

Abundance, habitat use and diet of *Callicebus nigrifrons* Spix (Primates, Pitheciidae) in Cantareira State Park, São Paulo, Brazil

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ABSTRACT. Between april 2005 and May 2006, according to the pressuposts of line transect methodology, census were carried to estimate abundance and population density of *Callicebus nigrifrons* Spix, 1823 (Pitheciidae) in Cantareira State Park, State of São Paulo, southeastern Brazil (23°23'42"S, 46°35'27"W). After 275.80 Km of census sampling effort, the titis were the second most abundant primate species, presenting an abundance index of 1.4 groups for each 10 km walked and a density estimate of 12.21 ind./km² (ranging between 8.45 a 17.63 ind./km²). The collection of ancillary data during the census allowed the determination of diet and habitat use by the titis groups, and results show a relative adaptability to disturbed habitats.

KEYWORDS. Atlantic forest; black-fronted titi monkey; conservation; density.

RESUMO. Abundância, uso do habitat e dieta de *Callicebus nigrifrons* É. Geoffroy (Primates, Pitheciidae) no Parque Estadual da Cantareira, São Paulo, Brasil. Entre abril de 2005 e maio de 2006, através de censos seguindo os pressupostos da metodologia de transeção linear, foram estimadas a densidade populacional e abundância de *Callicebus nigrifrons* Spix, 1823 (Pitheciidae) no Parque Estadual da Cantareira, Estado de São Paulo, Sudeste do Brasil (23°23'42"S, 46°35'27"W). Com um esforço amostral de 275,8 km de censos, os sauás foram a segunda espécie de primata mais abundante, apresentando um índice de abundância de 1,4 grupos para cada 10 km percorridos e uma estimativa de densidade de 12,21 ind./km² (variando de 8,45 a 17,63 ind./km²). A coleta de dados auxiliares durante os censos possibilitou a verificação da dieta e uso do hábitat pelos grupos de *Callicebus*, e os resultados evidenciaram uma relativa adaptabilidade à ambientes perturbados.

PALAVRAS-CHAVE. Conservação; densidade; sauás; Mata atlântica.

Titi monkeys, genus *Callicebus* (Thomas, 1903), are a diverse group of neotropical primates found in the Amazon and Orinoco basins, the Brazilian Atlantic Forest, and the Chaco forests of Paraguay and Bolivia (VAN ROOSMALEN *et al.* 2002, NORCONK 2007). *Callicebus nigrifrons* (Spix, 1823) (Pitheciidae) occurs in the Brazilian states of Rio de Janeiro, São Paulo, and Minas Gerais. It occurs on both banks of the upper São Francisco river, ranging eastwards as far as the distribution of *Callicebus personatus* (É. Geoffroy, 1812) (Pitheciidae) (VAN ROOSMALEN *et al.* 2002).

This range coincides with the most densely populated part of Brazil, which has a long history of colonization and deforestation (DEAN 1995). Present-day populations of *C. nigrifrons* are restricted to forest patches within a highly fragmented landscape, where local extinction is a constant threat (VAN ROOSMALEN *et al.* 2002, SÃO BERNARDO & GALETTI 2004). Given

this situation, *C. nigrifrons* has been assigned to the *near threatened* IUCN category (RYLANDS *et al.* 2003).

While there is a growing body on knowledge on the ecology and conservation of most Atlantic Forest primate genera, little is known of most *Callicebus* species, which include the recently discovered *Callicebus coimbrai* (Kobayashi & Langguth, 1999) (Pitheciidae) (KOBAYASHI & LANGGUTH 1999). Available studies have focused on *Callicebus personatus* (PRICE & PIEDADE 2001a, b) and *Callicebus melanochir* (Wied-Neuwied, 1820) (Pitheciidae) (MÜLLER 1996), although some data are available on populations of *C. nigrifrons* (OLIVEIRA *et al.* 2003, SÃO BERNARDO & GALETTI 2004). This study presents the results of a survey of the *C. nigrifrons* population of the Cantareira State Park in São Paulo, which includes detailed information on habitat use and diet. The park is a relatively large remnant of the original Atlantic Forest, located entirely within São Paulo, the largest city in South America.

MATERIAL AND METHODS

Study area

Situated in the Serra da Cantareira (23°23'42"S, 46°35'27"W), between the municipalities of São Paulo, Caieiras, Mairiporã and Guarulhos, the Cantareira State Park (CSP) is a 7,917 ha protected area administrated by the São Paulo state Forestry Institute. Totally encompassed by the urban area of São Paulo, Cantareira is not only the World's largest urban forest, but is also one of the most important remnants of the state's Atlantic Forest, and thus has a considerable potential for the conservation of local biodiversity. The park is divided into four administrative nuclei (Fig. 1), three of which (Pedra Grande, Águas Claras, and Engordador) were surveyed during the present study.

Surveys

To estimate relative abundance, and population density and size, primates were surveyed in Cantareira State Park using standard line transect methodology (BURNHAM *et al.* 1980, BUCKLAND *et al.* 1993), between April 2005 and May 2006. Transects were conducted along 12 trails, four trails located in each one of the nuclei. Transects length varied from 0.8 km to 6 Km, with a total length of 19.05 km. During surveys, special attention was paid to the collection of complementary data on the diet and use of habitat (habitat type and vertical spacing) by *C. nigrifrons*.

Habitat was classified according to the schemes provided by previous studies at the site (BAITELLO *et al.* 1993), modified according to the aims of the present study, with an emphasis on species composition and successional stage (Tab. I). The dominant habitat observed along each 50-m interval of the transects was assigned to one of these categories, providing an estimate of the relative cover of each forest type. Habitat preferences were assessed by comparing observed visitation rates (sightings) with those expected according to the relative availability of

different habitat types (corrected by sampling effort), and tested by chi-square (χ^2), following the studies of PERES (1993), BOBADILLA & FERRARI (2000), and PORT-CARVALHO & FERRARI (2004).

Analysis of the use of vertical space was based on 5-m height classes, following PERES (1993) and BOBADILLA & FERRARI (2000). Survey data on the diet of *C. nigrifrons* were complemented by *ad libitum* observations throughout the study period. Specimens were obtained from plants exploited by the titis for identification by a specialist.

RESULTS

Abundance

During the 13 month period, we walked a 98.4 km on the Águas Claras Nucleus, 98.6 km on the Pedra Grande Nucleus and 78.8 km on the Engordador Nucleus, with a total of 275.8 km sample effort, divided in 237 census sessions. The number of sessions in each trail varied from 15 to 25, so that the total sample effort in each trail was approximately the same for that nucleus. A total of 203 primate sightings were obtained, from which 39 belonged to groups of *Callicebus nigrifrons*, approximately 19% of all sightings. On the other 164 sightings, we encountered the following primate species (in order of encounters): *Alouatta clamitans* (Cabrera, 1940) (Atelidae), *Cebus nigritus* (Goldfuss, 1809) (Cebidae) and *Callithrix aurita* (É. Geoffroy, 1812) (Callitrichidae). *Callicebus nigrifrons* was the second most abundant species, presenting an abundance index of 1.4 groups for each 10 km walked. Table II presents this global abundance index as well as the same index for each nucleus.

The average size of troops found in this study was 2.27 individuals per sighting (range = one to five individuals), a slightly smaller troop size than usually observed for this genus (PINTO *et al.* 1993, NORCONK 2007). Sample size was not large enough for reliable calculations of the Effective Strip Width

Table I. Habitat categories used in the present study.

Forest category	Description
Primary	Continuous canopy with tall trees (> 20 m in height) and emergents, low density of lianas, and three well-defined strata
Late secondary	Discontinuous canopy (15-20 m tall) with few emergents, medium density of lianas, and two strata
Early secondary	Discontinuous canopy (< 15 m tall), very high density of lianas, and single stratum with dense vegetation
Exotic	Dominated by <i>Eucalyptus</i> spp., <i>Pinus</i> spp. and <i>Cryptomeria</i> spp. plantations, with sparse understorey of native species
Araucaria	Dominated by <i>Araucaria angustifolia</i> , with dense understorey of native species

Table II. Survey sightings (per 10 km walked) of the primate species observed in the Cantareira State Park.

Nucleus	<i>Callicebus nigrifrons</i>	<i>Alouatta clamitans</i>	<i>Callithrix aurita</i>	<i>Cebus nigritus</i>	All primates
Águas Claras	17 (1.73)	38 (3.86)	6 (0.61)	11 (1.12)	72 (7.32)
Pedra Grande	10 (1.01)	80 (8.11)	3 (0.30)	3 (0.30)	96 (9.74)
Engordador	12 (1.52)	17 (2.16)	5 (0.60)	1 (0.13)	35 (4.44)
All sites	39 (1.41)	135 (4.90)	14 (0.51)	15 (0.54)	203 (7.36)

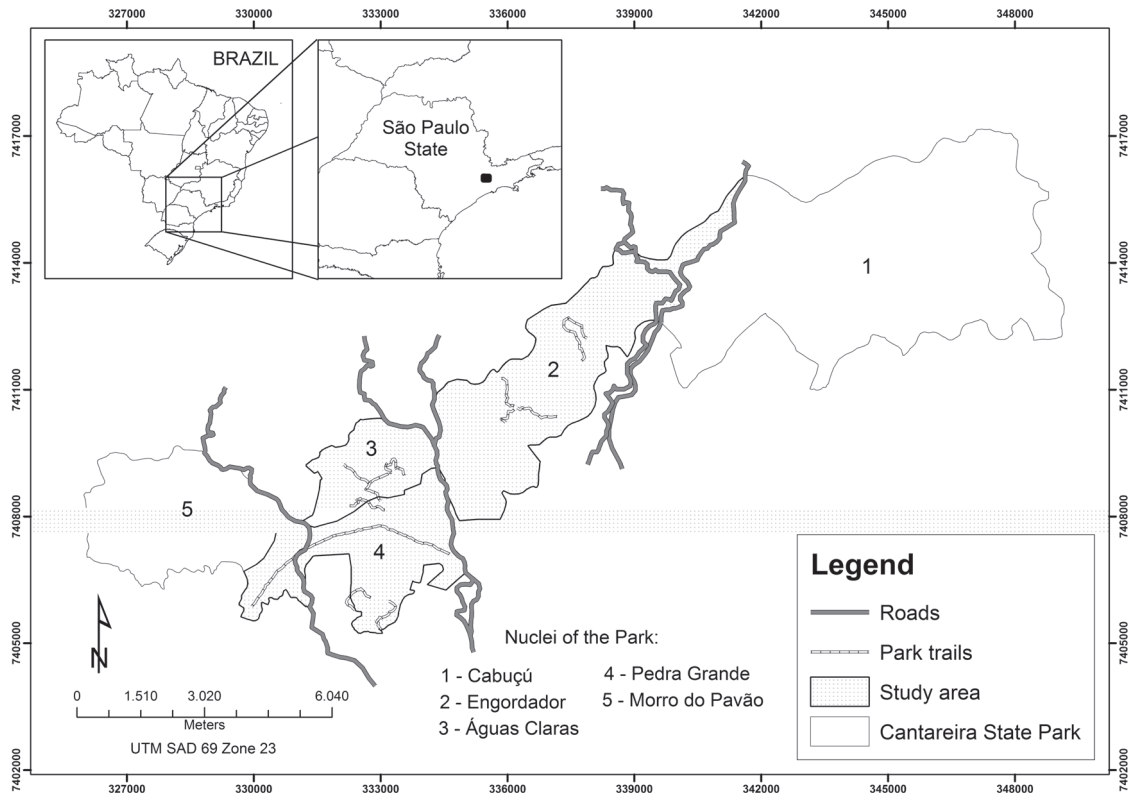


Figure 1. Localization of the Cantareira State Park in the Brazilian state of São Paulo and trails used in the study.

(ESW) and the density parameter in each nucleus separately. Thus the sighting data were pooled and analyzed for the area as a whole. The perpendicular sighting distances were tested for normality (Kolmogorov-Smirnov: 0.1321, $p > 0.05$) and later analyzed with the parametric ANOVA one-way test (F : 0.9085; $p = 0.5852$). It was possible therefore to generate overall density estimation based on the pooled data for the area as a whole (CHIARELLO & MELO 2001), since there was no significant difference between the three nuclei. The uniform key function with the cosine expansion was chosen, which provided the best fit ($AIC = 184.10$; $GOF: P = 0.84071$), although other models provided similar estimates of density, which may be interpreted as data consistency (Tab. III).

Habitat use

To obtain a reliable statistical analysis, the frequency of each available habitat, as well as the titi's sightings obtained on each nucleus were grouped and analyzed, statistically, in a global way. Since the trails used during the census were of different length and were walked distinctively, the total habitat availability was calculated in function of the effort employed on each trail (Tab. IV).

In the habitat preference analyses, some patterns could be verified, although no significant preference was confirmed for any special habitat ($\chi^2 = 4.546$, $df = 4$, $p > 0.05$). The Exotic Forest and the Initial Secondary Forest habitats didn't obtain any titi records and the Late Secondary Forest habitat obtained an

Table III. Estimated parameters using program Distance Sampling 4.1 (BUCKLAND *et al.* 1993).

Density		ESW		Abundance in sampled area (individuals)	Population size (individuals) ^a
(km ²)	CV (%)	(m)	CV (%)		
12,21	18.84	14.78	7.04	475	967
(8.45-17,63)		(12.81-17.05)		(329-685)	(670-1395)

^a Estimated values obtained through extrapolation for the whole CSP area (7916.52 ha) from the abundance data in the sampled area (3887 ha).

Table IV. Proportion of habitats sampled (%), sample effort (km) and nucleus representativity (%).

Localities	Habitats sampled (%)					Effort (km)	Representativity (%)
	Exotic Forest	Araucária Forest	Initial Secondary Forest	Late Secondary Forest	Primary Forest		
Águas Claras	6.28	61.94	0.43	25.41	5.95	98.4	35.68
Pedra Grande	0.00	0.00	6.34	77.99	15.67	98.6	35.75
Engordador	0.00	0.00	1.90	54.70	43.40	78.8	28.57
Total	2.24	22.10	2.96	52.57	20.12	275.8	100.00

inferior number than expected, while the *Araucaria* Forest and the "Primary" Forest obtained more records than it was expected.

The height data on which the titis were sighted were also pooled and analyzed as a whole, in order to make the analyses more robust. Also, with the same objective, and only for this analyses, the data obtained in opportunistic encounters (*ad libitum*) during the study were also considered, raising the number of records from 39 to 60 (Fig. 2).

Overall, there was a predominance of sightings in the forest canopy, the "10 to 14 m" class or lower canopy, the "15 to 19 m" class or intermediate canopy, and from "20 to 24 m" class or superior canopy, that together were responsible for 77% of the *Callicebus* sightings. We also noticed that the titis came down to the sub-canopy layer frequently (20% of the records), "05 to 09 m" class, and also occasionally used the emergent trees over the forest canopy, "25 to 30 m" class, with 3% of the records.

Diet

We observed the titis consume 15 species belonging to nine families. Fruit pulp was the principal item consumed for

most the species (Tab. V). We also observed some individuals ingesting arthropods on three occasions, indicating this food item may complete the titis diet.

DISCUSSION

The density and relative abundance estimates of the present study conform to similar studies carried out with species of the *Callicebus* genus in Brazilian Atlantic Forest (Tab. VI).

Abundance indexes expressed little difference between nuclei, except for the smaller Pedra Grande, where the total primate abundance was greater. This difference was probably related to the very high abundance of howler monkeys *Alouatta clamitans*, in contrast with the reduction of abundance indexes for *Callithrix aurita*, *Cebus nigritus* and the titis. The Pedra Grande nucleus had the greatest secondary forest availability, and the tourist pressure is often more intense, compared with the other nuclei. Despite this difference, the titis were the second most abundant primate species in all nuclei in CSP, and presented an overall density estimate larger than most of the studies presented

Table V. Plant species consumed by *Callicebus nigrifrons* during the study.

Family	Species	Habitat	Item consumed
Bignoniaceae	<i>Pithecoctenium</i> sp.	Tree	Immature seed *
Euphorbiaceae	<i>Alchornea triplinervia</i>	Tree	Fruit
	<i>Tetrorchidium rubrivenium</i>	Tree	Fruit
	<i>Croton floribundus</i>	Tree	Seed
Fabaceae	<i>Inga sessilis</i>	Tree	Fruit and flower
	<i>Inga marginata</i>	Tree	Fruit
Lauraceae	<i>Persea americana</i>	Tree	Fruit
Melastomataceae	<i>Miconia cinnamomifolia</i>	Tree	Leaf
Myrtaceae	<i>Eugenia involucreta</i>	Tree	Fruit
	<i>Myrciaria</i> sp.	Tree	Fruit
	<i>Psidium guajava</i>	Tree	Fruit
Rosaceae	<i>Prunus sellowiana</i>	Tree	Leaf
Sapindaceae	<i>Cupania oblongifolia</i>	Tree	Fruit
	<i>Paullinia</i> sp.	Liana	Fruit
Solanaceae	<i>Solanum mauritianum</i>	Tree	Fruit, flower, immature leaf and branch

* The collected material contained a Coleopteran larva, making it impossible to define precisely the consumed item.

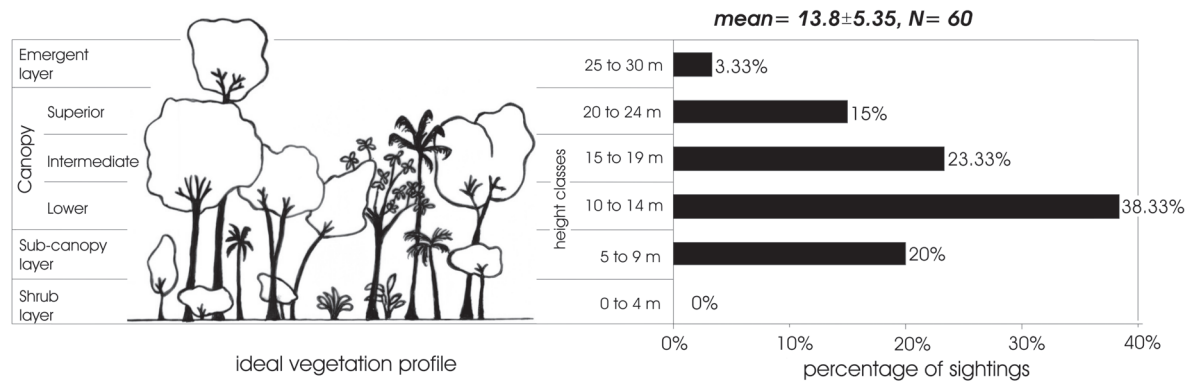


Figure 2. Ideal vegetation profile in Cantareira State Park with the vertical layer usage frequency by *Callicebus nigrifrons*.

in table VI, although they had a slightly lower troop size (2.27 individuals) than observed in most studies (PINTO *et al.* 1993, NORCONK 2007). Some of this variation can be explained by sample differences and systematic errors that may arise with violations of the basic assumptions of line transect census theory, but can we hypothesize this as adaptations to perturbation? CHIARELLO (2003), comparing primate census data for São Paulo and Espírito Santo, could not find any correlation between fragment size and density/abundance parameters for most primates, except for *Brachyteles hypoxanthus* (Kuhl, 1820) (Atelidae), indicating a certain ecological flexibility of the Brazilian Atlantic Forest primates, which demonstrates a rather extensive adaptive capacity to perturbation caused by fragmentation.

Some studies relate the occurrence and persistence of tities in secondary forests fragments from several sizes of Brazilian Atlantic forests (STALLINGS & ROBINSON 1991, PINTO *et al.* 1993, HEIDUCK

2002, SÃO BERNARDO & GALETTI 2004, MARTINS 2005). However, HEIDUCK (2002) showed that despite utilizing both secondary and primary forests, the home ranges of troops always contained a major portion of primary forest, and that habitat use was much more related to food resource availability than the proportional availability of each habitat. In the CSP, *C. nigrifrons* did not show any statistically significant preference for any kind of habitat, occurring in all habitats, except for initial secondary and exotic forests.

With regard to the vertical stratification observed, the tities exhibited a considerable preference for the lower canopy (10 to 14 meters class). This corroborates with the overall pattern relating the height of strata used to body size and locomotion mode for primates (CUNHA *et al.* 2006). *Callicebus* is a medium sized primate occurring in all strata, but showing a preference for intermediate strata (RYLANDS *et al.* 1996, CUNHA *et al.* 2006).

Table VI. Density and relative abundance estimates of *Callicebus* on different localities of Brazilian Atlantic Forest.

Species	Study area	Fragment area (km ²)	Density (ind/km ²)	Sighting rate (groups/10 km)	Reference
<i>C. nigrifrons</i>	Cantareira State Park, São Paulo	79.2	11.21	1.43	Present study
	Barreiro Rico, São Paulo	32.6	7.0-10.0	–	PINTO <i>et al.</i> (1993)
	São José, São Paulo	2.3	3.5	0.56	SÃO BERNARDO & GALETTI (2004)
	Serra do Brigadeiro, Minas Gerais	132.1	10.3	–	COSENZA & MELO (1998)
	Viçosa, Minas Gerais	0.8	14.86	1.83	OLIVEIRA <i>et al.</i> (2003)
<i>C. personatus</i>	Augusto Ruschi Biological Reserve, Espírito Santo	40.0	5.4	0.54	PINTO <i>et al.</i> (1993)
	Linhares Forest Reserve, Espírito Santo	218.0	7.7	1.23	CHIARELLO & MELO (2001)
	Linhares Forest Reserve, Espírito Santo	218.0	12.3-12.6	–	PRICE <i>et al.</i> (2002)
	M7/317, Espírito Santo	2.6	1.4	0.22	CHIARELLO & MELO (2001)
	Putiri, Espírito Santo	2.1	6.4	1.02	CHIARELLO & MELO (2001)
Sooretama Biological Reserve, Espírito Santo	242.5	9.5	1.66	CHIARELLO & MELO (2001)	
<i>C. melanochir</i>	CEPLAC, Bahia	10.0	17.0	–	MÜLLER (1996)
	Teimoso Farm, Bahia	2.4	17.7	–	PINTO <i>et al.</i> (1993)
	Una, Bahia	1.0	3.4-16.7	–	PINTO <i>et al.</i> (1993)

Observations of plant species consumed by *C. nigrifrons* are consistent with the literature, especially with the basically frugivorous pattern of diet (NORCONK 2007). However, the actual components of this diet are subject to debate, since various species of the *Callicebus personatus* group, especially *C. nigrifrons* show much variation in specific diet. KINZEY & BECKER (1983) studying *C. personatus*, MÜLLER (1996) studying *C. melanochir* and PRICE & PIEDADE (2001a) also studying the *C. personatus* species found the complement of diet to consist entirely of leaves, while HEIDUCK (1997) working with *C. melanochir* relate a diet complemented with insects in addition to leaves, which matches the observation of this feeding behavior in the CSP. Other interesting aspect was the major presence of typically secondary species in the titis diet, especially the tapiá (*Alchornea triplinervia*) and the ingás (*Inga sessilis* e *I. marginata*), which were frequently recorded during their fruiting season. Could these records again be evidence of the high adaptability of this species to secondary forest areas? This feeding flexibility and consequent adaptability to variations in resource availability, in terms of component diversity and feeding behavior, could explain not only these regional differences in diet but also the apparent persistence success in altered and fragmented forest areas. More specifically designed studies of diet aiming to solve these ecological questions for titis are of fundamental importance not only to the better understanding of this species, but also to its adequate management in protected areas.

The population size estimated for CSP by this study was approximately 967 individuals (Tab. III). If we choose to consider the average group size of 2.2 individuals obtained by linear transects to be lower than the literature data (NORCONK 2007), this estimate may be thought as an underestimate of the true situation. Even so, values somewhat higher than 967 individuals are still smaller than the minimal viable population size of 7,000 individuals, as suggested by REED *et al.* (2003) to avoid long-term genetics, demographics and stochastic effects. On the other hand, BRITO & GRELE (2006) working with stochastic population models for *Brachyteles hypoxanthus*, an Atlantic forest endemic primate species, estimated that a minimum viable population of 700 individuals could guarantee the long-term survival of this taxon. From this standpoint, if we assume that the estimated value for the the viability of the northern-muriqui population, a larger body sized species than *C. nigrifrons*, are also enough for smaller body size species, our estimates of titi monkey populations in CSP overcome the necessary for their long term survival.

A major concern, however, is that the situation in CSP is aggravated by the fact that the Park is strip-cut by roads that probably reduce mixing between, if not isolate (in the Fernão Dias Highway case, see figure 1), sub-populations of the whole *C. nigrifrons* park population. Roads alter animal behavior by causing changes in home ranges, movement, reproductive success, escape response, and physiological state, and studies show that the presence of roads is highly correlated with changes in species composition and population sizes (TROMBULAK & FRISSELL

2000), pointing this as a possible immediate threat to their long-term conservation.

This and other problems for the conservation not only of the titis, but of all other primate species that occur in the CSP are closely related to its proximity to the biggest urban center of Latin America. To guarantee the long term conservation of these primates in the metropolitan region of São Paulo city, legal and political measures and concrete actions must be orchestrated in conformity with a pre-defined strategy that supports the conservation of this and other taxa (CHIARELLO 2003).

This study showed that the *Callicebus nigrifrons* population in CSP, a medium sized primate species with intermediate abundance in the primate community, is comparatively well established in this 7,917 ha forest reserve. They present almost no habitat limitation on occurrence, responding well to secondary forest, a predominant habitat in the CSP. The population size we estimated could guarantee its short-term survival, but in the long-term, roads and the urbanization of the park's surroundings may represent a considerable threat for its conservation.

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