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New records of *Pedilus* (Coleoptera: Pyrochroidae) on *Meloe strigulosus* Mannerheim 1852 (Coleoptera: Meloidae)

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Abstract. One male specimen of *Pedilus punctulatus* LeConte, 1851 and one male specimen of *Pedilus inconspicuus* (Horn 1874) (Coleoptera: Pyrochroidae) were found firmly attached to two different dorsal intersegmental membranes on the abdomen of a male *Meloe strigulosus* Mannerheim, 1852. These two species, represent new records of *Pedilus* Fischer von Waldheim, 1822 association with species of *Meloe* Linnaeus, 1758 (Coleoptera: Meloidae). Additionally, this is the first record of *M. strigulosus* association with the genus *Pedilus*. Several *M. strigulosus* specimens were observed between 3:30 and 7:45 PM in Wildcat Canyon Regional Park, Contra Costa County, and Tilden Regional Park, Alameda County, California supporting previous suggestions that *M. strigulosus* is nocturnal or crepuscular.

Key Words. Coleoptera, Meloidae, *Meloe*, Pyrochroidae, *Pedilus*, cantharidin.

On 9 April 2003, a female *Meloe strigulosus* Mannerheim, 1852 was observed feeding on vegetation along Wildcat Canyon Creek Trail in Wildcat Canyon Regional Park Regional Park, Contra Costa County, California, U.S.A. (37°55.885′ N, 122°17.158′ W) at 5:00 PST (Fig. 1). On 11 April 2003, at the same site at 3:30 PM PST, we observed a male *M. strigulosus* walking along the edge of the trail with two specimens of *Pedilus* Fischer von Waldheim, 1822 attached via their mandibles to two different dorsal abdominal segments (Fig. 2). Both specimens of *Pedilus* stayed attached to the meloid for several hours during extensive handling in the field and transport to the lab. The two specimens of *Pedilus* were determined to be a male *Pedilus punctulatus* LeConte, 1851 and a male *Pedilus inconspicuus* (Horn 1874) (Pyrochroidae) (D. Young, personal communication). The elytra were completely intact on both *M. strigulosus* specimens. The male *M. strigulosus* died the next day, but the female *M. strigulosus* collected on 9 April survived for 11 days in the lab. A second female *M. strigulosus* was observed at dusk (7:45 PM) on 21 April 2003 near Wildcat Peak in Tilden Regional Park, Alameda County, California. These observations document two new *Pedilus* species associations with *Meloe* Linnaeus. Observations of *M. strigulosus* contribute additional support to suggestions that this species is either nocturnal (Pinto 1972) or crepuscular.

The genus *Pedilus* has been associated with various species of *Meloe* in North America, however, previous observations of *Pedilus* association with *Meloe* from 1827 to 1984 have only been encountered sporadically. Say (1827) reported *Pedilus impressus* (Say 1827) attached to *Meloe angusticollis* (Say 1824), and Harrington (1894) reported twice finding a male *Pedilus elegans* (Hentz 1830) attached to a male *Meloe niger* Kirby, 1837 in Canada. *Pedilus monticola* (Horn 1874) was reported to have caused feeding damage to the elytra of three different specimens of *M. niger* (Leech 1934). Pinto and Selander (1970) observed *Pedilus terminalis* (Say 1827) mounted on the dorsum of a male *M. angusticollis* in Fayette County, Pennsylvania and on a female *Meloe americanus* Leach, 1815 from Rankin. Missouri. Both *Meloe* exhibited chewed elytral margins. LeSage and Bousquet (1983) reported *Pedilus lugubris* (Say 1827) feeding on the elytra of a male

Figure 1. Female *M. strigulosus* Mannerheim, 1852 on trailside vegetation (Photograph by M. L. Heddle).

M. angusticollis in Rigaud, Quebec, and Butler (1984) reported two male specimens of *Pedilus collaris* (Say 1827) attached for 10 hours to the abdominal tergites of a *male M. angusticollis* in Triune, West Virginia. Males of *Pyrochroa serraticornis serraticornis* (Scopoli, 1763), a related genus in the family Pyrochroidae have been found associated with *Meloe proscarabaeus* Linnaeus, 1758 (Nardi & Bologna 2000) and *Meloe violaceus* Marsham, 1802 in Italy (Bologna & Havelka 1985). This information is summarized in Appendix 1.

Pedilus and other pyrochroids are attracted to cantharidin-baited traps (Görnitz 1937, Young 1984a, b, Dettner 1997, Nardi & Bologna 2000) suggesting that *Pedilus* spp. are attracted to *Meloe* due to the terpene anhydride cantharidin that many *Meloe* spp. biosynthesize and which is contained in their haemolymph and tissues. However, the purpose of canthariphily in *Pedilus* and related genera remained conjecture until recently. Cantharidin functions as feeding deterrent to predators (Pinto & Selander 1970, Carrel & Eisner 1974, McCormick & Carrel 1987), as a defense against entomopathogenic fungi (Pinetti & Biggio 1968, Blum 1996) and as an intraspecific attractant (Dettner 1997 review). Holz et al. (1994) demonstrated that the canthariphilous pyrochroid *Schizotus pectinicornis* Linnaeus, 1758 not only stores ingested cantharidin, but males also transfer cantharidin to females during copulation, which is subsequently incorporated into their eggs and larvae. Eisner et al. (1996a, b) have shown that cantharidin also functions as a close-range excitatory pheromone in some pyrochroids. Male *Neopyrochroa flabellata* Fabricius, 1787 store ingested cantharidin, and females preferentially mate with males that have ingested cantharidin. These females sample a cantharidin secretion from the male

Figure 2. Male *M. strigulosus* Mannerheim, 1852 with *P. inconspicuus* Horn, 1854 and *P. punctulatus* LeConte, 1852 attached to the abdomen (Photograph by L. S. Saul-Gershenz).

cephalic gland during courtship and cantharidin is transferred to the spermatheca of the female during copulation and then incorporated into their eggs.

Hence, like meloids, pyrochroids exhibit paternal investment by utilizing cantharidin to increase the survival of their offspring through chemical defense. However, pyrochroids obtain cantharidin by gathering it from external sources such as meloids. The cantharidin collected from meloids by pyrochroids and members of the family Anthicidae is also used to increase their attractancy to conspecific females. Females appear to assess the titre of cantharidin and select males with higher cantharidin loads (Eisner et al. 1996a, b). Other genera of pyrochroids (*Pyrochroa*) are also attracted to *Meloe* (Bologna & Havelka 1985, Nardi & Bologna 2000) in Europe. In a related group of canthariphilous beetles, *Notoxus monoceros* Linnaeus, 1761 (Anthicidae), Schütz & Dettner (1992) reported that females only copulated with cantharidin-fed males. The females bite elytral notch glands on the apices of the male elytra which store cantharidin and select males with higher cantharidin loads prior to copulation.

Clearly, cantharidin is functionally important in chemical defense, mate attraction and reproductive success for *Pedilus*, *Pyrochroa* and other members of the family Pyrochroidae. However, to date, only 14 individual field observations of the association between pyrochroids and *Meloe* have been made and reported in the literature since 1827, though 68 species in four different orders of insect have been found to be attracted to

cantharidin (Young 1984a). It is surprising that the association between the *Meloe* and *Pyrochroidae* has not been encountered more frequently since cantharidin sources in nature are thought to be restricted to Meloidae and Oedermeridae (Holz et al. 1994, Dettner 1997).

Several possible explanations may account for this. First, many species of *Meloe* are difficult to find in large numbers due to their very localized distribution and sometimes small population size. Second, the intersection between pyrochroids and meloids is relatively brief, so encountering this interaction would have to be finely timed. Pyrochroids and other cantharidin collecting insects may only need a short period of time to feed to acquire the necessary quantity of cantharidin. Third, it seems likely that there are additional natural sources of cantharidin other than members of the Meloidae and Oedermeridae. Oedermerids feed on rotten fungus containing wood (Dettner 1997), larval stages of Pyrochroidae feed on rotting plant tissue (Parker 1982) and *Pedilus* larvae live in decaying plant tissue such as acorns (Wharton 1979). Hence, fungi seem likely candidates as additional cantharidin sources since many canthariphilous live in situations associated with fungi (Young 1984a, Dettner 1997).

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Appendix 1. Literature review of observations of *Pedilus* and *Pyrochroa* species (Pyrochroidae) observed feeding on *Meloe* (Meloidae). The sex of the specimen has been included, if noted, in the citation.

Meloe (Meloidae)	♂/♀	*Pedilus* (Pyrochroidae)	♂/♀	Locality	Reference
M. niger Kirby		*P. monticola* Horn		Salmon Arm, B.C.	Leech 1934
	♂	*P. elegans* (Hentz)	♂	Canada	Harrington 1894
M. angusticollis Say		*P. impressus* (Say)			Say 1827
	♂	*P. terminalis* (Say)		Fayette County, PA	Pinto & Selander 1970
	♂	*P. lugubris* (Say)		Rigaud, QUE	LeSage & Bousquet 1983
	♂	*P. edilus collaris* (Say)	♂	Triune, WV	Butler 1984
M. americanus Leach	♀	*P. terminalis* (Say)		Rankin, MO	Pinto & Selander 1970
M. strigulosus Mannerheim	♂	*P. punctulatus* LeConte	♂	Alameda Co., CA	Saul-Gershenz & Heddle
	♂	*P. inconspicuus* (Horn)	♂	Alameda Co., CA	Saul-Gershenz & Heddle
		Pyrochroa (Pyrochroidae)			
M. proscarabaeus Linnaeus	♂	*P. serraticornis serraticornis* (Scopoli)	♂	Latium, Latina Province, Italy	Nardi & Bologna 2000
M. violaceus Marsham	♂	*P. s. serraticornis*	♂	Lazio, Italy	Bologna & Havelka 1985

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Figure 1. Female *M. strigulosus* Mannerheim 1852 on trailside vegetation (Photograph by M. L. Heddle).

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Figure 2. Male *M. strigulosus* Mannerheim, 1852 with *P. inconspicuous* Horn and *P. punctulatus* LeConte, 1852 attached to the abdomen (Photograph by L. Saul-Gershenz).