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Predation of a mustached bat, *Pteronotus* sp. (Mormoopidae), by an Amazon tree boa, *Corallus hortulanus* (Boidae), in the Brazilian Amazon

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ABSTRACT

Several bat species use caves as roosts and some of these caves can harbor high concentrations of individuals. Such caves may represent opportunities for certain predators, benefiting from the concentration of potential prey. Here, we report the predation of a *Pteronotus* bat by a *Corallus hortulanus* in the Brazilian Amazon. On three occasions over a year, individuals of *C. hortulanus* were observed around a cave that harbors populations containing tens of thousands of bats. On one occasion, an individual of this snake species was observed preying on a *Pteronotus* sp. as it left the cave. Our record extends the known diet for *C. hortulanus*, documenting the predation of a mormoopid bat by this snake species for the first time. This record reinforces the need for longitudinal studies at sites with exceptional bat populations to gain a deeper understanding of the ecological predator-prey relationships involving this diverse group of mammals.

KEYWORDS: ambush predator; cave-dwelling bat; Chiroptera; Carajás National Forest; predator-prey interaction

Predação de um morcego bigodudo, *Pteronotus* sp. (Mormoopidae), por uma suaçuboia, *Corallus hortulanus* (Boidae), na Amazônia brasileira

RESUMO

Várias espécies de morcego usam cavernas como abrigo e algumas dessas cavernas podem abrigar altas concentrações de indivíduos. Tais cavernas podem representar oportunidades para determinados predadores, beneficiados pela concentração de presas potenciais. Aqui, relatamos a predação de um morcego *Pteronotus* por uma serpente *Corallus hortulanus* na Amazônia brasileira. Em três ocasiões ao longo de um ano, indivíduos de *C. hortulanus* foram observados na entrada e entorno de uma caverna que abriga populações contendo dezenas de milhares de morcegos. Em uma ocasião, um indivíduo dessa espécie de serpente foi observado predando um *Pteronotus* sp. ao emergir da caverna. Nosso registro amplia a dieta conhecida para *C. hortulanus*, documentando pela primeira vez a predação de um mormoopídeo por esta espécie de serpente. Este registro reforça a necessidade de estudos longitudinais em locais com populações excepcionais de morcegos para obtermos uma compreensão mais profunda das relações ecológicas predador-presa envolvendo esse diversificado grupo de mamíferos.

PALAVRAS-CHAVE: predador de emboscada; morcego cavernícola; Chiroptera; Floresta Nacional de Carajás; interação predador-presa

Predator-prey coevolution is characterized as an inherently reciprocal process where the defensive adaptation of the prey results in a stronger selection of the predator to exploit such defenses (e.g., Brodie and Wilkinson 2010). Bats are known as predators of several species, and although non-phytophagous bats exploit a wide range of prey (i.e., insects, arachnids, small vertebrates), including groups displaying diverse adaptations to a more specialized diet (e.g., piscivorous, sanguivorous), there are very few natural predators specialized/adapted to hunt bats. Examples are the bat hawk, *Macheiramphus alcinus* Westermann, 1851, which feeds primarily on bats (Fenton *et al.* 1977; Black *et al.* 1979), the bat falcon, *Falco rufigularis* Daudin, 1800, whose dietary mammal component can be composed of up to 97% of bats (Beebe 1950), and the Puerto Rican boa, *Chilabothrus inornatus* (Reinhardt, 1843), which is often reported ambushing at the entrance of bat roosts such as caves (e.g., Rodríguez-Durán 1996). Bats are also opportunistically preyed upon by a large number of non-specialized predators, especially birds of prey, owls, and snakes, although records of natural predation (i.e., without any type of interference and/or human facilitation) are scarce in the literature (see Costa *et al.* 2016).

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Mormoopid bats (Chiroptera) have a wide geographic distribution, occurring from the southwestern USA, throughout Central America to northeastern Brazil and northeastern Bolivia (Pavan 2019). *Pteronotus* is the most specious genus of the Mormoopidae, with 16 currently recognized species (Pavan 2019). This genus is known to be obligate cave-dwelling where it forms large aggregations containing thousands of individuals (Rodríguez-Durán and Lewis 1987; Pavan 2019; Pimentel *et al*. 2022).

Boidae snakes mainly have ambush behavior (sit-and-wait predators), and the strategy of ambushing in places with greater flow/visitation of potential prey has been reported for some species (e.g., Rodríguez-Durán 1996; Esbérard and Vrcibradic 2007; Rocha-Santos *et al*. 2014). The Amazon tree boa, *Corallus hortulanus* (Linnaeus, 1758), an arboreal boid snake that exhibits both active and ambush foraging, is the most widespread species of *Corallus* in South America and feeds mainly on birds and mammals (including bats) (Henderson 1997; Scartozzoni and Molina 2004; Pizzatto *et al*. 2009; Handerson and Pauers 2012). In Brazil, as far as bats are concerned, this snake was previously recorded preying on *Artibeus obscurus* (Schinz, 1821), *Artibeus* sp., *Carollia perspicillata* (Linnaeus, 1758), *Myotis* sp., and *Platyrrhinus lineatus* (É. Geoffroy, 1810) (Barnett *et al*. 2007; Esbérard and Vrcibradic 2007; Pizzatto *et al*. 2009; Carvalho *et al*. 2019).

On April 1, 2022, during fieldwork for biomonitoring of caves in the Carajás National Forest, municipality of Parauapebas, Pará State, Brazil, the predation of a mustached bat (*Pteronotus* sp.) by a *C. hortulanus* was observed (in the cave N5SM2-0099; 06°08'09.2"S, 50°07'47.8"W; 480 m a.s.l.; Figure 1). Four species of *Pteronotus* shelter in sympatry in that cave: *P. alitonus* Pavan, Bobrowiec & Percequillo, 2018 (Amazonian common mustached bat), *P. gymnonotus* (Wagner, 1843) (big naked-backed bat), *P. personatus* (Wagner, 1843) (Wagner's lesser mustached bat), and *P. rubiginosus* (Wagner, 1843) (Wagner's common mustached bat). At least five other bat species use this cave: *Carollia perspicillata*, *Glossophaga soricina* (Pallas, 1766), *Lampronycteris brachyotis* (Dobson, 1879), *Phyllostomus hastatus* (Pallas, 1767), and *Trachops cirrhosus* (Spix, 1823).

On the same day of the predation event, we used a motion detection algorithm to automatically track and count the bats (Rodrigues *et al*. 2016; Otálora-Ardila *et al*. 2019). The emergence of bats began at 18:00 h and lasted for 90 min (= 5,400 s), and our population census showed 88,464 bats sheltering in the cave, mostly *Pteronotus* spp. Therefore, during the emergence period, there were an average of 16 bats per second leaving the cave (88,464/5,400). The Amazon tree boa was initially observed around 17:00 h, resting next to the vegetation just above one of the cave entrances, where there is a large bat outflow (Figure 2a,b). With the beginning of the emergence of bats, the snake left its resting position and assumed a hunting posture, heading closer to the bat flow (Figure 2c). At around 19:00 h, that snake captured a *Pteronotus* sp. (an individual of *P. alitonus* or *P. rubiginosus*) by the head and constricted it (Figure 2d). From the time of our observation to the complete ingestion of the bat, about 40 min passed (Figure 2e,f).

We excluded the possibility that the preyed bat was a *P. gymnonotus* because this species has the membrane of the wings

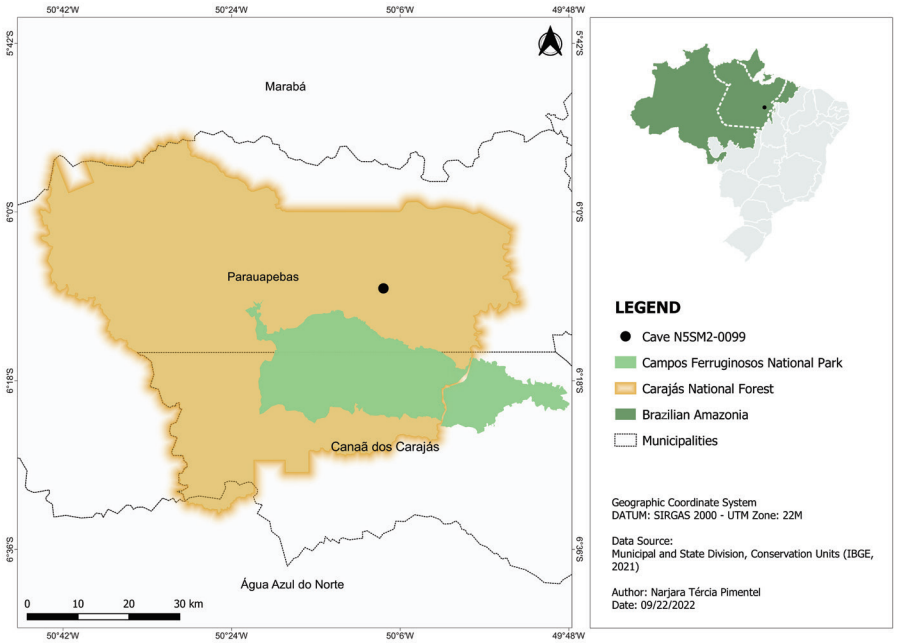

Figure 1. Location of the cave where the predation of a mustached bat, *Pteronotus* sp. (Mormoopidae), by an Amazon tree boa (*Corallus hortulanus*) was recorded. This figure is in color in the electronic version.

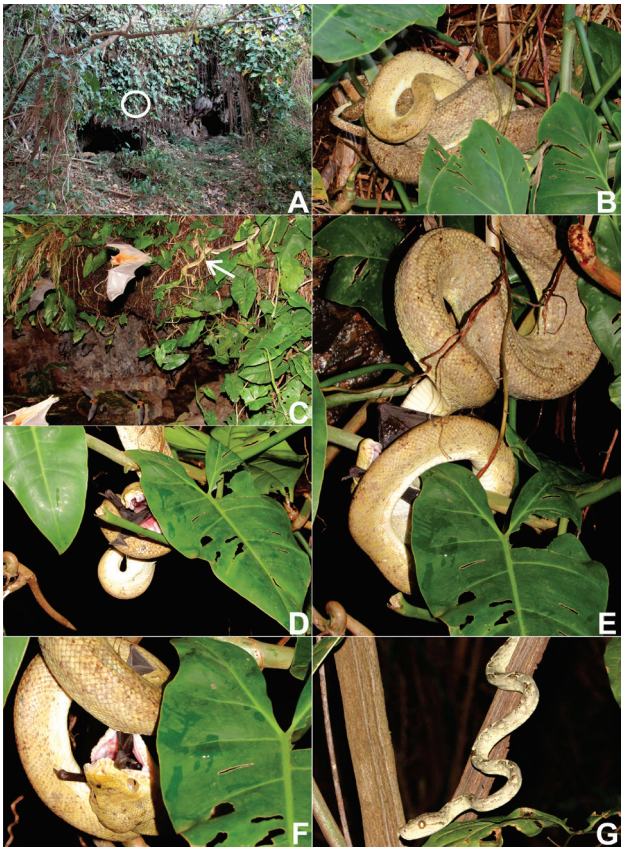

Figure 2. Details of the predation event of a mustached bat, *Pteronotus* sp. (Mormoopidae), by an Amazon tree boa (*Corallus hortulanus*) in the Brazilian Amazon. A – Cave entrances, with emphasis on the place where *C. hortulanus* was observed (white circle); B – *C. hortulanus* resting before the beginning of the bat emergence; C – Emergence of *Pteronotus* bats and movement of the snake towards the outflow to ambush (white arrow); D – Capture and constriction of a *Pteronotus* sp. by *C. hortulanus*; E – Beginning of the bat's ingestion; F – Finishing the bat's ingestion; G – Example of another *C. hortulanus* observed around the cave, exhibiting a sit-and-wait behavior. This figure is in color in the electronic version.

joined in the middle of the back, giving it the appearance of having a naked back (and this characteristic was not present in the preyed individual). We also excluded *P. personatus* because this is the smallest species occurring in the cave (body mass = 6.5–10 g; forearm length = 43–48 mm) (Pavan 2019). *Pteronotus alitonus* has a mass of 18–26 g and a forearm of 59–64 mm, while *P. rubiginosus* has 20–27 g and 61–67 mm, respectively (Pavan 2019). This size discrepancy can be easily distinguished *in situ*. On the other hand, due to the similarity of the external morphological characteristics, we were not able to differentiate the preyed individual between *P. alitonus* and *P. rubiginosus*.

On the same night of predation, other smaller individuals (probably younger) of *C. hortulanus* were observed on the vegetation around the cave entrance. During our field expeditions in July 2021 and June and July 2022, we also observed *C. hortulanus* individuals around the same cave and hanging in lianas close to the main flight path used by bats during their emergence, but predation was not observed (Figure 2g). This aggregation of individuals of *C. hortulanus* in the same area, and in a time interval of 1 year, suggest this bat caves may be serving as a known and preferred ambush site of successful predation for this snake.

Roosting in large aggregations provides advantages, but also disadvantages such as attracting potential predators (Kunz and Fenton 2003). Bat caves that house thousands of bats have a higher temperature and strong odor (Ladle et al. 2012), characteristics that can attract snakes. Indeed, the detection of potential prey by boid snakes seems to be an association of thermal, chemical, and visual stimuli (e.g., Cock Buning 1983; Scartozzoni and Molina 2004). All these factors likely favor the location of bat caves by these snakes. The clustering behavior at cave entrances with high densities of bats has also been reported for *C. inornatus* (e.g., Rodríguez and Reagan 1984; Rodríguez-Durán 1996). Studies using snake tagging, for example, may generate information on whether this behavior is restricted to a few individuals or if it is common to the species and shared.

Although bats emerge from the cave with considerable flight speed, the high number of individuals leaving at the same time should favor capture by snakes. *Corallus hortulanus* has the fastest lunge speed among four boid species, ranging between 90.91 and 151.52 cm sec^{-1} (Charles 2007). This attribute may favor the capture of moving prey, such as bats emerging from their diurnal roosts, in addition to thermal, chemical, and visual cues, as previously mentioned.

To the best of our knowledge, the only previous published records of predation by mormoopids in Brazil were by a spider (*Lasiodora* sp.) and anurans (*Leptodactylus vastus* Lutz, 1930 and *Rhinella jimi* (Stevaux, 2002)) (Gouveia *et al*. 2009; Dias *et al*. 2015). In all these previous cases, the preyed bat was *P. personatus*. Therefore, this is the first documented trophic interaction event for *C. hortulanus* and *Pteronotus* and the third record of predators preying on a mormoopid in Brazil. While bats play a fundamental ecological role by preying on different taxonomic groups, they can also participate in the food web as important prey for other animals such as snakes.

A review of bat predation in Brazil showed that snakes, along with birds, are the main predators of this mammalian group, and those predations occurred mainly in the bat's roost or its surroundings (Costa *et al*. 2016). So, roosts containing large aggregations of bats can be interesting sites for long-term trophic ecology studies involving the predation of these mammals. Among other matters of interest, this may indicate whether bats are predominant/preferred food items or they merely supplement the diet of their potential predators.

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DATA AVAILABILITY

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