Figure 1. Left. The larva and snare of C. shennongensis from Shen Nong Gong (Dragon God Palace) near Panling village in Wannian County, Jiangxi Province. Right. The snare of the sticky worm in Lagang Cave Gunung Mulu National Park.

NON-GLOWING STICKY WORMS AND GLOWING CENTIPEDES: OBSERVATIONS ON GUNUNG MULU CAVE FAUNA

– David Merritt[1] and Arthur Clarke[2]

The guano-based ecosystem of Mulu's caves is world famous, featuring in the "Caves" episode of the BBC series Planet Earth. One of the interesting cave inhabitants not directly associated with guano and the one that invoked the most questions is the so-called "non-glowing glowworm" seen in a number of the caves in Gunung Mulu. The larvae of this insect make snares composed of hanging silk lines that trap flying insects, just like the well-known glowworms of Australia and New Zealand (Arachnocampa). Some differences are immediately apparent: the Mulu larva is smaller and has a different body shape and colouration to Arachnocampa, the vertical silk lines don't have the same pattern of sticky droplets (Figure 1) and, most noticeably, they don't glow. First let's discard the term, "non-glowing glowworm". It is contradictory and it tends to embed an assumption that they are glowworms that have lost the ability to glow, or the "real" glowworms have evolved from them. Instead, let's stick to the local name "sticky worms".

The Mulu sticky worms are probably members of the Genus Chetoneura, possibly closely related to the species Chetoneura cavernae, first described by the Australian dipterist (fly specialist), Donald Colless (Colless, 1960). They were collected as adults from Batu Caves near Kuala Lumpur in peninsular Malaysia, by members of the United States Army Medical Research Unit. Maybe they were concerned that they were mosquitoes! Colless received two adults to identify, and didn't know the larva. He classified and named the new species based on its adult characteristics and recognised they were members of the fly family, Mycetophilidae, in a group now named as Family Keroplatidae within the reclassified Superfamily Mycetophiloidea. One of us (DM) contacted Liz Price, a Malaysian caver interested in biospeleology (see http://www.cavesofmalaysia.com/); she confirmed that Batu Cave has "sticky worms", or "web worms" so it is likely that Colless' adult keroplatids were the adult form of the sticky worms of Batu Cave. To be certain of their identity, it is necessary to rear larvae through to adulthood because it is only by examining adult features, such as wings, eyes, legs and reproductive structures that a formal identification can be made. So, the Mulu sticky worm larvae need to be reared to adulthood and then matched against Colless' description to see if they are Chetoneura cavernae or perhaps another related species that requires a new name. Given the island of Borneo is some distance from the Malaysian peninsula, they could be a different species. Relatives are found in caves throughout many parts of Asia. Arthur Clarke has collected and helped describe a related Chetoneura species called Chetoneura shennonggongensis from caves in Jiangxi Province, China. The publication was the first to classify and name the related sticky worms found in many Chinese caves (Amorim et al., 2008). They are likely to be widely distributed throughout the oriental region.

Next we examine the links between webs, living in caves and bioluminescing, and to do so we can't avoid using some scientific names. The Keroplatidae are members of the Superfamily Mycetophiloidea, the mushroom (or fungus) flies. The Family Keroplatidae is divided into three subfamilies: Arachnocampinae, Macrocerinae and Keroplatinae. (Some taxonomists include a fourth subfamily: Sciarokeroplatinae.) Note that among the 3 recognised subfamilies, there are some that have become cave-dwellers, some that have evolved the ability to bioluminesce and some that have developed the habit of hanging silk lines to trap prey (Figure 2). Within the Arachnocampinae it is only the monotypic Arachnocampa, the famous Australian and New Zealand glowworms, that has all three attributes. Arachnocampinae is the smallest subfamily of Keroplatidae, with 8 described species (Baker, 2010). Because of their restricted Gondwanan distribution they are considered an ancient group (Matile, 1990). The Asian species of the genus Chetoneura belong to the subfamily Keroplatinae.

Species of three generic groups within Keroplatidae exhibit bioluminescence; Arachnocampa, some Keroplatus species and Orfelia fultoni. Interestingly, they have evolved this ability independently because they produce light from completely different organ systems: Arachnocampa from the malpighian tubules, Keroplatus from fatty tissue and Orfelia from an unusual set of cells called "black bodies" whose origin is unclear. We can also conclude that the habit of hanging vertical silk lines has probably evolved independently among the Keroplatidae. Because of the wide geographic distribution of cave-dwelling keroplatids we can also conclude that the Keroplatidae have independently inhabited caves many times.

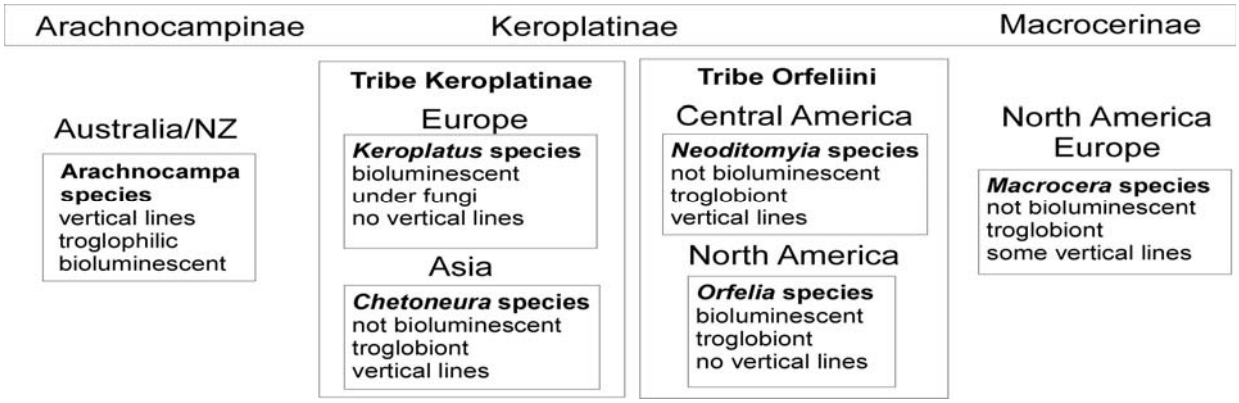

Figure 2. The subdivisions of the Family Keroplatidae and their association with caves, bioluminescence and web-building. Information from Peck and Russel (1976), Meyer-Rochow (2007), Coher (1996).

How come Arachnocampa glowworms evolved bioluminescence while the Chetoneura sticky worms didn't? We suspect that the answer lies in the guano-based food web in tropical caves that produces many flying insects. Cave sticky worms have done well enough without bioluminescence because all they have to do is hang snare thread lines and amongst the abundance of flying insects, some will blunder into the lines without the added lure of light. The same argument applies to the Macrocera cave worms of North America that also do not bioluminesce but have sticky webs and are associated with guano (Peck and Russell, 1976). It is interesting that the two Arachnocampa species that form very large colonies in caves are from New Zealand (Arachnocampa luminosa) and Tasmania (Arachnocampa tasmaniensis), neither of which has large bat colonies in the caves. So, in the absence of guano-based food-webs, the ancestral temperate-climate glowworms may have needed bioluminescence to actively lure prey into their webs.

Another fascinating arthropod, common in the guano piles in Deer Cave at Gulung Mulu National Park, is a small centipede, called Orphnaeus brevilabiatus. Individuals are about 2 cm long. A guide showed how they produce a bioluminescent secretion when disturbed. If an individual is pressed, with a finger, for example, it secretes a substance that glows bright blue for a few seconds. It is secreted from every segment so, in the dark, the outline of the animal is painted in light on the substrate. Meanwhile the centipede makes its escape. It is probably an adaptation for predator avoidance. I could find only one, brief scientific paper concerning bioluminescence in Orphnaeus. It confirms that the centipede's light-producing chemical reaction is based on a luciferin-luciferase interaction (Anderson, 1980), just as in glowworms and fireflies. It would be most interesting to examine the nature of the secretion and locate the glands that produce it. Maybe that is the excuse we need to go back to Gunung Mulu. In another paper we will look at some of the other Mulu cave organisms.

1. School of Biological Sciences, The University of Queensland.
2. School of Zoology, University of Tasmania.

REFERENCES

Amorim DDS, Niu C, Li XZ, Lei CL and Clarke AK (2008) Chetoneura shennonggongensis, a new species of cave-dwelling Keroplatini from China (Diptera: Keroplatidae), with a discussion of the position of Chetoneura. Zootaxa 1716:59-68.

Anderson JM (1980) Biochemistry of centipede bioluminescence. Photochemistry and Photobiology 31:179-181.

Baker C (2010) A new subgenus and five new species of Australian glow-worm (Diptera: Keroplatidae: Arachnocampa spp.). Memoirs of the Queensland Museum 55:149-177.

Coher EI (1996) Cave-associated tropical American Neoditomyia (Diptera: Mycetophilidae). Pan-Pacific Entomologist 72:152-159.

Colless DH (1962) Chetoneura cavernae n. gen., n. sp. from Batu Caves, Malaya (Diptera: Mycetopohilidae). Pacific Insects 4:437-439.

Matile L (1990) Recherches sur la Systematique et l'Evolution des Keroplatidae (Diptera, Mycetophiloidea), Museum National D'Histoire Naturell, Paris.

Meyer-Rochow V (2007) Glowworms: a review of Arachnocampa spp. and kin. Luminescence 22:251-265.

Peck SB and Russell DR (1976) Life-history of fungus gnat Macrocera nobilis in American caves (Diptera-Mycetophilidae). Canadian Entomologist 108:1235-1241.