Received: 1 December 2021 | Revised: 19 February 2022 | Accepted: 27 February 2022
DOI: 10.1111/btp.13095

NATURAL HISTORY FIELD NOTE

bioTROPICA ASSOCIATION FOR TROPICAL BIOLOGY AND CONSERVATION WILEY

A universal pharmacy: Possible self-medication using tree balsam by multiple Atlantic Forest mammals

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Funding information
Fundação de Amparo à Pesquisa do Estado de São Paulo, Grant/Award Number: #2014/14739-0; Fonds De La Recherche Scientifique - FNRS, Grant/Award Number: ASP/DM-A696; Conselho Nacional de Desenvolvimento Científico e Tecnológico, Grant/Award Number: 44349/2020-3; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

Associate Editor: Jennifer Powers
Handling Editor: Tharaka Priyadarshana

Abstract

We present camera trap evidence of 10 Atlantic Forest mammals fur-rubbing, licking, or biting balsam from *cabreúvas* (*Myroxylon peruiferum*, Fabaceae), native trees used in traditional medicine for their prophylactic and therapeutic virtues. Given the antiparasitic properties of *cabreúvas*, mammals may be using the balsam as topical self-medication to repel ectoparasites.

Abstract in Portuguese is available with online material.

KEYWORDS
cabreúva, camera trap, fur-rubbing, medicinal plants, *Myroxylon peruiferum*, zoopharmacognosy

Animal self-medication or zoopharmacognosy, the use of non-nutritional compounds by animals to prevent or control diseases or repel parasites (de Roode et al., 2013; Janzen, 1978), has been observed in a myriad of species across diverse taxa. This practice, which can have both prophylactic and therapeutic functions, encompasses a variety of behaviors such as the consumption of medicinal plants, geophagy, fur-rubbing, and anting (i.e., rubbing crushed ants on the body to appease irritated skin) (Raman & Kandula, 2008). In mammals, zoopharmacognosy has been repeatedly described in nonhuman primates (Huffman, 1997), though it has also been observed in elephants (*Loxodonta* sp.), bears (*Ursus* sp.), elks (*Cervus canadensis*), and some carnivores (Shurkin, 2014). Self-medication is often associated with the consumption of leaves, medulla, fruits, or husks of plants with antiparasitic, antimicrobial, anti-inflammatory, antioxidant, purgative, or hormonal effects (Fruth et al., 2014; Huffman & Pebsworth, 2018; Mclennan & Huffman, 2012). For example, baboons (*Papio* sp.) feed on leaves and fruits of *Balanites aegyptiaca* to control schistosomiasis, a disease caused by parasitic flatworms (Lozano, 1998). Fur-rubbing or self-anointing, the act of rubbing pungent substances on the skin or coat, is another self-medicating behavior. Although it is mainly displayed by some nonhuman primates (Huffman, 2006), this behavior is not limited to this taxon and has

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also been described in coatis (*Nasua nasua*) and interpreted as zoopharmacognosy (Gompper & Hoylman, 1993).

Fur-rubbing is generally attributed to self-medication, with a prevalence of prophylactic and therapeutic effects. For example, white-faced capuchin monkeys (*Cebus capucinus*) rub citrus fruits on their skin to repel insects (Baker, 1996), orang-outangs (*Pongo pygmaeus*) rub specific antibacterial and anti-inflammatory herbs on their joint areas (Morrogh-Bernard, 2008), while black lemurs (*Eulemur macaco*) spread toxins secreted by millipedes on their body as a repellent (Birkinshaw, 1999). Other than medicinal, fur-rubbing has also been linked to the reinforcement of social bonds (Leca et al., 2007) and territorial defense (Souza-Alves et al., 2021). It is therefore important to distinguish fur-rubbing from scent-rubbing, a behavior that is typically, although not exclusively, expressed in carnivores, in which they rub against an object in their environment to leave an olfactory signature. Scent-rubbing may have multiple purposes such as marking territory or intraspecies communication (Gosling & McKay, 1990; Hirano et al., 2008). This behavior is sometimes preceded by self-anointing where an animal impregnates its body with a specific odor (*e.g.*, urine, decaying meat, feces, etc.) (Gosling & McKay, 1990).

In this report, we describe the use of *Myroxylon peruiferum* balsam by various species of wild mammals inhabiting different fragments of Brazilian Atlantic Forest. During daily follows of black lion tamarin (Primates, Callitrichidae, *Leontopithecus chrysopygus*) groups for behavioral, endocrinal, seed dispersal, and movement ecology studies, our team witnessed tamarins fur-rubbing on a native tree species, the *cabreúva* (*M. peruiferum*, Fabaceae). *Cabreúvas*, which produce a balsam (i.e., a resinous exudate called Tolu balsam) with a typical and distinctive perfume, are recognized in traditional medicine to have both prophylactic and therapeutic properties (Lorenzi & Matos, 2002). Known to have wound-healing and anti-inflammatory properties, the balsam is used to treat a myriad of illnesses and conditions in humans such as scabies, external wounds, ectoparasite infections, bronchitis, rheumatism, urinary infections, tuberculosis, dysentery, and abscesses (Lorenzi & Matos, 2002). *In vitro* studies on *Myroxylon* sp. also revealed that the leaves have antioxidant and antibiotic actions (da Silva Junior et al., 2014; Trentin et al., 2011) and that the fruits have antimalarial activity (Muñoz et al., 2000). Furthermore, the bark is antibiotic (Gonçalves et al., 2005), antifungal (Pereira et al., 2018), inhibits leishmaniosis (Andrade et al., 2016), and is larvicidal against *Aedes aegypti*, one of the vector mosquitoes of yellow fever (Seo et al., 2012).

From March 2019 to March 2020, we studied two tamarin groups in two sites, the Morro do Diabo State Park (MDSP; 33.845 ha; 22°37′21′′S, 52°08′02′′W) and a private fragment in the municipality of Guareí (100 ha; 23°25′07′′S, 48°14′27′′W). Both study sites are composed of Brazilian Atlantic Forest, within the State of São Paulo, and are characterized by a rainy season (October–March) and a dry season (April–September). We followed the tamarins from sleeping site to sleeping site, collecting behavioral data through scan sampling every 5 min as well as all occurrence samplings for singular behaviors such as fur-rubbing. Over a total of 1246 h of direct observation, we recorded 17 events of fur-rubbing on *M. peruiferum*. In parallel, to evaluate the abundance of *cabreúva* trees in the home-range of the tamarins, we set up 20 botanical plots (10 × 10 m) in each site and identified all trees with a diameter at breast height (DBH) >4.8 cm. *M. peruiferum* density was of 20 individuals/ha in Guareí but absent from the plots in MDSP and SMA.

Generally, the tamarins directly rubbed their thoracic, abdominal, and inguinal regions on areas of the trunks with balsam exudation. They also frequently manipulated the bark of the trunk, smearing balsam on their hands before indirectly applying it over their body and tail. Moreover, on rare occasions, we observed the tamarins biting and licking the balsam, perhaps to stimulate exudation by the tree. Once, a juvenile was seen ingesting and then regurgitating the balsam, showing no signs of intoxication during the following days. In black lion tamarins, fur-rubbing was usually simultaneously performed by more than one individual (80% of the events) and sometimes performed cohesively by the entire group (20% of the events). The events of fur-rubbing only occurred during the afternoon, between 1:30 p.m. and 6:00 p.m., and lasted between 3 and 50 min (14 min 36 s ± 12 min 05 s/event). Throughout the study period, the tamarins were exclusively observed fur-rubbing on *cabreúva* balsam.

Based on the initial observations of fur-rubbing by black lion tamarins and the numerous pharmacological properties of the *cabreúva*, we decided to monitor the use of these trees placing camera traps. We set up camera traps in three different areas: the MDSP, the forest fragment in Guareí, and the fragment of Santa Maria (SMA), also inhabited by tamarins and located in the municipality of Presidente Epitácio (478 ha; 22°14′17′′S, 52°18′22′′W). In the MDSP and in Guareí, we selected a *cabreúva* tree that had previously been used by the groups of tamarins we were systematically monitoring. In Santa Maria (SMA), a fragment of Atlantic Forest in which we did not follow a group, we identified the *cabreúva* during a survey to verify the occurrence of tamarins, solely due to the strong perfume that emanated from the tree's balsam. In the MDSP, the camera trap was first set up during 130 days between February and June 2020, and then for 10 days in July 2021. In Guareí, we set up the camera traps between January and May 2020 for 65 days. In Santa Maria (SMA), the camera trap was set up between February and April 2021, totaling 41 days. We set up a single camera trap per site, 2–3m away from a *cabreúva* trunk, at 1–3 m from the ground, and oriented to the regions of the trunk with important exudation. The camera traps (Bushnell 119,435, 480p; Bushnell 119,676, 720p; Enkeeo PH760, 1080p) were running 24 h per day during the entire sampling period and programmed to record 10 s MP4 format videos with 5 s time-lags. For every video, we recorded the date, time, number, species, and described the behavior displayed by the animals present at the *cabreúvas*. To explore the daily temporal distribution of visits, we constructed radar charts for each species, revealing the different schedules during which each species visited the *cabreúvas* (Figure 2). When the time lapse between two videos of the same species was higher than 30 min, we considered this to be two distinct visits.

Camera trap footage from the different field sites unveiled novel and exclusive possible zoopharmacognosy behaviors from various Atlantic Forest mammals. The *cabreúva* trees were visited by a mammal species every 1.77 ± 1.49 days in Guareí, 1.77 ± 2.13 days in MDSP, and 4.85 ± 3.95 days in SMA. We recorded nine additional mammal species interacting with the *cabreúva* balsam (Figure 1). Black capuchins (*Sapajus nigritus*) and Ingram's squirrels (*Guerlinguetus brasiliensis*) were also spotted at the *cabreúvas* but did not seem to interact directly with the balsam. Tayras, collared peccaries, ocelots, coatis, black lion tamarins, northern tamanduas, neotropical fruit bats, and brocket deer displayed behaviors similar to fur-rubbing on the *cabreúva* trunks (see camera trap footage in Video S1). Furthermore, mouse opossums, white-eared opossums, brocket deer, tayras, ocelots, northern tamanduas, and neotropical fruit bats were also observed sniffing the trunk and/or licking the balsam. Although numerous species visited the same *cabreúva* tree individuals, two different species were never observed simultaneously at the sites. However, different species occasionally visited the trees on the same day in Guareí (i.e., ocelot–tayra; $N_{tot} = 2$) and in MSDP (i.e., peccary–mouse opossum, tayra–mouse opossum, tayra–deer, peccary–tamarin, mouse opossum–tamarin, coati–peccary, ocelot–peccary; $N_{tot} = 10$). Excepting the presence of an ocelot 11 min after a tayra on one occasion in Guareí, these coinciding visits were separated by 4.55 ± 3.63 h. Occurrences at the *cabreúvas* followed a certain temporal distribution with species visiting the sites at different schedules of the day (Figure 2). Ocelots, bats, mouse opossums, and white-eared opossums were exclusively nocturnal (i.e., 18:00–5:59), while coatis, tayras, and black lion tamarins were mainly diurnal (i.e., 6:00–17:59) (Figure 2). Similar to what was observed during direct observations of tamarin groups, the camera trap footage showed that black lion tamarins only visited the *cabreúvas* in the afternoon. Tayras were generally present at the trees at midday.

Behaviors resembling fur-rubbing had never been documented in peccaries, tamanduas, tayras, and neotropical fruit bats. Similar to the black lion tamarin, tayras, which most frequently visited the *cabreúvas*, rubbed their jaw, neck, chest, abdomen, and inguinal region against the *cabreúva* trunk. Tamanduas used their sizable claws to pry open the bark and subsequently rub their body against the exposed trunk. Collared peccaries rubbed their costal region on the trunk but also bit the bark and the roots to anoint their snout and apply balsam on their hind legs. Furthermore, multiple videos captured pairs of peccaries mutually spreading balsam on each other in head-to-tail positions. Coatis used their hands and snout to apply resin to their body and tail. In the only video showing the use of *cabreúva* by a neotropical fruit bat, the individual seems to rub both its thoracic and abdominal regions while simultaneously licking the balsam. Ocelots rubbed the base of their mandible, neck, and chest on the trunk of the *cabreúva*. This behavior was similar to scent-marking, which is common in carnivores, and may be triggered by novel odors. Indeed, a study on gray wolfs showed that the smell of perfume and motor oil provoked scent-marking in this species (Ryon et al., 1986). Lastly, deer rubbed their antlers and forehead against the trunk in vertical movements. Such a display is common in cervids, which is assumed to be associated with territory marking (Bowyer et al., 1994; Johansson et al., 1995).

In black lion tamarins, fur-rubbing on the *cabreúva* trees stood out from territory marking, a swift behavior related to inter- and intragroup social communication and commonly displayed by tamarins (Heymann, 2006). Indeed, callitrichids possess epithelial glands in their sternal and anogenital regions that produce specific odors (Miller et al., 2003; Moraes et al., 2006). Individuals rub these specific areas against horizontal or inclined substrates to deposit their

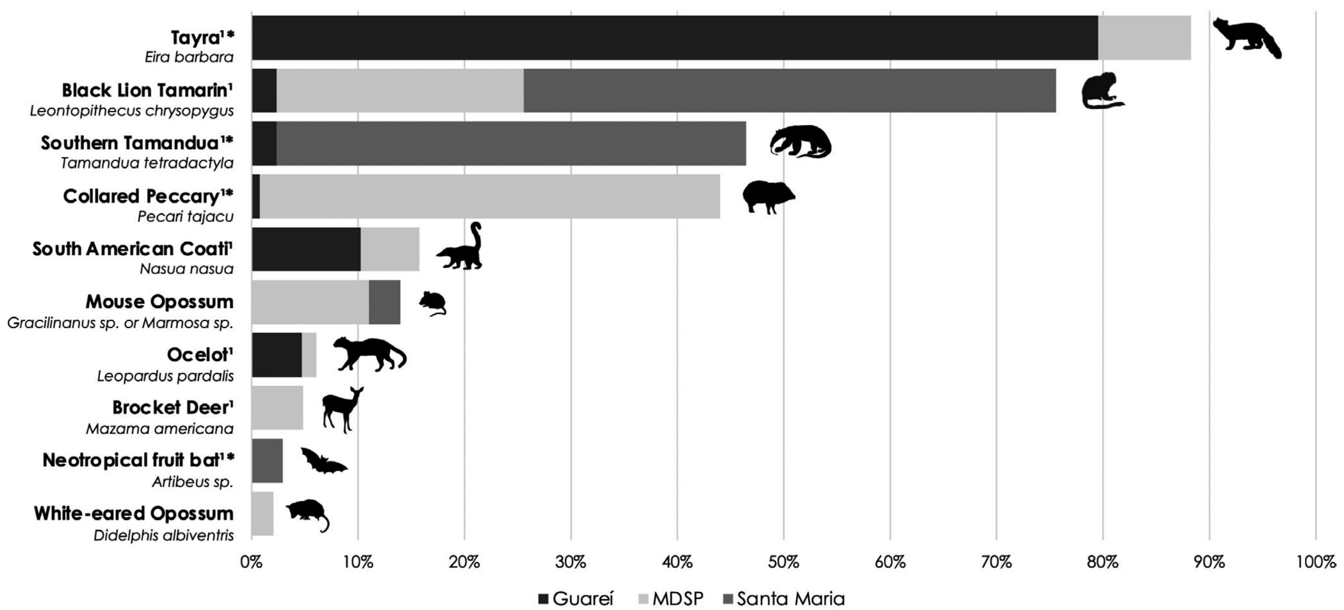

FIGURE 1 Percentage of videos captured at the *cabreúva* trees (*Myroxylon peruiferum*) per species, recorded by camera trap footage in three different field sites: a fragment in the municipality of Guareí (127 videos), the Morro do Diabo State Park (MDSP; 440 videos), and the Santa Maria (SMA) fragment (34 videos). Species that displayed fur-rubbing (1) and species for which fur-rubbing was observed for the first time (*)

(a)
(29)
(b)
(14)
(c)
(8)
(d)
(10) (17)
(e)
(7)
(f)
(5)
(g)
(5)
(h)
(3)
(i)
(1)
(j)
(1)
0
2
4
6
8
10
12
14
16
18
20
22
0
1
3
5
7
9
(k)
Guareí
(l)
MDSP
1
0.5
0
Rainy
Dry

FIGURE 2 Temporal distribution of visits to the *cabreúva* trees (*Myroxylon peruiferum*), based on camera trap footage, by (a) *Eira barbara*, (b) *Pecari tajacu*, (c) *Nasua nasua*, (d) *Leontopithecus chrysopygus*, (e) *Mazama americana*, (f) *Tamandua tetradactyla*, (g) *Leopardus pardalis*, (h) *Gracilinanus* sp. or *Marmosa* sp., (i) *Artibeus* sp., and (j) *Didelphis albiventris*. Direct behavioral observations, during daily follows, are also shown for *Leontopithecus chrysopygus* (d; light gray). Due to a technical problem with the camera traps, this figure is based on a subset of videos for which accurate time was available [Guareí: 93 videos, MDSP: 272 videos, Santa Maria (SMA): 34 videos]. The number of visits is specified in parentheses for each species. Frequency of *cabreúva* visits for *Leontopithecus chrysopygus* (K), based on direct observations, and for all mammal species (L), based on camera trap footage, between the rainy and dry season

olfactive signature (Heymann, 2006). In the case of the *cabreúvas*, fur-rubbing lasted up to 50 min and was performed directly and indirectly by black lion tamarins. Furthermore, unlike marking territory, which is mainly performed by adults, fur-rubbing was also accomplished by juveniles and often carried out by the entire group simultaneously. Regarding seasonality, although 70% ($N = 14$) of direct observations occurred during the dry season in Guareí, there were no significant differences in the frequencies of fur-rubbing between the rainy and dry season (chi-squared test: $N = 20$, $X^2 = 0.8$, $p = .371$; Figure 2k). Golden-headed lion tamarins (*Leontopithecus chrysomelas*) in Bahia, Brazil, displayed a similar behavior, fur-rubbing against the resin of *Myroxylon* sp. and *Thyrsodium spruceanum* (Guidorizzi & Raboy, 2009). Fur-rubbing associated to self-medication was predominant in the rainy season, presumably due to the abundance of hematophagous mosquitoes, such as *Aedes* sp., suggesting a possible use of *Myroxylon* sp. resin as a repellent (Guidorizzi & Raboy, 2009). However, during the dry season, tick nymphs, which are known to infect tamarins (Wilson et al., 1989), prevail in Brazil (Oliveira et al., 2000). Based on the camera trap footage, we found no significant difference in the frequency of visits, weighted according to the sampling effort in each site, between the rainy and dry season (chi-squared test: $N = 133$, $X^2 = 0.251$, $p = .616$; Figure 2). Nonetheless, a year-round monitoring of the *cabreúvas* would be needed to truly evaluate the effect of seasonality.

Considering the antiparasitic properties of *cabreúvas*, we suggest that the fur-rubbing displayed by the other mammal species may be regarded as prophylactic topical self-medication to repel potential ectoparasites and potentially reduce infection by parasitic diseases transmitted by mosquitoes and ticks. For black lion tamarins and other primates, the use of *cabreúva* balsam could therefore potentially play a key role in battling yellow fever infections, a mosquito-borne disease known to affect primate populations (Mares-Guia et al., 2020). Furthermore, when anointing their skin and fur, animals may also be benefiting from the multiple therapeutic, anti-inflammatory, and wound-healing properties of *cabreúvas*. Meanwhile, the species observed licking and biting the *cabreúvas* may be seeking other virtues of the balsam, used in traditional medicine to cure a myriad of diseases and infections (Souza et al., 2016). *Cabreúvas* may be a universal pharmacy for Atlantic Forest mammals in what could be described as convergent zoopharmacognosy. *M. peruiferum* may represent a valuable and disputed resource for mammal species, which may help sustain populations by promoting their health and increasing fitness. Future research should focus on gathering evidence of the use of *cabreúva* balsam and determine precisely which therapeutic or prophylactic properties may be sought out by Atlantic Forest mammals. Moreover, since *cabreúvas* are distributed in many vegetation types, occurring in both primary and secondary forests (Lorenzi, 2002; Sartori, 2015), it would be relevant to investigate the impact of forest loss and fragmentation on the abundance and distribution of this tree species, and how this may affect mammal populations.

ACKNOWLEDGMENTS

We would like to thank Guilherme Garbino for identifying the bat species in the video. OK received a fellowship from the National Fund for Scientific Research (FRS-FNRS, Belgium), RGA from the Coordination for the Improvement of Higher Education Personnel (CAPES), and FB from the Brazilian National Council for Scientific and Technological Development (CNPq: 443489/2020-3). This research was financed by a Young Investigator grant from the São Paulo Research Foundation (FAPESP) given to LC (#2014/14739-0).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.qnk98sfjv (Kaisin et al., 2022).

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How to cite this article: Kaisin, O., Rocha, F. C., Amaral, R. G., Bufalo, F., Sabino, G. P., & Culot, L. (2022). A universal pharmacy: Possible self-medication using tree balsam by multiple Atlantic Forest mammals. *Biotropica*, *00*, 1–7. https://doi.org/10.1111/btp.13095