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Herpetofauna in stingless bee hives (Meliponini) managed in a Brazilian Amazon forest fragment: predation or shelter?

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Bees play a fundamental role in environmental preservation, being responsible for up to 90% of the pollination of angiosperms in tropical forests (Giannini et al., 2015). The rearing of stingless bees is known to be an easy-to-manage practice (Nogueira-Neto, 1997; Campos and Peruqueti, 1999). However, several precautions are necessary to keep the hives in good condition and production effective, for instance, cleaning the meliponary to avoid attacks and incidents caused by predatory and/or venomous animals (Nogueira-Neto, 1997).

Honey production is an important activity for the socioeconomy of traditional communities in the Amazon region, especially in the state of Amapá (Heinzen, 2019). In Amapá, there are 143 species of bees described so far (Moure et al., 2024), of which at least 53 are species of social and stingless bees (Silveira et al., 2002; Frazão and Silveira, 2004).

Unlike apiculture (rearing of stinging bees), in meliponiculture the hives are installed for management, enabling to group a larger amount of hives with a focus on honey production. This model is implemented in the meliponary of the Bioparque da Amazônia Arinaldo Gomes Barreto, located in the municipality of Macapá (Amapá), where three species of bees are being managed and displayed as attractions for guided visits: *Melipona compressipes* (Fabricius, 1804), *Melipona fulva* Lepeletier, 1836, and *Melipona paraensis* Ducke, 1916 (Frazão and Silveira, 2004). These bees have several natural predators including invertebrates (e.g., ants and phorid flies, Villas-Bôas, 2012) and vertebrates (e.g., anurans, Silvester et al., 2018), which tend to stay around the hives, due to easy food and shelter, attacking bees when they are entering or leaving the hives (Pereira et al., 2012).

The research was carried out in populated and unpopulated hives, aiming to investigate which species of the local herpetofauna use the meliponary of the Bioparque da Amazônia Arinaldo Gomes Barreto (0.0391°N, 51.0968°W) for shelter or food. We started with the hypothesis that anuran species may be natural and opportunistic predators of stingless bees, and seek shelter in dark and humid places. The Bioparque has an area of 107 hectares that include three ecosystems: terra firme forest, Amazonian savannah, and periodically floodable fields (locally called *ressaca*). It is located in the green belt of Macapá city, among large forest fragments in the urban area (Fonseca and Silva, 2020).

To observe the presence of the herpetofauna species in the meliponary, we conducted inspections in 111 hives. The inspections took place over three days per week for a total of 11 weeks (October to December 2020), totalling 42 hours of observation. Observations took place in the morning (8:00–10:00 h).

The Common Snouted Treefrog, *Scinax ruber* (Laurenti, 1768), a Common Milk Frog, *Trachycephalus typhonius* (Linnaeus, 1758), and a Giant Parrot Snake, *Leptophis ahaetulla* (Linnaeus, 1758), were found during the inspections (Fig. 1). In unpopulated hives, we registered a total of 40 individuals of *S. ruber*, one *T. typhonius*, and one *L. ahaetulla*. Three individuals of *S. ruber* were recorded in a populated hive, in an empty space of the upper module between the lid and a geopropolis wall (composed of clay, resins and propolis) built by bees. We did not observe this *S. ruber*

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individual predating on bees.

Scinax ruber is a species commonly found in urbanised environments and disturbed areas (Lima et al., 2012). Several authors have commented on the ecology and feeding habits of *Scinax ruber*, that is mainly composed of insects (Muñoz-Guerrero et al., 2007; Blanco-Torres et al., 2017). Hence, the abundant presence of bees (~150,000) in a meliponary, combined with the presence of other natural invertebrate predators of bees in meliponaries, such as flies and ants (Villas-Bôas, 2012; Frazão, 2013), raises the hypothesis that this abundance of prey items favours the attraction of frogs to feed. Especially since the hives also offer shelter. Species of *Scinax* have generalist feeding habits and use the sit-and-wait foraging strategy (Silva et al., 2021). However, the observation that most *S. ruber* were present in empty hives, without evidence of bee predation, challenges this hypothesis. A potential preference to prey on other present insects, such as ants, spiders and mosquitoes (Muñoz-Guerrero et al., 2007; Blanco-Torres et al., 2017), may be an explanation for the absence of predation on bees inside the hives. However, we did not observe *S. ruber* preying on bees at the hive entrance. Unlike *Trachycephalus typhonius*, which was observed preying on bees at a hive entrance (Fig. 1C).

Local species interactions might however be more complicated. Namely, the presence of *Trachycephalus typhonius* at the hive entrance (Fig. 1C) and *Leptophis ahaetulla* that was on top of the hives (Fig. 1D), which are both generalist and opportunistic species in diet and habitat (Measey *et al*. 2015; Glaudas et al. 2019), indicate a predation web (snake-frog-bees). *Trachycephalus typhonius* is a nocturnal large hylid that inhabits disturbed environments such as agroecosystem and even human housing (Weiler et al., 2013). In general, their diet includes spiders, orthopterans, dipterans, homopterans, coleopterans and hymenopterans (Vaz-Silva et al., 2004; Dure and Kehr, 2006; Araújo-Silva et al., 2024), including other frog species (Sugai et al., 2017). *Leptophis ahaetulla* is a diurnal and semi-arboreal snake, harmless to humans, and feeds predominantly on hylid frogs, especially *Scinax* sp. (Albuquerque et al., 2007; Alcantara et al., 2017). In addition, observations of predation attempt by *Leptophis* on other large hylid frogs, including *Boana boans* (Gama and Costa-Campos, 2014), *Trachycephalus* cf. *mesophaeus* (Solé et al., 2010) and *Osteocephalus taurinus* (Cunha et al., 2023) have been documented. As anurans of the *Scinax* genus are abundant in the meliponary, the presence of *T. typhonius* and *L. ahaetulla* may thus be related to food availability.

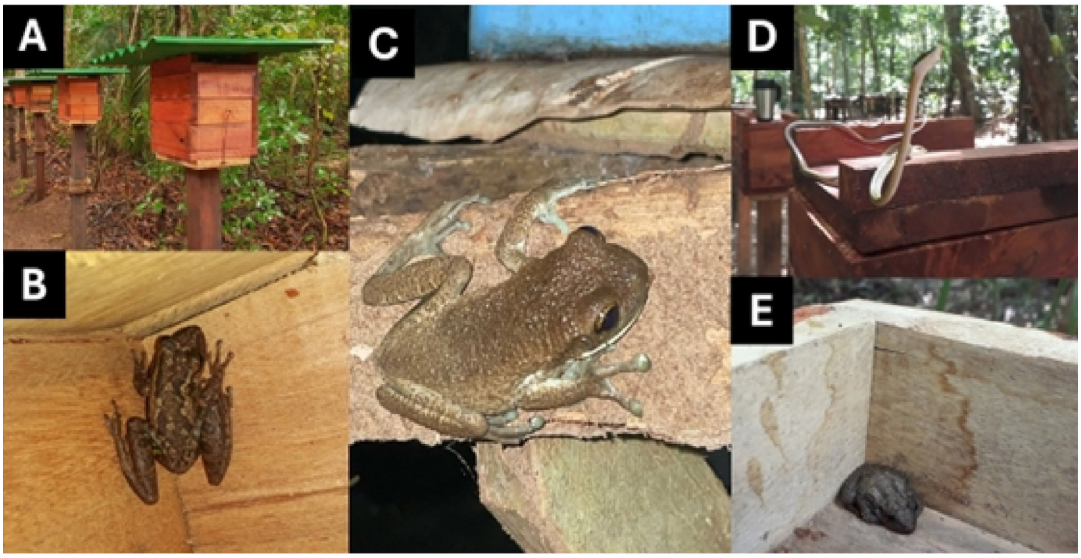

Figure 1. Mosaic of figures with individuals found in the hives of the Meliponary of the Bioparque da Amazônia Arinaldo Gomes Barreto. (A) Stingless bee system in meliponary. (B) *Scinax ruber* inside the hive. (C) *Trachycephalus typhonius* waiting at the hive entrance to prey on bees. (D) *Leptophis ahaetulla* under a hive in the meliponary at night. (E) Individual of *Scinax ruber* observed during the day in the meliponary. Photos by Richardson Frazão.

Our results indicate that *S. ruber* has a strong preference for the empty hives, using them as a diurnal artificial shelter. Additionally, the absence of stingless bee predation by *S. ruber* suggests that the hives become an ideal place for shelter, and since they are closed it prevents the entry of light and possible predators such as snakes. To date, our hypothesis that *S. ruber* would be a bee predator has not been confirmed. For a more conclusive analysis, the evaluation of the stomach content of *S. ruber* is another method to assess this hypothesis. We note that the hives offer a rich feeding opportunity for *Trachycephalus typhonius* (that preys on bees; Fig. 1C) and *L. ahaetulla* (that preys on ants, anurans). Trophic plasticity in generalist anurans and snakes provides them with an advantage in disturbed environments where prey availability changes (Segura et al., 2007; López et al., 2015). Our results suggest that stingless bee hives are important resources for multiple species of the herpetofauna. Future studies may demonstrate stingless bee hives are critical components to the environment in maintaining herpetological diversity.

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