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Cave spiders in Mindanao, Philippines

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Abstract. Spiders are found in a variety of habitats and are important in regulating insect population. However, cave spiders are poorly known. This study surveyed 11 caves in Mindanao using modified cruising method to determine diversity and microhabitat of spiders. Eighteen species of spiders belonging to two orders, 12 families and 12 genera were documented. Cave 10 in Tarragona, Davao Oriental had the highest number of species while caves 3 and 4 in Quezon, Bukidnon had the least number of species which was mainly attributed to the presence of high anthropogenic disturbances in the area. Spiders in caves have low diversity and the distribution was more or less even. Relative humidity was found to affect the abundance of spiders categorized as web spinners found at the entrance zone and twilight zone. *Diaea varians* was always found on the floor at the entrance zone. Spiders were observed mostly on walls of cave entrances. *Damon medius*, the most abundant species was present in all cave sites and widely distributed at the twilight and inner zones. Temperature, relative humidity, cave surface, and presence of disturbances in cave were seen as important elements influencing the microhabitat preferences of cave spiders. Surveys in other caves are necessary to come up with a more complete database of cave spiders in Mindanao and to better understand the ecology of spiders.
Key Words: Cave surface, cave entrance zone, microhabitat, twilight zone, web spinners.

Introduction. Spiders constitute one of the most abundant and species–rich arthropod orders (Buchholz 2009). There are about 34,000 described species, although the actual number of species has been estimated at around 170,000 (Gillespie & Spagna 2003). They are clearly an integral part of global biodiversity since they play many important roles in ecosystem as predators and in the food chain (Sharma et al 2010).

Spiders are also good bio-indicators for evaluating the impact of anthropogenic disturbance on natural ecosystems (Maelfait & Hendrickx 1998) and they are useful components in regulating insect population in many terrestrial habitats (Mathew et al 2009). Their group is characterized by considerable species richness and also by the presence of many endemics, at both the genus and species levels (Deltshev 2008). However, because of the degradation or destruction of habitats by some human activities, biological species are being threatened continuously at an unprecedented rate (Saini et al 2013). The study of Maya-Morales et al (2011) showed that human disturbance has an influence on spider communities which could significantly lower the species richness in the disturbed site. Spiders occupy virtually every habitat with wide range of life styles, behaviors and morphological adaptation (Saini et al 2013). Literally, they are found everywhere; on trees, under stone or logs and in rubbish and leaf litter on forest floor (Mathew et al 2009). Among these habitats, cave ecosystem which is among the most fascinating environments on Earth (Yap et al 2011) that constitutes strong environmental filters and an excellent system to study community assembly patterns (Cardoso 2012) provides home for many species of spiders that may reside temporarily or permanently inside.

Spiders are common denizens of caves, with numerous troglobitic forms known from temperate and tropical caves (Howarth 2003). The diversity of cave troglobitic spiders is great with numerous families being recorded essentially in every karst region worldwide (Reddell 2005). They are usually abundant inside caves from the entrance to the deepest galleries (Gunn 2004), and in highly isolated caves (Zhang & Li 2013). In many areas, they are better known than the spider fauna of the surface (Deeleman-Reinhold 1981) and occupy virtually a wide range of physiological adaptation (Saini et al 2013).

Rector (2009) reported that the spider's distribution has direct relation to the three ecological zones of the cave: the entrance zone which is immediately the area in the actual cave entrance and is physically connected to the surface environment exposed to climatic variation; the twilight zone which is the area beyond the entrance zone that provides an environment buffered from the extremes of the outside world and still receives light from the external environment; and the inner zone which is the region of the cave that is totally dark. In spite of these habitat characterizations, many animals live in cave environments, with invertebrates being especially common (Yap et al 2011).

Although spider diversity in temperate regions has been well studied, tropical areas have received relatively little investigation (Chen & Tso 2004) and many spider species are not yet known to science (Sharma et al 2010). In the Philippines, particularly in Mindanao, studies on spiders are mostly focused on forest habitats while studies on cave spiders are particularly lacking. In Mindanao caves, studies on ants (Batucan & Nuñeza 2013; Figueras & Nuñeza 2013) and crickets (Lagare & Nuñeza 2013) have been reported. This study determined the diversity of spiders as well as their microhabitats in the caves of Mindanao.

Materials and Methods. Eleven caves in four sampling sites were surveyed (Figure 1). Temperature and percent relative humidity were measured in each cave.

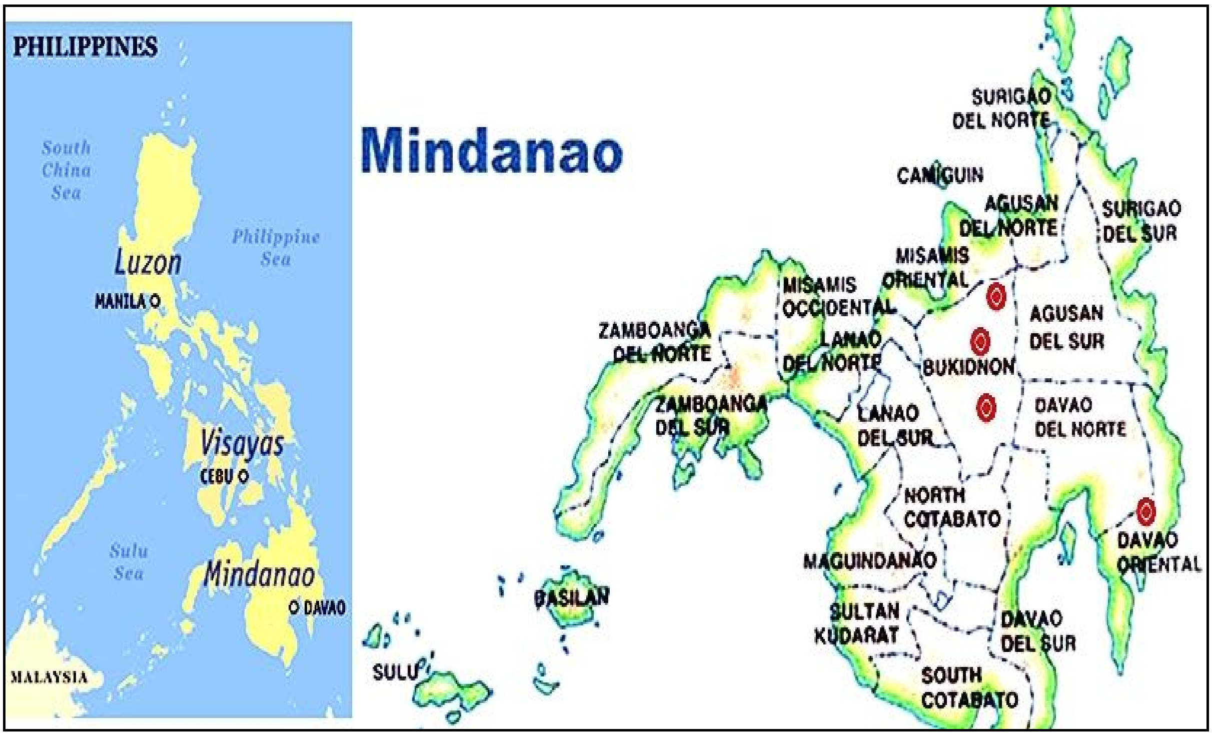

Figure 1. Map of the Philippines (A) (factgrabber.com) and Mindanao (B) (mcministries1.tripod.com) showing the location of the four sampling sites ( ).

Sampling site 1 in Quezon, Bukidnon had five caves which are all known tourist spots in the area. Mixed secondary forest and vegetation areas surround these caves. Sampling site 2 in Valencia, Bukidnon had two caves surrounded by vegetation areas and kaingin. Sampling site 3 in Kitaotao, Bukidnon had two caves surrounded with secondary forest. Sampling site 4 in Tarragona, Davao Oriental had two caves surrounded with mixed primary and secondary forests.

Sampling was done from April 19 to June 2, 2010 at 09:00 to 11:00 hours, for a total of 132 man-hours. Modified cruising method, hand collection and direct counting were used for the collection (Hunt & Millar 2001). Specimens collected were stored temporarily in plastics cups filled with 70% ethyl alcohol for preservation. These were then transferred to properly labeled glass containers in the laboratory.

Results and Discussion. Eighteen species of spiders from 12 families and 12 genera were collected from the 11 cave sites. *Damon medius* (Herbst, 1797), a hunter spider was found in all cave sites (Table 1).

Table 1

Distribution of spiders in 11 cave sites

Taxon	*Site 1 Quezon, Bukidnon*				*Site 2 Valencia, Bukidnon*		*Site 3 Kitaotao, Bukidnon*		*Site 4 Tarragona, Davao Oriental*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Order Araneae											
Family Araneidae											
Araneus sp.1 Clerck, 1757							+				
Araneus sp.2 Clerck, 1757							+				
Family Ctenidae											
Ctenus sp. Walckenaer,1805	+										
Family Dictynidae											
Dictyna grammica Simon, 1893										+	
Family Lycosidae											
Lycosa tarsalis Kolosváry, 1943										+	
Family Pholcidae											
Uthina sp.	+	+			+	+		+			
Family Salticidae											
Carrhotus sp. Thorell, 1891										+	
Family Sparassidae											
Heteropoda sp.1 Latreille, 1804										+	
Heteropoda sp.2 Latreille, 1804											+
Heteropoda maxima Jaeger, 2001					+	+		+	+		
Heteropoda venatoria Latreille, 1802					+				+		
Family Tetragnathidae											
Tetragnatha mandibulata Walckenaer, 1841	+										
T. praedonia (L. Koch, 1878)							+				
Family Titanoecidae											
Pandava laminata (Thorell, 1878)											+
Family Thomisidae											
Diaea varians Kulczynski, 1911					+			+		+	
Family Uloboridae											
Uloborus sp. Latreille, 1806	+										
Uloborus lugubris (Thorell, 1895)									+		
Order Amblypygi											
Family Phrynichidae											
Damon medius (Herbst, 1797)	+	+	+	+	+	+	+	+	+	+	+
Total no. of species/cave	5	2	1	1	5	3	4	4	4	6	3
Total no. of species						18					

1 - cave 1, 2 - cave 2, 3 - cave 3, 4 - blue water cave, 5 - kabyaw cave, 6 - salawaw cave, 7 - kariis cave, 8 - cave 1, 9 - cave 2, 10 - pianginan cave 1, 11 - pianginan cave 2; + - present.

Cave 10 (Site 4 in Tarragona, Davao Oriental) had the highest number of species (S = 6) while caves 3 and 4 (Site 1 in Quezon, Bukidnon) had the least number of species (S = 1). In cave 1, (Site 1 in Quezon, Bukidnon) *Tetragnatha mandibulata* Walckenaer, 1841 and *Uloborus* sp. Latreille, 1806 were the only web spinners found. According to Blackledge & Gillespie (2004), the genus *Tetragnatha* is relatively homogeneous in its behavior and Gillespie (2003) stated that it is noticeable for its poor representation. Another species, *Ctenus* sp. Walckenaer, 1805 was found only in cave 1 (Site 1 in Quezon, Bukidnon) and only one species *Damon medius* (Herbst, 1797) was observed in caves 3 and 4 (Site 1 in Quezon, Bukidnon). Anthropogenic disturbances such as spelunking and local tourism were observed in Site 1. Disturbances to these caves may have limited the number of species. This partly explains why caves 3 and 4 had only one spider species recorded. According to Martin et al (2003) persistent human disturbance is a major cause for the decline in population of the cave-obligate organism. In cave 7 (Site 2 in Valencia, Bukidnon), *Araneus* sp. 1 Clerck, 1757, *Araneus* sp. 2 and *Tetragnatha praedonia* L. Koch, 1878 were the web spinner spiders found. The two caves in site 2 were found to have streams inside where some species of spiders may consider as areas for food. In Southern Mexican sulphur cave, Horstkotte et al (2010) reported that three species of Araneae such as *Ctenidae* gen. sp., *Tinus* sp., and *Hemirrhagus pernix* were found to feed on cave-dwelling fish, *Poecilia mexicana.* This report of spiders feeding on fish was the first of its kind. Gillespie (1987) also reported that immature and mature females of spider species *Tetragnatha elongata* build their webs associated exclusively with aquatic habitat provided that there are suitable structural supports (twigs, branches, etc.). This indicates that the presence of aquatic habitat in caves with food availability and suitable structural support could contribute to the presence of spider species. Among the species found in the two caves of site 4 in Tarragona, Davao Oriental, *Dictyna grammica* Simon, 1893, *Heteropoda* sp. 1 Latreille, 1804, *Lycosa tarsalis* Kolosváry, 1943, and *Carrhotus* sp. Thorell, 1891 were only found in cave 10 while *Pandava laminata* (Thorell, 1878) was only found in cave 11 which is rich in guano.

The most preferred microhabitat of the majority of spider species was the wall of the entrance zone with seven species recorded (Table 2).

Table 2

Distribution of spiders in the different zones

Species	*Entrance zone*			*Twilight zone*			*Inner zone*		
	W	*R*	*F*	*W*	*R*	*F*	*W*	*R*	*F*
Araneus sp. 1			+						
Araneus sp. 2			+						
Carrhotus sp.	+								
Ctenus sp.	+								
Damon medius				+	+		+	+	+
Diaea varians			+						
Dictyna grammica	+								
Uthina sp.				+		+	+		+
Heteropoda sp. 1	+								
Heteropoda sp. 2	+								
Heteropoda maxima							+	+	
H. venatoria				+	+		+	+	
Lycosa tarsalis								+	
Tetragnatha mandibulata	+								
T. praedonia				+					
Pandava laminata				+		+			
Uloborus sp.	+		+						
Uloborus lugubris									+

W - wall surface, R - roof surface, F - floor surface, + - present.

Most of the species of spiders found at the entrance zone of the caves were the web spinners. The same result was obtained by Culver (2005), that the spiders of the genus *Meta* are common at the entrance zone and they usually feed at the entrance zone. According to Deeleman-Reinhold (1981), spiders in the entrance zone find abundant prey among the numerous insects that migrate through cave entrances and this may be one of the reasons of the existence of spider species at the entrance zone. However, no spiders were found on the roof of the entrance zone. On the floor of the entrance zone, three web spinners, namely, *Araneus* sp. 1, *Araneus* sp. 2, and *Uloborus* sp. and one hunter spider, *D. varians*, were found. In the twilight zone, *Tetragnatha praedonia* was observed on the walls while in the inner zone, *L. tarsalis* and *U. lugubris* were found on the roof and on the floor, respectively. *H. venatoria* and *D. medius* were the only spiders observed both on walls and on roofs of the twilight and the inner zones. Spiders found beyond the entrance may be for the reason of prey availability and other factors such as vegetation cover, micro-landscape, and microclimate (Samu et al 1999).

Table 3 shows the frequency and abundance of spiders in the four sites. The most abundant species in all sites was *D. medius* followed by *P. laminata.* The presence of prey may be one of the main factors for the abundance of *D. medius* in all caves. Horvath et al (2005) stated that prey availability can influence the density and diversity of spider assemblages. Lagare & Nuñeza (2013) observed species of crickets belonging to suborder Phalangopsinae on wall surface near *D. medius* at the inner zone of Kabyaw cave, Quezon, Bukidnon.

Table 3

Frequency and relative abundance of spider species in the four sites

Species	*Site 1 Quezon, Bukidnon*		*Site 2 Valencia, Bukidnon*		*Site 3 Kitaotao, Bukidnon*		*Site 4 Tarragona, Davao Oriental*		*Total Ni*	*RA (%)*
	Ni	*RA (%)*	*Ni*	*RA (%)*	*Ni*	*RA (%)*	*Ni*	*RA (%)*		
Araneus sp.1	0	0	15	18.3	0	0	0	0	15	4.7
Araneus sp.2	0	0	28	34.1	0	0	0	0	28	8.9
Carrhotus sp.	1	0.7	0	0	0	0	0	0	1	0.3
Ctenus sp.	1	0.7	0	0	0	0	0	0	1	0.3
Damon medius	93	66.4	35	42.7	16	43.2	16	28.1	160	50.6
Diaea varians	0	0	0	0	6	16.2	4	7	10	3.2
Dictyna grammica	0	0	0	0	0	0	1	1.8	1	0.3
Uthina sp.	22	15.7	1	1.2	2	5.4	0	0	25	7.9
Heteropoda sp.1	0	0	0	0	0	0	1	1.8	1	0.3
Heteropoda sp.2	0	0	0	0	0	0	1	1.8	1	0.3
Hetopoda maxima	7	5	1	1.2	10	27	0	0	18	5.7

Ni - number of individuals, RA (%) - Percent Relative Abundance.

Figure 2. Small cricket with *Damon medius* at the wall of inner zone (A) and Whip spider eating cockroach in cave 11 of Davao Oriental (B).

In cave 11 in Tarragona, Davao Oriental, a whip spider (Figure 2) was observed eating a cockroach. The same observation was obtained by Santer & Hebets (2009) that a whip spider species, *Phrynus marginemaculatus* was found to eat ground dwelling invertebrates such as cockroaches and crickets. This indicates that food availability could contribute to the existence of spider species in caves.

Table 4 shows low species diversity in 11 caves (H' = 0.3 - 1) with more or less even distribution. The presence of disturbances in the surrounding areas of all caves such as logging, kaingin, forest degradation through conversion of forest into coconut and banana farms may have strongly contributed to the low species diversity of the cave spiders. Topping & Love (1997) stated that very high disturbance levels of the sites result in low spider density and a species-poor richness. In Bukidnon, agricultural activities have been observed to pollute the ground water leading to the death of surface vegetation. According to Ayansola (2012) vegetation structure may be an important determinant of spider community attributes because it provides different types of substrate that may influence the preys available to it and also dictates the method by which they are obtained. In Tarragona, Davao Oriental, caves appear to be relatively undisturbed which contribute to higher number of spider species in cave 10.

Table 4

Biodiversity indices of spiders in 11 cave sites

Species indices	*Site 1 Quezon, Bukidnon*					*Site 2 Valencia, Bukidnon*		*Site 3 Kitaotao, Bukidnon*		*Site 4 Tarragona, Davao Oriental*	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Species (S)	4	2	2	1	5	3	4	4	4	6	3
Individuals	17	16	7	12	88	25	57	25	12	15	42
Dominance	0.4	0.7	0.8	0.4	0.7	0.8	0.4	0.3	0.3	0.4	0.7
Shannon (H')	1	0.5	0.4	1	0.5	0.3	1	1	1	1	0.6
Evenness	0.9	0.9	0.8	0.8	0.6	0.5	0.8	0.9	0.8	0.7	0.6

1 - cave 1, 2 - cave 2, 3 - cave 3, 4 - blue water cave, 5 - kabyaw cave, 6 - salawaw cave, 7 - kariis cave, 8 - cave 1, 9 - cave 2, 10 - pianginan cave 1, 11 - pianginan cave 2.

Table 5

Mean temperature and relative humidity in three ecological zones of 11 cave sites

Cave sites	*Entrance zone*		*Twilight zone*		*Inner zone*	
	Temperature (°C)	*Relative humidity (%)*	*Temperature (°C)*	*Relative humidity (%)*	*Temperature (°C)*	*Relative humidity (%)*
1	24.3	85.5	23.3	86.7	24	85
2	26.7	85	26.7	86.7	27.3	84.3
3	26.7	91	27.5	90.7	25.7	90.7
4	26	77.7	24.8	84.7	26.3	79.5
5	24	84.8	24.2	89.3	25.7	84.7
6	25	92	23.3	92	24.3	92
7	26.7	85.3	24.7	92	27	85
8	25.3	92	25	92	24	92
9	26.7	85.7	25	92	25	92
10	26	85	24.8	92	24.3	92
11	25	92	24.3	92	25.7	92

1 - cave 1, 2 - cave 2, 3 - cave 3, 4 - blue water cave, 5 - kabyaw cave, 6 - salawaw cave, 7 - kariis cave, 8 -cave 1, 9 - cave 2, 10 - pianginan cave 1, 11 - pianginan cave 2.

Table 5 shows the temperature variations and relative humidity values recorded from three ecological zones of the caves. Temperature in all caves from the entrance zone to the inner zone ranged from 23.3 °C to 27.5 °C. Temperature with least values (23.3 °C) was recorded in cave 1 at the twilight zone while high temperature values (27.5 °C) was recorded in cave 3 at twilight zone. Bukhari et al (2012) reported that maximum Araneid fauna was favored by the maximum temperature of 42.8 °C in the month of June. High relative humidity (92%) was recorded in three ecological zones of the caves, particularly at caves 6, 8, 9 and 11 where relative humidity is constant, while least value (84.3%) was recorded in cave 3 at the inner zone. According to Abdelmoniem et al (2003), relative humidity, and temperature had different effects, either positive or negative on the abundance of different spiders in caves.

Figure 3 shows the relationship of temperature, relative humidity and cave surface on abundance of species in different cave sites. Quadrant 1 shows that the species abundance of three web-spinners, namely, *D. grammica, P. laminata* and *L. tarsalis* and two hunter spiders *Heteropoda* sp. 1 and *Heteropoda* sp. 2 that were found in the two caves of site 4 of Tarragona, Davao Oriental is directly related to temperature*.* The three web spinners were found in the three ecological zones of the caves, while the two hunter spiders were observed on the walls at the entrance zone. Temperature in the two caves of site 4 from the entrance zone to inner zone was closely related (24.3 °C to 26 °C) which indicates that the species of spiders found in these caves prefer stable low temperature from the entrance zone to the inner zone. Glime (2013) stated that favorable or stable temperature increases the activity of spiders and it can be an important microclimate scale for nest, website selection and certain vegetational attributes for spiders.

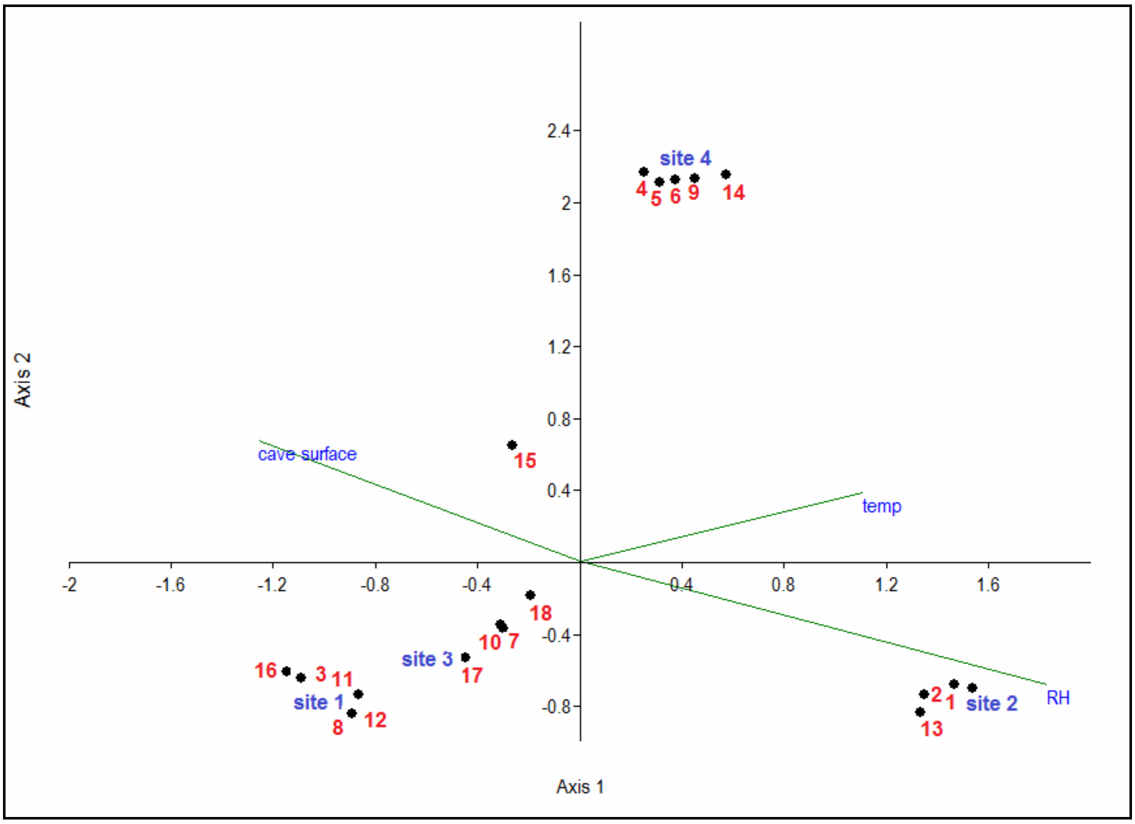

Figure 3. An ordination diagram showing the relationships of temperature, relative humidity and cave surface to the abundance of spider species in each sampling site. Eigen values of Axis 1=0.3697; Axis 2=0.1572; Axis 3=0.00477(1=*Araneus* sp.1, 2=*Araneus* sp.2, 3=*Ctenus* sp., 4=*Dictyna grammica*, 5=*Heteropoda* sp.1, 6=*Lycosa tarsalis*, 7= *Uthina* sp., 8=*Carrhotus* sp., 9=*Heteropoda* sp.2, 10=*Heteropoda maxima*, 11=*Heteropoda venatoria,* 12=*T. mandibulata*, 13=*T. praedonia*, 14=*Pandava laminata*, 15=*Diaea varians*, 16=*Uloborus* sp., 17=*Uloborus lugubris*, 18=*Damon medius*).

Quadrant 2 shows that the abundance of one of the hunter spiders, *D. varians*, is related to the cave surface. The ecology of this spider is not clearly known. However, this species was found in caves 5, 8 and 10 and observed to be regularly present on the floor surface at the entrance zone of the cave. The floor of the entrance zone in these three caves had numerous mossy and wet rocks near the stream. One individual of *D. varians* was found towards the outside environment of the cave.

Quadrant 3 shows that the species found in sites 1 and 3 (Quezon and Kitaotao, Bukidnon) are not directly related to the factors affecting their abundance and distribution. These species are: *Ctenus* sp., *Uthina sp.*, *Carrhotus* sp., *H. maxima, H. venatoria, T. mandibulata, Uloborus* sp., *Uloborus lugubris* and *D. medius.* Lubin (1978) stated that food can also be an important limiting factor for the presence of spiders in caves.

Quadrant 4 shows that the presence of spider species in cave 7 of sampling site 2 in Valencia, Bukidnon is related to relative humidity. This included three web spinners such as *Araneus* sp. 1 and *Araneus* sp. 2 under Family Araneidae and *T. praedonia* under family Tetragnathidae. These spiders which possess webs were found at the entrance zone (*Araneus sp.* 1 and 2) and at the twilight zone (*T. praedonia*) with relative humidity values ranging from 85.3% to 92%. These species of spiders were found in cave 7 which was near a stream. This indicates that the abundance of spider species may also be related to the ability of spiders to survive in high humidity and stable low temperature in the three ecological zones of the caves.

Conclusion and Recommendation. The distribution and abundance of species of spiders were affected by factors such as temperature, relative humidity and cave surface in three ecological zones of the cave. The temperature values were more or less stable and the relative humidity tends to go higher from the entrance zone to the inner zone. High relative humidity appears to be related to the abundance of some web spinners. *Diaea varians*, a hunter spider was always observed on the floor surface. Majority of the species of spiders found on the walls of the entrance zone in 11 caves were web spinners while majority of the species of spiders present on the walls of the inner zone were hunter spiders such as *D. medius*. *D. medius* was the most abundant among the species of spiders and was present in 11 caves having the highest total number of individuals recorded. High anthropogenic activities seem to negatively affect the diversity of cave spiders in Mindanao.

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