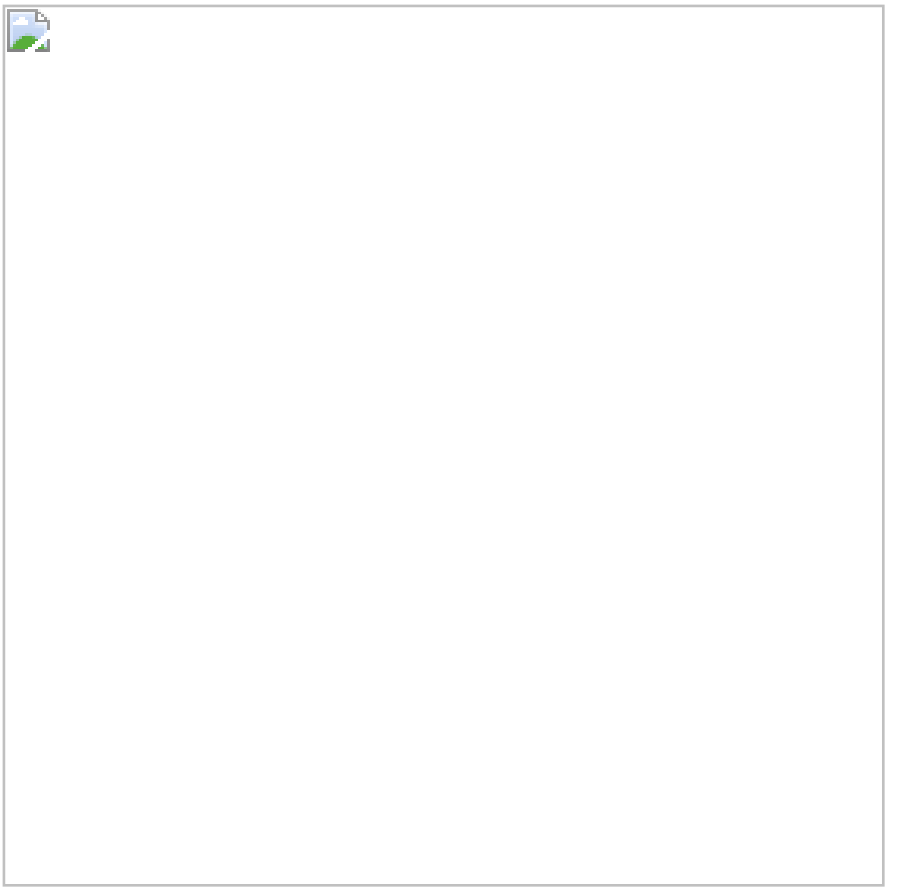

The Whip Scorpion, Mastigoproctus giganteus (Uropygi: Thelyphonidae), Preys on the Chemically Defended Florida Scrub Millipede, Floridobolus penneri (Spirobolida: Floridobolidae)

Authors: Carrel, James E., and Britt, Eric J.

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THE WHIP SCORPION, *MASTIGOPROCTUS GIGANTEUS* (UROPYGI: THELYPHONIDAE), PREYS ON THE CHEMICALLY DEFENDED FLORIDA SCRUB MILLIPEDE, *FLORIDOBOLUS PENNERI* (SPIROBOLIDA: FLORIDOBOLIDAE)

JAMES E. CARREL[1] AND ERIC J. BRITT[2, 3]
[1]University of Missouri, Division of Biological Sciences, 209 Tucker Hall, Columbia, MO 65211-7400 USA

[2]University of South Florida, Division of Integrative Biology, 4242 East Fowler Avenue, SCA 110, Tampa, FL 33620 USA

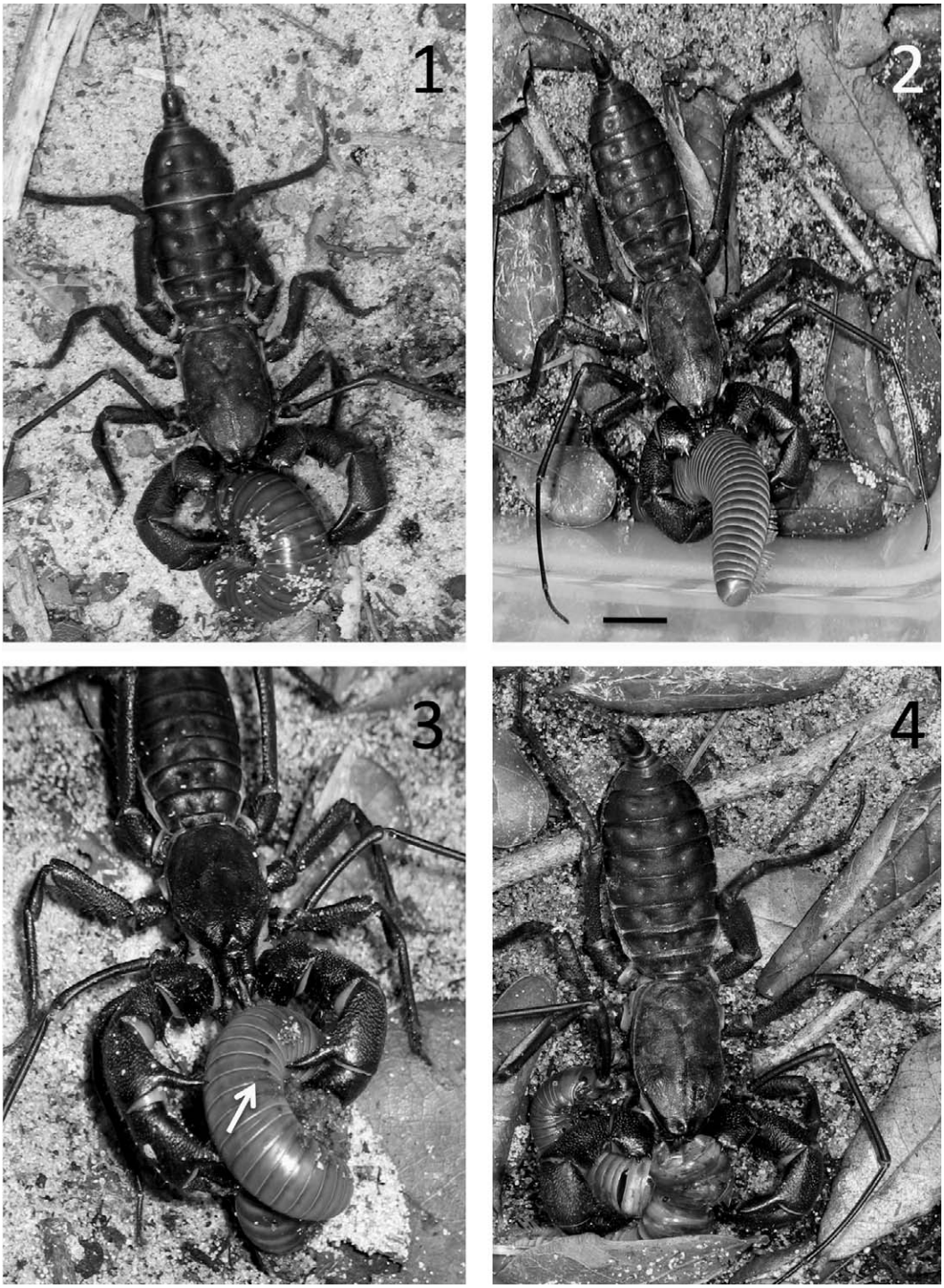
[2, 3]Current address: Archbold Biological Station, 123 Main Drive, Venus, FL 33960

The rare Florida scrub millipede, *Floridobolus penneri* Causey, is confined to xeric, sandy scrub habitats in the southern part of the narrow Lake Wales Ridge in Polk and Highlands Counties, Florida (Deyrup 1994). Although large in size (adult body length of about 90 mm and width of about 11.5 mm), little is known about this cylindrical animal because it is restricted in distribution and is nocturnally active aboveground only in mid-summer; it spends most of its secretive life buried in sand (Deyrup 1994). *Floridobolus* is the only genus and species in an entire family of spirobolid millipedes, the Floridobolidae (Shelley 2000).

Floridobolus, like most millipedes, is well protected from predators. When disturbed, it quickly coils into a tight spiral, shielding its head and all of its appendages with its smooth, hard integument and may remain coiled for a long time, for an average of 4.6 ± 0.7 min (n = 10, ± SEM) in laboratory tests. In response to mild to strong provocation, such as squeezing or biting, *Floridobolus* discharges large amounts of a liquid defensive secretion from paired glands that open along the sides of its body (Attygalle et al. 1993; Eisner et al. 1998). The volatile exudate, a blend of six 1,4-benzoquinones, appears to act as a conventional repellent to invertebrate and vertebrate enemies and the quinone vapors are potent irritants of the eyes of mice, birds, and humans (Eisner et al. 1978). Prior to this publication, the only known predator of *Floridobolus* is the larva of a phengodid beetle, *Phengodes laticollis meridiana* Wittmer. The larva instantly paralyzes the millipede by biting its neck with sharp mandibles and the defensive quinones remain sealed in the glands while the larva eats the uncontaminated internal tissues, starting at the neck and moving toward the anus, leaving behind empty rings of armored body segments (Eisner et al. 1998; Eisner et al. 2005).

We now report that the giant whip scorpion, *Mastigoproctus giganteus* (Lucas) (Arachnida: Uropygi) consumes *Floridobolus*, even if the quinone-based secretion is released upon attack. In Aug-Sep 2008 we collected millipedes at 3-day intervals in 96 pitfall traps arranged in sets of 12 each at 8 randomly chosen sites in scrubby flatwoods near the southern end of the Archbold Biological Station, Highlands County, Florida (ranging from 27°08" 20" N, 81°21' 18" W to 27°07' 19" N, 81°21' 54" W, elevation 40-43 m). Each trap consisted of a plastic bucket (17.5 cm diameter × 19 cm depth, 3.8 liter capacity) placed in the ground so that the rim was flush with the sandy soil and filled with 3-5 cm of sandy soil. During the first 2 weeks of Aug, while checking all of the buckets on 4 different days, we found 17 *M. giganteus* individually in the traps. In 6 instances there were partially consumed *Floridobolus* with them, 6 traps contained both *M. giganteus* and 1 or more living *Floridobolus*, and 5 had *M. giganteus* and no millipedes. An additional 35 traps each contained 1-4 living but zero dead *Floridobolus* on the days they were checked. In addition, at this time we never found dead or injured *Floridobolus* in the approximately 100 traps containing large carnivorous carabid beetles, *Pasimachus strenuus* LeConte, or in about 30 traps containing very large lycosid spiders, *Hogna osceola* (Gertsch and Wallace). Our field data suggested that millipede mortality was highly correlated with the presence of giant whip scorpions: dead, partially consumed millipedes were found only in buckets where *M. giganteus* were present. This conclusion subsequently was reinforced when on 3 occasions in the field we discovered a giant whip scorpion holding a millipede in its powerful pedipalps while it bit the prey middorsally at an intersegmental membrane (Fig. 1).

Fig. 1 shows sand grains adhering to the cuticle of the millipede, a sign that the prey may have discharged its defensive secretion in response to squeezing or biting inflicted by the giant whip scorpion. Secretory discharge was confirmed when several, but not all millipedes, were quickly attacked as they slowly approached *M. giganteus* during laboratory trials staged in sand-filled arenas. In some instances the predator's attack did not evoke release of secretion by the millipede (Fig. 2). Microscopic examination of the interior of the segmental rings a day after the millipedes



Figs. 1-4. Giant whip scorpions, *Mastigoproctus gigantea*, preying on Florida scrub millipedes, *Floridobolus penneri*. 1. Attack observed in field. Sand adhering to prey suggests millipede discharged after attack commenced. 2. Attack staged in laboratory arena. When grasped and bitten, prey uncoiled and, while it was consumed, it did not discharge defensive secretion. Scale bar = 1 cm. 3. Other staged attacks involved massive discharge of defensive secretion, as visible (arrow) by dozen or so lateral droplets of quinones and adherent sand on other segments. 4. Several hours post-attack, all millipedes were reduced to segmental rings and liquified internal tissues wrought by the arachnid predator's digestive enzymes.

were eaten, with the technique of Eisner et al. 1998, confirmed the presence of replete defensive glands.

However, in some instances a giant whip scorpion's powerful pedipalpal grasp and subsequent middorsal bite caused the millipede immediately to discharge quinones from many glands (Fig. 3), but the predator was not deterred. The odor of the secretion was very noticeable to us at this time. In all instances, within 15-30 min after an attack commenced, the whip scorpion had inflicted a fatal incision between 2 segments of its prey and liquefied tissues were ingested (Fig. 4).

Although we showed that *Floridobolus* is highly vulnerable to attack by *M. giganteus*, Florida scrub millipedes spend most of their lives underground and giant whip scorpions are not common predators in scrub, so we suspect the rate of predation might be low in the field. Our results extend the dietary diversity of *M. giganteus* beyond insects, arachnids, and amphibians (Cloudsley-Thompson 1958, Punzo 2000) to the diplopods.

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Summary

On several occasions in Aug-Sep 2008 we detected giant whip scorpions, *Mastigoproctus giganteus*, feeding on rare Florida scrub millipedes, *Floridobolus penneri*, in bucket-style pitfall traps in the field. Subsequently in laboratory feeding trials we determined that *M. giganteus* will readily attack, kill, and consume *F. penneri* even if the prey discharges its irritating defensive secretion.

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