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FINDING A RARE RESOURCE: BORNEAN SCARABAEOIDEA (COLEOPTERA) ATTRACTED BY DEFENSIVE SECRETIONS OF DIPLOPODA

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Abstract

Scarab beetles of four species, *Onthophagus penicillatus* Harold, *O. rudis* Sharp, *Phaeochridius derasus* (Harold) and *Phaeochroops gilleti* (Benderitter) (Scarabaeoidea: Scarabaeidae and Hybosoridae) were attracted by quinonous defensive secretions of Harpagophoridae (Diplopoda) in Sabah, Borneo. Unlike the Afrotropics, where some specialists feed on fresh millipede carcasses, in Borneo only generalist necrophages use this resource. This may be caused by the low abundance of juliform Diplopoda in Borneo prohibiting specialization on this resource.

Necrophagy is a common nutritional habit of dung beetles (Hanski and Cambefort 1991). The type of carcass used as resource for feeding or reproduction depends on availability (*i.e.,* on the sympatric fauna). In many regions of the tropics, huge millipedes are quite abundant (*e.g.,* in the Afrotropics: Dangerfield 1990:143, 146; Mahsberg 1997), or at least present (*e.g.,* in Borneo). In the Côte d'Ivoire, we found about 50 species of Scarabaeoidea feeding on diplopod carcasses (Krell *et al.* 1996), but only on those containing quinonous defensive secretions ("juliform" millipedes). Some beetles do not need the smell of rotting carcasses to find these resources, but are attracted directly by these secretions (Krell *et al.* 1997, 1998). The same attraction was also found in Southern Africa (Krell 1999). In Central America, *Canthon morsei* Howden, *C. cyanellus* LeConte and *Deltochilum valgum acropyge* Bates (Scarabaeidae: Scarabaeinae) were found on living juliform millipedes (Cano 1998; Villalobos *et al.* 1998). Kon *et al.* (1998) discovered two *Onthophagus* species (Scarabaeidae: Coprinae) on living millipedes in Thailand. This prompted us to attempt the present study, in which we tested whether this kind of olfactory detection is a widespread phenomenon in necrophagous dung beetles and whether it is found in dung beetle species of the Oriental region where large millipedes also exist.

Study Sites and Methods

This field study was conducted in three tropical lowland rainforests in Sabah, Malaysia:

1. Danum Valley Conservation Area (4°58′N, 117°48′E, 438 km^2; undisturbed primary forest; cf. Marsh and Greer 1992): 07–09 March 1999 (C.B.), 20–22

January 2000 (C.B.) and 10–12 October 2000 (F.-T.K.) (1999: West Trail, W9; 2000: Nature Trail near the Danum Valley Field Centre, see Anonymous 1997).

2. Kabili-Sepilok Forest Reserve (5°52′N, 117°57′E, 42.9 km^2; primary forest; cf. Fox 1973, Payne 1988): 15–17 October 2000, km 0.5 Waterfall Trail (Payne 1988: map 6) (F.-T.K.).
3. Deramakot Forest Reserve (*ca.* 5°24′N, 117°28′E, 551 km^2, secondary forests with different degrees of disturbance; cf. Burgess 1991; Chai 1994), near base camp: 06–07 May 1998 (C.B.).

The secretions of a large (20–35 cm) juliform millipede species of the family Harpagophoridae (in Sepilok: *Spissustreptus* sp. n.) were used as an attractant in the following set-up: The millipede was handled with unperfumed toilet paper until yellow drops of fluid were seen and a strong quinonous smell was prevalent. We did not use toilet paper soaked by anal excretions. The toilet paper was then wrapped around a wire stick or a small twig and placed over a pitfall trap. Four pitfall traps were situated at the corners of a square meter, controls (toilet paper without secretion) and attractants were placed at alternate corners. The traps were filled with water without adding any chemical to make sure that only the secretion worked as an attractant. The water was replaced every day as were attractant and control toilet papers. At each time two of these set-ups were run for two days (Deramakot: one day) at a distance of about 50 m. F.-T.K. installed a rain cover over the traps (plastic plate), C.B. did not.

The beetles were deposited in the Natural History Museum London and in the Forest Research Centre, Sepilok.

Results

Beetles were only caught in the pitfall traps with attractant, none was caught in the control traps. The trapping result is shown in Table 1.

The following four species were collected:

Onthophagus penicillatus Harold 1879 (Scarabaeidae, Coprinae), is distributed from Sikkim and southern China to Sumatra and Borneo (Balthasar 1963:472). Davis (1993:95, 108) has already found it in Danum. Although he did not state which kind of bait was used for each trap, it is most probable that he used human dung to attract *O. penicillatus*, since this was the bait that he mostly used. Kabakov and Napolov (1999:90) collected this species on human dung in Thailand as well. Hanski (1983:45) and Kikuta *et al.* (1997) attracted it with fish in Sarawak and Sabah, respectively. This species, as well as the following, were found by Kon *et al.* (1998) to be attracted by a copulating pair of millipedes in Thailand. Finally, Masumoto (2001) found it in Thailand on a large dead millipede.

Onthophagus rudis Sharp 1875 (Scarabaeidae, Coprinae), distributed from Assam and southern China to the Philippines and the Sunda Islands (Balthasar 1963:505), has already been recorded from Danum by Davis (1993:108) and from Sepilok by Ochi and Kon (1994:294) and Chung (1999:282). According to Hanski (1983:45) and Davis (1993) it is a carrion specialist. It has been trapped with fish and meat by Hanski (1983:45) in Sarawak and with rotten fish by Kikuta *et al.* (1997) on Mt. Kinabalu in Sabah.

Phaeochridius derasus (Harold 1880) (Hybosoridae), is known from Sumatra, Batu Islands, Java and Borneo (Kuijten 1985:33). One specimen from Sumatra was found "on decaying meat" (Kuijten 1985:33). Davis (1993) found it in traps with otter (*Lutrogale* sp.), human and orang-utan (*Pongo pygmaeus* (L.)) faeces and with carrion in Danum and Sepilok.

Phaeochroops gilleti Benderitter 1923 (Hybosoridae) is known from northern Borneo and Palawan (Kuijten 1981:28f). Davis (1993:109) found it in Danum, Chung

Table 1. Results of trapping experiments; number of beetles from single traps and single days pooled. The number in parentheses gives the number of beetles caught by the control traps (pooled). Trapping time: 36 trap-days with bait, 36 trap-days control. Since two traps of each type were always combined in each set-up, the effective number of trap-days is 18 each.

Locality	Danum	Danum	Danum	Sepilok	Deramakot	Σ
species/date	07–09. iii.1999	20–22. i.2000	10.–12. x.2000	15.–17. x.2000	06–07. v.1998	
Onthophagus rudis	0 (0)	14 ♂♂, 2 ♀♀ (0)	12 ♂♂, 8 ♀♀ (0)	2 ♀♀ (0)	1 ♂, 1 ♀ (0)	**27** ♂♂, **13** ♀♀ **(0)**
Onthophagus penicillatus	0 (0)	0 (0)	2 ♂♂, 1 ♀ (0)	0 (0)	1 ♂ (0)	**3** ♂♂, **1** ♀ **(0)**
Phaeocroops gilleti	0 (0)	0 (0)	4 ♀♀ (0)	0 (0)	0 (0)	**4** ♀♀ **(0)**
Phaeochridius derasus	0 (0)	0 (0)	3 ♂♂, 3 ♀♀ (0)	0 (0)	0 (0)	**3** ♂♂, **3** ♀♀ **(0)**
Σ	**0 (0)**	**16 (0)**	**33 (0)**	**2 (0)**	**3 (0)**	**54 (0)**

(1999:281) in Sepilok. It has formerly been trapped with fish and meat (Kuijten 1981:29; Hanski 1983:45).

At Danum, trapping on 20 January 2000 was started during heavy rain in the evening, which was thought likely to interfere with the experiment, but apparently did not. However, during the first trapping day at Sepilok, heavy rain filled three of the four baited traps despite a rain cover. Rainy weather during the trapping period certainly reduced the number of trapped beetles. The trap catch of dung beetles depends not primarily on the attractivity of the bait, but on local population size and flight activity of the beetles during the trapping time. Both parameters are strongly affected by weather conditions (Krell, Schmitt, Boutros, unpublished results).

As flight activity of dung beetles is not the same over time and space, we have to pool our data. There were 54 specimens in baited traps compared with no specimens in control traps during the 36 trap-days. This result is obvious and need not to be tested statistically. It is highly improbable that the beetles went into the baited traps by chance, since dung beetles generally do not walk randomly on the ground and do not land at a place where no resource is present. In the present case, even control traps only one meter from baited ones did not catch a single beetle.

Discussion

The dung beetle species we found on quinonous defensive secretions of millipedes in Africa are specialized on using freshly dead millipedes as a resource for feeding and reproduction. By contrast, in Borneo, only generalist necrophages were attracted by this bait. This may be caused by the low population density of juliform millipedes in Borneo, where they are generally considered to be rare. During about 100 man-days in the forests of Danum and Sepilok during the beginning of the rainy season in October 2000, only three specimens were found. Compared with the West African Parc National de la Comoé (Mahsberg 1997; Krell *et al.* 1997), where generally one person is able to collect 10 to 30 specimens within one hour, sometimes even within a few minutes, the Bornean millipedes are a comparatively rare resource. Specialization on such a rare and unpredictable resource might be very risky for scarab beetles. However, when this resource is actually available, i.e. when a millipede is killed or died, it can be exploited. Therefore, it might be an advantage for generalised necrophages to be able to find this additional resource. The quinonous smell emerges instantly after a millipede is killed, whereas the smell of rotting occurs later. Using the smell of defensive secretions of juliform millipedes as an attractant enables the dung beetles to be recruited to cadavers more rapidly than competitors that use the smell of rotting as a cue to find the resource.

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