

Activity budget of a group of black-horned capuchin monkeys (*Sapajus nigritus*) in an urban environment

Orçamento de atividades de um grupo de macacos-prego-pretos (*Sapajus nigritus*) em ambiente urbano

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Abstract

Urban growth and human impacts on the environment have forced animals to adjust to habitat fragmentation and reduced home ranges. Capuchin monkeys are known for their great social and behavioral flexibility, occupying even highly urbanized environments in a way that the time budget of this primate in synanthropic situation may be affected by the area they inhabit. This study aims to analyze the activity budget of a group of *Sapajus nigritus* living in an anthropized area, 1) comparing the behavioral frequencies in urbanized areas and forest fragments; 2) comparing behavioral frequencies in different sex-age classes. During the study, the number of individuals ranged from 35 to 40 individuals identified based on sex-age classes. Behavioral data were collected using the instantaneous scan sampling method, for two minutes with eight-minute intervals. We obtained 319 scans over 28 days, distributed between November 2021 and June 2022, with eight hours per day. We compared the behaviors different areas and between sex-age classes using the Kruskal-Wallis's test. Overall, the group performed a higher frequency of traveling (21.22%), followed by foraging (18.07%), feeding (16.57%) and vigilance (15.61%). The frequency of behaviors varied between areas, with vigilance, social, resting, interaction with humans and self-activity more frequent in urbanized areas compared to forest fragments. We also found variation between the sex-age classes, primarily with juveniles foraging more and adults performing more vigilance. The differences in the behaviors performed by the group express the behavioral flexibility of *S. nigritus*, adapting its activity pattern according to the area occupied.

Keywords: Anthropization; Behavioral flexibility; Primate; Urban capuchin monkeys.

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Resumo

O crescimento urbano e os impactos humanos no ambiente forçaram os animais a se adaptarem à fragmentação de hábitat e à redução da área de vida. Os macacos-prego são conhecidos por sua flexibilidade social e comportamental, ocupando até mesmo ambientes altamente urbanizados, sendo que seu padrão de atividades pode ser afetado pela área que habitam. Este estudo teve como objetivo analisar o padrão de atividades de um grupo de *Sapajus nigritus* vivendo em área antropizada, com base em: 1) comparação das frequências comportamentais em áreas urbanizadas e fragmentos florestais; e 2) comparação das frequências comportamentais em diferentes classes sexo-etárias. Durante o estudo, o número de indivíduos variou entre 35 e 40 indivíduos, identificados a partir de classes sexo-etárias. Os dados comportamentais foram coletados pelo método *scan sampling*, durante dois minutos com intervalo de oito minutos. Foram obtidos 319 *scans* ao longo de 28 dias (entre novembro de 2021 e junho de 2022), por oito horas diárias. Comparamos os comportamentos em diferentes áreas e entre classes sexo-etárias através do teste de Kruskal-Wallis. Em geral, o grupo apresentou frequência maior de deslocamento (21,22%), seguido de forrageio (18,07%), alimentação (16,57%) e vigilância (15,61%). A frequência dos comportamentos variou entre áreas (vigilância, social, descanso, interação com humanos e autoatividade foram mais frequentes em áreas urbanizadas) e classes sexo-etárias (principalmente com os juvenis forrageando mais e os adultos realizando mais vigilância). As diferenças nos comportamentos realizados pelo grupo expressam a flexibilidade comportamental de *S. nigritus*, adaptando seu padrão de atividade conforme a área ocupada.

Palavras-chave: Antropização; Flexibilidade comportamental; Macacos-prego urbanos; Primatas.

Introduction

Habitat loss and fragmentation could negatively affect the biodiversity,⁽¹⁾ and humans cause major impacts.⁽²⁾ This leads to the transformation of natural and continuous habitats into agricultural, urbanized areas and pastures, altering population dynamics.⁽³⁾ The Atlantic Forest currently has 28% of the remaining native vegetation,⁽⁴⁾ consisting of small remnants immersed in a matrix of agricultural lands and urbanized areas.⁽⁵⁾ Nevertheless, it is a hotspot that is home to 71 species of mammals endemic to the area, including the black-horned capuchin monkey (*Sapajus nigritus*).⁽⁶⁾

The black-horned capuchin monkey *Sapajus nigritus* is found in the southern and southeastern regions of Brazil.⁽⁷⁾ The species has a wide ecological niche with great behavioral flexibility, allowing it to occupy secondary forests, forest edges, and highly urbanized and cultivated areas,⁽⁸⁻¹⁰⁾ maintaining population densities even in regimes of medium and moderate fragmentation.⁽¹¹⁾ They are omnivorous, with a diet based primarily on fruits, flowers, leaves seeds, and invertebrates.⁽¹²⁻¹⁵⁾ Due to the capuchin's ability to adapt its diet depending

on the supply, populations living in urban areas also include anthropic food in their diet.⁽¹⁶⁻¹⁹⁾

The area occupied by the capuchin monkeys affects their behavior, especially in small fragments that occur in urbanized areas, where capuchin monkey populations may live in contact with humans and need to adjust their activity pattern to the anthropic influence.⁽¹⁷⁾ Several conflicts related to human-animal interactions have been described, either through direct contact with human food or through invasion of residential and cultivated areas.^(8,20-22) There is general agreement among researchers on the urgent need for studies of capuchin monkey groups living in areas not previously studied and subject to fragmentation and urbanization,⁽²³⁾ as a tool for understanding their behavioral flexibility,⁽¹⁷⁾ placing the behavioral ecology of these primates as a research priority.

The activity patterns of capuchin monkeys are also influenced by the individual sex-age class in the group, as some behaviors are more common in each class. For example, adult females that are pregnant or lactating, tend to spend more time feeding because they require more energy.⁽⁹⁾ Juveniles also tend to spend more time foraging because they

are more curious about the environment and have less access to food compared to adults.^(9,24) Also, juveniles engage more in play and social behaviors^(9,24) while adults show more vigilance.⁽⁹⁾

In the present study, we aimed to investigate the activity budget of an urban population of capuchin monkeys (*Sapajus nigritus*). We tested the following hypotheses: 1) The frequency of behaviors performed by *Sapajus nigritus* differs between urbanized areas and forest fragments; 2) The frequency of behaviors performed by *Sapajus nigritus* differs between sex-age classes.

Methods

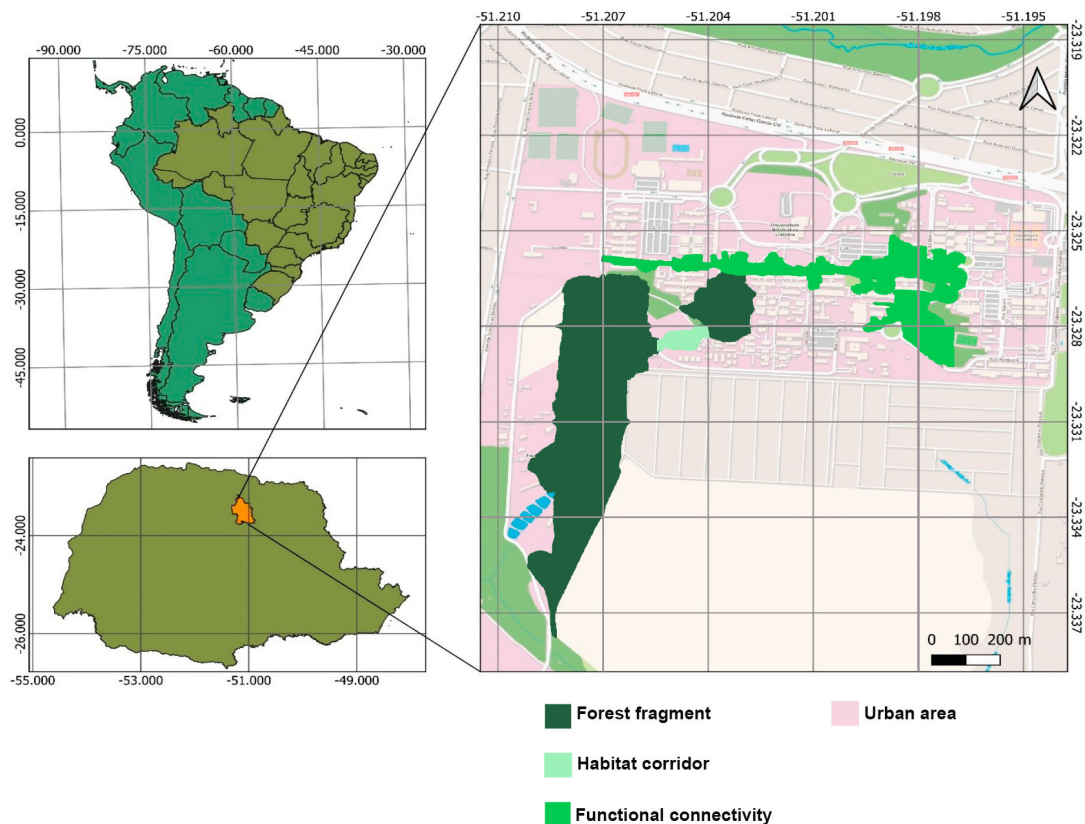
Study area

The study was conducted at the campus of State University of Londrina (UEL), located in the municipality of Londrina, state of Paraná, Brazil

(23°19'19" S, 51°12'04" W; Figure 1), which is the home range of a group of black-horned capuchin monkeys. The 235-hectare campus includes fragments of natural semideciduous seasonal forest, tree conglomerates, and riparian forests, as well as urbanized areas on the campus, with impervious surfaces such as buildings, streets and parking lots, and also agricultural crops and pastures. The larger forest fragment comprises a total area of 20 hectares. The climate of the region fits the humid subtropical climate profile (Cfa), with rainfall in all seasons and the possibility of drought in the winter period. The average temperature over the last 30 years is 21 °C, with an annual rainfall range of 1,400 to 1,600 mm.⁽²⁵⁾

There is a great diversity of plant species in the area that are part of the capuchin's diet, consisting of more than 100 species (native and exotic), with Fabaceae and Myrtaceae being the most representative families.⁽²⁶⁾

Figure 1 - Map of the campus of the State University of Londrina (UEL), showing the forest fragments and urbanized areas.



Source: author's own work.

Study group

The study group of southern black-horned capuchin monkey (*Sapajus nigritus* ssp. *cucullatus*),⁽²⁷⁾ ranged from 35 to 40 individuals during the study period and consisted a single social group of free-living primates. The group consisted of tree adult males, 12 adult females, and 25 juveniles at the end of the study.

Data sampling

We conducted the habituation process with the group from May to October 2021, tree days a week for four hours, until the monkeys tolerated the presence of the researcher and displayed their natural behavior with minimal interference.⁽²⁸⁻²⁹⁾ Despite the habituation process, it was not always possible to observe the group continuously for long periods of time because the monkeys often moved nimbly, without making sounds or vocalizations, or using places inaccessible to the researcher.

We classified the study site into two categories based on Rezende:⁽⁴⁾ urbanized areas (UA) and forest fragments (FF). We defined urbanized areas by the presence of buildings, such as study centers (forested or not), plantations, or highly degraded areas, whereas forest fragments were considered those areas with forest vegetation in intermediate or late successional stages, with 30 and 50 years of existence.

Field work was conducted from November (2021) to June (2022), three to five days per month for eight hours per day. The sample time was of 28 days. A monacle was often used to improve visualization and thus identification of sex and age class of individuals. We did not collect data from infants and used the age classes definition of Resende:⁽³⁰⁾ adult female (older than 5 years), adult male (older than 5 years), and juvenile (from 1 year to 5 years old). The total amount of contact time with the group was 46 hours, of which 29 hours were in an urbanized area and 17 hours in a forest fragment.

In order to define the activity pattern and to avoid bias due to behaviors concentrated in certain

periods of the day,⁽³¹⁾ the animals were followed, whenever possible, from dawn to dusk (8am to 5pm). Behaviors and activities were categorized into eleven classes: foraging, feeding, traveling, social, resting, vigilance, defecating or urinating, interaction with humans, interaction with non-human species, self-activities, and solitary play; according to Lorenzo.⁽²⁶⁾ (Supplementary Material 1 [Appendix 1]).

We used the method of instantaneous scan sampling, with a duration of two minutes and an eight-minute interval.⁽³²⁻³³⁾ During each scan, we recorded the sex-age classification of the individuals and the behaviors displayed. We also recorded the date and location of each scan, including the geographic coordinates of each point.

Data analysis

The data were tested for normality and homoscedasticity. We then used the frequency method,⁽³¹⁾ in which we divided the number of records of each behavior by the total number of records of all behaviors in each observation period (one hour), as replicates. We compared behaviors performed by different sex-age classes using the Kruskal-Wallis's test, with Dunn's post-hoc test for pairwise comparison of sex-age classes. Behaviors performed in urbanized areas (UA) and forest fragments (FF) were also compared using the Kruskal-Wallis's test.

All statistical analysis were performed using R software,⁽³⁴⁾ using the "rstatix" package and the graphs were built using the "ggplot2" package.⁽³⁵⁾ The R script is available in the Supplementary Material 2 (Appendix 2).

Results

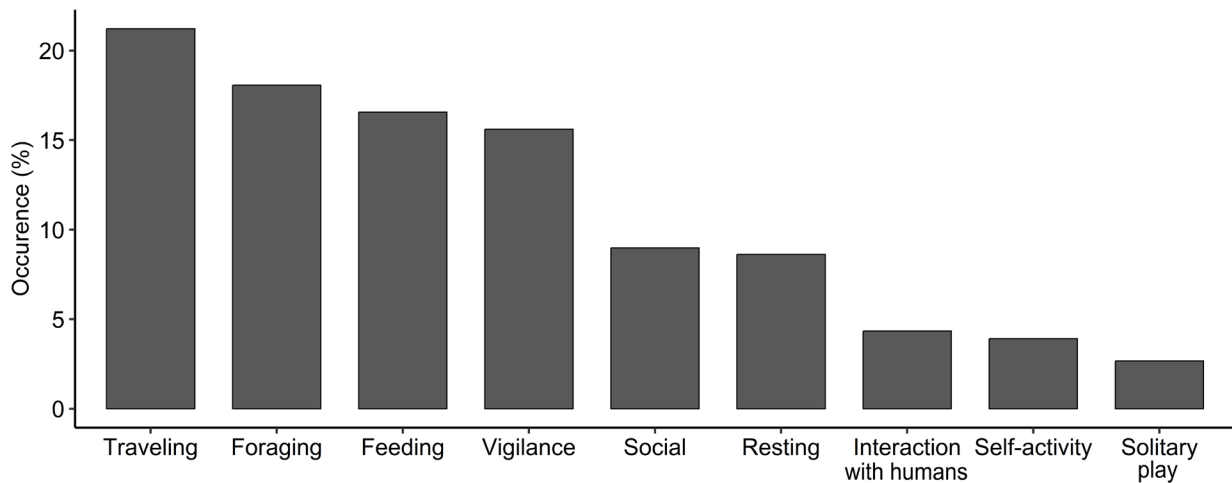
We obtained a total of 331 scans, but when it was not possible to obtain sex-age classification from individuals (n=4), the data were excluded from the analyses, resulting in 327 scans. The behavioral classes defecating or urinating, and non-human interspecific interaction were excluded because they did not provide sufficient data. In general, the

predominant activity of the group was traveling (21.22%), followed by foraging (18.07%), feeding (16.57%), and vigilance (15.61%) (Figure 2).

For most of the behaviors performed by the group, the frequency varied among the different sex-age classes, with adult females and juveniles spending more time feeding than adult males ($H=15.936$; $df=2$; $p<0.001$); vigilance was performed more often by adults ($H=13.411$ $df=2$ $p=0.001$); adult females traveled more than adult males ($H=$

19.072 ; $df=2$; $p<0.001$); juveniles foraged more than adults ($H=27.813$; $df=2$; $p<0.001$); juveniles interacted more with humans than adult females ($H=7.779$; $df=2$; $p=0.020$); and juveniles were the only ones to engage in solitary play ($H=60.860$; $df=2$; $p<0.001$). The occurrence of social ($H=2.504$; $df=2$; $p=0.286$), resting ($H=1.915$; $df=2$; $p=0.383$), and self-activity ($H=3.225$; $df=2$; $p=0.199$) behaviors did not differ significantly between sex-age classes (Table 1 and 2, Figure 3).

Figure 2 - Total occurrence of behaviors performed by the *Sapajus nigritus* group, considering all sex-age classes and sampled areas.



Source: author's own work.

Table 1 - Frequency of behaviors (%) performed by individuals of *Sapajus nigritus*, among different sex-age groups (adult females, adult males, and juveniles) on the campus of the State University of Londrina.

Behaviors	Adult female (%)	Adult male (%)	Juvenile (%)
Feeding	17.52	14.97	17.21
Vigilance	16.42	20.32	10.09
Traveling	22.99	21.39	19.29
Foraging	17.52	17.11	19.58
Social	9.85	9.09	8.01
Resting	8.76	9.09	8.01
Interaction with humans	2.55	4.81	5.64
Self-activity	4.38	3.21	4.15
Solitary play	0.00	0.00	8.01

Source: research data.

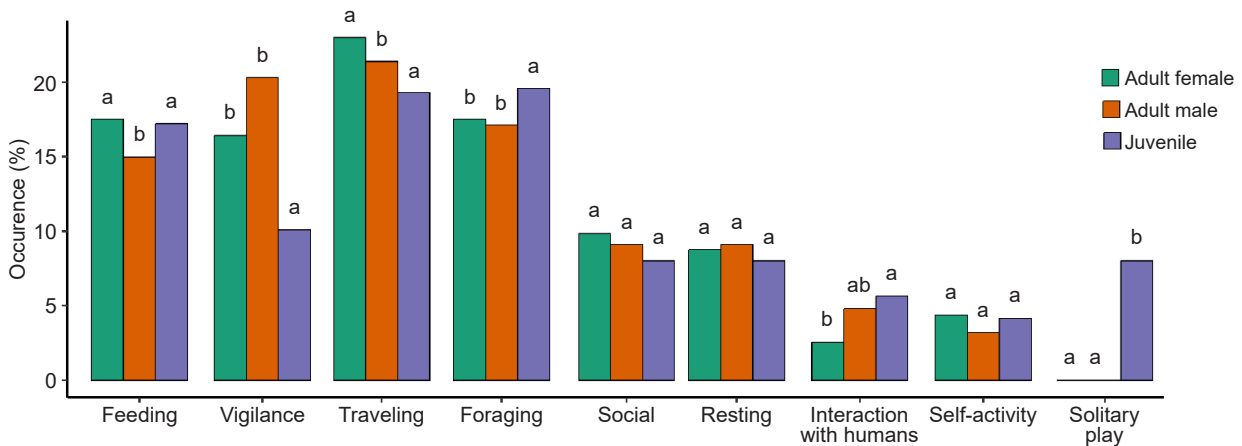
Table 2 - Dunn's test results, comparing and the behaviors performed by individuals of *Sapajus nigritus* in the campus of the State University of Londrina, between sex-age classes.

Sex-age classes	Behaviors / P-adjusted								
	Feeding	Vigilance	Traveling	Foraging	Social	Resting	Interaction with humans	Self-activity	Solitary play
FA vs MA	2.01e-2	0.698	6.22e-5	1.06e-1	0.444	0.650	0.497	0.356	1 e+ 0
FA vs JU	1.75e-1	0.00617	1.99e-1	8.02e-4	0.866	0.727	0.0219	0.722	4.25e-11
MA vs JU	2.55e-4	0.00244	5.90e-3	7.58e-7	0.444	0.546	0.0905	0.266	4.25e-11

Caption: FA: adult female; MA: adult male; JU: juvenile.

Source: research data.

Figure 3 - Occurrence of behaviors performed by *Sapajus nigritus* group, in each of the sex-age classes (adult females, juveniles, and adult males), at the campus of the State University of Londrina. Codes: different letters at the top of the box plots indicate statistically significant differences between behavior in the sex-age classes (Kruskal-Wallis's test and Dunn's post-hoc test; $P < 0.05$), while common letters indicate that behavior in the sex-age classes are not significantly different.



Source: author's own work.

Most activities performed by capuchins also differed significantly between urbanized areas and forest fragments, such as: vigilance ($H= 8.637$; $df=1$; $p= 0.003$), social ($H= 8.366$; $df=1$; $p= 0.004$), resting ($H= 29.989$; $df=1$; $p < 0.001$), interaction with humans ($H= 4.894$; $df=1$; $p= 0.027$), and self-activity ($H= 21.812$; $df=1$; $p < 0.001$), all more

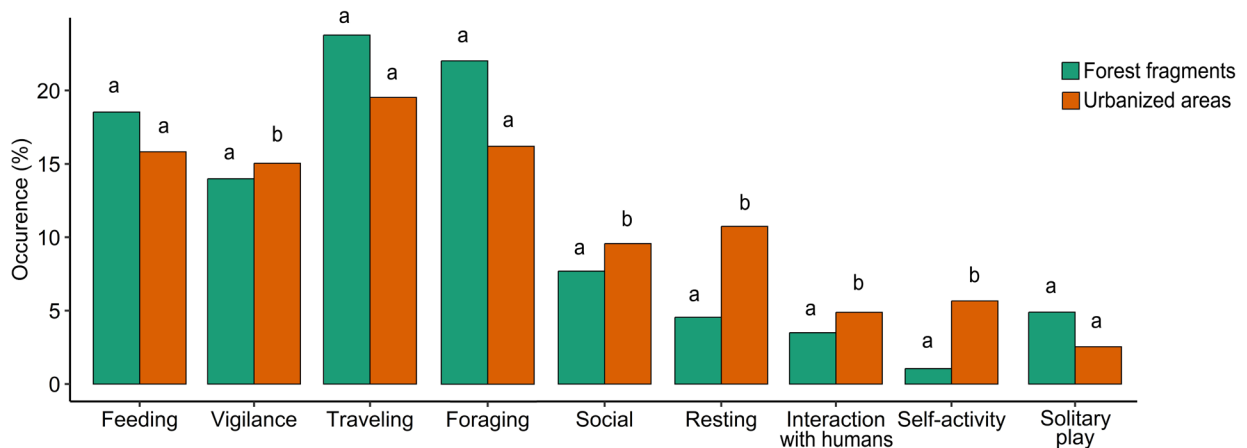
frequent in urbanized areas. The frequencies of feeding ($H= 1.757$; $df=1$; $p= 0.185$), traveling ($H= 0.0103$; $df=1$; $p= 0.919$), foraging ($H= 0.463$; $df=1$; $p= 0.496$), and solitary play ($H= 0.421$; $df=1$; $p= 0.516$) did not differ significantly between environments. The data are shown in Table 3 and Figure 4, on the next page.

Table 3 - Frequency of behaviors (%) performed by individuals of *Sapajus nigritus* in different areas (forest fragments and urbanized areas) in the campus of the State University of Londrina.

Behaviors	Forest fragments (%)	Urbanized areas (%)
Feeding	18.53	15.82
Vigilance	13.98	15.04
Traveling	23.78	19.53
Foraging	22.03	16.21
Social	7.69	9.57
Resting	4.54	10.74
Interaction with humans	3.50	4.88
Self-activity	1.05	5.66
Solitary play	4.89	2.54

Source: research data.

Figure 4 - Occurrence of activities performed by *Sapajus nigritus* group, between forest fragments and urbanized areas at the campus of the State University of Londrina. Codes: different letters at the top of the box plots indicate statistically significant differences between behavior in the sex-age classes (Kruskal-Wallis's test and Dunn's post-hoc test; $P < 0.05$), while common letters indicate that behavior in the sex-age classes are not significantly different.



Source: author's own work.

Discussion

Our results support our hypothesis that the behaviors performed by an urban population of black-horned capuchin monkeys (*Sapajus nigritus*) vary between urbanized areas and forest fragments. We identified certain behaviors occurring more frequently in urban areas. As monkeys habituating areas with anthropic influences adjust their activity pattern,⁽¹⁷⁾ in our case we argue that

anthropogenic foods are the ones that most explain this difference. These foods are abundant and easily accessible in garbage cans and also provided by members of the community, which are caloric and of low nutritional value, but more palatable and digestible, making them very attractive to capuchin monkeys.⁽³⁶⁾ The animals need to consume a smaller amount of these foods, compared to fruits, for example, to feel satiated.⁽³⁷⁾ Thus, they may have more time for non-food-related activities, such

as social behaviors and resting, since they would spend less time searching for resources.⁽¹⁵⁾

Vigilance was more frequent in urbanized areas, an environment shared with people and domestic animals and with less forest cover. These factors could make animals more alert, especially when approaching the ground.⁽¹⁷⁾ Another study conducted in our same study area, showed that the domestic dog is the vertebrate with the highest frequency of interactions with the capuchin monkeys, with most events being negative.⁽³⁸⁾ We did not record predation by domestic animals in the group, however, some individuals were recorded being chased by dogs.

In general, the group studied spent most time searching for food (traveling and foraging) and feeding, as well as observed in other urban species of capuchin monkeys, such as *Sapajus* sp.,^(24,39) *Sapajus libidinosus*^(17,19) and *Cebus olivaceus*.⁽⁴⁰⁾ However, the frequency of foraging in this study was lower than other studies, such as in the same species (*S. nigritus*) living in a forest reserve,⁽⁸⁾ in *S. libidinosus* inhabiting a mixed area formed by forest and urban environment,⁽³⁹⁾ and in *Sapajus* sp. living in urban area.⁽²⁴⁾ The study group also showed a slightly higher rate of resting behavior compared to other studies in *S. nigritus*⁽¹⁰⁾ and in *Sapajus* sp.⁽²⁴⁾ These differences could be related to the available of anthropic food (directly or indirectly) to the monkeys and reinforce that human presence in areas where the monkeys are inserted, affects their activity budget.

We also found support to the second hypothesis tested, that the frequency of behaviors performed by the group differs between sex-age classes. Juveniles, despite being the smallest in size and weight, they foraged the most, as found in other studies.^(19,24) This may be due to their higher level of curiosity, in addition to having less access to rich food sources due to the hierarchy of the group.⁽⁹⁾ Although the cited studies were mostly conducted during the rainy season, and the present study mostly during the dry season, it is known that seasonality can significantly affect the activity pattern in capuchin monkeys,⁽¹⁹⁾ a fact that should

be better evaluated in our study group. Another possible explanation is that juveniles need more resources to grow to maturity. Adults showed the highest levels of vigilant behavior, and adult males were also the most likely to initiate interactions with humans, most of which were threats or attacks directed to the researcher. This aggressiveness can be explained by their position as protectors of the group⁽⁹⁾ and high testosterone levels, as demonstrated in *S. libidinosus*.⁽⁴¹⁾

These differences in behaviors performed in urbanized areas and in forest fragments, highlights the behavioral flexibility of the species in fragmented areas. Through this study, it was possible to evaluate the differences in the frequency of behaviors in different areas at the campus site and understand how the animals respond to anthropization through their activity pattern. We conclude that *Sapajus nigritus* adapts to urbanization by adapting its activity pattern.

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Appendix 1

Supplementary Material 1

Behavior	Description
Foraging	Exploring and/or searching for food resources.
Feeding	Consumption of food items (stem, petiole, meristem, fruit, flower, seed, root, hive, vertebrate, invertebrate, natural human food, cultivated human food, industrialized food).
Traveling	Walking, running, jumping in a quadrupedal or bipedal position.
Social	Activity involving two or more individuals, agonistic or affiliative.
Resting	Individual resting, practically immobile or individual lying horizontally, not performing any activity.
Vigilance	Attentively observing their surroundings, emitting vocalizations or not.
Defecating or urinating	Individual expels feces or urine.
Interaction with humans	Behavior of peaceful approach and/or behaviors of aggression, threat, submission, or escape directed at humans.
Interaction with non-human species	Behavior of peaceful approach and/or aggression, threat, submission, or escape toward other vertebrates (except members of its own capuchin group and humans).
Self-activities	Inspecting their own body, running their hands through their fur to remove ectoparasites or imperfections; self-scratching.
Solitary play	Individual performs playful movements (rolling, hanging from branches with only one limb, running, throwing themselves into puddles of water).

Source: author's own work.

Appendix 2

Supplementary Material 2

```
# Packages
if(!require(rstatix))
  install.packages("rstatix")

# By area
# Kruskal-Wallis's test
Foraging <- kruskal.test(Foraging~Area, data = data)
Feeding <- kruskal.test(Feeding~Area, data = data)
Traveling <- kruskal.test(Traveling~Area, data = data)
Social <- kruskal.test(Social~Area, data = data)
Resting <- kruskal.test(Resting~Area, data = data)
Vigilance <- kruskal.test(Vigilance~Area, data = data)
Interaction_with_humans <- kruskal.test(Interaction_with_humans~Area, data = data)
Self_activity <- kruskal.test(Self_activity~Area, data = data)
Solitary_play <- kruskal.test(Solitary_play~Area, data = data)

# By sex-age classes
# Kruskal-Wallis's test
Foraging <- kruskal.test(Foraging~ID, data = data)
Feeding <- kruskal.test(Feeding~ID, data = data)
Traveling <- kruskal.test(Traveling~ID, data = data)
Social <- kruskal.test(Social~ID, data = data)
Resting <- kruskal.test(Resting~ID, data = data)
Vigilance <- kruskal.test(Vigilance~ID, data = data)
Interaction_with_humans <- kruskal.test(Interaction_with_humans ~ID, data = data)
Self_activity <- kruskal.test(Self_activity~ID, data = data)
Solitary_play <- kruskal.test(Solitary_play~ID, data = data)

# Dunn's post-hoc test (Sex-age classes)
dunn_test(Forrageio~ID, data=data)
dunn_test(Alimentação~ID, data=data)
dunn_test(Deslocamento~ID, data=data)
dunn_test(Social~ID, data=data)
dunn_test(Descanso~ID, data=data)
dunn_test(Vigilância~ID, data=data)
dunn_test(Interação_Humano~ID, data=data)
dunn_test(Brincadeira~ID, data=data)
dunn_test(Auto_atividade~ID, data=data)
```

