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Exploration of sugarcane crops by *Sapajus flavius* inhabiting a fragment of Atlantic Forest in State of Paraíba, Northeast Brazil

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Abstract. *Sapajus flavius* has a frugivorous-insectivorous diet, but also consumes food items from crops. Thus, we investigated the exploration of sugarcane cropping and processing by a group of *Sapajus flavius*. It was chosen the *ad libitum* and All Occurrences Observation Methods for collected data. Access to Sugarcane Plantations, Acquisition of Sugarcane, and Sugarcane Consumption behaviors were the most ones recorded. Surveillance and Back Without Sugarcane behaviors were the least ones recorded. There is an increase of exploration of sugarcane plantations during months with low rainfall, which coincides with the reduction of fruits in the forest fragment. Male and female adults were the ones who most exploit sugarcane plantations. The way individuals access, acquire and consume sugarcane highlights cognitive abilities, promoting the persistence of the species in fragmented areas with crops in the surrounding. The analyzed aspects will help on developing species conservation strategies, such as the implantation of native vegetation corridors to connect forest fragments that are isolated due to the expansion of sugarcane crops.

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Resumo. ***Exploração de plantações de cana-de-açúcar por* Sapajus flavius *habitando um fragmento de Mata Atlântica na Paraíba, Nordeste do Brasil***. *Sapajus flavius* possui dieta frugívora-insetívora, mas também consome alimentos oriundos de plantações. Assim, nós investigamos a exploração das plantações de cana-de-açúcar por um grupo de *Sapajus flavius*. Foram escolhidos os métodos de observação *ad libitum* e Todas Ocorrências para coleta de dados. Acesso as Plantações de Cana-de-açúcar, Aquisição e Consumo da Cana-de-açúcar foram os comportamentos mais registrados. Vigilância e Voltar Sem Cana-de-açúcar foram os comportamentos menos registrados. Ocorreu um aumento da exploração das plantações de cana-de-açúcar durante o período com pouca chuva, coincidindo com a redução dos frutos no fragmento de floresta. Machos e fêmeas adultos foram os que mais exploraram as plantações de cana-de-açúcar. A forma como os indivíduos acessam, adquirem e consomem a cana-de-açúcar destaca as habilidades cognitivas, promovendo a persistência da espécie em áreas fragmentadas com cultivos no entorno. Os aspectos analisados auxiliarão no desenvolvimento de estratégias de conservação da espécie, como a implantação de corredores de vegetação nativa conectando fragmentos florestais isolados devido à expansão da cana-de-açúcar.

Palavras-chave: Conservação; Etograma; Recursos antrópicos; Ecologia comportamental; Invasão de plantações.

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Introduction

The species of *Sapajus* genus show some behavioral flexibility and can adjust their behavior in response to changes in habitat, allowing them to occupy a variety of environments, including disturbed forest fragments (Fragaszy et al., 2004; Spagnoletti et al., 2017). Their manual dexterity, a large, heavy, and circumvolution brain (Auricchio, 1995), high sociability and terrestriality (Freese and Oppenheimer, 1981; Visalberghi et al., 2005) enable them to acquire food resources through complex foraging (Ludwig et al., 2006; Freitas et al., 2008; Lacerda, 2013; Liebsch and Mikich, 2015). In addition, they employ several strategies to obtain food resources during the period of fruit scarcity, including the exploration of underground and encapsulated items, or difficult to access items (Canale et al., 2009; Ferreira et al., 2009; Souto et al., 2011; Falótico et al., 2018, 2019).

Some populations benefit from food sources in anthropic environments, such as fruits in orchards and monocultures of pine, cassava, sugarcane, corn and eucalyptus (Ludwig et al., 2006; Lacerda, 2013; Rodrigues, 2013; Liebsch and Mikich, 2015). The proximity of cropped areas to forest edges (Spagnoletti et al., 2017), as well as the loss of natural habitat due to the increased commercial agriculture (Presotto et al., 2020), have allowed primates to access to anthropogenic resources; prompting them to forage on crops outside the forest (Hill, 2018). Old World Primates, such as chimpanzees (*Pan troglodytes schweinfurthii*), which are also known for their highly developed brains and

cognitive abilities, forage in agricultural fields (Rundus et al., 2022) and consume cropped cultures such as papaya, banana, cassava, cacao, corn, rice, millet, oil-palm, sugarcane, and mango (Tweheyo et al., 2005). Sugarcane consumption by chimpanzees (*Pan troglodytes verus*) increased during the dry season when there were few native fruits available in the forest (Hockings et al., 2009).

There are records of corn (*Zea mays*), sugarcane (*Saccharum* spp.) and even pinus (*Pinus* spp. and *Araucaria angustifolia*), among other native and exotic trees, being consumed by species of the *Sapajus* genus(Ludwig et al., 2006; Mikichand Liebsch, 2009; Liebsch and Mikich, 2015). More specifically, there are records of *Sapajus nigritus* consuming cassava (*Manihot esculenta*), eucalyptus (*Eucalyptus* spp.), and corn (*Zea mays*) (Ludwig et al., 2006; Lacerda, 2013; Liebsch and Mikich, 2015); *Sapajus libidinosus* consuming corn and sugarcane (Freitas et al., 2008); and *Sapajus flavius* consuming sugarcane (Valença-Montenegro, 2011; Rodrigues, 2013; Santos, 2013; Lins and Ferreira, 2019).

Sapajus flavius is found in Atlantic Forest region in Northeast Brazil (Oliveira and Langguth, 2006; Ferreira et al., 2009; Silva, 2010). In Northeast Brazil, the Atlantic Forest has been reduced to small patches due to anthropogenic activities, including the expansion of sugarcane crops (Pereira and Alves, 2006). A review of the areas where the species *Sapajus flavius* and *Alouatta belzebul* occur in the Centro de Endemismo Pernambucano, which covers the States from Rio Grande do Norte to Alagoas, the State of Paraíba showed the highest number of records and signs of these species (Fialho et al., 2014). In Paraíba, *Sapajus flavius* populations are found in forest patches where logging, shrimp farming, and extensive sugarcane plantations activities have promoted the reduction and fragmentation of their habitats (Barbosa, 1996).

The diet of *Sapajus flavius* includes not only fruit and insects, but also leaves, flowers, seeds, stems, roots, small vertebrates and invertebrates in its diet, as well as items from crops (Valença-Montenegro, 2011). Studies have recorded proportions of sugarcane in their diet ranging from 11.88% (Valença-Montenegro, 2011) to 37.83% (Rodrigues, 2013). During the dry season when the availability of fruits in the forest decreased, this proportion can reach up to 51.00% (Rodrigues, 2013). It is relevant to understand the exploration of sugarcane plantations by *Sapajus flavius*, as well as their methods and transport, in addition to their consumption of sugarcane. This is because when individuals leave the forest to exploit the crops, they may expose themselves to risks such as predation, hunting, and picking up.

From this perspective, it was investigated the exploration of sugarcane plantations by a group of *Sapajus flavius*. Specifically, we: (i) identified and described the behaviors in the exploration of sugarcane plantations; (ii) recorded the absolute frequencies of behaviors occurrence; (iii) recorded the monthly frequencies of exploration of sugarcane plantations; and (iv) recorded the sex-age class from individuals' who go to sugarcane plantations. We hypothesized that there would be variations in the number of visits to the sugarcane plantations. During low rainfall months, we expected an increase in visits because there is a shortage of fruits in the forest, making exploration of sugarcane plantations more appealing. We also hypothesized that adult male sex-age class would visit sugarcane plantations more often. Since adult males in this species are larger and stronger, we expected them to be more expose to danger and, therefore, to visit sugarcane plantations frequently.

Material and methods

Study area

We carried out this research in sugarcane plantations surrounding the Natural Heritage Private Reserve Engenho Gargaú (7° 00' 43.84" S, 34°7' 24.96" O), both

properties of Japungu Agroindustrial S/A, and local farmers' orchards. The reserve comprises a fragment of Atlantic Forest (1,058.62 ha), in the Municipality of Santa Rita, State of Paraíba, Northeast Brazil (Figure 1), which is surrounded by sugarcane plantations (5,202 ha) and orchards (0.92 ha) (Dantas et al., 2022). To carry out the study, authorization (N03/2018) was obtained from the Environmental Management Sector of Japungu Agroindustrial S/A, as well as from the owners of the orchards.

The sugarcane plantations have two different structures. The first structure consists of plants that are approximately 2-3 m in height and spaced about 5 cm, with regular irrigation and fertilization. The second one consists of plants that are approximately 1-2 m in height and spaced 30 cm apart, without regular irrigation and fertilization regime. The climate in the region is hot and humid (Kottek et al., 2006). In 2018, the average rainfall in Santa Rita Municipality was 1,035.4 mm and the average annual temperature in dry season ranged from 26 °C to 32 °C, while in the rainy season, it ranged from 23 °C to 28 °C (AESA, 2018).

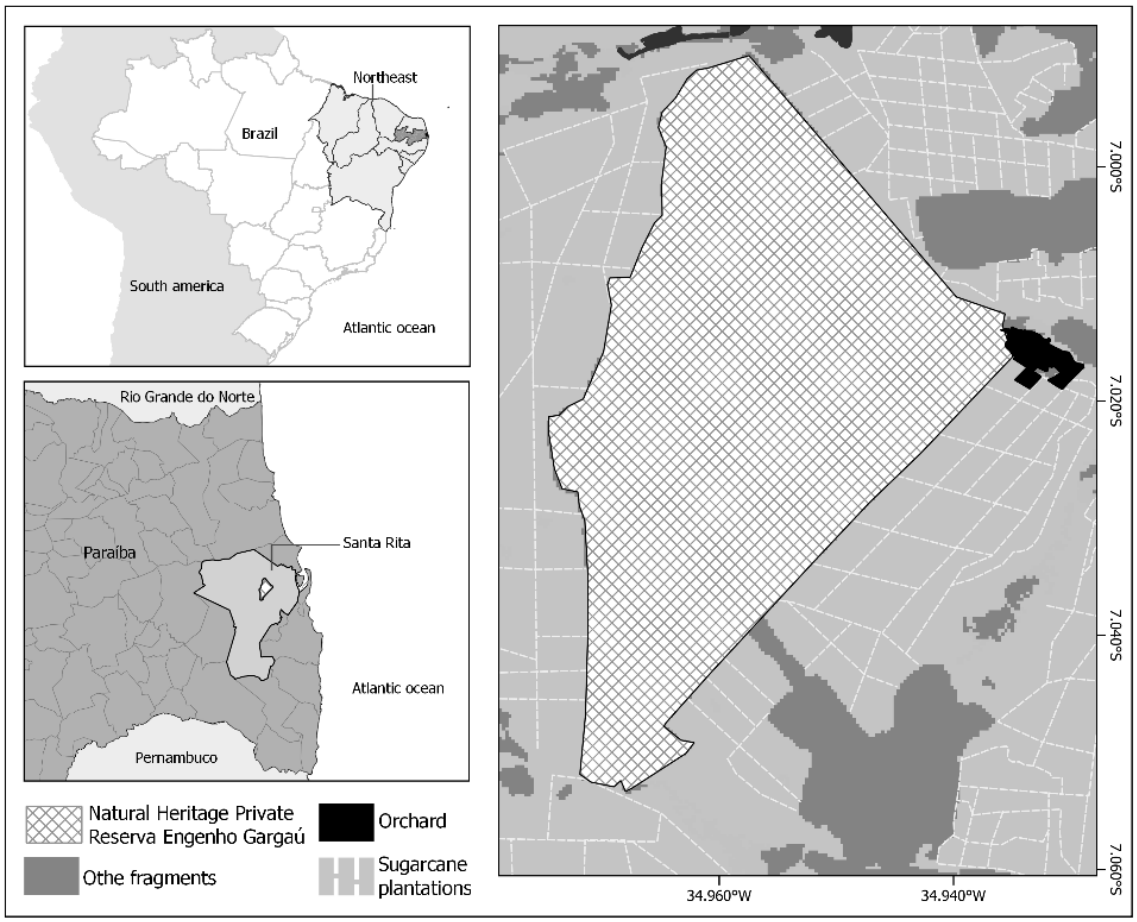

Figure 1. The top-left square of the map shows Paraiba in Northeast Brazil, while the bottom-left square describes the Municipality of Santa Rita, in Paraíba Region. The right square shows the studied area, which includes the Natural Heritage Private Reserve Engenho Gargaú, orchards, and sugarcane plantations in the Municipality of Santa Rita. The *Sapajus flavius* group inhabits the Natural Private Reserve Engenho Gargaú and exploits orchards, and sugarcane plantations in the surrounding area. This map was prepared for this study by Medeiros (2023).

The reserve is inhabited by the species *S. flavius* (Schreber, 1774), *Alouatta belzebul* (Linnaeus, 1766), and *Callithrix jacchus* (Linnaeus, 1758) (Fialho and Gonçalves, 2008). The first two species mentioned are targets of the National Action Plan for the Conservation of Primates of Northeast (ICMBio, 2019). From 2006 to 2007, the population of *S. flavius* was estimated to be 131 individuals (Fialho and Gonçalves, 2008). Subsequently, from 2009 to 2010, it was estimated to be around 180 individuals, divided into three social groups with approximately 30, 60, and 90 individuals, respectively (Valença-Montenegro, 2011).

Study group, data Collection and statistical analysis

We studied the same group of *Sapajus flavius* that was previously monitored by Valença-Montenegro (2011), Rodrigues (2013) and Santos (2013). Thus, in order to identify the sex of individuals we followed the descriptions provided by Valença-Montenegro (2011) and Santos (2013) and observed the individuals' genitalia when possible. Adult males were identified by the presence of a dewlap, an epidermal structure that is present only in some adult males, which facilitates their identification (Oliveira and Langguth, 2006). We counted a total of 78 individuals, including 37 adult males (11 of them males with dewlap), 14 adult females, 4 young males, 15 young females and 8 infants.

We carried out observations twice a week, from March to October 2018. The length of time we spent in the field ranged from 6 h (from 9:00 am to 3:00 pm) to 8 h (from 8:00 am to 4:00 pm), totaling 175 hours in the field, 120 hours of contact with individuals, and 90 hours of recording data related to the exploration of sugarcane plantation.

In order to active objective (i) (build an ethogram), *Ad libitum* Observation Method (Altmann, 1974) was adopted to identify and describe behaviors exhibited by individuals during their visit to the sugarcane plantations. All Occurrences Method (Altmann, 1974) was also adopted to register the studied individuals' behaviors while exploring sugarcane plantations. This allowed us to obtain absolute frequencies from number of times each behavior was observed (objective ii). Secondly, we recorded the monthly frequency of visit to the sugarcane plantation, counting the number of times the individuals visited the sugarcane plantations (objective iii). Additionally, we recorded the absolute frequency of behavior exhibited by individuals of different sex-age classes while exploring the sugarcane plantations (objective iv). Finally, we recorded the time the first individual entered and the time the last individual left the sugarcane plantations to calculate the total duration of their stay.

Thus, we used the generalized linear models (GLM) to analyze the behavioral data (objective ii). We treated the absolute frequency of each behavior observed as the dependent variable, and included each behavior as a factor to be analyzed. The Wald Test was applied to verify whether the explanatory variables were significant for the model under study. Additionally, the Chi-Square Test was used to determine which behaviors were the most frequent and which were the least frequent.

For objective iii, we used hierarchical cluster analysis to analyze the monthly frequency of sugarcane plantations exploration. We used count metrics that were appropriate for absolute frequencies and applied the average link method.

For objective iv, Chi-Square Test was used to analyze the absolute frequencies of behaviors exhibited by individuals of different sex-age classes, and Fischer's Exact Test was used to analyze absolute frequencies of sugarcane plantations exploration by individuals of different sex-age classes. All statistical tests were performed at a 5%-level of significance.

Results

The behaviors identified and described in the ethogram were Access to sugarcane plantations (ASP), Acquisition of sugarcane (ACS), Sugarcane Consumption (SC), Surveillance (SU), and Back without sugarcane (BWS) (Table 1).The Wald Test showed that the behaviors included in the model were statistically significant for this study. The Chi-Square Test showed behaviors Access to Sugarcane Plantations - ASP (χ^2 = 12.60, df = 1.0220, p < 0.001), Acquisition of Sugarcane - ACS (χ^2 = 10.371, df = 1.0860, p < 0.001), and Sugarcane Consumption - SC (χ^2 = 10.747, df = 1.1265, p < 0.001) were significantly more frequent, while Surveillance - SU (χ^2 = 1.743, df = 1.1119, p = 0.187) and Back Without Sugarcane - BWS, had lower frequencies (Figure 2).

Table 1. Ethogram with the behaviors exhibited in sugarcane plantations by the *Sapajus flavius* individuals of the study group.

Behavior	Description
Surveillance (SU)	The individual moves in quadruped or biped posture, turning his head and looking from side to side and/or emitting high-pitched vocalizations. This behavior usually occurs when the individual is at the edge of the forest, on the dirt road, or within the sugarcane plantations.
Access to Sugarcane Plantations (ASP)	The individual moves from the forest, towards the sugarcane plantations, in a biped or quadruped posture. This behavior can also start in the branches of the trees; in this case, the individual jumps from the tree branches, at the edge of the forest, to the ground, moves crossing the dirt road and enters the sugarcane plantations.
Acquisition of Sugarcane (ACS)	The individual pushes the body against the sugarcane plant to the front and back movements, holds the sugarcane plant with his hands, makes circular movements, and sometimes bites the plant base to force it to break. It pulls out and carries sugarcane plant using its tail or hands.
Back Without Sugarcane (BWS)	The individual moves from the plantations to the edge of the forest without a sugarcane plant.
Sugarcane Consumption (SC)	The individual plucks the leaves of the sugarcane plant with his hands and/or mouth, and beats the sugarcane plant on the tree trunks at the edge of the forest, breaking the plant into smaller pieces. The individual holds the sugarcane plant stem with its hands, takes the stem to the mouth, and sucks its insides, then uses the teeth to tear, bite and chew it.

The lowest monthly frequencies of exploration of sugarcane plantations (0 to 3 visits) were recorded from March to June. While, the monthly frequencies increased from 18 to 149 visits from July to October. Plantations with low-density structures (approximately 1-2 m high and spaced 30 cm apart, with no regular irrigation and fertilization regime) were harvested and burned in March and April. On the other hand, the high-density plantations (approximately 2-3 m high and spaced about 5 cm between

the plants, irrigated and fertilized regularly) were harvested in May. During this time, five individuals were observed picking up sugarcanes that remained on the ground after harvest. During this period, individuals were observed eating fruits of the native species *Bowdichia virgilioides* (11); *Tapirira guiannensis* (7); *Inga* sp. (3); *Protium heptaphyllum* (1), as well as the exotic species *Elaeis* sp. (161), inside the forest (reserve). They also consumed fruits from the species *Artocarpus heterophyllus* (3) in the orchards. The highest frequencies of sugarcane consumption were recorded in the months of August (453), September (65), and October (277). During these months it was also recorded the lowest-monthly rainfall in the study area. October was the month with the lowest rainfall (6.2 mm), and April was the rainiest month (287.5 mm) (AESA, 2018).

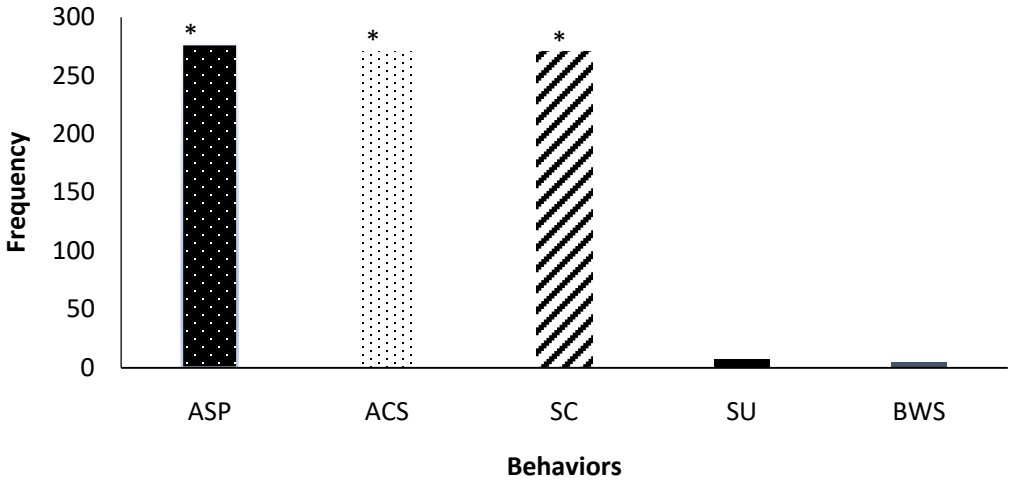

Figure 2. Absolute frequencies of behaviors in the sugarcane plantations. ASP: Access to Sugarcane Plantations; ACS: Acquisition of Sugarcane; SC: Sugarcane Consumption; SU: Surveillance; BWS: Back Without Sugarcane. *Significant values obtained by the Chi-Square Test.

When Accessing the Sugarcane Plantations (ASP) *Sapajus flavius* individuals moved from the forest to the ground in a quadrupedal posture, or jumped from the tree branches at the forest edge, and some of them crossed a dirt road to reach the sugarcane plantations (Figure 3). When they were in the trees, some individuals turned their heads, looked from side to side and/or emitting high-pitched vocalizations before descending or jumping to the ground. Others, when on the dirty road, approached the sugarcane plantation and moved in quadrupedal or bipedal posture, turning their heads, looking from side to side, and exhibiting the Surveillance (SU) behavior before entering the plantations.

On average, individuals remained within the sugarcane plantations for 5 min (± 3.69) and moved from edge to the inside of the plantations over an average distance of 13.70 m (± 3.07). When they moved within the plantations, they alternated quadrupedal and bipedal postures. In the Acquisition of Sugarcane (ACS) individuals assumed the bipedal posture, pushed the body against the sugarcane plant, making oscillatory movements and/or bit the base of the sugarcane plant. They held the sugarcane plant with their hands and rocked it, making circular movements to force it to break and pull it out. They used their hands and sometimes their tails to pull and transport sugarcane plants to the forest's edge (Figure 4). While five individuals accessed the plantations, they were unsuccessful in acquiring sugarcane (Back Without Sugarcane - BWS).

Figure 3. *Sapajus flavius* individual from study group during the Access to Sugarcane Plantations (ASP). Photo: Sandra Maria Rodrigues da Silva (2018).

Figure 4. *Sapajus flavius* individual from study group carrying sugarcane plants during the Acquisition of Sugarcane (ACS). Photo: Sandra Maria Rodrigues da Silva (2018).

Upon returning to the forest, they transported the sugarcane up to the trees located on the forest edge. They removed the sugarcane leaves by pulling them with their hands and/or by biting them. Another processing behavior was to beat the sugarcane against the tree trunks, breaking it into smaller pieces (Figure 5). They took the sugarcane stalks to their mouths, sucking them, and used their teeth to tear, bite, and chew them, corresponding to the Sugarcane Consumption (SC) behavior.

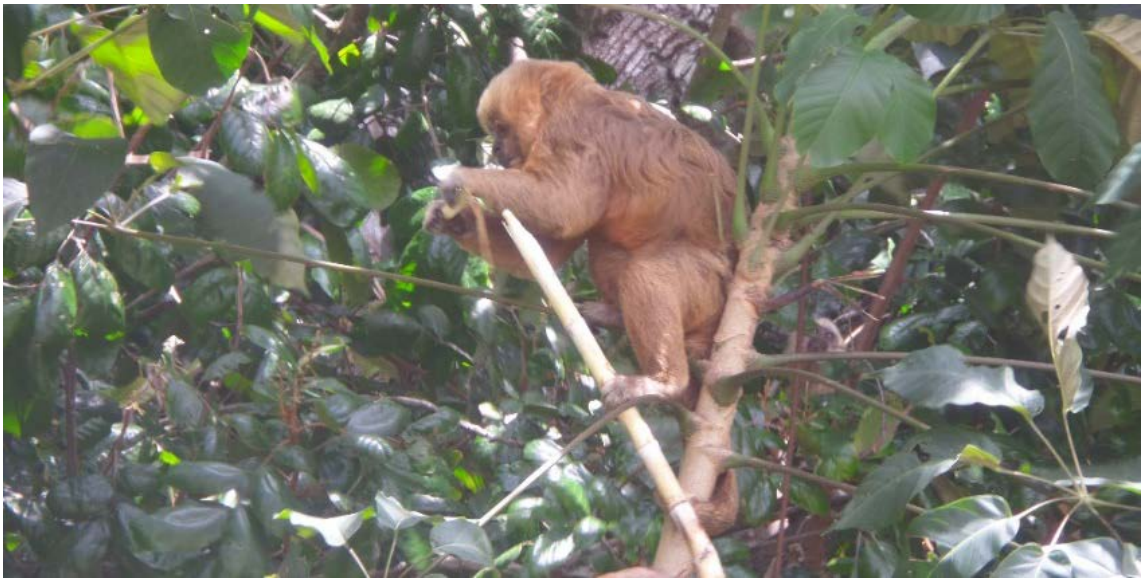

Figure 5. *Sapajus flavius* individual from study group during the Sugarcane Consumption (SC). Photo: Sandra Maria Rodrigues da Silva (2018).

Pieces of stalks, whether chewed or not, fell to the forest's edge, and four individuals went down to the ground to pick them up and consume them. We also observed individuals approaching those who were eating sugarcane (n = 5). The individuals who were already consuming sugarcane emitted agonistic vocalizations, and pushing them away. During our observations, we recorded only one episode of sugarcane sharing, in which an adult male handed a piece of sugarcane to a young individual who was close to the first one.

The group consisted of at least 78 individuals distributed across different sex-age classes. Among the records of visits to sugarcane plantations, 32.5% were adult males, 29.3% were adult females, 14.7% were young males, 12.7% were young females, and 10.8% were infants. Young individuals who accessed sugarcane plantations were always close to adult males and/or females, and adults carried infants.

The frequencies recorded during the exploration of sugarcane plantations by individuals of different sex-age classes, demonstrated that Access to Sugarcane Plantations (ASP), Acquisition of Sugarcane (ACS), and Sugarcane Consumption (SC) showed significant differences among adult males and young males ($x^2 = 99.21$, $p < 0.001$), as well as among adult females and young females ($x^2 = 77.01$, $p < 0.001$). Adult males and adult females were frequently observe on the Access to Sugarcane Plantations - ASP (242), Acquisition of Sugarcane - ACS (238), and Sugarcane Consumption - SC (238), but there was no significant difference among them. Surveillance - SU (7), and Back Without Sugarcane - BWS (5) were record only by adult males and adult females but at lower frequencies. There were significant differences in the frequency of exploration of sugarcane plantations by individuals of different sex-age classes (LSD: 0.534; p-value = 0.01). The most frequently registered classes were adult males (n = 51) and adult females (n = 46).

Discussion

It is know that sugarcane is an exotic food resource from the anthropic environment, but it is widely consumed by individuals of *S. flavius*. Previous studies have focused on the feeding behavior of *S. flavius* in relation of sugarcane, such as those carried

out by Valença-Montenegro (2011), Rodrigues (2013) and Santos (2013), although they have provided limited descriptions of the behaviors involved in exploring sugarcane plantations. Describing these behaviors can provide standardization for quantitative and comparative studies (Souto, 2005). Therefore, Access to Sugarcane Plantations (ASP), Acquisition of Sugarcane (ACS), Sugarcane Consumption (SC), Surveillance (SU), and Back Without Sugarcane (BWS) were identified and were described in an ethogram. As a result, researchers who will carry out future studies on the species in sugarcane plantations will be able to use this ethogram for standardized recording and comparison data.

The Surveillance behavior was shown by individuals before entering the sugarcane plantations and had a low occurrence record. This behavior was reported by Rodrigues (2013) and by Santos (2013), mainly for adult males, in the context of feeding. Similar to the behavior described in the ethogram produced in our study, these authors reported that adult males assumed a bipedal posture and turned their heads, attentively observing the environment around them. This behavior was shown by a few individuals before the group entered the sugarcane plantations. When individuals leave the forest and go to plantations to acquire sugarcane, they became more vulnerable to predation, harvesting, and hunting. Ludwig et al. (2006) reported the predation of a *Sapajus nigritus* infant by a dog on a cassava (*Manihot esculenta*) plantation. We did not observe individuals consuming sugarcane within the plantations, although, they have always transported stalks to consume them in the trees at the forest edge (reserve), where they have less risk of predation, harvesting, and hunting.

The low records of Surveillance (n = 7) in our study compared to other behaviors such as access, acquisition and consumption of sugarcane may be attributed to the habituation of study group to the researchers' presence. This is because the same group has been subject of previous studies (Valença-Montenegro, 2011; Rodrigues, 2013; Santos, 2013; Neco, 2015). Furthermore, the last author of our study has carried out some scientific dissemination and awareness in the region actions, and found out that locals do not hold a negative attitude toward the individuals of *S*. *flavius* who consume crops (Castro, personal communication). Moreover, locals are aware of individuals going to the plantation to obtain sugarcane. Similarly, Spagnoletti et al. (2017) pointed out that in Piauí, Northeast Brazil, farmers perceived consumed crops as having a moderate impact and generally showed a positive attitude towards *Sapajus libidinosus*.

The exploration of sugarcane plantations was frequent, but the highest frequencies were recorded in the months with low rainfall. Valença-Montenegro (2011) and Rodrigues (2013), studied the same group, demonstrated by phenological data that the availability of fruits in the months of low rainfall was reduced and the consumption of sugarcane increased. A similar result was observed by Hockings et al. (2009) for chimpanzees (*Pan troglodytes*), who also increased their consumption of sugarcane during periods of scarcity of wild foods.

In addition, according to our data, the exploration of sugarcane plantations was recorded for individuals of all sex-age classes, and the most records were for adult males and adult females. However, in chimpanzees, adult males tended to forage for longer on plantations, and were more likely to visit plantations near villages than females (Hill, 2017). The author explained the difference in sugarcane consumption between sexes as result of males having a greater inclination towards risk-taking behavior. The effort and exposure to risks for obtaining sugarcane may also explain the low frequency of sharing among the study group. Neco (2015) carried out an experiment using boxes containing corn and sugarcane, but only six instances of sharing were recorded out of a total of forty-one episodes of accessing the food from June to December 2014. The same argument, a greater tendency of adults to take risks, was used by Schweitzer et al. (2017) to explain the higher frequency of crop foraging initiation by *Papio hamadryas ursinus* adults when compared to non-adults. However, they also pointed out that higher energetic needs in

adults compared to non-adults, could also explain the frequency difference observed. Similar explanations could be applied to our study.

Our study also recorded that the individuals who consumed sugarcane emitted agonistic vocalizations, but there were no records of direct competition. Similarly, Neco (2015) recorded agonistic vocalizations in the first moments of individuals' arrival at the place of the food box. Since sugarcane is an abundant, dispersed and non-monopolizable resource, a low agonism rate was actually expected. On the other hand, Lins and Ferreira (2019) studied the same species during sugarcane crop raiding, and recorded a high rate of direct competition among individuals with fights and alliances among males who competed for a piece of sugarcane that still need be broken. The area where Lins and Ferreira (2019) carried out the study corresponds to a forest fragment with a total area of 270 ha, inhabited by 133 individuals of *S. flavius*. The author stated that sugarcane consumption has provided these individuals with half of the food they consumed throughout the year, consequently, in this way, it was crucial for their survival.

The individuals' behaviors during the complex foraging activities demonstrate their cognitive abilities (Ottoni, 2015; Fragaszy et al., 2017; Falótico et al., 2018, 2019). They have a brain that is disproportionately large in relation to body size, well-developed manual dexterity superior to other New World monkeys, as well as a high level of curiosity and propensity for exploring objects in their surroundings (Visalberghi and Fragaszy, 2012). The Acquisition of Sugarcane (ACS), described by our study, is a complex set of behaviors, which was began by individuals who used their own body to break the sugarcane. Their technique involves holding the sugarcane plant with their hands and making circular movements, using their bodies to apply the necessary force to break plant. This method is more complex than simply pulling the sugarcane plant, although it was also more effective.

Access to Sugarcane Plantations (ASP), Acquisition (ACS), and Sugarcane Consumption (SC), constitute several stages towards an end. These skills also required from those individuals their cognitive flexibility and problem-solving abilities, planning and anticipating results. The processes to access, acquire, and consume sugarcane, highlighted their abilities to plan and execute complex foraging strategies, as well as allowed their presence in fragmented areas surrounded by plantations.

The exploration of plantations was exclusively to acquire sugarcane. The average distance that individuals move from the edge of the plantations towards their inner areas, suggests a limitation in plantations permeability. Thus, we did not observe individuals using sugarcane plantations to reach other fragments of forest. On the contrary, Dantas et al. (2022) recorded individuals of *S. flavius* using a corridor of regenerating native vegetation to reach a fragment of forest, close to the fragment of the reserve, indicating that the forest matrix with regenerating vegetation is more permeable to *Sapajus flavius*.

Agriculture has been moving forward in the northeast of Brazil reducing the natural vegetation cover and threatening many wild animals' populations (Presotto et al., 2020). The expansion of sugarcane plantations is one of the main activities that have caused the reduction of *Sapajus flavius*' habitat in Paraíba (Barbosa, 1996). In addition to agricultural activities, climate change has also contributed to habitat reduction. The projections, considering the climate change scenario for the Northeast of Brazil, point to a loss of 94% of suitable habitats for populations of *Alouatta belzebul*, 98% for populations of *Sapajus flavius*, and 54% for populations of *Sapajus libidinosus* (Moraes et al., 2020). This loss of habitat will likely result in more frequent use of anthropic habitats as monocultures.

The aspects addressed by our study, in the exploration of sugarcane plantations, may assist in species conservation strategies. While populations of *S. flavius* are adapting their behaviors for the exploration of plantations, our observations did not reveal the use of theses plantations as bridges for individuals to access other forest fragments. Our

results highlights the importance of implementing corridors of native vegetation to connect isolated fragments of forest caused by the expansion of sugarcane plantations. The corridors can benefit the population of *S. flavius* and other species by allowing for great mobility. Additionally, they can provide indirect benefits to farmers such as preventing soil erosion and retaining soil moisture and organic matter (Anderson et al., 2007).

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Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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