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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

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Abstract Space is an important dimension of the ecological niche. Differentiation in the use of vertical strata of the forest is related to species body size, and explains in part species coexistence at a local scale. Large neotropical primates dwell in the canopy, moving quadrupedally on large branches, whereas smaller species leap between narrow branches in the understory. We tested this general pattern by observing focal individuals of the capuchin monkey (*Cebus* sp.) and the common marmoset (*Callithrix jacchus*), both non-native species, living in a forest fragment within the Rio de Janeiro city. Results were in accordance with the pattern for neotropical primates. Vertical use of the forest seems to be related with ecological interactions, especially for *C. jacchus* restricted to the lower strata due to aerial predation. Preliminary observations on diet corroborate the omnivory of *Cebus* and the gum feeding characteristic of *C. jacchus*. For *Cebus* sp. the exotic jack-fruit (*Artocarpus heterophyllus*) was the most important food item. Predation of both primates on vertebrates, especially by *C. jacchus* on passerines, could cause an uncommon impact on prey populations. In spite of anthropogenic impact, these non-native primates maintain the general pattern of habitat, support use and diet of the same or similar species in native neotropical communities.

Keywords Exotic species · Ecological niche · Vertical stratification · Locomotion · Diet · Anti-predation behaviour · Atlantic forest · Neotropical primates · Mammals

Introduction

Space use is an important factor to understand species distribution and coexistence, which can be perceived at different scales. For primates, for example, at a continental scale the geographic range is an important factor in understanding species distribution (Rylands et al.,

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1996; Peres, 1997; Peres and Janson, 1999). Habitat association explains species occurrences and sympatries at a regional scale, (Rylands, 1987; Peres and Janson, 1999), and vertical stratification in the forest allows the comprehension of coexistences and syntopies at a local scale (Fleagle et al., 1981; Terborgh, 1983; Peres, 1993). These factors together allow a detailed map of species distribution. In fact, space use was recognized as a fundamental dimension of the ecological niche (MacArthur, 1958; Connell, 1961; Schoener, 1974, 1983; Cunha and Vieira, 2004a). Differentiation in space use is a key factor in community structure, especially in three dimensional or complex environments (August, 1983; Grelle, 2003) such as tropical forests.

Neotropical primates vary in habitat use, body size, vertical stratification and diet, and considering all genera there is an extensive overlap in these niche dimensions (Table 1). However, focusing on spatial scales (continental, regional and local), it is possible to recognize specific spatial niches. Comparing available information for primate communities between the Amazon and the Atlantic forest, there is a more detailed differentiation in the vertical space use in the Amazon where four vertical strata are present (Table 1). However, Atlantic forest remains only in slope terrains, where only the canopy and the understory are clearly distinguishable and vertical differentiation seems to be coarser.

Overall, there is a clear relationship between body size and the height of strata used by the species, its locomotor mode, diet, and diameters of branches and trunks used. Large species occupy the highest strata, while small primates live mostly in the understory, and medium ones in all strata but mainly in the intermediate strata (Table 1). Quadrupedal and suspensory locomotor mode are typical for large neotropical primates, whereas for small species leaps are the main locomotor mode (Reed, 1999). Large species use large supports in the arboreal strata, and smaller species move mainly on small diameter branches. In diet, body size is negatively related with faunivory and positively associated with leaves and fruits consumed (Reed, 1999).

The Tijuca forest of Rio de Janeiro, Brazil, is one of the largest urban forests of the world, located inside the city. It represents a unique system to test the pervasiveness of this pattern of stratification related to body size in primates. This forest has a long history of disturbance. Before the 16th century the region harbored a dense indigenous population. With European colonization the real history of deforestation began, initially with the logging of Brazil wood (*Caeesalpinia echinata*) in the 16th and 17th centuries. After the commercial extinction of this tree, in the 18th and 19th centuries, almost half of the forest cover was replaced by coffee plantations (Dean, 1996). The rivers feeding the city of Rio de Janeiro dried up in the middle of 19th and the Emperor Dom Pedro II, recognizing the link between deforestation and maintenance of headwaters, ordered the reforestation of the Tijuca massif. The forest was restored with exotic and native trees (CCN, 1966). In the first decades of 20th century, exotic vertebrates, including primates, were accidentally introduced by runaways from a handling center of the environmental policy agency and by release of tamed animals. Nowadays, Tijuca forest is characterized by numerous species of non-native plants and animals.

The original primate community predictably included the southern muriqui (*Brachyteles arachnoides*), the howler monkey (*Alouatta guariba*), the black-horned capuchin (*Cebus nigritus*), the buffy-tufted ear marmoset (*C. jacchus*), and in lower elevations the golden-lion tamarin (*Leontopithecus rosalia*). Nowadays, the exotic common marmoset (*C. jacchus*), and the capuchin monkey (*Cebus* sp.) are the more abundant primate species. The

Table 1 Niche dimensions of diurnal neotropical primate genera

Genus	Size[a]	Diet[b]	Habitats (forests)[c]	Vertical strata[d]
Amazon				
Ateles	Large	Frugivorous–folivorous	Terra firme	Low canopy, upper canopy, emergents
Lagothrix	Large	Frugivorous–folivorous	Terra firme	Low canopy, upper canopy
Alouatta	Large	Folivorous–frugivorous	Várzea, terra firme	Low canopy, upper canopy, emergents
Cacajao	Medium	Frugivorous–granivorous	Várzea	Low canopy, upper canopy, emergents
Pithecia	Medium	Frugivorous–granivorous	Terra firme	Understory, low canopy, upper canopy
Cebus	Medium	Frugivorous–onivorous	Terra firme, Várzea	Understory, low canopy, upper canopy, emergents
Chiropotes	Medium	Frugivorous–granivorous	Terra firme	Low canopy, upper canopy, emergents
Callicebus	Medium	Frugivorous–onivorous	Terra firme	Understory, low canopy, upper canopy, emergents
Saimiri	Small	Frugivorous–onivorous	Várzea	Understory, low canopy, upper canopy
Callimico	Small	Insetivorous–onivorous	Terra firme	Understory, low canopy
Saquinus	Small	Insetivorous–onivorous	Terra firme	Understory, low canopy
Mico	Small	Insetivorous–onivorous	Terra firme	Understory, low canopy
Cebuella	Small	Insetivorous–onivorous	Terra firme	Understory, low canopy
Atlantic forest				
Brachyteles	Large	Frugivorous–folivorous	Montane, semi-decidous	Canopy
Alouatta	Large	Folivorous–frugivorous	Montane, semi-decidous, lowland, araucária	Canopy
Cebus	Medium	Frugivorous–onivorous	Montane, semi-decidous, lowland, gallery	Understory, canopy
Callicebus	Medium	Frugivorous–onivorous	Montane, semi-decidous, lowland, gallery	Understory, canopy
Leontopithecus	Small	Insetivorous–onivorous	Semi-decidous, lowland	Understory, canopy
Callithrix	Small	Gumivorous–onivorous	Montane, semi-decidous, lowland, gallery	Understory, canopy

[a] From Fonseca et al. (1996), classiffying as large (>4 kg); medium (1–4 kg); and small (<1 kg).

[b] Adapted from Fonseca et al. (1996).

[c] According with Rylands et al. (1996) for Atlantic forest; and Peres (1997), and Peres and Dolman (2000) for the Amazon.

[d] According with Rylands et al. (1996) for Atlantic forest; and synthesized from Rylands (1987); Mendes Pontes (1997); Peres (1997), and Peres and Dolman (2000) for the Amazon.

Amazonian squirrel monkey (*Saimiri*) and the black-tufted-ear marmoset (*Callithrix penicillata*) from Central Brazil also were reported to occur in the Tijuca forest, but were not seen in the study area (Cunha and Vieira, 2004b). The capuchin individuals of Tijuca forest have external morphological features resembling *C. nigritus*, *C. libidinosus*, *C. robustus* forming probably a hybrid species (*Cebus* sp.) (Silva Jr., personal communication). If the pattern of vertical stratification related to body size is maintained in such a unique and recent forest, it must be indeed a strong pattern.

We test this pattern of vertical stratification related to body size in this human built primate community of the Tijuca forest. Based on focal observation, we intend to describe: (1) the use of vertical space, (2) the main locomotory mode, (3) the diameters of supports used, and (4) the food items consumed by the capuchin monkey and the common marmoset in the Tijuca forest. Following Fleagle et al. (1981), we hypothesize that the larger species (*Cebus* sp.) moves predominantly in the canopy, walking in a quadrupedal fashion. The smaller marmoset is supposed to be detected mainly in the understory moving mainly by leaping. In addition we also expect a positive relation between body size and diameters of supports used. For diet, despite the factor of being introduced species, we expect that these monkeys eat the same items they eat in areas were they are native. Thus *Cebus* sp. would be more frugivorous, based on Freese and Oppenheimer (1981), whereas in accordance with Stevenson and Rylands (1988) and Rylands and de Faria (1993), *C. jacchus* will be characterized as a typical gum-eating primate.

Material and methods

Study area

The Tijuca forest is a 9.340 ha forest fragment, where the 3.466 ha of the the Parque Nacional da Tijuca is inserted. It is located inside the Rio de Janeiro city (22°55′–23°00′S e 43°11′–43°19′W), on the Tijuca massif, and represents an important area for tourism and leisure for the city of Rio de Janeiro.

In spite of the history of coffee plantations until the 19th century, the general forest structure and composition is of a typical secondary hill tropical rain forest, with palms, ferns, epiphytes and lianas. Most frequent trees are Leguminosae, Sapotaceae, Bombacaceae, Euphorbiaceae, Meliaceae, Lauraceae, Lecythidaceae, Moraceae and Melastomataceae (CCN 1966). Canopy height varies from 10 to 20 m, with some emergent trees above 25 m, particulaly *Cariniana estrellensis*. At some sites there is a clear dominance in biomass and structure of the exotic jackfruit (*Artocarpus heterophyllus*: Moraceae).

Field work was conducted from February to March and from July to August 2004 along a 7.7 km paved road, ranging from 100 to 500 m above sea level, and beginning from the edge to the interior of the forest fragment. The road was six meters wide with continuous tree canopy above it. The transect was crossed eighteen times by bicycle with an average speed of 3 km/h. Cunha (2005) estimated a population density of 100 to 177 *Cebus* sp. and 115 to 165 individuals/km^2 *C. jacchus* in the Tijuca forest.

Data analysis

Visual census began between 06:00 h and 07:30 h and finished between 10:30 e 11:30 h a.m. Encounters with groups lasted from 5 to 20 min. These primates are generally habituated to the presence of visitors, which frequently use the paved road to access other points of the Tijuca forest. Besides, animals did not demonstrate any major behavioral change when detected by the observer. In each encounter with a group the first adult observed was selected as a focal individual (Altmann, 1974) and four variables (Table 2) were measured only once in the following movement, avoiding problems of non-independent data. For diet observation, only the first observation of the group was used, even if it was not from the focal individual. The significance of differences in frequency of each category within each variable were tested with chi-square one-tailed tests and Yates correction if necessary, assuming as significant values of $P < 0.05$.

Results

Thirty six focal observations for *Cebus* sp. and 39 for *C. jacchus* were obtained. These primates differed significantly in the use of the vertical space of the forest. Individuals of *Cebus* sp. moved mostly in the canopy and less in the understory. Complementarily, individuals of *C. jacchus* were frequently observed in the understory and seldom in the canopy (Fig. 1a). Non-focal individuals were observed once on the ground for both species, but were not considered for statistical analysis.

Locomotory modes were significantly diferent for *Cebus* sp. and *C. jacchus* (Fig. 1b). Capuchins were quadrupedal, with few leaps observed for non-focal *Cebus* sp. and only by young individuals crossing short distances (30–50 cm) between large supports (>20 cm). Capuchin semi-prehensile tail was used in a few cases, once to help in the stabilization of an individual trying to open a hard fruit, and also by young individuals playing. For the common marmosets, leaping and quadrupedalism were the more frequent locomotory modes. Considering focal individuals, only *C. jacchus* moved by leaps, reaching more than two meters in some jumps.

Supports of all diameters were used by both primates. However, the frequency in each diameter class differed significantly (Fig. 1c). The difference is related to body size. *Cebus* sp. used large supports (>10 cm) in 70% of the observations. On the other hand, the smaller *C. jacchus* used thinner branches (<10 cm) in 80% of the movements considered here.

Food items consumed also differed between these primates (Fig. 1d). *Cebus* sp. was mainly frugivorous with around 60% of the observations made on fruits; invertebrates and vertebrates were also consumed. Individuals of *C. jacchus* were mainly gum feeders, secondarily searching for fruits and vertebrates. However, the most consumed fruit for both species was the exotic jackfruit (*A. heterophyllus*) accounting for 65% of the fruits consumed by *C. jacchus* and 80% for *Cebus* sp. In addition, these primates are potential vertebrate predators (Fig. 1d), but consume or pursuit different items. The capuchin monkey pursue Guianan squirrel (*Sciurus aestuans*) and ate chicken, whereas the common

Table 2 Variables measured in the behavior observations of focal individuals in the Tijuca forest, Rio de Janeiro, RJ, Brazil

Variable	Categories
Vertical strata	Ground, understory, canopy
Support diameter (centimeters)	0–5 cm, 5–10 cm, 10–30 cm, >30 cm
Locomotion mode	Quadrupedal, leap, climbing
Food items	Fruits, gum, invertebrates, vertebrates

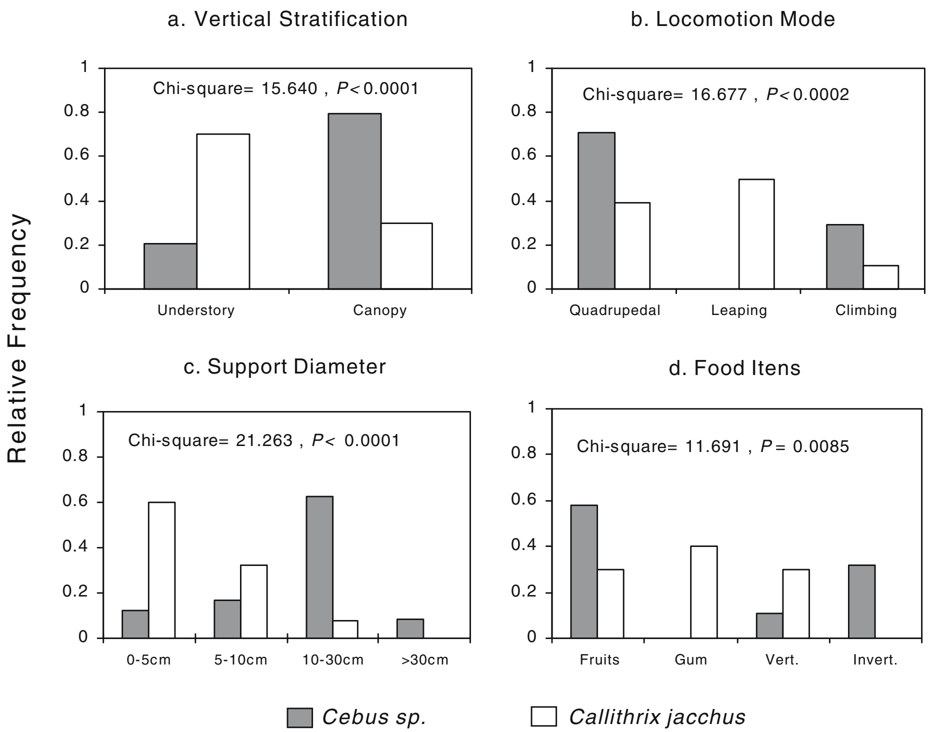

Fig. 1 Relative frequencies of *Cebus* sp. and *Callithrix jacchus* using (a) the vertical strata (n = 34 and n = 37, respectively), (b) locomotory modes (n = 24 and n = 28, respectively), (c) support diameters (n = 24 and n = 25, respectively), and (d) food items (n = 23 and n = 10, respectively) in the Tijuca Forest, Rio de Janeiro, RJ, Brazil. One-tailed chi-square tests values were based on the comparison of absolute frequencies

marmoset pursue passerines in the understory (n = 2), such as the *Myrmotherula cyanocephala*, and also in the canopy (n = 1), such as the *Tangara* sp. and other Passeriformes.

Discussion

The capuchin monkey (*Cebus* sp.) and the common marmoset (*C. jacchus*) partition the vertical space of Tijuca forest. In accordance with our hypothesis, these primates segregate clearly in the use of vertical stratum, locomotion modes, diameters of supports used, and also food items consumed. Common marmosets move by leaps in the understory on narrow branches. On the other hand, the capuchin monkey dwells mostly in the canopy moving quadrupedaly on large supports. Occasionally, both species climb down to the forest ground. The vertical differentiation of sympatric primates in this study is in accordance with the pattern observed for other neotropical primate communities (Fleagle and Mittermeier, 1980; Fleagle et al., 1981, Mittermeier and van Roosmalem, 1981; Charles-Dominique, 1983; Terborgh, 1983; Peres, 1993). In these studies larger species dwell in the canopy and move quadrupedally, such as *Cebus* sp. in the Tijuca forest. On the other hand, smaller species, such as *C. jacchus* in our study, move in the lower strata by leaps between the supports discontinues of the understory of tropical forests (see Fleagle and Mittermeier, 1980 and Richards, 1998). Despite the history of intensive disturbance and potential differences in vegetation composition and structure, today the vegetation structure of the Tijuca forest resembles other tropical forests, offering a similar arena for primates. As expected, based on the literature, these primates use the vertical space of Tijuca forest following the general pattern observed for neotropical primates (see Table 1).

Body sizes and the diameter of branches and trunks used were also related. Both species move in all diameter supports. However, *C. jacchus* (weight ca.0,35 kg; Cunha, unpublished data) used mainly narrow supports (<10 cm), and *Cebus* sp. (ca.3 kg, Auricchio, 1995) used supports with more than 10 cm. A similar pattern was observed by Fleagle et al. (1981) for sympatric *Cebus apella* and *Saimiri sciureus* in the Amazon, where even in mixed troops these primates segregate clearly in the use of vertical space and supports. Cunha and Vieira (2002) observed that larger Atlantic forest opossums used larger supports more frequently than smaller species did. Thus, the positive relationship between body size and diameter of supports used for arboreal species seems to be a general pattern, at least for neotropical mammals.

Space use seems to be related to habitat structure and ecological interactions. The low frequency of movements of *Cebus* sp. in the understory could be partially explained by absence of continuous and larger supports, and also by preferential use of canopy, with more abundant resources and supports (Richards, 1998).

Conversely, the high frequency of *C. jacchus* in the understory seems to be related to a combination of an anti-aerial-predator behaviour, compressing this species to the lower strata, and preference for smaller substrates. Hawks (*Leucopternis lacernulata* and *Rupornis magnirostris*) were frequently observed in the study area, mostly at or near the point of *C. jacchus* encounter (four out of five times). Aerial predation is an important factor influencing marmoset's movement behavior (Barrosa et al., 2004). Hawk calls induce marmosets to adopt antipredator behaviors, such as freezing and searching for a safe microhabitat (Searcy and Gaine, 2003). In the present study, two observations clearly indicated the influence of raptors in the use of space by *C. jacchus*. The first was a group of *C. jacchus* that promptly climbed down to hide under a dense understory foliage after a white-necked-hawk (*L. lacernulata*) attack. The second observation was of two marmosets hiding from a roadside hawk (*R. magnirostris*) perched in the understory. The two marmosets were frozen behind the leaves of a shrub near the forest floor, one meter above the ground and eight meters in front of the roadside hawk. Despite these observations, the large percentage of time spent in the understory by marmosets also could be explained by the preference for smaller supports, more abundant in this forest stratum. With no data on support availability along the vertical space of the forest this issue will need a further study. Overall, the association between understory use and leaping movements by small primates described in other studies (Fleagle and Mittermeier, 1980; Fleagle et al., 1981; Rylands, 1987; Peres, 1993) was corroborated here.

Preliminary observations on diet also agree with previous studies. In this study *Cebus* sp. were mainly frugivorous but also consumed animal items, corroborating the omnivore characteristic of the genus. The diet of *C. jacchus* during the study period was mainly gum, as expected for this species (Rylands et al., 1996; Rylands and de Faria, 1993). It also ate fruits and animal items, specifically birds, but not insects as do other small neotropical primates.

The consumption of passerines by the common marmoset would have an important significance for the management of wildlife in this urban fragment. According to Stevenson and Rylands (1988), marmosets rarely feed on birds and nestlings in its native habitats. But in the Tijuca forest the consumption of birds by this exotic primate seems not to be so rare, as more than 20% of the prelimirary observations on foranging behaviour were bird persecution, and actual adult bird consumption was also registered (J. Barroso, personal communication). Capuchin monkeys could also be a threat to the vertebrate fauna of Tijuca forest. Bird watchers attribute the apparent decline in the passerine abundance in the last decades in the Rio de Janeiro Botanical Garden, contiguous to the study area, to primate predation. Cunha (2005) suggests a possible overabundance of *Cebus* sp. and *C. jacchus* in this fragment, which would increase the predation impact on the bird fauna.

Other evidence of the extreme adaptability of *Cebus* sp. was the consumption of a chicken carcass on the forest ground. The consumption of small vertebrates is not frequent for *Cebus* (Freese and Oppenheimer, 1981), but seems to be not as rare as for *C. jacchus* (see Rose, 1997 and Resende et al., 2004). However carcass eating by *Cebus* spp. was not in the literature. In addition, the high frequency of the exotic jackfruit (*A. heterophyllus*), in *Cebus* sp. diet evidenciated the extreme adaptability of this genus.

Our preliminary observations on the diet of the capuchin monkey and common marmoset in the Tijuca forest partially agrees with observations of *Cebus* and *Callithrix* in other neotropical forests (Fleagle and Mittermeier, 1980; Rylands and de Faria, 1993), but the intense faunivory of *Callithrix* pointed here was never reported. This unique aspect of the diet could be related to the particular changes in composition and ecological interactions compared to the past, original community, and to the high abundance of primate populations in the Tijuca forest. These complex interactions between exotic and native animal and plant species should be studied in detail and considered in any management plan for this and other similar urban forest fragments.

In conclusion, the pattern of use of vertical space of the forest associated with body size was corroborated in the modified neotropical Tijuca forest, indicating that this pattern must be indeed general. Space use studies relating to species body sizes, support use, and locomotion modes are fundamental to understand species interactions within a spatially complex community. Trophic interaction studies between exotic and native species in the human built Tijuca forest should be carried out to investigate the possible impact of these primates on prey populations, especially on the bird fauna.

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