves have higher species richness than wet caves. This can be explained by the fact that the wet caves are regularly flooded which does not favor the presence of ants since regular floods drown them. A stream is flowing through Patag cave but it has an elevated inner chamber with one-inch thick guano which permits the presence of ants since food materials are present in this chamber and the location is far from flooding.

Table 2

Description of the caves sampled in the four municipalities of Siargao Island Protected Landscape and Seascape (SIPLAS)

Cave	Coordinates	Water Bodies, Flood depth	Speleothems	Guano Deposit (in.)
Buho	9° 48' 11" N 126 ° 06' 22.6" E	absent	Few Stalactites, stalagmites	Deep Zone, 1" thick
Bulod 1	49' 07.6" N 126° 00' 48.7" E	absent	Few Stalactites, stalagmites	absent
Bulod 2	9° 49' 07.7" N 126 ° 00' 48.7" E	absent	Few Stalactites, stalagmites	absent
Million Bat	9° 49' 38.2" N 126 ° 00' 55.7" E	absent	Few Stalactites, stalagmites, Boulders	30 m from entrance, 2 ft thick
Naugon	9° 49' 38.1" N 126 ° 00' 55.7" E	Pool, 4 m flood depth	Stalactites	absent
Sumiyot	9° 45' 49.1" N 126 ° 02' 21.4" E	pool	Abundant Stalactites, stalagmites, Boulders	absent
Patag	9° 59' 54.8" N 126 ° 04' 48.4" E	Stream, 0.6 m flood depth	Abundant Stalactites, stalagmites, Boulders	1" thick
Guano	10° 01' 04.8" N 126 ° 04' 27.2" E	absent	Stalactites, few stalagmites, boulders	Deep zone, 2" thick
Cave 2	9° 58' 58.5" N 126 ° 03' 13.1" E	absent	Stalactites, stalagmites,	absent

Ten species of ants were found at the entrance zone of all caves, four from the twilight zone, and three from the deep zone (Table 3). The high richness of the entrance zone is expected due to favorable conditions outside the cave compared to the deep zone. Most ants sampled in this zone were found foraging in the leaf litter and crawling under small plants growing in the cave. The twilight zone on the other hand had more or less similar richness with that of the deep zone with only one common species. The guano present in the deep zone of the caves might have allowed the ants to survive inside as it provides food plus reduced competition from other species. The apparent decrease in richness as one goes deeper inside a cave can be attributed to many factors like guano deposits, temperature, and relative humidity.

Roncin & Deharveng (2003) reported that structures implying troglobiomorphy in arthropods - reduced eyes, light pigmentation, slender body and very elongated legs and antennae – have been so far observed in only one species of ant, *Leptogenys khammouanensis* from the Khammouan Karsts of Laos. In this study, slender body and lightly pigmented legs were observed in *Camponotus* sp. collected from the deep zone of Million-bat Cave. Known "cave-restricted" ants in Asia and Europe have been found in outside habitats (Roncin & Deharveng 2003). Of the 14 species, six are considered cave dwellers since colonies were found inside, the remaining eight are accidentals which just drifted in the entrance zone of the caves to forage.

Table 3

Zonal distribution of ants in the caves

Species	Zone		
	Entrance	Twilight	Deep
Dolichoderus thoracicus	Present	-	-
Pheidologeton sp.	Present	Present	Present
Polyrhachis sp.1	Present	-	-
Polyrhachis sp.2	Present	-	-
Polyrhachis sp.3	Present	-	-
Polyrhachis sp.4	-	Present	-
Dolichoderus sp2.	Present	-	-
Odontomachus sp.	Present	-	Present
Camponotus sp.	-	-	Present
Crematogaster sp.	-	Present	-
Myrmicaria brunnea	Present	-	-
Pachycondyla sp.	Present	-	-
Nylanderia sp.	-	Present	-
Pheidole sp.	Present	-	-
TOTAL	10	4	3

Figure 3 shows how similar the caves are in terms of species composition and physical characteristics. Four groups were formed - three solitary ones (Bulod 1, Bulod 2, and Cave 2) and another group composed of the other six caves (Buho, Naugon, Sumiyot, Patag, Million-bat, and Guano Caves). Bulod 1, Bulod 2, and Cave 2 all have unique species, small entrance, and relatively short cave length. Guano deposits and water bodies were absent in the caves. The other group composed of 11 species from six different caves had varying cave lengths. The common feature of this group is the presence of guano, water bodies, or both inside the caves.

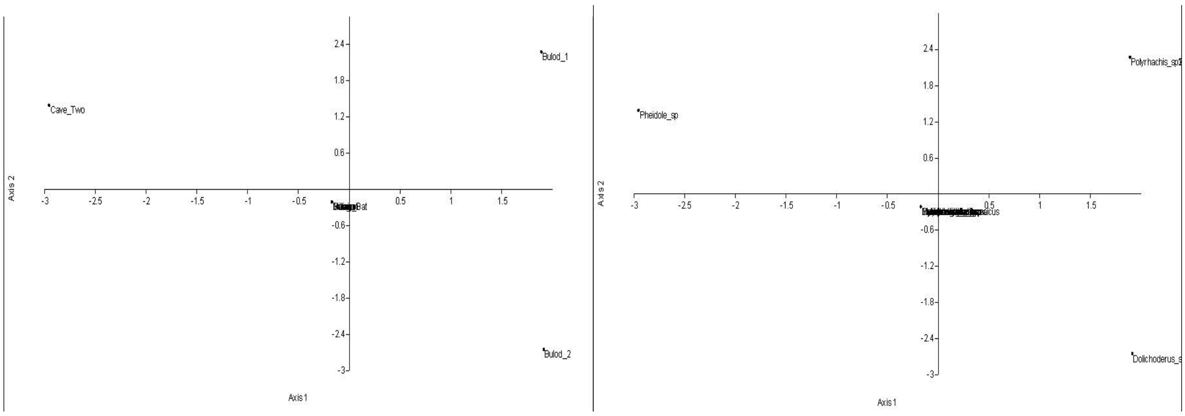

Figure 3. Ordination diagram showing the similarities of caves and species composition.

Table 4 shows a slight decrease in the average temperature as one goes deeper inside the caves. The relative humidity was highest at the deep zone. The difference in temperature and humidity in each zone can be attributed to the varying amount of sunlight reaching the cave and the amount of air that enters it. Doran et al (1999) in their study of caves in Tasmania, Australia reported that changes in the external environment can also directly influence the atmosphere of a cave by altering the differences in relative humidity and temperature between the surface and underground worlds. This may alter cave 'breathing' and air flows cycles, and enhance drying or warmer air penetration. These changes influence the presence of invertebrates inside the caves which includes ants.

Table 4

Temperature and relative humidity readings of the caves in relation to species richness

Cave	**Temperature (^{0}C)**			**Relative Humidity (%)**			**Species Richness**
	E[1]	**T[2]**	**D[3]**	**E[1]**	**T[2]**	**D[3]**	
Buho	28	29	28	80	81	85	2
Bulod 1	31	30.6	30.7	77	77	80	2
Bulod 2	30.4	30.2	28.5	78	79	87	1
Million-bat	30.5	30	28.9	77	74	87	5
Naugon	29	29.7	-	83	84	-	1
Sumiyot	31.1	30	30.1	78	77	81	2
Patag	30.1	30	27	80	80	97	3
Guano	28.4	28	27.4	83	84	98	3
Cave 2	28	27.2	27.2	90	83	85	1
Average	**29.61**	**29.41**	**28.48**	**80.67**	**79.89**	**87.5**	

[1] Entrance [2] Twilight [3] Deep

Using canonical correspondence analysis, it was found that temperature and relative humidity had the most effect on the distribution of ants in caves. The size of the caves' main access appears to also affect distribution (Figure 4). Delsinne et al (2010) reported that in arid environments, some factors restrict richness by limiting available resources. Variation of temperature in caves influences the presence of bats for their roosting which in turn will influence the presence of more number of ants since bat droppings are potential food sources, including other invertebrates that may be present. The size of the main access or entrance is significant because it serves as a conduit for air to enter and circulate inside the caves. A bigger entrance means a wider area for air to penetrate the deeper portions of the cave hence regulating the temperature and humidity which allow the presence of ants or other organisms in caves. Road access in turn signifies proximity to human habitation and other anthropogenic activity like farming, tourism, and quarrying. Million-bat cave located 1500 m from the main road, and which is on the steep slopes of a hill, had the highest species richness. On the other hand, Cave 2 which had only one species present is just 100m away from the main road.

A dendogram (Figure 5) of the similarities in richness of cave ants on the island of Siargao showed two major clusters which ultimately branched out into six. The first cluster composed of Buho, Naugon, and Million-bat caves all had *Pheidologeton* sp. present inside. The other major cluster which does not have *Pheidologeton*, branched out again into two groups composed of Bulod 1, Bulod 2, & Cave 2 and Guano, Sumiyot, & Patag caves. The similarity of Bulod 1, Bulod 2, and Cave 2 is that each of the three caves had unique species which cannot be found in any other cave. Guano, Sumiyot, and Patag caves were similar in the sense that some species like *Odontomachus* sp. and *Myrmicaria brunnea* are shared.

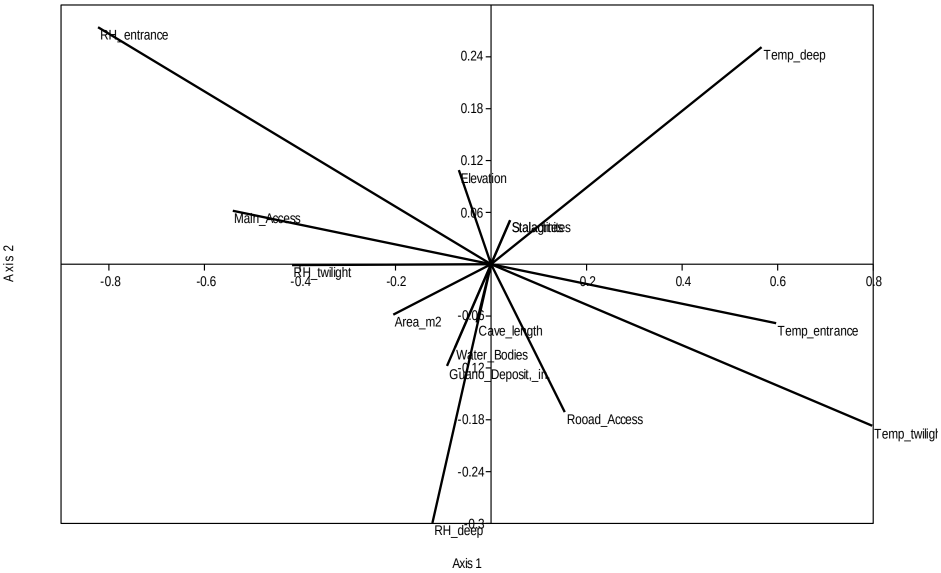

Figure 4. A graph of factors influencing ant distribution in caves of Siargao.

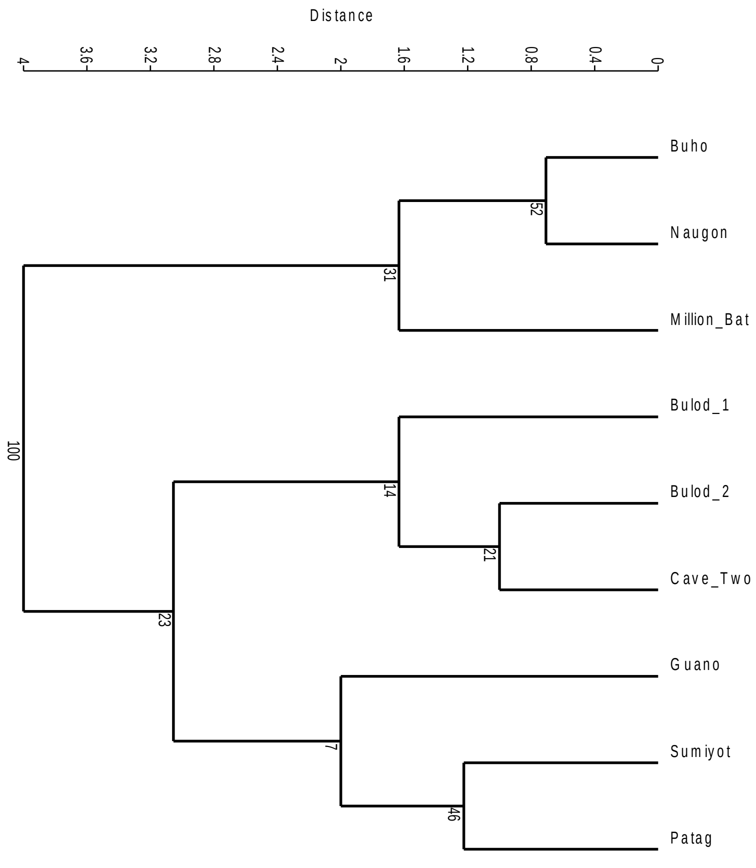

Figure 5. A dendogram on similarities between caves in terms of species composition.

Conclusions. Species richness of ants was high in large caves with guano deposits. Species richness was highest at the entrance zone of the caves and lowest at the deep or inner zone. Temperature, relative humidity, and the size of the caves appear to play a major role in the distribution of ants in caves.

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