Primates (2019) 60:459–465
https://doi.org/10.1007/s10329-019-00738-9

ORIGINAL ARTICLE

A green racer snake (*Philodryas nattereri*, Colubridae) killed but not eaten by a blonde capuchin monkey (*Sapajus flavius*, Cebidae)

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Received: 29 December 2018 / Accepted: 26 July 2019 / Published online: 7 August 2019

Abstract
We report the killing of a snake (*Philodryas nattereri*, Colubridae) by a blonde capuchin monkey (*Sapajus flavius*, Cebidae). This endemic primate species from the northeast of Brazil includes vertebrates such as lizards and marsupials in its diet, but we can find no previously published record of an attack upon or consumption of snakes by this species of platyrhine monkey. During the attack, the group mobbed the snake, with individuals uttering agonistic vocalizations and displaying behaviors such as raising their tails, moving tree branches, piloerecting, and baring their teeth. An adult male monkey seized the snake, bit and twisted its body, thereby killing it; he then dropped the carcass onto tree branches, but did not consume it. This single event suggests that this Cebidae species may be able to distinguish dangerous from harmless snakes, and it also may be an example of a lethally violent reaction to a potential predator or competitor, exemplifying the plasticity and cognitive skills exhibited by genus *Sapajus*.

Keywords Interspecific interaction · Competition · Prey · Predation · Snake detection · *Sapajus flavius*

Introduction

The blonde capuchin monkey (*Sapajus flavius,* Shreber 1774) is an endemic species from Brazil rediscovered in 2006, and highly endangered (Ministério do Meio Ambiente 2014). The estimated total population is only about 1000 individuals, living in limited distributions in Brazilian northeastern Atlantic Forest, and Caatinga regions (Valença-Montenegro et al. 2015; Silva and Valença-Montenegro 2017).

Although vertebrates such as lizards (Tropiduridae), marsupials (Didelphidae), and bird eggs have been documented as part of the blonde capuchin diet (Rodrigues 2013; Rodrigues et al. 2013; Santos 2013; Lins 2015), there is no record of consumption or attacks upon snakes by this primate species. However, cebid monkey interactions with snakes have been documented in the literature (Vitale et al. 1990; Boitani et al. 1995; Boinski 1988; Isbell 2006; Meno et al. 2013; Falótico et al. 2018).

The green racer snake (*Philodryas nattereri*, Colubridae, Steindachner 1870) is diurnal and mainly terrestrial, although the species can also be found in arboreal situations and even on the roofs of houses in the northeast of Brazil and in arid and semi-arid regions of Colombia and Paraguay (Filho 2015). The green racer feeds mainly on lizards (Scincidae, Gekkonidae, Gymnophthalmidae, Phyllodactylidae, Teiidae and Tropiduridae), but mammals (Vespertilionidae, Didelphidae, Cricetidae, Echimyidae and Muridae), birds (Emberizidae), frogs (Bufonidae, Hylidae, and Leptodactylidae), eggs, and even other snakes (Colubridae and

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Dipsadidae) can also be part of its diet (Vitt and Vangilder 1983; de Mesquita et al. 2011).

A growing body of evidence shows that New World primates can discriminate between different types of snakes. White-faced capuchins (*Cebus capucinus*) of all ages, even infants, can perceive the difference between models of predatory snakes (e.g., *Boa constrictor* and *Crotalus durissus*), relatively harmless ones (*Drymarchon corais*), a white snake-like model, and a white model airplane as a novel control. All age classes recognized snakes and displayed antipredator behaviors, increasing their mobbing activity and uttering specific calls in response to the presence of predatory snakes, however, infants (4 months old) reacted less frequently than other age classes. The white snake models provoked a lesser response, indicating that the absence of color and snake scale patterns affected snake recognition (Meno et al. 2013).

When toy rubber snakes, 65 cm long, and painted with natural color patterns were used to stimulate and test the responses of *Sapajus apella* and *Macaca fascicularis* in laboratory situations, both species reacted at the first exposure to the model with a high degree of fear response. Nevertheless, the *S. apell*a individuals quickly calmed down after repeated exposure to the model snake, and the monkeys eventually increased their use of space, exploratory behaviors, and object manipulation back to normal levels. Furthermore, *S. apella* used tools to get closer to the models and even settled down and shared space with the snake model (Vitale et al. 1990).

Sapajus species have been documented responding to the challenges of survival in areas with limited local resources using omnivory, opportunistic foraging, and sharing food (Isbell 2006; Van Schaik and Brockman 2005). Tool use and defensive strategies are common reactions to cognitive challenges (Falótico et al. 2018). The ability to accurately and quickly assess risks in dangerous circumstances is essential to the survival of primates that live under hunting pressure and the threat of habitat destruction (Pinto 2008; Rodrigues 2013; Santos 2013; Valença-Montenegro et al. 2015). We report here the first case of the killing of a snake by a blonde capuchin monkey and discuss similar occurrences involving members of other *Sapajus* species and other primate genera.

Methods

The following event was observed in a population of *S. flavius* inhabiting a 650-ha fragment of Atlantic Forest (Fig. 1) called Sucupira Torta (06°57′36.2″S; 35°04′26.2″W). The area is connected to other fragments known collectively as

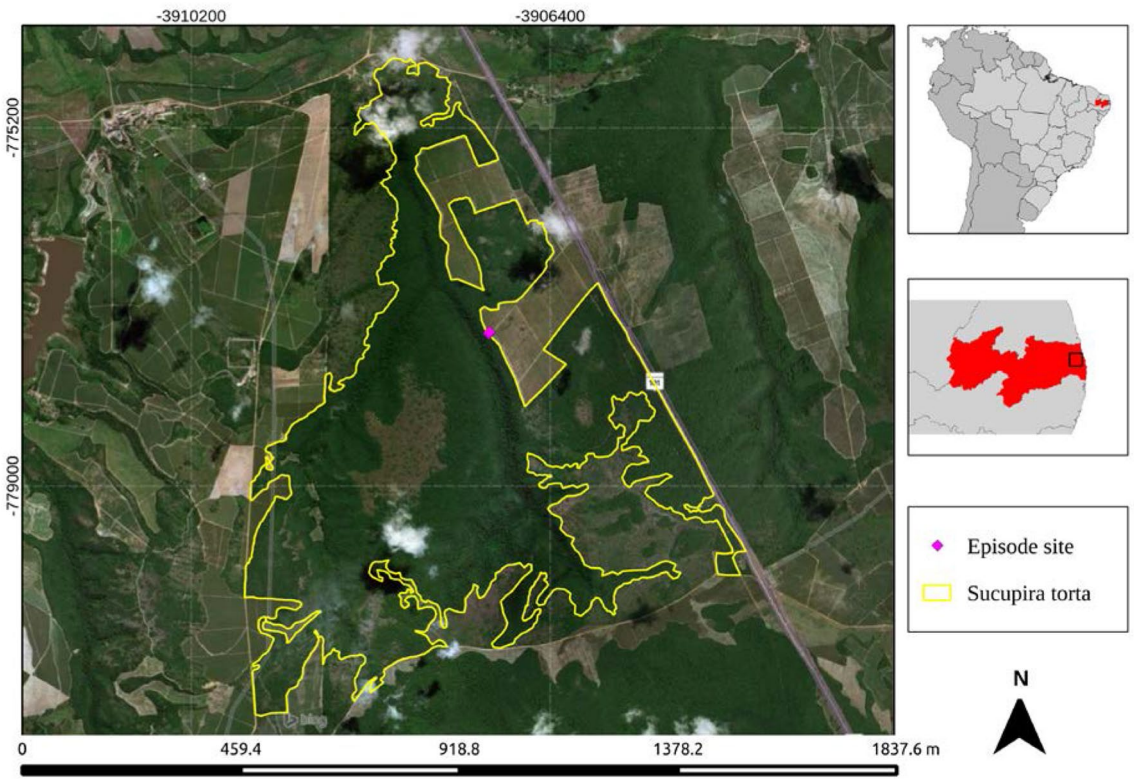

Fig. 1 Study area (Sucupira Torta) in Paraíba state (06°57′36.2″S; 35°04′26.2″W). The *point* marks the location of the attack upon *Philodryas nattereri* by *Sapajus flavius*. Source: Gibran Anderson

the Corridor Pacatúba-Gargaú in the state of Paraiba. In October 2016, the National Center for Research and Conservation of Brazilian Primates (Centro Nacional de Pesquisa e Conservação de Primatas Brasileiros/Instituto Chico Mendes de Conservação da Biodiversidade) initiated the first study of non-human primates species in the area.

The local capuchin population was in the process of habituation to the presence of humans. The monkeys did not receive supplementary food as part of this habituation, because other human activities were taking place in the forest, including hunting and illegal wood extraction. The total population was estimated at 60–120 monkeys. There were at least four groups composed of 10–40 individuals per group. These groups had been followed for 12 days, and had 4 h of direct observation when the event occurred. There were 30 individuals in the group that encountered the snake: 11 adult males, nine adult females, eight juveniles, and two infants, however, only 20 individuals mobbed the snake.

Observation

While G.A.O.S. and Mr. Adelson (his field assistant) were following a group of capuchins, they observed the attack, manipulation, and killing of a snake later identified as a 93-cm-long green racer (*P. nattereri*, Colubridae, Fig. 2). The attack occurred on December 19, 2016, at 15.45 h in a forest edge near a sugar cane plantation (*Saccharum* sp.) about 3 m away from the observing researcher and his guide (Fig. 3). The event lasted until 16.00 h (Fig. 3).

When recruitment vocalizations from the monkeys were heard, the blonde capuchins were seen close to the ground, foraging among the sugarcane. The monkeys then moved from the ground into the trees where the light was abundant, with clear observer visibility. Thereafter, continuous alarm vocalizations were uttered by the monkeys in the branches. The blonde capuchin monkeys were a few meters away from the green racer snake when a subgroup realized its presence. A subgroup of 20 monkeys were seen mobbing a snake settled in a tree near the sugarcane plantation: nine adult males, five adult females, five juveniles, and one infant. They exhibited various behaviors, including raising their tails; shaking, bending, and flailing tree branches back

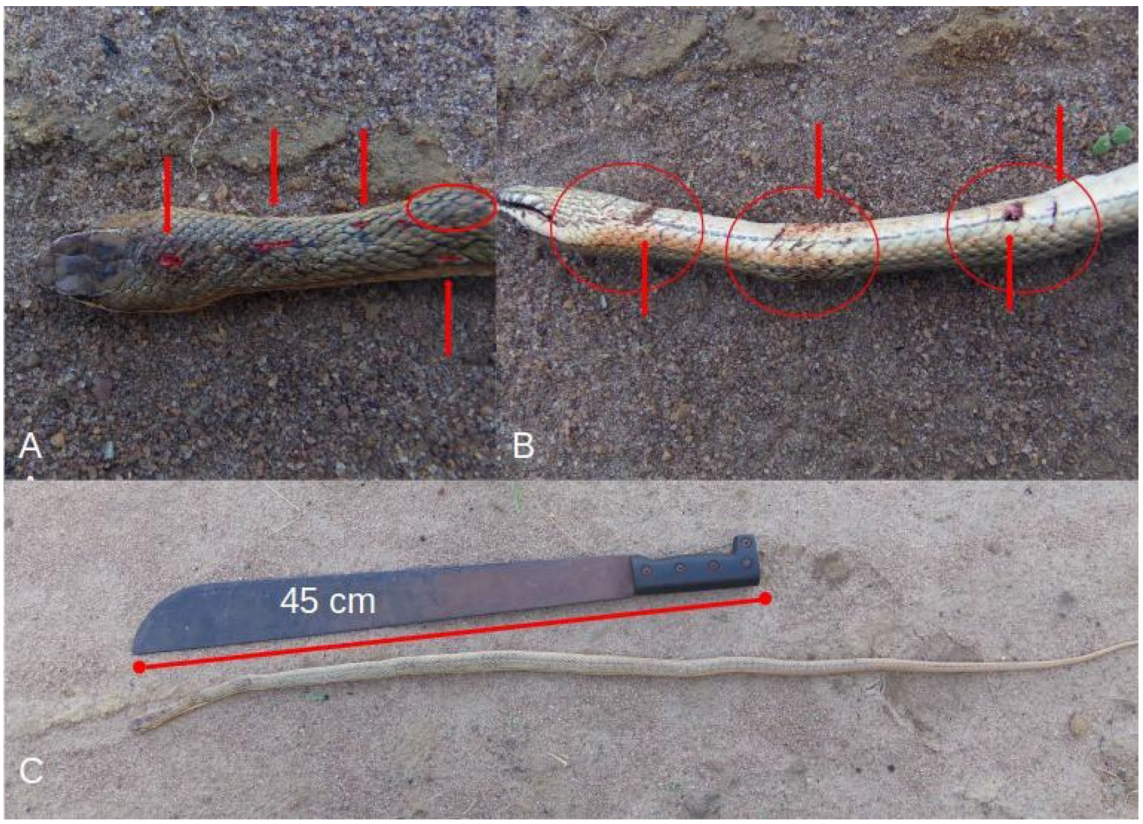

Fig. 2 Snake (*Philodryas nattereri*) carcass with bite marks (*arrows*) and evidence of twisting (*circles*). **a** Dorsal side, **b** lateral side, **c** full snake carcass. Source: Gibran Anderson

Fig. 3 Location of the attack by *Sapajus flavius* on *Philodryas nattereri.* **a** Forest edge (*right side*) near the sugarcane plantation (*left side*); **b** the branches from where the snake was dropped by the adult male monkey. Source: Gibran Anderson

and forth; piloerecting; baring their teeth and uttering alarm calls (de Araújo 2013). The juveniles and the infant avoided approaching the snake themselves, but they were watching, screaming, and piloerecting on tree branches further away.

At this point, some adult females and males were approaching the snake, flailing tree branches, baring their teeth, and uttering calls. Two adult males jumped closer to the reptile (about 40 cm), where they raised their tails and bent tree branches, but only one adult male initiated physical contact. He grabbed the snake, simultaneously biting and twisting its body (Fig. 2) while the other adult males, females, and juveniles continued to bark, watch, piloerect, and move the branches back and forth as the adult male bit the snake. After the death of the snake, the adult male dropped its body onto the branches below him (3 m above ground) and moved away from the scene. He did not consume the snake he had killed (Fig. 3). The group continued alarm calling as they fled from the location of the event.

Discussion

Snake killing by capuchin monkeys is rarely observed in the wild. Information about the interspecific interactions between snakes and primates is scarce. In this section, we discuss the hypotheses for the killing of a green racer snake by a blonde capuchin monkey, considering phenomena associated with the evolutionary history and ecological interactions between primate and snake lineages as prey, predators, and potential competitors (Headland and Greene 2011).

Primates feed on diverse small vertebrates and invertebrates, and they have been associated with attacks and killings of competitors and potential predators, such as snakes and other vertebrates (Headland and Greene 2011). The indigenous group Agta Negritos, from the Philippines, suffers predation attempts by reticulated pythons (*Python reticulatus*), but they prey upon and kill reticulated pythons, as well as wild pigs, deer, and monkeys, which are also eaten by pythons, exemplifying reciprocal interactions as prey, predator, and competitor between both lineages (Headland and Greene 2011).

Chimpanzees have been documented killing but not consuming a leopard cub as an anticipatory anti-predatory and anti-competitory act. Both species prey on bushbuck, bush pig, and other vertebrates. Because the cub was too young to predate on the chimpanzees, and it was not consumed as prey, it was likely a carnivore competitor (Takahata et al. 1986). In the same way, the attack executed by the blonde capuchin monkey can be attributed to defensive behavior to protect group members from a possibly dangerous animal, an opportunistic predator, and a potential competitor, which could be a threat to the monkeys.

Sapajus flavius and *P. nattereri* have overlapping diets and habitats, and could potentially compete for resources and space (Vitt and Vangilder 1983; de Mesquita et al. 2011; Rodrigues 2013; Rodrigues et al. 2013; Filho 2015; Lins 2015). At the study site, *S. flavius* expose themselves to danger in open areas between tree branches and on the ground on roads and on farms (Figs. 1, 3) to access food resources such as sugarcane (*Saccharum* sp.) and vertebrate species, including lizards (Tropiduridae), marsupials

(Didelphidae), and birds eggs (Rodrigues 2013; Rodrigues et al. 2013; Santos 2013; Lins 2015). The sugarcane plantations, roads, grounds, and trees are used as habitats by green racer snakes foraging for some of the same resources as the capuchins, such as lizards, mammals, frogs, eggs, and other snakes (Vitt and Vangilder 1983; de Mesquita et al. 2011; Filho 2015; Silva and Valença-Montenegro 2017).

Snakes are not specialized to prey upon primates, but approximately 26 different non-human primate species have been killed by snakes, perhaps as defense responses and as opportunistic prey items, including: six species of strepsirrhines and 20 species of haplorhines (Headland and Greene 2011).

There have been several documented interaction events between New World monkeys and snakes. For example: a juvenile *Callithrix jacchus* was killed by a *Bothrops leucurus* on the ground (Ferrari and Beltrão-Mendes 2011); a *B. constrictor* killed a bearded saki (*Chiropotes satanas*) (Ferrari et al. 2003); other *B. constrictor* and a green anaconda (*Eunectes murinus*) killed *Saguinus mystax* monkeys (Heymann 1987; Tello et al. 2002). Additionally, an adult female *Alouatta puruensis* in arboreal stratum at a height of 7.5 m above the ground was killed by a *B. constrictor* and fell to the ground (Quintino and Bicca-Marques 2013). However, a juvenile female white-faced capuchin (*C. capucinus*), which had been attacked by a *B. constrictor* escaped with help from her mother, another juvenile, and the alpha male (Perry et al. 2003).

Female capuchins with or without infants, juveniles, infants, and even adult males are easy targets for predators when they share terrestrial and arboreal strata with these animals, i.e., opportunistic foraging snakes (Chapman 1986; Ferrari and Beltrão-Mendes 2011; Headland and Greene 2011). An adult male *C. capucinus* approached a *B. constrictor,* and repeatedly picked up a stick from a small tree and dropped it onto the snake to defend a young monkey ambushed by the reptile. However, this *C. capucinus* adult male and other individuals from the group did not use physical contact to set the victim free (Chapman 1986; Perry et al. 2003).

Boinski (1988) reported two subadult and one adult white-faced capuchin (*C. capucinus*) attacking and killing a *Bothrops asper*, using a tree branch as a weapon to hit the snake. Another report involved small and medium-size primates and members of the ophidian families Elapidae and Colubridae: a tarsier, *Tarsius bancanus* preyed upon a *Calliophis intestinalis* (Niemitz 1973); lion tamarin species, such as *Leontopithecus chrysomelas* and *Leontopithecus rosalia* have been documented preying upon and consuming snakes *Micrurus* sp. resulting in the primates death by envenomation (Pissinatti et al. 2017). Another report showed an adult female *Lagothrix flavicauda* killing and consuming a green racer snake (Colubridae) at a height of 16 m above the ground (Fack et al. 2018).

Falótico et al. (2018) studied two wild bearded capuchin monkey populations (*S. libidinosus*) 320 km apart, and they observed differences in the animals' reactions according to the perceived degree of threat posed by various snakes. The snake species were distinguished by their size, skin pattern, and the sounds produced by them, and the monkeys apparently use these characters to help them identify dangerous as opposed to harmless snakes. While dangerous snakes were avoided and mobbed, such as rattlesnakes (*C. durissus*), pit vipers (*Bothrops* sp.), boas (*Boa constrictor*), and coral snakes (*Micrurus* sp.), the harmless ones were frequently preyed upon and eaten (e.g., Colubridae, vine snake-*Chironius* sp.).

Most of the snakes consumed by the bearded capuchin monkeys were smaller than the dangerous species, and usually smaller than the monkeys' body length, but they also predated upon bigger snakes and mobbed small dangerous snakes (e.g., coral snakes, *Micrurus* sp., 10−20 cm). Falótico et al. (2018) reported Colubridae as the main group of snakes preyed upon and consumed by the capuchins.

In the present event, the Colubridae snake had a length of 93 cm, about 12 cm longer than the blonde capuchin monkeys, which can reach a length of 81 cm when adult (head and body length = 40 cm and tail length = 41 cm) (Bacalhao et al. 2016), *P. nattereri* had no aposematic and mimic patterns in its skin (Fig. 2 and appendices), and it weighed less (body mass = 665.57 g) than the blonde capuchin monkey (body mass = 2.920 kg) (Vitt and Vangilder 1983; de Mesquita et al. 2011; Filho 2015; Bacalhao et al. 2016).

Defensive or aggressive behavior by *P. nattereri* specifically towards the blonde capuchin monkeys has not been observed, but under other circumstances, the snake is certainly capable of it. *Philodrya*s snakes have a complex defensive behavior, in which they try to bite their antagonist or escape on the ground or onto branches, all the while exhibiting a wide-open mouth combined with an "S"-shaped body posture, and a simultaneous lateral depression of the body (Natera-Mumaw et al. 2008).

Perhaps the ambiguous responses showed by the monkeys in the event were caused by confusion regarding the snake's morphological characters (Fig. 2 and appendices), however, these elements were enough to elicit a threat response from most of the monkeys. Previous interactions between *S. flavius* (Cebidae) and *P. nattereri* (Colubridae) should also be considered. Probably, those blonde capuchin monkeys present in the event recognized the snake as a potentially harmful animal or competitor.

Scavenging has been observed in nonhuman primates such as baboons, orangutans, and chimpanzees. Occasionally, Gombe chimpanzees scavenge animals freshly killed by baboons, while Mahale chimpanzees scavenge

animals that they have found dead or have died from diseases (Hasegawa et al. 1983). Protohominids, hominids in early Pleistocene, early modern *Homo sapiens* from southern Africa and the contemporaneous Neanderthals from Europe likely all relied on scavenging large animals, such as hippopotami and elephants (Hasegawa et al. 1983; Blumenschine and Cavallo 1992).

Sapajus libidinosus adult males have been documented as the main predators of snakes, but juveniles and infants have also been recorded eating snakes, although 73% of those events were actually cases of scavenging (Falótico et al. 2018). *Sapajus flavius* juveniles have been seen scavenging resources provided by adults in a study with a habituated population in a natural environment (Neco 2015). Moreover, studies with a captive group show juveniles as the main consumers of scavenged items left by adult monkeys (da Silva et al. 2018). Perhaps the unconsumed body of the snake on the tree branch (3 m above ground, Fig. 3) could be used as a future scavenged resource for other individuals.

Sucupira forest is frequently used by hunters, although there is no record that *S. flavius* is hunted there. However, red-handed howler monkeys (*Alouatta belzebul*) and other mammals (e.g., *Bradypus variegatus* and *Dasyprocta* sp.) are known to be targets of local hunters. In the neighboring Paraíba state, hunters kill adult blonde capuchin monkeys to eat, for traditional medicinal practices, and they also capture juveniles for the pet trade (Silva and Valença-Montenegro 2017; Pessoa et al. 2018). Hunting pressure may have resulted in fear and flight responses by the blonde capuchin monkeys on meeting humans in the Sucupira forest region (Fig. 1). In this event, the monkey was aware of the observer's presence and it is possible that this caused the animal to flee and leave the snake carcass unconsumed.

These ecological responses shown by blonde capuchin monkeys reflect their great behavioral and ecological plasticity and highly developed cognitive skills they have in common with Cebids lineages, which ensure group integrity, survival, and general health over time in both natural and rural anthropogenic environments.

Acknowledgements We are grateful to the Centro Nacional de Pesquisa e Conservação de Primatas Brasileiros and Instituto Chico Mendes de Conservação da Biodiversidade (CPB/ICMBio) and all their members, to the Laboratory of Mastozoology (MAME) particularly to Mr. Pedro Cordeiro Estrela, and to Laboratory of Applied Ecology and Conservation (LEAC) both from Department of Systematics and Ecology–University Federal of Paraíba. Thanks to Mr. Lucas Cavalcanti, Mr. Fagner Delfim, and the Herpetology Laboratory of University Federal of Paraíba for the snake identification and references, and to Monte Alegre, the owner of Sucupira torta, for all of the support given during the data collection. We are grateful to Mr. William McGrew and other reviewers from *Primates*, and to Ms. Illiana E. Anise for their very helpful suggestions for the improvement of this paper. Special thanks to the Brazilian Society of Primatology, to Mr. Tarcísio Alves Cordeiro, Mr. Ronilson José da Paz, and Mr. Adelson, a great field partner, without whose help this work would not have been possible.

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