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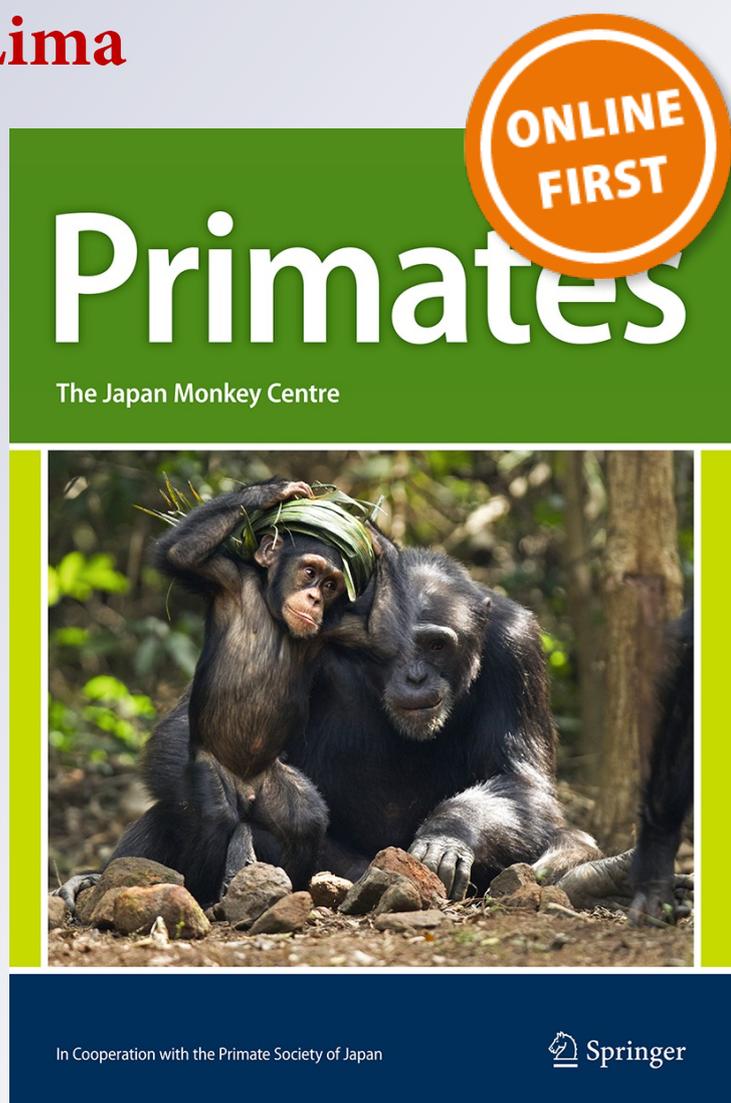
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Predation of a squirrel monkey (*Saimiri sciureus*) by an Amazon tree boa (*Corallus hortulanus*): even small boids may be a potential threat to small-bodied platyrrhines

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Abstract Predation has been suggested to play a major role in the evolution of primate ecology, although reports of predation events are very rare. Mammalian carnivores, raptors, and snakes are known predators of Neotropical primates, and most reported attacks by snakes are attributed to *Boa constrictor* (terrestrial boas). Here, we document the predation of a squirrel monkey (*Saimiri sciureus*) by an Amazon tree boa (*Corallus hortulanus*), the first record of the predation of a platyrrhine primate by this boid. The event was recorded during a nocturnal herpetological survey in the Piratuba Lake Biological Reserve, in the north-eastern Brazilian Amazon. The snake was encountered at 20:00 hours on the ground next to a stream, at the final stage of ingesting the monkey. The *C. hortulanus* specimen was 1620 mm in length (SVL) and weighed 650 g, while the *S. sciureus* was a young adult female weighing 600 g, 92 % of the body mass of the snake and the largest prey item known to have been ingested by a *C. hortulanus*. The evidence indicates that the predation event occurred at the end of the afternoon or early evening, and that, while

capable of capturing an agile monkey like *Saimiri*, *C. hortulanus* may be limited to capturing small platyrrhines such as callitrichines.

Keywords Amazonia · Boid snake · Cebidae · Platyrrhini · Stomach contents

Introduction

Predation pressure and associated behaviours have been suggested to play a central role in the evolution of primate ecology and behaviour patterns such as group living (Cheney and Wrangham 1987; Isbell 1994, 2006; Miller 2002; Stanford 2002; Miller and Treves 2011; Campos and Fedigan 2014; Coleman and Hill 2014). However, predation events are infrequent and unpredictable, and are recorded very rarely (Cheney and Wrangham 1987; Stanford 2002; Ferrari 2009), limiting the analysis of predation rates and risks (van Schaik 1983; Cheney and Wrangham 1987; Boinski et al. 2000; Ferrari 2009; Miller and Treves 2011). Even when cases are documented, the descriptions are often incomplete (e.g., Quintino and Bicca-Marques 2013; Teixeira et al. 2016). Despite the paucity of direct evidence, the growing body of individual case studies has provided a basis for the analysis of certain trends in primate ecology and behaviour (see Isbell 1994, 2006; Mitani et al. 2012).

A number of studies have provided evidence that the principal predators of primates are mammalian carnivores and raptors (Isbell 1994; Miller and Treves 2011; Cristóbal-Azkarate et al. 2015). In the Neotropics, snakes also play a major role, with attacks being attributed to anacondas, vipers, and terrestrial boas (Heymann 1987; Corrêa and Coutinho 1997; Perry et al. 2003; Ferrari et al. 2004;

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Cisneros-Heredia et al. 2005; Ferrari and Beltrão-Mendes 2011; Quintino and Bicca-Marques 2013; Teixeira et al. 2016).

Nine species of tree boa, genus *Corallus*, occur between Central America (Guatemala) and southern South America (south-eastern Brazil), including in the oceanic islands (Henderson et al. 2013). This genus includes *Corallus hortulanus*, one of the most common snakes found in the Neotropics, which ranges between tropical rainforests of the Guianas, southeast Venezuela, southeastern Colombia, Ecuador, Peru, Bolivia, and Brazil, as well as the arid scrub of the Brazilian Cerrado and Caatinga (Henderson et al. 1995, 2013; Rodrigues 1996; Henderson 1997; Henderson and Pauers 2012). In a comprehensive study of the diet of *C. hortulanus*, Henderson and Pauers (2012) analysed 126 prey records from the Guianas, Amazonia, and the Brazilian Atlantic Forest, and recorded a variety of items, including birds, bats, marsupials, rodents, frogs, and lizards. Pizzatto et al. (2009) provided additional prey records, including nestling psittacids.

Squirrel monkeys (genus *Saimiri*) are widespread in the Amazon Basin and southern Central America, where they inhabit the middle strata of the forest (Terborgh 1983; Hershkovitz 1984; Boinski 1989). The genus comprises eight species with 11 terminal taxa (Mercês et al. 2015). *Saimiri sciureus* is restricted to northeastern Amazonia, north of the Amazon River and east of the Negro and Branco rivers. Only two predation events have been reported to date in squirrel monkeys. One is the recent observation of the remains of a *Saimiri cassiquiarensis* in the nest of an ornate hawk-eagle, *Spizaetus ornatus*, in the western Amazon basin (Lopes et al. 2015), and the other was a personal communication reported by Martins and Oliveira (1998:12), which referred to the predation of a *S. sciureus* by a *Boa constrictor*.

Here, we report on the predation of a squirrel monkey (*S. sciureus*) by an Amazon tree boa (*C. hortulanus*). Although Henderson (2015) speculated that species of *Corallus* prey on small primates, here we present the first documented predation of a monkey by *Corallus*, which is much smaller than *Boa* or *Eunectes*. The snake was, in fact, virtually the same size (body mass) as its prey, and while this arboreal species may represent a major potential threat to small-bodied platyrrhines such as callitrichines, it seems unlikely that it will normally prey on larger monkeys, even male *Saimiri*.

Methods

Study site

The case of predation was documented during a herpetological survey in Rego do Duarte (01°46'29''N,

50°19'26''W) in the Piratuba Lake Biological Reserve (Rebio Lago Piratuba), Amapá state, Brazil. The area is located in the Atlantic sector of the Amapá coastal plains, near the delta of the Amazon River, an area where the coastal plain expands into a large complex of lakes (Martins et al. 2011). The Piratuba Lake reserve is a fully protected conservation unit (only the indirect use of natural resources is permitted) of 392,469.11 ha, in Brazilian Amazonia. About 45 % of the area is covered by periodically or permanently flooded marshlands with small patches of rainforest, and about 36 % by mangrove forest dominated by palms (Costa-Neto 2004). The remaining area is mangrove forest without palms (~13 %) and savanna grassland (~6 %). The climate is AF-AM in the Köppen classification, with a short dry season from September to November. Annual rainfall is over 3250 mm, with a mean monthly temperature of 25 °C (Silveira 1998).

Field observations and data collection

During the survey in the Rebio Lago Piratuba, groups of squirrel monkeys were observed frequently. In the mangroves of Rego do Duarte, groups of *S. sciureus* comprised of about 20 individuals were observed feeding, often forming mixed-species groups with capuchins (*Cebus olivaceus*). Four other primate species are found in the mangrove of this region (Silva et al. 2013).

The primary purpose of the survey was the collection of specimens for an inventory of the reptilian and amphibian faunas of the study area. Specimens were located through active searching, during which, substrates were investigated systematically for evidence of the presence of the target species. Specimens of interest were captured by and processed following McDiarmid et al (2012). Fieldwork was conducted between November 9 and 28, 2006, with a total of 40 h of surveying during the nocturnal period.

All the specimens collected were deposited in the Amapá State Institute of Scientific and Technological Research (IEPA), Macapá, Amapá, Brazil. Specimen collection was authorized by ICMBIO/SISBIO through special license 248/2006.

Results

On 27 November 2006, at 19:58 hours, a specimen of *C. hortulanus* was encountered on the ground at the margin of the Rego do Duarte stream. It was nearing the end of the ingestion of a prey (the tip of the tail was still visible; Fig. 1). The specimen was then collected, measured, and fixed following the work of McDiarmid et al (2012). The analysis of the specimen revealed that it was an adult female: 1620-mm snout–vent length (SVL); 440-mm tail

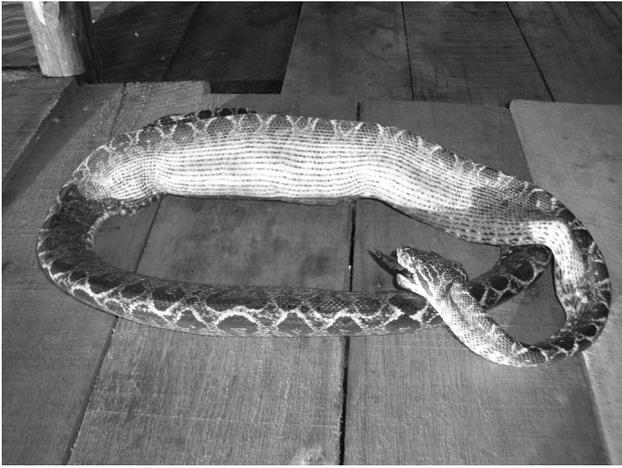


Fig. 1 The specimen of *C. hortulanus* (adult female; IEPA 311) collected during the herpetological survey in the study area. The end of the tail of the squirrel monkey can be seen emerging from the snake's mouth

length (TL); and 1250-g total weight (specimen + stomach contents). This is close to the maximum size recorded for snakes of this species, i.e., 1760 mm SVL (Pizzatto et al. 2009) and 1640 mm (Henderson 1997). The specimen was deposited under catalogue number IEPA 311, with the monkey being registered as associated content.

After 48 h, when the specimen was fixed, analysis of the stomach contents revealed a young, nulliparous adult female *S. sciureus* (Fig. 2), with a head-body length of 270 mm and body mass of 600 g. The dentition was fully-erupted, with no signs of wear. Once the stomach contents were removed, the body mass of the *C. hortulanus* specimen was confirmed at 650 g, only 7.7 % (50 g) heavier than the *Saimiri* specimen. The prey item was intact (Fig. 2).

Discussion

Boid snakes, especially *B. constrictor*, are known to prey on a wide variety of mammals (Pizzatto et al. 2009) and appear to be a major snake threat to platyrrhine primates such as *Alouatta puruensis* (Quintino and Bicca-Marques 2013), *Callicebus discolor* (Cisneros-Heredia et al. 2005), *Callithrix penicillata* (Teixeira et al. 2016), *Cebus albifrons* (Defler 1979), *Cebus capucinus* (Chapman 1986; Perry et al. 2003), *Chiropotes utahickae* (Ferrari et al. 2004), *Leontopithecus rosalia* (Kierulff et al. 2002), and *Saguinus mystax* (Tello et al. 2002). Heymann (1987) also recorded the predation of a moustached tamarin (*S. mystax*) by an anaconda (*Eunectes murinus*). Predation of platyrrhines by the Amazon tree boas (*Corallus* sp.) has not been recorded previously, possibly at least in part because



Fig. 2 Analysis of the stomach contents of the specimen of *C. hortulanus* (adult female; IEPA 311) showing the squirrel monkey (*S. sciureus*; adult female) still intact

of the relatively small size of this snake, which typically preys on small vertebrates, such as birds, bats, and rodents (Henderson and Pauers 2012). However, Bardecki and Heymann (1987) documented a case of snake-mobbing by tamarins against tree boas, supporting the claim that these snakes may represent a predatory threat.

Both *C. hortulanus* and *S. sciureus* are found typically in the middle strata of the forest and only occasionally come to the ground (Henderson 2002; Mercês et al. 2015). As *C. hortulanus* forages primarily between 18:00 and 23:30 hours (Henderson 2002; Silva and Henderson 2010) and takes 9–50 min to attack and ingest its prey

(Scartozzoni and Molina 2004, and Silva and Henderson 2010), the fact that the monkey was still intact (Fig. 2) indicates that the attack occurred between 1 and 2 h before the snake was encountered, at 19:58 hours, still ingesting the prey. This would be consistent with an attack at the end of the day (sunset on November 27 was at 18:15 hours), probably when the monkey was settling for the night, and was more vulnerable to predation (see Anderson 1998; Leichter 2012). Even though squirrel monkeys typically sleep at the ends of branches or palm fronds to minimize predation risk (Boinski 1987; Boinski and Sirot 1997; Leichter 2012), the Amazon tree boa is highly adapted for arboreal locomotion, and may easily access such locations (Henderson 2002; Pizzatto et al. 2007). The position of the snake when captured suggests that it fell or descended to the ground after capturing the monkey, presumably as a result of the relatively large size of the prey.

In primates, predation risk varies considerably among individuals and species of different body sizes (Schmitt and Di Fiore 2015). Smaller-bodied primates are more vulnerable to predation in general and to a wider range of potential predators than larger ones (Struhsaker 1986; Cheney and Wrangham 1987; Mitchell et al. 1991; Isbell 1994; Hill and Dunbar 1998; Ferrari 2009). While *C. hortulanus* is one of the most common and conspicuous bovid species in Amazon forests, it has rarely been observed capturing prey (Henderson 2002; Silva et al. 2012), and is probably too small to capture monkeys larger than an adult female *Saimiri*. This snake has an extremely diverse diet (Henderson 1993, 2002; Pizzatto et al. 2009; Henderson and Pauers 2012), and its short, narrow head and slender body may enable it to access prey in a variety of arboreal microhabitats (Pizzatto et al. 2007; Henderson et al. 2013). Pizzatto et al. (2009) found that more than half of the prey items ingested by *C. hortulanus* weighed up to 20 % of the snake's body mass, although some items weighed up to 95 % of the predator's mass. In general, high prey:predator ratios were recorded in the smaller snakes. In fact, the largest prey recorded was a southeastern four-eyed opossum (*Philander frenatus*) of 405 g, captured by a female *C. hortulanus* of 1300 g (prey:predator ratio of 31.2 %). The female squirrel monkey ingested by *C. hortulanus* was thus close to the upper limit of the predator:prey body mass ratio (92 %), and was by far the largest prey known to be captured by this snake species. Given this, it seems unlikely that this snake would normally present a real potential risk, even for adult male squirrel monkeys, which are 15–20 % heavier than females. While the Amazon tree boa may represent a potentially important predator of small platyrrhines, such as callitrichines and squirrel monkeys, it is perhaps surprising that no events have been recorded previously, which may mean either that the monkeys' anti-predator strategies are relatively effective or that predation

events are mostly restricted to periods (crepuscular, nocturnal) and environments (forest canopy) in which events are difficult to observe.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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