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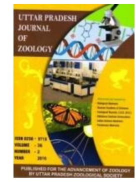

SPECIES RICHNESS AND MICROHABITATS OF SPIDERS IN CAVES OF AGUSAN DEL SUR, PHILIPPINES

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration with all authors. Author RJCLM managed the literature search, conducted the f ield sampling, performed the statistical analysis and wrote the first draft of the manuscript. Author OMN designed the study, conducted the field sampling, managed the interpretation of results together with author RJCLM reviewed and revised the manuscript. Author ALBD provided the method of spider collection and identified the specimens. All authors read and approved the final manuscript.

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ABSTRACT

Spiders are widely distributed in a variety of habitats. However, spider fauna in caves of Agusan del Sur has not been widely studied. This study aimed to determine the species richness and microhabitats of spiders belonging to 12 families in the caves of Agusan del Sur. Eight caves in three municipalities and one city in Agusan del Sur were surveyed on June 24 to July 10, 2015. A combination of vial tapping and handpicking methods was done to collect specimens. Forty-eight species of spiders were documented in the eight caves of Agusan del Sur. Agpan Cave had the highest species richness (S=19) and abundance (43.16%) which is attributed to the presence of guano deposit. Five spider microhabitats were identified. Family Sparassidae occupied all five cave microhabitats, while the family Araneidae was found on both rock surfaces and shrubs. The wall of the cave had the highest species richness of spiders. Guano deposit and habitat structures appear to be the major factors for the species richness of spiders and the continuation of the food chain in caves.

Keywords: Araneidae; guano; habitat structures, Sparassidae; vial tapping.

1. INTRODUCTION

The most engrossing environments on Earth are caves [1]. Caves are generally characterized by complete darkness where air and water temperatures are nearly constant, with nearly saturated relative humidity and low energy input [2]. Despite these characteristics, caves harbor a variety of unique and sensitive organisms, many of which are cave obligates [3]. Troglobites are cave-dwelling organisms that have

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adapted to living in darkness which caused them not to survive outside of a cave [4]. Spiders are one of the most familiar types of troglobites [5]. These organisms are among the more important groups of invertebrates that occur in caves, with nine of the 11 extant orders containing troglobites [6] known from temperate and tropical regions [7].

Spiders occupy virtually every habitat with a wide range of physiological adaptations, behavioral adjustments, and morphological adaptation [8]. Spiders are suspected predators of arthropod pests, usually insects [9] which make them highly essential in the regulation of insect population in many terrestrial habitats [10,11]. There are 43,500 known spider species [12] terrestrially distributed on all continents excluding Antarctica [13]. In the Philippines, there are about 517 species of spiders belonging to 225 genera and 38 families [14]. Some of these species of spiders belong to families Pholcidae, Sparassidae, Theraphosidae, and Thomisidae in caves of Siargao Island [15]. Microhabitat selection plays an important role in determining the local distribution patterns of small terrestrial animals, particularly spiders [16].

Most studies on spiders have focused on temperate areas in the western region specifically on agricultural ecosystems such as wheat fields [17], soybean agroecosystems [18], sugarcane [19], and all major crops [20,21], while studies of spider diversity in tropical areas are rare [22]. In the Philippines, there are limited studies on spiders. Published reports were on the fauna of lowland habitats such as rice fields [14,23].

In Mindanao, the second biggest major island of the Philippine archipelago [24], studies were on spider fauna from mountains [25,26] and waterfalls [27]. Studies in caves were on ants [28] and crickets [29]. Although there have been reported studies on spiders in the caves of Mindanao particularly on Siargao island [15] and Bukidnon and Davao Oriental [30], little is known on spiders in the caves of Agusan del Sur. This study was conducted to determine the species richness of spiders and microhabitats of spiders in caves.

2. MATERIALS AND METHODS

2.1 Study Area

Eight caves were surveyed in three municipalities and one city in Agusan del Sur, Philippines, namely: Bayugan City and the municipalities of Prosperidad, Loreto, and Trento (Fig. 1). Sampling sites were described following the cave description form of the Department of Environment and Natural Resources (DENR) [31].

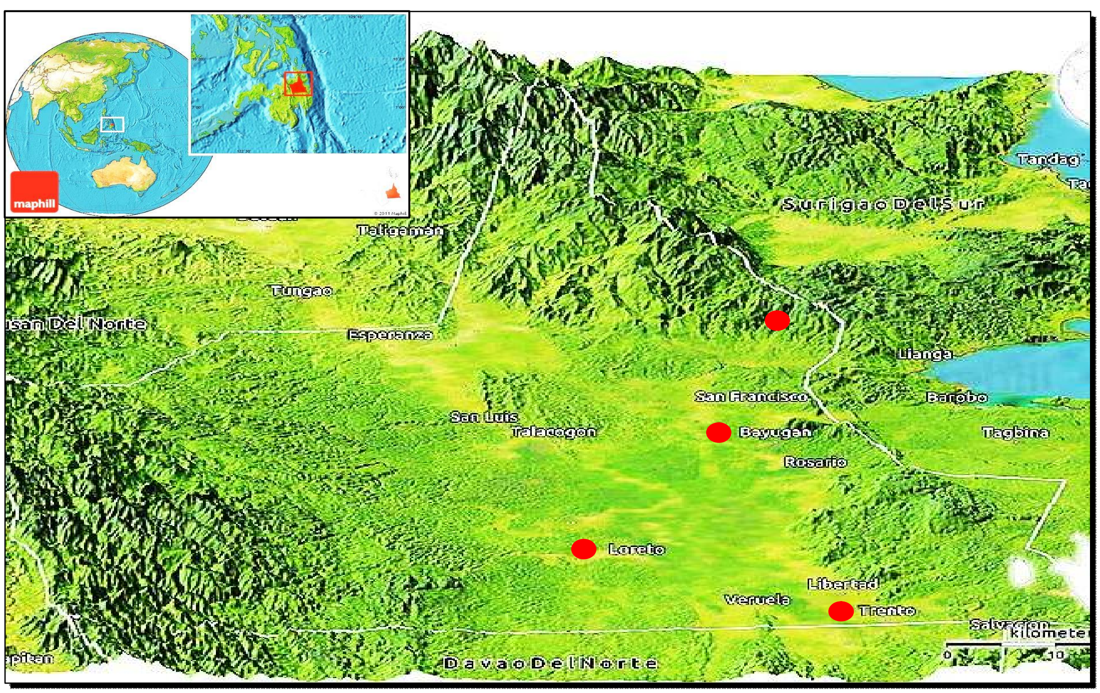

Fig. 1. Map of Agusan del Sur, the Philippines showing the location of the sampling areas (Bayugan City, Prosperidad, Loreto, and Trento) [32]

2.2 Cave Sites

Cave 1, Wilderness cave which has three floors is located in Barangay Mt. Carmel, Bayugan. The first floor has coordinates of 8°28'20.38'' N and 125°50'51.4'' E, elevation of 733 meters above sea level (masl), and is situated 200 m from the anthropogenic clearing. The entrance is not easily accessible due to a vertical orientation (1.5ft by 50cm dimension) with a 60 degrees slope. The cave had a temperature of 24˚C in the twilight zone, 23 ˚C in the deep zone, and a humidity of 92%. Outside the cave is a secondary vegetation type with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy-sticky soil in the twilight Zone (TZ) and sandy in the deep zone at the upper chamber. Guano material from birds was present. The cave has a stream. Stalactites, stalagmites, and crystal lining were present but very few. Column and flowstones were absent. Presence of fallen logs, exposed rocks, vandalism, and holes for treasure- hunting activity and cutting of stalactites were indicative of disturbance inside the cave. The second floor is situated at 8°48'22.7'' North and 125°50'58.7'' East. It has an elevation of 687 masl. The entrance in the second floor of the cave is not easily accessible due to a vertical orientation (2ft by 1m dimension) with a 10 degrees slope. The cave has two chambers. Twilight zone has a temperature of 24.5˚C and 23˚C in the deep zone. The cave has 92% humidity. Outside the cave is a secondary type of vegetation with canopy epiphytes, vines, and understory plants (shrubs and ferns). The twilight zone has a loamy-sticky soil type and the deep zone has a sandy soil type. Guano material from birds was present. The cave has a stream. The cave also has a moderate presence of stalactites. Stalagmites and column were present but very few. Crystal lining and flowstones were absent. Logs, exposed rocks, vandalism, holes for treasure-hunting activity, and cutting of stalactites were indicative of disturbance inside the cave. The third floor has an opening (2m by 1.5m dimension), not easily accessible due to a vertical orientation with a 60 degrees slope. The cave has one chamber with a temperature of 24˚C in the twilight zone, 24˚C in the deep zone, and 92% humidity. Outside this chamber is a secondary type of vegetation consisting of canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate with bird guano. Stalactites were present but very few. Stalagmites, column, crystal lining, and flowstones were absent. Fallen logs, exposed rocks, vandalism, holes for treasure hunting activity, and cutting of stalactites were indicative of disturbance.

Cave 2, Magdaguhong Cave is located in Barangay Mt. Carmel, Bayugan (8°47'42.9'' North and 125°50'26.4'' East) at an elevation of 569 masl. The entrance of the cave (10m by 10-15m dimension) is easily accessible with a horizontal orientation and flat slope. The cave has three chambers with a temperature of 24.5˚C in the twilight zone, 24˚C in the deep zone, and 92% humidity. Outside the cave is a deciduous type of vegetation. Canopy epiphytes were absent. Canopy vines and understory plants (shrubs and ferns) were present. The cave has a loamy substrate. Guano material was absent. Stalactites were abundant. Stalagmites, column, crystal lining, and flowstones were present but very few. Vandalism and cutting of stalactites were indicative of disturbance.

Cave 3, Ararat Cave is located in Barangay Mt. Ararat, Bayugan (8°49'43.1'' N and 125°50'15.3'' East) at an elevation of 693 masl. The entrance (10m by 10-15m dimension) is not easily accessible due to a vertical orientation with 80 degrees slope. The cave has two chambers. Twilight zone had a temperature of 24˚C, 22˚C in the deep zone, and a humidity of 92%. A secondary vegetation type was present outside the cave with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate. Guano material from birds was absent. Stalactites and stalagmites were abundant. The cave has a moderate presence of column and crystal lining. Flowstones were present but very few. Cutting of stalactites was indicative of disturbance.

Cave 4, Katam-isan Cave is located in Barangay Mt. Ararat, Bayugan (8°49'38.2'' N and 125°50'9.2''E) at an elevation of 598 masl. The entrance (50cm by 1m dimension) is not easily accessible due to a vertical orientation with a 30 degrees slope. The cave has three chambers with a temperature of 25˚C in the twilight zone, 24˚C in the deep zone, and 92% humidity. A secondary vegetation type was present outside the cave with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate. Guano material was absent. The cave has a stream in the deep zone. Stalactites and crystal lining were abundant. The cave has moderate stalagmites. Column and flowstones were present but very few. Cutting of stalactites and vandalism were indicative of disturbance.

Cave 5, Agpan Cave is located in Barangay Manat, Trento (8˚07'17.5'' North and 126˚06'08.5'' East) at an elevation of 83 masl. The cave has five entrances which are easily accessible. The first entrance (75m by 50m dimension) and the second entrance (10m by 15m dimension) have 10 degrees slope. The third entrance (50m by 30m dimension) has 45 degrees slope while both the fourth entrance (10m by 15m dimension), and the fifth entrance (10m by 5m dimension) have 10 degrees slope. The cave has seven to eight chambers with a temperature of 25.5˚C in the twilight zone and 24˚C in the deep zone.

Relative humidity was 92% in the twilight zone and 85% in the deep zone. Outside the cave is a secondary type of vegetation with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate in the twilight zone and sandy in the upper portion due to soil erosion brought about by Typhoon “Senyang”. Guano material from bats was present around one foot in thickness. The cave has a stream in one chamber. Stalactites were abundant. Stalagmites, column, and crystal lining were present but very few. Flowstones were absent. Guano harvesting and soil erosion due to typhoon “Senyang” were indicative of disturbance inside the cave.

Cave 6, Tao-naga cave is located in Barangay Magsaysay, Prosperidad (8°2’33.4’’ North and 126°3’45.7’’ East) at an elevation of 63 masl. The cave has two entrances. The main entrance is flat, easily accessible, with 2m by 5m dimension. The second entrance with a 0.75m by 15m dimension has 5- degree slope. The cave has three chambers. Twilight zone had a temperature of 25.5˚C and 92% humidity while deep zone had a temperature of 24.5˚C and 85% humidity. Outside the cave is a secondary vegetation type with canopy vines and understory plants (shrubs and ferns) but no canopy epiphytes. The cave has a sandy soil substrate with small rocks. Guano material from bats was present. The cave has a stream about 1-2 m in width. Stalactites and crystal lining were abundant. Stalagmites and flowstones were moderately present. Columns were present but very few. This cave has been utilized as a treasure-hunting area.

Cave 7, Simbahan cave is located in Barangay Waloe, Loreto (8°9’25.3’’ N and 125°40’26.3’’ East) at an elevation of 63 masl. The cave has two entrances. The main entrance (6m by 4m dimension) is not easily accessible due to a vertical orientation with 30 degrees slope. The second entrance of 2mm by 1.5m dimension is flat and easily accessible. The cave has four to six chambers with a temperature of 27˚C in the twilight zone, 26˚C in the deep zone, and 78% humidity. Outside the cave is a secondary vegetation type with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate. Guano material from bats was present but very few. Stalagmites, column, and flowstones were present but very few. Presence of stalactites is moderate. Crystal lining was absent. This cave has been utilized for treasure hunting.

Cave 8, Sampyagit cave is located in Barangay Waloe, Loreto (8°9’16.7’’ N and 125°41’26.6’’East) at an elevation of 99 masl. The cave has a vertically-oriented entrance of 4m by 1.5m dimension. The cave has five to six chambers with a temperature of 26˚C in the twilight zone, 25˚C in the deep zone, and a relative humidity of 78%. Outside the cave is a secondary type of vegetation with canopy epiphytes, vines, and understory plants (shrubs and ferns). The cave has a loamy soil substrate. Guano material from birds was present but very few. The cave has two main chambers, on the left and right portion of the cave. At the left main chamber, stalactites, stalagmites, crystal lining, and flowstones were present but very few and a column was absent. At the right main chamber, stalactites were abundant. Stalagmites and column were present but very few. Crystal lining and flowstones were absent. This cave has been utilized as a treasure-hunting area.

2.3 Collection, Processing, and Identification of Samples

Selected caves in Agusan del Sur were surveyed for cave-dwelling spiders on June 22 – July 10, 2015, for approximately 95 man-hours. Temperature, relative humidity, and cave description were noted for each cave. Following the modified cruising method, a combination of hand picking and vial tapping methods was used to collect samples of 12 spider families (Anapidae, Araneidae, Clubionidae, Corinnidae, Dipluridae, Lycosidae, Mimetidae, Psechridae, Sparassidae, Tetragnathidae, Theraphosidae, Thomisidae). Spiders were searched on shrubs, rock surfaces, and other possible microhabitats at the entrance of the cave. Inside the cave, the cave floor, wall, ceiling, and other possible microhabitats were searched. For the preservation of the specimens, 70% ethanol was used. Each sample was placed in vials and labeled with the following information (cave name, the location of collection, and cave zone). Spiders were classified up to family level. The third author identified the spiders up to species level.

2.4 Analysis of Data

Analysis of data was done through PAleontological STatistics version 2.17c (PAST) for biodiversity indices and seriation analysis. Seriation would test the presence or absence of species per microhabitat. This would show shaded part which indicates that the species is present for a type of microhabitat, otherwise, it is absent.

3. RESULTS AND DISCUSSION

3.1 Species Richness and Abundance

Forty-eight species of spiders belonging to 12 families were documented in eight caves of Agusan del Sur (Table 1). Agpan cave had the highest species richness (S=19) and abundance (49; 43.16%) while Magdaguhong, Simbahan, and Sampyagit caves had the lowest species richness (S=2). Agpan cave was dominated mostly by *Phlogiellus bundokalbo* and *Phlogiellus* sp. of family Theraphosidae and *Pardosa* sp.1 of family Lycosidae. *Phlogiellus bundokalbo, Phlogiellus* sp., and *Pardosa* sp. 1 yielded a high number of individuals that were found on the ground of Agpan cave where guano material from bats is one foot thick. Caves inhabited by high-density populations of bats receive large quantities of nutrient-rich guano [33]. One of the main food sources for cave invertebrates is bat guano and so invertebrate activity is stimulated within the guano heap [34]. The thick guano materials present in Agpan cave due to the thousands of bats inhabiting this cave suggests that it is positively associated with the high species richness and abundance of spiders. Cabili and Nuñeza [15] also found that species richness of spiders is positively related to the presence of guano materials. In addition, Chroňáková et al. [35] found that caves with guano material increase the colonization of invertebrates providing carbon and other nutrients essential for cave-dwelling organisms. Moreover, caves with guano are more favorable to cave inhabitants like spiders that could result in their high species richness and abundance. Furthermore, the large size of Agpan cave yields more capacity for a higher number of species, more opportunities for isolation, and higher habitat diversity [36].

Many species of spiders in this study only have 1-4 individuals. Some ecological structures of caves like guano may be completely absent which could affect the distribution of species. Hence, species abundance would also depend on the area and the ecological structure present (guano deposits). Female spiders were found to be more abundant than males in the caves. The female spiders are juveniles, sub-adults, and adults. There were no male juveniles and male sub-adult. According to Andrade et al. [37], seasonal availability negatively affects the number of male spiders. Although the distribution of male spiders may be inadequate for spider productivity, female spiders have the tendency to be not choosy in mating because there are only a few male spiders so female spiders have no reason to intensify their sexual preference towards males spiders since male spiders are few [38]. Six species which are probably new species were documented, namely: *Chasmocephalon* sp., *Cyclosa* cf. *ginnaga* or sp. 1, *Pardosa* sp. 1, *Sinopoda* sp. 1, *Guizygiella* sp. 1, and *Orsinome* sp. 1.

3.2 Biodiversity Indices

Agpan cave had the highest species diversity while lowest species diversity was observed in Magdaguhong and Simbahan caves (Table 2). Distribution was more or less even in the cave sites. The high diversity in Agpan cave suggests that it is positively associated with the presence of guano material. This concurs with the findings of Ferreira and Martins [39] that species diversity of spiders is positively correlated with the area of the guano. Thus, the presence of bat guano in caves supports a great diversity of organisms including arthropods [40]. However, Katam-isan cave had no guano material but had high species diversity with more species under families Araneidae and Lycosidae. According to Ferreira and Martins [39], spiders are not always associated with bat guano piles but can also be found preying upon other organisms that feed on other alternative sources in the caves (e.g. vegetable debris). This suggests that despite the absence of guano piles in Katam-isan cave, the microhabitats found at the entrance of this cave such as shrubs and rock surfaces contribute to high spider diversity since other organisms also inhabit and feed on plants. In addition, cave entrance has more spider species due to the availability of insects, and these insects are rare in deep caves [36]. Yet, some invertebrates, especially those living on the ground inside the cave along with the ground-dwelling spiders were usually seen on piles of guano and decaying logs. Hence, the horizontal ecological niche of these caves is enormously abundant of nutrients which cause the different kinds of invertebrates to thrive which in turn could serve as prey for spiders. Due to the difficult access to Katam-isan cave where entryway is not easily accessible at the deep portion, only the microhabitats at the cave entrance were assessed. Sampyagit and Simbahan caves had low species richness because there were only a few samples collected owing to difficult access. Accessibility could also affect the study of spatial distribution of spiders within the cave system [41] in this study.

3.3 Microhabitat Preferences

Table 3 shows the biodiversity indices of spiders in five microhabitats. The wall had the highest species richness and was the most diverse microhabitat. This suggests that it is the preferred microhabitat of spider species in the sampled caves. Biomass and energy flow through various species populations [42] is one common explanation for the high species richness and diversity of spiders of cave wall microhabitats. Higher spider abundance in a microhabitat may imply that refuge plays an important role in spider habitat choice since different spiders will need different habitat qualities [43]. Also, scarcity of prey in an area could result in less species richness. The shrubs are the microhabitats at the cave entrance mostly with Family Araneidae. The ground microhabitat inside the cave has more number of spider individuals making it as the second species-rich microhabitat.

Table 1. Species richness and abundance of 12 families of spiders in Caves of Agusan del Sur

Species		Cave								Total
		Wilderness	Magdaguhong	Ararat	Katam-isan	Agpan	Taonaga	Simbahan	Sampyagit	
ARANEAE										
Family Anapidae										
1	*Chasmocephalon* sp. 1 F (E)	0	0	0	0	0	1	0	0	1 (1.05)
Family Araneidae										
2	*Anepsion* sp. 1 F (E)	0	0	0	1	0	0	0	0	1 (1.05)
3	*Araneus* sp. F (E)	0	0	0	0	1	0	0	0	1 (1.05)
4	*Cyclosa* cf. *ginnaga* M(E)	0	2	0	0	0	0	0	0	2 (2.11)
5	*Cyclosa bifida* F	0	0	0	0	1	0	0	0	1 (1.05)
6	*Cyclosa* sp. F, F(E)	0	0	0	1	0	1	0	0	2 (2.11)
7	*Gasteracantha* cf *diadesenia* FsubA (E)	0	0	0	0	0	0	0	1	1 (1.05)
8	*Gasteracantha clavigera* F (E)	2	0	0	0	1	0	0	0	3 (3.16)
9	*Gasteracantha* sp.	0	0	0	0	1	0	0	0	1 (1.05)
10	*Gea* sp. imm(E)	1	0	0	1	0	0	0	0	2 (2.11)
11	*Neoscona* sp. M(E)	0	0	1	0	0	0	0	0	1 (1.05)
Family Clubionidae										
12	*Clubiona* sp. imm(E)	1	0	0	0	0	0	0	0	1 (1.05)
13	*Clubionid* undet. imm(E)	0	0	0	0	0	1	0	0	1 (1.05)
Family Corinnidae										
14	*Castianeirinae* imm	0	0	1	0	0	0	0	0	1 (1.05)
Family Dipluridae										
15	*Masteria* sp. imm	1	0	0	0	1	0	0	0	2 (2.11)
Family Lycosidae										
16	*Leucage argentina* F(E)	0	0	0	1	0	0	0	0	1 (1.05)
17	*Leucage* sp. imm	1	0	0	5	1	0	0	0	7 (7.37)
18	*Leucauge* sp. cf. *xiuying* F(E)	0	0	0	1	0	0	0	0	1 (1.05)
19	*Leucauge blanda* F	0	0	0	1	0	0	0	0	1 (1.05)

Species		Cave								Total
		Wilderness	Magdaguhong	Ararat	Katam-isan	Agpan	Taonaga	Simbahan	Sampyagit	
20	*Pardosa* sp. 1 [imm, FsubA, F]	1	0	2	0	6	0	0	0	9 (9.47)
21	*Pardosa* sp. 2 [F]	0	0	0	0	3	0	0	0	3 (3.16)
22	*Pardosa* sp. 1 [F]	0	0	1	0	0	0	0	0	1 (1.05)
23	*Trochosa* cf *alviolai* [F]	0	0	0	0	1	0	0	0	1 (1.05)
24	*Trochoso* sp. [F]	0	0	0	0	1	0	0	0	1 (1.05)
Family Mimetidae										
25	*Mimetus* sp. [F]	1	0	0	0	0	0	0	0	1 (1.05)
Family Psechridae										
26	*Fecenia* sp. [FsubA]	0	0	0	0	1	0	0	0	1 (1.05)
27	*Psechrus* sp. [imm]	0	0	0	2	0	1	0	0	3 (3.16)
28	Psechridae A [imm]	0	0	0	0	0	1	0	0	1 (1.05)
Family Sparassidae										
29	*Heteropoda* sp. 1 [imm]	3	0	1	0	3	1	0	0	8 (8.42)
30	*Heteropoda* cf. *venatoria* [F]	1	0	0	0	0	0	0	0	1 (1.05)
31	*Heteropoda* sp. 2 [Fimm]	1	0	0	0	4	0	0	0	5 (5.26)
32	*Heteropoda* sp. 2A [F]	1	0	0	0	0	0	0	0	1 (1.05)
33	*Heteropoda* sp. 3 [imm]	0	0	0	0	1	0	0	0	1 (1.05)
34	*Sinopoda* sp. 1 [F(E)]	0	0	0	1	0	0	0	0	1 (1.05)
35	Sparassidae-unknown sp. 1	0	0	0	0	0	0	1	0	1 (1.05)
36	Sparassidae-unknown sp. 2 [(E)]	0	0	0	0	0	0	1	0	1 (1.05)
Family Tetragnathidae										
37	*Guizygiella* sp. 1 [F]	0	0	0	0	1	0	0	0	1 (1.05)
38	*Orsinome* sp. 1 [F(E)]	0	0	0	0	0	1	0	0	1 (1.05)
39	*Tylorida* cf. *ventralis* [FsubA]	0	0	0	0	0	1	0	0	1 (1.05)
40	*Tylorida* sp. [M(E)]	0	0	0	0	0	1	0	0	1 (1.05)
41	*Tetragnatha* sp. [imm]	0	0	0	1	0	0	0	0	1 (1.05)
Family Theraphosidae										
42	*Phlogellus bundokalbo* [imm, FsubA]	0	0	0	0	6	0	0	2	8 (8.42)

Species		Cave								Total
		Wilderness	**Magdaguhong**	**Ararat**	**Katam-isan**	**Agpan**	**Taonaga**	**Simbahan**	**Sampyagit**	
43	*Phlogiellus* sp. 1 [imm, F]	0	0	0	0	6	0	0	0	6 (6.32)
44	*Phlogiellus* sp. 2 F	0	0	0	0	1	0	0	0	1 (1.05)
45	*Phlogiellus* sp. 3 [M]	0	0	0	0	1	0	0	0	1 (1.05)
46	Theraphosidae A [imm]	1	0	0	0	0	0	0	0	1 (1.05)
47	Theraphosidae B [Fimm]	1	0	0	0	0	0	0	0	1 (1.05)
Family Thomisidae										
48	*Oxytate* cf. *virens* [F]	0	1	0	0	0	0	0	0	1 (1.05)
Total No. of Species		**48**								
No. of Species Per Cave		**13**	**2**	**5**	**10**	**19**	**9**	**2**	**2**	
No. of Spider Individuals Present Per Cave		**16 (16.84)**	**3 (3.16)**	**6 (6.32)**	**15 (15.79)**	**41 (43.16)**	**9 (9.47)**	**2 (2.11)**	**3 (3.16)**	**95**
No. of Probably New Species		**0**	**1**	**1**	**1**	**1**	**2**	**0**	**0**	**6**

Legend: imm – immature; subA – sub-Adult; F – Female; M – Male; (E) – spiders sampled at Entrance zone; () - % abundance

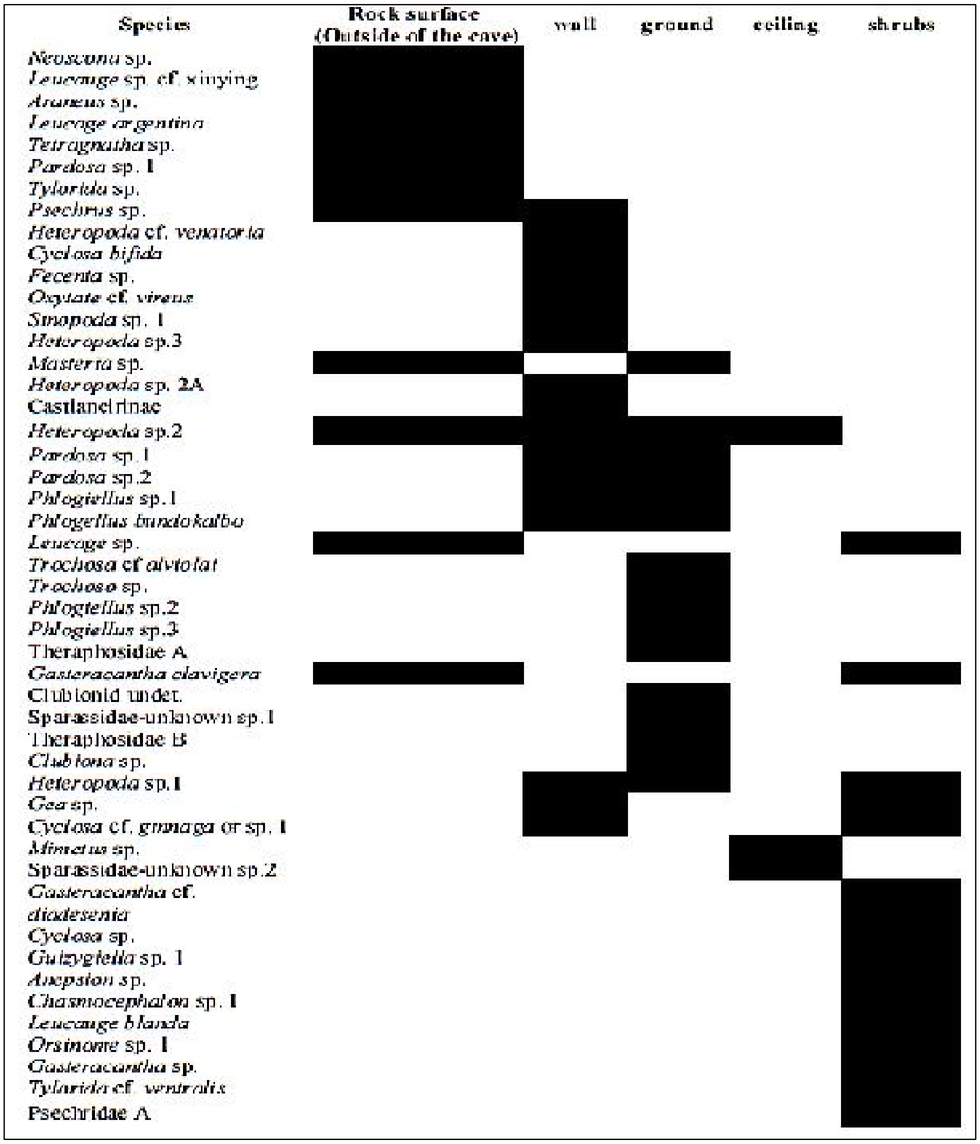

Fig. 2. Seriation showing five types of microhabitats and the spider species. The shaded part indicates the presence of species in a microhabitat

The microhabitats which had more species of spiders were the wall, ground, shrubs, and rock surfaces. The ceiling was the least inhabited microhabitat. The distribution of spiders and spider families across microhabitats may also be explained by the structural diversity, the kind of microhabitat which can be suitable for living or level of disturbance occurring in the habitat [44]. Spiders are observed at higher densities in the complex habitat structure composed of both live plants and thatch [45]. In the case of spiders of family Araneidae, they prefer locations that are greatly influenced by the presence of plants and shaded vegetation [27] which serve as anchors or stabilizing posts in building their webs [46]. Also, the study of Enriquez and Nuñeza [30] found that family Sparassidae prefers to inhabit cave walls which concur with the findings in this study. The presence of spider species on the walls, ceiling, and ground of the cave is due to the food availability [47] such as crickets which were found on the cave walls, ceiling, ground [48] and cockroaches on the cave ground. On the other hand, spider families that were found at only one site were not necessarily rare. They may be cryptic or have a patchy distribution and thus may not have been adequately sampled [49].

Table 2. Biodiversity indices of spiders in eight cave sites

Caves	No. of individuals	Species richness	Shannon (H')	Evenness e^H/S
Wilderness Cave	17	13	2.48	0.9185
Magdaguhong Cave	3	2	0.6365	0.9449
Ararat Cave	6	5	1.561	0.9524
Katam-isan Cave	15	10	2.079	0.7998
Agpan Cave	41	19	2.631	0.7309
Taonaga Cave	9	9	2.197	1
Sampyagit Cave	2	2	0.6931	1
Simbahan Cave	3	2	0.6365	0.9449

Table 3. Biodiversity indices of spiders in five microhabitats

	No. of individuals	Percent (%)	Species richness	Shannon (H)	Evenness e^H/S
Outside rock surface	17	17.9	12	2.344	0.8685
Wall	21	22.1	17	2.756	0.9253
Ground	35	36.8	16	2.437	0.7148
Ceiling	3	3.2	3	1.099	1
Shrubs	19	20	15	2.625	0.9203

Fig. 2 shows the seriation where rock surface and shrubs were dominated mostly by spider species in the families of Araneidae and Lycosidae while the cave wall was highly inhabited by Sparassidae. The ground microhabitat was dominated by six species from family Theraphosidae, namely: *Phlogiellus* sp.1, *Phlogiellus* sp.2, *Phlogiellus* sp.3, Theraphosidae A, Theraphosidae B and *Phlogellus bundokalbo*. *Mimetus* sp. from family Mimetidae and *Heteropoda* sp.2 and Sparassidae-unknown sp.2 from family Sparassidae were the only species of spiders in this study that inhabit the ceiling-type of microhabitat. *Heteropoda* sp.2 was the only spider species that was present in all microhabitats sampled except in shrubs. Among the microhabitats, rock surfaces and shrubs outside the cave have more species commonly due to the favorable conditions suitable for most species to live. Furthermore, the spider families Thomisidae and Mimetidae were only found at a single site (ceiling and wall, respectively).

4. CONCLUSION

High species richness of spiders was documented in the cave sites of Agusan del Sur. Among the sampled caves, Agpan Cave had the highest abundance and species richness due to the presence of guano deposits. Species in the families Lycosidae and Araneidae were the most abundant. Among the microhabitats identified, the wall microhabitat was the most species-rich and diverse while the ceiling microhabitat was the least inhabited. The family Sparassidae was found to occupy all five types of cave microhabitats. Presence of guano materials and availability of microhabitats appear to be the factors that contributed to the high species richness and diversity of spiders in caves of Agusan del Sur.

DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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