SO WHAT LIVES at MULU? PRELIMINARY SURVEY of CAVE FAUNA in the GUNUNG MULU WORLD HERITAGE AREA, SARAWAK, MALAYSIA PART 2 – THE RESULTS

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This article is a follow on from the introduction to the Australian biospeleological expedition to the Mulu Caves in Sarawak, Malaysia previously published in the ACKMA Journal no. 90. This second part of the article presents the results of the survey and interpretation of the results.

Survey Results

The survey recorded over 19,000 specimens using a combination of collection and observation of species abundance that presently represents 93 different morpho-species, from 25 orders and 8 classes. The number of morpho-species is expected to increase with additional sampling and further identification effort. Forty different species have been photo-inventoried thus far.

The spider *Heteropoda* sp. (Sparassidae) was the most widespread species found in all caves sampled, followed by the millipede sp. A, Opilione Phalangodidae? sp.A, Lepidoptera: Tinea? sp. and Araneae: Pholcidae sp. A that were recorded in six of the seven caves comprehensively surveyed (excluding Clearwater Cave and Deer Water Caves). The majority of species (44.6%) were recorded from a single cave, with very few species recorded from five or more of the caves surveyed (Figure 1).

The most diverse order was Coleoptera with 13 species recorded, followed by Araneae (10 spp.), Isopoda (10 spp.), Diptera and Hemiptera (9 spp. each) and Diplopoda (8 spp.). Eleven orders are represented by single species.

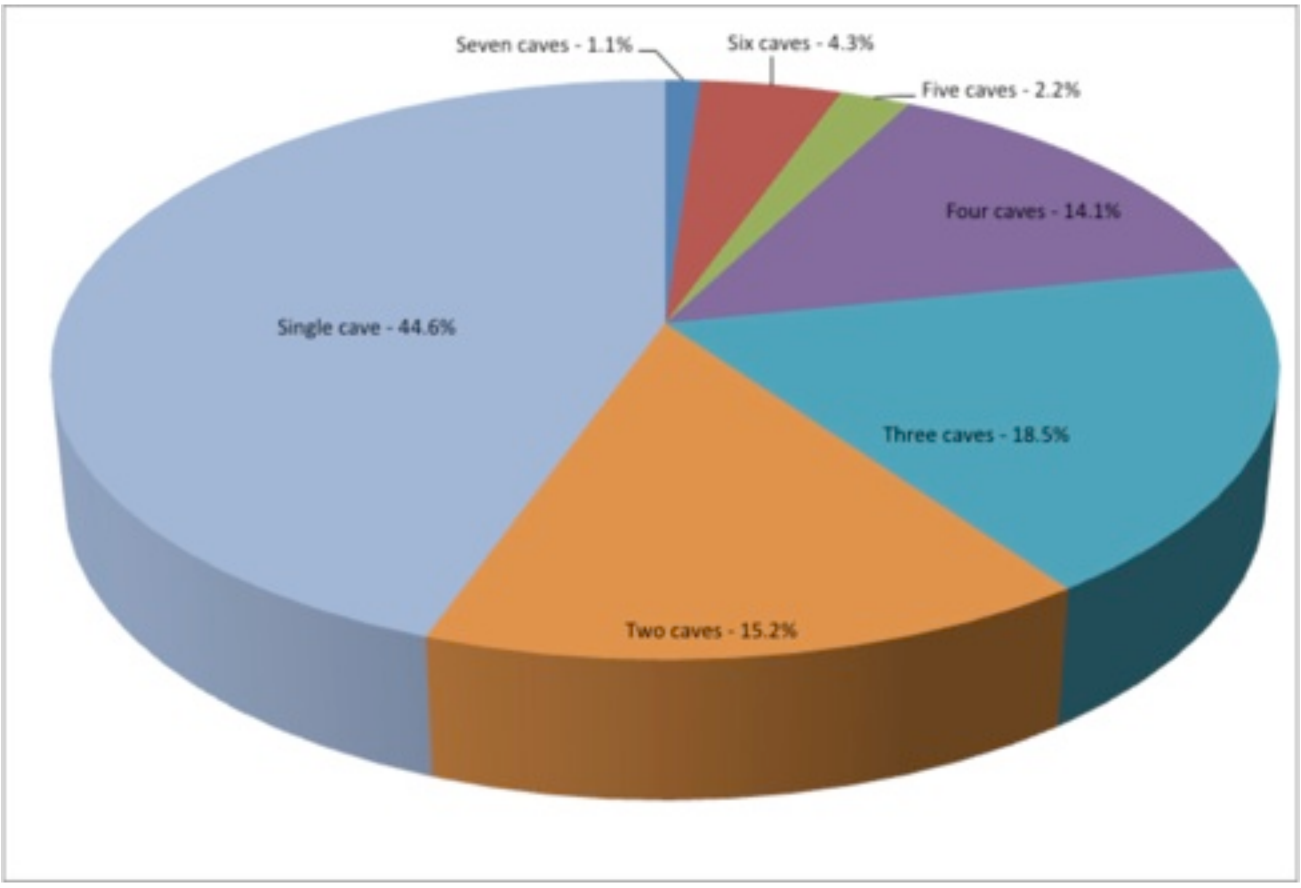

Figure 1 Percentage of species recorded from multiple caves.

Deer Cave

Deer Cave was sampled in three primary areas, the main entrance, Antler passage and the massive guano piles located near the Garden of Eden Track. The massive guano areas were not sampled extensively, and abundance of species was not recorded due to a lack of available time and the immensity of the task due to the extremely high abundance present. These are certainly the habitat for the largest arthropod diversity within the cave.

Antler passage, which is located above the main passage was found to be quite dry, and largely free of guano, providing very different microhabitats from those in the main passage.

Figure 2. Deer Cave guide rail with a naked bat and numerous symbiotic hairy earwigs.
Photo: Jane Pulford

Deer Water Cave

This is the outflow for the river that enters Deer Cave from the Garden of Eden entrance and sampling was limited to a single visit and a single microhabitat of damp sediment. The invertebrates present consisted of a several highly abundant dipteran species, including chironomids and phorids. Several beetle species were also present in high abundance including a species of staphylinidae.

Green Cave

Green Cave was sampled in the Entrance Zone and in the Dark Zone (lower River Area). The Entrance Zone contained several species of isopod and also Hemiptera: Vellidae? within a small gour pool, and Rhyparochromid bugs. The area sampled, although a substantial distance from the entrance, still received light for much of the day due to the large entrance size and these species are most likely accidentals to the cave environment.

The Dark Zone area associated with the small river passage contained a very high abundance of Anobiid beetles, clustering in groups of five to twenty individuals. Two species of cave cricket were also present here, the large *Rhaphidopora oophaga* and the smaller *Diestrammena mjobergi.*

Figure 3. Seeds and sprouting bodies in Fruit Bat Cave alternate entrance.
Photo: Tony Veness

Fruit Bat Cave

The entrance area of Fruit Bat Cave consists of a large chamber with an almost continuous cover of dry guano, with small patches of fresh guano under roof bell holes. This dry guano microhabitat supports an abundant population of the small cockroach *Pyenoscelus indicus*, the cricket *Diestrammena sarawakana* and several species of reduviid bugs. The emesine species is likely to be *Baguada? sp. cf. cavernicola* which was identified by Chapman within Deer Cave. Also collected were two species of harpactocoid reduviids, which were unrecorded by Chapman (1982).

The deeper sections of Fruit Bat Cave are dominated by scattered fresh guano throughout, resulting in a series of the more common and widespread species such as *Diestrammena mjobergi* and the widespread millipede sp.

A. Some of the small water pools located within formations contained aquatic isopods *Cyathura* sp. nov.

The alternate entrance area of Fruit Bat Cave is a roosting area for Fruit Bats (*Balionycteris maculata*) which gives the cave its name and contains numerous discarded seeds within the associated guano. This area was not sampled for invertebrates.

Kenyalang Cave

Kenyalang Cave is located in the same limestone block as Fruit Bat Cave and the entrance is located vertically above. The invertebrate assemblage recorded was similar to that of Fruit Bat but due to the lower amounts of guano was slightly different in composition. The cave contained a high abundance of collembolan, not observed in any other cave examined during the current survey. A possible copepod was observed in a small pool of water which may have been washed out of the epiphreatic zone. It was unable to be collected with the tools available, but if further collections are made in this cave the potential presence of stygofauna within drip pools should be examined.

Stonehorse Cave

This was one of the two most intensely sampled caves undertaken by the expedition, along with Lagang Cave. The cave was sampled throughout the Entrance and main passage to the large pit section, where considerable guano is present. The cave showed a very similar assemblage of species as Lagang and Racer Cave, with guano areas dominated by Tineidae moths and their larvae, and associated Braconid wasp parasitoids. Schizomid arachnids are also common in guano deposits. Numerous cave crickets are present throughout, as well as amblypygids and scutigerid centipedes. Pools of water associated with speleothem development contained aquatic isopods.

Stonehorse Cave is currently being developed as a tourist cave with a staircase built from the main boardwalk to the cave entrance. No development has thus far been undertaken within the cave, apart from fixed ropes as part of the adventure cave tour infrastructure.

Figure 4. Philosciid? isopod in Stonehorse Cave
Photo: Ross Anderson

Lagang Cave

This cave had the most intense sampling of all caves examined as it shows a wide variety of habitats, with both tourism and wild caving usage. Six separate areas within the cave were surveyed, including the two entrances that form part of the tourist route, one site on the boardwalk, an area of Fast Lane, and two sites away from cave infrastructure including on top of the large blocks near the intersection with the main passage and one sampling site within the extension passage. The ability to sample the newly discovered extension provided an excellent opportunity to record completely undisturbed invertebrate assemblages with no obvious potential impacts from cave infrastructure.

Figure 5. Anobiid? beetles on a piece of fresh guano in Fast Lane, Lagang Cave
Photo: Ross Anderson

The diversity is dominated by the abundant millipede Polydesmid? sp. A which was associated with both old and fresh guano deposits at both entrance areas, Fast Lane and the extension. Other abundant species include the schizomid, sparassid spider, two species of opiliones, amblypygdid and the cave cricket Diestrammena sarawakana. Interestingly the large cave cricket *Rhaphidophora oophaga* was only observed within the extension area.

One of the most notable species recorded from Lagang Cave was collected from the Fast Lane and was a linyphiid spider recorded near fresh guano that upon detailed inspection was found to be blind, depigmented and possessing an elongate process from the centre of the cephalothorax.

Racer Cave

Racer Cave is used for adventure tours and receives moderate visitation. It was found to contain a very similar diversity to Lagang and Stonehorse Caves with a few exceptions. The Barychelid trapdoor spider *Idiommata sp.* was relatively abundant in the deeper parts of the cave associated with damp sediments and guano deposits (Figure 6). Isolated drip fed pools associated with speleothems were found to contain two different species of aquatic isopods, Asellidae: Stenasellus sp. and Anthuridae: Cyathura sp. These species were previously recorded from similar habitats by Chapman (1982) from Water Polo Cave, and the later species from other karst areas in southern Sarawak.

Figure 6. Location of burrows of the Barychelid trapdoor spider Idiommata *sp. near the end of Racer Cave*
Photo: Ross Anderson

Figure 7. Troglobitic scorpion Chaerilus chapmani *from Racer Cave*
Photo: Ross Anderson

The current survey recorded the scorpion *Chaerilus chapmani* from this cave (Figure 7), a new distribution record, but not unsurprising as it was previously known from the Clearwater system (Chapman 1982). Two specimens were collected from the deep cave zone, near the end of the main adventure route, associated with fresh guano and damp sediment. A further two smaller scorpion individuals were also collected and may represent an additional undescribed species or potentially juveniles of *Chaerilus chapmani.* Detailed assessment by a scorpion taxonomist will be required to determine this.

Clearwater Cave

Invertebrate surveying within the Clearwater system was opportunistic only, and primarily only species that had not been observed by the survey previously in other caves were collected. Several different microhabitats were also observed in this cave and opportunistically sampled including bog (mush) guano and streamway (Figure 8).

Figure 8. Clearwater river streamway in the Clearwater System
Photo: Ross Anderson.

PATN* Analysis

The data were analysed used for similarity using PATN (version 3.12, Blatant Fabrications Pty. Ltd. 2009). Data were analysed using Bray and Curtis association, and nearest neighbour fusion algorithm. Data for two caves which were not comprehensively sampled were removed from the analysis the analysis to increase clarity of results. The caves not included in the analysis were Deer Water Cave and Clearwater Cave.

The PATN analysis by total diversity and abundance for each cave shows Racer, Lagang and Stonehorse Caves to contain very similar invertebrate assemblages and are these also similar to both Kenyalang and Fruit Bat Caves. Green Cave and Deer Cave are the most dissimilar in their invertebrates assemblages.

* PATN *is a software program that performs pattern analysis*

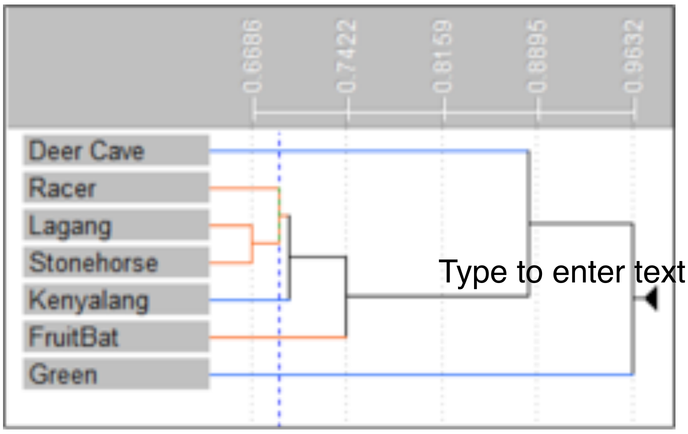

Figure 9. Column Fusion dendogram Nearest neighbour analysis – by cave

The PATN analysis by microhabitat showed strong similarity between invertebrate assemblages within microhabitat, especially fresh guano, with most of the specialised habitats being dissimilar to all others, such as the massive guano in Deer Cave and the streamway sections of Clearwater Cave.

Cave Biodiversity Discussion

Cave Biodiversity in Gunung Mulu World Heritage Area

The diversity of the Mulu karst area is very high and contains numerous obligate subterranean species, although the exact number is still currently unknown. The majority of species collected during the current survey appear to match those recorded by Chapman (1982), however, several previously unknown species were recorded. Further, more detailed identification will be required prior to confirmation.

The patterns of diversity between the caves examined is complex with no obvious patterns evident from similarity analysis, although it would appear that caves are showing similarity based upon presence of similar micro-habitat rather than similarity of light zones. The Deer Cave, due to its complete dominance by massive guano piles appears to make it distinctly different in invertebrate composition from caves with far less guano such as Stonehorse or Langang Cave. It is currently unknown whether there exists any difference in invertebrate composition between the different limestone blocks such as Fruit Bat/Kenyalang to Deer Cave/ Green Cave to Lagang/Clearwater local areas of Mulu. The caves do show some level of association but the strength of the current analysis is weak and further data, and identification of existing collected specimens, may alter the results significantly. The determination of this will require far greater knowledge of both specific cave diversity and will almost always be linked to the geological history and karst geomorphology of Mulu.

Endemicity

The Mulu karst most certainly contains endemic species, although the exact number is currently hard to determine as many of the invertebrate identifications are still incomplete, for both Mulu and other karst areas in Borneo and South East Asia.

Some of the invertebrate diversity found in Deer Cave could possibly be endemic, including the 'Hairy earwig' *Arixenia esau* that is associated with the naked bat species *Cheiromeles torquatus*, although this is more likely associated with the endemicity of the bat host rather than the cave itself. Much of the other specialised invertebrate fauna recorded by Chapman (1982) was found to occur in other karst areas in Borneo, Java and Sulawesi.

Regional Significance

The results of the current preliminary study allow a cursory comparison with other karst areas, in Borneo or the remainder of Asia. This is primarily due to the often incomplete identification of many of the specimens, both in Mulu and the rest of the vast majority of the South East Asian karst. Comparison of species richness and taxonomic diversity is also difficult due to the highly variable nature of invertebrate collections from tropical caves. Very few surveys are comprehensive in nature, with many focussing on troglobiont species only or a specific taxonomic group or specific habitat such as guano. This leads to inherent bias in collecting focus and methods, giving a misleading impression of diversity of richness when considering that most of the species richness in tropical caves is composed of guano associated species and non-troglobiont species (Deharveng and Bedos 2000).

As the specimens collected are identified further and additional surveys are undertaken, a greater understanding of Mulu's subterranean biodiversity will become apparent, especially within a regional context. The preliminary results do, however, make it abundantly clear that the diversity and biogeographical significance of these species is very high and further work is required to truly appreciate the scientific values of this unique and important karst area.

Management Implications

The currently available data provide an insight into the diversity of subterranean faun in the Mulu caves. In the future this will provide a greater understanding of localised distribution within the karst system and eventually at a localised cave scale.

The current data does not enable a meaningful interpretation of cave invertebrate biodiversity as it relates to specific cave use for tourism, adventure caving or wild caving, however, it is readily apparent to the authors that existing cave usage is not impacting upon the subterranean fauna observed in Mulu.

The authors note that the cave infrastructure within Mulu is very high by world standards and promotes minimal impacts to both cave habitats and cave invertebrates generally. The Mulu Park staff provide excellent visitor education and supervision prior to and during cave tours, eliminating predictable and avoidable impacts to the caves. The issues of rubbish and floor preservation are not the only areas that management should consider some future actions with regard to the specific instances outlined.

Rubbish

Rubbish within caves is almost exclusively associated with illegal bird nester activity. Much of the rubbish was located in the far reaches of wild caves. It appeared historical in nature and was removed by the authors. Due to the complete removal of bird nests in most of these areas, the future accumulation of rubbish is unlikely to occur.

Floor preservation

The compaction of floor sediments is potentially one of the most significant impacts to cave invertebrates. It is most important in high use caves, and due to the excellent pathways and elevated boardwalks throughout the majority of Mulu tourist caves compaction is largely absent. In some adventure caves, while track marking is present to some degree, some sections of caves may require additional/more obvious track marking to reduce potential future impacts. This is evident especially for some aquatic habitats within Stonehorse and Fruit Bat Caves where aquatic fauna may be impacted as the path crosses directly over water pools. While it may not be practical to divert paths in some instances, these habitats should be noted to cave visitors to help minimise impacts.

Recommendations for Future Work

The current study provides a very preliminary assessment of the general subterranean invertebrate diversity of Mulu since it was initially studied 30 years previously by Chapman (1982). The current study allows the site to be interpreted within a modern biospeleological context. This initial assessment has allowed the authors to gain a substantial understanding of the order of magnitude of the invertebrate diversity of Mulu, and the level of complexity of the biodiversity patterns likely to be present.

Key recommendations and focus for future cave biodiversity studies are:

1. Further photo inventory be undertaken for remaining specimens collected
2. Further species identification and cross checking of species collected between different caves to further define morpho-species distribution within the various karst blocks in Mulu.
3. Focussed studies on particular microhabitats such as guano or aquatic systems.
4. Undertake species inventories for all major caves in Mulu NP to enable a better comparison of invertebrate diversity both within the Mulu and also with other karst areas in Sarawak, Borneo and the remainder of South East Asia.
5. Dedicated sampling of stygofauna, as only opportunistic specimens have been collected to date and true diversity is unknown.
6. The specimens collected during the current survey should be held by an appropriate research institute with suitable laboratory space and access to specialised library resources, such as the Sarawak Museum, to enable their continued identification and study by taxonomic experts.
7. Training of local staff about cave fauna and local invertebrate diversity so they can recognise common species and identify habitats

Conclusions

The present study has provided a preliminary investigation of the invertebrate diversity across nine different caves within the Gunung Mulu World Heritage Area. This study complements and builds upon the only other broad scale cave invertebrate diversity study of Mulu by Chapman (1982) and provides a modern context for future research in Mulu. The patterns of diversity are complex in Mulu, invariably due to the very high diversity of species, the large number of microhabitats present within caves, the multitude of energy inputs and the systems and the geomorphological history of the area. It will take considerable further effort to start to unravel these complexities but it should prove very rewarding as Mulu is undoubtedly a premier site of world cave tropical cave invertebrate diversity and provides a superb opportunity to investigate evolutionary processes in such a setting.

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