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The cavernicolous crickets in selected caves in Davao Oriental and northern Mindanao, Philippines

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Abstract. Cavernicolous crickets are poorly known in the Philippines. Information on the abundance and distribution of cave crickets in Mindanao, the second largest island in the country, is particularly lacking. Sampling of crickets was done using a combination of modified cruising, hand searching, and pitfall trapping methods. Eight hundred twenty six individuals were recorded in 19 selected cave sites in Mindanao. *Macropathus* sp., a troglophile cave cricket was found to be the most abundant (59.07%) and widely distributed in 15 of the 19 cave sites. Aggregate number of *Macropathus* sp. was observed on the cave floors with thick guano. Some were observed on cave holes and others were found on high wall interior from the cave entrance. *Endacusta* sp., one of the cavernicolous species of subfamily Phalangopsinae comprised 40.79% of the total number of individuals and mostly found roosting on dry cave walls and crevices in the twilight zone area. Only one individual of *Pteronemobius* sp. (0.121%) was observed near the cave entrance and absent in all other 18 cave sites. Large caves with stable temperature and relative humidity were found to have more abundant number of crickets while the least number of crickets was observed in extensively disturbed caves as observed in two cave sites in Gitagum, Misamis Oriental. It was observed that caves with more guano deposits have more number of crickets. Temperature, relative humidity, and guano deposits were the factors observed to affect abundance and distribution of cavernicolous crickets. It appears that there is a need to survey more caves to better understand the ecology of cave crickets and to have complete database of crickets in Mindanao.
Key Words: cave walls, guano, *Macropathus* sp., troglophile, twilight zone.

Introduction. Caves are homes of vertebrates, invertebrates and other organisms that have adapted to the cave environment. The variety of life in a cave is small and the ecosystem is far more fragile than most of those on the surface (Jones 2009). With relatively constant temperature (Culver 1982), the cave environment offers crickets protection from heat and refuge from predators (Culver 2005).

Orthopterans particularly the cavernicolous species such as the cave crickets exhibit various modifications and adaptations to the cave environment (Richards 1968b). These adaptations include elongated antennae and femora that help the cave crickets to stride on uneven surfaces in total darkness inside the cave (Lavoie et al 2007). Body coloration may also vary and eyes may be reduced as to some obligate troglobites (Hunt & Millar 2001). Most of the cricket species under subfamily Phalangopsinae are common in the tropical regions especially long-legged crickets (Zefa 2006). The lawn ground crickets are inhabitants of short-grass communities while band-legged ground crickets are common on ground sparsely covered with short herbs (Masaki 1983).

Cave crickets are often important keystone species (Lavoie et al 2007) in cave communities because these crickets often occur in large number of individuals and are one of the primary modes of transporting energy from the surface (Taylor et al 2007a). The cave crickets' contribution on the food base in many caves made them dominant species (Lavoie et al 2007). These crickets are also one of the most common terrestrial invertebrates (Graening et al 2003). Within their geographic range they are found in virtually every cave with high densities in roosts just inside cave entrances (Culver &

White 2005). The understanding on the roles that each species plays within cave communities is also important for the management and protection of endangered karst invertebrates (Taylor et al 2007a).

Cave crickets are widely distributed in caves and as one of the dominant cave dwellers, cave crickets are more studied than most other cavernicolous invertebrates because they are relatively large and abundant (Lavoie et al 2007). Cave cricket abundance is used as an indicator of integrity of cave ecosystems (Weckerly 2012) while the endangered species are hard to find due to their relative lack of numbers and because they live deep between caves (Peterson et al 2009).

Southeast Asia has some of the richest cave faunas in the world (Whitten 2009) and Philippine caves are very crucial for the conservation of biodiversity (DENR-PAWB 2008). However, there are only few identified cricket species in the Philippines (Baltazar & Salazar 1979). Hundreds and even thousands of caves are scattered throughout the 7,107 islands of the Philippines. Despite these numbers, only few studies on caves and cave fauna were conducted (Lavoie et al 2007). Recent studies were those of Figueras & Nuñeza (2013) on species diversity of ants in karst limestone areas of Bukidnon and Davao Oriental, Philippines and Batucan & Nuňeza (2013) on ants in caves on Siargao Island, Philippines. This study determined the relative abundance, species richness, diversity and evenness of cavernicolous species of crickets in selected cave sites in Mindanao. The threats to cave crickets were also identified.

Material and Method

Sampling areas. Nineteen cave sites in Mindanao were established (Figure 1).

Sampling area 1 - this consisted of five cave sites: four caves on the mountain side (Hindang cave 1, Hindang cave 2, Hindang cave 3, Hindang cave 4) and one cave in the lowland (Dalipuga cave) in Iligan City, Northern Mindanao. The four cave sites in Barangay Hindang, Iligan City were situated at the mountain side with sparse vegetation and moderate canopy cover. Entrance to the caves was sloping but does not require a rope to get into the cave. All the four caves were closed caves and no stationary or moving water was observed inside. The guano materials were moderately accumulated. Dalipuga Cave in the lowland has a moderate canopy cover and apparently no water was flowing horizontally inside the cave but may be flooded during rainy season. There were numerous formations of old stalactites. Guano materials were patchily accumulated throughout the cave.

Sampling area 2 - two cave sites (Gitagum cave 1, Gitagum cave 2) were surveyed in Barangay Matangad, Gitagum, Misamis Oriental, Northern Mindanao. These were coralline caves located about 20 m from each other. Both caves have bare vegetation and low canopy cover. Soil substrate is dry without guano deposit. The caves were extensively disturbed. Burning of firewood was observed.

Sampling area 3 - five caves (Minsalirac cave 1, Minsalirac cave 2, Minsalirac cave 3, Blue Water Cave, Kabyaw cave) were assessed in Quezon, Bukidnon, Northern Mindanao. One cave is a religious shrine and religious devotees consider this as a quiet place for prayer and solitude. Just 50 m from this cave is another cave which is a serene site for nature lovers. Both these caves have high degree of disturbance. Blue Water Cave has an underground water source which flows out towards the Pulangi River. This cave is extensively disturbed because it is used as tourist destination by locals and tourists. The biggest cave in this sampling area is Kabyaw Cave which is considered as one of the biggest caves explored in this study. The guano materials accumulated were thick and found in many parts of the cave. There were numerous formations of stalactites and stalagmites.

Sampling area 4 - three caves (Kitaotao cave 1, Kitaotao cave 2, Kitaotao cave 3) were sampled in Barangay Poblacion Kitaotao, Bukidnon, Northern Mindanao and these caves have many openings. Cave 1 has three openings, cave 2 is an open cave, and cave 3 also has three openings. These caves have sparse vegetation with moderate canopy cover.

Stagnant bodies of water were observed in cave 3. This cave is also prone to flooding during rainy season.

Figure 1. Map of Mindanao showing the six sampling areas indicated by ( ) and 19 cave sites ( ) (saripedia.wordpress.com)

__Sampling area 5__ - two caves, Salawaw Cave and Kariis Cave, were surveyed in Barangay Concepcion, Valencia City, Bukidnon, Northern Mindanao. Water is horizontally flowing inside the caves. Based on the survey of the Department of Environment and Natural Resources (DENR) and Mines and Geosciences Bureau Region 10 in the year 2008, both caves were within the DENR geohazard zone.

__Sampling area 6__ - two caves, Pianginan Caves 1 and 2, located 50 m from each other were surveyed in Barangay Limot Tarragona, Davao Oriental. These caves were located at the mountainside of the forest with dense canopy cover. Compared to the other 17 caves sites, the two caves have the lowest degree of disturbance and considered as undisturbed caves.

Collection and processing of samples. Sampling was done from April to May 2010 using a combination of the modified cruising method, pitfall trapping, hand searching, and direct counting techniques for a total of 420 sampling hours. The selective nature of hand searching makes it the most preferable method of sampling cave fauna (Hunt & Millar 2001). Since crickets are efficient jumpers, sweep net was used to capture crickets on the floor and high walls. Searching and direct counting started from the cave entrance to chambers accessible to an average-sized person. Crickets were mostly found on cave entrances, on walls, crevices, holes, and cave floor. Temperature and relative humidity were recorded.

The crickets captured in the caves were placed directly into a plastic bag. Specimens were transferred to plastic cups containing 70% ethanol and were air-dried for 2 to 3 hours before mounting them on pins. Crickets were pinned through the middle of the thorax. The pinned crickets were placed in a small box for identification. The mounted specimens were deposited at the Wildlife laboratory, Department of Biological Sciences, Mindanao State University - Iligan Institute of Technology. Due to the insufficiency of taxonomic key to the cricket species in the Philippines, the collected specimens were brought to the Philippine National Museum for identification by an expert on cricket taxonomy.

Observation of existing threats and data analysis. Existing threats in the cave sites were noted. The local guides were interviewed regarding threats to the caves. The degree of human disturbance was noted as extensive, high, moderate, low, and undisturbed. Biodiversity indices were calculated using Biodive Pro software. SPSS version 17 was used in ordination analysis to determine the similarity and distribution of cricket species as well as the relationship on the abundance of crickets to temperature and relative humidity.

Results and Discussion. Two families, Rhaphidophoridae and Gryllidae with 826 individuals were recorded from 19 cave sites (Table 1). *Macropathus* sp. of Family Rhaphidophoridae was found to be the most abundant (59.07%) and widely distributed in 15 of the 19 cave sites. Kabyaw Cave in Quezon, Bukidnon had the most number of *Macropathus* sp. (175 individuals) followed by those observed in Kariis Cave, Valencia, Bukidnon (107 individuals). *Endacusta* sp., one of the cavernicolous species of subfamily Phalangopsinae was also found to be abundant (40.79%) and distributed in 14 cave sites. Kabyaw Cave had the most number of *Endacusta* sp. Only one individual of ground cricket, *Pteronemobius* sp. was observed in Barangay Matangad, Gitagum and absent in all other 18 cave sites. This cricket was found exactly at the cave entrance and was probably wandering into the cave. Otte & Alexander (1983) reported that this cricket usually inhabits the stream bank, mountain grassland, rainforest, caves and ground crevices.

Macropathus sp. was observed throughout the five cave sites in Iligan City (sampling area 1) and no other cricket species was observed in that area. Hindang Caves are situated on the mountainside (522-533 masl) with sparse vegetation and moderate canopy cover. Richards (1954) in his study on the ecology of *Macropathus* sp. found that this species occurs in variety of habitat as long as it has high humidity and various percentage of illumination. A solitary existence is preferred even though other cave invertebrates are found in the same habitat.

Figure 2 shows that the least number (2.90%) of crickets was recorded in Gitagum, Misamis Oriental. The two cave sites in Gitagum are located on a cleared land and cultivated field. Land clearance and agricultural activities are the most common and widespread threats to cave inhabitants and negative impacts are the alteration of cave microclimate and increased nutrient inputs both from grazing animals and artificial fertilizer. Taylor et al (2007b) reported that a low number of cricket reflects elevated levels of human disturbance, and probably a reduction in food input (natural litter input, cricket guano). Agriculture, urban development, waste disposal, deforestation, and resource extraction constitute environmental pressures leading to polluted aquifers which could destroy caves (van Beynen et al 2012). Land clearance and cultivation may have affected the number of crickets thriving in Gitagum caves. The study of Elliot (2000) showed that many caves have been disturbed, filled, quarried, mined or polluted and it is possible that many species have disappeared without being known. Small changes in the temperature, humidity, water quality, nutrient inputs, or other environmental parameters affect how a cave functions (Toomey & Nolan 2005).

Table 1

Number of individuals and relative abundance of cricket species in 19 cave sites

Cave sites	*Family Rhaphidophoridae*	*Family Gryllidae*		*Total no. of species*	*Total no. of individuals*
	Macropathus sp.	*Endacusta sp.*	*Pteronemobius sp.*		
A	40	0	0	1	40
B	32	0	0	1	32
C	38	0	0	1	38
D	25	0	0	1	25
E	15	0	0	1	15
F	2	16	1	3	19
G	0	5	0	1	5
H	0	11	0	1	11
I	1	29	0	2	30
J	2	20	0	2	22
K	0	22	0	1	22
L	175	68	0	2	243
M	15	60	0	2	75
N	0	17	0	1	17
O	5	17	0	2	22
P	3	1	0	2	4
Q	107	55	0	2	162
R	3	5	0	2	8
S	25	11	0	2	36
Total	488	337	1	3	826
RA (%)	59.07	40.79	0.121		

Legend: A - Hindang Cave 1, B - Hindang Cave 2, C - Hindang Cave 3, D - Hindang Cave 4, E - Dalipuga Cave, F - Gitagum Cave 1, G - Gitagum Cave 2, H - Minsalirac Cave 1, I - Minsalirac Cave 2, J - Minsalirac Cave 3, K - Blue Water Cave, L - Kabyaw Cave, M - Kitaotao Cave 1, N - Kitaotao Cave 2, O - Kitaotao Cave 3, P - Salawaw Cave, Q - Kariis Cave, R - Pianginan Cave 1, S - Pianginan Cave 2.

The most abundant crickets were recorded in Kabyaw Cave (29.42 %) and Kariis Cave (19.61%). Kabyaw and Kariis caves are two of the biggest caves explored in this study. Organic guano materials were thickly accumulated above the soft and muddy soil surface throughout all parts of the cave but more abundant in twilight and deep cave zones. According to Culver & White (2005) the distinct population of cave crickets can be found in larger caves and individual caves may harbor a unique population of one or more of these forms. The study of Northup et al (1993) on the bioenergetics of three cricket species also showed that the food of these crickets often consists of bat guano and essentially identical to its crop content. More guano indicates more source of food.

In Blue Water Cave, none of the *Macropathus* sp. was observed and only 22 individuals of *Endacusta* sp. were found roosting on dry cave walls. Blue Water Cave is one of the tourist spots in Quezon, Bukidnon and visitors can freely access the cave. Intensive trampling causes the compaction of soft floor sediment rendering it less suitable as habitat of cave crickets and egg deposition by cave crickets will no longer survive (Eberhard & Hamilton-Smith 1996). Sensitivity to surrounding resources is a factor in the survival of cricket populations (Peterson et al 2009). Howarth (1973) reported that many caves have been directly disturbed by man, or more importantly the overlying forest has been cut or removed, thus drastically altering the ecology of the cave beneath. Lavoie et al (2007) hypothesized that weather effects are directly seen on the guano communities because weather caused changes on the cricket's foraging activity, guano deposition, and cricket's survival. Prior to the sampling the weather was unfavorable in three cave sites in Kitaotao, Bukidnon which contributed to fewer crickets observed (14.50%). Decreased number of crickets coincides with a period of unfavorable weather condition in this study.

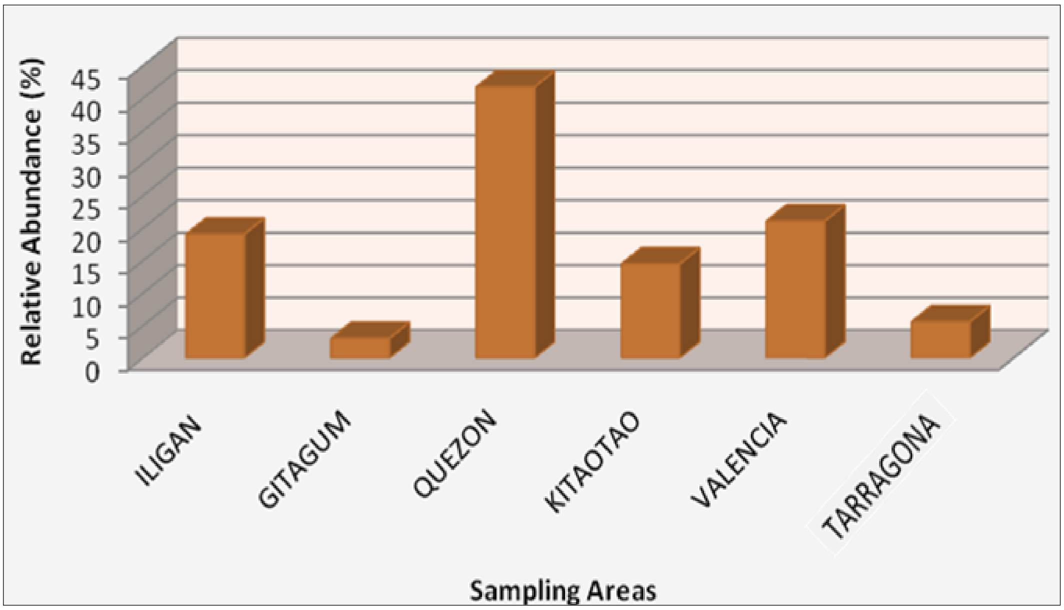

Figure 2. Relative abundance of cricket species in six sampling areas.

The two cave sites in Tarragona, Davao Oriental were large caves located at the mountainside with dense canopy cover and lesser disturbance. However, few crickets (5.60%) were observed. Inside the cave, crickets are preyed upon by spiders and in some caves, specialized beetles prey on cricket eggs (Lavoie et al 2007). Cave-adapted *Rhadine* beetles are also known to feed upon the eggs of *Ceuthophilus* species (Taylor et al 2007a).

Table 2 shows the biodiversity indices in the six sampling areas. The most number of cricket species was recorded in Gitagum and least in Iligan. Results were similar to that of Carlsbad Cavern wherein only three different crickets were observed (Lavoie et al 2007). The sampling areas were found to have low diversity with more or less even distribution. *Endacusta* sp. was the dominant species in Gitagum and Kitaotao caves. This was similar to the observation of Richards (1972) that *Endacusta* sp. is the most common inhabitant of rabbit burrows and widely distributed all over the Plain. *Endacusta* sp. was observed to dominate when *Macropathus* sp. was either least in number or absent.

Table 2

Biodiversity indices in six sampling areas

Biodiversity indices	*Sampling areas*						
	Iligan	*Gitagum*	*Quezon*	*Kitaotao*	*Valencia*	*Davao*	*Total*
Species richness	1	3	2	2	2	2	3
No. of individuals	150	24	328	114	166	44	826
Dominance	1	0.7743	0.5036	0.7107	0.5529	0.5372	0.5087
Shannon index	0	0.4563	0.6895	0.4644	0.6393	0.6555	0.692
Species evenness	1	0.5261	0.9964	0.7955	0.9475	0.963	0.6659

The 19 cave sites were grouped into four according to the number of crickets observed and the presence and absence of species (Figure 3). The most similar cave sites were

Gitagum Cave 1, Gitagum Cave 2, Minsalirac Cave 1, Minsalirac Cave 2, Minsalirac Cave 3, Blue Water Cave, Kitaotao Cave 2, Kitaotao Cave 3, and Salawaw Cave. The number of crickets from these cave sites ranged from 5 to 39. Temperature and relative humidity were more or less the same. Hindang Cave 1, Hindang Cave 2, Hindang Cave 3, Hindang Cave 4, Dalipuga Cave, and Pianginan Cave 2 were similar in abundance of *Macropathus* sp. ranging from 15 to 40 and had the least number of *Endacusta* sp. These cave sites may have provided *Macropathus* sp. favorable environmental conditions. According to Richards (1968a) crickets of the family Rhaphidophoridae where *Macropathus* sp. belongs are apterous insects, extremely sensitive to temperature changes, and requiring a very high relative humidity. Most are restricted to caves and appear to disperse a litte between these patchy habitats (Allegrucci et al 2010). Kabyaw Cave and Kariis Cave have the most abundant crickets. This indicates that guano materials thickly accumulated on the muddy soil surface of both caves provide food and support more crickets.

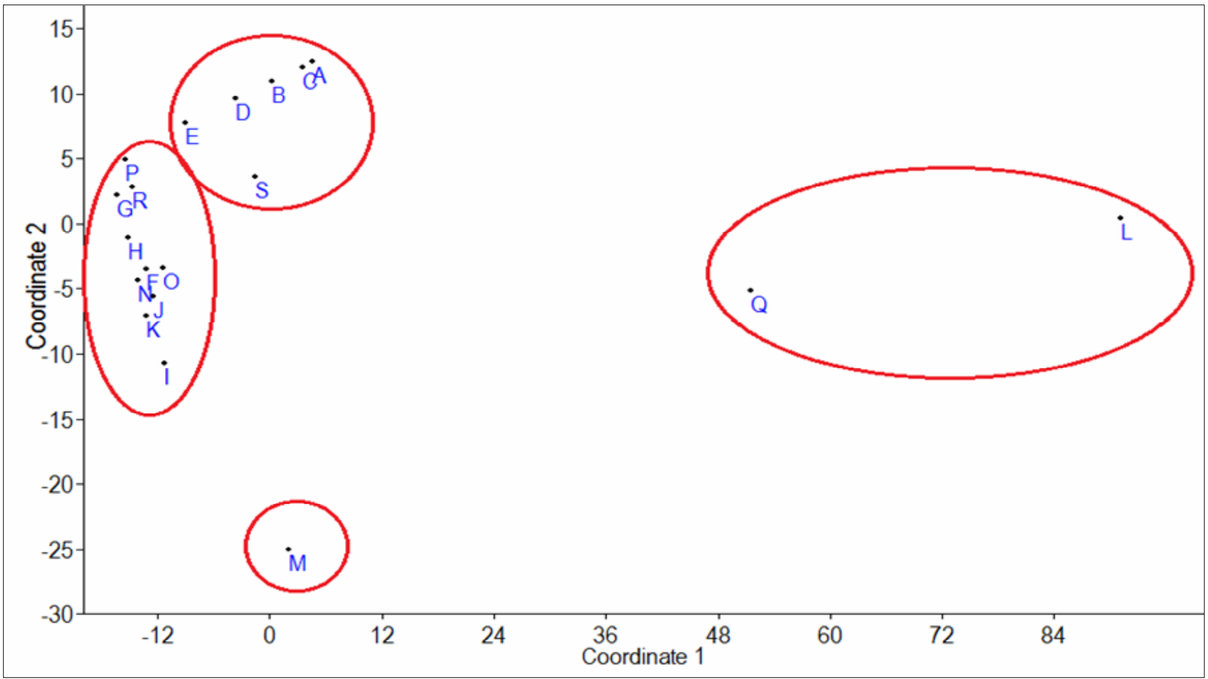

Figure 3. Similarity and distribution of cricket species in 19 cave sites (A - Hindang Cave 1, B - Hindang Cave 2, C - Hindang Cave 3, D - Hindang Cave 4, E - Dalipuga Cave, F - Gitagum Cave 1, G - Gitagum Cave 2, H - Minsalirac Cave 1, I - Minsalirac Cave 2, J - Minsalirac Cave 3, K - Blue Water Cave, L - Kabyaw Cave, M - Kitaotao Cave 1, N - Kitaotao Cave 2, O - Kitaotao Cave 3, P - Salawaw Cave, Q - Kariis Cave, R - Pianginan Cave 1, S - Pianginan Cave 2).

Among the caves, Kitaotao Cave 1 was different. This cave site had an average number of *Macropathus* sp. and *Endacusta* sp. Kitaotao Cave 1 is an open cave with three cave entrances. Large boulders were observed at the first cave entrance. Soil substrate was observed to be dry and guano materials were patchily accumulated in the inner cave area. Several rock fall and stalactites which have broken off from their attachments were observed in the other two cave entrances. This condition might have affected the roosting crickets. Besides, guano deposits were not sufficient enough to supply the crickets inside the cave. Guano deposits indicate where cave crickets regularly roost because roosts must be used over time to build guano deposits whereas clusters of cave crickets can be transient as they cycle to and from the cave entrance (Woodman et al 2004).

Figure 4 shows the relationship of the abundance of crickets to temperature and relative humidity. Crickets were more abundant at temperature of 24°C and relative humidity of 89-92% and the least at a temperature of 28°C and relative humidity below 80%. The study of Weckerly (2012) showed that relative humidity and temperature influence the count or the emergence of crickets, but the greatest influence is from temperature. Kabyaw and Kariis caves seem to have suitable conditions for foraging activity of a large number of crickets. Ectotherms such as crickets cannot metabolically regulate their body temperatures, so body temperature changes in changing environmental temperature. The metabolic rate of crickets is expected to increase with increasing temperature (Studier & Lavoie 1990). This explains why there was least number of crickets found in caves with high temperature and low relative humidity.

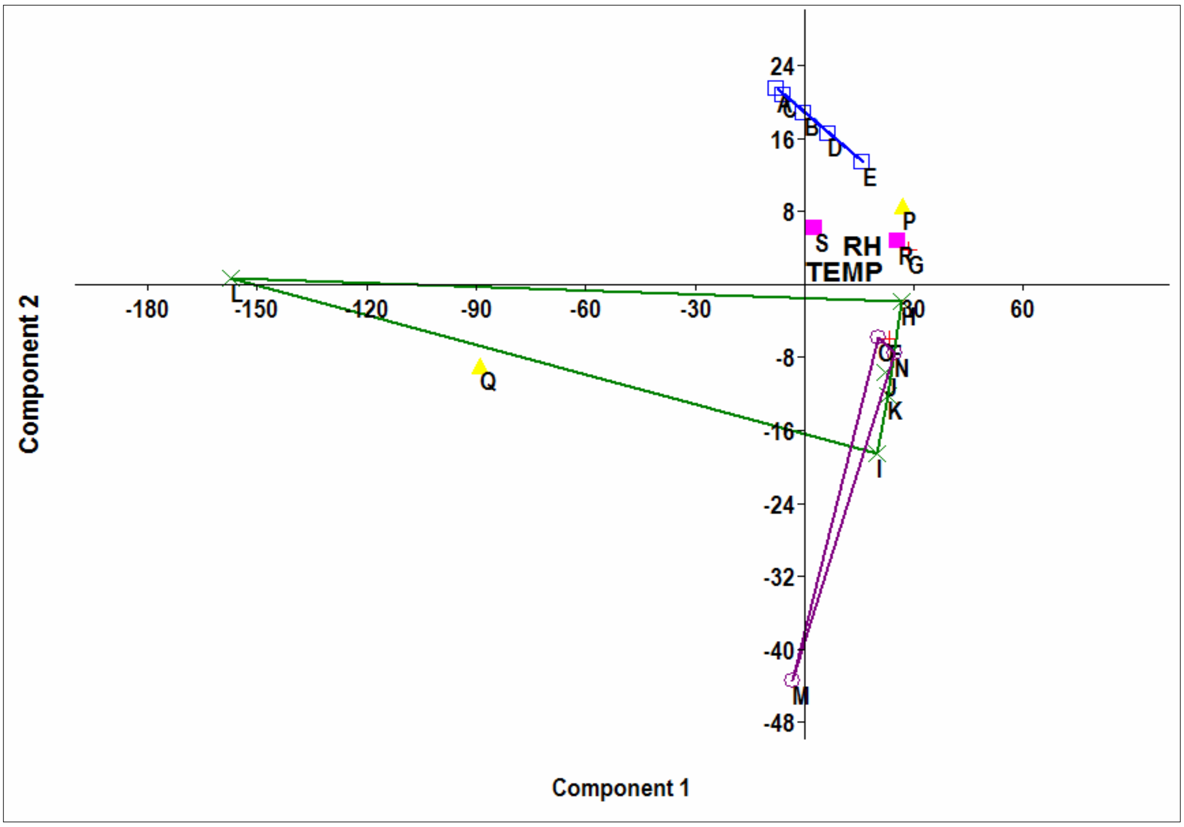

Figure 4. Ordination diagram showing the correlation between the abundance of crickets to temperature and relative humidity in 19 cave sites - blue: Iligan City, red: Gitagum, green: Quezon, violet: Kitaotao, yellow: Valencia, Pink: Tarragona (A - Hindang Cave 1, B - Hindang Cave 2, C - Hindang Cave 3, D - Hindang Cave 4, E - Dalipuga Cave, F - Gitagum Cave 1, G - Gitagum Cave 2, H - Minsalirac Cave 1, I - Minsalirac Cave 2, J - Minsalirac Cave 3, K - Blue Water Cave, L - Kabyaw Cave, M - Kitaotao Cave 1, N - Kitaotao Cave 2, O - Kitaotao Cave 3, P - Salawaw Cave, Q - Kariis Cave, R - Pianginan Cave 1, S - Pianginan Cave 2).

Figure 5 shows some of the threats to the caves. Two cave sites in Gitagum and Blue water cave in Quezon have extensive degree of disturbance. The caves in Gitagum were located in a forested area. Treasure hunting was very prominent in Quezon Cave 1. One big hole estimated to be more than 10 m deep was observed inside the cave. In Blue Water Cave, many plastic wrappers, cigarettes, and broken bottles were left at the cave entrance. Graffiti and markings on cave walls were observed in almost cave sites. Detrimental human impacts include habitat disturbance due to soil compaction, changes in temperature and humidity, vandalism, abandonment of the cave by associated surface animals and accumulation of toxic trash (Campbell 1995). Any natural/unnatural disturbances that can alter/modify the originality of cave ecosystem could become a major deciding factor to destroy/alter its complete biodiversity and mostly human encroachments (mining, quarrying, tourism, waste, disposal and rapid ways of agricultural practices) are some of the factors thar are responsible for the same (Biswas 2009).

Figure 5. Some of the existing threats observed in cave sites (A - land clearance, B and C - fire burning at cave entrance, D and E - treasure hunting and, F - graffiti on cave walls).

Conclusions and Recommendations. Among the cavernicolous crickets, *Macropathus* sp. and *Endacusta* sp. were the most abundant and widely distributed. The abundance of crickets appears to be related to temperature, relative humidity and guano deposits. Common threats observed in the caves include extensive vandalism, treasure hunting, and use of the cave as recreational area. It is recommended that more extensive surveys be done on caves in Mindanao to better understand the ecology of cave crickets and to have complete database of crickets in Mindanao.

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References

Allegrucci G., Trewick S. A., Fortunato A., Carchini G., Sbordoni V., 2010 Cave crickets and cave weta (Orthoptera, Rhaphidophoridae) from the southern end of the world: a molecular phylogeny test of biogeographical hypotheses. Journal of Orthoptera Research 19(1):121-130.

Baltazar C. R., Salazar N. P., 1979 Philippine insects: an introduction. Quezon City: University of the Philippines Press, pp. 37-39.

Batucan Jr. L. S., Nuñeza O. M., 2013 Ant species richness in caves of Siargao Island Protected Landscape and Seascape, Philippines. ELBA Bioflux 5(2):83-92.

Biswas J., 2009 The biodiversity of Krem Mawkhyrdop of Meghalaya, India, on the verge of extinction. Current Science 96(7):904-910.

Campbell L., 1995 Endangered and threatened animals of Texas: their life history and management. Austin, Texas, University of Texas Press, pp. 120-123.

Culver D. C., 1982 Cave life: ecology and evolution. Harvard University Press, Cambridge, Massachusetts, 189 pp.

Culver D. C., 2005 Species interactions. In: Encyclopedia of caves. Culver D. C., White W. B. (eds.), Elsevier, Burlington, Massachusetts, pp. 539-543.
Culver D. C., White W. B., 2005 Encyclopedia of caves. Academic Press, San Diego, 654 pp.
DENR-PAWB, 2008 A handbook on cave classification for the Philippines. pp 1-51.
Eberhard S., Hamilton-Smith E., 1996 Conservation of cave fauna in Australia. Journal of the Australian Cave and Karst Management Association Inc 23:4-14.
Elliott W. R., 2000 Conservation of the North American cave and karst biota. In: Ecosystems of the world 30: subterranean ecosystems. Wilkins H., Culver D. C., Humphreys W. F. (eds), Amsterdam, Elsevier Press, pp. 665-689.
Figueras G. S., Nuneza O. M., 2013 Species diversity of ants in karst limestone habitats in Bukidnon and Davao Oriental, Mindanao, Philippines. AES Bioflux 5(3):306-315.
Graening G. O., Slay M. E., Tinkle K. K., 2003 Subterranean biodiversity of Arkansas, part 1: bioinventory and bioassessment of caves in the Sylamore Ranger District, Ozark, National Forest, Arkansas. Journal of the Arkansas Academy of Science 57:44-58.
Howarth F. G., 1973 The cavernicolous fauna of Hawaiian lava tubes, part 1: introduction. Pacific Insects 15(1):139-151.
Hunt M., Millar I., 2001 Cave invertebrate collection guide. Department of Conservation Technical Series 26, Wellington, New Zealand, Department of Conservation. P.O. Box 10-420, pp. 1-28.
Jones C., 2009 A guide to responsible caving. 4th Edition. National Speleological Society, 2813 Cave Avenue Huntsville, AL 35810, pp. 1-24.
Lavoie K. H., Helf K. L., Poulson T. L., 2007 The biology and ecology of North American cave crickets. Journal of Cave and Karst Studies 69(1):114–134.
Masaki S., 1983 Climatic speciation in Japanese ground crickets. GeoJournal 7(6):483-490.
Northup D. E., Lavoie K. H., Studier E. H., 1993 Bioenergetics of camel crickets (*Ceuthophilus carlsbadensis, C. longipes* and *C. conicaudus*) from Carlsbad Caverns National Park, New Mexico. Comparative Biochemistry and Physiology 106A(3):525–529.
Otte D., Alexander R. D., 1983 The Australian crickets (Orthoptera: Gryllidae). Academy of Natural Sciences of Philadelphia, Monograph 22, Allen Press, Inc., 477 pp.
Peterson T., Rossmann B., Drake J. E., Westervelt J., 2009 A spatially explicit model of red imported fire ant behavior for managing species at risk on military lands. US Army Corps of Engineers Research Laboratory, CERL Report No. TR-09-19, pp. 1-29.
Richards A. M., 1954 The systematics and ecology of the genus *Macropathus* Walker, 1869 (Orthoptera, Rhaphidophoridae). Transactions of the Royal Society of New Zealand 82(3):739-762.
Richards A. M., 1968a The Rhaphidophoridae (Orthoptera) of Australia, part 6: two new species from Northern Tasmania. Pacific Insects 10(1):167-176.
Richards A. M., 1968b The cavernicolous status of some species of Macropathinae (Orthoptera: Rhaphidophoridae). Journal of Australian Entomologist Society 7:87-89.
Richards A. M., 1972 The migration of cave arthropods across the Nullarbor Plain, Southern Australia. Helictite - Journal of Australasian Speleological Research 10(3):60-72.
Studier E. H., Lavoie K. H., 1990 Biology of cave crickets, *Hadenoecus subterraneus,* and camel crickets, *Ceuthohilus stygius* (Insecta: Orthoptera): metabolism and water economies related to size and temperature. Comparative Biochemistry and Physiology 95A:157-161.
Taylor S. J., Weckstein J. D., Takiya D. M., Krejca J. K., Murdoch J. D., Veni G., Johnson K. P., Reddell J. R., 2007a Phylogeography of cave crickets (*Ceuthophilus* spp.) in central Texas: a keystone taxon for the conservation and management of federally listed endangered cave arthropods. Illinois Natural History Survey Technical Report 58:1-45.

Taylor S. J., Krejca J. K., Hackley K. C., 2007b Examining possible foraging differences in urban and rural cave cricket populations: carbon and nitrogen isotope ratios (δ13C, δ15N) as indicators of trophic level. Illinois Natural History Survey Technical Report 59:1-97.

Toomey R. S. III., Nolan G., 2005 Environmental change at Kartchner Caverns: trying to separate natural and anthropogenic changes. Kartchner Caverns State Park, Arizona State Parks, Benson, AZ. USDA Forest Service Proceedings RMRS-P-36, pp. 264-270.

van Beynen P., Brinkmann R., van Beynen K., 2012 A sustainability index for karst environments. Journal of Cave and Karst Studies 74(2):221-234.

Weckerly F. W., 2012 Cave cricket exit counts: environmental influences and duration of surveys. Journal of Cave and Karst Studies 74(1):1–6.

Whitten T., 2009 Applying ecology for cave management in China and neighbouring countries. Journal of Applied Ecology 46:520–523.

Woodman R., Helf K. L., Moore B., Byrd R., 2004 Cave cricket monitoring protocol for Mammoth Cave National Park, Kentucky. National Park Service, U.S. Department of the Interior, 113 pp.

Zefa E., 2006 Comparison of calling songs in three allopatric populations of *Endecous itatibensis* (Orthoptera, Phalangopsinae). Iheringia, Ser Zool 96(1):13-16.

*** Saripedia.wordpress.com, 2012 Mindanao Map. Retrieved from http://saripedia.wordpress.com/2012/02/21/sejarah-perkembangan-islam-di-filipina-selatan/mindanao/

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