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Species richness and abundance of cave-dwelling crickets on Siargao Island, Surigao Del Norte, Philippines

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Abstract. Cavernicolous crickets were surveyed in selected caves on Siargao Island, Surigao del Norte, Philippines to determine species richness, evenness, distribution, and abundance. Sampling was carried out in 10 caves using hand searching, direct counting, pitfall traps and sweep nets. Three species of crickets with 644 individuals were recorded in eight out of the 10 caves sampled. *Ceuthophilus* sp. which was observed on cave holes, bedrock ceilings, and on floors with guano deposits was found to be the most abundant. *Pteronemobius* sp., the second most abundant (42.92%) was observed on cave walls and crevices in the twilight zone. Only one individual of *Gryllotalpa* sp. was present in only one cave site. Results indicate that larger caves with more guano deposits, high relative humidity and low temperature have more number of crickets.
Key Words: Cave, cavernicolous, guano, species, twilight zone.

Introduction. The Philippine archipelago is one of the largest aggregations of islands in the world, with over 7,000 islands said to be included within the country's boundaries (Heaney & Heideman 1987). It is also among the five most important biodiversity hot spots in the world, with high levels of biodiversity and endemism (Meniado et al 2001). The unique conditions of caves make cave life mysterious and challenging to research (Ronca 2009), and our knowledge of caves in the tropics is even more acute especially its species diversity which is inadequately quantified (Moseley et al 2012). Caves are generally overlooked because they are uncharismatic and difficult to study (Percival 2006). Ecology of cave crickets is poorly known and rarely studied. The value of cave species to the public often is considered low but cave species have potential scientific, practical, and educational value.

Caves are natural, ideal and unsustainable resource for distinctive vertebrates and invertebrates. It is the world’s most remote and fragile wilderness that provides irreplaceable habitat for rare species (Jones 2009). Caves are especially vulnerable and probably more so than most other land resources and important as host for special cave species both at surface and underground (Watson et al 1997). It is characterized by many adverse conditions like perpetual darkness, high humidity and poor and sporadic food sources (Bernabo et al 2011).

Cave species may have good potential value to humans as "indicator species" in karst areas. Some cave communities are highly dependent on cave crickets, which exit at night to scavenge on the surface, like different species of troglobitic beetles that prey on cricket eggs (Elliot 2000). Crickets occur almost everywhere on the earth wherein the largest numbers of species audible from a single location occur in tropical regions (Alexander & Otte 2003).

Recognizing the role that cave crickets play in cave systems is important for the management and protection of endangered karst invertebrates. Crickets are often keystone species in cave ecosystems (Fagan et al 2007; Taylor et al 2007) and improve the overall health of the cave (Yoder et al 2011) maintaining cricket guano communities

(Lavoie et al 2007). The cave food chain is quite complex, but everything ultimately depends on the bats for survival (Price 2002) which means that the bat guano is very nutritious which supports invertebrates like cave crickets.

The population of crickets often numbers in thousands, in Texas (several *Ceuthophilus)* and Kentucky (*Hadenoecus* and *Ceuthophilus*) where there are many troglobitic and troglophilic carabid beetles, such as *Pseudanophthalmus*, and *Neaphaenops* preying on cricket eggs (Lavoie et al 2007). About 1% of known 3000 species of crickets have been studied experimentally (Masaki & Walker 1987).

Only few studies have been reported on cave macroinvertebrates in the Philippines. Recent studies were those of Batucan & Nuñeza (2013) on species richness of ants on Siargao Island and Figueras & Nuñeza (2013) on species diversity of ants in karst limestone areas in selected areas in Mindanao. The most recent study is that of Lagare and Nuñeza (2013) on crickets in Davao Oriental and Northern Mindanao. In this study, caves on Siargao Island were assessed to determine the species richness and abundance of cave-dwelling crickets as well as find out the key factors influencing the distribution of cricket species in the caves.

Material and Method

Sampling areas. Cave sampling was conducted in the four municipalities of Siargao Island namely Burgos, Del Carmen, General Luna and Sta. Monica (Figure 1).

Cave 1 (Buho Cave, General Luna). This cave in Barangay Consuelo, General Luna (9^o 48' 11" N and 126^o 06' 22.6" E) with elevation of 62 m above sea level (masl) is located 700 m from the main road, has 2 openings with main entrance which is easily accessible (width: 8.67 m, height: 5.67 m). The second opening is sloping with a width of 5 m and height of 3 m. Total cave length is 84 m with only 1 chamber, an accessible depth of 2 m with an accessible area of 750 m^2. Guano material with a guano depth of 1 inch was found 30 m from the main entrance. Stalactites and stalagmites were present but the latter are very few. Boulders were present from the main entrance to the twilight zone while muddy soil substrate with depth of 4 inches was found 35 m from the main entrance.

Cave 2 (Bulod Cave 1, Del Carmen). This cave in Barangay Antipolo, Del Carmen (9^o 49' 07.6" N and 126^o 00' 48.7" E, elevation 47 masl) is located 500 m from the main road, has 1 opening with entrance not easily accessible due to entrance size (width: 1 m, height: 1.5 m) but not sloping. Total cave length is 40 m with no chamber, an accessible depth of 1.5 m and accessible area of 41 m^2. Stalactites and stalagmites were present but the latter are present only at the inner recess zone. Muddy soil substrate was present all throughout with depth of 5 in.

Cave 3 (Bulod Cave 2, Del Carmen). This cave about 5 meters away west of Cave 2 (9^o 49' 07.7" N and 126^o 00' 48.7" E, elevation 44 masl) is located 500 m from the main road, has 1 opening with entrance not easily accessible due to entrance size (width: 1 m, height: 1.5 m) but not sloping. Total cave length is 40 m with no chamber, no accessible depth. An accessible area was 41 m^2. Stalactites and stalagmites were present but the latter are present only at the inner recess zone. Muddy soil substrate was present all throughout with depth of 4 in.

Cave 4 (Million Bat Cave, Del Carmen). This cave in Barangay Antipolo, Del Carmen (9^o 49' 38.2" N and 126^o 00' 55.7" E, elevation 57 masl) is located 1500 m from the main road. It has one opening with an entrance easily accessible (width: 5 m, height: 4 m) but slightly sloping. This cave has a total length of 140 m with only 1 chamber, an accessible depth of 1 m and an accessible area of 1400 m^2. Boulders were present at the entrance zone and at the inner recess zone. Guano material with depth of 2 ft. was present 30 m from the main entrance. Stalactites and several stalagmites were present with very few columns. Muddy soil substrate was present 100 m from the entrance with depth ranging from 1 - 2 in.

Cave 5 (Naogon Cave, Del Carmen). This cave in Barangay Antipolo, Del Carmen (9^o 49' 38.1" N and 126^o 00' 55.7" E, elevation 60 masl) is located several meters southwest of Cave 4 and is 1500 m from the main road. Low canopy covered the surface of the cave.

The cave has one vertical hardly accessible entrance, 3 m in diameter, which required rappelling. Accessed cave length was 20 m and the cave has no chamber. Accessible depth relative to the opening was 1 m. Accessed area was 100 m^2. Underground pool was present but was very risky to reach. Flood depth marking was 4 m. Guano material was absent. Stalactites were present but no stalagmites. Muddy soil substrate had a maximum depth of 7 in.

Figure 1. Map of the Philippines (A) (www.nationsonline.org) and Mindanao (B) (www.travpl.com) showing the location of Siargao Island(C) (surigaoislands.com) and the four sampling sites (☆).

Cave 6 (Sumiyot Cave, Burgos). This cave in Barangay Poblacion 1, Burgos (9^o 45' 49.1" N and 126^o 02' 21.4", elevation 16 masl) is located 400 m from the main road. It has one opening (width: 2.5 m, height: 2 m) with sloping, hardly accessible entrance. An accessed cave has length of 30 m with no chamber, accessible depth of 1 m and an accessible area of 150 m^2. Pool was present at the inner recess but very risky to reach. Stalactites and stalagmites were extremely abundant with several columns; boulders at twilight zone and muddy soil substrate were present at the entrance zone with depth of 2 in.

Cave 7 (Patag Cave, Burgos). This cave in Barangay Poblacion 2, Burgos (9^o 59' 54.8" N and 126^o 04' 48.4" E, elevation 22 masl) is located 600 m from the main road. It has one opening (width: 10 m, height: 5 m). The entrance is sloping and easily accessible, the estimated cave length is 1000 m with no chamber. Accessible depth was 5 m, with accessible area of 3000 m^2. Stream flowing out of the cave, guano material with depth of 1 in, and flood depth marking of 0.6 m were present. Stalactites and stalagmites were abundant with several columns. Muddy soil substrates were present with depth of 4 in, and boulders at the twilight zone.

Cave 8 (Guano Cave, Sta. Monica). This cave in Barangay Libertad, Sta. Monica (10^o 01' 04.8" N and 126^o 04' 27.2" E, elevation 33 masl) is located 250 m from the main road. It has one opening (width: 10 m, height: 3 m), entrance easily accessible. The accessed cave has length of 70 m with no chamber, accessible depth of 1 m and an accessible area of 2000 m^2. Water bodies and flood depth were absent. Boulders were present at the twilight zone. Muddy soil substrate was present at the inner recess zone with depth of 3 in. Guano material at inner recess zone had depth of 2 in. Stalactites and stalagmites were present but the latter were very few.

Cave 9 (Cave II, Sta. Monica). This cave in Barangay Libertad, Sta. Monica (9^o 58' 58.5" N and 126^o 03' 13.1" E, elevation 51 masl) is located about a hundred meters southwest of cave 8, and is 100 m from the main road. It has one opening, 7 m in diameter. The cave is located near a grassland and an agricultural area and it has a low canopy cover on its surface. The opening was sloping and mossy making it difficult to walk through. Accessed cave length was 20 m and the cave has no chamber. Accessible depth relative to the opening was 1 m. Accessed area was 500 m^2. Water bodies and flood depth marking were absent. Guano material was absent. Speleothems were few and monotonous. Stalactites and stalagmites were present at the entrance area but the latter were absent at the twilight zone. Boulders were absent. Muddy soil substrate was present at the twilight zone with depth of 2 in.

Cave 10 (Cave III, Sta. Monica). This cave in Barangay Libertad, Sta. Monica (9^o 47' 46.2" N and 126^o 06' 27.7" E, elevation 29 masl) is located 70 m east of Cave 9, and is 30 m from the main road, has one opening (width: 2 m, height: 1 m). Vertical entrance was hardly accessible. Cave length was 18 m with no chamber. An area of 108 m^2 was assessed. Water bodies, flood depth, guano material, stalactites and stalagmites were completely absent but few boulders were present at the inner recess zone. Muddy soil substrate was present all throughout the cave with depth of 3 in.

Collection, processing of data and data analysis. Ten caves were assessed on October 28 - 31, 2011 for a total of 168 man-hours. Two to three voucher samples of each species were randomly captured for identification. Collection was done using hand searching, direct counting, pitfall traps and sweep nets. Hunt & Millar (2001) reported that hand searching is the more preferable technique used in collecting cave fauna. Physico-chemical parameters were taken in every zonal area of the cave using a field thermometer, pH meter, lux meter and digital psychrometer.

Collected samples were placed in plastic bags which were later transferred to plastic cups for sorting with a fixing agent, 70% ethanol, for 30 minutes. Samples were naturally dried before mounting them using stainless steel pins. Voucher specimens were deposited at the Wildlife Laboratory, Department of Biological Sciences, Mindanao State University – Iligan Institute of Technology. Due to inadequacy of taxonomic key to the cricket species in the Philippines, collected specimens were sent to the Philippine National

Museum for identification by an expert. Biodive Pro software was used to determine biodiversity indices. Disturbances to the caves were noted.

Results and Discussion. Three species of crickets were recorded in eight out of the 10 caves (Table 1). Lagare and Nuňeza (2013) also recorded three species in the caves of Davao Oriental and Northern Mindanao but only one species, *Pteronemobius sp.* was also found in this present study. Buho cave had the highest number of cricket species which could be due to the rich guano material and boulders inside the cave. Elliot (2007) reported that large boulders are the roosting sites of bats and these bats are the source of guano on which cave crickets thrive on.

No crickets were observed in Naogon cave and Cave II. It is in these caves where anthropogenic activities were present. Boulders and guano materials were absent which probably explains the absence of crickets.

Ceuthophilus sp. of Family Prophalangopsidae had the highest abundance (56.93%) and is widely distributed in eight out of 10 caves. Lavoie et al (2007) reported that total numbers of emerging *Ceuthophilus* sp. were influenced by temperature, relative humidity and light intensity. *Gryllotalpa* sp. a mole cricket, of Family Gryllotalpidae was the least abundant (0.15%) and was found only in Buho cave which had the most abundant guano material. *Gryllotalpa* is a subterranean insect (Ulgaraj 1974) that is generally univoltine (species having one brood per year) in its ranges and mostly stay underground in extensive tunnel systems (Silcox 2011). According to Frank & Parkman (1999), species of this genus is innocuous and some are rare. They inhabit soil that is easily overlooked by man (Nickel & Castner 1984).

Brandenburg et al (2001) reported that mole crickets construct a tunnel structure similar to that observed in the southeastern U.S. Walker & Masaki (1989) also stated that this species survives in submerged soil for at least several hours and can swim on the surface for about 24 hours.

Table 1

Distribution of crickets in the caves

Cave sites	*Families*	*Gryllidae*	*Prophalangopsidae*	*Gryllotalpidae*	*Total species*	*Total individ.*
	Species	*Pteronemobius* sp.	*Ceuthophilus* sp.	*Gryllotalpa* sp.		
Buho cave		44	14	1	3	59
Bulod cave 1		4	3	0	2	7
Bulod cave 2		3	6	0	2	9
Million-bat cave		138	95	0	2	233
Naogon cave		0	0	0	0	0
Sumiyot cave		12	4	0	2	16
Patag cave		28	156	0	2	184
Guano cave		48	94	0	2	142
Cave II		0	0	0	0	0
Cave III		8	6	0	2	14
Total		285	378	1	3	664
RA (%)		42.92	56.93	0.15	-	-

RA (%) - Percent Relative Abundance.

Table 2 shows low diversity with more or less even distribution in all cave sites. Cave environments generally allow the maintenance of small populations as the result of food scarcity and a lower biodiversity (Rétaux & Casane 2013) but organisms found in caves have special characteristics and features to survive in such an environment (DENR-PAWB 2008).

Table 2

Biodiversity indices in ten cave sites

Parmeter	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*	*C9*	*C10*	*Total (Ni)*
Species	3	2	2	2	0	2	2	2	0	2	3
Individuals	59	7	9	233	0	16	184	142	0	14	664
Dominance	0.613	0.510	0.556	0.517	0	0.625	0.742	0.553	0	0.510	0.508
Shannon	0.629	0.683	0.637	0.676	0	0.562	0.427	0.639	0	0.683	0.694
Evenness	0.625	0.989	0.945	0.983	0	0.877	0.766	0.948	0	0.989	0.667

C1 – Buho cave, C2 – Bulod cave 1, C3 - Bulod Cave 2, C4 – Million-bat cave, C5- Naogon cave, C6 – Sumiyot cave, C7 – Patag cave, C8 – Guano cave, C9- Cave II, C10 – Cave III, Ni- Number of individuals.

Table 3 shows the variations of measured air temperature and relative humidity values at each monitoring location of three distinct zones which includes the floor, wall and roof surfaces in all cave sites.

Table 3

Cave environmental conditions in three ecological zones of 10 cave sites

Cave zones	*Physico-chemical parameters*	*Cave surface*	*Cave sites*									
			1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Entrence zone	Temperature (°C)	Ground	27.9	30.7	30.8	30	28	31.3	30.3	28	27	28.1
		Wall	27.8	31.0	30.8	30	28.2	31.5	30.2	28.4	27.1	28
		Roof	27.8	30.8	30.7	30	28	32	30.2	28.2	27.2	28
	Relative humidity (%)		80	77	78	77	83	78	80	83	90	84
	Light		2.9(A)	2.6	2.6	1.4	4.2	1.3	12.4	7.6	1.7	1.9
	Illuminance (lux)		2.5(B)	-	-	-	-	-	-	-	-	-
Twilight zone	Temperature (°C)	Ground	29.7	30.0	30.0	30.0	28.8	32.1	30.2	28.2	27	27.9
		Wall	28.2	30.6	30.1	30.1	29.6	32.0	30.2	28.0	27.6	27.9
		Roof	28.0	30.5	29.9	29.0	29.0	30.1	30.3	28.0	26.8	27.8
	Relative humidity (%)		81	77	79	74	84	77	80	84	93	83
Inner zone	Temperature (°C)	Ground	27.7	30.5	30.5	28.7	NA	30.0	27.0	27.0	27	27.0
		Wall	27.9	30.6	30.6	28.5	NA	30.0	27.1	27	27.2	27.1
		Roof	27.8	30.4	30.4	28.0	NA	29.8	27	27.1	27.1	27
	Relative humidity (%)		85	80	87	87	NA	81	97	98	94	85
	Cave type		dry	dry	dry	dry	wet	wet	wet	dry	dry	dry

Cave 1 – Buho cave, Cave 2 – Bulod cave 1, Cave 3 - Bulod Cave 2, Cave 4 – Million-bat cave, Cave 5- Naogon cave- Cave 6 – Sumiyot cave, Cave 7 – Patag cave, Cave 8 – Guano cave, C9- Cave II C10 – Cave III, NA – Not accessible/ risky to reach (underground pool) A- 1st opening; B- 2nd opening.

Temperature of the ground, wall, and roof at the entrance zone ranged from 27°C to 32°C and relative humidity ranged from 77 to 90%, however, there were no crickets found in this zone. In the twilight zone, temperature ranged from 26.8°C to 32.1°C and relative humidity ranged from 74% to 93%. In this zone, *Pteronemobius* sp. was found to be most abundant mostly observed on wall surface of the caves. The inner recess zone which had a temperature range of 27 - 30.6°C and relative humidity of 81 - 98% had the most number of crickets. *Ceuthophilus* sp. was the most abundant at this zone since most of the species in this zone are cave-adapted species (Biswas 2009). Large and deep caves showed lower temperatures and higher relative humidity values compared to shallow and small caves. Patag, Naogon, and Sumiyot are wet caves. These caves were observed to have higher humidity and lower temperature compared to dry caves.

Table 4 shows the distribution of crickets in various cave zones. The most preferred microhabitat was the wall of the twilight and inner zones with two species recorded (*Ceuthophilus* sp. and *Pteronemobius* sp.*).*The high humidity and abundant food (guano) in caves support a high population density (Ladle et al 2012) which is the reason why no crickets were present in the entrance zone because of warmer temperature and the lack of guano. Crickets are possibly a significant prey item for several subtroglophiles, as described by Howarth (1973) that these are species which live and reproduce in caves but which are also found in similar dark humid microhabitats. One individual species of *Gryllotalpa sp.* was found on the floor of the inner zone of Buho cave. *Gryllotalpa sp.* is an insect that has a burrowing mode of life (Houston 2011), readily identifiable by its large size and enlarged front legs that are adapted for digging in soil (Heinrichs & Barrion 2004). It is a typical animal living underground. In order to adapt to these surroundings, soil-burrowing animals have geometrically nonsmooth structures or rough structures on their body surfaces (Ren et al 2001). All mole crickets spend their lives underground in tunnel system they construct with powerful forelegs specially modified for digging (Walker & Masaki 1989). They occur in varying abundance, from solitary to several hundred insects in one habitat, and are nocturnal in their habits.

Table 4

Distribution of crickets in various ecological cave zone

Species	*Entrance zone*			*Twilight zone*			*Inner zone*		
	W	*R*	*F*	*W*	*R*	*F*	*W*	*R*	*F*
Pteronembius sp.	-	-	-	+	+	-	+	+	-
Ceuthophilus sp.	-	-	-	+	-	-	+	-	+
Grylootalpa sp.	-	-	-	-	-	-	-	-	+

W– wall surface, R – roof surface, F – floor surface.

An analysis of similarities of cave sites showed that the 10 caves belong to two main groups (Figure 2). The first group composed of cave 5 (Naogon cave), Cave 2 (Bulod cave 1), cave 3 (Bulod cave 2), cave 6 (Sumiyot cave), cave 9 (Cave II), cave 10 (Cave III) and cave 1 (Buho cave) is the most similar according to temperature and relative humidity. These caves were observed to be smaller in size with warmer temperature and lower relative humidity. These caves have the least number of crickets which varied between 0 - 16. Crickets were absent in cave 5 (Naogon Cave). Temperature and relative humidity were relatively the same. For the second group, Million-bat cave, Sumiyot and Patag caves were large caves which obtained the highest abundance of *Ceuthophilus* sp. reaching 48 - 138 individuals*.* These caves have the most numerous crickets, lower temperature and higher relative humidity. Biswas (2009) reported that temperature and relative humidity curves track each other, indicating that as temperatures fall, so does relative humidity since initially, cooling of an air mass should cause a rise in relative humidity, not a decline. Poor surface weather conditions negatively affect cricket foraging and the trophic cascade based on guano resupply (Lavoie et al 2007). Thick guano materials which pile up on the muddy soil surface of the caves provide more food and support more crickets. These piles of guano materials afford more hiding areas for crickets. Northup et al (1993) reported that based on morphological characteristics, extremes of cave adaptations are seen with the less adapted *Ceuthophilus carlsbadensis,* living in food-rich areas and the smaller more cave-adapted *Ceuthophilus longipes* found in food poor areas.

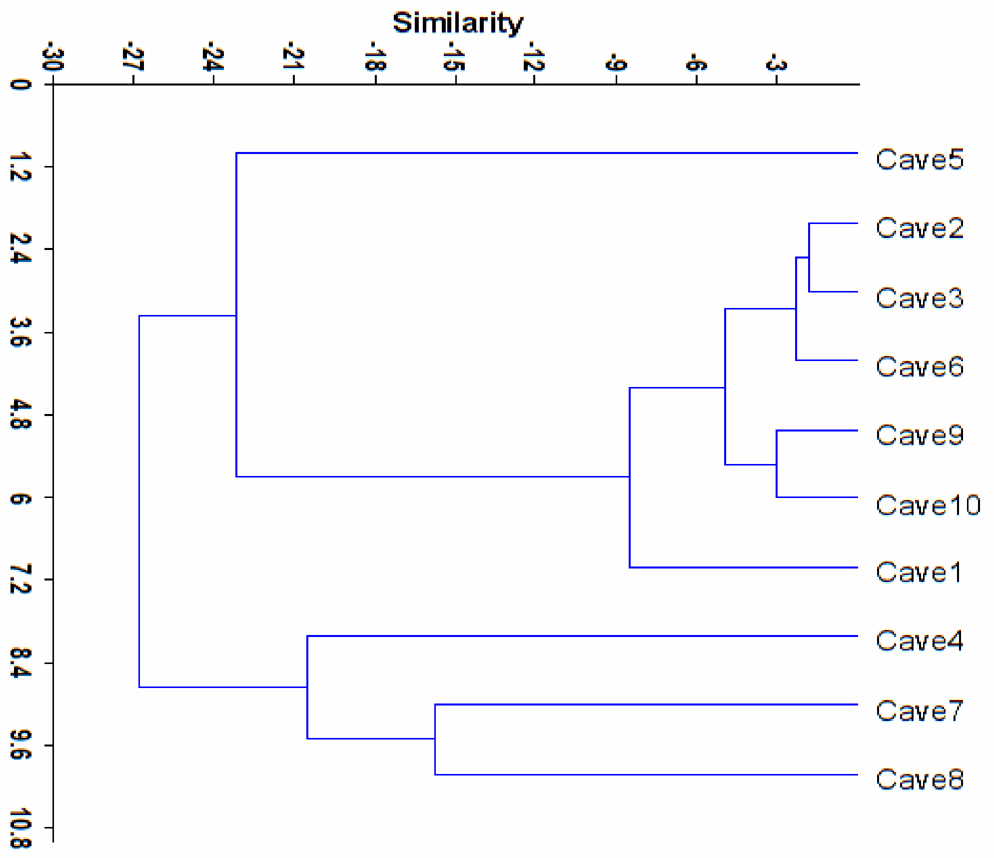

Figure 2. A dendrogram showing similarities of cave sites in relation to temperature and humidity and cave crickets (Cave 1- Buho cave, Cave 2- bulod cave 1, Cave 3- Bulod cave 2, Cave 4- Million-bat cave, Cave 5- Naogon cave, Cave 6- Sumiyot cave, Cave 7- Patag cave, Cave 8- Guano cave, Cave 9- cave II, Cave 10- Cave III).

Figure 3 shows the relationship between cricket abundance and temperature, relative humidity and light availability in 10 cave sites. Crickets were more abundant in Million-bat cave, Patag cave and Guano cave which had light illumination of 7.1 lux. As pointed out by Ulgaraj (1974), crickets do not come out of the ground until it becomes dark (light intensity <20 lux) which explains that light illuminance is one factor which influences cricket abundance. Crickets were least in number in Cave II, Cave III and Buho cave at relative humidity of 80% and temperature of 28°C. The number of crickets was positively correlated with surface temperature. Surface activity of these cave crickets is limited by temperature and markedly influenced by relative humidity. Studier et al (1986) stated that crickets cannot metabolically regulate their body temperatures, so body temperature changes in changing environmental temperature. This signifies that crickets are more likely sensitive to unstable temperature which explains why there were few crickets found at high temperature and low relative humidity.

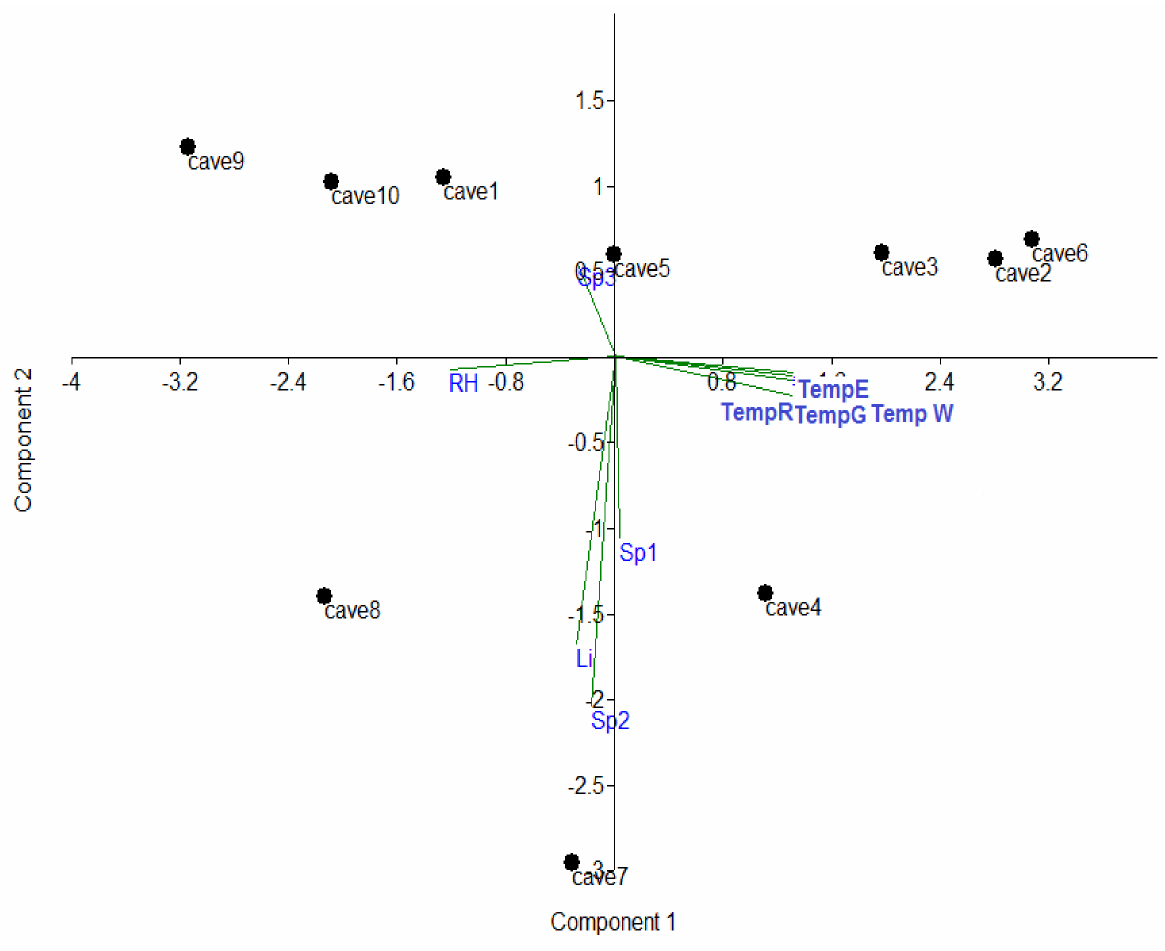

Figure 3. Ordination diagram showing the correlation between species' abundance to temperature, relative humidity and light in 10 cave sites (Cave 1- Buho cave, Cave 2- Bulod cave 1, Cave 3- Bulod cave 2, Cave 4- Million-bat cave, Cave 5- Naogon cave, Cave 6- Sumiyot cave, Cave 7- Patag cave, Cave 8- Guano cave, Cave 9- cave II, Cave 10- Cave III, Sp1- *Pteronemobius* sp., Sp2- *Ceuthophilus* sp., Sp3- *Gryllotalpa* sp., Li- light, Rh- relative humidity).

Conclusion and Recommendations. *Ceuthophilus* sp. was the most abundant and widely distributed cave cricket in this study. Low diversity and more or less even distribution of crickets in the caves were recorded. Temperature, relative humidity and guano deposits appear to be the key factors that affect the distribution and abundance of crickets. It is recommended that more caves be surveyed in Mindanao and in other parts of the country to get more substantive data not only on cricket species richness but on other aspects as well like cave adaptations and behavior.

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