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Scientific Note

A rare trophic interaction: Carnivory by *Helicogonus princeps* (Brölemann, 1902) (Diplopoda, Spirostreptida, Spirostreptidae) on the frog *Physalaemus cuvieri* Fitzinger, 1826 (Anura, Leptodactylidae) in Brazil

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Abstract. Millipedes (Diplopoda) are predominantly detritivores, and reports of carnivory in the group remain rare. Here, we describe a potential case of perimortem predation involving the frog *Physalaemus cuvieri* Fitzinger, 1826 (Anura, Leptodactylidae) and the millipede *Helicogonus princeps* (Brölemann, 1902) (Diplopoda, Spirostreptida, Spirostreptidae) in Brazil. Two adult females of *H. princeps* were observed tightly coiled around the frog and consuming its tissues over a 20-hour period. Although it was not possible to determine whether the frog was alive at the onset of the interaction, the behavior suggests either opportunistic predation or carrion feeding. This event represents one of the few documented instances of vertebrate consumption by millipedes and highlights the need for further investigation into the trophic ecology of this understudied group.

Keywords: Carnivory, postmortem, Cerrado, Taphonomy, Spirostreptida.

The arthropod class Diplopoda (millipedes) is recognized for playing a crucial part in the decomposition of plant matter and nutrient cycling (David 2015; Nsengimana et al. 2018; Potapov et al. 2019). Millipedes do not possess any known behavior or anatomical structures associated with active predation, which makes any carnivory in the group a rare event. Nonetheless, reports of carnivory in millipede species date back to the late 19th century (Latzel 1884; Plateau 1887; vom Rath 1891). One of the millipede groups that stands out for their carnivorous behavior is the order Callipodida (not found in Brazil), with some species documented feeding on invertebrates, including immature millipedes (Enghoff et al. 2015). In general, invertebrates are the most common prey for millipedes, such as earthworms, flies, crickets, and spiders (Hoffman & Payne 1969). Hoffman & Payne (1969) summarized some field observations of millipede species associated with the carcasses of baby pigs, with individuals taking cover beneath the dry skin, cartilage, and bones (Payne 1967; Payne et al. 1968).

One of the few cases of frog predation by a millipede in Brazil was documented by Schubart (1947), who observed nearly a dozen individuals of *Heteropyge araguayensis* (Schubart, 1947) (Spirostreptida, Spirostreptidae) feeding on a treefrog of the genus *Hyla* Laurenti, 1768 (Hylidae) throughout the night. In this context, and to contribute to the understanding of predatory behavior in millipedes, we report here a rare interaction involving the frog *Physalaemus cuvieri* Fitzinger, 1826 (Anura, Leptodactylidae) and the milliped *Helicogonus princeps* (Brölemann, 1902) (Spirostreptida, Spirostreptidae) in Brazil. To our knowledge, this represents one of the few documented instances of a frog potentially falling prey to a millipede during or shortly after death.

The event occurred at the "Parque Estadual das Furnas do Bom Jesus" - PEFBJ (-20.256622; -47.460104; WGS84, 1,011 m a.s.l. (meters above sea level) (Fig. 1), which covers a total of approximately 2070 hectares located in the municipality of Pedregulho, São Paulo, Brazil (Fig. 1A) (Branco et al. 1991). The area is part of the Brazilian Cerrado, characterized by a type of xerophytic forest known as "cerradão" (Fig. 1B–C). On October 21st, 2023, during the early morning hours, we found an individual of *P. cuvieri* (snout-vent length = 26.52mm – MRCM 1419; collected and transported under permit SISBIO #81669-1) being tightly constricted by two adult females of *H. princeps* (Fig. 2A–B) inside a pitfall trap that had been installed by the field team approximately 12 hours earlier. Based on our observation, it was not possible to determine whether the frog was still alive or already dead when the constriction began. All the millipedes and frog individuals were carefully accommodated and transported to the laboratory for better observation. During the whole event it was possible to see the millipedes foraging in parts of the frog with their mandibles and gnathochilarium (Fig. 2A–B). After being intentionally disturbed, the millipedes released the frog, revealing that there was no skin, only a few soft tissues and the skeleton almost entirely dried (Fig. 2C–D). The entire event lasted approximately 20 hours, from the accommodation of the individuals until the release of the frog. Females of the millipede species were first identified based on the species description by Brölemann (1902). Subsequent samplings were conducted in the region to locate adult males and confirm species identification through the morphology of their sexual structures. The material examined of millipede is deposited at the Instituto Butantan, São Paulo, Brazil (IBSP; curator: A.D. Brescovit).

The relatively well-documented biology of *P. cuvieri*, a widely distributed and adaptable frog species found across diverse Brazilian ecosystems and beyond (Frost 2024), contrasts sharply with the limited knowledge regarding its interactions with millipedes. *Physalaemus cuvieri* is considered a relatively tolerant species to anthropized environments, as indicated by its relative abundance in open and warm areas typical of human-modified landscapes in the Cerrado (e.g., Diaz-Ricaurte et al. 2020), suggesting ecological plasticity that favors survival

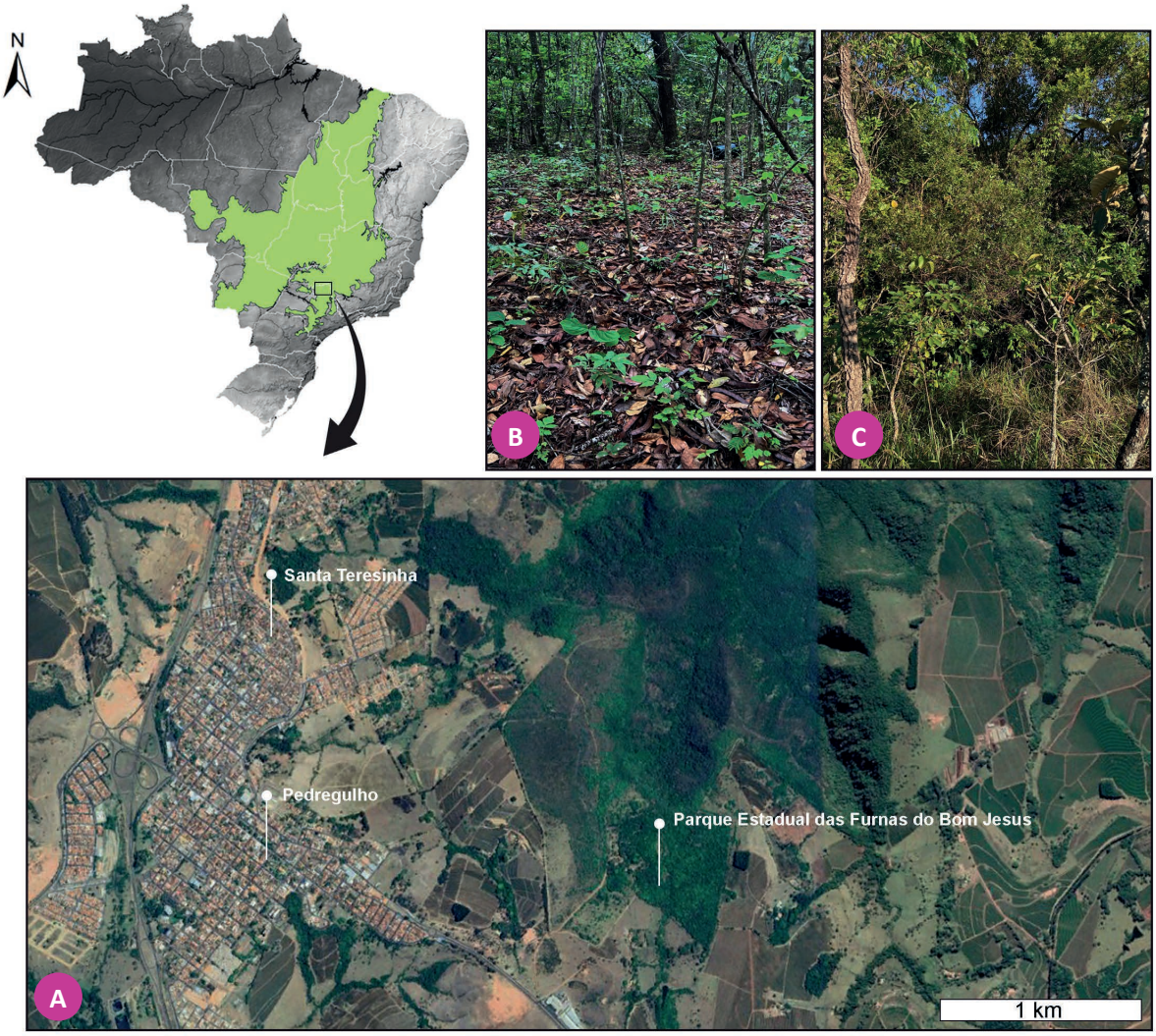

Figure 1. Brazil with the Cerrado highlighted in green: A) Locality of the event, referencing the municipality of Pedregulho, Santa Teresinha, and the Parque Estadual das Furnas do Bom Jesus (PEFBJ); B–C) Fragments of "Cerradão" where the frog and the millipede were observed.

Figure 2. The event involving the frog *Physalaemus cuvieri* by the millipede *Helicogonus princeps*: A–B) Millipede females involving the frog. Note the head of a millipede actively foraging on the frog body; C) Frog body partially exposed after millipede release *in situ*; D) Frog body exposed.

in disturbed habitats. While various vertebrates and invertebrates are known to prey upon *P. cuvieri* (Brasileiro et al. 2005; Duryea et al. 2008; Teles et al. 2018), our study provides the first documented association between this frog species and millipedes. This observation of two adult female *H. princeps* consuming a *P. cuvieri* individual over an extended period is particularly noteworthy, given the predominance of detritivory within Diplopoda. It suggests a potentially opportunistic or even facultative carnivorous behavior in this species. The significant size disparity between *H. princeps* (110-160 mm) and *P. cuvieri* (approximately four times smaller) likely played a crucial role in enabling this interaction. The suffocation hypothesis, proposed by Hoffman & Payne (1969) for the predation event involving *H. araguayensis* is also plausible in our case, supported by the larger size of *H. princeps* and the defensive coiling behavior typical of spirostreptidan millipedes.

Given the scarcity of studies on the biology of Neotropical millipedes (Hoffman et al. 1996; Iniesta et al. 2023), our findings represent a valuable contribution by documenting a rare trophic interaction between *P. cuvieri* and *H. princeps*. Although the observed behavior resembles active predation–considering the physical restraint, prolonged interaction, and targeted tissue consumption, we cannot confirm whether the frog was alive at the onset of the interaction. As such, we acknowledge the alternative possibility of carrion feeding. Nevertheless, the ecological significance of this event remains, as it reveals a poorly known interaction between millipedes and small vertebrates. These observations provide novel insights into the diet of *H. princeps* and raise new questions about the complexity of predator–prey dynamics in Brazilian ecosystems.

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Authors' Contributions

JCDR, JPSVA: Conceptualization, Investigation, Writing-original draft, Editing; LFMI: Investigation, Writing-review, Editing; RSB: Investigation, Writing-review; MM: Supervision, Editing.

Conflict of Interest Statement

The authors declare that there is no conflict of interest related to the publication of this manuscript.

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