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Article

New records of Sarcophagidae and Phoridae (Insecta: Diptera) associated with scorpions in Panama (Arachnida: Scorpiones)

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Abstract

Very little is known about insect parasitoids or scavengers of scorpions. In this study we found three cases of endoparasitoidism by Sarcophagidae (Diptera) in three species of *Tityus* Koch: *Lepidodexia* sp. on *Tityus festae* Borelli and larvae of unidentified flesh flies on *Tityus jaimei* Miranda, Bermúdez, Flórez, Armas and *Tityus cerroazul* Lourenço. We recorded a case of scavenging by *Puliciphora fenestrata* Borgmeier on *T. jaimei*.

Key words: *Centruroides*, endoparasitoidism, *Lepidodexia, Puliciphora*, scavengers, *Tityus*

Resumen

Se sabe muy poco sobre los insectos parasitoides o carroñeros de escorpiones. En este estudio encontramos tres casos de endoparasitoides por Sarcophagidae (Diptera) en tres especies de *Tityus* Koch: *Lepidodexia* sp. en *Tityus festae* Borelli y larvas de moscas de la carne no identificadas en *Tityus jaimei* Miranda, Bermúdez, Flórez, Armas y *Tityus cerroazul* Lourenço. Registramos un caso de carroñeo por *Puliciphora fenestrata* Borgmeier en *T. jaimei*.

Palabras clave: carroñeros, *Centruroides,* endoparasitoide, *Lepidodexia, Puliciphora, Tityus*.

Introduction

Scorpions are nocturnal, predaceous arthropods, and many have a long life expectancy, being able to live for 2-10 years (Polis and Sissom 1990). They are viviparous and iteroparous, and females care for the youngs during the first weeks of their life (Lourenço 2018). Some species are capable of forming social groups (Polis and Lourenço 1986).

Natural enemies of scorpions include predators, parasites and parasitoids (McCormick and Polis 1990, Gillung and Borkent 2017). The main predators of scorpions are arachnids, especially spiders and other scorpions, with other predators being birds, reptiles, mammals, toads, frogs, centipedes and some insects (Polis et al. 1981, Polis and McCormick 1987, McCormick and Polis 1990, Lourenço et al. 2006, Almeida et al. 2022, Cubas-Rodríguez and Armas 2024, Martins et al. 2024). Mites of the families Acaridae, Audyanidae, Erythraeidae, Laelapidae, Pterygosomatidae and Trombiculidae are scorpion ectoparasites (Lourenço 1982, Fain and Rack 1988, Seeman and Miller 2002, Ibrahim and Abdel-Rahman 2011, Felska et al. 2018), and nematodes from the families Mermithidae, Thelastomatidae and Rhabditidae are the most important endoparasites

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(Poinar and Stockwell 1988, Baruš and Koubková 2002, Miranda et al. 2020). Parasitoids of scorpions include members of two families of Diptera, Sarcophagidae and Tachinidae (Williams et al. 1990, Gillung and Borkent 2017, Zhang et al. 2017).

The scorpion fauna of Panama is currently composed of 15 species, belonging to the families Hormuridae, Chactidae and Buthidae, with the genera *Centruroides* Marx and *Tityus* Koch (Buthidae) being the most diverse, with five and seven species respectively (Miranda and Armas 2020). Regarding the natural enemies of these scorpions, six species of birds, one species of mammal, two species of ants, and a species of social wasp have been reported as predators (Kaufman 1962, Heatwole 1967, Polis et al. 1981, Miranda et al. 2014, 2020). Among the parasites, some Laboulbeniales fungi and Rhabditida nematodes have been found on and inside some Panamanian scorpions (Miranda et al. 2020, Armas et al. 2021).

The objective of this work is to present the first contribution on Diptera associated with scorpions in Panama, either as parasitoids or scavengers.

Materials and methods

The scorpions were collected with long metal tweezers, during day and night field work, and placed individually inside plastic containers for transfer to the laboratory. During daytime work we checked under fallen logs and rocks, while nighttime collections were made using portable ultraviolet light lamps (Bioquip model 2921, LED bulb, 400 nm wavelength), generally between 7:00 p.m. and 11:00 p.m. The plastic containers used for the collection of scorpions did not have perforations as a security measure against the escape of small specimens or the entry of ants. Cotton moistened with water was placed inside the containers, but without substrate or prey for the scorpions. In the laboratory, the scorpions were individually transferred to clean plastic containers, while maintaining humidity and safety conditions.

The identification of the scorpions was carried out by R. J. Miranda following the key for *Tityus* species from Panama (Miranda, 2022) while the Diptera were identified by B. Brown (Phoridae) with the taxonomic literatures of Borgmeier (1962) and Disney (2003); and by T. Pape (Sarcophagidae) using Pape and Dahlem (2010).

The scorpions were collected as part of several research projects under the Ministry of the Environment's scientific permit SC/A-31-18.

Results

Three cases of endoparasitoidism by Sarcophagidae flies on three species of *Tityus*, the second instar larvae of Sarcophagidae and adults and larvae of *Puliciphora* Dahl on a recently dead scorpion were observed.

Sarcophagidae: *Lepidodexia* Brauer and Bergenstamm (Figures 1, 2).

Scorpion collected in Reserva Natural Privada Chucantí, Darien Province (8°47'53.59" N, 78°27'23.99" W, 980 msnm), during daytime inspection on 20/II/2013, under a rotten trunk. At the time of being collected, the scorpion showed rigidity of the body and little response when manipulated with the tweezers. The specimen was identified as a male of *Tityus festae* Borelli, coll. R. Miranda, S. Bermúdez. The fly larvae (n = 22) were observed on 22/II/2013 and pupated on 23/II/2013, placed in plastic containers with soil substrate (approx. 3 cm deep). Eleven females and 8 males emerged between 9-10/III/2013, three individuals did not emerge.

Sarcophagidae: genus sp. (Figure 3)

Scorpion collected alive and apparently healthy in Trinidad de Las Minas, Capira, Panama Oeste (8°46'24.17" N, 80°00'39.61" W, 338 msnm), during night field work on 1/IV/ 2019. The specimen was identified as a female of *Tityus jaimei* Miranda, Bermúdez, Flórez, Armas, coll. R. Miranda, J. Lezcano. Twelve larvae were observed the day after collection, and they pupated in the container of the scorpion the same day. Unfortunately, adults did not emerge.

Sarcophagidae: genus sp. (Figure 4)

Scorpion collected alive and apparently healthy at Sendero Gray, Centro Mamoní, Chepo, Panama Province (9°19'24" N, 79°8'33" W, 320 msnm), during night field work on 23/II/2021. The scorpion was found walking on the ground of the trail, in an area with rotten logs and abundant leaf litter. The specimen was identified as a female of *Tityus cerroazul* Lourenço, coll. C. Morán, Y. Juárez, A.C. de Martínez. The scorpion was preserved in 70% ethanol the day after, before detection of six Sarcophagidae larvae, which still remained inside its body.

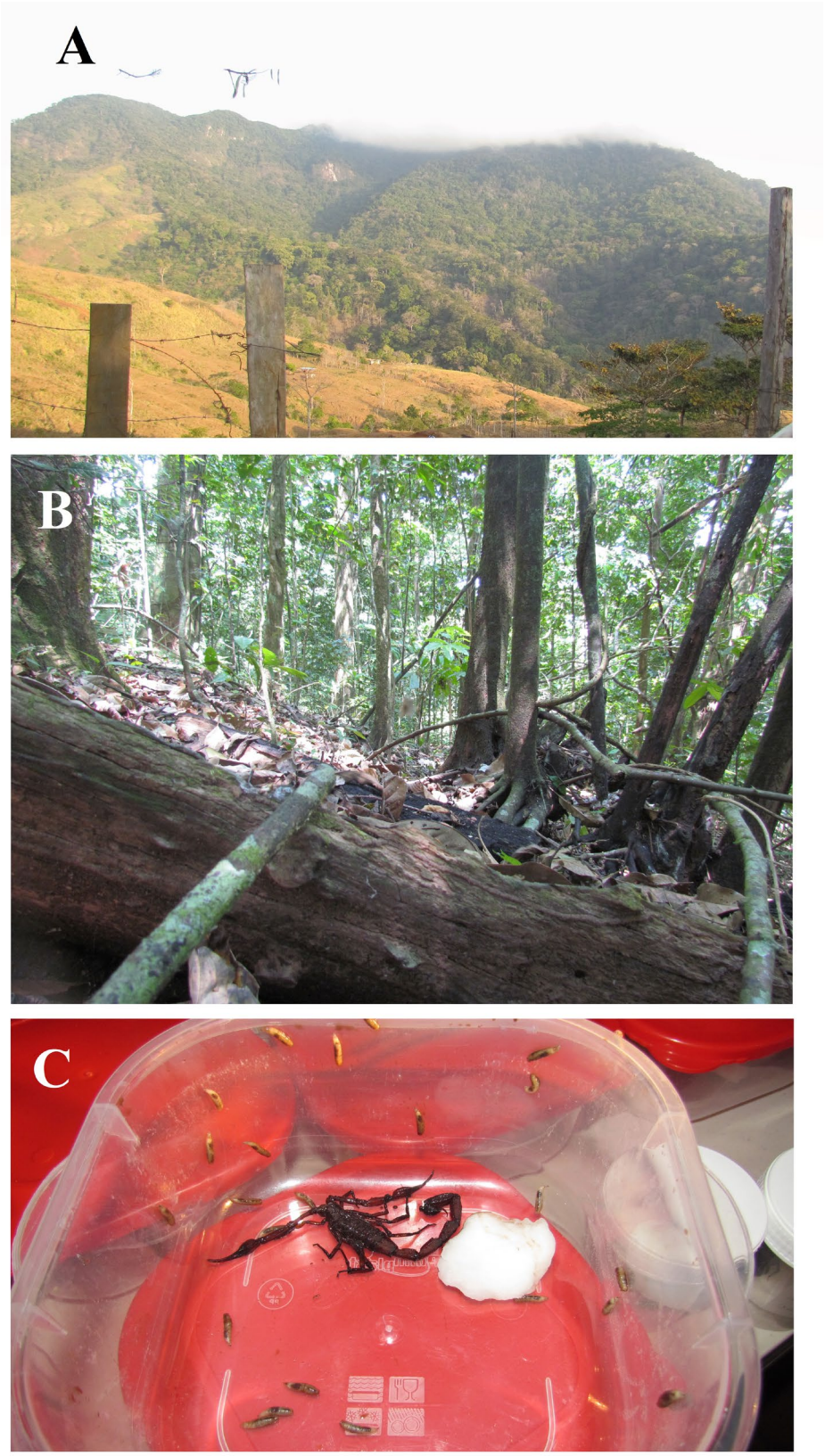

Figure 1. Case of parasitoidism by *Lepidodexia* sp. (Sarcophagidae) on *Tityus festae*. (A) View of Reserva Natural Privada Cerro Chucantí, Darién. (B) collection site for parasitized *Tityus festae*. (C) *Lepidodexia* larvae emerging from male *Tityus festae*.

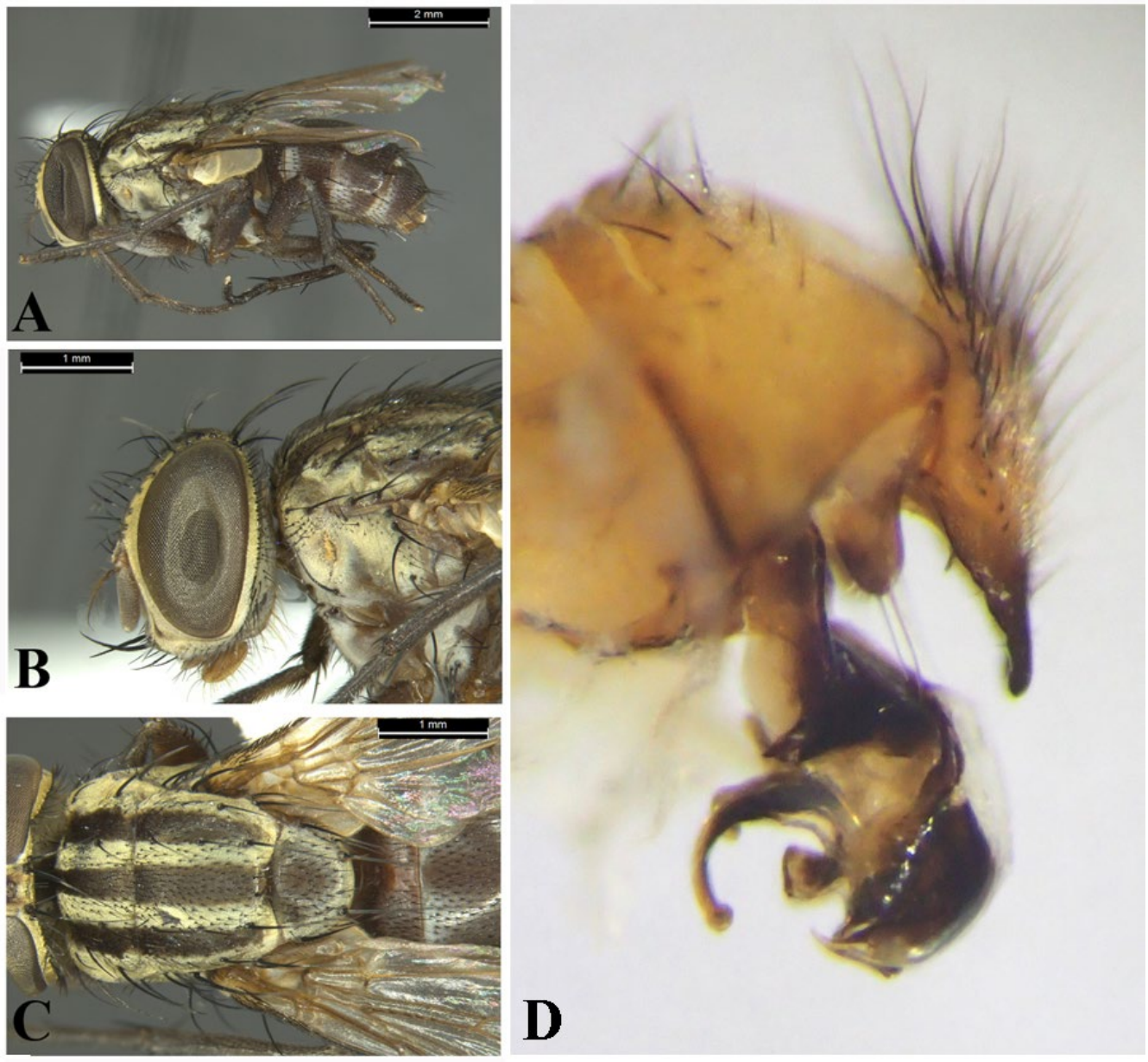

Figure 2. *Lepidodexia* sp. (Sarcophagidae) parasitoid on *Tityus festae* (Buthidae). (A) Habitus, lateral view. (B) Head, lateral view. (C) Scutum, dorsal view. (D) Male, genitalia.

Sarcophagidae (larvae) and Phoridae: *Puliciphora fenestrata* Borgmeier (Figures 5-6)

The scorpion was collected in Altos de Campana National Park, Panama Oeste Province (8°40' 33.30" N, 79°55'46.35"W), on 21/IX/2017 during night field work. The specimen was identified as *Tityus jaimei*. This scorpion had been marked with fluorescent paint two days before, as part of an ecological study, which allowed its recognition when it was found dead with 11 adults and 29 larvae of *P. fenestrata* (Figure 6), five larvae of Sarcophagidae, four beetles and five ants not identified. In the scorpion, a hole could be seen in the soft tissue surrounding the pecten and the genital operculum (Figure 5C).

Discussion

Species of three families of Diptera have been bred from scorpions: Phoridae, Sarcophagidae and Tachinidae (Gillung and Borkent 2017, Zhang et al. 2017). The first report of alleged parasitoidism by flies on scorpions was made by Townsend (1893), who described *Sarcodexia sternodontis* Townsend [= *Peckia* (*Sarcodexia*) *lambens* (Wiedemann)] allegedly parasitizing *Centruroides edwardsii* (Gervais) from Jamaica. However, the report does not provide any detail that rules out infection of a moribund or dead specimen, and considering the very broad range of breeding media known for *P. lambens* (Buenaventura and Pape 2013), this is most likely a case of scavenging. More recently, Shi et al. (2015) describe the parasitism of *Sarcophaga dux* Thompson on *Mesobuthus martensii* (Karsch) in China. The authors suggest that *S. dux* is capable of larvipositing at night on scorpions, which would be an unusual behaviour for this species, which is known to readily larviposit on vertebrate carrion as well as faeces (Bänziger and Pape 2004).

In this work the genus *Lepidodexia* is added to the Sarcophagidae facultative parasitoids of scorpions. The genus *Lepidodexia* as recently redefined by Riccardi et al. (2024) is taxonomically very complicated, with a large number of species classified in several subgenera. The present species falls in the *Neophyto* group, but a species-level identification would require extensive revisionary work falling outside the scope of the present paper.

Here we report a case of scavenging in the field by *Puliciphora fenestrata* Borgmeier on *T. jaimei*, along with other insects (Sarcophagidae, ants and beetles). Previously, Zhang et al. (2017) reported facultative parasitoidism between *Megaselia scalaris* (Loew) and *Mesobuthus eupeus mongolicus* (Birula). *Megaselia scalaris* has saprophagous, sarcophagous, and necrophagous feeding habits, and is capable of attacking injured hosts or those weakened by holding in captivity, including insects and arachnids (Diyes et al. 2015). In the case of scavenging reported here, the larvae were found within the mesosoma (Figure 5D) and legs; no damage was

Figure 3. Case of parasitoidism by Sarcophagidae flies on *Tityus jaimei* (Buthidae) in Trinidad de Las Minas, Capira, Panamá Oeste. (A) Collection site for parasitized *Tityus jaimei*. (B) *Tityus jaimei* with Sarcophagidae pupae.

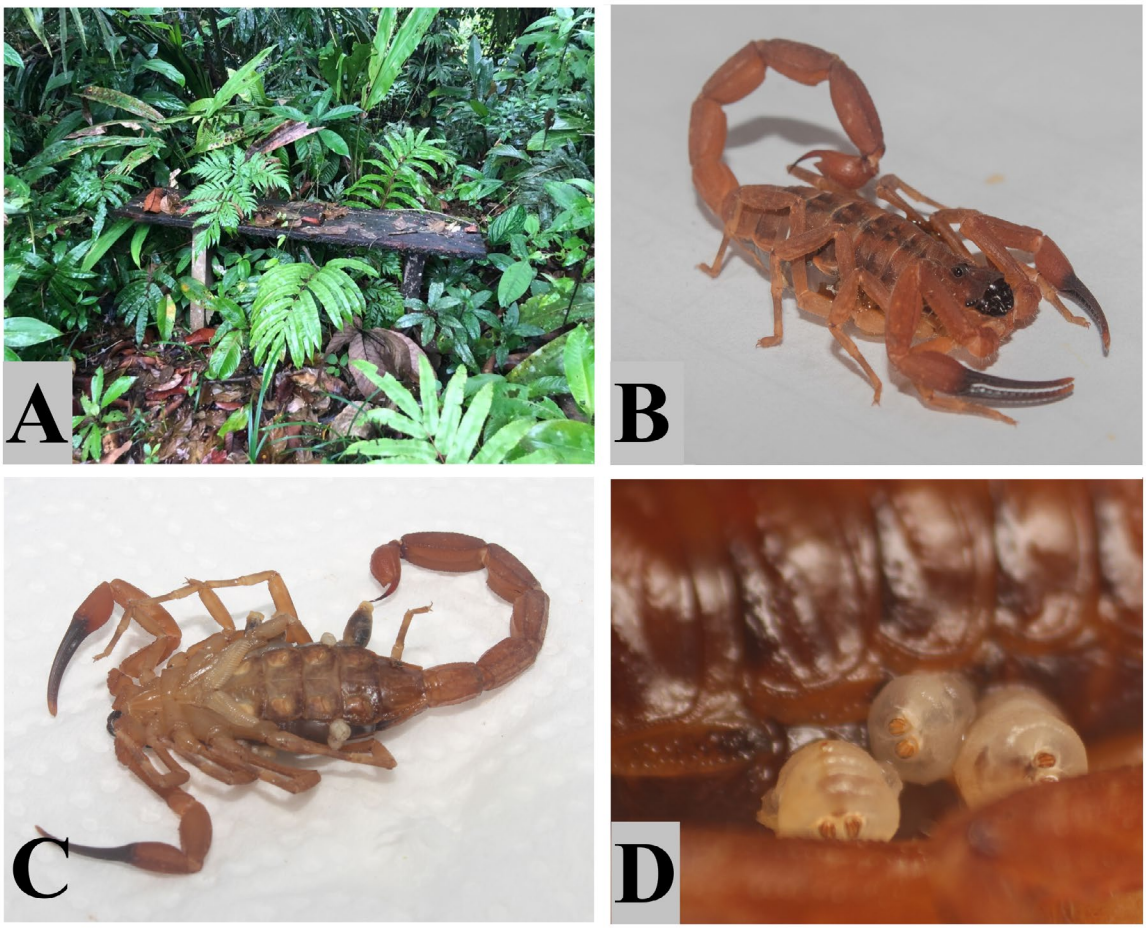

Figure 4. Case of parasitoidism by Sarcophagidae larvae on *Tityus cerroazul* (Buthidae) in Centro Mamoní, Chepo, Panama. (A) Collection site for parasitized *Tityus cerroazul*. (B-D) *Tityus cerroazul* parasitized: (B) Live. (C) Dead, after putting it in ethanol 70%. (D) Detail of mesosoma with Sarcophagidae larvae.

observed to the musculature of pedipalps or metasoma. This specimen of *T. jaimei* had external damage in the area of the genital operculum and the pecten (Figure 5C), unlike the cases of endoparasitism by Sarcophagidae, in which the larvae consumed the internal organs and muscles of the mesosoma and legs, however the pecten and the genital opening did not show external damage.

Reports of fly parasitoidism on scorpions are very rare, and it remains to be seen if the reports by Williams et al. (1990) of the tachinid fly *Spilochaetosoma californicum* Smith bred from *Anuroctonus phaiodactylus* (Wood) and *Vaejovis spinigerus* (Wood) in southern California and Arizona, respectively is an obligate association. In natural environments, fly parasitoidism on scorpions is of low occurrence, except for what was reported by Shi et al. (2015), who found a high prevalence (17.03%) of *S. dux* parasitoidism on *M. martensii*.

Ecological observations on scorpions in natural environments are difficult to conduct and document due to their secretive habits. This may be biased, considering that parasitoidism can occur in underground shelters (Williams et al. 1990) or inside tree trunks, far from the view of researchers.

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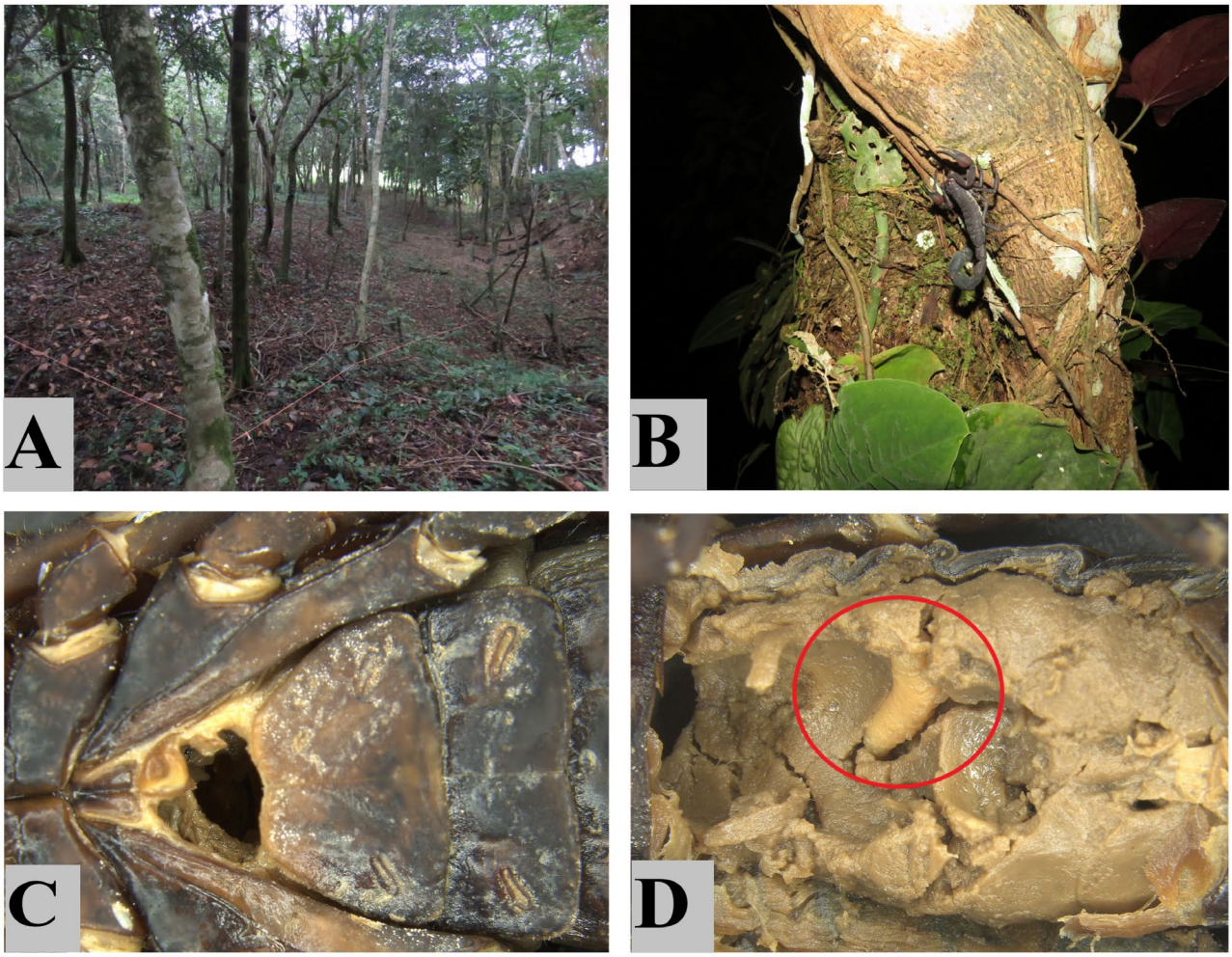

Figure 5. Case of larval flies of Sarcophagidae and *Puliciphora fenestrata* (Phoridae) feeding on dead male *Tityus jaimei*, Altos de Campana National Park, Panama Oeste. (A) Collection site for *Tityus jaimei*. (B) Male live. (C-D) Ventral view of the mesosoma of *T. jaimei* showing external and internal damage by fly larvae (tergites removed), red circle indicating Sarcophagidae larva.

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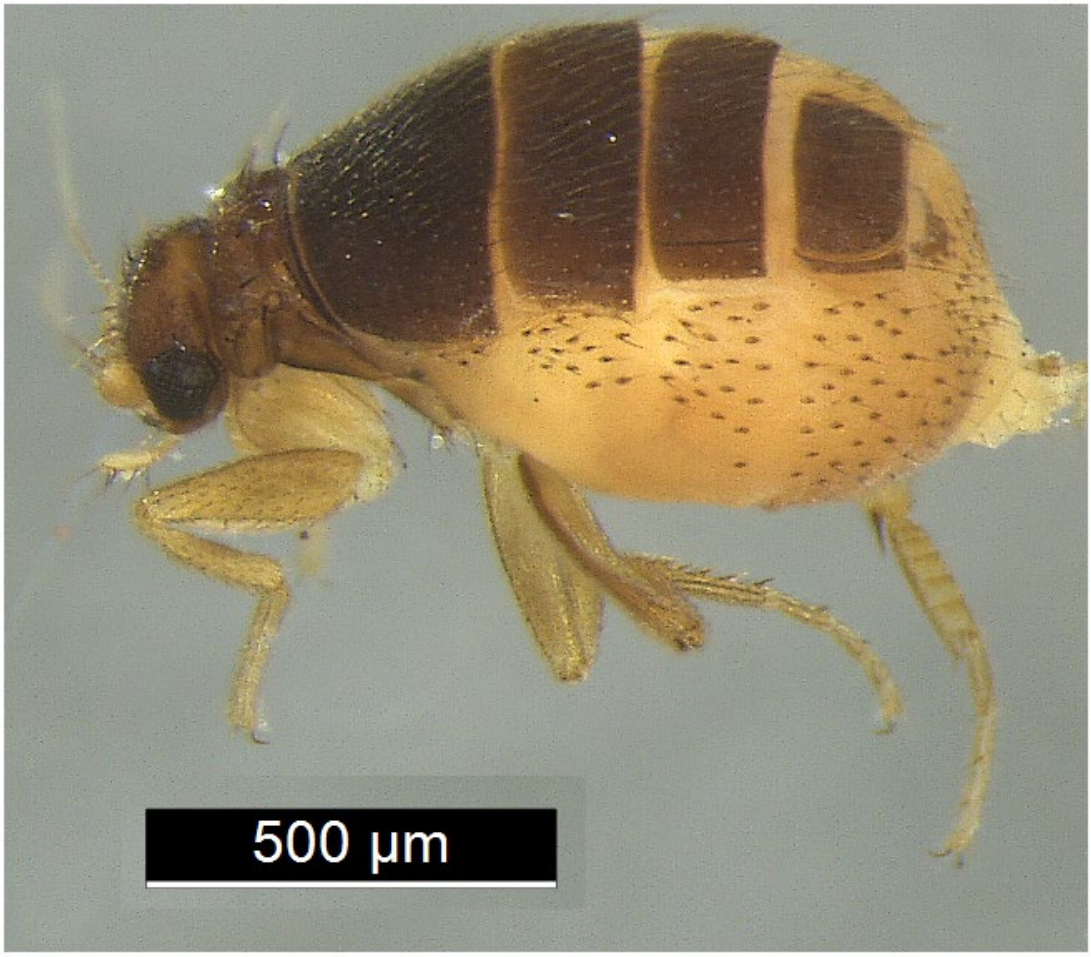

Figure 6. Female of *Puliciphora fenestrata* (Phoridae) collected on dead *Tityus jaimei* male, Altos de Campana National Park, Panama Oeste.

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