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SHORT COMMUNICATION

What's for dinner? Prey consumption by Neotropical scorpions across contrasting environments

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Abstract. The overall assumption that scorpions are generalist predators is often based on conspicuous information from the literature. Here, we compiled a list of prey consumption by scorpions from different environments in Brazil to produce a documentation of predations by this taxon. This list is based on observations made under natural conditions in Atlantic Forest, Caatinga, and Cerrado formations. We compiled 135 predation instances including 11 scorpion species from field work through 14 years. The observed diet composition of the scorpions was mainly based on cockroaches, crickets, grasshoppers, spiders, and other scorpions. Such data highlights the generalist diet and cannibalism of scorpions with many cannibalistic events among the records of intraguild predation. Overall, this study broadens the knowledge of the diet composition of Brazilian scorpions under natural conditions.

Keywords: Dietary breadth, diet composition, food webs
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Several studies have investigated the trophic interactions of predators and their influence on ecosystem functioning (e.g., Welch et al. 2012; Sanders et al. 2015; Staudacher et al. 2018). These studies usually use empirical data, such as prey abundance, habitat complexity, and resource partitioning, to investigate the predator-prey population dynamics (e.g., Sanders et al. 2015; Dionisio-da-Silva et al. 2018; Staudacher et al. 2018; van Schrojenstein-Lantman et al. 2021). Unfortunately, the relative scarcity of empirical information regarding the diet composition of many predators has led us to make several generalizations when it comes to ecological inferences of trophic interactions (e.g., Chen & Wise 1999; Schmitz & Suttle 2001; Welch et al. 2012; Lira et al. 2016). Several arthropods, for example, are arbitrarily classified as generalists, which is the case for many scorpions and spiders (McCormick & Polis 1990; Sanders et al. 2015).

Scorpions are known to be voracious predators, feeding on many invertebrates (including other scorpions) (Polis 1990) and even small vertebrates (McCormick & Polis 1982; Valdez 2020). It does not mean, however, that all scorpions are generalist predators. There are a few examples showing that some scorpion species may have very specific requirements in terms of food preferences. For instance, *Tityus uruguayensis* Borelli, 1901, tends to preferentially feed on spiders, compared to other arthropods (McCormick & Polis 1990; Toscano-Gadea & Costa 2006). Yet, cannibalism was frequently observed among specimens of the sand scorpion *Smeringurus mesaensis* (Stahnke, 1957), constituting an impressive amount of ingested biomass in this species (Polis 1988). The limited examples of predation under natural conditions in scorpions may result from the scarcity of data addressing the feeding behavior of these animals. Thus, to extend the current knowledge about feeding ecology of these animals in natural habitats, we summarized a list of prey species consumed by scorpion species from different habitats in Brazil. This list was compiled from occasional observations made under natural conditions, as part of many field experiments conducted by our research group in Brazil over the last 14 years.

All observations on scorpion predation occurrences were performed under natural conditions throughout active search and recorded between 2008 and 2022 in three contrasting habitats in Brazil – Atlantic forest, Caatinga, and Cerrado biomes (Fig. 1). The annual temperature ranges from 12 to 25°C in Atlantic Forest (Colombo & Joly 2010); 25 to 30°C in Caatinga drylands (Andrade et al. 2017), and 22 to 27°C in Cerrado formations (Ribeiro & Dias 2007). Pluviometric indexes are usually more than 4,000 mm per year in Atlantic forest and bounded between 600 mm to 1,000 mm in Caatinga, and 2,000 to 2,200 mm in Cerrado landscapes (Oliveira-Filho & Fontes 2000; Câmara 2003; Ribeiro & Dias 2007; Andrade et al. 2017). Whenever possible, predation events were photographed and both the scorpions and their prey were collected and preserved in 70% ethanol (Fig. 2). Scorpions were identified according to Lourenço (2002). The specimens consumed by scorpions were primarily classified according to their taxonomic order. A second classification level was applied to holometabolic taxa present in our dataset (e.g., larva or adult). In addition, Hymenoptera was subdivided into Apoidea (bees) and Vespoidea (ants). From a functional perspective, this classification system is justifiable as many insects exhibit ontogenetic shifts in their life stories and resource use, as is the case with Coleoptera and Lepidoptera (e.g., Werner & Gilliam 1984; Unsicker et al. 2008; Grof-Tisza et al. 2015; Kerley et al. 2018). Theoretically, these shifts may affect the energy flow of ecosystems (Nakazawa 2015). When scorpions were found preying on other scorpions, the specimens preyed upon were identified as conspecifics or non-conspecifics. The specimens were deposited at the Arachnological collection of Universidade Federal de Pernambuco, Entomological collection of Universidade Federal de Pernambuco, and the Invertebrate Collection of Laboratory of Subterranean Studies of Universidade Federal de São Carlos.

Figure 1.—Sampling localities of scorpion predation events in the Atlantic Forest, Caatinga and Cerrado biomes.

A total of 135 predation events were recorded. These included 11 scorpion species: *Ananteris mauryi* Lourenço, 1982, *A. balzanii* Thorell, 1891, *Bothriurus asper* Pocock, 1893, *Bothriurus rochai* Mello-Leitão, 1932, *Jaguajir rochae* (Borelli, 1910), *Physoctonus debilis* (C.L. Koch, 1840), *Tityus pusillus* Pocock, 1893, *T. carvalhoi* Mello-Leitão, 1945, *Troglorhopalurus lacrau* (Lourenço & Pinto-da-Rocha, 1997), *Tr. translucidus* Lourenço, 2004, and *Ischnotelson peruassu* Esposito, Yamaguti, Souza, Pinto-da-Rocha & Prendini, 2017. In general, scorpions preyed on a wide range of arthropod taxa (Fig. 3). Predation was observed on 19 arthropod groups (Table 1) according to the functional classifications adopted here: Araneae, Blattodea, Chilopoda, Coleoptera (larvae), Coleoptera (adults), Diptera, Apoidea, Vespoidea, Lepidoptera (larvae), Lepidoptera (adults), Mantodea, Opiliones, Orthoptera, Phasmatodea, Scorpiones (conspecifics), Scorpiones (non-conspecifics), Zygoptera, Isoptera, and Hemiptera. Among them, Blattodea (14.1%), non-conspecific scorpions (14.1%), Araneae (12.6%), conspecific scorpions (12.6%), and Orthoptera (11.9%) were the five most common prey (Table 1). The scorpion species with more predation records were *T. pusillus*, *J. rochae*, and *P. debilis*; these were found preying on 11, eight, and seven arthropod groups, respectively. On the other hand, *A. balzanii* and *T. carvalhoi* were found preying on only one arthropod group (Table 1). Most of the observations ($n = 74$) were performed in Caatinga habitats, while Atlantic forest and Cerrado accounted for 56 and five predation records, respectively.

In this study, we summarized a list of prey consumed by scorpion species from different habitats in Brazil. Our findings suggests that, under natural conditions, scorpions, cockroaches, spiders, and orthopterans were the most recorded prey consumed by Brazilian scorpions. Prey selectivity is generally a result of nutritional quality and easy seizure. Although highly nutritional prey may increase a predator's fitness (e.g., fecundity, growth rate, and survival), generalist predators may show preferences for prey items that are easy to capture (Eubanks & Denno 2000; Fantinou et al. 2009). This depends not only on prey abundance but also on other factors such as microhabitat use (Feitosa et al. 2002; Desneux & O'Neil 2008; Sanders et al. 2015). Overall, scorpions are sedentary animals that capture prey that inhabits the same microhabitat where they live (McReynolds 2008). So, the prey items reported here may reflect the interactions between scorpions and other arthropods that share the same microhabitat.

Scorpions are aggressive with smaller species and their own juveniles, and many times they prey on them (Polis & McCormick 1987; Lira et al. 2017). The recurrent record of intraguild predation and cannibalism in this work is also observed in previous studies (e.g., Lira & Costa 2014; Lira et al. 2017; Dionisio-da-Silva & Lira 2019). The predation of others scorpion species and their own juveniles may be beneficial to the predator as potential competitors are eliminated (Polis et al. 1989). Many studies point to intraguild prey constituting the most

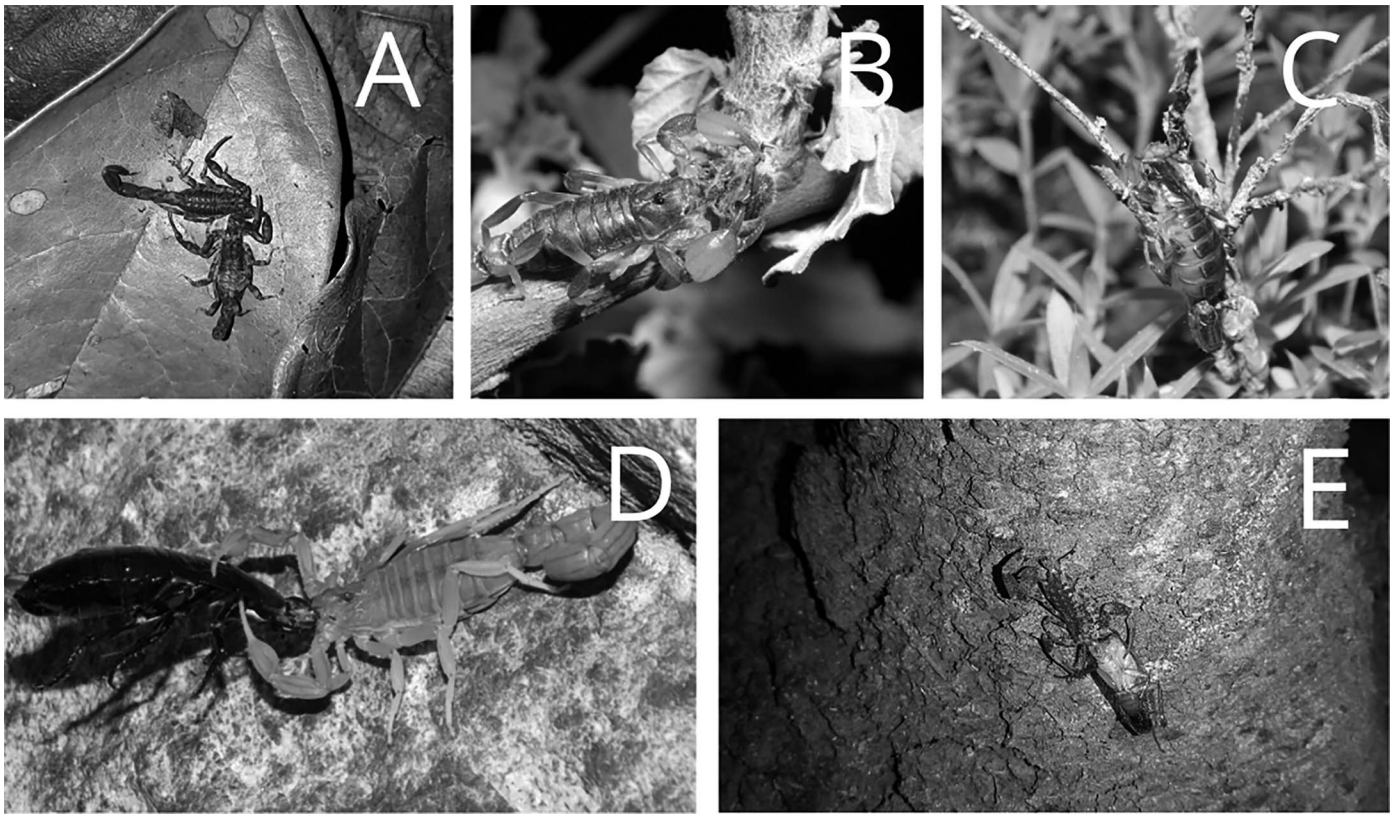

Figure 2.—Scorpion species preying upon many arthropod groups. (A) *Ananteris mauryi* Lourenço, 1982 preying upon a conspecific, (B) *Bothriurus rochai* Mello-Leitão, 1932 preying upon a spider, (C) *Bothriurus asper* Pocock, 1893 preying upon an ant, (D) *Jaguajir rochae* (Borelli, 1910) and (E) *Tityus pusillus* Pocock, 1893 preying upon cockroaches.

consumed prey items by scorpions, with such antagonistic interaction influencing behavior and population dynamics of these arachnids (e.g., Polis & McCormick 1987; Sánchez-Piñero & Urbano-Tenorio 2016; Feitosa et al. 2022).

In general, this work extended the knowledge of the dietary items of Brazilian scorpions, by providing a descriptive list of prey items consumed by these arachnids under natural circumstances. Such information, if coupled with ontogenetic shifts and functional traits of scorpions (and their prey), may offer the opportunity to develop further studies addressing trophic webs and their impact on ecosystem functioning in neotropical habitats.

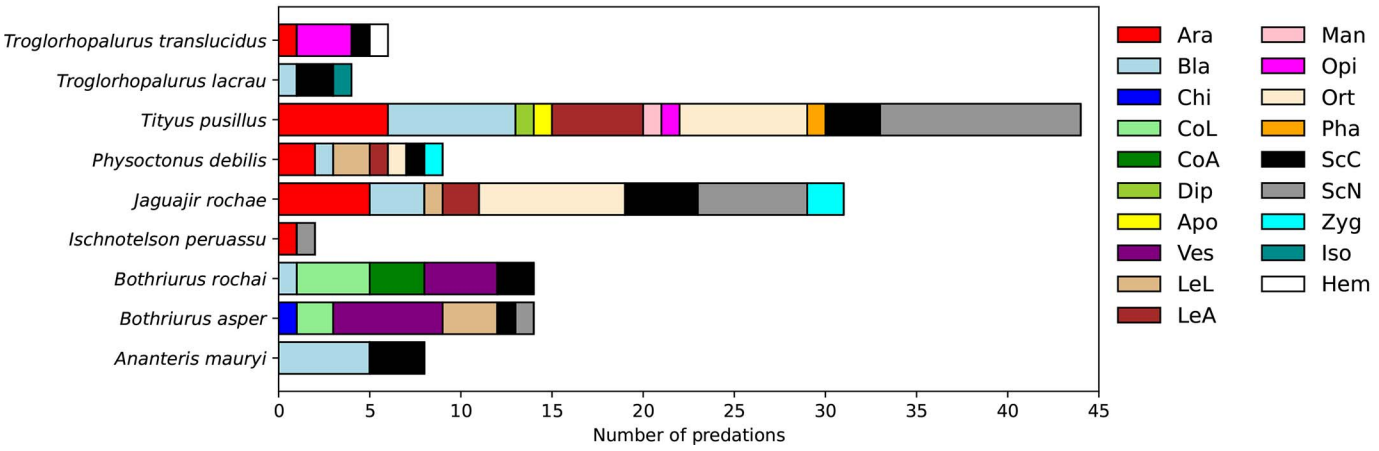

Figure 3.—Number of arthropod prey items consumed by scorpion species from Brazil. Scorpion species that preyed on only one type of prey (see Table 1) were excluded from the plot. Abbreviations are: Apoidea (Apo), Araneae (Ara), Blattodea (Bla), Chilopoda (Chi), Coleoptera – adult (CoA), Coleoptera – larvae (CoL), Diptera (Dip), Hemiptera (Hem), Isoptera (Iso), Lepidoptera – adult (LeA), Lepidoptera – larvae (LeL), Mantodea (Man), Opiliones (Opi), Orthoptera (Ort), Phasmatodea (Pha), Scorpiones – conspecific (ScC), Scorpiones – non-conspecific (ScN), Vespoidea (Ves), and Zygentoma (Zyg).

Table 1.—Number of prey items consumed by scorpion species from the Caatinga dry forest and the Atlantic Forest, northeastern Brazil: Apoidea (Apo), Araneae (Ara), Blattodea (Bla), Chilopoda (Chi), Coleoptera – adult (CoA), Coleoptera – larvae (CoL), Diptera (Dip), Hemiptera (Hem), Isoptera (Iso), Lepidoptera – adult (LeA), Lepidoptera – larvae (LeL), Mantodea (Man), Opiliones (Opi), Orthoptera (Ort), Phasmatodea (Pha), Scorpiones – conspecific (ScC), Scorpiones – non-conspecific (ScN), Vespoidea (Ves), and Zygentoma (Zyg).

		Prey captured																			
Scorpion species	Site	Ara	Bla	Chi	CoL	CoA	Dip	Apo	Ves	LeL	LeA	Man	Opi	Ort	Pha	ScC	ScN	Zyg	Iso	Hem	Total
Ananteris balzanii	Cerrado	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Ananteris mauryi	Atlantic forest	—	5	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	8
Bothriurus asper	Caatinga	—	—	1	2	—	—	—	6	3	—	—	—	—	—	1	1	—	—	—	14
Bothriurus rochai	Caatinga	—	1	—	4	3	—	—	4	—	—	—	—	—	—	2	—	—	—	—	14
Ischnotelson peruassu	Cerrado	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	3
Jaguajir rochae	Caatinga	5	3	—	—	—	—	—	—	1	2	—	—	8	—	4	6	2	—	—	31
Physoctonus debilis	Caatinga	2	1	—	—	—	—	—	—	2	1	—	—	1	—	1	—	1	—	—	9
Tityus carvalhoi	Cerrado	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Tityus pusillus	Atlantic forest	6	5	—	—	—	1	1	—	—	5	1	1	7	1	3	11	—	—	—	42
Tityus pusillus	Caatinga	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Troglorhopalurus lacrau	Caatinga (cave)	—	1	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	1	—	4
Troglorhopalurus translucidus	Atlantic forest (cave)	1	—	—	—	—	—	—	—	—	—	—	3	—	—	1	—	—	—	1	6
Total		17	19	1	6	3	1	1	10	6	8	1	4	16	1	17	19	3	1	1	135

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