Vegetable Exudates as Food for *Callithrix* spp. (Callitrichidae): Exploratory Patterns

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Abstract

Marmosets of the genus *Callithrix* are specialized in the consumption of tree exudates to obtain essential nutritional resource by boring holes into bark with teeth. However, marmoset preferences for particular tree species, location, type, and other suitable factors that aid in exudate acquisition need further research. In the current study, the intensity of exudate use from *Anadenanthera peregrina* var. *peregrina* trees by hybrid marmosets *Callithrix* spp. groups was studied in five forest fragments in Viçosa, in the state of Minas, Brazil. Thirty-nine *A. peregrina* var. *peregrina* trees were examined and 8,765 active and non-active holes were analyzed. The trunk of *A. peregrina* var. *peregrina* had a lower number of holes than the canopy: 11% were found on the trunk and 89% were found on the canopy. The upper canopy was the preferred area by *Callithrix* spp. for obtaining exudates. The intensity of tree exploitation by marmosets showed a moderate-to-weak correlation with diameter at breast height (DBH) and total tree height. The overall results indicate that *Anadenanthera peregrina* var. *peregrina* provides food resources for hybrid marmosets (*Callithrix* spp.) and these animals prefer to explore this resource on the apical parts of the plant, where the thickness, location, and age of the branches are the main features involved in the acquisition of exudates.

Introduction

Vegetable exudates, such as saps and gums, are constitutive or periodic amounts of gums confers a competitive advantage to these primates, who have relatively high energy demands because of their small size [1]. The availability of exudates favors the social use of a food resource [3], with more exudativorous species inhabiting smaller areas because of the predictable and more or functional characteristics that enable them to extract exudates from plants [12,14], including a specialized lower dentition with modification of the architecture of the mandible and bones of the masticatory apparatus [6]. Accordingly, tree-gouging is characterized by the use of the maxillary teeth to puncture and hold onto a plant branch and the mandibular incisors to scrape the branch [12,13]. These characteristics enable gouging animals to drill holes of various shapes and sizes to reach ducts in the plant tissue and release the exudates [12,13,18–20]. Additionally, marmosets have evolved a specialized system for digesting exudates through fermentation, as their cecum and colon are disproporionately large compared to the rest of their body [14,21]. This is an important feature because fermentation by microorganisms is essential for the extraction of energy from the complex polysaccharides contained within plant exudates [11,22]. The use of exudates as a food has implications for the ecology and social organization of primates [1,3,18]. The predictability of periodic amounts of gums confers a competitive advantage to these primates, who have relatively high energy demands because of their small size [1]. The availability of exudates favors the social use of a food resource [3], with more exudativorous species inhabiting smaller areas because of the predictable and more or
less constant presence of their food source. Apart from metabolism, exudative activity also appears to have an impact on the development of psychological differences among species [29].

Exudates are significant sources of complex carbohydrates, proteins and certain minerals, especially calcium [1,2,4,24–26]. Callithrix species often extract exudates from trees of the genus Anadenanthera (Fabaceae) especially Anadenanthera peregrina var. peregrina (L.) Speg. [19,20,27–29]. Species of the genus Anadenanthera are widely distributed in the photogeographical areas of the Caatinga, Cerrado (Brazilian savannah), and Atlantic Forests in the Northeast, Midwest, and Southeast regions of Brazil [30].

The exploitation of Anadenanthera spp. by marmosets is surprising because this plant can produce tannin, dyes, timber, and high tannin levels [31,34,36], both which can repel primates [37]. However, these characteristics do not appear to dismay Callithrix species in obtaining exudate from this plant. Such species include C. penicillata E. Geoffroy, 1012 [18,20,30], Callithrix jacchus L., 1758 [18,19,20,29], and Callithrix flaviceps Thomas, 1903 (Primates: Cebidae) [27,39]. Callithrix species are well known for consuming exudates from plants, but their exploitation of gum produced by trees, in particular, is poorly studied. However, this information is important for understanding the relationships between the behavioral and ecological traits of marmosets and their target tree species.

The study of plant-animal interactions has a key role in ecological theories and in the understanding issues related to the conservation of biodiversity. This is the first study to describe the ecological relationships between marmosets and their target trees and this work contributes to a better understanding of the exudative activity exerted by these primates. Here we specifically evaluate the intensity of exploitation of exudates from A. peregrina var. peregrina by Callithrix spp. in forest fragments of the Atlantic Forest in the state of Minas Gerais, Brazil. We also determine the preferred foraging location on the tree and the number of holes made to obtain exudates, and link this information to dendrometric data (DBH diameter at 1.3 m height and total height) of Anadenanthera peregrina var. peregrina.

Materials and Methods

Study areas

The study was conducted in areas used by five marmosets groups, each with six to twelve hybrid individuals with intermediate characteristics of C. penicillata × C. jacchus and C. penicillata × Callithrix Geoffroyi. The study of tree orifices gouged by hybrid marmosets is complementary to previous studies of the behavioral ecology of these animals [12,40]. Moreover, populations of hybrid marmosets are increasing in number in the Atlantic Forest as a result of anthropogenic environmental disturbance and illegal trafficking of wild animals [41].

Our study areas referred to as Fragments 1 (20°45’34.71’S, 42°51’57.84’’W); 2 (20°45’22.28’S, 42°52’23.81’’W); 3 (20°45’11.16’’S, 42°52’16.80’’W); 4 (20°45’13.85’S, 42°52’26.90’’W), and 5 (20°46’17.41’’S, 42°52’37.03’’W) (Fig. 1) were located on the campus of the Universidade Federal de Viçosa, Viçosa, in the state of Minas Gerais State, Brazil, at 675 to 709 m above sea level.

The region studied has montane seasonal semideciduous forest [42] and a highland tropical climate with rainy summers and cold, dry winters, which is classified as ‘Cwb’ based on the Köppen climate classification [43]. The area's average annual rainfall and temperature are 1221 mm and 19°C, respectively [44].

Data collection and analysis

Anadenanthera peregrina var. peregrina was selected as the focal study tree because it is the only tree species exploited by the groups of Callithrix spp. present within the study area.

Thirty-nine A. peregrina var. peregrina trees exploited by marmosets were sampled (Fig. 2). These trees were marked with sequentially numbered aluminum plates and the tree holes were measured and quantified with rock climbing equipment and techniques adapted for canopies [45]. This method enabled data collection from the higher and less accessible parts of the tree. The total tree height was measured with a hypsometer (Suunto PM 5, Finland) and the DBH with a diameter tape.

Plants with holes, which characterize its use by marmoset were collected for identification, except those that were difficult to access.

The fertile parts (branches with flowers and fruits) of four voucher specimens were collected in the field, herbarized with floristic methodology, and sent to relevant experts for identification. This material was incorporated into the collection of the Herbarium of the Universidade Federal de Viçosa with the numbers VIC, 38241; 38240; 38239; and 38615.

Individuals of A. peregrina var. peregrina were divided into two ecological zones: the trunk and the canopy [46] (Fig. 3a), with the canopy subdivided into three segments: lower, middle, and upper canopy [46,47] (Fig. 3b). All holes on the trunk were counted and measured, whereas those in the canopy were counted and measured as high up as it was safe for the researcher to go. Therefore, the percentage of holes was estimated for the canopy. The basal and distal diameter and the total length of the branches of the canopy sampled were also measured and an average diameter was obtained for the sampled branches.

Gouged tree holes were classified as inactive, characterized by presence of scar tissue and as active, without presence of scar tissue. The size of holes was measured with a digital caliper and the height (to the bark, in a vertical stroke), width (up to the bark, in a horizontal stroke), and depth (deepest portion in the hole) recorded. These parameters were obtained for active holes only, because these were assumed to be currently exploited by the marmosets. All the holes were counted, including those with scar tissue and those that were not being used by the animals. The intensity of marmoset exploitation of A. peregrina var. peregrina plant excudates was assessed by: (1) the number of active and non-active holes, and (2) height, width, and depth of the active holes.

The relation between the total number of gouged holes and the trunk diameter at 1.3 m from the soil (DBH) and tree height was analyzed by using the Pearson correlation test. The chi-square test was applied to determine whether the number of active and non-active holes differed between the three canopy segments. Analysis of variance (ANOVA) and post hoc Tukey test was used to assess whether the average diameter of the branches of each canopy segment and the dimensions of the active holes differed between these segments. Differences between the volumes of active holes in the trunk versus those in the canopy were evaluated with Student’s t-test. All analyses were carried out using the computer program R 3.0.1. [48].

No specific permits were required for to study A. peregrinarvar. peregrina and Callithrix spp. in Brazil. The field studies did not involve endangered or protected species.
Results

Measurements from 39 *A. peregrina* var. *peregrina* trees recorded ranges of DBH and total height of 6.8–64.9 cm and 6.9–35.5 m, respectively. We counted a total of 8,765 gouged holes, with 970 (11%) of holes located in the trunk and 7,795 (89%) holes located in the canopy. The total number of holes per tree ranged from 8 to 2288.

Hybrid marmosets preferentially obtained exudates from branches in the canopy of *A. peregrina* var. *peregrina*. The upper canopy showed the higher number (χ² = 143.38; p < 0.001) of both active and inactive holes (48%) followed by middle (30%) and lower canopy (22%).

A separate analysis of active gouge holes showed the same type of variation in the three regions of the tree canopy (Figure 3), showed that there was a significant difference in means of tree holes present in the three different portions of the canopy in the upper. (ANOVA, df = 2, F = 53.45, p < 0.001). In the upper canopy, the average branch length was smaller (32.19 ± 0.95; p < 0.001) than those in the middle canopy (39.36 ± 1.33 cm) and lower canopy (53.30 ± 2.03 cm) respectively.

Of the 915 active holes recorded, 810 (89%) were in the canopy and 105 (11%) were in the trunk (Table 1). The lower canopy had a smaller number and dimension of holes than the upper canopy (Table 1). The marmosets exploited the upper canopy more than the lower canopy to obtain exudates (Table 2).

The total number of gouged holes showed weak to moderate correlation with the DBH (Pearson correlation; r² = 0.530) and total height (Pearson correlation; r² = 0.435 of trees). These correlations suggest a positive relationship between concentration of gouged holes and their location in the canopy and that marmoset preferably obtain exudates from canopy branches in the canopy of *A. peregrina* var. *peregrina*.

Discussion

The feeding by marmosets on gum from holes in trees depends on various tree features. *Anadenanthera peregrina* var. *peregrina* are among the 80 species identified as sources of exudates exploited by *Callithrix* spp. [2]. The high number of scarifications on this tree species recorded in this study highlights it as a preferred source of food for marmosets; in addition, no scarifications were found on the other plant species such as *Tapirira guanensis* Aubl., *Allophylus edulis* Radlk. ex Warm.; *Astronium fraxinifolium* Schott, which are used by *C. jacchus*. However, the use of only one plant species differs from the results in the Caatinga and Cerrado, where *Callithrix jacchus* and *C. penicillata* exploited a larger number of gum trees species [20,28,29,49]. The greater number and size of holes in the canopy compared with those in the trunk can be explained by the smaller branch diameter in the canopy. The positive correlation between the number of scarifications with DBH and tree height may be explained by a larger area to be exploited to obtain exudates.

The exclusive use of *A. peregrina* var. *peregrina* by hybrid marmosets to obtain exudates in the five forest fragments and the absence of scarification on other tree species merits further study. Our results particularly raise the question if there are particular nutrients present in *A. peregrina* that are lacking other plants to explain the exclusive use of just a single plant species. Further study of this question would help us understand the marmosets selection and exploitation of exudate resources. It is known that the exudates of *Anadenanthera* have high concentrations of polysaccharides and calcium [50,51] and exudate polysaccharides are an important energy source for marmosets [52]. Calcium plays an important role to maintain the calcium/phosphorus metabolism balance of organisms [53]. Female marmosets typically give birth to twins twice a year, and calcium may be especially important during pregnancy and milk production for these animals [18,54]. Thus, one possibility for the exclusive utilization
of Anadenanthera by marmosets in our study may be a unique role of the tree species to fulfill the dietary and energetic needs of these primates.

The use of exclusive trees by Callithrix spp. to obtain exudates is uncommon given that, generally, these species use a large number of gum tree species to obtain exudates. Phaner furcifer Blainville, 1839 in Madagascar [55], Nycticebus coucang Boddaert, 1875 in West Malaysia (Manjung District, Perak State), Cebuella pygmaea in Northeastern Ecuador [56] and C. pygmaea in Iquitos, Peru [57] fed on 10, 9, 18 and 58 plant species, respectively. In the Brazilian Cerrado, Callithrix penicillata used 14 gum tree species [2,20,58,59] and this same number was reported to have been used by Callithrix jacchus in the Caatinga [28,29]. The scarce availability of resources in these ecosystems, with more extreme climatic conditions, could explain the use of different plant species [18]. However, C. jacchus explores mainly exudates from Anadenanthera peregrina [28] in the Caatinga, a biome with poor gum tree diversity. Therefore, further phytosociological studies of A. peregrina in different habitats are necessary to explain patterns of marmoset preference for gum trees.

The marmosets evaluated in this study fed only exudates of A. peregrina var. peregrina, despite the fact that the study areas were inhabited by other plant gum trees, e.g., Tapirina guianensis Aubl. used for C. jacchus [13,18]; Callithrix kuhli Coimbra Filho, 1985 [60]; C. penicillata [49]; Mico melanurus (E. Geoffroy in Humboldt, 1812) [61], Piptadenia gonoacantha (Mart.) J.F. Macbr. used for C. flaviceps [62] and Astronium fraxinifolium Schott. used for C. jacchus [18,63]; which show a preference of marmosets for A. peregrina var. peregrina.

The absence of scarification on some A. peregrina var. peregrina plants is similar to the pattern for other plant gums as Vochysia pyramidalis Mart., Callisthene major Mart. & Zucc. and Tapirina guianensis Aubl. used for C. penicillata [2] and on Anacardium occidentale L. [18]. Anadenanthera peregrina (L.) Speg., Astronium fraxinifolium Schott, Enterolobium contortisiliquum (Vell.) Morong, and Coccoloba sp. by C. jacchus [28].

The preference for certain trees of the same species can be explained by differences between the trees, such as increased production and nutritional quality of exudates, smaller amount of...
secondary metabolites, such as tannins, and greater protection from predators [1,26,55,58].

The preference of the animals for the canopy, as shown by the number and dimensions of the holes between the ecological zones of the tree (trunk and canopy) in A. peregrina found in this study, might be related to the presence of thinner branches in this region, which are preferred by marmosets to exploit this resource. This preference also might be the result of physical and mechanical factors, such as a thicker bark, and properties that facilitate scarification by these animals [6]. The quantity and nutritional quality of exudates in the canopy might be better due to a higher metabolic rate in this part of the tree and a lower quantity of secondary compounds [31,34]. However, in ecosystems with more extreme environmental conditions, such as the Caatinga and Cerrado, Callithrix spp. (C. jacchus and C. penicillata) use both the trunk and canopy of gum trees [18,20,28,49,59], with a greater number of holes found in the trunk [28,49]. Thus, the strategy of using such tree species by C. jacchus and C. penicillata might be affected by environmental conditions [28,59]. Similarly, Nycticebus spp. (P. c. Bonhote, 1907 (Primates: Lorisidae) made more use of the trunk than of the canopy for exudate feeding in a mixed deciduous forest in the Seima Protection Forest, Eastern Cambodia [5].

The increased preference of marmosets for the apical segments of the canopy, with a higher percentage of exudates and larger scarified holes, agrees with observations made between canopy segments. The increased branch use in the external parts of the canopy, where younger branches are found, reflects a preference for plant parts that are less thick, facilitating scarification. The preference of marmosets for tree segments with flatter branches horizontally and thinner bark reduces the energy used for foraging and effort in obtaining exudates. Marmoset species such as C. penicillata and C. jacchus have a bimodal pattern of exudate exploitation, with peaks in the morning and late afternoon [38,64]. After consuming the exudates, the marmosets scarify the bark and holes in parts of the tree that have a higher metabolic rate, justifying the exploration of more exposed and thinner branches of the canopy. The benefits of acquiring the exudates must be higher

**Table 1.** Height, width, depth and number (Num.) of active holes scarified by hybrid marmosets in the stem and canopy of *Anadenanthera peregrina* var. *peregrina* (Fabaceae).

| Parameters | Tree Zone | Num. | Average (mm) ± standard error |
|------------|-----------|------|-----------------------------|
| Height     | Trunk     | 105  | 10.21 ± 0.18                |
|            | Canopy    | 810  | 11.70 ± 0.10                |
| Width      | Trunk     | 105  | 14.13 ± 0.28                |
|            | Canopy    | 810  | 18.49 ± 0.24                |
| Depth      | Trunk     | 105  | 4.98 ± 0.26                 |
|            | Canopy    | 810  | 7.05 ± 0.09                 |

Student’s t-test (p < 0.01) (n = 915).

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than the associated costs, which will depend on the energy required to keep the marmosets in the canopy and involved in scarification. These factors both have an impact on the energy spent by marmosets in obtaining exudates, as reported for other primate species [63,66].

The forest fragments used by marmosets are inside an anthropogenic matrix, surrounded by urbanized areas and/or through-ways for humans, which could have a negative impact on the animals [67–70]. The marmosets might have a lower predation risk in these areas, facilitating the exploration of exudates in the canopy, especially those in the outside part of the trees. Furthermore, exploration of the external canopy to acquire exudates is favored by the small size of the animal.

The positive relation between the number of scarified holes and the dendrometric data of trees (DBH and total height) agrees with results observed previously for *C. penicillata* and *C. jaccus* on *Qualea parviflora* Mart. [59], * Astronium fraxinifolium*; *Enterolobium contortisiliquum*, and *Anadenanthera peregrina* [28]. This result suggests that larger trees tend to be more heavily scarified by *Callithrix*, and this choice is related to the ability of these animals to climb trees and the larger area available for scarification. However, the low correlation between the number of holes and DBH and tree height indicates that this preference is not determined by tree size, but by other factors, such as bark thickness and the chemical composition of the exudates [1,26].

The preference of *Callithrix* sp. for *A. peregrina* var. *peregrina* exudates in the Atlantic Forest differs from the pattern for these animals in the Caatinga and Cerrado forests, where primates, in general, exploit many species of gum trees [28,29,49,58]. The external canopy is further explored by these animals to obtain this resource with a positive correlation between the number of scarifications and DBH and tree height.

The high number of scarifications highlights the importance of *A. peregrina* var. *peregrina* as a source of exudates for *Callithrix* spp. These results contribute to understanding of the selective pressures exerted by marmosets on certain tree species and individuals to obtain this valuable resource.

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### Author Contributions
Conceived and designed the experiments: TMF DRC IOS VB. Performed the experiments: TMF DRC. Analyzed the data: TMF VB. Contributed reagents/materials/analysis tools: DRC VB IOS. Contributed to the writing of the manuscript: TMF JES JCZ VB.

### References
1. Nash LT (1996) Dietary, behavioral, and morphological aspects of gummivory in Primates. Yearb Phys Anthropol 29: 113–137.
2. Smith AC (2010) Influences on gum feeding in primates. In: Burrows A, Nash L, editors. The evolution of exudativity in primates. New York: Springer. 109–122.
3. Harrison ML, Tardif SD (1994) Social implications of gummivory in marmosets. Am J Phys Anthropol 93: 399–408.
4. Power ML (2010) Nutritional and digestive challenges to being a gum feeding Primates. In: Burrows A, Nash L, editors. The evolution of exudativity in Primates. New York: Springer. 25–44.
5. Starr C, Nickaris KA (2013). Obligate exudativory characterizes the diet of the Pygmy Slow Loris *Nycticebus pygmaeus*. Am J Primatol 75: 1054–1061.
6. Vinyard CJ, Wall CE, Williams SH, Hylander WL (2003) Comparative functional analysis of skull morphology of tree-gouging Primates. Am J Phys Anthropol 120: 153–170.
7. Taylor AB, Vinyard CJ (2004) Comparative analysis of masseter fiber architecture in tree-gouging (*Callithrix jaccus*) and non-gouging (*Sogmodus oedipus*) callitrichids. J Morph 261: 276–285.
8. Sussman RW, Kinze WG (1984) The ecological role of the Callitrichidae. Am J Phys Anthropol 64: 49–419.
9. Martins MM, Setz EZF (2000) Diet of buffy tufted-eared marmosets (*Callithrix aurita*) in a forest fragment in Southeastern Brazil. Int J Primatol 21: 467–476.
10. Passamani M, Kylands AB (2000) Feeding behavior of Geoffroy’s Marmosets (*Callithrix geoffroyi*) in an Atlantic Forest fragment of south-eastern Brazil. Primates 41: 27–38.
11. Power ML, Offedal OT (1996) Differences among captive callitrichids in the digestive responses to dietary gum. Am J Primatol 40: 131–144.
12. Coimbra-Filho AF, Mittermeier RA (1976) Exudate eating and tree-gouging in marmosets. Nature 262: 630–632.
13. Coimbra-Filho AF, Mittermeier RA (1977) Exudate-eating and the “short-tusked” condition in *Callithrix* and *Cebuella*. In: Kleinman DG, editors. The biology and conservation of the Callitrichidae. Washington: Smithsonian Institution Press. 105–115.
14. Coimbra-Filho AF, Rocha NC, Pininatti A (1980) Morfologia do ceco e sua correlação com o tipo odontológico em Callitrichidae (Platyrrhini, Primates). Rev Bras Biol 40: 177–185.
15. Roseburger AL (1978) Loss of incisor enamel in marmosets. J Mammal 59: 207–208.
16. Natori M, Shiogehara N (1992) Interspecific differences in lower dentition among eastern Brazilian marmosets. J Mammal 73: 668–671.

### Table 2. Height, width, depth and number (Num.) of active holes scarified by hybrid marmosets in the lower, middle and upper canopy of *Anadenanthera peregrina* var. *peregrina* (Fabaceae).

| Parameters | Canopy segments | Num. | Average (mm) ± standard error |
|------------|-----------------|------|-------------------------------|
| Height     | Lower           | 145  | 10.35±0.19                    |
|            | Midle           | 377  | 11.63±0.15                    |
|            | Upper           | 288  | 12.45±0.16                    |
| Width      | Lower           | 145  | 16.01±0.49                    |
|            | Midle           | 377  | 17.92±0.29                    |
|            | Upper           | 288  | 20.48±0.48                    |
| Depth      | Lower           | 145  | 5.73±0.17                     |
|            | Midle           | 377  | 6.93±0.14                     |
|            | Upper           | 288  | 7.88±0.17                     |

ANOVA, Tukey test, post hoc (p<0.01) (n = 810).

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29. Amora TD, Beltrão-Mendes R, Ferrari SF (2013) Use of alternative plant resources by common Marmosets (Callithrix jacchus). J Exp Biol 212: 4040–4055.
31. Carneiro ACO, Vital BR, Castro AFNM, Santos RCS, Castro RVO, et al. (2012) Parametros cine ticos de adesivos produzidos a partir de taninos de madeira de angico-vermelho (Anadenanthera peregrina (Benth) Speng) para a a gregacao social de jacaras de Campo (Mystax ega, Potamotrygonidae). Rev Bras Biol 41: 579–583.
32. Ferrari SF, Martins ES (1992) Gummivory and gut morphology in two sympatric callithricids (Callithrix emiliana and Saginus fusiicollis weddelli) from western Brazilian Amazonia. Am J Phys Anthropol 89: 97–103.
33. Pereira ZV, Fernandes SSL, Sangalli A, Mussury RM (2012) Usos mul tiplos de Substancias ta ni cas presentes em varias partes da a rvore angico-vermelho (E. Geoffroy, 1982), em arvores do Cerrado (Callitrichidae, Primates). Rev Bras Biol 41: 141–147.
34. Thompson CL, Rohl NJ, Melo LCC, Valeca na-Montenegro MM, Valle YBM, et al. (2015) Spatial distribution and exploitation of trees gouged by common marmosets (Callithrix jacchus). Int J Primatol 34: 143–159.
35. Nature environmental and for statistical computing R Foundation for Statistical Computing, Vienna, Austria. Available at: http:// www.R-project.org/.
36. Smith AC (2000) Composition and proposed nutritional importance of exudates eaten by saddleback (Saginus fus iicollis) and mustached (Saginus mystax) tamarins. Int J Primatol 21: 69–83.
37. Taiz L, Zeiger E (2009) Fisiologia vegetal. 4. ed. Porto Alegre: Artmed. 819p.
38. Miranda GHB, De Faria DS (2001) Ecological aspects of black-pincelled marmoset (Callithrix penicillata) in the Cerrada o and dense Cerrado of the western Brazilian Amazon. Int J Primatol 34: 65–85.
39. Carvalho PER (1994) Esp cies Florestais Brasileiras: Recomendac es sil viculturais, potencialidades e uso da madeira. Colombo: EMBRAPA/CNPFP/SP. Brasilia. 639p.
40. Lacher TE Jr, Fonseca GAB, Alves C Jr, Magalha es-Castro B (1984) Parasitism of tree by marmosets in a central Brazilian gallery forest. Biotropica 16: 202–209.
41. Laperas AB (1984) Exudate-eating and tree-gouging by marmosets (Callitrichidae, Primates). In: Chavdwick AC, Sutton SL, editors. Tropical Rain Forest: The Leeds Symposium Leeds Philosophical and Literary Society. 155–158.
42. Veloso HP, Rangel Filho ALR, Lima JCA (1991) Classific ac o da vegetac ao brasileira, adaptada a um sistema universal. Rio de Janeiro, Brasil: IBGE. 123p.
43. Gollfari L (1975) Zoneamento ecol ogico do Estado de Minas Gerais. Centro de Pesquisa Florestal da Regiao do Cerrado. Belo Horizonte, MG: PRODE-PEF. 65p.
44. Vianello RL, Alves AR (1991) Meteorologia básica e aplicações. Viçosa, MG: Universidade Federal de Viçosa. 448p.
45. Perry DR (1972) A method of access into the crowns of emergent and canopy trees. Biotropica 10: 155–157.
46. Giongo C, Waechter JL (2004) Composic es florísticas e estrutura comunitaria de espécies vegetais em vegetacao de galeria na Depressao Central do Rio Grande do Sul. Rev Bras Bot 27: 563–572.
47. Johansson DR (1974) Ecology of vascular epiphytes in West African rain forest. Acta Physiogrup suec 59: 1–129.
48. R Core Team (2012) R: A language and environment for statistical computing R Foundation for Statistical Computing, Vienna, Austria. Available at: http:// www.R-project.org/.
49. Schulke O (2003) To breed or not to breed–food competition and other factors involved in female breeding decisions in the pair-living nocturnal fork-marked lemurs (Phaner furcifer), Behav Ecol Sociobiol 55: 11–21.
50. Yepez P, Torres S, Snowden CT (2005) Interpopulation differences in exudate feeding of Pygmy Marmosets in Ecuadorian Amazonia. Am J Primatol 66: 149–151.
51. Amora TD, Beltrão-Mendes R, Ferrari SF (2015) Use of alternative plant resources by common Marmosets (Callithrix jacchus) in the Semi-Arid Caatinga Scrub Forests of Northeastern Brazil. Am J Primatol 75: 333–341.
52. Lacher TE Jr, Fonseca GAB, Alves C Jr, Magalha es-Castro B, editors. (2015) Ecologia dos marmosetes. 1st ed. Piracicaba: EMBRAPA-CNPF/SPI. 639p.
53. Moro CILO, Vital BR, Castro AFNM, Santos RCS, Castro RVO, et al. (2012) Parâmetros cênicos de adesivos produzidos a partir de taninos de Anadenanthera peregrina (Benth) Speng. Rev. Árvores 36: 767–775.
54. Fleagle JG (1999) Primate Adaptation and Evolution. 2. ed. Academic Press. San Diego. 596p.
55. Chavdwick AC, Sutton SL, editors. (2015) Tropical Rain Forest: The Leeds Symposium Leeds Philosophical and Literary Society. 155–158.
56. Yepez P, Torres S, Snowden CT (2005) Interpopulation differences in exudate feeding of Pygmy Marmosets in Ecuadorian Amazonia. Am J Primatol 66: 149–151.
57. Soini P (1988) The pygmy marmosets, genus Cebuella. In: Mittermeier RA, Laperas AB, Coimbra-Filho AF, Fonseca GA, editors. Marmosets and tamarins: systematics, behavior and ecology. Oxford Science Publications. 158.
58. Patterson ME, Montag JM, Williams DR (2003) The urbanization of wildlife problems of anthropogenic food and food digestibility. Appl Anim Behav Sci 81: 1–31.
59. Basso JE (1992) Food and feeding, scent marking and territoriality in wild population of marmosets. Am J Phys Anthropol 104: 471–486.
60. Hanna JB, Schmitt D (2011) Locomotor energetics in Primates: gait mechanics and the urbanization of wildlife problems of anthropogenic food and food digestibility. Appl Anim Behav Sci 81: 1–31.
61. Yepez P, Torres S, Snowden CT, Arruda MF (1999) Scent-marking behavior in wild groups of common marmosets (Callithrix jacchus), Behav Ecol Sociobiol 46: 313–324.
62. Raboy BE, Canale GR, Dietz JM (2008) Ecology of Callithrix kuhlli and a review of eastern Brazilian Marmosets. Int J Primatol 29: 449–467.
63. Laperas AB (1984) Exudate-eating and tree-gouging by marmosets (Callitrichidae, Primates). In: Rylands AB editor. Marmosets and tamarins: systematics, behavior and ecology. Oxford Science Publications. 158.
64. Lazaro-Perea C, Snowdon CT, Arruda MF (1999) Scent-marking behavior in wild groups of common marmosets (Callithrix jacchus), Behav Ecol Sociobiol 46: 313–324.
65. Warren RD, Crompton RH (1997) Locomotor ecology of Leptemys edwardsi and Anolis occidentalis. Am J Phys Anthropol 104: 471–486.
66. Hanna JB, Schmitt D (2011) Locomotor energetics in Primates: gait mechanics and their relationship to the energetics of vertical and horizontal locomotion. Am J Phys Anthropol 145: 43–54.
67. Patterson ME, Montag JM, Williams DR (2003) The urbanization of wildlife management: Social science, conflict, and decision making. Urban For & Urban Greening 1: 171–183.
68. Pontes ARM, Normande IC, Fernandes ACA, Ribeiro PFR, Soares ML (2007) Fragmentation causes rarity in common marmosets in the Atlantic forest of northeastern Brazil. Biodivers Conserv 4: 1173–1192.
69. Milliopp A, Bear C (2000) Density and reproduction of burrowing owl along an urban development gradient. J Wildl Manage 64: 33–41.
70. Or novi I, Oliveira FFR, Young RJ (2009) Estimating the diet of urban birds: The problems of anthropogenic food and food digestibility. Appl Anim Behav Sci 117: 42–46.
71. Nogueira DM, Ferreira AMR, Goldschmidt R, Pinzatti A, Carelli JB, et al. (2011) Cyto genetic study in natural hybrids of Callithrix (Callitrichidae: Primates) in the Atlantic forest of the state of Rio de Janeiro, Brazil. Herit Genet Zoo 101: 156–160.