

## ANTI-PREDATOR BEHAVIOR OF COIMBRA-FILHO'S TITI MONKEYS (*CALLICEBUS COIMBRAI*)

João Pedro Souza-Alves<sup>1,3</sup> and Isadora P. Fontes<sup>2</sup>

<sup>1</sup> Postgraduate Program in Animal Biology, Department of Zoology, Federal University of Pernambuco. Av. Professor Moraes Rego, 1235, Cidade Universitária, Recife - PE, Brazil, 50670-901, e-mail: <souzaalves1982@gmail.com>

<sup>2</sup> Programa de Pós-graduação em Desenvolvimento e Meio Ambiente, Universidade Federal de Sergipe, São Cristóvão, Sergipe, Brazil

<sup>3</sup> Laboratório de Ecologia, Comportamento e Conservação (LECC), Departamento de Zoologia, Universidade Federal de Pernambuco, Recife, Brazil

### Abstract

Predation pressure has an important role in shaping the behavioral, ecological and social patterns of primates. In this study, we describe two types of anti-predator behavior performed by Coimbra-Filho's titi monkeys (*Callicebus coimbrai*), and compare our reports with the anti-predator strategies adopted by other Neotropical primates. The reports were performed on a small and isolated Atlantic forest fragment (14 ha) located in a highly-fragmented landscape in north-eastern Brazil. Although the titi monkey group was systematically monitored (July/2009 - August/2012: 1,513 hours) over the years, the events were recorded *ab libitum* method. Four events of anti-predator behavior were reported: three were in response to a medium-sized arboreal primate, the yellow-breasted capuchin monkey (*Sapajus xanthosternos*), and one in response to a large bird, the turkey vulture (*Cathartes aura*). When in the presence of *S. xanthosternos*, the titi monkeys emitted a quiet alert vocalization and descended to the dense undergrowth in order to avoid predation. On the other hand, when the titi monkeys were exploiting fleshy fruit on a tree, they verified the presence of an individual of *C. aura* and jumped to the ground. Both types of anti-predator behavior had been previously described for Neotropical primates. The anti-predator behaviors performed by the titi monkeys can contribute to the understanding of the adaptive processes of these poorly studied primates in fragmented habitats. Moreover, the passive behavior and the habitat characteristics may be an important aspect in the choice of strategy to be used, since the habitat provided adequate refuges and allowed the titi monkeys to seek an alternative escape route.

**Key Words:** Atlantic Forest, *Sapajus xanthosternos*, *Cathartes aura*, anti-predator strategy

### Resumo

A pressão da predação tem um papel importante nos padrões comportamentais, ecológicos e sociais dos primatas. Neste estudo, descrevemos dois tipos de comportamento anti-predadores realizados por indivíduos de um grupo de Guigó-de-Coimbra-Filho (*Callicebus coimbrai*) e comparamos nossos registros com as estratégias anti-predadores adotadas por outros primatas neotropicais. Os registros foram realizados em um pequeno e isolado fragmento de Mata Atlântica localizado em uma paisagem altamente fragmentada na região nordeste do Brasil. Embora o grupo tenha sido sistematicamente monitorado (julho/2009 – agosto/2012: 1,513 horas) ao longo dos anos, os eventos foram registrados de forma *ab libitum*. Foram relatados quatro eventos de comportamento anti-predador: três foram em resposta a um primata arborícola de tamanho médio, o macaco-prego-do-peito-amarelo (*Sapajus xanthosternos*), e um em resposta a uma ave de grande porte, o urubu-de-cabeça-vermelha (*Cathartes aura*). Quando na presença de *S. xanthosternos*, os guigós emitiram vocalização de alerta e desceram até o sub-bosque denso a fim de evitar a predação. Por outro lado, quando os guigós estavam consumindo frutos, eles verificaram a presença de um indivíduo de *C. aura* e pularam para o chão. Ambos tipos de comportamentos anti-predador já tinham sido previamente descritos para primatas Neotropicais. Os comportamentos anti-predadores realizados pelos guigós podem contribuir para a compreensão dos processos adaptativos destes primatas pobremente estudados em áreas fragmentadas. Além do mais, o comportamento passivo e as características do seu hábitat podem ser um aspecto importante na escolha de estratégia a ser utilizada, uma vez que proporcionavam refúgios adequados e permitiam que os guigós buscassem uma rota de fuga alternativa.

**Palavras-chave:** Mata Atlântica, *Sapajus xanthosternos*, *Cathartes aura*, estratégia anti-predador

### Introduction

It is extremely difficult to document predation on primate species due to the low occurrence of events, the difficulty in observing quick predatory attacks, the nocturnal habits of many predators (owls and leopards), the effect

of the presence of human observers to inhibit predation bouts, and therefore the large amount of time and energy needed to obtain these reports (Isbell, 1994). However, predation pressure has an important role in the behavioral, ecological and social patterns of primates (van Schaik, 1983; Cheney and Wrangham, 1987; Stanford, 2002).

This pressure results in specific behavioral responses linked to different types of predators and prey (Ferrari, 2009). Predators or potential predators of primates include hawks (Heymann, 1990; Sherman, 1991; Julliot, 1994; Gilbert, 2000; Vasquez and Heymann, 2001; Deffler, 2004), felids (Olmos, 1993; Novak et al., 2005; Ludwig et al., 2007), other primate species (Sampaio and Ferrari, 2005), and even snakes (Heymann, 1987; Corrêa and Coutinho, 1997; Teixeira et al., 2016). In order to avoid predation, the behavioral response of primates can vary between active (i.e., mobbing, monitoring or alarm calling) and passive (i.e., avoiding, hiding or fleeing) behaviors (Ferrari, 2009).

Anti-predator strategies can be strongly linked to predator type (Edmunds, 1974; Table 1). Practically all predators (or potential predators) of primates demonstrate solitary foraging behavior (Ferrari, 2009). Terrestrial predators such as mammalian carnivores can either engage in astonishing high-speed pursuits in open habitats or can stalk, ambush and pounce to overpower prey (Macdonald et al., 2010; Wilson et al., 2013; Wilson et al., 2013). On the other hand, aerial predators (raptors) tend to use active search or sit-and-wait strategies to pursue and capture prey (see Tables 1 and 2 in Jaksic and Carothers, 1985). Moreover, arboreal predators (primates) seem to have used a “surprise attack or ambush” strategy to capture a small-bodied primate (Albuquerque et al., 2014).

Active anti-predator behaviors may be used to communicate the presence of such surprise-effect dependent predators (terrestrial predators) to conspecifics. In the presence of terrestrial predators, primate behavior can vary between mobbing (*Brachyteles hypoxanthus*: Dias and Strier, 2002; *Cacajao calvus*: Bowler, 2007), ascending up trees (*B. hypoxanthus*: Mendes, 1997), approaching and mobbing (*Callicebus nigrifrons*: Cäsar et al., 2012), or producing alarm calls (*Chiropotes utahicki*: Ferrari et al., 2004). In terms of aerial predators, primates can adopt a combined active/passive anti-predation strategy aiming to avoid predation. When under attack from aerial predators, primates variously produce loud calls and descend within the forest canopy (*Alouatta clamitans*: Miranda et al., 2006), hide and remain vigilant (*A. palliata*: Gil-da-Costa et al., 2003; *Callithrix jacchus*: Bezerra and Souto, 2008), demonstrate mobbing behaviors (*Saimiri oerstedii*: Boiniski 1987), or display piloerection (*Plecturocebus cupreus*: Dolotovskaya et al., 2019). When potential arboreal predators are noticed, primates can flee quickly and hide in vine tangles (*Plecturocebus cupreus*: Dolotovskaya et al., 2019), or moving rapidly, produce alarm call and mobbing vocalizations (*Callithrix jacchus*: Albuquerque et al., 2014). Thus, the anti-predator strategy adopted will depend on the context of each predation event as well as the primate species involved.

Primates that display passive anti-predator behaviors tend to present cryptic pelage coloration, live in small

family groups and maintain strong social structures (Ferrari, 2009; Dolotovskaya et al., 2019). Owl monkeys (*Aotus*) and titi monkeys (*Callicebus*, *Cheracebus* and *Plecturocebus*) are Neotropical primates that possess all these features (Norconk, 2011). Titi monkeys (*sensu* Byrne et al., 2016) are small-bodied primates (*ca.* 2 kg) distributed widely across diverse habitats in South America (Bicca-Marques and Heymann, 2013). They live in small groups comprising a monogamous breeding pair with one to three offspring (Bicca-Marques and Heymann, 2013). They are primarily frugivorous, exploiting alternative food resources such as new leaves and invertebrates during periods of lower fruit availability (Caselli & Setz, 2011; DeLuycker, 2011; Souza-Alves et al., 2011) and use low and middle forest strata (Heiduck, 2002; Chagas and Ferrari, 2010). Owing to behavioral and morphological characteristics (shiny and cryptic pelage), titi monkeys have demonstrated efficient passive anti-predator strategies (Ferrari, 2009).

Here we described two types of anti-predator behavior performed by Coimbra-Filho's titi monkeys (*Callicebus coimbrai*) inhabiting a small Atlantic forest fragment in north-eastern Brazil, and we compare them to the anti-predator strategies adopted by other Neotropical primates. Coimbra-Filho's titi monkeys are a highly frugivorous species; they live in small groups, use low and middle forest strata, inhabit disturbed sites, demonstrate an income breeding strategy, and use the forest floor frequently (Chagas and Ferrari, 2010; Chagas and Ferrari, 2011; Souza-Alves et al., 2011, Souza-Alves et al., 2019), all features that put them at a high risk of predation (Ferrari, 2009). As such, we expected that Coimbra-Filho's titi monkeys would demonstrate different anti-predator behaviors when facing terrestrial, arboreal and aerial potential predators living in fragmented habitats.

## Methods and Study Site

Our study took place in a small Atlantic forest fragment (14 ha) at Fazenda Trapsa (11°12' S, 37°14' W), located in the municipality of Itaporanga d'Ajuda, state of Sergipe, north-eastern Brazil. The site is embedded in a mosaic of eight forest fragments varying in their forest structure, size, shape and degree of conservation (Chagas and Ferrari, 2011). The study site is characterized by small trees (mean = 8.3 m) with basal area of 39.5 m<sup>2</sup>, high density of lianas (940 ind/ha) and is classified as being in an early stage of regeneration (Souza-Alves et al., 2018). The predominant botanical families are Fabaceae, Myrtaceae, and Sapotaceae (Souza-Alves et al., 2014). Monthly rainfall level (mm) was collected at the meteorological station of RPPN Caju – Embrapa Sergipe, located 1 km from the study area. During the 11-year period from 2000-2011 the annual mean of rainfall recorded there was 120.9 mm (Semarh, 2017). Köppen's classification characterizes the regional climate as *As* (Tropical zone with dry summer: Alvares et al., 2013).

At the time of the study, the Coimbra-Filho's titi group comprised four individuals, with one monogamous breeding pair, a juvenile and an infant (Souza-Alves, 2010). The subjects were previously well-habituated to human presence (Souza-Alves and Ferrari, 2010). Observations described here were obtained during the behavioral and ecological monitoring of this titi group through scan sampling for five days per month (see Souza-Alves, 2013 for more details). Unusual behaviors, such as anti-predator behavior performed by individuals, were reported using an *ad libitum* method (Altmann, 1974). When in the presence of the predator, we recorded the time of day, predator taxon, and titi monkey behavior during and after the encounter. Here we present data related to anti-predator strategies.

## Results

The Coimbra-Filho's titi monkey focal group was observed from July 2009 to August 2012, for a total of 1,513 hours. Four events of anti-predator behavior were reported; three of these were in response to a medium-sized arboreal primate, the yellow-breasted capuchin monkey (*Sapajus xanthosternos*), and one towards a large-sized bird, the turkey vulture (*Cathartes aura*).

The first event took place in July 2009, at approximately 6:30 am, when the Coimbra-Filho's titi group was at one of their sleeping trees (*ca.* 1 m), *Licania littoralis* (Chrysobalanaceae). A group of *Sapajus xanthosternos* composed of 18 to 19 individuals approached quickly and extremely noisily. These factors allowed the members of Coimbra-Filho's titi group to leave the sleeping site quickly. The titi monkeys moved to another tree in order to facilitate their observation of the capuchin monkeys, and one individual emitted a quiet call to alert the group. On the same day around 10:45 am, the capuchin monkeys were foraging and walking towards the titi monkey group. This advance triggered the titi monkeys to quickly and quietly descend from their current location (at 12 m height) to approximately 3 m, where they remained and kept silent and still. All four of the titi monkeys remained stationary and quiet for 15 to 20 minutes to avoid detection before returning to their activities. Throughout this day, however, the group of titi monkeys monitored the capuchin monkey group and sought to perform their activities with caution, keeping close together and scanning the area due to the continued presence of the capuchin monkeys.

The second event occurred on May 2011 at 12:00 pm. Three members of the titi monkey group were eating fleshy fruits on the *Tapiriva guianensis* tree (Anacardiaceae) at ~15 m height and perceived the approach of the capuchin monkey group. All the titi monkeys descended to the understory (*ca.* 3 m) and hid in the vine tangles. The third event was reported on February 2010 at 10:00 am when

the adult male of the focal titi monkey group visually noticed the capuchin monkeys and began moving rapidly between trees in the opposite direction. The researchers did not hear any alarm call from this individual to alert the other members of titi group, but the other members followed this individual to avoid interaction with the capuchin group. The titi breeding pair ran in one direction and lay at rest 6 m from the ground until the capuchin monkey group had passed. In contrast, the infant titi moved in the opposite direction of the titi breeding pair and eventually came close to a capuchin monkey. The infant titi sighted a capuchin 3 m away and stopped. The capuchin monkey looked at the infant and continued on his route, then the infant titi moved towards the breeding pair where they remained until after the capuchin monkeys left the quadrant, at which time the titi monkeys resumed their usual activities. The titi monkeys also left and did not return to this location until the end of the day.

The last anti-predator strategy event was reported in October 2009, at approximately 09:40 am. A turkey vulture flew near three members of the Coimbra-Filho's titi group. One adult and the infant were at a height of between 7 and 9 m, feeding on *Xylopia frutescens* seeds (Annonaceae). The sub-adult was at a height between 2 and 3 m feeding on young leaves of unidentified vines. Noticing the turkey vulture flying over the tree canopy, the titi monkeys jumped to the ground, stood still for 1 to 2 min and emitted an alert vocalization (quiet call). The individuals looked up in an attempt to observe the vulture and see if it had left the area. When on the ground, the titi monkeys were at distances of between 1 and 2 m from the human observer, without showing any concern. After departure of the vulture, the individuals returned to their normal activities.

## Discussion

Our results demonstrate that, like other Neotropical primates, Coimbra-Filho's titi monkeys respond differently when threatened by an arboreal versus an aerial potential predator (Table 1). When exposed to a potential arboreal predator (*Sapajus xanthosternos*), the titi monkey group tended to descend to lower forest strata (understory), hide in vine tangles, remain still and give quiet alarms. They remained in the understory to perform all their daily activities. Robust capuchins are known to prey on titi monkeys (see Sampaio & Ferrari, 2005 – *Sapajus apella*) as well as on common marmosets (see Albuquerque et al. 2014 – *Sapajus xanthosternos*). In contrast, in the presence of a potential aerial predator (*Cathartes aura*), the titis fled to the forest floor in order to avoid predation. Although some other studies have verified primate anti-predation behavior in the presence of vultures, there are no reports of vulture predation on live primates (Gleason & Norconk, 2002; Suscke et al., 2017).

**Table 1.** Overview of response of the passive anti-predator behavior from Neotropical primates.

Type of predator	Species	Anti-predator response	Source
Aerial	<i>Alouatta clamitans</i>	Descend trees	Miranda et al. (2006)
	<i>Alouatta palliata</i>	Hide	McKinney (2009)
		Hide/Vigilant	Gil-da-Costa et al. (2003)
	<i>Brachyteles hypoxanthus</i>	Infant ran	Dias and Strier (2002)
	<i>Cacajao calvus</i>	Look up and alert	Bowler (2007)
	<i>Callicebus coimbrai</i>	Looking up and jumping down from trees	<b>Present study</b>
	<i>Callicebus nigrifrons</i>	Hide/descend trees	Căsar et al. (2012a, b)
	<i>Callithrix jacchus</i>	Hide	Bezerra and Souto (2008)
	<i>Cebus capucinus</i>	Scan the sky/descend trees	Fitchel et al. (2005), Gros-Louis et al. (2008), Digweed et al. (2005)
	<i>Plecturocebus cupreus</i>	Piloerection/hide	Dolotovskaya et al. (2019)
Terrestrial	<i>Brachyteles hypoxanthus</i>	Ascend trees	Mendes (1997)
	<i>Callithrix jacchus</i>	Stay motionless	Bezerra and Souto (2008)
	<i>Cebus capucinus</i>	Ascend trees	Fitchel et al. (2005), Gros-Louis et al. (2008), Digweed et al. (2005)
	<i>Plecturocebus cupreus</i>	Piloerection/hide	Dolotovskaya et al. (2019)
	<i>Plecturocebus discolor</i>	Call/hide/piloerection	De Luna et al. (2010)
Arboreal	<i>Callicebus coimbrai</i>	Hide	<b>Present study</b>
	<i>Callithrix jacchus</i>	Alarm and mobbing calls/moving	Albuquerque et al. (2014)
	<i>Plecturocebus cupreus</i>	Flee and hide	Dolotovskaya et al. (2019)
	<i>Plecturocebus moloch</i>	Call/agitated	Sampaio and Ferrari (2005)

Both types of anti-predator behavior were previously observed in other titi monkeys (*Callicebus nigrifrons*, *Plecturocebus cupreus*, and *P. discolor*) when in the presence of eagles and tayras (De Luna et al., 2010; Căsar et al., 2012) and capuchin monkeys (Dolotovskaya et al., 2019). When in the presence of an aerial predator, red titi monkey (*P. cupreus*) individuals have been found to emit alarm vocalizations, display piloerection, and move to denser parts of the tree crown (Dolotovskaya et al., 2019). On the other hand, *Callicebus nigrifrons* individuals have been observed to move to protected areas and “freeze” (Căsar et al., 2013).

Neotropical primates often use lower and denser forest vegetation in order to hide from and avoid potential arboreal predators. These sites appear to be an optimal refuge chosen by primates. Cryptic pelage coloration and the small size of Coimbra-Filho's titi monkeys has likely favored flight behaviors and increased their ability to hide from capuchin monkeys to avoid predation. Similar passive anti-predator behavior has been verified for other titi monkey species. For example, *Plecturocebus discolor* in equatorial Amazonia hid in vine tangles in more than half of its encounters with tayras (De Luna et al., 2010), and *P. cupreus* hid in vine tangles to avoid encountering tayras, squirrel monkeys and capuchin monkeys at the Estación Biológica Quebrada Blanco, north-eastern Peruvian Amazon (Dolotovskaya et al., 2019).

Several anti-predator strategies against aerial predators have been reported for Neotropical primates, including alarm calls, freezing or taking cover instantaneously (Ferrari, 2009). Brown howler monkeys (*Alouatta guariba clamitans*) have been observed to descend to the understory and remain silent and motionless when under attack from a black-hawk eagle (*Spizaetus tyrannus*) (Miranda et al., 2006). An adult *Plecturocebus cupreus* male emitted alarm calls and moved to a denser part of the forest in the presence of a juvenile grey-headed kite (*Leptodon cayanensis*) (Dolotovskaya et al., 2019). Similarly, sakis (*Pithecia aequatorialis*) have been shown to give alarm calls for 10 minutes and drop to lower branches due to the presence of an unknown bird species (De Luna et al., 2010).

Escaping to the ground seems to be a common behavioral activity of Neotropical primates in the presence of a potential aerial predator. Most of species tend to descend to the lower forest strata with the aim of hiding. Under predation pressure from a turkey vulture, common marmosets (*Callithrix jacchus*) emitted alarm vocalizations, hid under leaves, and descended to the forest ground (Lyra-Neves et al., 2007). *Callithrix* parents also transferred their infants from their back to their ventral region while descending and hiding (Lyra-Neves et al., 2007). A novel anti-predator strategy by *Saguinus mystax* and *Leontocebus fuscicollis* is to fall down out of trees after observing aerial predators (Heymann, 1990).

At our study site, jumping to the ground may be a risky escape alternative for Coimbra-Filho's titi monkeys, due to presence of a large terrestrial predator (*Puma concolor*: Chagas et al., 2010). However, risk of being predated by a puma – these felids present an ambush strategy – probably is lower than being predated by raptors. It is likely that the vegetation structure of the forest fragment (edge forest, discontinuous canopy) and the structure of the feeding tree (open canopy, low leaves, thin and long branches) “forced” the titi monkeys to jump to the ground. Their cryptic pelage coloration reduces the probability of being found in suitable hiding places (vine tangles). However, in open areas the same pelage can facilitate localization of titis by potential predators.

Unlike *Plecturocebus cupreus* individuals, who did not emit alarm calls during encounters with capuchin monkeys (Dolotovskaya et al., 2019), Coimbra-Filho's titi monkeys emitted an alarm vocalization at least once in this study to alert the other individuals to the presence of a potential predator. Titi monkeys are known for emitting different types of alarm calls when in the presence of aerial and terrestrial predators (Cäsar and Zuberbühler, 2012; Cäsar et al., 2013) and alarm calls were emitted by individuals of *Callicebus nigrifrons* groups when observing capuchin monkeys (Cäsar et al., 2012). Emitting loud alarm calls in the presence of an arboreal predator will likely increase the chances of a predator finding their potential prey. However, quiet calls will favor intra-group communication in order to coordinate the escape. In this event, Coimbra-Filho's titi monkeys appeared to emit an alarm (short and high-pitched: Cäsar et al., 2012) call solely to get the attention of other group individuals, signaling them to flee and hide. This allowed for the group to move together to a suitable area to avoid predation.

Anti-predator behaviors performed by Coimbra-Filho's titi monkeys can contribute to the understanding of adaptive processes of these understudied primates in fragmented forest areas. In this study, Coimbra-Filho's titi monkeys used different strategies to avoid predators and potential predators. Their cryptic behavior aided in their escape from capuchin monkeys, however, they were required to choose an alternative escape route when under the predation pressure of a potential aerial predator. An active anti-predator strategy, such as emitting quiet alarm calls, was used only to bring the small group together. Coimbra-Filho's titi monkeys usually adopted passive anti-predator strategies, and the characteristics of their habitat seemed to be an important aspect in their choice of strategy, as it provided suitable hiding places and allowed the titi monkeys to search for an alternative escape route.

## Acknowledgments

This study was supported by the Deutscher Akademischer Austausch Dienst (DAAD) and CAPES during the MSc and PhD courses of JPS-A, respectively. IPF was supported

by Deutscher Akademischer Austausch Dienst (DAAD) during the master course. We would also like to thank Sr. Ary Ferreira, the owner of Fazenda Trapsa, and José Elias “Bóia” for his assistance during fieldwork. Currently, JPS-A is supported by FACEPE (BFP-0149-2.05/19). We also are grateful to Cristiane Cäsar and Jessica W. Lynch for valuable comments on the initial draft of this manuscript.

## References

- Albuquerque, N. M., Silvestre, S. M., Cardoso, T. S., Ruiz-Esparza, J. M., Rocha, P. A., Beltrão-Mendes, R., & Ferrari, S. F. 2014. Capture of a common marmoset (*Callithrix jacchus*) by a capuchin monkey (*Sapajus* sp.) in the Ibura National Forest, Sergipe (Brazil). *Neotrop. Primates* 21(2): 218–220.
- Altmann, J. 1974. Observational study of behaviour: sampling methods. *Behaviour* 49: 227–266.
- Alvares, C. A., Stape, J. L., Sentelhas, P. C., de Moraes, G., Leonardo, J., and Sparovek, G. 2013. Köppen's climate classification map for Brazil. *Meteorol. Z.* 22(6): 711–728.
- Bezerra, B. M. and Souto, A. S. 2008. Structure and usage of the vocal repertoire of *Callithrix jacchus*. *Int. J. Primatol.* 29: 671–701.
- Bicca-Marques, J. C. and Heymann, E. W. 2013. Ecology and behavior of titi monkeys (genus *Callicebus*). In: *Evolutionary biology and conservation of titis, sakis and uacaris*, A. Barnett, L. M. Veiga, S. F. Ferrari and M. A. Norconk (eds.), pp. 196–207. Cambridge University Press, Cambridge.
- Boinski, S. 1987. Birth synchrony in squirrel monkeys (*Saimiri oerstedii*): a strategy to reduce neonatal predation. *Behav. Ecol. Sociobiol.* 21:393–400.
- Bowler, M. 2007. The ecology and conservation of the red uacari monkey on the Yavarí river, Peru. PhD Thesis, University of Kent, UK.
- Byrne, H., Rylands, A. B., Carneiro, J. C., Alfaro, J. W. L., Bertuol, F., da Silva, M. N., ... and Hrbek, T. 2016. Phylogenetic relationships of the New World titi monkeys (*Callicebus*): first appraisal of taxonomy based on molecular evidence. *Frontiers Zool.* 13(1): 10.
- Cäsar, C., and Zuberbühler, K. 2012. Referential alarm calling behaviour in New World primates. *Current Zool.* 58(5): 680–697.
- Cäsar, C., Byrne, R., Young, R. J., and Zuberbühler, K. 2012. The alarm call system of wild black-fronted titi monkeys, *Callicebus nigrifrons*. *Behav. Ecol. Sociobiol.* 66(5): 653–667.
- Cäsar, C., Zuberbühler, K., Young, R. J., and Byrne, R. W. 2013. Titi monkey call sequences vary with predator location and type. *Biol. Letters* 9(5): 20130535.
- Caselli, C. B. and Setz, E. Z. F. 2011. Feeding ecology and activity pattern of black-fronted titi monkeys (*Callicebus nigrifrons*) in a semideciduous tropical forest of southern Brazil. *Primates* 52(4):351.
- Chagas, R. R. D. and Ferrari, S. F. 2010. Habitat use by *Callicebus coimbrai* (Primates: Pitheciidae) and sympatric species in the fragmented landscape of the Atlantic Forest of southern Sergipe, Brazil. *Zoologia* 27(6): 853–860.

- Chagas, R. R. D. and Ferrari, S. F. 2011. Population parameters of the endangered titi monkey, *Callicebus coimbrai* Kobayashi and Langguth, 1999, in the fragmented landscape of southern Sergipe, Brazil. *Brazil. J. Biol.* 71(3):569–575.
- Chagas, R. R. D., Júnior, E. M. S., Souza-Alves, J. P., and Ferrari, S. F. 2010. Fazenda Trapsa, a refuge of mammalian diversity in Sergipe, Northeastern Brazil. *Rev. Nord. Biol.* 19(2):35–43.
- Cheney D. L. and Wrangham, R. W. 1987. Predation. In: B. B. Smuts, D. L. Cheney, R. M. Seyfarth, R. W. Wrangham, and T. T. Struhsaker (eds.), *Primate Societies*, pp. 227–239). Chicago: Chicago University Press, USA.
- De Luna, A. G., Sanmiguel, R., Di Fiore, A. and Fernandez-Duque, E. 2010. Predation and predation attempts on red titi monkeys (*Callicebus discolor*) and equatorial sakis (*Pithecia aequatorialis*) in Amazonian Ecuador. *Folia Primatol.* 81(2):86–95.
- Defler, T. R. 2004. Primates of Colombia, Conservation International Tropical Field Guide Series, Conservation International, Bogotá.
- DeLuycker, A. M. 2012. Insect Prey Foraging Strategies in *Callicebus oenanthe* in Northern Peru. *Am. J. Primatol.* 74(5):450–461.
- Dias, L. G. and Strier, K. B. 2002. Agonistic encounters between muriquis *Brachyteles arachnoides hypoxanthus* (Primates, Cebidae) and other animals at the Estação Biológica de Caratinga, Minas Gerais, Brazil. *Neotrop. Primates* 8:138–141.
- Digweed, S. M., Fedigan, L. M. and Rendall, D. 2005. Variable predator specificity in the anti-predator vocalizations and behaviour of the white-faced capuchin *Cebus capucinus*. *Behaviour* 142:997–1021.
- Dolotovskaya, S., Flores Amasifuen, C., Haas, C. E., Nummert, F., and Heymann, E. W. 2019. Active anti-predator behaviour of red titi monkeys (*Plecturocebus cupreus*). *Primate Biol.* 6(1):59–64.
- Edmunds, M. 1974. *Defence in animals: a survey of anti-predator defences*. Longman Publishing Group.
- Ferrari, S. F. (2009) Predation risk and antipredator strategies. In: S. F. Ferrari, P. A. Garber, A. Estrada, J. C. Bicca-Marques, E. W. Heymann (eds.), *South American Primates. Developments in Primatology: Progress and Prospects*, pp. 251–277. New York: Springer New York, USA.
- Ferrari, S. F., Pereira, W. L. A., Santos, R. R., and Veiga, L. M. 2004. Fatal attack of a Boa constrictor on a bearded saki (*Chiropotes satanas utahicki*). *Folia Primatol.* 75:111–113.
- Fichtel, C., Perry, S. and Gros-Louis, J. 2005. Alarm calls of white-faced capuchin monkeys: An acoustic analysis. *Anim. Behav.* 70:165–176.
- Gilbert, K. A. 2000. Attempted predation on a white-faced saki in the Central Amazon. *Neotrop. Primates* 8:103–104.
- Gleason, T. M. and Norconk, M. A. 2002. Predation risk and antipredator adaptations in white-faced sakis, *Pithecia pithecia*. In: L. E. Miller (ed.), *Eat or Be Eaten: Predator Sensitive Foraging among Primates*, pp. 169–186. Cambridge, Cambridge University Press, USA.
- Gros-Louis, J. J., Perry, S. E., Fichtel, C., Wikberg, E., Gilkenson, H. et al., 2008. Vocal repertoire of *Cebus capucinus*: Acoustic structure, context, and usage. *Int. J. Primatol.* 29:641–670.
- Heiduck, S. 2002. The use of disturbed and undisturbed forest by masked titi monkeys *Callicebus personatus melanochir* is proportional to food availability. *Oryx*, 36(2): 133–139.
- Heymann, E. W. 1987. A field observation of predation on a moustached tamarin (*Saguinus mystax*) by an anaconda. *Int. J. Primatol.* 8:193–195.
- Heymann, E. W. 1990. Reactions of wild tamarins *Saguinus mystax* and *Saguinus fuscicollis* to avian predators. *Int. J. Primatol.* 11:327–337.
- Isbell, L. A. 1994. Predation on primates: ecological patterns and evolutionary consequences. *Evol. Anthropol.* 3(2):61–71.
- Jaksić, F. M. and Carothers, J. H. 1985. Ecological, morphological, and bioenergetic correlates of hunting mode in hawks and owls. *Ornis Scand.* 165–172.
- Julliot, C. 1994. Predation of a young spider monkey (*Ateles paniscus*) by a crested eagle (*Morphnus guianensis*). *Folia Primatol.* 63(2):75–77.
- Kátia, H., Corrêa, M., Paulo, E., and Coutinho, G. 1997. Fatal attack of a pit viper, *Bothrops jararaca*, on an infant buffy-tufted ear marmoset (*Callithrix aurita*). *Primates* 38(2):215.
- Kierulff, M. C., Raboy, B. E., Oliveira, P. P., Miller, K., Passos, F. C., and Prado, F. 2002. Behavioral ecology of lion tamarins. In: D. G. Kleiman and A. B. Rylands (eds.), *Lion Tamarins: Biology and Conservation*, pp. 157–187. Washington DC: Smithsonian Institution Press, USA.
- Ludwig, G., Aguiar, L. M., Miranda, J. M. D., Teixeira, G. M., Svoboda, W. K., Malanski, L. S., Shiozawa, M. M., Hilst, C. L. S., Navarro, I. T., and Passos, F. C. 2007. Cougar predation of black-and-gold howlers on Mutum Island, southern Brazil. *Int. J. Primatol.* 28:39–46.
- Lyra-Neves, R. M. D., Oliveira, M. A., Telino-Júnior, W. R., and Santos, E. M. D. (2007). Interspecific behaviour between *Callithrix jacchus* (Linnaeus) (Callitrichidae, Primates) and some birds of the Atlantic forest, Pernambuco State, Brazil. *Rev. Brasil. Zool.* 24(3):709–716.
- Macdonald, D., Loverridge, A. and Nowell, K. 2010. Dramatis personae: an introduction to the felids. In: D. Macdonald and A. Loveridge (eds.), *The biology and conservation of wild felids* (Vol. 2), pp. 3–58. New York, Oxford University Press, USA.
- McKinney, T. 2009. Anthropogenic change and primate predation risk: Crested caracaras *Caracara planctus* attempt predation on mantled howler monkeys *Alouatta palliata*. *Neotrop. Primates* 16: 24–27.
- Mendes, F. D. C. 1997. Padrões de interação vocal do muriqui *Brachyteles arachnoides hypoxanthus*. In: S. F. Ferrari, H. Schneider (eds.), *A Primatologia no Brasil*, vol. 5. pp. 95–118. Belém: Editora Universitária.
- Miranda, J., Bernardi, I. P., Abreu, K. C., and Passos, F. C. (2005). Predation on *Alouatta guariba clamitans* Cabreira (Primates, Atelidae) by *Leopardus pardalis* (Linnaeus) (Carnivora, Felidae). *Rev. Brasil. Zool.* 22(3):793–795.

- Norconk, M. A. 2011. Saki, uakaris, and titi monkeys: behavioral diversity in a radiation of primate seed predators. In: C. J. Campbell, A. Fuentes, K. C. MacKinnon, M. Panger and S. K. Bearder (eds.), *Primates in perspective*, pp. 123–138. New York: Oxford University Press, USA.
- Novak, A. J., Main, M. B., Sunquist, M. E., and Labisky, R. F. 2005. Foraging ecology of jaguar (*Panthera onca*) and puma (*Puma concolor*) in hunted and non-hunted sites within the Maya Biosphere Reserve, Guatemala. *J. Zool.* 267:167–178.
- Olmos, F. 1993. Notes on the food habits of Brazilian caatinga carnivores. *Mammalia* 57:126–130.
- Sampaio, D. T. and Ferrari, S. F. 2005. Predation of an infant titi monkey (*Callicebus moloch*) by a tufted capuchin (*Cebus apella*). *Folia Primatol.* 76(2):113–115.
- Semarh (2017) Secretaria de Meio Ambiente e Recursos Hídricos de Sergipe. Available <http://www.semarh.se.gov.br/biodiversidade/modules/tinyd0/index.php?id=11>. Accessed 26 Sept 2012.
- Sherman, P. T. 1991. Harpy eagle predation on a red howler monkey. *Folia Primatol.* 56:53–56.
- Souza-Alves, J. P. 2013. Ecology and Life-history of Coimbra-Filho's titi monkeys (*Callicebus coimbrai*) in the Brazilian Atlantic forest. PhD thesis. Universidade Federal da Paraíba, Brazil.
- Souza-Alves, J. P., Thomas, W. W. and Barbosa, M. R. V. 2018. Phytosociology of angiosperms in a highly-fragmented landscape of coastal Atlantic forest in northeastern Brazil. *Rev. Nord. Biol.* 26:124–137.
- Souza-Alves, J. P. 2010. Ecologia alimentar de um grupo de Guigó-de-Coimbra-Filho (*Callicebus coimbrai* Kobayashi & Langguth, 1999): perspectivas para a conservação da espécie na paisagem fragmentada do sul de Sergipe. Master's thesis, Universidade Federal de Sergipe.
- Souza-Alves, J. P. and Ferrari, S. F. 2010. Responses of wild titi monkeys, *Callicebus coimbrai* (Primates: Platyrrhini: Pitheciidae), to the habituation process. *Zoologia*, 27(6).
- Souza-Alves, J. P., Mourthe, I., Hilário, R. R., Bicca-Marques, J. C., Rehg, J., Gestich, C. C., ... and Bowler, M. 2019. Terrestrial behavior in titi monkeys (*Callicebus*, *Cheracebus*, and *Plecturocebus*): potential correlates, patterns, and differences between genera. *Int. J. Primatol.* 40(4-5):553–572.
- Souza-Alves, J. P., Ferrari, S. F., Barbosa, M. R. V., and Thomas, W. W. 2014. Diversity of trees and lianas in two sites in the coastal Atlantic Forest of Sergipe, northeastern Brazil. *Check List* 10:709.
- Souza-Alves, J. P., Fontes, I. P., Chagas, R. R., and Ferrari, S. F. 2011. Seasonal versatility in the feeding ecology of a group of titis (*Callicebus coimbrai*) in the northern Brazilian Atlantic Forest. *Am. J. Primatol.* 73(12):1199–1209.
- Stanford, C. B. 2002. Avoiding predators: expectations and evidence in primate antipredator behavior. *Int. J. Primatol.* 23:741–757.
- Suscke, P., Verderane, M., de Oliveira, R. S., Delval, I., Fernández-Bolaños, M., and Izar, P. 2017. Predatory threat of harpy eagles for yellow-breasted capuchin monkeys in the Atlantic Forest. *Primates* 58(1):141–147.
- Teixeira, D. S., Dos Santos, E., Leal, S. G., de Jesus, A. K., Vargas, W. P., Dutra, I., and Barros, M. 2016. Fatal attack on black-tufted-ear marmosets (*Callithrix penicillata*) by a *Boa constrictor*: a simultaneous assault on two juvenile monkeys. *Primates* 57(1):123–127.
- Van Schaik, C. P. 1983. Why are diurnal primates living in groups? *Behaviour* 120–144.
- Vasquez, M. R. O. and Heymann, E. W. 2001. Crested eagle (*Morphnus guianensis*) predation on infant tamarins (*Saguinus mystax* and *Saguinus fuscicollis*, Callitrichinae). *Folia Primatol.* 72(5):301–303.
- Veiga, L.M., Sousa, M.C., Jerusalinsky, L., Ferrari, S.F., de Oliveira, M.M., Santos, S.S.D., Valente, M.C.M. and Printes, R.C. 2008. *Callicebus coimbrai*. *The IUCN Red List of Threatened Species* 2008: e.T39954A10297332. <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T39954A10297332.en>. Downloaded on 16 December 2019.
- Wilson, A. M., Lowe, J. C., Roskilly, K., Hudson, P. E., Golabek, K. A., and McNutt, J. W. 2013. Locomotion dynamics of hunting in wild cheetahs. *Nature* 498(7453):185.
- Wilson, J. W., Mills, M. G., Wilson, R. P., Peters, G., Mills, M. E., Speakman, J. R., ... and Scantlebury, M. 2013. Cheetahs, *Acinonyx jubatus*, balance turn capacity with pace when chasing prey. *Biol. Letters* 9(5):20130620.