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Research article

SPECIES DIVERSITY OF CAVE-DWELLING SPIDERS ON SIARGAO ISLAND, PHILIPPINES

Michael Henry D. Cabili and Olga M. Nuñeza*

Department of Biological Sciences, College of Science and Mathematics, MSU-Iligan Institute of Technology, Andres Bonifacio Avenue, Tibanga, 9200 Iligan City, Philippines
*Corresponding author, email: olgamnuneza@yahoo.com

ABSTRACT: Siargao Island is home to many caves that are interesting habitats because of their extreme environments. Spiders that are good indicators of biodiversity are also known to be common cave dwellers. However, studies on cave spiders in Siargao Island are poorly known. This study was conducted to determine the species diversity of spiders in Siargao caves. Sampling was done through modified cruising method. Eight species belonging to six families were recorded in 10 caves sites of Siargao. Caves 1 and 4 where rich guano material was present had the highest species richness. The dark zone of these caves was found to have more number of species and individuals than the entrance or twilight zone. Low species diversity with more or less even distribution was recorded in Siargao caves. It appears that the presence of guano material contributes to the higher number of spiders in caves especially in the dark zone. Physico-chemical factors such as temperature and relative humidity appear to play an important role in the distribution and abundance of spiders in the different cave zones.
Keywords: Biodiversity, caves, dark zone, guano

INTRODUCTION

Caves are found world-wide, and are natural laboratories for the study of evolution [1]. A cave is considered to be an extreme environment [2] that is characterized by total darkness, almost constant air and water temperature, relative humidity approaching saturation and a relatively poor supply of nutrients [3]. Despite these characteristics, cave ecosystem harbors a variety of unique and sensitive organisms, many of which are cave obligates [4] including spiders with numerous troglobitic forms known from temperate and tropical caves [5]. Cave fauna are unique and constitute one of the important components of biodiversity [6]. They are also worth analyzing because all of these species have successfully invaded one of the harshest environments [7]. Spiders are common denizens of caves [5] with a wide range of physiological and morphological adaptation [8]. They are one of the most abundant predatory groups in the terrestrial ecosystems as they feed on insects and some other arthropods and thus, they can play an important role in pest control [9]. They are important food source for birds, lizards, wasps and other animals, and they are predators feeding on insects and small arachnids [10]. Spiders are also excellent indicators of environmental features of biodiversity [11]. There are approximately 40,000 spider species that have been described worldwide belonging to 109 families, [12] and new species are still being discovered.

There are thousands of obligate subterranean animals and majority of them have been found in caves [13]. A study on the colonization of subterranean habitats by spiders in Central Europe showed a total of 161 spider species with the number of species declining with increasing habitat depth [14]. Several studies on spiders are on the comparative biology of cave-dwelling spitting spiders (araneae: scytodidae): parental care, cooperative prey-capture, cannibalism, natal dispersal and reproductive behavior [15] and the diversity of cave-dwelling spiders in Greece [16]. However, in the Philippines, there are only few studies on the diversity of cave fauna especially in Mindanao, the country's second largest island. Recent studies were on the species richness of ants on Siargao Island [17], the species richness of cavernicolous species of crickets in selected cave sites in Mindanao [18] and the cave spiders in Mindanao [35]. This study aimed to provide information on the species richness, diversity, and the distribution of spiders within the caves on Siargao Island.

MATERIALS AND METHODS

Sampling was conducted in four municipalities of Siargao Island namely: Burgos, Del Carmen, General Luna and Sta. Monica (Figure 1). Ten caves were sampled and assessed in terms of basic cave information, environmental conditions (temperature and humidity), spider species richness and cave use.

Caves Sites

Cave 1, Buho Cave is located in Barangay Consuelo, General Luna (9° 48' 11" N and 126° 06' 22.6" E) with elevation of 62 meters above sea level (masl) and about 700 meters (m) from the main road. The cave has two openings with the main entrance easily accessible (width: 8.67 m; height: 5.67 m) while the second opening has a downward slope (width: 5m; height: 3 m). The total cave length is 84 m with only one large chamber. The cave has an accessible depth of 2 m and an accessible area of 750 m^2. Flood depth marking was absent and no pool of water was seen in the cave. Guano material was present which was found 30 m from the main entrance. Stalactites and few stalagmites were present. Boulders were present, found from the main entrance to the twilight zone while muddy soil substrate with a depth of 4 inches was found 35 m from the main entrance. Light illuminance was 2.9 lux (31 m from the main entrance) and 2.5 lux (5 m from the second opening). Wooden poles and other debris, broken stalagmites and holes on the cave floor were observed indicating a disturbed cave with treasure hunting or mining activities.

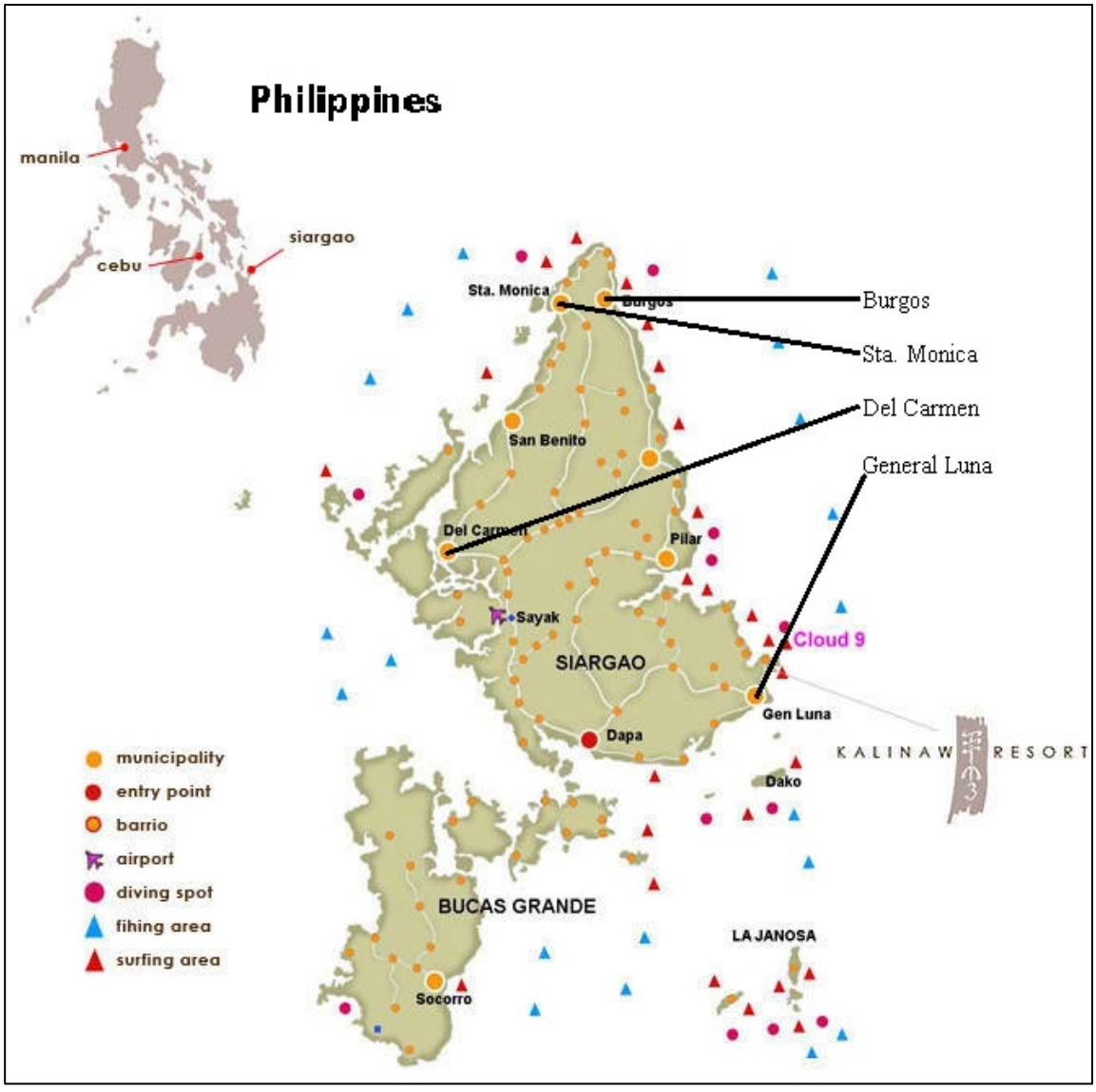


Figure 1. Map of Siargao Island [19] showing the location of four municipalities

Cave 2, Bulod Cave 1 is located in Barangay Antipolo, Del Carmen (9° 49' 07.6" N and 126° 00' 48.7" E; elevation 47 masl) about 500 m from the main road. It has only one opening that was not easily accessible due to its small size (width: 1 m; height: 1.5 m). The total cave length is 40 m with no large chambers. Accessible depth was about 1.5 m with accessible area of 41 m^2. Water source, flood depth marking, and guano material were absent. Stalactites and stalagmites were present, but stalagmites were present only at the inner zone of the cave. Boulders were absent while muddy soil substrate was present with a thickness of 5 inches. Light illuminance at 4 m from the main entrance was 2.6 lux. Human disturbances were absent.

Cave 3, Bulod Cave 2, is located five meters west of Cave 2 (9° 49' 07.7" N and 126° 00' 48.7" E; elevation 44 masl), about 500 m from the main road. It has only one entrance that is not easily accessible due to entrance size (width: 1.5 m; height: 1.3 m). Total cave length is 40 m with no chamber; an accessible area of 41 m^2. Water source, flood depth marking, and guano material were absent. Stalactites and stalagmites were present, but stalagmites were only at the inner zone. Boulders were absent while muddy soil substrate was present all throughout the cave area with a depth of 4 inches. Light illuminance at 5 m from the main entrance was 4 lux. Human disturbance was absent.

Cave 4, Million Bats Cave, is located in Barangay Antipolo, Del Carmen (9° 49'38.2" N and 126° 00' 55.7" E; elevation 57 masl) about 1500 m from the main road. It has one opening with an entrance (width: 5 m; height: 4 m) having a slight slope downwards. The total cave length is 140 m with only one chamber; an accessible depth of 1 m and an accessible area of 1400 m^2. Water source and flood depth markings were absent. Guano material with a depth of 1 m was present 30 m from the main entrance. Stalactites and several stalagmites were present. Boulders were present at the entrance and inner zones. Muddy soil substrate was 15 m from the main entrance present 100 m from the entrance with depth ranging from 1 to 2 inches. Light illuminance at 15 m from the main entrance was 1.4 lux. Presence of bottle and other debris and breakdown of some stalagmites suggests human disturbance in the cave.

Cave 5, Naogon Cave which has a vertical entrance located in Barangay Antipolo, Del Carmen (9° 49' 38.1" N and 126° 00' 55.7" E; elevation 60 masl) is located 80 m southwest of Cave 4 and 1500 m from the main road. It has only one opening that was not easily accessible (diameter: 3 m) due to its vertical position. An accessible cave length was 20 m with an accessible depth of 1 m. Accessed area was 100 m^2. Water source was present in the form of a pool. Flood depth marking was 4 m. Guano materials were absent; stalactites were present, but no stalagmites were seen. Boulders were absent while muddy soil substrate was present with a depth of 7 in. Light illuminance at1 m from the main entrance was 4.2 lux. Human disturbance was absent.

Cave 6, Sumiyot Cave, in Barangay Poblacion 1, Burgos (9° 45' 49.1" N and 126° 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 a downward slope. The accessed cave has a length of 30 m with no chamber; an accessible depth of 1 m with accessible area of 150 m^2. A pool of water was present at the inner recesses, and water droplets from the roof were abundant. Flood depth marking and guano material were absent. Stalactites and stalagmites were abundant. Boulders were present at the twilight zone while muddy soil substrate with a depth of 2 in was present at the entrance zone. Light illuminance about 3 m from the entrance was 1.3 lux. Broken pieces of stalagmites were noted. Beautiful rock formations were present in the cave.

Cave 7, Patag Cave in Barangay Poblacion 2, Burgos (9° 59' 54.8" N and 126 ° 04' 48.4" E; elevation 22 masl) is located 600 m from the main road. It has one opening (width: 20 m; height: 8 m). The entrance was sloping and easily accessible with estimated cave length of 1000 m. The cave was formed like a large tunnel. Accessible depth was 5 m while the accessible area was 3000 m^2. Streams were present inside which flow out from the inner part of the cave. Flood depth marking was visible at 0.6 m. Guano material was present with a depth of 1 inch. Stalactites and stalagmites were abundant. Boulders were present at the twilight zone, and muddy soil substrate was present with a depth of 4 inch. Light illuminance about 7 m from the entrance was 12.4 lux. Broken pieces of some stalagmites were observed. It appears that the cave can serve as a wildlife habitat, site for spelunking, and as a water source for nearby rice fields.

Cave 8, Guano Cave in Barangay Libertad, Sta. Monica (10° 01' 04.8" N and 126° 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 was easily accessible. Accessed cave length was 70 m with no chamber, accessible depth of 1 m and accessible area of 2000 m^2. Water source and flood depth markings were absent. Guano material was present at the inner zone with a depth of 2 in. Stalactites and stalagmites were present. Boulders were present at the twilight zone while muddy soil substrate with a depth of 3 in was present at the inner zones of the cave. Light illuminance at 10 m from the entrance was 7.6 lux. Human disturbance was present in the form of treasure hunting (according to local inhabitants) and guano collection. Presence of wood poles and holes inside the cave indicates treasure hunting.

Cave 9, Sta. Monica Cave 2 in Barangay Libertad, Sta. Monica (9° 58' 58.5" N and 126° 03' 13.1" E; elevation 51 masl) is 150 m southwest of cave 8 and is located 100 m from the main road. It has only one opening (width: 4 m; height: 3 m).

Accessed cave length was 20 m with accessible depth of 1 m. Accessed area was 500 m^2. Water source, flood depth marking, and guano material were absent. Stalactites and stalagmites were present, but more numerous at the entrance zone than the other zones. Boulders were absent while muddy soil substrate was present at the twilight zone with a depth of 2 inches. Light illuminance at 15 m from the entrance was 1.7 lux. Breakdown of speleothems and man-made holes for treasure hunting at the inner recess zone was indicative of human disturbance.

Cave 10, Sta. Monica Cave 3 in Barangay Libertad, Sta. Monica (9^o 47' 46.2" N and 126^o 06' 27.7" E; elevation 29 masl) is about 70 m east of Cave 9 and 30 m from the main road. It has only one opening (width: 2 m; height: 1 m). The vertical entrance of the cave was hardly accessible. The accessed cave length was 18 m. No chamber was found. Accessed area was 108 m^2. Water source, flood depth markings and guano material were absent. Stalactites and stalagmites were completely absent, but few boulders were present at the inner cave zone. Muddy soil substrate was found throughout the cave with a depth of 3 in. Light illuminance at 4 m from the entrance was 1.9 lux.

Collection of Samples

The walls, roofs, holes, crevices, rocks and floors of the entrance, twilight, and dark zones of the caves were examined. Only the dark zone of cave 5 was not examined due to difficult accessibility. Sampling of spiders followed the cave invertebrate collection guide [20]. The total number of spiders observed in the cave was counted. 0ne to three specimens were captured for each species and kept as voucher specimens. In some cases, only one specimen was caught per species due to limited availability of specimens in the cave.

Processing and Analysis of Data

Eighty percent ethanol was used to preserve the specimens. The samples were sent to the Philippine National Museum for identification of the spiders by an expert. Biodiversity indices were measured using Bio Dive Pro.

RESULTS AND DISCUSSION

Eight species of spiders were collected belonging to two orders and six families (Table 1). Caves 1 and 4 had the highest species richness (S=3). These caves contained guano material indicating that species richness of spiders is positively related to the presence of guano. Cave 4 had the most number (33.1%) of spiders followed by cave 8 (32.4%). Spider communities flourish in these caves because of the presence of guano materials. Spiders (Araneidae) were found in almost all types of guano in nearly all conditions [21]. This indicates that guano supports a high diversity of organisms including spiders [22] representing different trophic levels [23]. Caves 3, 6 and 10 had the least abundance (1.5%) of spiders. Guano was absent in these three caves along with the presence of human disturbance in caves 6 and 10. Human disturbance could negatively affect some spiders while others are more tolerant to changes [24]. It appears that guano plays a very important role in the food web of cave ecosystem because, without it, macro-invertebrates and all other communities will not survive. Lack of guano in the cave cannot support lower forms of organisms that can also serve as food to spiders. The presence of communities of organisms in caves is actually dependent on the guano microenvironment [25].

Table 1. Species Richness and Abundance of Spiders in Caves of Siargao Island

Order	Family	Species	Cave										
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total No. of Individuals**
Araneae	Deinopidae	*Deinopis* sp.						1					**1**
	Pholcidae	*Pholcus* sp. 1	3										**3**
		Pholcus sp. 2							15				**15**
	Sparassidae	*Heteropoda* sp.		6	2	2	5			8	3	2	**28**
	Theraphosidae	*Unidentified* sp.2	5							36			**41**
	Thomisidae	*Neosparassus* sp.				40							**40**
	Uncategorized	*Unidentified* sp. 1	1										**1**
Amblypygida	Phrynichidae	*Damon* sp.				3		1	3				**7**
Total No. of Spiders Present Per Cave			**9**	**6**	**2**	**45**	**5**	**2**	**18**	**44**	**3**	**2**	**136**
Total No. of Species Per Cave			**3**	**1**	**1**	**3**	**1**	**2**	**2**	**2**	**1**	**1**	**8**
Relative Abundance of Spiders Per Cave (%)			**6.6**	**4.4**	**1.5**	**33.1**	**3.7**	**1.5**	**13.2**	**32.4**	**2.2**	**1.5**	**100**

Legend: 1= Buho Cave, General Luna, 2= Bulod Cave 1, Del Carmen, 3= Bulod Cave 2, Del Carmen, 4= Million Bat Cave, Del Carmen, 5= Naogon Cave, Del Carmen, 6= Sumiyot Cave, Burgos, 7= Patag Cave, Burgos, 8= Guano Cave, Sta. Monica, 9= Cave 2, Sta. Monica and 10= Cave 3, Sta. Monica

Table 2 shows the distribution of spiders in the different cave zones. A higher number of species and individuals was found in the dark zone. This was clearly observed in 9 out of 10 caves sampled in Siargao Island. All caves except cave 5 where guano materials were absent showed that the species richness and abundance of spider are higher in the dark zone as compared to the other zones. The same result was obtained [16] in the study on cave dwelling spiders of Greece where a group of spiders comprising 11 species occurs mainly at the dark zone of crevices and caves. In some tropical caves, swiflets (*Aerodramus* sp.) colonize the dark zone where their droppings that form large piles serve as food source [26]. This indicates that the presence of spiders in the dark zone of caves is related to the presence of food which can support life. Tropical cave dwellers may colonize other cave parts through adaptive shifts to look for new resources [27]. In terms of species, *Deinopis* sp. was only found at the dark zone of cave 6 consisting of one individual while *Pholcus* sp. 2 was found only in cave 7 at the twilight and inner zones. *Pholcus* sp. 1 and the *Unidentified* sp. 1 were only found both at the dark zone of cave 1. *Deinopis* is a nocturnal spider that forages at night or in dim diurnal sites [28]. The genus *Pholcus* prefers humid and shaded places for protection from strong air current which could alter their webs [29]. The search for food and other opportunities may have influenced the spiders to forage in the dark zones and through time, their new –found niche may have allowed further diversity and abundance of the spider population.

Table 2. Distribution of Spiders in Different Zones

Species	Cave																											
	1			2			3			4			5			6			7			8			9			10		
	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D	E	T	D
Deinopis sp.																		+												
Pholcus sp. (1)			+																											
Pholcus sp. (2)																				+	+									
Heteropoda sp.					+	+			+		+			+								+	+	+			+			+
Unidentified sp. 2		+	+																				+	+						
Neosparassus sp.											+	+																		
Unidentified sp.1			+																											
Damon sp.											+	+						+			+									
Total No. of Individuals	**0**	**1**	**8**	**0**	**2**	**4**	**0**	**0**	**2**	**0**	**4**	**41**	**0**	**5**	**0**	**0**	**0**	**2**	**0**	**2**	**15**	**1**	**9**	**34**	**0**	**0**	**3**	**0**	**0**	**2**

Legend: E= Entrance zone, T= Twilight zone, D= Dark zone, 1= Buho Cave, General Luna, 2= Bulod Cave 1, Del Carmen, 3= Bulod Cave 2, Del Carmen, 4= Million Bat Cave, Del Carmen, 5= Naogon Cave, Del Carmen, 6= Sumiyot Cave, Burgos, 7= Patag Cave, Burgos, 8= Guano Cave, Sta. Monica, 9= Cave 2, Sta. Monica, 10= Cave 3, Sta. Monica; present (+)

Table 3 shows that six out of 10 caves have decreasing temperature as one gets from the entrance to the dark zone. For relative humidity, it increases as one enters the cave making it higher in deeper and darker zones than in the entrance zone.

Table 3. Physico-Chemical Parameters in the Different Zones Inside Caves

Cave	Entrance zone		Twilight zone		Dark zone	
	T (^{o}C)	RH (%)	T (^{o}C)	RH (%)	T (^{o}C)	RH (%)
1	27.6	80	28.8	81	28.0	85
2	31.0	77	30.6	78	30.7	80
3	30.4	78	30.2	79	28.5	80
4	30.5	77	30.0	78	28.9	87
5	29.0	83	29.7	84	NA	NA
6	31.1	76	30.0	77	30.1	81
7	30.1	80	30.0	81	27.0	97
8	28.4	83	28.0	84	27.4	98
9	27.8	90	27.0	93	26.9	94
10	28.0	83	27.2	84	27.1	85
Average	**29.39**	**80.7**	**29.15**	**81.9**	**28.29**	**87.4**

Legend: 1= Buho Cave, General Luna, 2= Bulod Cave 1, Del Carmen, 3= Bulod Cave 2, Del Carmen, 4= Million Bat Cave, Del Carmen, 5= Naogon Cave, Del Carmen, 6= Sumiyot Cave, Burgos, 7= Patag Cave, Burgos, 8= Guano Cave, Sta. Monica, 9= Cave 2, Sta. Monica, 10= Cave 3, Sta. Monica, T = Temperature, RH = Relative Humidity

The adaptation of the spiders to high humidity, cooler temperature and the presence of guano materials could be the reason for their diversity and abundance in the dark zones of caves. Some species of spiders can adapt to arid conditions, keep their activity and hunt slow-moving prey [30]. Table 4 shows low species diversity with more or less even distribution in the caves. Lower spider diversity but higher abundance was recorded in more productive habitats [31]. Low diversity and a more or less even distribution of cave spiders were recorded in 11 cave sites in Mindanao [32].

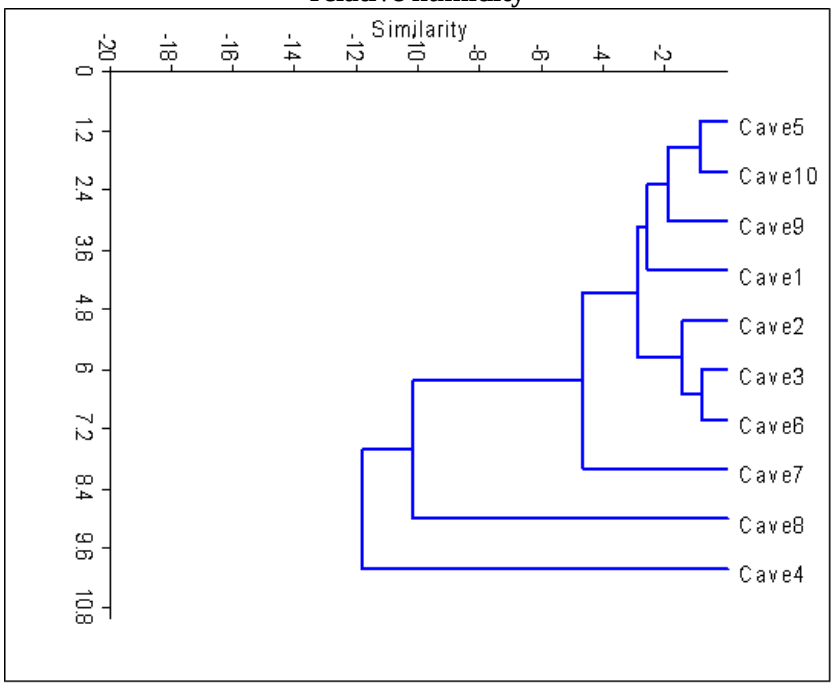
Table 4. Biodiversity Indices of Spiders in 10 Cave Sites

Indices	Caves										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**All Caves**
Species	3	1	1	3	1	2	2	2	1	1	8
Individuals	9	6	2	45	5	2	18	44	3	2	136
Dominance	0.432	1	1	0.797	1	0.5	0.722	0.702	1	1	0.235
Shannon	0.937	0	0	0.424	0	0.693	0.451	0.474	0	0	1.599
Evenness	0.851	1	1	0.509	1	1	0.785	0.803	1	1	0.619

Legend: 1= Buho Cave, General Luna, 2= Bulod Cave 1, Del Carmen, 3= Bulod Cave 2, Del Carmen, 4= Million Bat Cave, Del Carmen, 5= Naogon Cave, Del Carmen, 6= Sumiyot Cave, Burgos, 7= Patag Cave, Burgos, 8= Guano Cave, Sta. Monica, 9= Cave 2, Sta. Monica, 10= Cave 3, Sta. Monica

Figure 2 shows the similarities between the cave sites sampled with respect to the species abundance, temperature, and relative humidity of the caves. The caves that are of closest similarities are caves 5 and 10, and caves 3 and 6. This suggests that environmental factors such as physico-chemical parameters (temperature and relative humidity) affect diversity. The distribution of spiders, as in any animal, is affected by their physiological tolerance to environmental variables like temperature or rainfall and by the requirements of the dispersing phase of the life cycle [33]. In general, different species have varying humidity and temperature preferences and are limited within the range of their physiological tolerance [34].

Figure 2. A dendrogram showing similarities between caves in terms of species abundance, temperature and relative humidity



Legend: E= Entrance zone, T= Twilight zone, D= Dark zone, 1= Buho Cave, General Luna, 2= Bulod Cave 1, Del Carmen, 3= Bulod Cave 2, Del Carmen, 4= Million Bat Cave, Del Carmen, 5= Naogon Cave, Del Carmen, 6= Sumiyot Cave, Burgos, 7= Patag Cave, Burgos, 8= Guano Cave, Sta. Monica, 9= Cave 2, Sta. Monica, 10= Cave 3, Sta. Monica

Caves 5 and 4 are dissimilar. Cave 4 is a cave richer in diversity and richness as compared to cave 5. Cave 4 is rich in guano material due to the presence of bats while guano in cave 5 was absent. This indicates that the conducive physico-chemical factors (temperature and humidity) in cave 4 along with the presence of food contribute to species richness and abundance.

CONCLUSION AND RECOMMENDATION

Spider diversity is low with more or less even distribution in the caves of Siargao Island. Caves 1 and 4 had the highest species richness. The dark zone had higher abundance and species richness. The presence of guano material along with higher humidity and cooler temperature appears to be the key factors for the existence of spider species in the caves especially in the dark zone. It is recommended that adaptation and behavior of cave spiders be investigated in future studies.

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