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Diversity and relative abundance of cockroaches in cave habitats of Siargao Island, Surigao del Norte, Philippines

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Abstract Cave-dwelling cockroaches are poorly known and mostly unaccounted for in cave habitats. The diversity and relative abundance of cockroaches were determined by utilizing pitfall traps, quadrat and modified cruising methods in cave habitats of Siargao Island Seascape and Landscape. Four species were recorded in three out of ten cave sites with *Polyzosteria limbata* as the most abundant and commonly distributed. Buho cave had the highest abundance of cockroaches. Cave-dwelling cockroaches were found to have affinity to temperatures between 27˚C to 28˚C and relative humidity of 85% and above. Microhabitat preferences of cockroaches were noted to be the dense desiccated guano deposits and boulders found at the inner zones of caves. More assessments on caves in Mindanao are needed for a complete database and for a better grasp on the ecology of cave-dwelling cockroaches.
Key Words: cave-dwelling, guano, inner zone, microhabitats, Mindanao.

Introduction. Karts landscape represents an important facet of the Earth's geodiversity (Watson et al 1997). It occupies 10-20 percent of the Earth's surface (Palmer 1991). Karst environments are known for their diverse array of rare and interesting features which provide habitats for rare and threatened plant and animal species (www.environment.nsw.gov.au), among them are the arthropods that are, by far, the most diverse and abundant group of animals (Vasconcelos & Bruna 2012). Of these arthropods, the cockroaches are among those often discussed as if they are a homogeneous group when in reality they are remarkably diverse (Bell et al 2007). The cockroaches have been on Earth for about 350 million years with nearly 4,000 species, of which only 1% are considered domestic pests (Cochran 2009). However, with their diversity, cockroaches remain widely uninvestigated (Bell et al 2007).

Several studies on cockroaches are on rediscription and new identified species in Mainland China (Wang & Che 2013), in Europe (Bohn et al 2013) and in South Vietnam (Anisyutkin 2013). Species richness of cockroaches in North Guyana (Evangelista et al 2014) and their ecology in Virgins Island (Lu et al 2014) were also studied.

Cockroaches are not generally considered as charismatic (Bell et al 2007), and have not been commonly utilized in biodivesity studies (Evangelista et al 2014). Nevertheless, they are an integral part of a stable and productive ecosystem (Bell et al 2007). They contribute by breaking down organic matter and aiding in release of nutrients (Capinera 2008). They recycle dead animals, plants, and excrement, a process that is critical to a balanced environment (Bell et al 2007). They also provide waste elimination services because they feed on the fecal matter of animals in all trophic levels (Roth & Willis 1957) hence they are considered garbage collectors in terrestrial ecosystems (Bell et al 2007).

Cockroaches 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). However, they

are largely distributed and considered to be most diverse in the tropics (Gunn 2004; Peck & Herrera 2012).

The Philippines, a country in the tropics with numerous patches of isolated islands, is both a hotspot and a megadiverse country with high species diversity in some groups of organisms as well as high levels of endemism (Conservation International 2008). In addition, the country is endowed with a wide array of karst landscapes (Restificar et al 2006).

Caves in Mindanao have been assessed for ants (Figueras & Nuñeza 2013; Batucan & Nuñeza 2013), spiders (Enriquez & Nuñeza 2014; Cabili & Nuñeza 2014) and crickets (Novises & Nuñeza 2014). However, even with the assortment of karst habitats, studies on cave-dwelling cockroaches are uncommon. Siargao Island of Surigao del Norte in Mindanao is an apt study site to assess the distribution of cockroaches since it is among the many islands of the country which has not been accounted for.

This study aimed to assess the species richness of cockroaches in cave habitats of Siargao Island, Surigao del Norte. The distribution of species as well as the diversity and relative abundance were determined.

Material and Method

Study Area. Ten caves in four municipalities of Siargao Island, Surigao del Norte (Figure 1) were surveyed for cave-dwelling cockroaches.

Figure 1. Map of the Philippines and Mindanao (A) showing the location of Siargao Island (B) and the four municipalities where the caves are located (C) (www.googlemaps.com)

Cave Sites. Only the three caves where the cockroaches were found are described here. The seven other caves sampled in this study were described in Cabili & Nuñeza (2014) and Novises & Nuñeza (2014).

Buho Cave, General Luna, Siargao Island, Surigao del Norte. This cave in Barangay Consuelo, General Luna is situated 9° 48' 11" North and 126° 06' 22.6" East. It is 62 meters above sea level (masl) and 700 m from the main road. It has two openings with easily accesible main entrance of 8.67 m by 5.67 m dimension. The second opening is sloping, 5 m by 3 m dimension. The total cave length is 84 m with only one chamber. The accessible area was 750 m^2 with accessible depth of 2 m. Guano material was present 30 m from the main entrance. Stalactites and stalagmites were present, but the latter were very few all throughout the cave. Boulders were present from the main entrance to the twilight zone. Muddy soil substrate was present 35 m from the main entrance with depth of 4 inches. Light illuminance was 2.9 lux, taken 31 m from the main entrance, and 2.5 lux, taken 5 m from the second opening. Presence of wood poles, breakdown of some stalagmites and holes for treasure hunting were indicative of disturbance. This cave is utilized as a wildlife habitat, also as spelunking and treasure-hunting site.

Million-bat Cave, Del Carmen, Siargao Island, Surigao del Norte. This cave in Barangay Antipolo, Del Carmen is situated 9° 49' 38.2" North and 126° 00' 55.7" East. It has an elevation of 57 masl and about 1500 m from the main road. It has one opening with entrance slightly sloping but easily accesible, of 5 m by 4 m dimension. Total cave length is 140 m with only one chamber. The accessible area was 1400 m^2 with accessible depth of 1 m. Guano material was present 30 m from the main entrance with depth of 1 m. Stalactites and several stalagmites were present, but with few columns. Boulders were present at the entrance and inner recess zones. Muddy soil substrate was present 100 m from the entrance with depth ranging from 1-2 inches. Light illuminance was 1.4 lux, taken 15 m from the main entrance. Presence of rhum bottles and breakdown of some stalagmites indicated disturbance. This cave is utilized as a wildlife habitat and a site for guano collection.

Guano Cave, Sta. Monica, Siargao Island, Surigao del Norte. This cave in Barangay Libertad, Sta. Monica, situated between 10° 01' 04.8" North and 126° 04' 27.2" East, has an elevation of 33 masl and located 250 m from the main road. It has one opening of 10 m by 3 m dimension. The cave opening was easily accessible but the walkway to the entrance area was steep and sloping making it hardly accessible without rappelling. The accessed cave length was 70 m with no chamber. The accessed area was 2000 m^2 and accessible depth of 1 m. Guano material was present at the inner recess zone with depth of 2 inches. Stalactites and stalagmites were present but the latter were very few. Boulders were only present at the twilight zone. Muddy soil substrate was present at the inner recess zone with depth of 3 inches. Light illuminance was 7.6 lux, taken 10 m from the entrance. Soft drink bottles, wood poles probably used for hooking bats, breakdown of speleothems, and man-made holes for treasure hunting were indicative of disturbance. This cave is utilized as a wildlife habitat and an area for treasure hunting and guano collection.

Collection and Identification of Samples. Ten caves were surveyed for cave-dwelling cockroaches from October 28-31, 2011 for a total of 168 man-hours. Basic cave information including the physico-chemical parameters was taken for each cave.

Sampling was done using pitfall traps, quadrat, and modified cruising methods. Collected samples were soaked in 70% ethanol for 15 minutes and subsequently air-dried before mounting them with stainless steel pins. Each sample was labeled containing the following information: cave name, location of collection, and cave zone. The mounted samples were kept in sealed boxes with naphthalene balls to keep opportunistic insects away. The collected samples were deposited at the Wildlife Laboratory of the Department of Biological Sciences, Mindanao State University-Iligan Institute of Technology,

Philippines. Due to unavailability of taxonomic keys for cockroaches in the Philippines, collected samples were sent to the Philippine National Museum for proper identification by an expert.

Results and Discussion

Diversity and Relative Abundance. Four species of cockroaches were recorded in three out of ten cave sites (Table 1) on Siargao Island, Surigao del Norte. Four species were recorded in Buho cave, three in Guano cave and only one in Million-bat cave. A lower species richness of crickets (Novises & Nuñeza 2014) and spiders (Cabili & Nuñeza 2014) was also recorded in the same cave sites. A higher number of cockroach species was recorded by Lu et al (2014) in Virgins Island. According to Bell et al (2007), the distribution of cockroaches is often associated with the proximity of appropriate food sources. Buho cave was observed to be rich in guano deposits and had the highest number of individuals (88) and cockroach species. Novises & Nuñeza (2014) and Cabili & Nuñeza (2014) also found that Buho cave was rich in guano material which is also the reason for the higher number and abundance of species. Clements et al (2006) stated that in karst environment, guano deposition supports most invertebrates including cockroach communities which occur mainly in tropics. Caves with a source of vertebrate guano sustain cockroaches than caves that lack such input (Bell et al 2007), which explains why the cockroaches were only found in the three caves with guano.

Polyzosteria limbata of Family Blattidae was found to be the most abundant (47.68%) and commonly distributed in the three cave sites. Buho Cave in Barangay Consuelo, General Luna had the most number of *Polyzosteria limbata* with 39 individuals. *Calolampra irrorata* of Family Blaberidae was also found to be abundant (32.45%) and distributed in two out of the three caves. Buho Cave had the most number of *Calolampra irrorata* with 28 individuals. *Methana marginalis* of family Blattellidae was found in Buho Cave but absent in the two other caves. Cave communities depend on organic debris and fecal material (Capinera 2008) which are present in Buho, Million-bat and Guano caves. Caves with guano deposits typically contain large numbers of few cockroach species able to maintain dense populations and exploit the abundant, rich, but rather monotonous food (Darlington 1970).

Table 1

Relative abundance of cockroaches in the three cave sites

Cave Sites	Species				Total Number of Species	Total Number of Individuals
	Family Blaberidae	Family Blattidae	Family Blattellidae			
	Calolampra irrorata	*Polyzosteria limbata*	*Methana marginalis*	*Ellipsidion* sp.		
Buho Cave	28	39	8	13	4	88
Million-bat Cave	0	6	0	0	1	6
Guano Cave	21	27	0	9	3	57
Total	49	72	8	22		151
RA (%)	32.45	47.68	5.30	14.57		

Table 2 shows the biodiversity indices in the three cave sites. The caves were found to have low species diversity and more or less even distribution of cockroaches. Novises & Nuñeza (2014) and Cabili & Nuñeza (2014) also obtained low species diversity of crickets and spiders with more or less even distribution in the same cave sites. This low diversity significantly contributes to the overall function of the ecosystem of which these species

are part of and to the diversity of species assemblages within the communities (Elmqvist et al 2010).

Table 2

Biodiversity indices in the three cave sites

Diversity Indices	Buho Cave	Million-bat Cave	Guano Cave	Total
Species Richness	4	1	3	4
Number of Individuals	88	6	57	151
Dominance	0.3277	1	0.385	0.3567
Shannon-Weiner Index	1.226	0	1.013	1.155
Species Evenness	0.8515	1	0.9182	0.7932

Figure 3 shows the relationship of the distribution of cockroaches to temperature and relative humidity. Cockroaches 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 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 cockroaches with a predictable source of water (Schal et al 1984). Behavioral studies regarding temperature and humidity preferences of several cockroach species reveal that many species select narrow environmental ranges although they may tolerate significantly greater values (Schal et al 1984) which may be the case for *Polyzosteria limbata* found in Million-bat cave.

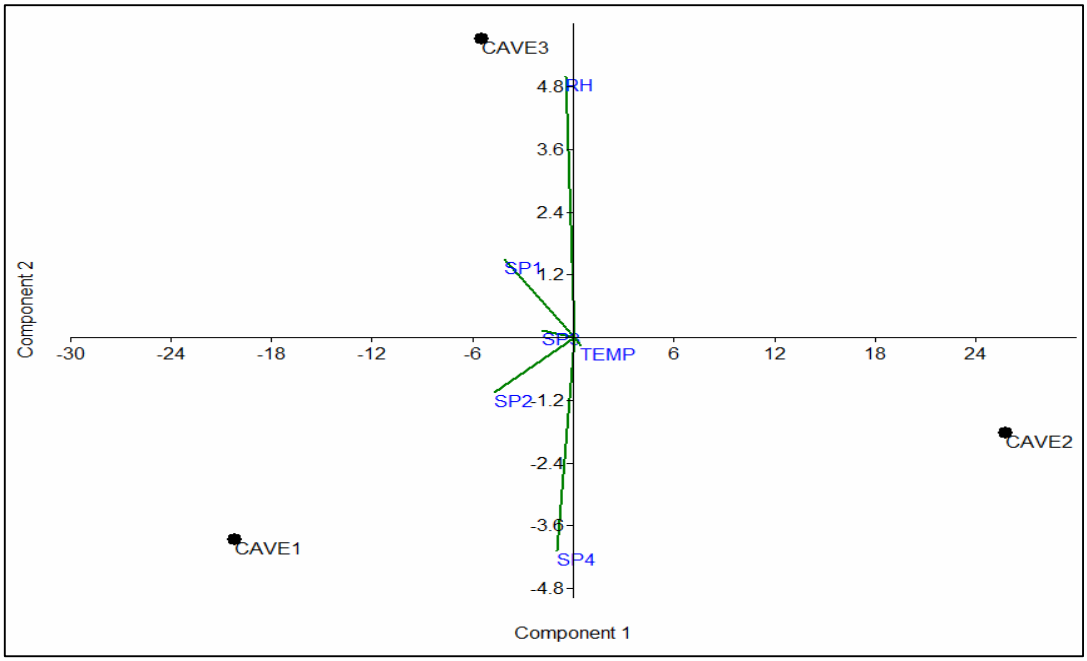

Figure 3. An ordination diagram showing the relationship between species, temperature and relative humidity in the different caves (SP1 – *Calolampra irrorata*, SP2 – *Polyzosteria limbata*, SP3 – *Methana marginalis*, SP4 – *Ellipsidion* sp., RH – Relative Humidity, TEMP – Temperature, Cave 1 – Buho Cave, Cave 2 – Million-bat Cave, Cave 3 – Guano Cave).

Caves have different zones with varying temperature, substrate and moisture (Batucan & Nuñeza 2013), as well as humidity that may support different community of organisms. Almost all species of cockroach were found in the cave's inner zone (Table 3), where complete darkness is permanent and relative humidity is constant (Schal et al 1984). According to Bell et al (2007), many species thrive and live in a continuum of dark, humid and often confined spaces. The microhabitats of cockroaches in Buho and Guano caves were desiccated guano deposits while their microhabitats in Million-bat cave were boulders near compacted guano deposits. Cockroaches tend to be attracted to irregularities such as boulders when guano is compacted (Darlington 1970). Moulds (2006) reported also, that microhabitat variation in caves is strongly controlled by guano deposition.

Table 3

Distribution of cockroaches in the different cave zones

Species	Buho Cave			Million-bat Cave			Guano Cave		
	E	TZ	IZ	E	TZ	IZ	E	TZ	IZ
1	0	2	26	0	0	0	0	0	21
2	0	0	39	0	0	6	0	0	27
3	0	0	13	0	0	0	0	0	9
4	0	0	8	0	0	0	0	0	0

Legend: E – Entrance, TZ – Twilight Zone, IZ – Inner Zone, 1 – *Calolampra irrorata*, 2 – *Polyzosteria limbata*, 3 – *Methana marginalis*, 4 – *Ellipsidion* sp.

Conclusion and Recommendation. The caves on Siargao Island have low species diversity of cockroaches. *Polyzosteria limbata* was the most abundant and widely distributed. The abundance of cockroaches was highest in Buho Cave and lowest in Million-bat cave. The distribution of cockroaches appears to be related to temperature and relative humidity. Microhabitat preferences of cockroaches were dense desiccated guano deposits and boulders at the inner zones of caves. It is recommended that more extensive assessments be conducted in caves in Mindanao to have a complete database of cockroaches and for a better grasp on the ecology of cave-dwelling cockroaches.

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