

SHORT COMMUNICATION

Behavioral responses of exotic marmosets to a native apex predator in an urban Araucaria Pine Forest fragment

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ABSTRACT. Low predation pressure is considered one of the main factors enabling invasive species to reproduce and spread outside their native habitats. In Curitiba, Paraná State, southern Brazil, the black-tufted-ear marmoset *Callithrix penicillata* has established populations in urban parks within the threatened Araucaria Pine Forest (Mixed Ombrophilous Forest). Here we report two events involving allochthonous marmosets in an urban park responding to the presence of an apex predator, the black-hawk-eagle *Spizaetus tyrannus* (M. Wied-Neuwied, 1820), a raptor known to prey on primates and other arboreal mammals in Brazil's tropical forests. On the first occasion, when a hawk silently flew overhead, one member of the marmoset group emitted a single, high, loud peep, prompting the others to scatter into the understory. On the second occasion, members of another group produced 'tsiks' and short peeps interspersed with the hawk's vocalizations as it flew farther away; the group did not flee but remained feeding and alert. Although based on few observations, our data suggest that black-tufted-ear marmosets respond adaptively to a native apex predator in the urban Araucaria Pine Forest. Further field research is needed to better understand interactions between these introduced marmosets and the native fauna, including experiments assessing variation in behavioral responses as a function of distance from vocal and/or visual cues of native and domestic predators.

KEYWORDS. Allochthonous, *Callithrix penicillata*, predation, *Spizaetus tyrannus*, urban ecology.

Predation on primates has been a significant evolutionary pressure and continues to influence their demography, group size, distribution (Urbani 2005), life-history and morphological traits, cognition, and behaviors such as vigilance and alarm calls used to warn conspecifics of potential predators (Zuberbühler and Jenny 2003, Ferrari 2009, Strier 2021). In response, primates may display mobbing behavior, become vigilant, escape silently, or remain immobile (Ferrari 2009). Behavioral responses to avoid predation can be shaped primarily by social learning, when juveniles observe and learn from adult behaviors (Janson and van Schaik 1993,

Ferrari 2009), although the genetic basis of these behaviors should not be overlooked (Alcock 2009, Ferrari 2009). For example, primates can evolve distinct alarm calls for different predators, such as aerial (e.g., raptors), terrestrial (e.g., carnivorous mammals), and arboreal (e.g., snakes) threats (Seyfarth et al. 1980, Ferrari 2009, Price et al. 2015). Although these alarm calls appear to be innate, their correct contextual use seems to be learned throughout life (Strier 2021).

All primates, from the gorillas (*Gorilla*) to the smallest mouse lemurs (*Microcebus*), are potential prey for an array of meso- and apex predators. However, predation tends to

be more pronounced in smaller species (Urbani 2005, Ferrari 2009, Fleagle 2013, McGraw and Berger 2013). Smaller, more vulnerable species give alarm calls for a broader range of predators than larger ones (Janson and van Schaik 1993). For small and arboreal platyrrhines, besides humans, raptors are often the most significant predators and may pursue monkeys through the tree canopy (Urbani 2005, Hart 2007, Ferrari 2009). The black-hawk-eagle, *Spizaetus tyrannus* (M. Wied-Neuwied, 1820), a large raptor known for preying on primates and other arboreal mammals, occurs in tropical forests of the Amazon and Atlantic Forest in South America, but it is generally absent or rare in fragmented landscapes (Ferrari 2009). Black-hawk-eagles hunt primates such as large monkeys like howlers (*Alouatta* spp.), medium-sized species such as squirrel monkeys (*Saimiri* spp.), and even small, agile prey like Amazonian marmosets (*Mico*; Barnett et al. 2015). Black-hawk-eagles have been observed attempting to prey on native brown howler monkeys, *Alouatta guariba* (Humboldt, 1812), near the present study site in state of Paraná, southern Brazil, with howlers escaping predation by dropping to the lower forest strata during attacks (Miranda et al. 2006).

The black-tufted-ear marmoset, *Callithrix penicillata* (É. Geoffroy Saint-Hilaire, 1812), is among the smallest platyrrhines and has a wide distribution, occurring mainly in the Cerrado region of east-central Brazil, a xeric biome (Malukiewicz et al. 2021, Valle et al. 2021). They primarily feed on plant exudates and insects, and like other marmoset species, females—particularly dominant ones—commonly produce twins (Yamamoto et al. 2014). These traits can be seen as adaptations that enable them to survive and colonize disturbed habitats (Fleagle 2013), such as urban fragments where predators may be rare or absent. This ability has also allowed them to colonize other biomes where they were improperly released by humans (Malukiewicz et al. 2021). Marmosets are highly social and have complex vocal communication (Oren et al. 2024), including calls related to predation pressures, such as distress vocalizations, alarm calls, and mobbing vocalizations (Kato et al. 2014, Agamaite et al. 2015). Despite their adaptability, marmosets can be preyed upon by snakes, tayras, owls, and raptors (Urbani 2005, Bezerra et al. 2009, Ferrari and Beltrão-Mendes 2011, Barbosa et al. 2022), and in urban areas, by domestic cats (Duarte and Young 2011, McKinney 2009).

In Curitiba, Paraná State, southern Brazil, the black-tufted-ear marmoset is an allochthonous species introduced into urban parks. The species is now widespread, with people frequently feeding them in several fragments of Araucaria Pine Forest (Sukow et al. 2025), a threatened local vegetation formation of the Atlantic Forest (Zorek et al. 2024). In

Barigui Municipal Park, one of the most popular urban parks in Curitiba, where people feed free-ranging marmosets, we and local birdwatchers have frequently observed solitary individuals and pairs of black-hawk-eagles flying over the site and resting in trees. These raptors were identified through their characteristic vocalizations and morphology, direct observations, and photographs taken by local birdwatchers during our marmoset research project. These records suggest that the hawks reside in or near the park.

Because predation events involving platyrrhines and their responses are rarely reported (Ferrari 2009), especially in urban forests where predators are often absent and humans may shield prey (Berger 2007), we describe observations of black-tufted-ear marmosets reacting to a top predator, the black-hawk-eagle, during fieldwork in Barigui Park. The research was conducted between September 2022 and September 2024, totaling 130 hours of fieldwork with free-ranging monkeys. At our study site, mean group size was seven individuals (range 2–12, $N = 21$) and the density estimate was three individuals per hectare (M. Retondo unpublished data). We habituated five to six different social groups using bananas as bait to recognize individuals or to capture, handle, and mark them for population and behavioral studies. The observations below come from two social groups living approximately 600 m apart. The recorded vocalizations follow the descriptions provided by Kato et al. (2014) and Agamaite et al. (2015).

On July 14, 2023, around 02:00 p.m., while we were baiting one of the groups to recognize individuals, an adult marmoset sitting on a tree branch in the understory near the forest edge, about one meter from one of us, was looking at the bananas. Suddenly, it stopped and looked upward, prompting us to do the same, and we noticed a shadow moving above the canopy. Immediately, it emitted a single, high, loud peep and remained still. Other nearby marmosets were alarmed and fled into the understory, causing the group to scatter. The vocalizing marmoset stayed in place but remained vigilant. One of us went to the forest edge and observed a black-hawk-eagle silently gliding overhead, about 20 m above us. The bird was identified by its size, characteristic wing shape, black body, and the banded black-and-white pattern on the ventral surface of its flight feathers.

On August 27, 2024, during another baiting session with a different group to capture individuals, around 10:30 a.m., while we were video recording a focal adult marmoset, another adult nearby emitted 'tsik' calls and short peeps. The focal marmoset looked up, also emitting tsik calls, and we then heard consecutive vocalizations of a black-hawk-eagle at least three times, from a bird flying farther away compared

to the first event. Our focal marmoset also emitted the same peeps as its group mate, interspersed with the hawk's vocalizations (Supplementary Video 1). Some monkeys inside the trap also peeped. These peeps were less high-pitched and loud than the one recorded in 2023. During the hawk's vocalizations, the marmosets outside the trap remained seated, watching their group mates in the open trap. The monkeys inside the trap became agitated but continued eating the bananas. The group did not flee or scatter.

Our observations confirm the presence of an apex raptor in an urban forest fragment that lacks native populations of medium- and large-bodied monkeys, such as howler and capuchin monkeys (*Sapajus* spp.; Sukow et al. 2025), but that has a high population of marmosets (M. Retondo unpublished data). Although we did not observe successful predation attempts by black-hawk-eagles on local marmosets, the monkeys' antipredator behavior suggests that such interactions could occur.

Although marmosets are agile, attentive, and cooperatively warn each other against almost any shadow (Ferrari 2009), our few observations indicate that they responded adaptively to the native aerial predator in the urban forest, showing different levels of perceived risk from these local hawks. In the first event, one individual marmoset reacted displaying a loud, sharp whistle, and its group mates escaped in an evasive action similar to that observed in brown howlers (Miranda et al. 2006). During the second event, the hawk was conspicuously vocalizing farther away, and the monkeys became anxious and alerted each other but continued their activities, including those inside the trap.

The abundant marmoset population in the small forest fragment of Barigui Park may serve as a source prey population for predators (Ferrari 2009, Strier 2021), potentially attracting vagile primate-eating raptors such as the black-hawk-eagle to urban environments. However, marmosets are difficult prey within the arboreal matrix and dense vegetation (Ferrari 2009), and when they become invasive, they can disrupt ecosystems (Ballarini et al. 2021, Zaluar et al. 2021). The role of these primates in this altered food chain requires further study, including their responses to wild and domestic predators. Future investigations should examine differences in behavioral responses as a function of distance from vocal and/or visual sources—feasible field experiments once primates are habituated to people in the park.

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Author Contributions

MR: Conceptualization, data curation, investigation, methodology, visualization, writing. SLNK: Conceptualization, data curation, investigation, methodology. KCA: Conceptualization, investigation, methodology. ASJ: Conceptualization, investigation. PWS: Funding acquisition, Project adminis-

tration, resources. LMA: Conceptualization, formal analysis, methodology, supervision, visualization, writing.

Competing Interests

The authors have declared that no competing interests exist.

Data Availability

Datasets generated or analyzed in this study are available from the corresponding author on reasonable request.

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Supplementary material

Supplementary Video 1. Vocal responses of black-tufted-ear marmosets to the calls of a black hawk-eagle in an Araucaria Pine Forest fragment of an urban park in Curitiba, southern Brazil.

Authors: Kluck SLN.

Data type: Species data.

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