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History of biological investigations at Batu caves, Malaysia, and consequences for the progress of tropical speleobiology: Part 2 – early 20th century to Present

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Abstract: The history of zoological investigations at the Batu caves and elsewhere in Southeast Asia from the early 20th century to the present is reviewed. Although there were major surveys and Dark Cave at Batu became the most intensively biologically investigated cave in the region, until the 1970s there was little change in the prevailing view that tropical caves had little of speleobiological importance. Key advances in speleobiology in the last half century that have changed this perception and drawn attention to tropical cave biology are briefly discussed, and their possible significance for the research potential of the Batu caves assessed.

Keywords: Malaysia, Selangor, Batu caves, Dark Cave, history, Dover, McClure, Howarth

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Within only the last two decades there has been a virtual revolution in our thinking on cave biology. This radical change was precipitated by the discoveries of significant faunas in tropical caves, in lava tubes, and in the smaller voids within fractured subterranean substrates. These discoveries open up whole new fields of biospeleological investigation.
(F Howarth, 1987)

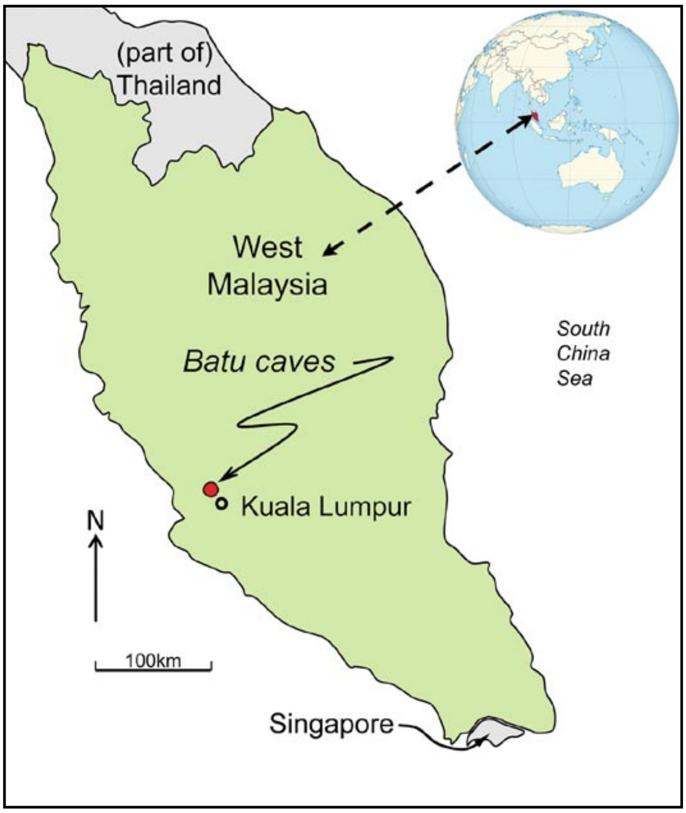

***Figure 1:** Simplified map showing the approximate location of the Batu caves area within West (Peninsular) Malaysia, with inset to indicate the position of West Malaysia in its global context.*

The pre-Great War period

Although they were not examined by the BAAS committee, the invertebrate collections made at Batu caves (Fig.1) in 1896 by Henry Ridley (Moseley, 2014) and a small collection made a few years later at Dark Cave by John (1914) did include several new species that were described in the years leading up to the Great War. None show any obvious morphological adaptation to subterranean life. Pocock (1899) described a scorpion *Chaerilus agilis* on the basis of a female specimen from Dark Cave, whilst the abundant guanobious cockroach *Pycnoscelus striatus* (Fig.2) was described by Kirby (1903) from a series of Ridley's specimens in the British Museum.

***Figure 2:** The cave cockroach* Pycnoscelus striatus. *This guanophilous cockroach was only the second of many new species to be described from the Batu caves. (Photo: CMG.)*

Figure 3: *Terrestrial isopod* (Armadillo intermixtus) *on a cave wall in the dark zone of Dark Cave. Note the well-developed eyes. Most of the animals living in tropical guano caves in Southeast Asia are unspecialized species that also live in surface habitats. This led zoologists to believe mistakenly that there were almost no true cave animals in the tropics.*

According to Chilton (1929) the type specimens of the terrestrial isopod *Armadillo intermixus* (Fig.3), described by Budd-Lund (1904), were also among Ridley's Batu material. A new species of antlion *Neglurus* (now *Dendroleon*) *vitripennis* was collected and described just before the Great War (Navás, 1912; John, 1914), whereas Champion (1916) described a new aderid beetle *Xylophilus* (now *Euglenes*) *troglodytes*. These are the first five good species for which Dark Cave is the type locality. There can be little doubt that the original BAAS collections must have included at least some of the many other new species that were discovered in later years: Dark Cave is now the type locality for one collembolan, 32 insects and 25 other invertebrates (Moseley *et al*., 2010).

There was no other fieldwork in the Batu caves until after the Great War but some collections had been made in 1899–1900 in a few caves farther north on the Malay Peninsula during an ethnological and zoological expedition led by **William Walter Skeat (1866–1953)** (Annandale, 1900; Anon, 1900; Skeat, 1901). Starting from 'Singgora' (the modern southern Thai town of Songkhla) in Lower Siam the **Cambridge University Exploring Expedition to the Siamese Malay States** (usually referred to as the '**Skeat Expedition'**) was first based at Phattalung from where the team explored islands in the Tale Sap (Inland Sea). The expedition then moved south to 'Jalar' (= modern Yala Province) and finally on to the north of British Malaya. Skeat had been a District Officer in the Selangor Civil Service. The Cambridge University scientists participating in the expedition were Yapp, Laidlaw and Gwynne-Vaughan; whilst Oxford University also participated, represented by Evans and the Scottish zoologist **Thomas Nelson Annandale (1876–1924)**. Annandale did undertake some collecting personally in the Siamese caves, though he does not appear to have visited any caves in British Malaya. Collections from the expedition are deposited in the Cambridge University Museum of Zoology.

Most of the literature from this period is essentially taxonomic with little by way of ecological context. However, some years after the Skeat expedition Annandale collaborated with the eminent English entomologist, arachnologist and authority on cave-associated Orthoptera **Frederic Henry Gravely (1885–1965)** on a review of what little was then known of the cave fauna of Southeast Asia, tabulating and discussing Leonardo Fea's collections in Burma (Myanmar) (see Part 1 [Moseley, 2014]), the Skeat Expedition findings in Siam, and Ridley's Batu results (Annandale and Gravely, 1914). Annandale and Gravely's paper did little to dispel the impression left by the BAAS report, apparently merely echoing and reinforcing the idea that, at least in Southeast Asia, there were no troglobionts:

"…there can be no danger in asserting that no species found in the caves of Burma and the Malay Peninsula is so highly specialized in correlation with this mode of life as are certain species found in the caves of Europe and North America."

(Annandale and Gravely, 1914. p.422)

Careful reading of their paper reveals that this sentence was referring only to those species that had *so far been found*. They point out, correctly, that many 'troglobites' are aquatic and/or minute inconspicuous forms and these had not yet been searched for. This left open the possibility, especially in the case of aquatic fauna, that more careful exploration might reveal specialized cave species. However, this suggestion had no impact at the time, and in any case the Great War brought all such studies to a complete halt for the duration.

The inter-war years

At the cessation of hostilities in 1918 Great Britain remained firmly in control of India, Burma and Malaya. It was in these British colonial territories that the few speleobiological investigations carried out in the Old World humid tropics during the inter-war years were done.

Lucien Chopard (1885−1971) published a review of cave-associated Orthoptera of Burma and the Malay Peninsula (Chopard, 1919). Then in early 1922 the **Zoological Survey of India** undertook a comprehensive faunal survey of Siju Cave, Assam (now in Meghalaya), a subtropical region of India (Kemp and Chopra, 1924). Of the 102 species found within the cave only four displayed some partial degree of reduction in eye size and pigmentation when compared to epigean species (Harries *et al*., 2008). All four are now considered *bona fide* subterranean species but, probably because their troglomorphic traits are not pronounced, this did little to overturn preconceptions regarding the presence of troglomorphs in the tropics. The Siju Cave survey did, however, prompt **Cedric Dover (1904–1961)**, an Anglo-Indian entomologist and anthropologist working at the Selangor Museum, to undertake a comparable zoological survey of Dark Cave at Batu (Dover, 1928, 1929a).

Around the same time the first glimmers emerged of evidence that ought at least to have caused questioning of the perception that tropical Asian caves supported little of special zoological interest. A troglomorphic dictyopteran (*Typhloblatta caeca*) and an orthopteran (*Eutachycines caecus*) were described by Chopard in 1921 and 1924 respectively from caves in Assam (Harries *et al*., 2008). Meanwhile there was the formal recognition and description of *Liphistus batuensis* at Batu. Whilst this mesothelid trapdoor spider is not a troglobiont the existence of this conspicuous 'living fossil' in the Batu caves was an important discovery that must have drawn attention to the possibility of other significant finds. The genus *Liphistus* was not new: two epigean species had already been discovered – *L. desultor* from Malaysia in 1849 and *L. birmanicus* very recently (1923) from Burma (Myanmar) described by **H C Abraham**. Apparently Abraham was aware of the existence of a *Liphistus* in the Batu caves but it was not until a specimen was sent to him that he realised that it was new and not the known species *L. birmanicus* (Abraham, 1923a, 1923b; Buxton, 1924).

During 1926 Cedric Dover and his assistant **Maria Heynes-Wood** (to whom he was later married) made extensive zoological collections and a preliminary topographical survey of Dark Cave. They published the first map of the cave at a scale of 1 inch = 120 feet [1:1440] and labelled the cave's main sections with the letters A to E (Heynes-Wood and Dover, 1929). This nomenclature currently remains in use.

Unfortunately their work at Batu was discontinued earlier than planned when Dover was reassigned from his post at the Selangor Museum to another government department (Kloss, 1929). The survey was therefore not as thorough as originally intended and some of the published reports give the impression of having been prepared hurriedly and based upon incomplete data. Nevertheless, this time the collections were processed and investigated properly. They were first sorted by taxonomic group and then distributed for study to some of the pre-eminent taxonomists of the day, including specialists who were also working on the Siju Cave collections. Their work resulted in a valuable series of papers on the invertebrates (Banks, 1929; Blair, 1929; Carpenter, 1933; Chilton, 1929; Chopard, 1929; de Man, 1929; Dover, 1929c, 1929d; Edwards, 1929; Fage, 1929; Ghose, 1929; Hirst, 1929; Meyrick, 1929; Pendlebury, 1929; Sars, 1929), flora (Dover, 1929b) and geology (Willbourne, 1929). Strangely, the vertebrates found in the cave were dismissed, rather cavalierly, by Kloss (1929) as being uninteresting and unimportant.

In many respects the fauna of the cave was found to be essentially similar to that in Siju Cave (Heynes-Wood and Dover, 1929) though, of course, differing in detail, particularly at the species level. The project brought to light the rich zoological diversity of Dark Cave, but there were no troglobiontic beetles, woodlice or other terrestrial cave species. However, sampling of minute animals from pools and streams did result in the discovery of specialized subterranean species; as Annandale and Gravely (1914) had predicted.

In 1930–1931 **W S Bristowe (1901–1979)** collected arachnids in Dark Cave but without finding any specialist cave species (Bristowe, 1952). This was the last work before the outbreak of the Second World War and the occupation of the region by the Japanese.

Elliott McClure's survey

Between May 1959 and January 1961 the ornithologist and epidemiologist **Dr Howe Elliott McClure (1910–1988)** (US Army Medical Research Unit) and co-workers conducted the most extensive investigation to date of the fauna of Dark Cave. This survey included monthly records of the relative abundance of some of the more common or conspicuous species as well as their distribution within the cave. Although they did not use the usual accepted terminology of 'threshold', 'deep threshold' and 'dark zone' it is evident that these authors were well aware that Dark Cave is a zonal environment, emphasising for instance that, in contrast to deeper perpetually dark parts of the system, Cavern A is a *"semi-subterranean"* habitat that is not in total darkness. The nature of biological communities depends upon substrate (frugivorous bat guano, insectivorous bat guano, cave soil, etc.), light level, humidity, temperature and other physical and biological factors. Some species display seasonality, and there are diurnal changes in the threshold/deep threshold communities (McClure, 1965; McClure *et al*., 1967).

Most of the specimens collected during the 1959–1961 survey were deposited in the permanent collections of the Bishop Museum (Hawaii) where some were used as the basis of specialist taxonomic papers on Diptera (Alexander, 1961; Colless, 1962; Das Gupta and Wirth,1968; Freeman, 1962; Maa, 1962; Quate, 1962; Sabrosky, 1964; Wirth, 1980), Coleoptera (Chûjô, 1963; Werner, 1962), Psocoptera (Thornton, 1962); Diplopoda (Hoffman, 1977) and arachnids (Beier, 1963; Roewer, 1962) that were published in the journal *Pacific Insects*. Some of these collections (e.g. some Coleoptera families) have still not been examined in detail.

The survey also resulted in the publication of the most comprehensive published checklist of the fauna available until very recently. This list (McClure, 1965) is a compilation of previous records together with those from the 1959–1961 work (which was only itself fully published two years later) but is somewhat deficient. McClure does not cite any of his sources and it takes a considerable amount of bibliographical detective work to establish the provenance (and hence the probable validity or ecological significance) of the listed species occurrence records. It is also incomplete: a note by Bullock (1965) in the same issue of the journal adds seven species reported in the prior literature that had been overlooked. There are also numerous spelling errors in the names of taxa and other mistakes e.g. the naming authority is incorrect for some of the listed species. This list, upon which later workers have often relied, thus appears to have been assembled and proof-read with some absence of due care. When added together, these publications (McClure, 1965; Bullock, 1965; McClure *et al.,* 1967) list 151 invertebrate and 22 vertebrate taxa from Dark Cave.

The tide turns: the 1960s

By 1971 the records of the diverse fauna of Dark Cave that had been accumulated since its discovery in the late 19th century constituted the most comprehensive catalogue of the fauna of any cave in Southeast Asia (Deharveng and Bedos, 2000; Moseley, 2009). This fauna is dominated by a huge preponderance of unremarkable species with highly adapted subterranean forms represented only by small aquatic species (<5mm in size) and a springtail. It seems to have been assumed to be typical for the region. Nothing that had been found here or elsewhere in tropical Asia had served to overturn the legacy of the conclusion reached by the BAAS. Also little notice was taken of McClure and colleagues' observations on the structure of biological communities within the cave and the zonal nature of the environment.

Figure 4: *Millipedes are usually abundant in tropical guano caves, where they perform a similar role to earthworms elsewhere. Though the illustrated species,* Plusioglyphiulis grandicollis*, is abundant in the Batu caves and is eyeless, it is almost certainly not exclusively subterranean. (Photo: CMG.)*

Elsewhere, however, further indications that the BAAS had been premature in their conclusions had begun to appear. For example **Narcisse Leleup (1912–2001)** collected cave insects in the Congo in the 1960s and also found the first obligatory terrestrial cave organisms on oceanic islands during a Belgian expedition to the Galapagos Islands (Leleup, 1968). By the end of the decade the highly respected French speleobiologist **Albert Vandel (1894–1980)** was beginning to recognize that cave fauna is much more widely distributed than previously believed. It was already known that the cave fauna of Japan and Australasia was as rich and varied as that of the northern temperate zone, and the finds in tropical Africa meant that attention was now starting to turn towards tropical regions (Vandel, 1969).

Post-1971 revolution

Although the foundations had already been laid by finds elsewhere, Howarth's report of a diverse fauna of troglobionts from the Hawaiian Archipelago (see Moseley, 2014) was totally unexpected. It could not be ignored and it began a revolution in speleobiology. His discovery of the eyeless planthopper, followed by over 75 other troglobiontic species from Hawaiian lava tubes, definitively falsified the 'no tropical troglobites' hypothesis (Stone, 2010). But not only had it to be accepted that troglobionts existed on these tropical islands but it was evident too that they were not relictual species but instead proved active colonization of subterranean habitats. In geological terms the Hawaiian Islands are very young (Hawaii is believed to be less than a million years old), they have not experienced extreme climatic changes and closely-related ancestral species of many of the cave forms still exist (Howarth, 1981). It was clear that these were non-relictual troglobites and this opened up the possibility, first recognized then dismissed by the BAAS, that cave-adapted animals could evolve in other tropical regions and indeed almost anywhere in the world.

Figure 5: *Cockroaches* (Periplaneta sp.) *adults and nymphs on a cave wall in Dark Cave. Two species of* Periplaneta *were unintentionally introduced into Dark Cave at some time in the past and are now present in enormous numbers in some parts of the cave. They are extremely harmful ecologically and efforts are being made to reduce their numbers. (Photo: CMG.)*

Figure 6:
The Batu Caves Bent-toed Gecko (Cyrtodactylus metropolis)*; adult female on limestone rock face, east of Temple Cave.* Cyrtodactylus *is a diverse genus of Asian geckos with many species reported from surface karstic habitats and shallow caves. They do not show any apparent morphological cave adaptations but their commonly observed presence underground suggests active exploitation of the habitat. They probably prey on the parietal (wall) fauna of the cave ecotone.* C. metropolis *is almost certainly an endemic restricted to the Batu massif. It was first observed more than a century ago, but only recently (2014) recognized and described as a new species.*
(Photo courtesy of Lee Grismer.)

Initially there was resistance from some speleobiologists, who suggested that oceanic islands are a special case, but there was also growing evidence from Africa and elsewhere. Once the search began, troglobionts were discovered almost everywhere that was examined. They were reported from other tropical and subtropical areas, including Jamaica, the Canary Islands, Thailand, and Central America. Many more species were collected in Australia (Stone, 2010).

Rapid progress was made on Southeast Asian cave fauna from 1980 onwards (Deharveng and Leclerc, 1989). For the first time experienced "caver-biologists" were involved who had the skills to investigate the more difficult caves and knew what to look for. A number of French and British expeditions undertook zoological collecting in caves in the continental northwest part of the region (Thailand, peninsular Malaysia, Singapore, Laos, Cambodia, Vietnam and southern China) and the chain of islands lying to the southeast (Philippines, Indonesia, East Malaysia, Brunei and Timor). Numerous troglobionts were found including Thermosbaenacea (Cambodia, Thailand); Palpigradia, Opiliones, dytiscid, paussid and pselaphid Coleoptera (Thailand); noterid Coleoptera (Sulawesi); and anthurid Isopoda (Sarawak). Most are non-relictual, derived from epigenic or edaphic ancestors still present in the same geographical region as the subterranean sister species (Deharveng and Leclerc, 1989).

The focus during this period was on finding and describing troglomorphs. By the end of the 1980s it had been realized that eutrophic guano caves such as those at Batu had simply been the wrong places to look: troglomorphs must be looked for in the deeper, less accessible oligotrophic subterranean regions. However, this meant that mainstream biospeleologists had little interest in the unspecialized fauna of the Batu caves and they were bypassed. Zoological research was still being done at Batu but it was largely by local naturalists and researchers and not by experienced cave biologists.

Current status of Batu caves biology

The discoveries in Hawaii and elsewhere led to fundamental changes in the way that speleobiologists and evolutionary theorists view and understand the fauna of subterranean environments. Widespread abandonment since the 1970s of the view that most cave animals are derived from isolated relict populations in favour of evolutionary models based on active colonization of the underground environment by vigorous expansive species has been just one important advance (Howarth, 1981; Rouch and Danielpol, 1987). An accompanying trend has been a shift away from a traditional exclusive focus on highly adapted, cave-limited troglobionts to recognition of the ecological and evolutionary significance of the many other organisms that make up subterranean communities (Gibert and Deharveng, 2002).

These new conceptual paradigms greatly enhance the ecological and evolutionary significance of the faunal communities inhabiting guano caves in the humid tropics. These consist of populations comprised almost exclusively of non-troglobiontic taxa so have been largely neglected historically due to the focus on troglobionts. There is now a need for detailed investigation and description of the fauna of suitable representative examples of caves in the humid tropics, including the poorly studied Southeast Asia region, and the existing knowledge of Batu caves provides a good foundation for such studies. As the only zoologically well investigated caves in the Malay Peninsula and the most thoroughly sampled anywhere in Southeast Asia the Batu caves have the potential to serve as a regional type example of a guano cave.

The absence of appropriate speleobiological expertise and sometimes simple carelessness means that much of the past work undertaken on the fauna of Batu Caves lacks academic rigour. This problem is not only historical. Undue reliance on McClure's lists (McClure, 1965; McClure *et al*., 1967) led Dittmar *et al*. (2005) mistakenly to report a number of invertebrates as new records for the cave (Moseley, 2009). The potential utility of faunistic surveys already completed has never been fully realized because until recently the available records were scattered, contained errors and, in many cases, had become taxonomically out-dated. In order to provide a solid foundation for future investigations the first definitive annotated checklist of fauna reported from the caves has recently been published (Moseley *et al*., 2012). All known historical fauna records were assembled, checked, brought up to date and collated. The inventory (which includes a few records from caves other than Dark Cave within the Batu Caves massif) more than doubles the total invertebrate list to 310 species, of which 270 are confirmed or considered probably reliable, distributed in 172 families (158 confirmed/reliable). There are 59 (39 confirmed/reliable) vertebrates in 30 families (25 confirmed/reliable). Much still remains to be done on the basic task of cataloguing and describing the fauna. This is well illustrated by the recent discovery of a new species of Bent-toed Gecko (*Cyrtodactylus metropolis*) endemic to the Batu Caves massif (Grismer *et al*., 2014) (Fig.6).

At present there is optimism that Dark Cave can be protected and its biology conserved. It is recognized as an important natural heritage site by the Selangor State government. The Malaysian Nature Society (MNS) is entrusted to protect the cave for conservation and eco-tourism on behalf of the State, and have contracted a specialist cave management company, Cave Management Group (CMG), to manage it. CMG and MNS consider conservation of the site a priority. Currently the cave is gated, access and biological collecting are controlled, guano mining is absolutely prohibited and the ecologically critical deep cave areas are managed as an ecological reserve with strictly enforced restricted access. A scientific advisory panel is in place to review applications for research permits and to assist CMG with cave management policy. The company strongly encourages and is committed to the use of the caves for appropriate ecological and biological research. Being close to Kuala Lumpur, a major urban and academic research centre, the site is readily accessible to scientific investigators, and much of Dark Cave is physically undemanding, with large spacious passages and chambers and a system of concrete walkways.

It is hoped that with this protection Dark Cave can be managed and conserved effectively, and that it will become an increasingly important site for the study of Southeast Asian cave biology.

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