Common marmosets *Callithrix jacchus* (Linnaeus, 1758) (Primates: Cebidae: Callitrichinae) in an urban mangrove: behavioral ecology and environmental influences

Saguis-de-tufos-brancos *Callithrix jacchus* (Linnaeus, 1758) (Primates: Cebidae: Callitrichinae) em um manguezal urbano: ecologia comportamental e influências do ambiente

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Abstract: The common marmoset (*Callithrix jacchus*) is a primate found in urban forests and in high density of human population sites, however there is insufficient informations about its behavior in mangroves. One group of marmosets was monitored in the *Espaço Ciência* museum, in the state of Pernambuco, Northeastern Brazil, located in a mangrove area that has been deforested for years, but has a few remaining fragments. We used scan sampling and all occurrences methods for behavioral data collection, between September 2012 and February 2013. Moving was the most frequent behavior, occupying 24.4% of the behavioral repertoire and human-provided food made up 52% of their diet. The group of marmosets interacted with people, wild and domestic animals and objects introduced by humans, such as buckets and nets for collecting organic material belonging to other research projects. While the urban environment offered conditions for group establishment in the study area, the inclusion of human foods in the diet and the relation of the marmosets with various abiotic and biotic components of the landscape endanger the health and survival, and that of other animals and people involved in the interactions.

Keywords: Activity pattern. *Callithrix*. Diet. Urban space.

Resumo: O sagui-de-tufos-brancos (*Callithrix jacchus*) é um primata encontrado em florestas urbanas e em locais de alta densidade humana, mas não há informações suficientes sobre seu comportamento em áreas de manguezal. Um grupo de saguis foi monitorado no museu Espaço Ciência, no estado de Pernambuco, Nordeste do Brasil, construído em uma área de manguezais que sofreu devastações durante anos e mantém, dentro dos seus limites, um dos poucos fragmentos que restou. Para a coleta de dados comportamentais, foram utilizados os métodos varredura instantânea e todas as ocorrências, entre setembro de 2012 e fevereiro de 2013. Locomoção foi o comportamento mais frequente, ocupando 24,4% do repertório comportamental, e alimentos providos compuseram 52% da sua dieta. O grupo de saguis interagiu com pessoas, animais do manguezal, animais domésticos e com objetos inseridos por humanos, como baldes e redes para coleta de material orgânico pertencentes a outros projetos de pesquisa. Enquanto o ambiente urbano ofereceu condições para o estabelecimento do grupo na área de estudo, a inclusão de alimentos antropogênicos na dieta e a relação dos saguis com variados componentes abióticos e bióticos da paisagem colocaram em risco a saúde e a sobrevivência dos saguis, dos demais animais e das pessoas envolvidos nas interações.

Palavras-chave: Padrão de atividades. *Callithrix*. Dieta. Espaço urbano.

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INTRODUCTION

The accelerated growth of urban landscapes and the ecological consequences of this growth are topics of interest and frequent research, regarding the various aspects related to environmental and human health (Bradley & Altizer, 2007; Mucelin & Bellini, 2008). Urbanization modifies the landscape, promotes physical and biological changes over time, compromises ecosystems, and causes environmental impacts such as, the reduction of natural vegetation and the home range of animals (Adams, 2005; McKinney, 2008). Humans see wild species as problems when these species occur near human activities. However, interactions with humans can affect the health of wild animals (Angelici, 2016). The presence of wild animals in urban environments is not uncommon and as such, it is likely that the increasing proximity of these animals to humans is expected. Soulsbury & White (2015) explain that wild animals and humans in urban areas inevitably interact. Yet, the nature of these interactions can vary greatly from admiration, pleasure, fear and loathing (Soulsbury & White, 2015).

Urban areas offer opportunities to study questions on anthropogenic influence on wild animals and natural processes (Parker & Nilon, 2012). From the point of view of behavioral ecology and wildlife conservation, studies on wildlife living in urban environments are relevant and have been increasing over the last few decades (Marion, 1988; Hadidian, 1992; Hadidian & Smith, 2001; Magle *et al.*, 2012; Poessel *et al*., 2017). The process of wild animals adjusting to live in urban conditions is known as synurbization (Luniak, 2004; Adams, 2005). Humans living in high densities and the type of activities they perform play an important role in determining which species are able to adjust to urban ecosystems and how this adjustment affects their behavior (Soulsbury & White, 2015). Animal behavioral responses to urbanization can be classified into three types (Goulart *et al.*, 2010): (1) animals that avoid contact or fail to thrive in urban environments; (2) urban explorers: animals living in higher densities in urban environments compared to their natural environments, and (3) urban adapters: animals living in the same densities in both their urban and natural environments.

Several species can survive in environments that suffer from anthropic disturbance. Important adjustments for the successful establishment of these animals in urban environments include anthropogenic foods in their diet, animals may increase their circadian activity and/or decrease the constancy of their migratory behavior (Lowry *et al.*, 2013). These adjustments can result in behavioral changes, allowing for better interactions with the environment and among conspecifics (Jokimäki *et al.*, 2011). This is the case of the common marmoset *Callithrix jacchus* (Linnaeus, 1758), a Neotropical primate commonly found in Brazilian urban areas within parks, gardens, yards, and villages (Rangel *et al.*, 2011; Silva, G. *et al.*, 2011; Albuquerque *et al.*, 2012; Silva, J. *et al.*, 2014).

Callithrix jacchus is native in Northeastern Brazil, occurring in the Caatinga, Atlantic Forest, Cerrado and associated habitats such as mangrove forests (Silva, G. & Monteiro da Cruz, 1993; Paula *et al*., 2005; Rylands *et al*., 2009; Rylands & Mittermeier, 2013). In Southeastern Brazil, the species was introduced as a result of animal trafficking (Ruiz-Miranda *et al.*, 2000; Rangel *et al.*, 2011). All literature available on *C. jacchus* in urban areas, focuses on their occurrence in Atlantic Forest areas (Silva, G. & Monteiro da Cruz, 1993; Mendes Pontes & Soares, 2005; Cunha *et al*., 2006; Lyra-Neves *et al*., 2007; Silva, M. *et al*., 2018), as well as several studies focusing mainly on their behavioral ecology within urban parks or densely populated places by humans (Silva, G. *et al.*, 2011; Traad *et al*., 2012; Silva, J. *et al.*, 2014).

Little is known about the behavior of primates in urban mangroves due to the scarcity of research on this type of habitat (Cutrim, 2013). Mangrove ecosystems are heterogeneous habitats with an unusual variety of animals and plants adapted to the extreme environmental conditions of high salinity, frequent submersion and a

soft-bottomed anaerobic mud (Khairnar *et al*., 2009). Depending on climate, land conditions, or human impact, species of mangrove vegetation and animal species may vary and this variation ranges from microfauna to large mammals, including resident and occasional populations and individuals, such as generalist carnivores and primates (Vannucci, 2001).

The aims of this study were: (1) to monitor and describe the behavioral and ecological repertoire of a group of common marmosets (*C. jacchus*) in an urban mangrove fragment; (2) investigate the influence of factors associated with urbanization, including the effect of human presence on the group's behavior; (3) evaluate how these influences develop; and (4) how these factors affect the welfare of marmosets.

MATERIAL AND METHODS

STUDY AREA

This study was carried out in the *Espaço Ciência* museum, located in Olinda, a city adjacent to Recife, the capital of Pernambuco state, Northeastern Brazil (Figure 1). The museum has a total area of 12 hectares (Figure 2). It is the largest open science museum in the country (SECTEC, 2016), with areas where visitors circulate and two hectares of an urban mangrove called

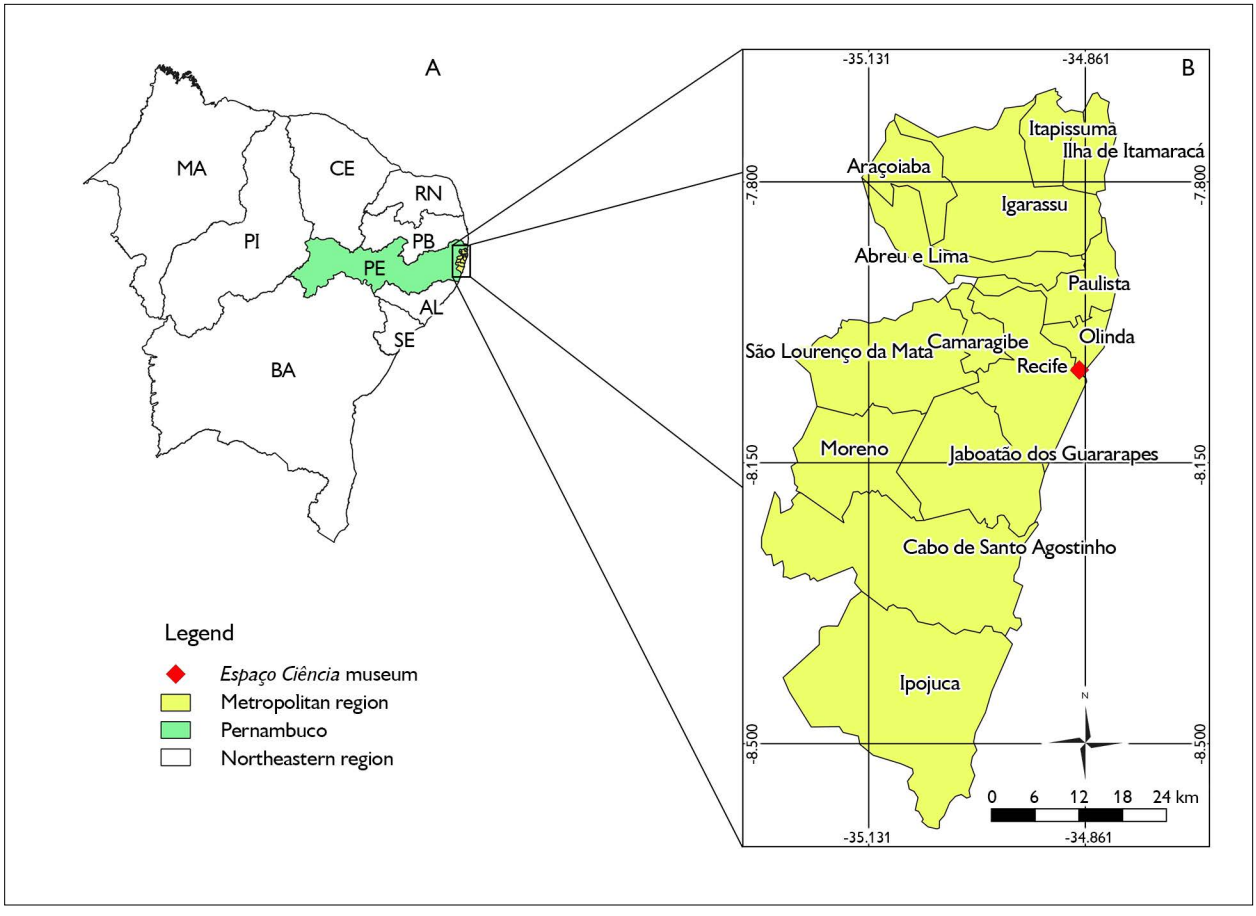

Figure 1. A) Map shown Pernambuco state highlighted (green) within the Northeastern region of Brazil; B) Recife and the Metropolitan Region cities (yellow), where the red dot indicates the location of the *Espaço Ciência* museum, at the city limits of Recife and Olinda municipalities. Sources: adapted from IBGE (2020) and PCR (2020).

Figure 2. Satellite image of the study area, *Espaço Ciência* museum (red outline) and the Chico Science Mangrove (yellow outline). Source: Google Earth®.

Chico Science Mangrove (08° 02' 40" S, 34° 52' 00" W). This mangrove fragment is located approximately 500 m from the Atlantic Ocean, at the mouth of two important rivers in the region, the Beberibe and Capibaribe. Its vegetation is in regeneration, with trees reaching approximately five meters, consisting mainly of red mangrove *Rhizophora mangle* (Linnaeus, 1753) (Rhizophoraceae), white mangrove *Laguncularia racemose* (Linnaeus, 1807) (Combretaceae) and black mangrove *Avicennia schaueriana* (Stapf & Leechman, 1939) (Acanthaceae) species. Several species of resident and migratory birds feed and reproduce in this mangrove forest (Periquito *et al.*, 2008).

The *Espaço Ciência* is surrounded by highways, named the Salgadinho Complex, located in the vicinity of the northern boundary of the fluvial-marine plain of Recife. The landscape of the study area has undergone profound transformations between the years 1970 and 2000, when the original mangrove area was, for years, cut down for the construction of the Salgadinho Complex and later chosen for the development of urban residences and commercial areas (Souza, 2006).

SUBJECTS AND DATA COLLECT

One group of common marmosets, *C. jacchus,* was monitored. The group was the only one found to inhabit the mangrove and adjacent areas of the museum (Figure 3).

Figure 3. Group of the study marmosets, *Callithrix jacchus* (A), at the edge of the Chico Science Mangrove. (B) Two marmosets of the group (indicated by arrows) between the roots of the mangroves during foraging, and (C) three marmosets in a built-up area of the *Espaço Ciência* museum visitation area. Photos: Juliana Ribeiro de Albuquerque (2012).

During the observations, the animals were individually identified by age, estimated by morphological and behavioral characteristics (body size, length of periauricular tufts). Infants were identified through their being carried and fed by older animals: infant ≤ 5 months, juvenile 6-10 months, subadult 11-15 months and adult > 15 months (Yamamoto, 1993; Albuquerque *et al.*, 2012), sex (male or female) and by marks such as scars or distinguishable physiognomy whenever possible. Group size varied between eight and ten animals due to births and dispersions. The composition of the group at the end of the study was eight animals: two adults (one male and one female), two subadults (one male and one female), two young (one male and one of unidentified sex), and two infants of unidentified sex.

Data were collected from September 2012 to February 2013, throughout the dry season. Observations occurred every month, twice a week, with each period of observation lasting three hours, totaling 150 hours of sampling effort. We used the scan sampling and all occurrences methods (Altmann, 1974) for behavioral data collection. The first behavior displayed and the distances of each animal from the nearest neighbor were described during sessions of five minutes, alternated with five minutes of pause, totaling ten minutes for each scan.

The all occurrences method was applied throughout the observation period, including during the scan period, for the detailed recording of rare or uncommon behaviors and when these behaviors were associated with the presence of biotic or abiotic elements typical of an urban environment. All data were recorded on field recording sheets and, additionally, moments of foraging and feeding behavior were recorded with a digital camera (Sony®, DSC-S 3000).

STATISTICAL ANALYSES

Descriptive statistical analyses and analyses of variance (ANOVA) complemented with the Tukey test were conducted. These tests made it possible to compare the difference between the most frequent behavioral activities and the occurrence of food seeking behaviors (foraging) and consumption (feeding), in the museum's visiting areas and in the mangrove. The Bioestat software version 5.3 was used to perform the descriptive and variance analyses, considering a significant result at $p < 0.05$ and highly significant at $p < 0.01$.

RESULTS

ACTIVITIES PATTERN

For 144 hours of the total 150 hours of sampling effort, 912 sessions of scan were performed and 2,936 behavior records of *C. jacchus* group were collected. Thirty-three behaviors were exhibited by the group of marmosets (Table 1), with a variable pattern between individual and social activities, including both affiliative and agonistic behaviors. Some individual, affiliative and all low agonistic behaviors ($n \leq 88$) were grouped into a single behavioral category, in which case six categories were included: 1 - Social grooming; 2 - Parental care; 3 - Other individual behaviors; 4 - Agonistic behaviors; 5 - Other affiliative behaviors; and 6 - Defecate or urinate.

Callithrix jacchus individuals spent a considerable percentage of time moving (24.4%), followed by resting (15.5%), stationary (13.7%), foraging (12.4%), playing (9.5%), feeding (6%) and social grooming (5.7%) behaviors. The categories of agonistic behaviors (1%), other affiliative behaviors (0.4%), interact with people (0.5%), defecate or urinate (0.1%) and interact with animals (0.03%) were expressed for less than 2% of their activity repertoire (Table 2).

The relationships between the monthly means of the highest percentage for each of the seven behavioral categories are shown in Table 3. Mean of moving (119.3 ± 30.1) was highly significant in relation to resting (76.2 ± 16.3) ($p < 0.01$), stationary (67.2 ± 16.3) ($p < 0.01$), foraging (60.5 ± 20.6) ($p < 0.01$), feeding (29.5 ± 18.4) ($p < 0.01$), social grooming (27.8 ± 9.3) ($p < 0.01$) and playing (46.7 ± 15.2) ($p < 0.01$) behaviors. Resting had a highly significant mean in relation to the other categories (feeding, social grooming and moving, $p < 0.01$ in each behavior). Stationary behaviors presented a significantly different mean ($p < 0.05$) in relation to the means of feeding, social grooming and this category was even more significant ($p < 0.01$) when compared to moving. The difference between foraging and playing behaviors was only significant in relation to the moving category ($p < 0.01$). Feeding had a significantly different mean ($p < 0.05$) compared to the stationary behavior category and was significant ($p < 0.01$) compared to resting and moving behaviors.

Table 1. Behavioral categories and their respective descriptions (adapted from Monteiro da Cruz, 1998), referring to the activities pattern of the group of *C. jacchus* observed between September 2012 and February 2013 in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

Behaviour	Description
Moving	Move slowly or fast
Jump	Movement without physical contact with any substrate by jumping
Resting	Lie in relaxed posture, closing its eyes or not
Stationary	Remain still, but attentive to the environment
Foraging	Search for natural or processed foods
Feeding	Chew, eat or carry food in the mouth
Social grooming	Included the behaviors involving cleaning the hair of another marmoset and being cleaned by another marmoset, either involving two or more marmosets simultaneously
Playing	Act of running or fighting, pursuing or grabbing another marmoset without apparent intentions
Defecate or urinate	It included the excretion of faeces or urine
Parental care	Included behaviors: nurse or infant (carrying nursing behaviors feeding breast milk to the infant or transporting infants on the back or under the breast) and: be breastfed or to be carried (act of an infant feeding from breast milk or being transported on the back or under the breast of another marmoset)
Other individual behaviors	Individual behaviors (itching, autogrooming, marking, gnawing tree barks, vocalizing, hiding) emitted with low frequency by marmosets
Agonistic behaviors	Included behaviors involving running away, running away from the observer, chasing, being chased, bristling hair, stealing food, attempting to steal food and applying spankings
Other affiliative behaviors	Included affiliative behaviors such as contacting or approaching performed with low frequency by marmosets
Interaction with people	Interacting directly or indirectly with people
Interaction with animals	Interacting directly or indirectly with animals (pets or not)

Table 2. Behavioral categories, total number of occurrences (N) and equivalent percentage (%) obtained for the *Callithrix jacchus* group observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

(Continue)

Categories	N	%
Moving	716	24.4
Jump	35	1.2
Resting	457	15.5
Stationary	403	13.7
Foraging	363	12.4
Feeding	177	6.0
Social grooming	167	5.7
Playing	280	9.5
Defecate or urinate	3	0.1
Parental care	161	5.5
Other individual behaviors	119	4.1

Table 2. (Conclusion)

Categories	N	%
Agonistic behaviors	27	1.0
Other affiliative behaviors	13	0.4
Interaction with people	14	0.5
Interaction with animals	1	0.03
Total	2,936	100

Table 3. Monthly mean values (Mean C1 and C2), difference between the means (Difference), studentized range distribution (Q) and p of the means for the seven most frequent behavioral categories in the *Callithrix jacchus* group, observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil. Legends: C1 = first category of the line; C2 = second category of the line; ns = not significant.

Categories	Mean C1 and C2	Difference	Q	p
Moving (C1) and Resting (C2)	119.3 and 76.2	43.1	5.6	< 0.01
Moving (C1) and Stationary (C2)	119.3 and 67.2	52.1	6.8	< 0.01
Moving (C1) and Foraging (C2)	119.3 and 60.5	58.8	7.6	< 0.01
Moving (C1) and Feeding (C2)	119.3 and 29.5	89.8	11.7	< 0.01
Moving (C1) and Social grooming (C2)	119.3 and 27.8	91.5	11.9	< 0.01
Moving (C1) and Playing (C2)	119.3 and 46.7	72.6	9.4	< 0.01
Resting (C1) and Stationary (C2)	76.2 and 67.2	9.0	1.1	ns
Resting (C1) and Foraging (C2)	76.2 and 60.5	15.7	2.0	ns
Resting (C1) and Feeding (C2)	76.2 and 29.5	46.7	6.09	< 0.01
Resting (C1) and Social grooming (C2)	76.2 and 27.8	48.4	6.3	< 0.01
Resting (C1) and Playing (C2)	76.2 and 46.7	29.5	3.8	ns
Stationary (C1) and Foraging (C2)	67.2 and 60.5	6.7	0.8	ns
Stationary (C1) and Feeding (C2)	67.2 and 29.5	37.7	4.9	< 0.05
Stationary (C1) and Social grooming (C2)	67.2 and 27.8	39.4	5.1	< 0.05
Stationary (C1) and Playing (C2)	67.2 and 46.7	20.5	2.6	ns
Foraging (C1) and Social grooming (C2)	60.5 and 27.8	32.7	4.2	ns
Foraging (C1) and Playing (C2)	60.5 and 46.7	13.8	1.8	ns
Foraging (C1) and Feeding (C2)	60.5 and 29.5	31.0	4.0	ns
Feeding (C1) and Social grooming (C2)	29.5 and 27.8	1.7	0.2	ns
Play (C1) and Feeding (C2)	46.7 and 29.6	17.1	2.2	ns
Play (C1) and Social grooming (C2)	46.7 and 27.8	18.9	2.4	ns

DIET

Foraging areas used by the *C. jacchus* group included sites such as the Chico Science Mangrove, the medium and large trees of the surrounding area for visitors and the areas with buildings. The diet of the marmosets (n = 177) included natural foods such as gum (11%), fruits (0.6%), flowers (0.6%), invertebrates (1.1%), vertebrates (2%) and human-provided food (52%), as well as food that could not be classified (33%) (Figure 4). Foods classified as human-provided were obtained under the following

Figure 4. Marmosets during feeding. Eating bird eggs from a nest in an artificial tree (A), during the gomivory of tree of the species *Terminalia catappa* (B), eating watermelon (C), and marmoset with infants on their back, eating bananas (D). In these last two cases the food was provided by people. Photos: Juliana Ribeiro de Albuquerque (2012).

conditions: a) interaction with visitors and workers, b) removed from the garbage or on the soil, and c) food disposed by humans. In addition to the cited items, the marmosets were observed eating bird eggs, in a nest built on an artificial tree constructed by the museum.

Gum was obtained from trees of *Terminalia catappa* (Linnaeus, 1767) (Combretaceae) and unindentified Leguminosae species. The only fruits identified as food were figs (*Ficus* sp., Moraceae) and a flower from an unidentified plant was also recorded. Among human-provided foods were various fruits (banana, papaya and watermelon), popcorn and cookies. Arthropods consumed were exclusively orthopterans and vertebrates consumed were lizards (Squamata). Gum, fruits, flowers and eggs were acquired in the museum's visiting area, and human-provided food, insects and vertebrates were obtained both in the visitation area and in the mangrove.

ENVIRONMENTAL INTERFACE: REFLECTIONS OF THE URBAN LANDSCAPE ON THE BEHAVIOR OF THE GROUP OF COMMON MARMOSETS

The *Espaço Ciência* museum occupies 12 hectares, with several outdoor areas for visitors to move around freely, administrative and experimental buildings and the Chico Science Mangrove with 2 hectares. The home range of

the marmosets group covered only the mangrove and the visitation area around it. Almost half of the activity occurred (49.3%, n = 1,447) in the mangrove and 50.7% (n = 1,489) occurred in the museum visitation area. There was no significant difference in the use of space between the two sites (ANOVA, F = 0.0211, p = 0.8821).

The descriptive analysis of the seven most common behaviors (Table 4) shows that moving, resting, foraging and social grooming occurred most often in the mangrove and the stationary, playing and feeding activities occurred mainly in the visitation area of museum. The ANOVA test did not indicate significant differences between moving (F = 0.1657, p = 0.6937), resting (F = 0.0483, p = 08245), stationary (F = 0.1763, p = 0.6851) playing (F = 1.6905, p = 0.2212), feeding (F = 1.3835, p= 0.2662), and social grooming (F = 0.8029, p = 0.6052) in the mangrove or visitation area. Regarding the activities associated with diet, *i.e*., foraging and feeding, it was evident that foraging was, on average, more frequent than feeding, in the mangrove ($p < 0.05$) (Table 5).

Direct (for example, the person fed the marmoset directly, initiating physical contact) or indirect contact (the person placed the food in a certain place where it could be reached by a marmoset) between humans and marmosets (n = 14, 0.5%) related to food provisioning was observed. The people involved in the interactions with marmosets were visitors, museum workers, groundskeepers and snack merchants who passed through the visitor areas and who provided food items to the marmosets in order to observe their behaviors more closely.

Table 4. Behavioral categories, total number of occurrences (N), minimum and maximum values (Min-Max) of monthly occurrence recorded during the research, total amplitude (Ta), monthly mean and standard deviation ($\mu \pm$ SD) obtained for the *Callithrix jacchus* group by area use, observed in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil.

Categories	Mangrove				Visitation Area			
	N	Min-Max	Ta	$\mu \pm$ SD	N	Min-Max	Ta	$\mu \pm$ SD
Moving	372	34-103	69	62.0 ± 25.0	344	47-82	35	57.3 ± 12.8
Resting	238	5-66	61	39.7 ± 23.5	219	11-79	68	36.5 ± 26.3
Stationary	191	14-48	34	31.8 ± 13.1	212	24-60	36	35.3 ± 15.7
Foraging	218	7-52	45	36.3 ± 16.8	145	11-41	30	24.2 ± 11.3
Playing	111	11-28	17	18.5 ± 6.1	169	9-50	41	28.2 ± 17.2
Feeding	64	2-21	19	10.7 ± 7.9	113	2-38	36	18.8 ± 15.1
Social grooming	98	4-37	33	16.3 ± 11.9	69	2-18	16	11.5 ± 5.7

Table 5. Monthly mean values by area use, difference, studentized range (Q) and p of the comparison between the means of foraging and feeding by area of use, obtained for the *Callithrix jacchus* group observed between September 2012 and February 2013, in the *Espaço Ciência* museum, Olinda, Pernambuco state, Brazil. Legends: C1 = first category of the line; C2 = second category of the line; ns = not significant.

Categories	Means C1-C2	Difference	Q	p
Foraging in mangrove (C1) and Foraging in visitation area (C2)	36.3-24.2	12.1	2.2	ns
Foraging in mangrove (C1) and Feeding in mangrove (C2)	36.3-10.7	25.6	4.7	< 0.05
Foraging in mangrove (C1) and Feeding in visitation area (C2)	36.3-18.8	17.5	3.2	ns
Foraging in visitation area (C1) and Feeding in mangrove (C2)	24.2-10.7	13.5	2.4	ns
Foraging in visitation area (C1) and Feeding in visitation area (C2)	24.2-18.8	5.4	0.9	ns
Feeding in visitation area (C1) and Feeding in mangrove (C2)	18.8-10.7	8.1	1.5	ns

Adult marmosets interacted with night herons *Nyctanassa violacea* (Linnaeus, 1758) (Aves: Ardeidae), a species associated with wetlands. The birds behaved agonistically, waving their feathers and flapping in the presence of marmosets, especially when the animals attempted to approach their nests. An attempt of physical contact with a crab, *Goniopsis cruentata* (Latreille, 1803) (Crustacea: Brachyura: Grapsidae), probably to capture it, was also observed.

The presence of domestic dogs *Canis familiaris* (Linnaeus, 1758) (Mammalia: Canidae) on two different occasions caused the marmosets to emit alert vocalizations, encouraging the group to seek protection in the mangrove foliage. On one occasion a dog approached the marmosets observing other animals in the Chico Science Mangrove, while the marmosets vocalized in a continuous and agonistic way, until one of the marmosets attacked the dog by defensively jumping on its back.

Objects introduced by humans, set up for other studies conducted simultaneously to ours, were used by the group of marmosets to perform certain behavioral activities. Buckets used to collect *Aedes aegypti* (Linnaeus, 1762) (Diptera: Culicidae) mosquito eggs in the visitation area and nets to collect biological material in the mangrove were used by infants and young (n = 153) as well as by adults (n = 10) for playing. Due to the velocity of the play movements, during which they often formed a type of entangled 'animal ball', with several individuals rolling together, it was not always possible to identify the subjects involved (n = 117).

A dead marmoset, likely a victim of electrocution, was found a few meters outside the boundaries of the *Espaço Ciência* museum. Due to the proximity of the corpse to the area frequented by the monitored group, it is possible that this was one of the animals that had dispersed from the study group. Reports by the museum monitors and local workers often mention marmosets and other animal mortalities due to electrocution and roadkill in the vicinity of the museum. On one occasion, the group of marmosets was on a tree on the edge of a viaduct that passes over the museum, however, the animals did not remain there for a long time due to the sound of the passing vehicles.

DISCUSSION

ACTIVITIES PATTERN IN THE URBAN LANDSCAPE

Our results show that the overall time devoted to moving, resting, stationary, foraging and playing behaviors was similar to the behavioral pattern exhibited by *C. jacchus* (Martins, 2007; Amora *et al*., 2013) and *Callitrhix* spp. (Modesto & Bergallo, 2008) in natural environments. However, the distribution of the activities differed between the study group and wild marmosets, as moving or displacement was the least represented behavior by *C. jacchus* in the Caatinga (Martins, 2007; Amora *et al*., 2013), but it was frequently observed in congeners and conspecifics that inhabit the Atlantic Forest whereas, animals inhabiting the anthropic area devoted more time to resting and foraging (Modesto & Bergallo, 2008).

Moving also accounted for highest percentage in two groups of *C. jacchus* studied by Silva, G. *et al.* (2011) in urban areas, totalizing respectively 28% and 48.6% of the activity patterns, respectively, whereas one of the groups resting was the second most frequent behavior with 24.1%. Displacement was also found to be the highest occurring behavior in urban groups of *Callithrix penicillata* (É. Geoffroy, 1812) with 22.4%, followed by resting, with a percentage of 16.58% and inactive alert with 14.95% (Santos, M. *et al.*, 2014) (equivalent to stationary) and therefore, these results are in accordance with the behavior pattern of *C. jacchus* observed in the museum study area. Although fragmentation and human disturbance affect the activity pattern and spatial and temporal use of wild animal habitat (Tigas *et al.*, 2002; Ditchkoff *et al.*, 2006), the high movement of visitors in the museum grounds and the loud noise from the surrounding highway, did not impede moving behaviors of *C. jacchus.* This is especially important since moving is necessary for food acquisition and consequent intake of enough nutrients for the performance of other individual and social activities.

DIET: NATURAL FOODS X HUMAN-PROVIDED FOODS

The results showed the inclusion of gum, fruits, flowers, invertebrates, vertebrates and bird eggs in the diet of the study group, reaffirming the omnivorous diet of *C. jacchus* (Digby *et al*., 2007; Power & Myers, 2009) and also the inclusion of human-provided foods. Gomivory is an important aspect of the behavioral ecology of *C. jacchus* and their specialized anterior dentition, robust lower incisors lacking lingual enamel, canine height reduction, reduced condylar height, longer jaw-muscle fibers and the enlarged intestinal cecum allows for the inclusion of large amounts of gum in the diet, which is an important food component for marmosets in free-living, natural or urban areas (Rosenberger, 1978; Vinyard *et al.*, 2009; Smith, 2010; Silva, J. *et al.*, 2014; Garbino, 2015).

The amount of gum ingested in natural and urban environments may be different. This difference can be explained by primates' access to food which has been improperly disposed of or through food being offered to these animals on purpose by humans, as a means to attract the animals for closer observation, as was observed in the study site. Additionally, the urban landscapes can make it difficult for animals to access trees that, when present, could serve as a source of food. In an urban environment, outside the native range of the species, gum was found to be the main food source for *C. jacchus* accounting for approximately 40% of their diet, besides fruits and vertebrates which were ingested in smaller quantities (Cunha *et al*., 2006). Silva, J. *et al.* (2014) monitored a group of *C. jacchus* in an urban park surrounded by Atlantic Forest, within the species' native range, and in this case, gum composed 61.9% of the diet, besides the food provided and other foods of vegetal and animal origin.

The diet of another congener, *Callithrix geoffroyi* (Humboldt, 1812), studied in urban areas was found to be comprised of 40.7% gum and 28% fruits, which represents more than half of the total food intake (Nicolaevsky & Mendes, 2011). Unlike other studies (Cunha *et al*., 2006; Nicolaevsky & Mendes, 2011; Veríssimo *et al.*, 2012; Silva, J. *et al.*, 2014), we observed that gum was a secondary food item in the diet of the marmosets observed in our study site. However, gum consumption in our study has assumed the same secondary role in the diet of the animals studied by Amora *et al.* (2013). In the cited study, the proportion of gum in the diet of *C. jacchus* in the Caatinga (28.73% of the diet) was different from the diet of *C. jacchus* in the museum (11%), in relation to the other foods consumed in the diet in each study. The predation of bird eggs and nestlings by *C. jacchus* occurs in their natural environment and although birds demonstrate agonistic behaviors, the marmosets often succeed in this activity (Lyra-Neves *et al*., 2007). As with the group monitored in this study, Begotti & Landesmann (2008) also described the predation of nests by *Callithrix* spp. hybrids in urban areas and emphasized that the local avifauna can be harmed by this type of behavior.

Human-provided foods, i.e. exotic fruits and industrialized items, comprised more than half the study group diet and were obtained through interactions with humans, collected in dumpsters or picked off the ground. The same foraging strategy was used by other species of monkeys in urban areas that fed on human foods (Sabbatini *et al.*, 2006; Nicolaevsky & Mendes, 2011; Albuquerque & Oliveira, M., 2014; Silva, J. *et al.*, 2014). The availability of human food in urban areas can modify the foraging patterns and diets of wild animals, promoting dramatic differences in dietary habits (Ditchkoff *et al.*, 2006) and the behavior of the *C. jacchus* group in the study area corroborates the effects of the presence of this type of food.

RELATIONSHIP BETWEEN URBAN LANDSCAPE, HOME RANGE AND BEHAVIOR OF COMMON MARMOSETS

The home range of *C. jacchus* can vary between at least one and five hectares in natural and urban environments.

Groups of marmosets in natural environments were found to have home ranges of 4.9 ha (Alonso & Langguth, 1989), 0.7 ha and 2.4 ha (Castro, 2003) in the Atlantic Forest, 1.1 ha and 1.5 ha (Veríssimo *et al.*, 2012) in the Restinga and 2.7 ha (De la Fuente *et al*., 2014) in the Caatinga. In urban environments, groups of marmosets have been found to have home ranges of between 0.2 ha and 4.1 ha (Mendes Pontes & Monteiro da Cruz, 1995), 0.6 ha (Oliveira, I., 2003), 4.7 ha (Albuquerque *et al.*, 2012), 1.9 ha and 3.4 ha (Rocha, 2019). Therefore, there does not appear to be much difference in the home range size of *C. jacchus* in urban and natural areas. In the same way, 2 ha of mangroves and part of the surrounding visitation area used by the study marmosets, is within the described limits for the home range sizes of marmosets observed in the previous studies. Comparatively, the movement and home range size of common raccoons *Procyon lotor* (Linnaeus, 1758), living in urban and suburban areas in Northeastern Illinois, has been found to be lower in relation to the animals living in rural areas due to the abundant presence of artificial foods (Prange *et al.*, 2004).

In accordance with all these studies, the influence of the urban environment on the marmosets group observed at the *Espaço Ciência* museum was evidenced by the frequency of certain activities, which were carried out more often in the mangrove, where marmosets took advantage of the shading provided by vegetation. We noted that the group made fewer trips to open areas, which experienced higher temperatures and greater noise levels from people and vehicle traffic, and sought food mainly in the visitation area, where success was almost always guaranteed. This strategy optimized the acquisition of nutrients to meet the energy needs of the animals. Thus, the study marmosets group also demonstrated a similar adaptation to that of raccoons, observed in a study by Prange *et al.* (2004), reducing their home range, diversifying their diet and avoiding risks. There was no significant difference in the use of the mangrove and visitation areas by the group of marmosets. Although the occurrence of moving, resting, foraging and social grooming activities was higher in the Chico Science Mangrove, and the stationary, playing and feeding activities were more common in the visitation area, there was no significant difference in the performance of these activities between any of the locations. In contrast, the *C. jacchus* group studied by Albuquerque *et al.* (2012) in the Atlantic Forest of Pernambuco state, demonstrated a preference for the visitation area in an urban park for the performance of displacement, social grooming and playing activities, instead of remaining in the forest area.

Regarding the activities associated with diet, foraging was significantly more common compared to feeding in the mangrove ($p < 0.05$). The mangrove is a place with a myriad of microhabitats for small vertebrates and insects, items that usually required a significant amount of time to find and whose capture is not always successful as these prey are large, mobile and may use camouflage to avoid predators (Digby *et al*., 2007). Foods readily available, such as gums, fruits and, especially, human-provided food, were found and consumed, on most occasions, in the visitation area and occasionally human-provided food was placed on the branches of the mangrove by humans for the marmosets. Direct and indirect contact between the public and the *C. jacchus* group involving food was observed. The study area was a place of public visitation, with people passing by and often stopping in close proximity to gaze at the animals or to observe their behavior, they used food to attract the marmosets. Similarly, Paula *et al*. (2005), Leite *et al.* (2011), and Albuquerque & Oliveira, M. (2014) mentioned the use of food by people to attract *Callithrix* spp., *C. penicillata* and *C. jacchus*, respectively.

The study marmosets interacted agonistically with the mangrove night heron *N. violacea*. Lyra-Neves *et al.* (2007) also described behaviors such as flying over and blows with the beak or breast by birds as antipredatory behavior, as an attempt to make marmosets move away from the nests. Furthermore, on two occasions adult marmosets observed the crab, *G. cruentata*, with an unsuccessful contact attempt. Cutrim (2013), in its turn,

observed the inclusion of crustaceans, gastropods and bivalves in the diet of *Sapajus libidinosus* (Spix, 1823) in a mangrove fragment and Santos, A. S. (2011) reported the predation of the crab, *Aratus pisonii* (H. Milne Edwards, 1837) by *Callithrix kuhlii* (Wied, 1826) in Bahia state, northeastern Brazil. However, the crab *G. cruentata* was not eaten by the study group.

The presence of domestic dogs during two different occasions elicited the emission of alert vocalizations by the marmosets, after which the group sought protection in the mangrove and on one of the occasions, the marmosets attacked the dog. Free-living domestic dogs can chase and kill primates, as described by Srbek-Araujo & Chiarello (2008), who even reported the predation of a medium-sized primate, the titi monkey *Callicebus personatus* (É. Geoffroy, 1812). To mitigate the effects of predation on capuchin monkeys *Sapajus nigritus* (Goldfuss, 1809), Oliveira, V. *et al.* (2008) proposed an action plan which involved the capture and removal of the dogs.

During playing activities, the common marmosets used objects introduced by humans. This behavior allows for the exploration of the environment and neuromotor and cognitive development in young individuals and infants (Santos, A. C. *et al.*, 2010). As objects were usually hidden in the vegetation, the selection of play sites might be associated with sites safe from predator attacks (Cavalheiro, 2008). One marmoset was found dead, thought to be a victim of electrocution, a consequence of the negative effects of urban land use on local biodiversity (McKinney, 2008). In the urban environment, marmosets can use electric wires as bridges and, when they do not die, they commonly suffer burns or limb amputation (Oliveira, M., 2008).

CONCLUSION

The behavior of the study marmosets, *C. jacchus,* and the exploration of their home range were adjusted according to the environment in which they were inserted and what it had to offer, allowing for their survival. On the other hand, certain aspects of the urban landscape and anthropic activities in this environment interfered, in different ways, on the relationships between *C. jacchus* and the biotic and abiotic factors of the urban ecosystem.

In our study, the behavior of the marmosets inhabiting the urban mangrove within an outdoor museum was similar to other studies with primates and other wild animals in urban areas, exposed to high circulations of people and different from primate studies in natural areas, particularly in relation to diet. The results of this study will contribute to the continuous monitoring of nonhuman primates living in urban areas and thus outline future actions that may support strategies mitigating the putative and actual conflicts caused by a disturbed environment and by animals and humans living in urban areas.

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REFERENCES

ADAMS, L. W., 2005. Urban wildlife ecology and conservation: a brief history of the discipline. **Urban Ecosystems** 8(2): 139-156. DOI: https://doi.org/10.1007/s11252-005-4377-7

ALBUQUERQUE, J. R., J. M. SILVA, M. A. B. OLIVEIRA & V. L. SILVA, 2012. Tamanho e uso da área domiciliar por um grupo silvestre de *Callithrix jacchus* (Primates: Cebidae: Callitrichinae) no Parque Estadual Dois Irmãos, Recife-PE. **Revista Nordestina de Zoologia** 6(2): 1-18

ALBUQUERQUE, J. R. & M. A. B. OLIVEIRA, 2014. Interações entre humanos e *Callithrix jacchus* (Linnaeus, 1758) no Parque Estadual Dois Irmãos, Recife-PE, Brasil. In: F. C. PASSOS & J. M. D. MIRANDA (Ed.): **A primatologia no Brasil**: vol. 13: 110-123. SBPr, Curitiba.

ALONSO, C. & A. LANGGUTH, 1989. Ecologia e comportamento de *Callithrix jacchus* (Primates: Callitrichidae) numa ilha de Floresta Atlântica. **Revista Nordestina de Biologia** 6(2): 105-137.

ALTMANN, J., 1974. Observational study of behaviour: sampling methods. **Behaviour** 49(3): 227-267. DOI: http://doi.org/10.1163/156853974X00534

AMORA, T. D., R. BELTRÃO-MENDES & S. F. FERRARI, 2013. Use of alternative plant resources by common marmosets (*Callithrix jacchus*) in the semi-arid caatinga scrub forests of northeastern Brazil. **American Journal of Primatology** 75(4): 333-341. DOI: http://doi.org/10.1002/ajp.22110

ANGELICI, F. M., 2016. Problematic wildlife at the beginning of the Twenty-First Century: Introduction. In: F. M. ANGELICI (Ed.): **Problematic wildlife**: a cross-disciplinary approach: 3-18. Springer, New York. DOI: http://doi.org/10.1007/978-3-319-22246-2_1

BEGOTTI, R. A. & L. F. LANDESMANN, 2008. Predação de ninhos por um grupo híbrido de sagüis (*Callithrix jacchus/penicillata*) introduzidos em área urbana: implicações para a estrutura da comunidade. **Neotropical Primates** 15(1): 28-29. DOI: http://doi.org/10.1896/044.015.0107

BRADLEY, C. A. & S. ALTIZER, 2007. Urbanization and the ecology of wildlife diseases. **Trends in Ecology and Evolution** 22(2): 95-102. DOI: http://doi.org/10.1016/j.tree.2006.11.001

CASTRO, C. S. S., 2003. Tamanho da área de vida e padrão de uso do espaço em grupos de sagüis *Callithrix jacchus* (Linnaeus) (Primates, Callitrichidae). **Revista Brasileira de Zoologia** 20(1): 91-96. DOI: https://doi.org/10.1590/S0101-81752003000100011

CAVALHEIRO, M. C., 2008. **O brincar em saguis (*Callithrix penicillata*) (Primates: Callitrichidae) sob o foco da teoria do excedente de energia**. Masther Dissertation – Universidade de Brasília, Brasília.

CUNHA, A. A., M. V. VIEIRA & C. E. GRELLE, 2006. Preliminary observations on habitat, support use and diet in two non-native primates in an urban Atlantic forest fragment: the capuchin monkey (*Cebus* sp.) and the common marmoset (*Callithrix jacchus*) in the Tijuca forest, Rio de Janeiro. **Urban Ecosystems** 9: 351-359. DOI: https://doi.org/10.1007/s11252-006-0005-4

CUTRIM, F. H. R., 2013. **Padrão comportamental e uso de ferramentas em macacos-prego (*Sapajus libidinosus*) residentes em manguezal**. Doctoral Thesis – Universidade de São Paulo, São Paulo.

DE LA FUENTE, M. F. C., A. SOUTO, M. B. SAMPAIO & N. SCHIEL, 2014. Behavioral adjustments by a small neotropical primate (*Callithrix jacchus*) in a semiarid caatinga environment. **The Scientific World Journal** 2014: 326524. DOI: https://doi.org/10.1155/2014/326524

DIGBY, L. J., S. F. FERRARI & W. SALTZMAN, 2007. Callitrichines: the role of competition in cooperatively breeding species. In: C. J. CAMPBELL, A. FUENTES, K. C. MACKINNON, M. A. PANGER & S. K. BEARDER (Ed.). **Primates in perspective**: 85-106. Oxford University Press, New York.

DITCHKOFF, S. S., S. T. SAALFELD & C. J. GIBSON, 2006. Animal behavior in urban ecosystems: modifications due to human-induced stress. **Urban Ecosystems** 9(1): 5-12. DOI: https://doi.org/10.1007/s11252-006-3262-3

GARBINO, G. S. T., 2015. How many marmoset (Primates: Cebidae: Callitrichinae) genera are there? A phylogenetic analysis based on multiple morphological systems. **Cladistics** 31(6): 652-678. DOI: https://doi.org/10.1111/cla.12106

GOULART, V. D. L. R., C. P. TEIXEIRA & R. J. YOUNG, 2010. Analysis of callouts made in relation to wild urban marmosets (*Callithrix penicillata*) and their implications for urban species management. **European Journal Wildlife Research** 56: 641-649. DOI: https://doi.org/10.1007/s10344-009-0362-4

HADIDIAN, J., 1992. Interactions between people and wildlife in urbanizing landscapes. **Conservation Biology** 15: 216-227.

HADIDIAN, J. & S. SMITH, 2001. Urban wildlife. In: D. J. SALEM & A. N. ROWAN (Ed.): **The state of the animals**: 165-182: The Humane Society Press, Washington, DC.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE), 2020. **Mapas escolares**. Available at: https://mapas.ibge.gov.br/escolares. Accessed on: November 1, 2020.

JOKIMÄKI, J., M. KAISANLAHTI-JOKIMÄKI, J. SUHONEN, P. CLERGEAU, M. PAUTASSO & E. FERNÁNDEZ-JURICIC, 2011. Merging wildlife community ecology with animal behavioral ecology for a better urban landscape planning. **Landscape and Urban Planning** 110(4): 383-385. DOI: https://doi.org/10.1016/j.landurbplan.2011.02.001

KHAIRNAR, S. O., A. R. SATHE, V. D. MHATRE, S. S. JADHAV & K. B. DESAI, 2009. Mangrove biodiversity of India. **Aqua International** 16(12): 29-30.

LEITE, G. C., M. H. L. DUARTE & R. J. YOUNG, 2011. Human-marmoset interactions in a city park. **Applied Animal Behaviour Science** 132(3-4): 187-192. DOI: https://doi.org/10.1016/j.applanim.2011.03.013

LOWRY, H., A. LILL & B. B. M. WONG, 2013. Behavioural responses of wildlife to urban environments. **Biological Reviews** 88(3): 537-549. DOI: https://doi.org/10.1111/brv.12012

LUNIAK, M., 2004. Synurbization-adaptation of animal wildlife to urban development. In: W. W. SHAW, L. K. HARRIS & L. VANDRUFF (Ed.): **Proceedings of the 4th International Symposium on Urban Wildlife Conservation**: 50-55. University of Arizona, Arizona.

LYRA-NEVES, R. M., M. A. B. OLIVEIRA, W. R. TELINO-JÚNIOR & E. M. SANTOS, 2007. Comportamentos interespecíficos entre *Callithrix jacchus* (Linnaeus) (Primates: Callitrichidae) e algumas aves de Mata Atlântica, Pernambuco, Brasil. **Revista Brasileira de Zoologia** 24(3): 709-716. DOI: https://doi.org/10.1590/S0101-81752007000300022

MAGLE, S. B., V. M. HUNT, M. VERNON & K. R. CROOKS, 2012. Urban wildlife research: past, present, and future. **Biological Conservation** 155: 23-32. DOI: https://doi.org/10.1016/j.biocon.2012.06.018

MARION, W. R., 1988. Urban wildlife: can we live with them? In: A. C. CRABB & R. E. MARSH (Ed.): **Proceedings of the Thirteenth vertebrate pest conference**: 13: 34-38. Universidade da Califórnia em Davis, Davis.

MARTINS, I. G., 2007. **Padrão de atividades do sagui *Callithrix jacchus* numa área de Caatinga**. Masther Dissertation – Universidade Federal do Rio Grande do Norte, Natal.

MCKINNEY, M. L., 2008. Effects of urbanization on species richness: A review of plants and animals. **Urban Ecosystems** 11(2): 161-176. DOI: https://doi.org/10.1007/s11252-007-0045-4

MENDES PONTES, A. R. & M. A. O. MONTEIRO DA CRUZ, 1995. Home range, intergroup transfers, and reproductive status of common marmosets *Callithrix jacchus* in a forest fragment in North-Eastern Brazil. **Primates** 36(3): 335-347. DOI: https://doi.org/10.1007/BF02382857

MENDES PONTES, A. R. & M. L. SOARES, 2005. Sleeping sites of common marmosets (*Callithrix jacchus*) in defaunated urban forest fragments: a strategy to maximize food intake. **Journal of Zoology** 266(1): 55-63. DOI: https://doi.org/10.1017/S095283690500662X

MODESTO, T. C. & H. G. BERGALLO, 2008. Ambientes diferentes, diferentes gastos do tempo entre atividades: o caso de dois grupos mistos do exótico *Callithrix* spp. na Ilha Grande, RJ, Brasil. **Neotropical Biology and Conservation** 3(3): 112-118. DOI: https://doi.org/10.4013/nbc.20083.02

MONTEIRO DA CRUZ, M. A. O., 1998. **Dinâmica reprodutiva de uma população de saguis-do-nordeste (*Callithrix jacchus*) na Estação Ecológica do Tapacurá, PE**. Doctoral Thesis – Universidade de São Paulo, São Paulo.

MUCELIN, C. A. & M. BELLINI, 2008. Lixo e impactos ambientais perceptíveis no ecossistema urbano. **Sociedade & Natureza** 20(1): 111-124. DOI: https://doi.org/10.1590/S1982-45132008000100008

NICOLAEVSKY, B. & S. L. MENDES, 2011. Comportamento alimentar do sagüi-da-cara-branca, *Callithrix geoffroyi* (É. Geoffroy *in* Humboldt, 1812) (Primates, Callitrichidae), em ambiente urbano. In: J. M. D. MIRANDA & Z. M. B. HIRANO (Ed.): **A primatologia no Brasil**: vol. 11: 52-61. SBPr, Curitiba.

OLIVEIRA, I. A. A., 2003. **Padrão de dispersão e análise da área de uso de uma população urbana de sagüis-do-nordeste *Callithrix jacchus* (Callitrichidae, Primates)**. Masther Dissertation – Universidade Federal de Pernambuco, Recife.

OLIVEIRA, M. A. B., 2008. Ética e bem-estar em animais silvestres: Primatas. **Ciência Veterinária dos Trópicos** (1): 56-58

OLIVEIRA, V. B., A. M. LINARES, G. L. C. CORRÊA & A. G. CHIARELLO, 2008. Predation on the black capuchin monkey *Cebus nigritus* (Primates: Cebidae) by domestic dogs *Canis lupus familiaris* (Carnivora: Canidae), in the Parque Estadual Serra do Brigadeiro, Minas Gerais, Brazil. **Revista Brasileira de Zoologia** 25(2): 376-378. DOI: https://doi.org/10.1590/S0101-81752008000200026

PARKER, T. S. & C. H. NILON, 2012. Urban landscape characteristics correlated with the synurbization of wildlife. **Landscape and Urban Planning** 106(4): 316-325. DOI: https://doi.org/10.1016/j.landurbplan.2012.04.003

PAULA, H. M. G., R. S. TÁVORA, M. V. ALMEIDA, L. S. PELEGRINI, G. V. SILVA, R. L. ZAGANINI & A. LUCINDO, 2005. Estudos preliminares da presença de sagüis no município de Bauru, São Paulo, Brasil. **Neotropical Primates** 13(3): 6-11. DOI: http://dx.doi.org/10.1896/1413-4705.13.3.6

PERIQUITO, M. C., G. A. PEREIRA & M. T. BRITO, 2008. Aves no manguezal do Espaço Ciência, Olinda, Pernambuco. **Atualidades Ornitológicas On-line** (145): 36-38.

POESSEL, S. A., E. M. GESE & J. K. YOUNG, 2017. Environmental factors influencing the occurrence of coyotes and conflicts in urban areas. **Landscape and Urban Planning** 157: 259-269. DOI: https://doi.org/10.1016/j.landurbplan.2016.05.022

POWER, M. L. & W. MYERS, 2009. Digestion in the common marmoset (*Callithrix jacchus*), a gummivore–frugivore. **American Journal of Primatology** 71(12): 957-963. DOI: https://doi.org/10.1002/ajp.20737

PRANGE, S., S. D. GEHRT & E. P. WIGGERS, 2004. Influences of anthropogenic resources on raccon (*Procyon lotor*) movements and spatial distribution. **Journal of Mammalogy** 85(3): 483-490. DOI: https://doi.org/10.1644/BOS-121

PREFEITURA DA CIDADE DO RECIFE (PCR), 2020. **Caracterização de território, Prefeitura do Recife**. Available at: http://www2.recife.pe.gov.br/pagina/caracterizacao-do-territorio. Accessed on: November 1, 2020.

RANGEL, C. H., F. S. F. SOUSA & C. E. GRELLE, 2011. Dieta de *Callithrix jacchus* (Linnaeus, 1758) e *Callithrix penicillata* (E. Geoffroy, 1812) (Callitrichidae - Primates) e seus híbridos, alóctones no Jardim Botânico do Rio de Janeiro. In: J. M. D. MIRANDA & Z. M. B. HIRANO (Ed.): **A primatologia no Brasil**: vol. 11: 74-84. SBPr, Curitiba.

ROCHA, P. I. A., 2019. **Efeito da dieta nas atividades de dois grupos de vida livre de saguis do Nordeste (*Callithrix jacchus*) do Parque Estadual do Dois Irmãos, Recife, Pernambuco, Brasil**. Monography – Universidade Federal Rural de Pernambuco, Recife.

ROSENBERGER, A. L., 1978. Loss of incisor enamel in marmosets. **Journal of Mammalogy** 59(1): 207-208. DOI: https://doi.org/10.2307/1379899

RUIZ-MIRANDA, C. R., A. G. AFFONSO, A. MARTINS & B. BECK, 2000. Distribuição do sagui (*Callithrix jacchus*) nas áreas de ocorrência do mico-leão-dourado (*Leontopithecus rosalia*) no estado do Rio de Janeiro. **Neotropical Primates** 8(3): 98-101.

RYLANDS, A. B., A. F. COIMBRA-FILHO & R. A. MITTERMEIER, 2009. The systematics and distributions of the Marmosets (*Callithrix, Callibella, Cebuella*, and *Mico*) and *Callimico* (Callimico) (Callitrichidae, Primates). In: S. M. FORD, L. M. PORTER & L. C. DAVIS (Ed.): **The smallest anthropoids**: the Marmoset/Callimico radiation: 25-61. Springer, New York.

RYLANDS, A. B. & R. A. MITTERMEIER, 2013. Family Callitrichidae (marmosets and tamarins). In: R. A. MITTERMEIER, A. B. RYLANDS & D. E. WILSON (Ed.): **Handbook of the Mammals of the World**: vol. 3: Primates: 262-346. Lynx Edicions, Barcelona.

SABBATINI, G., M. STAMMATI, M. C. H. TAVARES, M. V. GIULIANI & E. VISALBERGHI, 2006. Interactions between humans and capuchin monkeys (*Cebus libidinosus*) in the Parque Nacional de Brasília, Brazil. **Applied Animal Behaviour Science** 97(2-4): 272-283. DOI: https://doi.org/10.1016/j.applanim.2005.07.002

SANTOS, A. C. L., M. P. MNEGUSSO, V. BOTTNCOURT, R. MOURA & P. G. B. S. DIAS, 2010. Comportamento de brincadeiras em um grupo de saguis-de-tufo-preto *Callithrix penicillata* (Geoffroy, 1812) cativos do zoológico Bosque Guarani, Foz do Iguaçu, PR. **Pleiade** 7(7): 7-32.

SANTOS, A. S. R., 2011. **Predation of marine crab (*Aratus pisonii*) by Weid's black tufted-ear marmoset (*Callithrix kuhlii*) in mangroves of Comandatuba Island, Una, Bahia, Brazil**. Available at: http://www.aultimaarcadenoe.com.br/wp-content/uploads/2011/06/Predation-of-marine-creb-by-Callithrix-kuhlii_IComadatuba-BA_AS-ingles.pdf. Accessed on: November 2, 2020.

SANTOS, M. N., M. H. L. DUARTE & R. J. YOUNG, 2014. Behavioural and ecological aspects of black tufted-ear marmosets, *Callithrix penicillata* (Geoffroy, 1812) (Primates: Callitrichidae) in a semi-urban environment. **Revista de Etologia** 13(1): 37-46.

SECRETARIA DE CIÊNCIA, TECNOLOGIA E INOVAÇÃO DO ESTADO DE PERNAMBUCO (SECTEC), 2016. **Espaço Ciência**. Available at: http://www.sectec.pe.gov.br/web/sectec/espaco-ciencia. Accessed on: February 7, 2016.

SILVA, G. S. & M. A. O. MONTEIRO DA CRUZ, 1993. Comportamento e composição de um grupo de *Callithrix jacchus* Erxleben (Primates, Callitrichidae) na mata de Dois Irmãos, Recife, Pernambuco, Brasil. **Revista Brasileira de Zoologia** 10(3): 509-520. DOI: https://doi.org/10.1590/S0101-81751993000300018

SILVA, G. M. M., K. C. S. VERÍSSIMO & M. A. B. OLIVEIRA, 2011. Orçamento das atividades diárias de dois grupos de *Callithrix jacchus* em área urbana. **Revista de Etologia** 10(2): 57-63.

SILVA, J. M., J. R. ALBUQUERQUE & M. A. B. OLIVEIRA, 2014. Em busca de alimento: um estudo sobre a influência de itens providos por humanos na dieta de um grupo de *Callithrix jacchus* (Linnaeus 1758) de vida livre, no Parque Estadual Dois Irmãos, Recife-PE, Brasil. In: F. C. PASSOS & J. M. D. MIRANDA (Ed.): **A primatologia no Brasil**: vol. 13: 152-160. SBPr, Curitiba.

SILVA, M. A. F., C. E. VERONA, M. CONDE & A. S. PIRES, 2018. Frugivory and potential seed dispersal by the exotic-invasive marmoset *Callithrix jacchus* (Primates, Callitrichidae) in an urban Atlantic Forest, Rio de Janeiro, Brazil. **Mammalia** 82(4): 343-349. DOI: https://doi.org/10.1515/mammalia-2016-0075

SMITH, A. C., 2010. Exudativory in primates: interspecific patterns. In: A. M. BURROWS & L. T. NASH (Ed.): **The evolution of exudativory in primates**: 45-88. Springer, New York.

SOULSBURY, C. D. & P. C. L. WHITE, 2015. Human-wildlife interactions in urban ecosystems. **Wildlife Research** 42(7): 3-5. DOI: https://doi.org/10.1071/WRv42n7_PR

SOUZA, R. M., 2006. **Alterações na paisagem urbana**: uma análise morfodinâmica da área do entorno do Manguezal Chico Science, Olinda-PE. Masther Dissertation – Universidade Federal de Pernambuco, Recife.

SRBEK-ARAUJO, A. C. & A. G. CHIARELLO, 2008. Domestic dogs in Atlantic forest preserves of south-eastern Brazil: a camera-trapping study on patterns of entrance and site occupancy rates. **Brazilian Journal of Biology** 68(4): 771-779. DOI: https://doi.org/10.1590/S1519-69842008000400011

TIGAS, L. A., D. H. V. VUREN & R. M. SAUVAJOT, 2002. Behavioral responses of bobcats and coyotes to habitat fragmentation and corridors in an urban environment. **Biological Conservation** 108(3): 299-306. DOI: https://doi.org/10.1016/S0006-3207(02)00120-9

TRAAD, R. M., J. C. M. LEITE, P. WECKERLIN & S. TRINDADE, 2012. Introdução das espécies exóticas *Callithrix penicillata* (Geoffroy, 1812) e *Callithrix jacchus* (Linnaeus, 1758) em ambientes urbanos (Primates: Callithrichidae). **Revista Meio Ambiente e Sustentabilidade** 2(1): 9-23.

VANNUCCI, M., 2001. What is so special about mangroves? **Brazilian Journal of Biology** 61(4): 599-603. DOI: https://doi.org/10.1590/S1519-69842001000400008

VERÍSSIMO, K. C. S., L. IANNUZZI & M. A. B. OLIVEIRA, 2012. *Callithrix jacchus* (Linnaeus, 1758) em uma restinga de Pernambuco: influência da distribuição espacial da vegetação sobre a área de uso. In: A. C. A. EL-DEIR, G. J. B. MOURA & O. E. L. ARAÚJO (Ed.): **Ecologia e conservação de ecossistemas no Nordeste do Brasil**: 387-400. Nuppea, Recife.

VINYARD, C. J., C. E. WALL, S. H. WILLIAMS, A. L. MORK, B. A. ARMFIELD, L. C. O. MELO, M. M. VALENÇA-MONTENEGRO, Y. B. M. VALLE, M. A. B. OLIVEIRA, P. W. LUCAS, D. SCHMITT, A. B. TAYLOR & W. L. HYLANDER, 2009. The evolutionary morphology of tree gouging in marmosets. In: S. M. FORD, L. M. PORTER & L. C. DAVIS (Ed.): **The smallest anthropoids**: the marmoset/callimico radiation: 395-409. Springer, New York.

YAMAMOTO, M. E., 1993. From dependence to sexual maturity: the behavioural ontogeny of Callitrichidae. In: A. B. RYLANDS (Ed.): **Marmosets and Tamarins**: systematics, behaviour, and ecology: 235-250. Oxford University Press, New York.