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Report of *Sphenochernes camponoti* (Beier, 1970) (Pseudoscorpiones, Chernetidae) in phoresy on Fanniidae (Diptera)

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ABSTRACT. Phoresy is a common dispersal behavior among pseudoscorpions. Neotropical pseudoscorpions, mainly from the North and Northeast regions of Brazil, are known for their dispersal relationships with beetles and flies. Here, we report phoretic association among nymphs of *Sphenochernes camponoti* (Chernetidae) and *Fannia* flies (*F. pusio*, *F. yenhedi,* and *F. canicularis*) (Diptera, Fanniidae). Twelve flies, each carrying a young pseudoscorpion, were collected in *Caatinga* vegetation in Pernambuco State, Brazil. *Sphenochernes camponoti* is a myrmecophilous pseudoscorpion that lives in *Camponotus* and *Acromyrmex* colonies. Despite its association with ants, this pseudoscorpion uses other winged arthropods to disperse. This is the first report of phoresy by *Sphenochernes camponoti*.

Keywords: pseudoscorpion, dispersal strategies, species interactions, Caatinga.

Relato de *Sphenochernes camponoti* (Beier, 1970) (Pseudoscorpiones, Chernetidae) em forésia em Fanniidae (Diptera)

RESUMO. A forésia é um comportamento de dispersão comum entre os pseudoescorpiões. Os pseudoescorpiões neotropicais, principalmente das regiões Norte e Nordeste do Brasil, são conhecidos por sua relação de dispersão com besouros e moscas. Neste estudo, relata-se a associação forética entre as ninfas de *Sphenochernes camponoti* (Chernetidae) e *Fannia* (*F. pusio*, *F. yenhedi* e *F. canicularis*) (Diptera, Fanniidae). Foram coletadas doze moscas em vegetação de caatinga, no Estado de Pernambuco, Brasil, cada uma delas transportando um pseudoescorpião jovem. *Sphenochernes camponoti* é um pseudoescorpião mirmecólifo, encontrado anteriormente em colônias de formigas *Camponotus* e *Acromyrmex*. Embora se associem com formigas, esses pseudoescorpiões utilizam outros artrópodes alados para se dispersarem. Este é o primeiro relato de forésia de *Sphenochernes camponoti*.

Palavras-chave: pseudoescorpião, dispersão, interação entre espécies, Caatinga.

Introduction

Order Pseudoscorpiones represents 3.3% of all known arachnid species (Harvey, 2002; Harvey, 2007). These small arachnids are commonly distributed over almost all regions of the world. Although the group represents an important proportion of all known arachnid species, studies of its natural history, ecology, and behavior are still scarce (Tizo-Pedroso & Del-Claro, 2005). In Brazil, 167 species and 14 families from different biomes are known (Harvey, 2011).

The cryptic habits of pseudoscorpions make them very difficult to study in natural environments (Weygoldt, 1969; Tizo-Pedroso & Del-Claro, 2005). At times, species inventories of other arthropods can facilitate the collection of ecological and behavioral data on pseudoscorpion dispersal (Lira, Tizo-Pedroso & Albuquerque, 2014). These small arachnids establish a form of commensal relationship with other arthropods called "phoresy," in which they attach themselves to the body of a larger animal (usually another arthropod) and are carried to another area or environment (Poinar, Curcic, & Cokendolpher, 1998; Szymkowiak, Górski, & Bajerlein, 2007). Phoretic association can be an important attribute for arthropod communities (involving mites, pseudoscorpions, nematodes, fungi, and microorganisms) that depend on ephemeral and patch habitats like decaying trees, contributing to increased community complexity (Wilson, 1988).

Although occurrences are rare, during field studies researchers sometimes collect phoretic vectors with pseudoscorpions on their bodies. These opportunities improve our knowledge about the distribution of species, details of their behaviors, relationships established with other species (Lira et al., 2014), and in some more specific cases, their coevolution, as demonstrated by studies involving the pseudoscorpion *Semeiochernes armiger* (Balzan, 1892), which disperses when large adult of fly *Pantophthalmus tabaninus* Thunberg, 1819 emerge from their larval development on tree trunks (Zeh & Zeh, 1992a). Pseudoscorpions and flies co-occur in same kinds of tree trunks, and the development and dispersal of these arachnids are synchronized with the flies' emergence. Similarly, *Cordylochernes scorpioides* (Linnaeus, 1758) uses large beetles such as *Acrocinus longimanus* (Linnaeus, 1758) (Cerambycidae) as phoretic vectors. Its dispersal on beetles constitutes an important feature in the reproduction and sexual selection of pseudoscorpions (Zeh & Zeh, 1991; Zeh & Zeh, 1992b). In both cases, the relationship established between the pseudoscorpion and the phoretic vector favored the selection of more specific behaviors for dispersal or complex reproductive behaviors that partially depend on vector presence (Zeh & Zeh, 1992c; Zeh & Zeh, 1992d).

Phoresy is a phylogenetically old behavior and is well known among pseudoscorpions (Judson, 2003). This relationship mainly involves flying insects (Poinar et al., 1998), but there are cases of more specific association with vertebrates, birds, and mammals (Francke & Villegas-Guzmán, 2006; Finlayson, Madani, Dennis & Harvey, 2015; Turienzo, Di Iorio & Mahnert, 2010; Villegas-Guzman & Pérez, 2005). Phoresy has been reported in at least 24 species and 10 families of pseudoscorpions (Poinar et al., 1998). This behavior also seems to be common among Brazilian pseudoscorpion species. Studies conducted in the Amazonian region reported associations among 30 pseudoscorpion species and 59 arthropod vectors (Aguiar & Bührnheim, 1998; Santos, Tizo-Pedroso & Fernandes, 2005). In the Brazilian savannah, or Cerrado, social pseudoscorpion *Paratemnoides nidificator* (Balzan, 1888) depends on insects like beetles and stinkbugs to propagate a fraction of adult individuals to found colonies in new habitats (Tizo-Pedroso & Del-Claro, 2007). Recently, a study reported phoretic dispersal of *Americhernes* aff. *incertus* Mahnert (1979), in Atlantic rain forest fragment in Northeastern Brazil. In this case, adult pseudoscorpions attach themselves to the abdominal sternites of the fly *Fannia canicularis* (Linnaeus, 1761) (Lira et al., 2014).

Despite this, studies involving pseudoscorpions in Brazil are still scarce and recent (Del-Claro & Tizo-Pedroso, 2009; Tizo-Pedroso & Del-Claro, 2011; Tizo-Pedroso & Del-Claro, 2014). In the present study, we report phoresy of the Chernetid pseudoscorpion *Sphenochernes camponoti* (Beier, 1970) on flies in the *Caatinga* biome in Northeastern Brazil. The findings of the present study on the ecology and behavior of these arachnids will contribute to a better understanding of the structure of phoretic interactions in the *Caatinga* of Brazil and stimulate future studies on pseudoscorpions.

Material and methods

A field study was performed in January 2015 - the rainy season - in two areas of *Caatinga* vegetation in Northeastern Brazil, Pernambuco State (Buíque – 08º35'08.2"S, 037º14'29.3"W, and Betânia – 08º16'29"S, 38º02'03"W). Although near each other, the sample sites each present a specific phytophysiognomy regulated by different bioclimatic characteristics. Buíque houses the Catimbau National Park and has vegetation predominantly composed of sub-deciduous and deciduous forest, with insertions of *Caatinga* (Andrade, Rodal, Lucena & Gomes, 2004; Vital, Santos & Alves, 2008). It climate is semiarid with an average annual temperature of 21°C and precipitation of 926 mm year^{-1}. By contrast, Betânia is characterized as typical *Caatinga* vegetation and can be classified as hyperxerophilic *Caatinga* with areas of deciduous forest (Rodal, Costa, & Silva, 2008). The climate is semiarid with an average annual temperature of 26°C and 432 mm/year of irregularly distributed precipitation (Vasconcellos et al., 2010).

Suspended traps containing bovine spleen in the initial stages of decomposition as bait (Carmo & Vasconcelos, 2016) were used to collect insects in the study areas. At each sample site, a grid of 10 traps was laid out, with 20 m between traps, and exposed for 48 hours. Adult flies collected from traps were placed in 70% alcohol and identified using specific taxonomic keys (Carvalho, Moura & Ribeiro, 2002; Wendt & Carvalho, 2009). The pseudoscorpions attached to the bodies of the flies were recorded and identified using the Adis and Mahnert (2002) specific taxonomical key and by the comparison with species descriptions provided by Mello-Leitão (1925), Turk (1953), and Beier (1970). To confirm the identification of pseudoscorpions, measurements of their body size and appendages (pedipalps, legs, and chelicerae) were performed using a microscope (Coleman XTB-3AT). Voucher specimens of dipterans and pseudoscorpions were deposited at the Entomological and Arachnological

Collection of *Universidade Federal de Pernambuco*, Brazil, respectively. Pseudoscorpion individuals used for identification were deposited at the Arachnological Collection of *Universidade Estadual de Goiás*, câmpus Morrinhos, under code SCR-001/2016.

Results and discussion

The flies collected were identified as *Fannia pusio* (Wiedemann, 1830), *F. yenhedi* Albuquerque, 1957, and *F. canicularis,* which all belong to family Fanniidae, and the pseudoscorpions were identified as *S. camponoti*. We captured 12 flies (*F. pusio,* n = 7; *F. yenhedi* n = 4; and *F. canicularis* n = 1), carrying only one pseudoscorpion per fly. The animals remained fixed to the phoretic vectors even after collection and preservation in 70% alcohol and were manually removed for identification.

The pseudoscorpions were confirmed as nymphal stages including three tritonymphs and nine deutonymphs; they were positioned ventrally, attached to sternite II using both of their pedipalps. Each pseudoscorpion was positioned parallel to the fly's body, with its ventral side turned toward the ventral side of the fly. All pseudoscorpions were collected during the wet season. The three fly species are morphologically very similar, with nearly identical body size. Furthermore, the flies present similar behaviors and feeding habits, which could favor their relationship with pseudoscorpions.

In total, we obtained 12 pseudoscorpions, all nymphs (second or third instars). For species identification, it is necessary to compare measurements of adult appendages. Thus, identification based on young individuals may favor the comparison of several taxonomic attributes, but not all. Here, we proceeded with identification by determining the pseudoscorpion family and genus based on taxonomic keys presented by Beier (1970), Mahnert, Di Iorio, Turienzo, and Porta (2011). However, the literature does not provide an extensive description of young individuals.

Morphological analysis showed the venom apparatus present in the movable finger, tarsi with proximal raised slit sensillum, and chelal fingers with an accessory tooth (Chernetidae family). The tarsus of leg IV lacked a long tactile seta. Setae on the pedipalps were strongly clavate. The carapace had two clear transverse grooves and densely grained bristles (genus *Sphenochernes*). Two eye spots were present. The pedipalpal femur was 2.26–2.28 times, the patella 2.0–2.1 times, and the chela 2.59–2.62 times longer than broad.

Until this time, there have been three known species in genus *Sphenochernes* (Harvey, 2011). Here, we consider that species we obtained might correspond with a known *Sphenochernes* species. According to the key and *Sphenochernes* species characteristics provided by Mahnert et al. (2011), the species obtained in our study do not correspond with *S. schulzi* Turk, 1953 or *S. bruchi* (Mello-Leitão, 1925). Although we collected only young individuals, morphometrical measurements approximated those presented by Beier (1970) and Mahnert (1985) for *S. camponoti*. Thus, we considered all specimens in our study as belonging to *S. camponoti* (Figure 1).

Figure 1. A tritonymph *Sphenochernes camponoti* (Beier 1970) (Chernetidae) obtained in phoresy from *Fannia* dipteran collections in the Northeast region of Brazil (Pernambuco state). Scale bar = 1 mm

To our knowledge, we report here the first documentation of phoresy by *Sphenochernes camponoti*. Specimens examined by Beier were obtained from nests of *Camponotus rufipes* (Fabricius, 1775) ants in the São Paulo region (Beier, 1970). The same author reported many pseudoscorpions (both adults and nymphs) living inside *C. rufipes* colonies, in numbers reaching hundreds of individuals.

Although the myrmecophilous habit of *Sphenochernes* spp. and their association with at least two ant species (Mello-Leitão, 1925; Turk, 1953) is known, to our knowledge there have been no studies on phoretic relationships among pseudoscorpions and ants. Considering that previous studies found young and adult individuals living inside ant nests, *Sphenochernes* pseudoscorpions probably have a complex relationship with ants, which could involve behaviors and adaptations to prevent detection and killing by the ants. However, we can suppose that such association could be facultative.

Additionally, some studies found fly species and *Camponotus* visiting and feeding on animal carcasses in different regions of Brazil. The cooccurrence of flies and ants could give pseudoscorpions the opportunity to find new hosts or dispersal insects (Carvalho, Thyssen, Linhares, & Palhares, 2000; De Faria, Paseto, Couri, Mello-Patiu, & Mendes, 2017; Faria et al., 2013). Pseudoscorpions transported to carcasses on flies' bodies could locate new host ants and attach themselves to ant bodies to be transported to the colony or simply follow the ants returning to their colonies. This habitat overlap among pseudoscorpions and their host and dispersal vector species could favor new studies on the evolution of species interactions.

Likely, there is little habitat overlap among host ants and *Fannia* flies Robineau-Desvoidy, 1830. Pseudoscorpions must access the flies by eventual contact on the ground or vegetation. Thus, *S. camponoti* should leave ant nests to find phoretic vectors. Here, we report dispersal only by nymphal pseudoscorpions. Phoresy seems to be predominant in adult pseudoscorpions, which makes it difficult to speculate about dispersal in the juvenile phase.

In the present study, only one pseudoscorpion was found on each fly. A similar pattern was described by Lira et al. (2014) for phoretic relationships between pseudoscorpion *A. incertus* and fly *F. canicularis*. These authors argued that similarity in the body size of these animals, with the pseudoscorpions encumbering the vector, prevents the transportation of more than one specimen at a time. Frequently, pseudoscorpions attach themselves to appendages, such as arthropod's legs, antennae, or wings (Poinar et al., 1998). These appendages are easier to hold on to and probably offer less risk of damage from the host. In the present study, the pseudoscorpions were observed to attach to the vectors in a different manner. Apart from the more typical attachment to a fly's legs (Christophoryová, Stloukal & Stloukalová, 2011; Santos et al., 2005), the attachment of a pseudoscorpion to the fly's abdomen might be a specialized behavior making flight easier.

In addition, the highly seasonal nature of the Caatinga is almost certainly a determining factor for phoretic relationships owing to the marked influence rainfall and temperature patterns exert on the ecosystem. Arthropod reproduction and dispersal are more commonly associated with the rainy season (Silva, Frizzas & Oliveira, 2011; Vasconcellos et al., 2010), and so the wet season in arid and semi-arid ecosystems such as the Caatinga provides favorable environmental conditions for the development of many invertebrates (Araújo, Candido, Araújo, Dias, & Vasconcellos, 2010; Vasconcellos et al., 2010). This increase in invertebrate abundance is associated with renewed plant growth and acceleration in the decomposition of the leaf litter accumulated during the dry season (Whitford, 1996; Wolda, 1988). The rainy season could promote conditions favorable to pseudoscorpions encountering their dispersal vectors and finding new hosts. However, the mechanisms and processes related to phoresy in pseudoscorpions remain little known. Thus, this study may provide an opportunity for further investigations to increase our understanding of species interactions and the mechanisms involved in the evolution of phoresy in pseudoscorpions.

Conclusion

Although it is known for its myrmecophilous habit, the pseudoscorpion *Sphenochernes camponoti* associates with other species of arthropods for dispersal. The association established with Diptera in this study suggests that the pseudoscorpion needs to leave ant nests to find the phoretic vector, and thus, reach new habitats and probably new host colonies.

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