**Journal of Biodiversity and Environmental Sciences (JBES)**
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 6, p. 107-121, 2014
http://www.innspub.net

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**RESEARCH PAPER** OPEN ACCESS

# Cave macro-invertebrates of Wao, Lanao Del Sur, Philippines

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Article published on December 06, 2014

**Key words:** Cavernicolous, fauna, *Heteropoda* sp., *Macropathus* sp., spider.

**Abstract**

Among the cavernicolous species, invertebrates make up the majority of the entire cave fauna. With their extremely restricted distribution, macro-invertebrates are important in determining the health of a cave. This study was conducted to assess the diversity and abundance of macro-invertebrates in two unexplored caves in Wao, Lanao del Sur. Sampling was done through a combination of methods: hand grabbing technique, pitfall traps, visual search, and direct counting method. Ten species belonging to seven orders were recorded in Wao caves. More species were found in Cave 1. *Macropathus* sp. was the most abundant species comprising half of the species recorded. The huntsman spider, *Heteropoda* sp.1, was found in the two sampling sites. Moderate diversity was recorded in Cave 1 while Cave 2 had low diversity. Majority of the macro-invertebrate species were found on the cave wall and floor. Guano deposition, temperature, and relative humidity are environmental factors which appear to be significant to the distribution of the macro-invertebrate species in the caves. Disturbances present in the caves also seem to have negatively affected the distribution of species and individuals.

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**Introduction**

Caves are recognized as the world's most remote and fragile wilderness (Jones, 2009). Cave fauna constitutes one of the important components of biodiversity (Biswas, 2009) that are also worth analyzing because all of these species have successfully invaded one of the harshest environments on earth (Christman and Culver, 2001). Cave is a home for wildlife, which is among the most delicate and unusual to man. Cave habitats are usually dark and with almost constant geographical factors, temperature, saturated humidity, and low energy input (Biswas, 2010). Due to this kind of environment, cave-dwelling organisms have showed some structural modification, behavioral changes, and specialized function (Pan *et al.,* 2010). Thus, cave environments host fauna which are capable of surviving with their unique characteristics. There are various reasons why species live in caves; this could be because of the need for temporary shelter, protection against predators, or to escape from the persistent unfavorable environmental conditions on surface outside the cave (Biswas, 2010).

Cave organisms inhabit various zones on the cave, depending on their needs and adaptation. The caves are divided into three ecological zones –the entrance zone which is the area in the actual cave opening or mouth with the direct exposure to sunlight, variable temperature, and green vegetation; the twilight zone which is adjacent to the entrance zone and with less light, minor temperature changes, and minimal plant life; and the deep zone which is the innermost part of the cave where there is total darkness and constant temperature (Smithers, 2005). According to Biswas (2010), cavernicolous species are usually categorized according to ecological zones. There are obligate cave-dwellers which are unable to survive in cave surface area, and others may be temporary visitors with limited reliance on the cave environment. Cave species could be troglobites, troglophiles, and trogloxenes. Hunt and Millar (2001) describe troglobites as cave-adapted species, troglophiles as the cave-loving species that can live out the entire life cycle inside the caves but can supposedly live in other habits, and trogloxenes are the accidental or visitor species of the cave or those that live in caves but cannot complete their life cycle inside.

Among the cavernicolous species, invertebrates make up the majority of the cave fauna, and as a result of their sheer diversity, surveys consistently yield new genera and species from Southeast Asian karsts (Juberthie and Decu, 2001). Chapman (1983) reported 57 invertebrate species on 15 large study sites in caves of Gunung Mulu National Park, Sarawak. Holsinger and Peck (1971) documented a total of 130 species of invertebrates from the cave of Georgia which include snails, pseudoscorpions, spiders and beetles. In Peninsular Malaysia, 28% of the 53 invertebrate species collected were new records, and a further 6% were likely to be new to science (Dittmar *et al.,* 2005). Peck and Lewis (1978) recorded 215 species of invertebrates in the caves of Illinois and Missouri. Welbourn (1999) also noted 38 invertebrate species in Kartchner Cavers of Arizona.

The Philippines has over 1, 500 caves and 37% of these are in Mindanao (DENR-PAWB, 2008) that serve as home to diverse flora and fauna (Tuttle and Moreno, 2005). However, there are only few studies on the cave invertebrates in the Philippines, especially in Mindanao, the country's second largest island. Recent published reports on cave diversity of macro-invertebrates in Mindanao region were on crickets (Novises and Nuñeza, 2014; Lagare and Nuñeza, 2013), ants (Batucan and Nuñeza, 2013; Figueras and Nuñeza, 2013), spiders (Enriquez and Nuñeza, 2014; Cabili and Nuñeza, 2014), and cockroaches (Mag-usara and Nuñeza, 2014). Furthermore, most of the country's caves are in peril due to lack of specific statutory protection on collection of cave resources (DENR-PAWB, 2008) which could cause local extinction of cave-dwelling invertebrate populations (Eberhard and Hamilton-Smith, 1996).

Macro-invertebrates which have extremely restricted distribution are largely located in areas with sufficient amount of nutrients and food source (Hunt and Millar, 2001). These cavernicolous species are important indicators (as biological indicator) for the health of the cave. Moreover, with the little taxonomic information and studies of cave macro-invertebrates, especially in Mindanao, this study is valuable.

Wao, Lanao del Sur, a municipality located at the Autonomous region of Muslim Mindanao consists of four caves. These caves are not yet explored and assessed and there are no known studies done or published regarding the macro-invertebrates in these caves. With the increasing human population of Wao and awareness of citizens about the cave, these people become attracted to the benefits one could get from the cave. This means that the caves become vulnerable to human activities. In this case, there is a need to conduct surveys and assess the biodiversity of macro-invertebrates and the threats present in the caves. An assessment of these caves and their macro-invertebrate fauna would provide baseline information which in turn could be helpful for future researches and other uses concerning the cave environment.

In this study, two selected caves of Wao, Lanao del Sur were assessed to determine the species richness, relative abundance, and diversity of macro-invertebrates in the caves. Existing threats to the cave fauna were also determined.

## Materials and methods

*Sampling Sites*

Four unexplored caves are located in the municipality of Wao, Lanao del Sur at the Autonomous Region of Muslim Mindanao in the Philippines. Two of the caves were selected for sampling in accordance with their location and accessibility. The first cave (Cave 1) is located in Barangay Amoyong and the second cave (Cave 2) is situated in Barangay Piriruan, Wao, Lanao del Sur (Fig. 1). Four subsites were established in Cave 1 while three subsites were established in Cave 2.

Cave 1 is located 7°37’55” N, 124°47’35” E, and is 3 (masl). It is situated at the foot of a mountain near the bank of a river. It has two main openings. The entrance of the cave, also usually used as the exit, is approximately 1.65 meter in width and 1.37 meter in height. The second mouth or opening, which is located at the other end of the cave, is wider with approximately two meters wide and 2.35 meters high, but is partly blocked by a fallen-off part of the cave caused by the previous attempt of permanently closing the cave, according to the guide that was interviewed. The cave is somewhat honeycomb in structure consisting of numerous irregular, huge, and small chambers, and with lateral and downward passages. The main tunnel is approximately 275 meters long from the entrance to the exit. The presence of stalactites and stalagmites was also observed in this cave. Drippings of water from the roof and wall caused the floor on some areas of the cave to be muddy. The amount of guano deposit increased from the entrance to the deep zone of the cave.

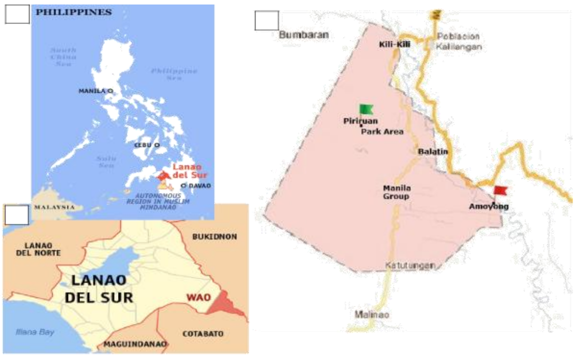


**Fig. 1.** Map of the Philippines (A) (www.statemaster.com, 2005) Lanao del Sur (B) (pam.wikipedia.org, 2014), and Wao (C) showing the location of the sampling sites: Cave 1(red flag) and Cave 2 (green flag).

Subsite 1 of Cave 1 is the twilight zone of the cave, the immediate area around the entrance of the cave. There is less amount of sunlight, but it receives higher amount of light compared to the other zones. The amount of light able to penetrate through the inside was 11.5 lux and was measured at 2.8 meters from the mouth of the cave. Minimal amount of plant life was observed along the zone. For Cave 1, the substrate of the zone was hard due to stones, and dry soil. It has a high ceiling or roof with several crevices and holes but without any stalactite and stalagmite. Roosting sites of bats were also absent in this zone. No guano was observed on the substrate of the floor. Subsite 1 temperature was 27.3°C, ground temperature was 29°C, wall temperature was 26°C, roof temperature was 24.7°C, and 77% relative humidity.

Subsite 2 of Cave 1 is the area adjacent to the twilight zone. This is termed as the transition zone. In the case of Cave 1 with two openings, Subsite 2 is denoted as transition zone 1. Here the amount of light is decreasing, and some areas were no longer penetrated by light. The temperature was more likely to be constant. Transition zone 1 was approximately 25 meters long; with 25°C ambient temperature, 24.3°C ground temperature, 24°C wall temperature, 23.3°C roof temperature and 80% relative humidity. Several to numerous stalactites and stalagmites were present. This zone has a floor of soft to muddy soil and moderate amount of guano. There were also huge stones present. A single large chamber with downward passages was located in this zone.

Subsite 3 of Cave 1 is right next to the transition zone 1 and is the most inner area, referred to as the deep zone or dark zone, pertaining to the absolute absence of light. Numerous roosting areas of bats were located in this area, making the floor substrate to be mainly composed of guano. Deep zone of Cave 1 has numerous large and small chambers, with several stalactites. The main tunnel is approximately 200 meters long. Temperature was 22.7°C, ground temperature was 21°C, wall temperature was 21.3°C, and 92% humidity. This zone was muddy and with thick guano deposits. Few large stones were in the area, also lots of smaller ones were scattered throughout the zone.

Subsite 4 or transition zone 2 of Cave 1 is 15 meters long, measured from the twilight zone of the second opening of the cave. The zone had 27.7°C air temperature, 25.7°C ground temperature, 26.3°C wall temperature, and a 77% relative humidity. Light illumination was 1.2 lux (5m from the second opening). The floor had a muddy to hard substrate. Guano deposition was minimal to absent as one moves from the deep zone to the exit or the second mouth of the cave. Relatively few stalactites were observed and there was an absence of bat roosting sites. Small chambers were also present.

Cave 2 is located at 7°41'33"N 124°42'34" E and is smaller in size compared to Cave 1. The height and width of the caves are in uniform measurement throughout the tunnel, which is 2 meters in width and 2.5 meters in height. It has a single opening which is used as entrance and exit with an approximate width opening of 0.75 meter and a height of 0.90 meter. The cave is oriented in a Y-shaped tunnel on each side measuring approximately 25 meters in length with one meter width and two meters height. There were no other chambers and passages. The floor, roof, and wall of the cave are made up of soil. Roots from plants above the cave were seen. Stalactites and stalagmites were absent. On the entrance zone, roots and plants hang above the ceiling of the cave. There was a minimal amount of guano deposition in the different zones of the cave.

Subsite 1 of Cave 2 is the twilight zone of the cave. The floor is made of soft soil and very minimal amount of guano. Along the entrance opening was growth of some mosses and ferns. The roof was with bigger plant roots compared to those found on the wall. Crevices and holes were also observed on the wall and roof of the zone. There were no roosting sites of bats. Temperature of the zone was 28.3°C, ground temperature was 24°C, wall temperature was 26°C, roof temperature was 22°C, and with a relative humidity of 74%. Light illumination was 1.6 lux measured one meter from the entrance of the cave.

Subsite 2 or transition zone 1 of Cave 2 has floor substrate made of soft soil with minimal amount of guano deposition, and the roof and wall had roots of plants on them. There was zero light penetration. Temperature along the zone was: 27.7°C (ambient), 24°C (ground), 26°C (wall), and 22°C (roof). Recorded relative humidity was 78%. Since the cave is Y-shaped, there were two zones, each measuring 5 meters in length. These two areas were denoted as one subsite.

Subsite 3 or deep zone is the last subsite in Cave 2. It is the end point of the cave where a roosting site for bats was situated adding guano to the floor substrate, but only with minimal amount. In the case of Cave 2, the two zones both measured 15 meters in length, and were referred to in this study as one subsite. Air temperature was 28°C and relative humidity was 86%; the ground, wall, and roof temperatures were the same with the transition zone (Subsite 2) of this cave, which were 24°C, 26°C, and 22°C, respectively.

*Sampling Method*

Sampling was conducted in Cave 1 on January 4 and 6, 2012, from 1200 hours to 1630 hours for a total of 63 man-hours. Sampling was conducted in Cave 2 on January 5, 2012, from 1200 hours to 1630 hours for a total of 27 man-hours. A visual-search sampling method was done in this study. Chambers, crevices, holes and the floor were thoroughly searched for the presence of macro-invertebrates using hand searching, hand grabbing technique, and live capture pitfall traps. The selective nature of these methods makes them the most preferable method of sampling cave macro-invertebrates; which allows the researchers to be more selective in catch, only those needed for taxonomic purposes were collected, and results are immediate and much can be achieved in a single sampling visit (Hunt and Millar, 2001). Direct counting method was employed to determine the species richness and abundance of macro-invertebrates found inside the cave.

Captured specimens were placed in plastic containers upon collection, and were transferred to vials and other plastic containers with 70% ethanol for preservation, for later identification. Each container was properly labeled with the date, cave number, subsite number or zone, time of collection and temporary names. Samples were brought to the Philippine National Museum for identification.

Physical factors of the cave were measured to determine environmental conditions. Light penetration was determined using a Lux/Light meter. The ambient, floor, wall, and roof temperature was measured using field thermometer while relative humidity was measured with the use of a sling psychrometer. The readings were taken after 1-2 minutes. Cave structures were examined for the presence of stalactites and stalagmites. The size of the cave and the cave openings (height, length, and width) were measured; subsites were marked with the use of a transect line.

Habitat was described following the Invertebrate Collecting Guide of Hunt and Millar (2001). Existing threats in each cave site were recorded after direct observations of the caves and interview with the local guides regarding threats to the caves.

*Analysis of Data*

Relative abundance was calculated to show the abundance of individuals per subsite and per cave. Biodiversity indices were calculated (dominance, Shannon-Weiner index, and evenness) using Biodive Pro software. SPSS version 17 was used in ordination analysis to determine the correlation of the number of macro-invertebrates with temperature and relative humidity.

## Results and discussion

*Species Distribution and Relative Abundance*

Ten cave macro-invertebrate species belonging to seven orders were identified in Wao, Lanao del Sur (Table 1). Of these, seven species were observed in Cave 1 at Barangay Amoyong and four species from Cave 2 at Barangay Piriruan. Cave macro-invertebrates identified include one species of whip spider (Amblypygi), two species of huntsman spiders

(Araneae), one species of tarantula (Araneae), one species of cockroach (Blattodea), two species of ants (Hymenoptera), one species of mantis (Mantodea), one species of cave cricket or cave-weta (Orthoptera) and one species of harvestmen (Opiliones). Cave 1 had higher species richness than Cave 2. A reason for this could be the difference in cave structure and amount of guano deposits in the two caves. Cave 1 had high guano deposit from the entrance to the deep zone. This observation concurs with the observation of Iskali (2011) that macro-invertebrate abundance and richness are significantly correlated with guano depth and the distance from the entrance. According to Pape (2014), guano serves as the foundation of the cave invertebrates and the presence of communities of organisms in caves is actually dependent on the guano microenvironment Ferreira *et al.,* (2007). The same number of macroinvertebrate species was recorded by Macud and Nuñeza (2014) in Mighty Cave, Tagoloan, Lanao del Sur, Philippines. However, a higher number of macro-invertebrates species was recorded by Campbell *et al.,* (2011) in the limestone cave of North Alabama and Georgia and by Pape (2014) in Grand Canyon National Park, Arizona. Higher number was also recorded by Novises and Nuñeza (2014) on cave crickets in Surigao del Norte, Enriquez and Nuñeza (2014) on spiders in some caves in Mindanao, and (Batucan and Nuñeza, 2013) on ants in Siargao Island. According to Turner *et al.,* (2003), the number of species encountered may be explained by the number of areas (habitat types) surveyed.

*Heteropoda* sp. 1 (huntsman spider) was found in both cave sites, foraging mostly on the floor and wall of the caves. The same observation was obtained by Enriquez and Nuñeza, (2014) that this species was found on the walls and floor in the caves of Mindanao. Cabili and Nuñeza (2014) also recorded *Heteropoda* sp. in the caves of Siargao Island. Novises and Nuñeza (2014); Enriquez and Nuñeza (2014) also found that the most preferred habitat of macro-invertebrates species was the wall of the cave.

**Table 1.** Species distribution of cave macro-invertebrates in Wao, Lanao del Sur.

| Species | CAVE 1 | | | | CAVE 2 | | |
|---|---|---|---|---|---|---|---|
| | **Subsite 1** | **Subsite 2** | **Subsite 3** | **Subsite 4** | **Subsite 1** | **Subsite 2** | **Subsite 3** |
| **Order** Amblypygi (Whip Spiders) | | | | | | | |
| **Family** Phrynoidea | | | | | | | |
| *Damon medius* | (W) | (W) | (W, R) | (W) | - | - | - |
| **Order** Araneae (Spiders) | | | | | | | |
| **Family** Sparassidae | | | | | | | |
| *Heteropoda* sp. 1 (huntsman spider 1) | - | (F) | (F) | (F) | (W) | (W,F) | (F) |
| *Heteropoda* sp. 2 (huntsman spider 2) | - | - | - | - | (W, R) | (R) | (W, R) |
| **Family** Theraphosidae | | | | | | | |
| *Aphonopelma* sp. (Tarantula) | - | - | (F) | (F) | - | - | - |
| **Order** Blattodea (Cockroaches) | | | | | | | |
| **Family** Blaberidae | | | | | | | |
| *Eublaberus* sp. | ( F) | - | - | - | - | - | - |
| **Order** Hymenoptera (Ants) | | | | | | | |
| **Family** Formicidae | | | | | | | |
| *Pachycondyla* sp. | (F) | - | - | - | - | - | - |
| *Pheidologeton* sp. | (F) | - | - | - | - | - | - |
| **Order** Mantodea (Mantis) | | | | | | | |
| **Family** Mantidae | | | | | | | |
| *Tenodera* sp. | - | - | - | - | - | (W) | - |

| Species | CAVE 1 | | | | CAVE 2 | | |
|---|---|---|---|---|---|---|---|
| | Subsite 1 | Subsite 2 | Subsite 3 | Subsite 4 | Subsite 1 | Subsite 2 | Subsite 3 |
| **Order** Orthoptera (Grasshoppers, Locust, Crickets, Katydids) | | | | | | | |
| **Family** Rhaphidophoridae | | | | | | | |
| *Macropathus* sp. (Cave-Weta) | (W) | (W, R) | ( F, W, R) | (W, R) | - | - | - |
| **Order** Opiliones (Harvestman) | | | | | | | |
| **Family** Sclerosomatidae | | | | | | | |
| *Leiobunum* sp. | - | - | - | - | (R) | (R) | - |
| **Total number of species in each subsites** | 5 | 3 | 4 | 4 | 3 | 4 | 2 |
| **Total number of species in Cave 1** | 7 | | | | | | |
| **Total number of species in Cave 2** | 4 | | | | | | |
| **Total number of species** | 10 | | | | | | |

Legend: Subsite 1 - Twilight Zone, Subsite 2 - Transition Zone 1, Subsite 3 - Deep Zone, Subsite 4 - Transition Zone 2, (-) - absent, F- Floor, W- Wall, and R – Roof

In Cave 1, the twilight zone (subsite 1) was observed to have the greatest number of species (5). Most of the macro-invertebrates in cave 1 were located on the floor of the cave. *Macropathus* sp. (cricket) and *Damon medius* (whip spider) were found in all subsites of Cave 1. *Macropathus sp.* was also observed to be widely distributed in 15 of the 19 cave sites in Davao Oriental and Northern Mindanao which were aggregated on cave floors with thick guano (Lagare and Nuñeza, 2013). The wide distribution of *Macropathus* sp. within the cave could be related to the observation of Welbourn (1999) that cave crickets feed on carrion or bat guano and usually leave the cave to feed. Moreover, *Macropathus* sp. was also found solitary on the floor and was in groups on the wall and roof of the cave. Richards (1954) found that this species of cave crickets prefers solitary existence even though other cave invertebrates are present in the same habitat and it can occur in variety of habitats as long as it has high or saturated humidity even with various percentage of illumination. This could explain why a number of *Macropathus* sp. was located in the twilight zone. *Damon medius*, a hunter spider was observed on the walls and roof of cave 1 together with *Macropathus* sp. (cave cricket). *D. medius* was also present in the 11 cave sites of Mindanao, widely distributed in twilight and inner zones (Enriquez and Nuñeza, 2014) and distributed in all caves site sampled by Cabauatan *et al.,* (2014) in Northern Cagayan Valley, Philippines. A species of spider (tarantula), *Aphonopelma* sp., was found burrowing on muddy floor creating a funnel web or trap-door kind of habitat, in cracks and under rocks along the big rooms or chambers of the deep zone (subsite 3) and some parts of the transition zone 2 (subsite 4) of cave 1 where it makes irregular web formation. According to Jackman and Drees (1998), tarantulas dig their own burrow and use this burrow as shelter. They usually remain in their burrow waiting for prey to come by but may move a few meters out to forage when necessary. *Heteropoda* sp. 1 was noticed on the cave floor of the deep zone with *Aphonopelma* sp. and *Macropathus sp*. The same observation was obtained by Harries *et al.,* 2008 that *Heteropoda* sp. occurs much deeper within the cave of Meghalayan, India and also tends to be most common on passage walls and ceilings near cave entrances. *Eublaberus* sp. (cockroach) and the two species of ants under family Formicidae, *Pachycondyla* sp. and *Pheidologeton* sp. were only located on the twilight zone of Cave 1. A nymph of *Eublaberus* sp. was found burrowing on the floor along the base of the cave wall. This species of cockroach is considered a troglophile; habitually found in caves but is able to live in or outside of caves (Bell *et al.*, 2007). *Pachycondyla* sp. and

*Pheidologeton* sp. are trogloxenes or accidental cave species. Batucan and Nuñeza (2013) recorded *Pheidologeton* sp as the most abundant species present in the twilight zone, however *Pachycondyla* sp. was also recorded but was present in the entrance and not in the twilight zone. which is in contrast with the observation in the present study. The presence of the two ant species only in the twilight zone along the entrance zone of the cave could be due to the food source such as the vegetation on the surface outside the cave. Food preference of ants varies from plant seeds, nectar and honey dew secreted by sap-sucking insects (LaSalle and Gauld, 1993).

In Cave 2, the transition zone 1 or Subsite 2 had more number of species than the other subsites. Most of the macro-invertebrate species in cave 2 preferred the roof and wall microhabitat of the cave. Two species of *Heteropoda* were distributed in all the zones of the cave. Likewise, Jaeger (2001) found large species of *Heteropoda* in the entrance and deep zones of Laos caves. *Heteropoda* sp. 1 was on the wall and floor while *Heteropoda* sp. 2 was observed on the roof and wall of the cave. *Heteropoda* sp. was also recorded by Enriquez and Nuñeza (2014) on the cave walls of the entrance zone. The presence of this spider species on the walls and floor of the cave may be due to the food availability in the area. Harries *et al.*, (2008) stated that *Heteropoda* sp., in some caves of India, prefers cave crickets as their prey. According to Doyle and Baldwin (1975), *spiders may feed on insects that come near the cave wall*. Moreover, the females of this species were observed carrying a flattened disc-shaped egg-sac under their body. The egg-sac being carried under their body makes the females relatively immobile (Biswas, 2010). A very small *Tenodera* sp. (mantis) was found only on the wall at the transition zone 1 (subsite 2) of cave 2. Harvestmen belonging to genus *Leiobunum* were observed on the roof of the twilight zone and transition zone 1 of cave 2. According to Newton (2006), most harvestmen species are found in moist, shady environments and some live deep in caves, while others are found in basements or in the deep shade of woods or plant growth where insects could be found.

Table 2 shows the number of individuals and relative abundance of macro-invertebrates. Of the 3,663 individuals of cave macro-invertebrates recorded from the caves of Wao, Lanao del Sur, 3,516 individuals were from Cave 1 and 147 individuals from Cave 2. A major factor why Cave 1 harbored more number of macro-invertebrates could be the high amount of guano deposition observed in the cave which serves as food sources for macro-invertebrates. This observation concurs with the study of Lagare and Nuñeza (2013), Cabili and Nuñeza (2014), Novises and Nuñeza (2014) and Mag-Usara and Nuñeza (2014) that presence of more guano deposit contributes to higher number of macro-invertebrates. Guano plays a very important role in the food web of cave ecosystem (Cabili and Nuñeza, 2014) which supports most invertebrates (Clements *et al.,* 2006). Caves with a higher source of vertebrate guano support different and higher number of macro-invertebrate communities than cave that lack such support (Bell *et al.,* 2007). Disturbances to these caves may have also limited the number of species. Persistent human disturbance is a major cause of the decline in population of the cave-obligate organisms (Martin *et al.,* 2003).

*Macropathus* sp. which was present only in Cave 1 had the highest abundance (52.53%). *Eublaberus* sp. and *Tenodera* sp. had the least abundance (0.027%). Cave 1 had an abundant amount of guano deposits on which crickets like *Macropathus* sp thrive on. This factor could be the reason why *Macropathus* sp. was the most abundant species that can only be found in Cave 1. Lagare and Nuñeza (2013) also recorded *Macropathus* sp. to be the most abundant species in their study and one of the factors for its abundance is the presence of guano deposits. Richards (1954) in his study about the ecology of *Macropathus* sp.reported that this species of cave crickets has a wider range of habitat compared to other crickets.

**Table 2**. Relative abundance of cave macro-invertebrates in Wao, Lanao del Sur.

| Species | CAVE 1 | | | | | | | | CAVE 2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Subsite 1 | | Subsite 2 | | Subsite 3 | | Subsite 4 | | Subsite 1 | | Subsite 2 | | Subsite 3 | | TOTAL | |
| | Ni | RA | Ni | RA | Ni | RA | Ni | RA | Ni | RA | Ni | RA | Ni | RA | Ni | RA |
| **Order** Amblypygi | | | | | | | | | | | | | | | | |
| *Damon medius* | 3 | 1.38 | 110 | 16.96 | 520 | 21.05 | 50 | 27.78 | 0 | 0 | 0 | 0 | 0 | 0 | **683** | **18.65** |
| **Order** Araneae | | | | | | | | | | | | | | | | |
| *Aphonopelma* sp. | 0 | 0 | 0 | 0.00 | 430 | 17.41 | 30 | 16.67 | 0 | 0 | 0 | 0 | 0 | 0 | **460** | **12.56** |
| *Heteropoda* sp. 1 | 0 | 0 | 8 | 1.24 | 220 | 8.91 | 20 | 11.11 | 4 | 3.28 | 2 | 9.52 | 1 | 25 | **255** | **6.962** |
| *Heteropoda* sp. 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 14.75 | 7 | 33.33 | 3 | 75 | **28** | **0.764** |
| **Order** Blattodea | | | | | | | | | | | | | | | | |
| *Eublaberus* sp. | 1 | 0.46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** | **0.027** |
| **Order** Hymenoptera | | | | | | | | | | | | | | | | |
| *Pheidologeton* sp. | 150 | 68.81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **150** | **4.095** |
| *Pachycondyla* sp. | 50 | 22.94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **50** | **1.365** |
| **Order** Mantodea | | | | | | | | | | | | | | | | |
| *Tenodera* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4.76 | 0 | 0 | **1** | **0.027** |
| **Order** Orthoptera | | | | | | | | | | | | | | | | |
| *Macropathus* sp. | 14 | 6.42 | 530 | 81.79 | 1300 | 52.63 | 80 | 44.44 | 0 | 0 | 0 | 0 | 0 | 0 | **1924** | **52.53** |
| **Order** Opiliones | | | | | | | | | | | | | | | | |
| *Leiobunum* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 81.97 | 11 | 52.38 | 0 | 0 | **111** | **3.03** |
| **TOTAL** | **218** | **100** | **648** | **100** | **2470** | **100** | **180** | **180** | **122** | **100** | **21** | **100** | **4** | **100** | **3663** | **100** |

Legend: Subsite 1 - Twilight Zone, Subsite 2 - Transition Zone 1, Subsite 3 - Deep Zone, Subsite 4 - Transition Zone 2,Ni –Number of individuals; RA - Relative Abundance.

*Macropathus* sp. was also abundant in the deep zone (subsite 3) of cave 1 where the floor is composed of guano deposits. Cave crickets are associated with the amount of guano deposition (Marshall and Beehler, 2007). The relationship between guano deposit and cave crickets could be the reason why the twilight zone, with relatively very small amount of guano (<1cm deep) and higher illumination (11.5 lux) compared to the other zones, had the least number of cave crickets recorded. Novises and Nuñeza (2014) stated that thick guano materials which pile up on the muddy soil surface of the caves provide more food and support more crickets. Subsite 3 or the deep zone of Cave 1 had a greater number of macro-invertebrates compared to the other part of the cave. It supports 2,470 individuals from four species.

*Damon medius* (whip spider), the second most abundant (18.65%) species was only present in all subsites of Cave 1. Enriquez and Nuñeza (2014) observed that this whip spider species eats ground-dwelling invertebrates such as cockroaches and crickets. The high abundance of cave crickets observed in cave 1, which are likely the prey for the whip spider, appears to be the major factor for the abundance and distribution of the whip spiders.

Movement of bats significantly affects the abundance of invertebrates (Welbourn, 1999). Areas with roosting sites of bats had the greatest amount of guano accumulation and also had a high abundance of macro-invertebrates. Decomposing bat guano accumulation supports micro-invertebrates which in turn supports macro-invertebrates (McFarlane, 2004). Cave macro-invertebrates are related to guano availability (Iskali, 2010) and thus guano deposits provide an immensely rich food resource for the species (Hamilton-Smith, 2009). This was considered as the main factor for the distribution and abundance of cave macro-invertebrates recorded in Cave 1. Subsites 1 and 4 having the least amount of guano deposition also had the least number of individuals.

On the other hand, Subsites 2 and 3 with increasing amount of guano had high abundance of macro-invertebrates. The ant species, *Pheidologeton* sp. *and Pachycondyla* sp. had low abundance. According to Andersen and Majer (2004), some groups of ants are especially sensitive and decline in abundance with the increase in disturbance.

In Cave 2, the twilight zone or Subsite 1 had the highest number of macro-invertebrate individuals. *Leiobunum* sp. (harvestman) having the most number was found in Subsites 1 and 2. Gregarious behavior or its tendency to clump in groups was observed among this species. Moreover, harvestmen camouflage within the roof and the roots, thus, this species was not easily observed upon entering the cave. This behavior was likely to be a strategy against climatic odds and predators, through combining scent secretion effects and reducing the probability of each individual being eaten (Machado *et al.*, 2007). Furthermore, Storer *et al.,* (2004) stated that this species often aggregates in caves and cave-like habitat, generally feeds on a wide variety of foods and bob rhythmically when disturbed.

Enriquez and Nuñeza (2014) observed that the distribution and abundance of species of spiders are affected by factors such as temperature, relative humidity and cave surface in three ecological zones of the cave. The presence of guano material could also contribute to the higher number of spiders in caves (Cabili and Nuñeza, 2014). Moreover, Samu *et al.*, (1999) reported that distribution of species of spiders has a strong relationship with the structural surface of the caves. Consequently, habitat alteration of the caves like clear cutting of forest and urbanization adjacent to the cave relatively affects spider abundance. This relationship of spiders and the kind of habitat was considered with regard to the distribution and abundance of the species of spiders in the two cave sampling sites.

*Biodiversity Indices*

Table 3 shows that Cave 1 has moderate diversity of cave macro-invertebrates with more or less even distribution. The low species diversity, in particular, in Subsite 2 or transition zone 1 appears to be due to the relatively high abundance of *Macropathus* sp. in this zone. The amount of guano deposit accounts for the distribution of macro-invertebrates in the different ecological zones of the cave. According to Chapman (1983), the number of macro-invertebrates and diversity could also be correlated with substrate heterogeneity.

In Cave 2, the large number of *Leiobunum* sp. in Subsite 1 was the main reason for this zone to have a high dominance value (0.69). Subsite 2 or the transition zone 1 was observed to have moderate diversity of species. In general, Cave 2 was found to have low species diversity (H'=0.71) with more or less even distribution. The diversity in cave 2 could be due the minimal amount of guano deposition and even the disturbances present in the cave.

**Table 3.** Biodiversity indices of cave macro-invertebrates of Wao, Lanao del Sur.

| Indices | CAVE 1 | | | | | CAVE 2 | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| | Subsite | | | | General Diversity | Subsite | | | General Diversity | |
| | 1 | 2 | 3 | 4 | | 1 | 2 | 3 | | |
| **Species** | 5 | 3 | 4 | 4 | 7 | 3 | 4 | 2 | 4 | **10** |
| **Individual** | 218 | 648 | 2470 | 180 | 3516 | 122 | 21 | 4 | 147 | **3663** |
| **Dominance** | 0.32 | 0.70 | 0.36 | 0.31 | 0.36 | 0.69 | 0.37 | 0.50 | 0.61 | **0.33** |
| **Shannon** | 1.29 | 0.52 | 1.19 | 1.26 | 1.33 | 0.56 | 1.07 | 0.56 | 0.71 | **1.43** |
| **Evenness** | 0.80 | 0.47 | 0.86 | 0.91 | 0.68 | 0.51 | 0.77 | 0.81 | 0.51 | **0.62** |

*Temperature, Relative Humidity and the Number of Macroinvertebrates*

Table 4 shows the relationship of the abundance of species with temperature and relative humidity in the cave sample sites. Results indicate that cave macro-invertebrates prefer to inhabit zones with high relative humidity and low temperature. Physico-chemical factors such as temperature and relative humidity appear to play an important role in the distribution and abundance of spiders (Cabili and Nuñeza, 2014), ants (Batucan and Nuñeza, (2013) and crickets in caves (Lagare and Nuñeza, 2013; Novises and Nuñeza, 2014). For the cave crickets which frequently go out of the cave to look for food, surface temperature must be close to cave temperature and relative humidity must be close to saturated (Lavoie *el al.*, 2007). According to U.S. Fish and Wildlife Service (2008), invertebrates depend on high humidity, stable temperatures, and surface nutrients such as animal droppings. However, in Cave 2, relationship of number of individuals with temperature and relative humidity was not significant. The recorded temperature of the cave was more likely uniform throughout the different subsites, hence, distribution of species and individuals was not greatly affected.

**Table 4.** Relationship of temperature and relative humidity with the number of macro-invertebrates.

| | Subsite 1 | Subsite 2 | Subsite 3 | Subsite 4 | Pearson Correlation value | p-value | Decision |
|---|---|---|---|---|---|---|---|
| **CAVE 1** | | | | | | | |
| Temperature (°C) | 27.3 | 25 | 22.7 | 27.7 | -0.942 | 0.05 | Significant |
| Relative Humidity (%) | 77 | 80 | 92 | 77 | 1 | 0.01 | Significant |
| Species | 5 | 3 | 4 | 4 | none | none | None |
| Individuals | 218 | 648 | 2470 | 180 | none | none | None |
| **CAVE 2** | | | | | | | |
| Temperature (°C) | 28.3 | 27 | 28 | - | 0.575 | 0.05 | Not Significant |
| Relative Humidity (%) | 74 | 78 | 86 | - | -0.688 | 0.01 | Not Significant |
| Species | 3 | 4 | 2 | - | none | none | None |
| Individuals | 122 | 21 | 4 | - | none | none | None |

*Existing threats to the macro-invertebrates in the study area*

Graffiti on the walls and roof of the cave, remains of bonfire on the entrance zone, and garbage left inside the cave were observed in the caves in Wao and indicated disturbances. According to Enriquez and Nuñeza (2014) disturbances to caves may have limited the number of species and a major cause of for the decline in population of the cave-obligate organism (Martin *et al.,* 2003). Based on information from local guides, farmers stay in the cave during their rest hours and some may even stay there for the night. But there are times of the year, especially during the Holy Week, when a lot of people would go for spelunking in the cave.

In Cave 2, a wooden chair was observed in the transition zone of the cave, and a bed was located in the deep zone. According to the local guides, the cave was originally made as hiding place of a certain religious affiliation, thus, it is located in an area where it is least expected to be there. As of the present state, the cave is no longer used as a hiding place, yet some people still sometimes utilize the cave as a temporary living quarters. This activity is considered to be a threat to the cave. The more humans engaged themselves near or inside the cave, the more threatened it becomes. Stress caused by human disturbance in cave may have been a limiting factor for most species (Figueras and Nuñeza, 2013). Elliot (2011) reported that the White-nose Syndrome in North America which killed a total of one million bat species was due to human visitation to the cave which brought the chytrid spore inside. Residential developments may bring exotic species like the aggressive fire ant, which had caused many problems in caves of Texas. The public knows very little about caves and the organisms that inhabit them. The importance of protecting the cave and cave inhabitants are not fully appreciated and are taken for granted.

**Conclusion**

Wao, Lanao del Sur had high abundance of cave macro-invertebrates with moderate degree of diversity. Guano deposition, temperature and relative humidity are environmental factors which are significant to the distribution of the macro-invertebrate species. Majority of the species preferred the cave wall and floor as microhabitat. The hunter spider, *Damon medius* was predominantly seen on the wall. *Macropathus* sp. was the most abundant of all the macro-invertebrates, while *Heteropoda* sp. 1 was found in the two cave sampling sites. Anthropogenic activities seem to negatively affect the diversity of cave macro-invertebrates.

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