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Behavioral Changes of Free-living Squirrel Monkeys (*Saimiri collinsi*) in an Urban Park

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Abstract: This paper describes changes in the ecology and behavior of a group of squirrel monkeys (*Saimiri collinsi*) in a semi-natural environment of an urban forest fragment. The observation method used was instantaneous scan sampling, with a minute to register all individuals observed, and 5-min intervals between samples. We collected data in two study periods: during five months in 2007 and five in 2009. In both periods the animals were very active, spending most of the time in foraging and locomotion, while resting little, as expected for the species' natural behavior. However, in 2009, we recorded frequent interactions between monkeys and visitors and a strong change in some aspects of the monkeys' behavior and feeding. The monkeys had changed their daily activity budget, home range use and diet. They had abandoned the native plants as food sources and begun to feed on processed foods that they obtained directly and indirectly (littering) from visitors. The most frequented areas were associated with the availability of food of this sort, but in 2009 monkeys were preferring sectors associated with junk foods from visitors. The animals used the lower strata more frequently. The behavioral differences seen in the second period in relation to the first probably result from the development of interactions with humans. These interactions may have undesirable consequences to both and indicate the need for awareness campaigns to warn visitors about the risks of direct contact and to advise them on how they should behave towards the monkeys for the monkeys' good and their own.

Key Words: Neotropical primate, daily activity budget, diet, use of space, human-primate interaction

Introduction

With easy access and other facilities, zoos and urban parks can offer excellent opportunities to carry out behavior studies of the animals in their keeping. In some cases, they are free-living in semi-natural environments, defined as those with similar characteristics to the natural habitat, where the animals can forage for food on their own, while also receiving a complementary diet (Schapiro *et al.* 1986).

Primates are commonly encountered in such places (Taylor and Leon 1997; Sabbatini *et al.* 2006; Rangel 2010) probably reflecting their ability to adapt to somewhat different conditions from their natural habitat. In Brazil, capuchin monkeys (*Sapajus*) and marmosets (*Callithrix*) are common in a number of parks, zoos and botanical gardens (Rocha 2003; Sabbatini *et al*. 2006; Rangel 2010), as a result of their ability to adapt to anthropogenic environments (Stevenson and Rylands 1988; Jack 2007). Where those primates interact directly with visitors, they can even turn aggressive, with implications for the health and physical integrity of the humans and monkeys.

Their small size and the relative ease with which they can be manipulated and managed have contributed to squirrel monkeys (*Saimiri*) being successfully bred in captivity, and in the United States they became the Neotropical primate most used in biomedical research (Dukelow 1985). They also adapt well to anthropogenic environments (Baldwin and Baldwin 1981) besides being a potentially invasive species in the Atlantic Forest (Camarotti *et al.* 2015). They are commonly found in semi-natural environments (Nadler *et al*. 1986) in urban parks in the Brazilian Amazon, such as the Bosque Rodrigues Alves in Belém in the state of Pará.

An understanding of their ecology and behavior is important to manage adequately both captive and free-living primates, particularly where there is the possibility of interactions with humans. The aim of this paper is to examine changes in the general behavioral patterns of squirrel monkeys (*Saimiri collinsi*) living freely in an urban park in eastern Amazonia. We compared their daily activity patterns, diet and use of space between two study periods, 2007 and 2009, and compare the two periods with a previous study of squirrel monkeys in the Bosque Rodrigues Alves (Souza *et al.*

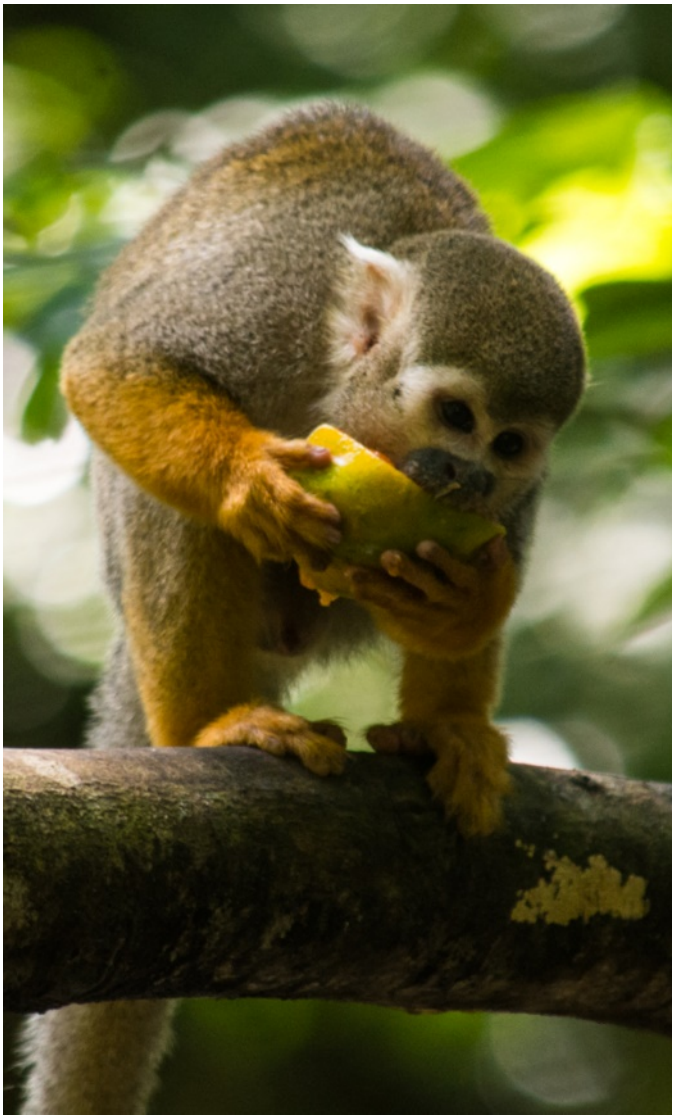

Figure 1. Collins' squirrel monkey (*Saimiri collinsi*) in the Bosque Rodrigues Alves, Belém, Pará. Photo: Raphael Nunes.

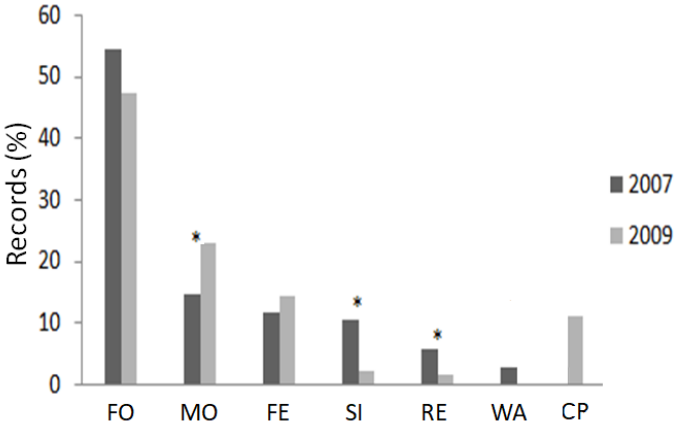

Figure 2. Daily activity budgets of free-living squirrel monkeys (*Saimiri collinsi*) in the Bosque Rodrigues Alves during the two study periods (2007 and 2009): FO = foraging; MO = moving; FE = feeding; SI = social interaction; RE = resting; WA = waiting. Asterisks indicate the categories that differed significantly in frequency between the two study periods. In 2007, N was 3120 records, and in 2009, N was 5084 records.

1997) and in natural sites in Amazonia (Lima 2000; Lima *et al.* 2000; de Thoisy *et al.* 2002; Stone 2007; Paim *et al.* 2017).

Methods

Study site

The Bosque Rodrigues Alves (1°25'49"S, 48°27'22"W) is a park open to public visitation. It is a 15-ha, managed fragment of native forest in the city of Belém. The average annual temperature is 26.3°C and the annual average precipitation is 3,055 mm (Silva and Portela 2006). The climate includes a rainy period from December to April and a less-rainy period from June to November. The vegetation is terra firma tropical rainforest, with a canopy at 25−40 m and a clear understory with low to regular luminosity (Contente 2004). There are some native animal species kept in captivity, and a few free-living native mammals, which include squirrel monkeys (Saimiri collinsi), agoutis (*Dasyprocta*), three-toed sloths (*Bradypus variegatus*) and two-toed sloths (*Choloepus didactylus*).

Study species

Squirrel monkeys (*Saimiri*) are small, agile primates. Head-body length is about 20−40 cm, females weigh 500−750 g and males 700−1110 g (Baldwin and Baldwin 1981). They are widespread in the Amazon, extending north to tributaries of the upper Orinoco in southern Venezuela and east central Colombia, with an isolated species (*S. oerstedii*) occurring in Costa Rica and Panama (Baldwin and Baldwin 1981; Rylands *et al.* 2013). Group size varies from 10-80 individuals in disturbed areas to 120 or more individuals in preserved areas (Baldwin and Baldwin 1971, 1981; Terborgh 1983). Home range varies from 12.7 to 250 ha (Terborgh 1983; Boinski 1987; de Thoisy *et al.* 2002), and recorded daily path lengths range from 1.1 to 4.5 km, depending on food availability and distribution and group size (Izawa 1976; de Thoisy *et al.* 2002). Their diet is composed largely of small fruits and insects, but also includes nectar, flowers, buds, seeds, and small vertebrates such as bats, small birds and birds' eggs (Janson and Boinski 1992; Stone 2007; Paim *et al.* 2017).

Collins' squirrel monkey (*Saimiri collinsi* Osgood, 1916) (Fig.1) was recognized by Cruz Lima (1945), Cabrera (1957) and Hill (1960), but considered a synonym of *S. sciureus* by Hershkovitz (1984) and Groves (2001). Molecular genetic studies of the mtDNA cytochrome b gene by Carretero-Pinzón *et al.* (2009) and Lavergne *et al.* (2010), however, confirmed the distinctiveness of *S. collinsi*, and Mercês *et al*. (2015; see also Lynch Alfaro *et al.* 2015) showed that the form on the Ilha de Marajó (mouth of the Amazon) and south of the lower Rio Amazonas was *S. collinsi*, with *S. sciureus*, restricted to the north of lower Rio Amazonas.

Study group

A pilot study was conducted from February to April in 2007 and the main study from May to September in both 2007 and 2009, totaling more than 157 hours of observation in the

first year and 216 hours in the second. We also compare our findings in 2007 and 2009, with a previous study of the park's squirrel monkeys carried out by Souza *et al.* (1997). The study group was composed of at least 58 animals in 2007 and 45 in 2009.

Data collection

The observation method used was instantaneous scan sampling (Altmann 1974; Cullen Jr. and Valladares-Pádua 1997) with a minute to register all individuals observed, and 5-min intervals between samples. In each scan, we took the following data for each individual: date, hour, location, activity, and height above the forest floor (rounded to a meter). Food items ingested were recorded as animal, plant and others. We marked the fruiting trees visited and collected botanical samples for taxonomic identification. We recorded the group's position at each scan using a map of the study site, divided into a grid of 16 equally sized sectors. The activities recorded were resting, foraging (searching for any kind of food), moving (the individual in movement), interacting socially, feeding (manipulating and ingesting any kind of food), chasing people (visitors, hawkers or park guards, who were handling anything edible), and waiting (waiting for the daily food supplementation). We recorded all events of rare behaviors such as mating during and between scans.

Data analysis

Daily activity budget, diet and use of space (vertical and horizontal) were determined from relative frequencies (F_x) of behavioral categories, food items and visited sectors, respectively (Altmann 1974; Cullen Jr. and Valladares-Pádua 1997). The equation used was $F_x = (x/N) \times 100$, where x is the number of each behavioral category, food item or visited sector; and N the total number of records. To examine the use of vertical strata, heights from the forest floor were grouped in 5-m classes (0 <5, 5 <10, 10 <15, 15 <20, and 20 m or more), and the frequency of use was estimated for each class (Altmann 1974; Cullen Jr. and Valladares-Pádua 1997). We tested for differences in behavioral patterns and vertical use of space in the two study periods using the t test, and a contingency table to compare frequencies of horizontal use of space.

Results

Daily activity budget

The most frequent activities were foraging, moving and feeding (N_{2007} = 3120 and N_{2009} = 5084; Fig. 2). The least recorded category in the first study period was "waiting" and in the second it was "socially interacting." The monkeys moved more in 2009 (t = -2.6; df = 8; p = 0.03), whereas in 2007 they rested more (t = 3.8; df = 8; p = 0.004) and had more social interactions (t = 2.8; df = 8, p = 0.025). There were no significant differences between the two study periods in the frequencies of foraging (t = 2.08; df = 8; p = 0.07) and feeding (t = -2.14; df = 8; p = 0.06).

Diet

The recorded diet in both study periods was predominantly of plant items (N_v) (N_v2007 = 361 and N_v2009 = 734; Fig. 3) and did not differ significantly in terms of the relative proportions of plant or animal items. Junk food, however, was registered only in 2009. The monkeys consumed native plant items only in 2007 (12% of the total of 247 plant item records). They ate the fruits of *Inga alba* and *I. edulis* (Leguminosae) and the flowers of *Eschweilera odora* (Lecythidaceae). The remainder of the plant items consumed in 2007 and 100% of the plant items consumed in 2009 were of the food provided daily by the park staff—a mix of banana, papaya, watermelon, grape, orange, mango, sweet potato and beet. Animal prey in both periods included adult Coleoptera, Orthoptera and Odonata and caterpillars (Lepidoptera). In 2009, they ate large amounts of junk food, such as popcorn, cakes, crackers, sweets and cookies. The monkeys obtained these items mainly from visitors, park guards and hawkers, but they also took leftovers from the restaurant tables or in food-waste bins.

Use of space

The sectors the monkeys used most in 2007 were D1 (36%) and C3 (19%) (N_{2007} = 3124; Fig. 4). These sectors correspond to the location of the kitchen, where they received fruit every morning from the park staff, and the macaws' enclosure, from where they would steal fruits. In 2009, the sectors most used were B3 (22%), corresponding to the location of hawkers (mobile vendors) and the restaurant, followed by C3 (16%) (N_{2009} = 5084; Fig. 4). Sectors were used differently between study periods (χ^2 = 1396.78; df = 15; p < 0.05). The monkeys used all but one of the sectors at some time during both study periods; the exception was sector A2 not used in in 2007.

The monkeys spent most time in the lower strata (up to 5 m) during both study periods (N_{2007} = 3121 and N_{2009} = 5083; Fig. 5). The use of three levels was different between study periods. In 2007, they spent significantly more time at the highest level, above 20 m, and between 5.1 and 10 m, than they did in 2009: >20 m (t = 2.76; df = 8; p = 0.024), 5.1−10 m (t = 4.48; df = 8; p = 0.002). In 2009, the monkeys spent more time low down at the lowest level between the ground and 5 m up; 0−5 m (t = -2.32; df = 8, p = 0.04). The use of the other two strata did not differ (10.1−15 m: t = -0.65; df = 8; p = 0.52; 15.1−20m: t = -2.05; df = 8; p = 0.07). The monkeys rarely went to the ground, only occasionally to pick up food items.

Discussion

Even though fed by the park staff, the monkeys remained very active, spending almost half of their time foraging and dedicating little time to rest. In general, this result coincides with those from a previous study with the same animals in the Bosque Rodrigues Alves (Souza *et al.* 1997), and with others

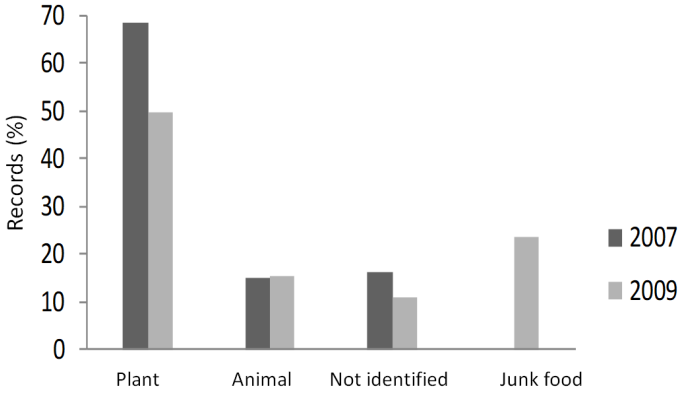

Figure 3. Diet of the free-living squirrel monkeys in the Bosque Rodrigues Alves during the two study periods (2007 and 2009). In 2007, N was 361 records, and in 2009, N was 734 records.

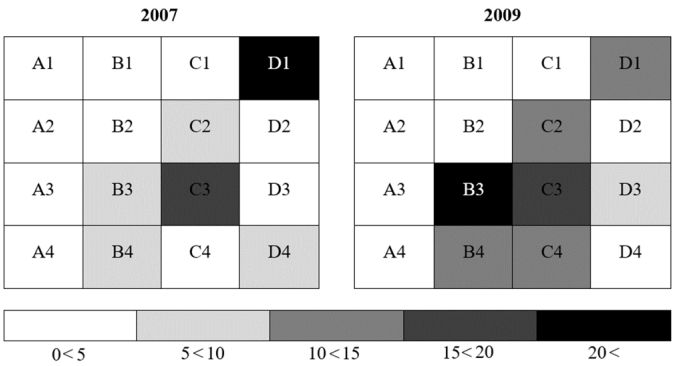

Figure 4. Horizontal use of space by the free-living squirrel monkeys in the Bosque Rodrigues Alves. Results in percentages of records during scans. The different shades (lighter to darker) indicate the frequency of use of the sectors, the least used being the lightest (0 <5%) and the most used the darkest (20% or more). In 2007, N was 3124 records and in 2009, N was 5084 records.

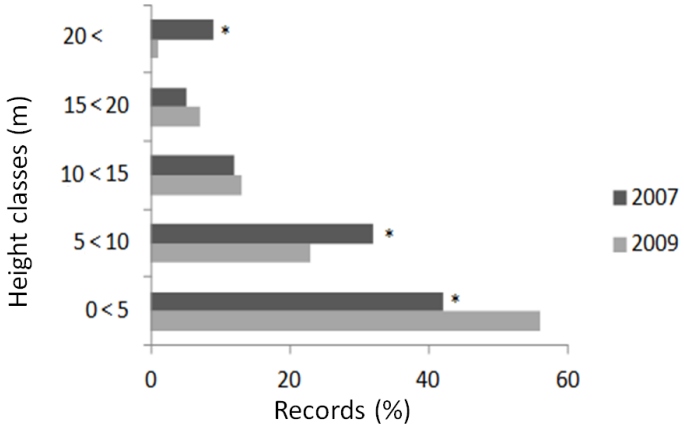

Figure 5. Vertical use of space by the free-living squirrel monkeys in the Bosque Rodrigues Alves. Asterisks indicate the categories that differ in frequency between the two study periods. In 2007, N was 3121 records and in 2009, N was 5083 records.

in natural sites in Amazonia (Lima 2000; Lima *et al*. 2000; de Thoisy *et al.* 2002; Stone 2007; Paim *et al.* 2017). Yet, Lima *et al*. (2000) registered a much higher frequency of moving in a group of *S. collinsi* and related their result to the highly heterogeneous spatio-temporal distribution of food resources and to the size of the study group's home range.

The drop in the time spent resting and interacting socially from 2007 to 2009 might be related to the novelty of their interactions with humans to obtain food. High food availability frees up time to engage in social interactions (Baldwin and Baldwin 1981; Stone 2007). The supplemental feeding by the park staff perhaps would explain why the category of interacting socially was registered more frequently in 2007, than is typical for studies carried out in natural environments (Terborgh 1983; Lima *et al.* 2000; de Thoisy *et al.* 2002). Although the time spent feeding was similar in 2007 and 2009, and the food supplementation by the park staff remained the same, by 2009 the monkeys were spending time chasing visitors to get junk food or seeking leftovers in the areas near the restaurant, a behavior not recorded in 2007, and this may have been at the cost of resting and social interaction.

The diet in 2007 was quite different from that registered in a study in the park ten years earlier by Souza *et al.* (1997). Then there was still no food provisioning (fruit) by the park staff, and the diet recorded included a higher diversity of plant species and animal prey, similar to that observed in wild groups (Fleagle *et al.* 1981; Stone 2007). The changes in diet and behavior patterns in 2009, as compared to groups in natural environments and the study group in 2007, evidently reflect the narrower interaction observed between monkeys and humans, including visitors, hawkers and park guards. A similar situation has been reported for squirrel monkeys (*S. boliviensis*) living in a semi-natural environment in Florida (Taylor and Lehman 1997). Analysing the cranium of one group member after its death, the authors found evidence of dental pathologies, probably deriving from an altered diet.

Cases of aggression toward visitors have been reported for capuchin monkeys (*Sapajus libidinosus*) living in similar conditions in a park in Brasília, Brazil (Sabbatini *et al.* 2006), and in other localities for Old World monkeys (Lee *et al.* 1986; Zhao and Deng 1992), and all point to the need for management measures to avoid risks of this kind. Sabbatini *et al*. (2006) recorded that aggression by the capuchin monkeys in Brasília resulted from interactions initiated by the visitors. In 2007, we noted that the public in the Bosque Rodrigues Alves were already trying to feed the monkeys but then their offers were rejected. In 2009, the squirrel monkeys were accepting offers from visitors as well taking the initiative of approaching them, and grabbing food directly from them, or stealing their leftovers.

In Uganda, Saj *et al.* (1999) studied a *Chlorocebus aethiops* group that spent half their feeding time eating human-produced food items. The groups' home range was smaller than is typical of conspecifics living in their natural habitat. In both 2007 and 2009, the squirrel monkeys in the Bosque Rodrigues Alves showed a preference for sectors where people fed them. In 2007, they spent much time in the park's fruit supply sector, while in 2009 they preferred the sectors with junk food. This change in use of space is associated with the increase in animal-visitor interactions and a consequence of new perception from monkeys of the visitors as food sources.

Conclusion

Interactions between monkeys and humans have evidently led to changes in the daily activity budget, home range use, and the diet of the monkeys. The monkeys reduced their consumption of native plant food items, and started to feed on processed foods – undoubtedly a threat to their health in terms of their diet and disease transmission. The direct physical contact with humans may result in accidental injuries beside risks of contagious diseases for both. Improper foods can also cause direct health problems for the monkeys, including diabetes, obesity, tooth problems, food infections, and so on. These interactions must be discouraged in places of public visitation such as zoos and urban parks. Squirrel monkeys in the Bosque Rodrigues Alves have changed their behavior towards humans in less than two years, indicating the need of a constant monitoring of their behavior, which, in turn, can permit the formulation of a sensible management of these monkeys and public awareness campaigns concerning this ill-advised practice.

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