Bats (Mammalia, Chiroptera) of an urban park in the metropolitan area of Rio de Janeiro, southeastern Brazil

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ABSTRACT. Some bat species are able to adapt to urban areas, where they find food and roosts. Despite the high number of parks in Brazilian cities, they did not yet raise the interest of most zoologists, except for some surveys of birds and butterflies. The objectives of the present study were: (i) to inventory the bat species of Quinta da Boa Vista (QBV), a large (25 ha) urban park centrally located in densely populated Rio de Janeiro, which is Brazil's second largest metropolis; (ii) to compare the species richness observed in roosts with the richness recorded through mist netting in flight routes and near fruiting fig trees; and (iii) to analyze recaptures of bats marked in this park and recaptured in other sites and vice-versa. Sampling totaled 104 sampling nights resulting in 3,256 captures (including 133 recaptures) between April 1989 and December 2004. We also sampled roosts and received some specimens from park visitors and city workers. We documented 21 bat species, predominantly large frugivores. The number of expected species for this park was 24.0 ± 4.6, and the total sampled represented 87.5% of the expected. The recapture of bats marked in surrounding forest fragments and in QBV shows the importance of urban parks for the maintenance of bat diversity. Inspection of roosts produced two species that had not been captured with other methods. Sampling near fruiting fig trees did not differ in terms of richness from sampling carried out far from these trees or during their non-fruiting periods.

KEYWORDS. Diversity, long-term, samples, urban area.

RESUMO. Morcegos (Chiroptera) de um parque urbano na região metropolitana do Rio de Janeiro, sudeste do Brasil. Algumas espécies de morcegos são capazes de se adaptar às áreas urbanas, onde encontram alimento e abrigo. Apesar do elevado número de parques nas cidades brasileiras estas ainda não despertaram o interesse dos zoólogos, exceção feita a inventários de aves e borboletas. Os objetivos do presente estudo foram: (i) inventariar as espécies de morcegos da Quinta da Boa Vista (QBV), um grande (25 ha) parque urbano centralmente localizado na povoada cidade do Rio de Janeiro, a segunda maior metrópole do Brasil; (ii) comparar a riqueza de espécies observadas em refúgios com a riqueza registrada através de redes de neblina abertas em rotas de voo e perto de figueiras em frutificação; e (iii) analisar as recapturas de morcegos marcados neste parque e recapturados em outras localidades, e vice-versa. A amostragem totalizou 104 noites, resultando em 3.256 capturas (incluindo 133 recapturas) entre abril de 1989 e dezembro de 2004. Nós também amostramos abrigos e recebemos alguns exemplares de visitantes do parque e dos cidadãos. No total, nós documentamos 21 espécies de morcegos, com a predominância de grandes frugívoros. O número de espécies esperadas para este parque foi de 24,0 ± 4,6, e o total amostrado representado foi de 87,5% do esperado. As recapturas de morcegos marcados em torno dos fragmentos florestais e em QBV mostram a importância de parques urbanos para a manutenção da diversidade de morcegos. As buscas e amostragens em abrigos resultaram em duas espécies que não tinham sido capturadas com outros métodos. As amostragens perto de figueiras em frutificação não diferiram em termos de riqueza em relação às amostragens realizadas longe destas árvores, ou durante os seus períodos de não frutificação.

PALAVRAS-CHAVE. Diversidade, longo prazo, amostragens, área urbana.

The Brazilian bat fauna of urban areas has received little attention, though it presents an opportunity to investigate which species can adapt to the increasing human alterations in the environment (Lima, 2008). Public awareness of urban forestry (Santos *et al*., 2009) and maintenance of green areas, such as urban parks with trees, is recent in Brazil (e.g., Gomes & Soares, 2003; Santos *et al*., 2009). In these areas live both species that survived human alterations and those that benefited from them (e.g., Bredt *et al*., 1996; Kurta & Teramino, 1992; Ávila-Flores & Fenton, 2005).

Some bat species are able to adapt to urban areas, where they find food and roosts (e.g., Côrtes *et al*., 1994; Bredt *et al*., 1996; Sazima *et al*., 1994; Fenton, 1997; Esbérard *et al*., 1999; Zórtea & Aguiar, 2001; Lima, 2008; Gazarini & Pedro, 2013). In these areas they can reach high density, as a result of the absence of predators and potential competitors, and of the abundance of resources. Urban forestry, in spite of giving preference to resistant, fast-growing plant species regardless of origin (Milano & Dalcin, 2000; Santos *et al*., 2009), produces areas that are frequently used by urban bats.

Some insectivorous bats can easily obtain their prey in urban areas, which can be attracted by street lighting (Bredt & Uieda, 1996; Silva *et al*., 1996). However, the diversity of insectivorous bats in urban areas is lower than in neighboring natural areas (Kurta & Teramino, 1992). Even hematophagous bat species can be found in urban areas, where they attack pets and humans (Uieda, 1995; Esbérard, 1999; Carneiro *et al*., 2005; Ferraz *et al*., 2007). Within urban environments, bat density and diversity can vary due to several factors, such as roost availability, presence and distance among trees, and water availability (Côrtes *et al*., 1994; Bredt *et al*., 1996; Fenton, 1997; Sazima *et* *al.*, 1994; Esbérard *et al.*, 1999; Zórtea & Aguiar, 2001; Lima, 2008; Oprea *et al.*, 2009).

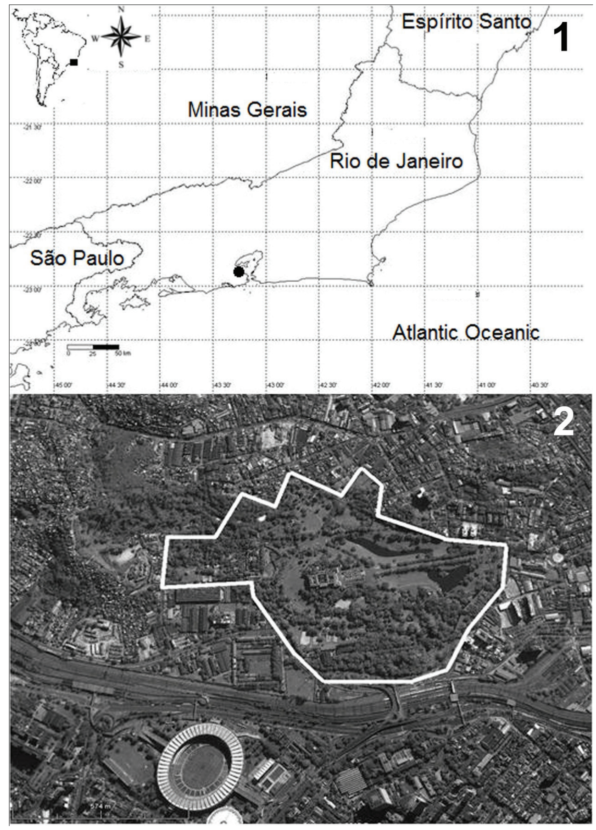
Urban parks differ from forest fragments, because they have lower tree density, lower plant diversity, and higher predominance of exotic tree species. Because these parks are urban areas and not true forest remnants, their bat fauna is expected to comprise only species that are highly adapted to urban environments, and lack species that depend on a minimum forest area to survive (Ávilla-Flores & Fenton, 2005; Oprea *et al.*, 2009). Despite the high number of parks in Brazilian cities, they did not yet raise the interest of most zoologists, except for some surveys of birds and butterflies (Matarazzo-Neuberger, 1995; Villanueva & Silva, 1996; Fortunato & Ruszczyk, 1997; Ruszczyk *et al.*, 1987).

Lima (2008) compared the bat fauna of several Brazilian cities, using lists available in papers and conference abstracts. However, several localities included in this analysis are forest fragments that were preserved and are currently used by the public, as in Rio de Janeiro, where eight parks have been sampled, which are actually forest remnants and not urban parks (see Esbérard, 2003a). Lists of bat species of Brazilian metropolitan areas are available for Brasília (Bredt & Uieda, 1996), Belo Horizonte (Knegt *et al.*, 2005), Juiz de Fora (Barros *et al.*, 2006), São Paulo (Silva *et al.*, 1996; Gazarini & Pedro, 2013), and Londrina (Reis *et al.*, 2002). However, these lists were based mainly on donated animals (Silva *et al.*, 1996) or on few sampling nights in most localities (Bredt & Uieda, 1996; Reis *et al.*, 2002; Knegt *et al.*, 2005; Barros *et al.*, 2006). There are no studies based on a large sample taken at a single sampling site in an urban area in Brazil. For the city of Rio de Janeiro there is no published bat inventory, though it is known that at least 27 species recorded for the state use roof lining and other human structures as day or night roosts (Esbérard *et al.*, 1999).

A bat inventory made in an urban park within a Brazilian metropolis would be something new and it could help advance the knowledge of species that are well adapted to urbanization. Therefore, the objective of the present study was to inventory the bat species of Quinta da Boa Vista, a large urban park with large amount of trees in the second largest Brazilian metropolis. We aimed also at comparing the species richness observed in roosts with the richness recorded through mist netting in flight routes and near fruiting fig trees, and at analyzing recaptures of bats marked in this park and recaptured in other sites and vice-versa.

MATERIAL AND METHODS

The metropolis of Rio de Janeiro (6.32 million inhabitants) is occupied mainly by residences, with small-scale agriculture and cattle raising located mainly in the periphery. The city occupies an area of 1,200 km², with an average density of 5,265 inhabitants/km² (IBGE, 2010). Forest remnants, which correspond to 18% of the city's area (Fundação SOS Mata Atlântica, 2002), are restricted to elevations varying from 100 m to over 400 m a.s.l., with a predominance of second-growth Atlantic Forest (Bergallo *et al.*, 2009). The predominant climate is humid tropical, with minimum temperatures of 17 ºC and maximum of 36 ºC, average relative humidity around 80%, average annual rainfall of 1,107 mm, and 124 rainy days per year (IPLANRIO, 1992).



Figs 1, 2: 1, South America and the state of Rio de Janeiro, with Quinta da Boa Vista marked in black; 2, Ortophoto of 2004, with Quinta da Boa Vista (sampled from 1989 to 2004) marked in white, (provided by Prefeitura da Cidade do Rio de Janeiro, number 587).

Quinta da Boa Vista (hereafter QBV) is an urban park of 25 ha, located in a central area of Rio de Janeiro (Figs 1,2), in an industrial area with population density of 839.0 inhabitants/km², where the Museu Nacional and the Zoological Gardens are located. It is destined to public recreation and receives a total of 100,000 visitors every weekend (IPLANRIO, 1992).

QBV has low tree density (0.04 trees/km²), had its landscape architecture designed by Auguste Glaziou in 1878, and is protected by the Institute of National Heritage (Instituto do Patrimônio Histórico Nacional, PCRJ, 1998). Its predominant plant species are fruiting trees, such as *Lecythis pisonis* (Lecythidaceae), *Licania tomentosa* (Chrysobalanaceae), *Mangifera indica* (Anacardiaceae), *Spondias dulci* (Anacardiaceae), *Terminalia catappa* (Combretaceae), *Ficus* spp. (Moraceae) (several native species, but mainly the exotic species *Ficus religiosa*, *Ficus microcarpus*, *Ficus tomentella*, and *Ficus clusiaefolia*), *Chrysophyllum caimito* (Sapotaceae), *Achras zapota*

(Sapotaceae), *Artocarpus integrifolia* (Moraceae), and *Syagarus romanzoffiana* (Palmae) (PCRJ, 1998). Most trees are older than 115 years. The area has also artificial lakes and an artificial cave. It is mainly characterized by vast lawns and an alley with cream nuts (*Lecythis pisonis*), locally known as "sapucaias", which delimit the entrance of the Museu Nacional. Part of the area was used for the City Garden, currently part of the Museu Nacional (PCRJ, 1998).

Sampling was carried out between April 1989 and December 2004, without a temporal criterion and at all moon phases (Esbérard, 2007). We carried out 104 sampling nights (0.60 sampling nights/month), summing up 793 h (average of 7.6 h per sampling night) and 4,050 m of mist nets (10,125 m^2.h). At each night, from five to 13 nets were opened (7 x 2.5 m, mesh 20 mm, average of 97.5 m^2 per night) from before sunset to 24:00 (from 1989 to 1993) or until sunrise (from 1994 to 2004). Nets were set up in eight different sites of the park: four in the zoo and four in other areas. In the four sites of the zoo, nets were opened in the visitation alleys or inside animal enclosures without bars and close to animals that were reported to have been attacked by hematophagous bats (Esbérard *et al*., 1994). In the other sites, nets were set up around fruiting trees, mainly *sapucaias* and fig trees (Nunes *et al*., 2007; Pereira & Esbérard, 2009). Until the 50^{th} night, we sampled only sites in the zoo; afterwards, sampling in the zoo was interpolated with 20 nights of sampling near fruiting trees.

In addition to mist netting, roosts were sampled (38 times) and in eight occasions we received bats found by park visitors or city employees, who worked in the maintenance and pruning of the trees or in the cleaning of the park. Roosts were identified based on information given by gardeners, street-sweepers, and other park employees, or by finding feces or fruit remains near the sampling sites. We investigated human constructions (bridges, manholes, disused rooms, cellars, and roofs – see Esbérard *et al*., 1999), hollow trees, rock crevices, palm canopies (Simmons & Voss, 1998), and the artificial cave. After locating each roost, bats were captured preferably during the day by hand, with long tweezers covered with foam on the extremities, entomological hand nets or traps (Esbérard, 2003b). When capturing was not possible with these methods, we used fishing nets (mesh 1½") or mist nets set up at the access to the roost, in order to capture bats while leaving the roost. These working hours and number of nets were not considered in the total sampling effort.

The captured animals were marked with holes in the dactylopatagium (punch-marking - Bonaccorso & Smythe, 1972) until 1992, with a tattoo plier until 1995, or with plastic necklaces with colored cylinders (Esbérard & Daemon, 1999) from 1996 on. Recaptures were not included in estimates of diversity, expected number of species, and capture efficiency. Vouchers were obtained by killing one or more specimens of each species (Vizotto & Taddei, 1973), and deposited in the reference collection of the Laboratory of Bat Diversity (Laboratório de Diversiade de Morcegos – LADIM) (Process 1755/89 – IBAMA/ SUPES/RJ), located at Universidade Federal Rural do Rio de Janeiro. The captured bats were identified in the field using keys (mainly Vizotto & Taddei, 1973; Marques-Aguiar, 1994; Emmons & Feer, 1997; Gregorin & Taddei, 2002). The nomenclature followed Simmons (2005), but *Artibeus planirostris* (Spix, 1823) was considered as a valid species in the study region.

The expected number of species and the completeness of richness estimates were calculated using the Chao-BC estimator in the program Spade (Chao & Shen, 2009). Species accumulation curves were built using as sampling units nights, roosts and individuals. Curves based on captures were built through randomization (1,000 iterations) in the program Ecosim 7.0.

The samples are separated into two groups: (1) with mist nets opened far from fruiting *Ficus* tree and other fruit trees (more than 30 m) and (2) with mist nets opened near Fig trees, enclosing each tree in a circle 5-10 m of the trunk. Separate accumulation curves were built and compared using data from captures near fig trees and far from them; separate species rankings were also built and compared. Rarefaction was calculated separately for data from captures in roosts, in nets close to fig trees, and in nets far from fig trees in the program Past, in order to compare species richness among these groups. Diversity was estimated using the Rényi series (Melo, 2008) and compared between captures made close to fig trees and far from fig trees. Movements of recaptured bats in QBV were assessed in terms of linear distance, origin and destination.

RESULTS

We analyzed 3,256 captures, including 133 recaptures, out of which 2,928 were obtained in mist nets and 187 inside roosts; eight specimens were received from park visitors or gardeners. Twenty-one bat species were confirmed in QBV (Tab. I): 19 captured in mist nets, 14 in day roosts, one in a night roost, and two found by park visitors or gardeners. The capture efficiency in mist nets was 28.15 captures/night, 3.69 captures/h, 0.61 captures/ net-h, and 0.04 captures/m^2.h.

The dominant species was *Artibeus lituratus* (Olfers, 1818), which represented 38.02% of all captures and was present in 91.35% of the sampling nights, followed by *Artibeus fimbriatus* Gray, 1838 with 29.18% of all captures and present in 88.46% of the sampling nights. *Desmodus rotundus* (E. Geoffroy, 1810) was present in 26.92% of the sampling nights and was captured only in the zoo. The other species with at least five captures were found both in the park and in the zoo.

Thirty roosts were sampled (Tab. II); 10 in hollow trees, with confirmed use by *Noctilio leporinus* (Linnaeus, 1758), *A. fimbriatus, Sturnira lilium* (E. Geoffroy, 1810), *Cynomops abrasus* (Temmink, 1827), and *Molossus molossus* (Pallas, 1766) (Tab. II). The tree species in which roosts were found were *sibipiruna* (*Caesalpinia*

Tab. I. Species captured in mist nets, roosts and received through donations, and the total of recaptures in Quinta da Boa Vista, Rio de Janeiro, Brazil, from 1989 to 2004 (F, in nets set up near fruiting fig trees).

Species	Captures	Nets Total/F	Roosts	Donations	Recaptures
Family Noctilionidae					
Noctilio leporinus (Linnaeus, 1758)	37	4/0	33	0	0
Family Phyllostomidae					
Phyllostomus hastatus (Pallas, 1767)	37	36/17	1	0	0
Glossophaga soricina (Pallas, 1766)	47	35/2	11	0	1
Carollia perspicillata (Linnaeus, 1758)	7	6/1	1	0	0
Artibeus fimbriatus Gray, 1838	997	939/275	11	0	47
Artibeus planirostris (Spix, 1823)	165	155/80	2	1	7
Artibeus obscurus (Schinz, 1821)	23	22/9	0	0	1
Artibeus lituratus (Olfers, 1818)	1,299	1,255/427	16	5	23
Chiroderma doriae Thomas, 1891	3	3/0	0	0	0
Chiroderma villosum Peters, 1860	1	1/1	0	0	0
Sturnira lilium (E. Geoffroy, 1810)	178	157/15	9	2	10
Desmodus rotundus (E. Geoffroy, 1810)	52	49/0	0	0	3
Platyrrhinus lineatus (E. Geoffroy, 1810)	180	173/70	1	0	6
Platyrrhinus recifinus (Thomas, 1901)	5	5/5	0	0	0
Family Vespertilionidae					
Myotis nigricans (Schinz, 1821)	35	33/11	2	0	0
Myotis **cf.** *riparius* Handley, 1960	9	8/3	0	0	1
Lasiurus ega (Gervais, 1856)	8	1/0	7	0	0
Lasiurus blosevillii (Lesson & Garnot, 1826)	1	1/0	0	0	0
Family Molossidae					
Molossus molossus (Pallas, 1766)	157	45/11	78	0	34
Cynomops abrasus (Temmink, 1827)	14	0/0	14	0	0
Nyctinomops macrotis (Gray, 1840)	1	0/0	1	0	0
	3,256	2,928/927	187	8	133

Tab. II. Roosts found in Quinta da Boa Vista, Rio de Janeiro, Brazil from 1989 to 2004.

Bat species	Roost type/description	Number of roosts
Noctilio leporinus	Hollow palm tree at 15 m above ground	1
Phyllostomus hastatus	Tree hollow at 2 m above ground	1
Glossophaga soricina	Abandoned room Artificial cave	1 1
Artibeus fimbriatus	Hollow trees, height – 2 and 3 m, and artificial cave	2
Artibeus lituratus	Palm tree leaves, from 1 to 15 m above ground	5
Artibeus planirostris	Artificial cave	1
Sturnira lilium	Tree hollow with access at ground level, but bats roosted at over 3m above ground	1
Platyrrhinus lineatus	Palm tree leaves, from 2 to 4 m above ground	4
Myotis nigricans	Artificial cave	1
Lasiurus ega	Among dead leaves of palm trees (5 isolated individuals) from 2 to 4 m above ground and inside the artificial cave	5
Molossus molossus	Hollow trees from 2 to 4.5 m above ground	5
Cynomops abrasus	Hollow tree at 6 m above ground and one individual in the roof lining of a residence	1
Nyctinomops macrotis	Crevice in a stone wall	1
Total		30

Tab. III. Sampling sites, total of captures, species richness, estimated species richness, sample completeness, and exclusive species (N, sampling events in roosts or sampling nights, [a], number of roosts inspected).

Sampling	N	Captures	Richness	Estimate	Completeness (%)	Exclusive species
Roosts	38 (31)[a]	187	14	18.0 ± 5.3	77.78	*C. abrasus* *N. macrotis*
Nets	104	3,102	19	22.0 ± 4.5	86.36	*A. obscurus* *D. rotundus* *M. riparius* *L. blosevilli*
Fig trees	20	927	14	16.0 ± 3.7	87.50	*C. villosum* *P. recifinus*
Without fig trees	84	2,055	16	16.0 ± 0.5	100	*C. doriae*
Total	142	3,282	21	24.0 ± 4.6	87.50	

peltophoroides), mango tree (*Mangifera indica*), money tree (*Pachira aquatica*), fig tree (*Ficus religiosa*), flamboyant (*Delonix regia*), silk floss tree (*Chorisia speciosa*), *angico-branco* (*Anadenanthera colubrina*), and royal palm (*Roystonea regia*). Fifteen roosts were found in palm trees, one in a hollow tree, five among dead leaves and the others in the underside of green leaves. Most roosts were located high, at 1 to 15 m above ground. Only two species were captured in roosts and not sampled with mist nets: *C. abrasus* and *Nyctinomops macrotis* (Gray, 1840).

On the seventh sampling night, thirteen out of the 19 species captured in mist nets had been already confirmed and the collector's curve stabilized until the 50th sampling night (0.26 species/night) (Fig. 3). The other six species were captured between the 51st and the 89th sampling night (0.12 species/night). The last species to be captured, *Platyrrhinus recifinus* (Thomas, 1910) and *Chiroderma villosum* Peters, 1860, were sampled in the 87th and 89th sampling nights, in nets set up around a fruiting *Ficus tomentella* (Figs 3-8). The randomized species accumulation curve had a small slope [Richness = 2.6849*Log(captures) – 3.5211, r = 0.85] (Fig. 4).

The collector's curve for 84 sampling nights far from fig trees grew slow after 1,100 captures, with the addition of three species, reaching 16 species in total [Richness = 1.9837*Log(captures) + 0.5113] (Fig. 6). The curve for 20 sampling nights near fig trees grew fast until 500 captures, reaching 14 species, and no more species were added [Richness = 2.3103*Log(Captures) – 1.0957] (Fig. 6). The six species of non-frugivorous bats captured near fig trees [*M. molossus*, *Myotis nigricans* (Schinz, 1821), *Myotis riparius* Handley, 1960, *Phyllostomus hastatus* (Pallas, 1767), *Lasiurus blosevillii* (Lesson & Garnot, 1826) and *Lasiurus ega* (Gervais, 1856)] were added until the sixth sampling night, and the last three species were frugivorous (*C. villosum*, *P. recifinus* e *Carollia perspicillata* (Linnaeus, 1758)]. Two species were captured only near fig trees (*C. villosum* and *P. recifinus*), and only one frugivorous species was not captured near fig trees (*Chiroderma doriae* Thomas, 1891). In samples far from fig trees, eight frugivorous species [*A. lituratus*, *A. fimbriatus*, *Artibeus obscurus* (Schinz, 1821), *A. planirostris*, *C. perspicillata*, *C. doriae*, *Platyrrhinus lineatus* (E. Geoffroy, 1810 and *S. lilium*)] were captured between the 1st and the 6th sampling nights (average 2.71 nights), and the last species captured were *N. leporinus*, *M. riparius* and *L. ega*.

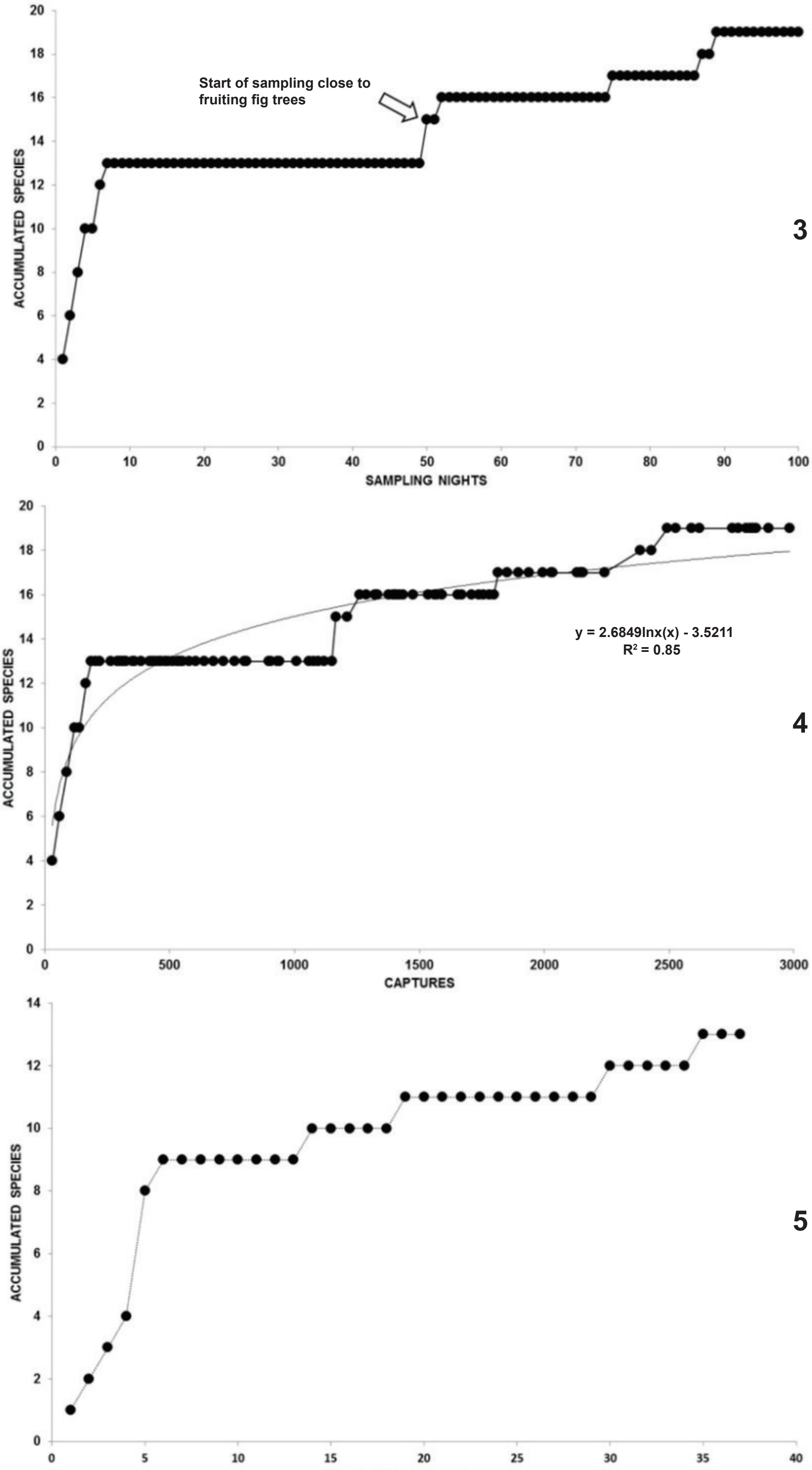
The number of expected species for this park was 24.0 ± 4.6 (Tab. III), and the total sampled represented 87.5% of the expected. The number of expected species considering only roosts was 18.0 ± 5.3 (Tab. III), so sampling in roosts was 77.78% complete. The species accumulation curve did not stabilize (Fig. 5). The number of species, pooling captures in nets near and far from fig trees, was over 85% of the expected (Tab. III); eight frugivorous species were captured in nets near fig trees, and nine were captured in nets far from fig trees. The samples from nets close to fig trees and far from them did not differ in terms of the two most frequent species: *A. lituratus* and *A. fimbriatus* (Figs 7, 8). The rarefaction curves show that higher richness is expected for captures in roosts (Fig. 9). Captures in nets near fig trees had lower richness than captures far from fig trees (Fig. 9). Diversity was similar between samples near fig trees and far from them (Fig. 10).

Six movements of 13 bats of three species were observed in this study (Fig. 11). Three came from QBV and had as destination other sites in the urban area. One specimen of *A. fimbriatus* marked in QBV was found in a backyard in a moderately urbanized area (houses with backyards, 6.0 km away); other four *A. fimbriatus* marked in QBV were recaptured in the campus of the Oswaldo Cruz Foundation (6.0 km away); and one specimen of *A. lituratus* marked in QBV was recaptured in Campo de Santana, another park (4.8 km away) located in a highly urbanized area. The three movements originated in other sites, which had QBV as destination, came from reserves, two with secondary Atlantic Forest and one with restinga vegetation. In QBV, two specimens of *A. lituratus* and three of *A. fimbriatus* were recaptured, which were ringed by M. R. Nogueira (UFRRJ) in the Botanical Gardens of Rio de Janeiro (7.5 km away); there were also one *D. rotundus*, marked by one of the authors (C. E. L. Esbérard) in Grajaú State Park (4.5 km away), and one *A. fimbriatus* marked by B. Costa (UFRRJ) in the park Bosque da Barra (27 km away).

DISCUSSION

Twenty-one bat species in an urban park within a metropolis is a remarkable richness. However, even with a high mist netting effort it was not possible to reach the expected richness. In addition to the species analyzed in the present study there is also one specimen of *Nyctynomops laticaudatus* (E. Geoffroiy, 1850) captured in QBV and deposited in the Museu Nacional (MN6513, captured in 22 February 1943). Green areas in urbanized regions of Brazil exhibit richness varying from 16 (Belo Horizonte) to 25 species (Londrina and São Paulo) (Lima, 2008). Previous studies carried out in urban environments showed that urbanization results in a decrease in bat diversity (Kurta & Teramino, 1992; Rydell *et al*., 1994; Ávila-Flores & Fenton, 2005). However, several local conditions can lead to high species richness, such as the presence of water, the connectivity among green areas through tree corridors, and the high availability of roosts and food (e.g., McKinney, 2002).

Among the species captured in QBV, there are species usually considered as abundant in the Neotropics, which have broad geographic distribution, including *P. hastatus*, *Glossophaga soricina* (Pallas, 1766), *C. perspicillata*, *S. lilium*, *Artibeus* spp., *D. rotundus*, *M. nigricans*, and *M. molossus* (e.g., Peracchi & Albuquerque, 1971, 1986; Jones, 1976; Pedro *et al*., 1995; Reis & Müller, 1995; Bredt & Uieda, 1996; Silva *et al*., 1996). Most of these



Figs 3-5: 3, Collector's curve for Quinta da Boa Vista from 1989 to 2004 based on sampling nights; 4, species accumulation curve and randomized species accumulation curve (line) based on specimens captured; 5, species accumulation curve for the 38 sampling events in day roosts.

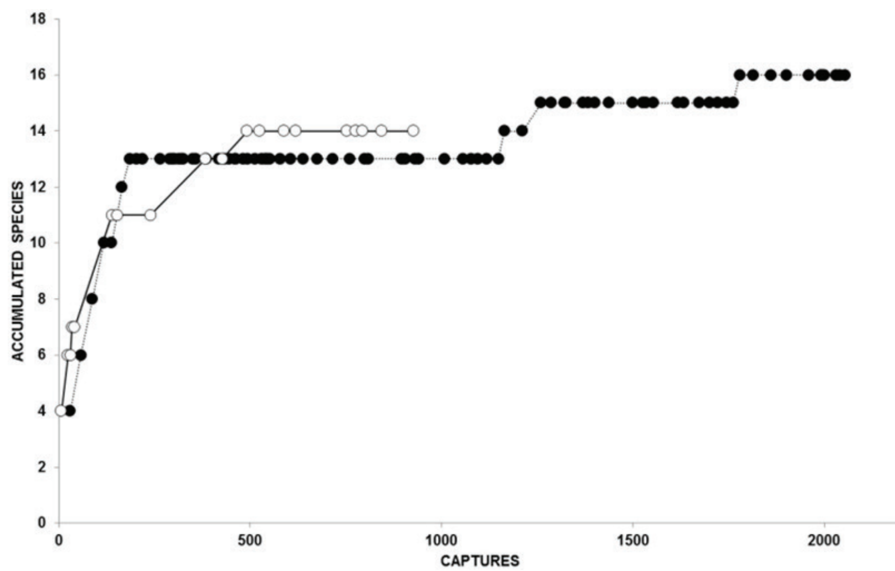


Fig. 6. Species accumulation curve for sampling near fig trees (white circles) and far from fig trees (black circles).

species occur in all Americas (see Simmons, 2005).

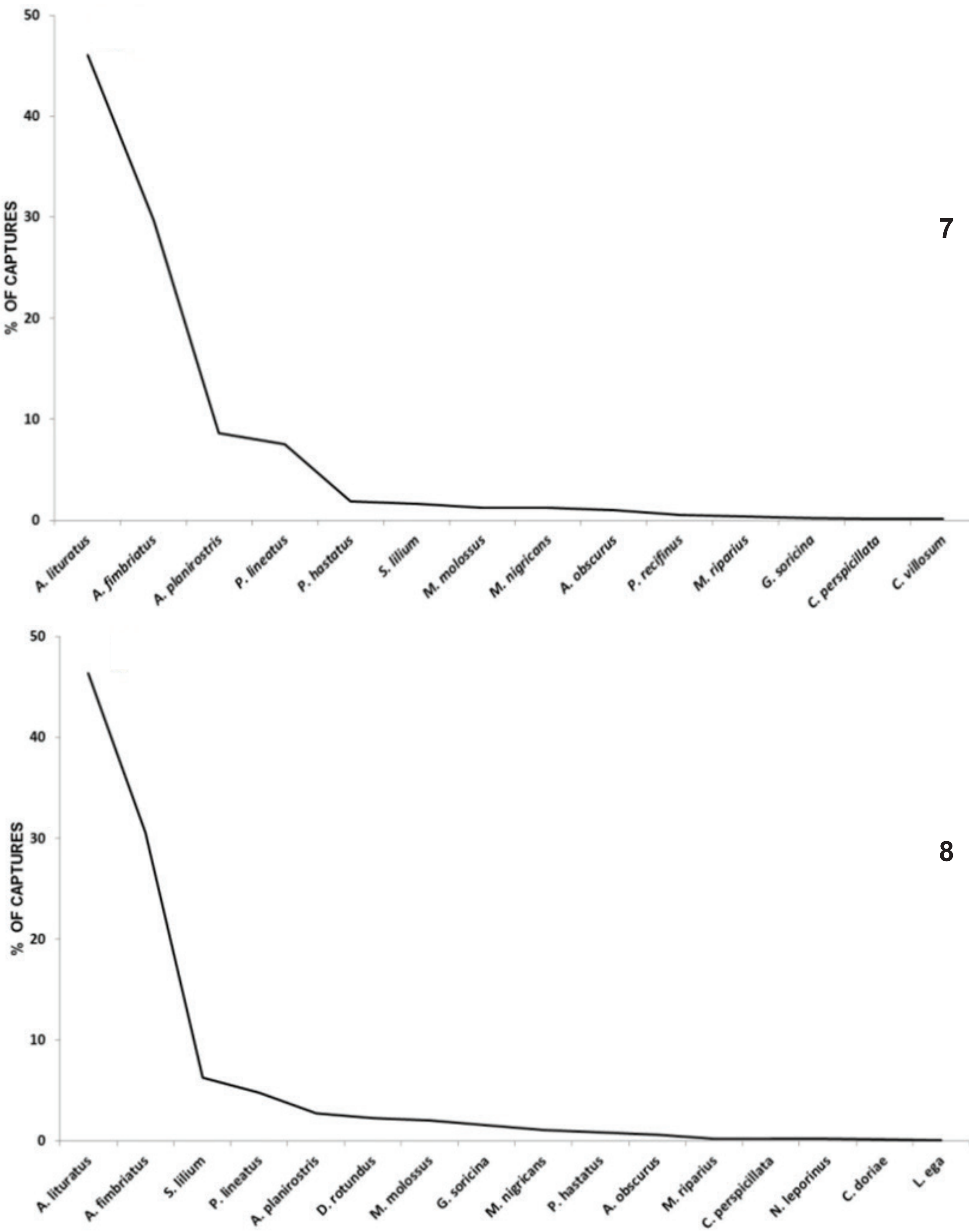
In QBV six insectivorous species were captured. A higher abundance and richness of insectivorous bats can be found in roosts; studies in urban areas in Brazil report more insectivorous species than in forests (e.g., Silva *et al*., 1996). Sampling in roosts reached 77% of expected number of species, whereas the total sample and samples near and far from fig trees surpassed 85% of the expected number of species. In order to reach the goal of 85% of the expected number of species in roosts (Sampaio *et al*., 2003), a higher effort would be needed, and probably more species of Molossidae and Vespertilonidae would be sampled.

The high number of roosts found in palm trees and tree hollows in QBV suggests that bats can find high availability of these roosts in urban areas. The availability of hollow trees and other roosts is an important factor that should be considered in the analysis of bat occurrence (e.g., Humphrey, 1975; Kunz, 1982; Brigham *et al*., 1997; Johnson *et al*., 2008). Bats may show fidelity to roosts in hollow trees (e.g., Lewis, 1995), but there are species that periodically change roosts and so need a high availability of them (e.g., Yasui *et al*., 2004). Hollows are more frequent in trees that undergo pruning or breakage of branches (Milano & Dalcin, 2000) or in trees that are old (Lewis, 1995; Brigham *et al*., 1997; Yasui *et al*., 2004), such as many trees in our study site and on streets of Rio de Janeiro. In Brazil, mainly Molossidae and Vespertilionidae bats do frequently use roof lining and other structures in residences as roosts in urban areas (Bredt & Uieda, 1996; Esbérard *et al*., 1999; Lima, 2008), but we still need to investigate the availability of hollow trees and their occupancy rates by these bats (Yasui *et al*., 2004). A study carried out in a roof lining and in a hollow tree, where colonies of *Molossus rufus* E. Geoffroy, 1805 roosted, showed that bats use these sites during the whole year, but each individual uses them for short periods, suggesting that the animals change roosts periodically (Esbérard, 2002).

Artibeus lituratus is the predominant species in urban areas of Brazil (Barros *et al*., 2006; Lima, 2008; Oprea *et al*., 2009; Gazarini & Pedro, 2013). This predominance evidences the high plasticity of this species (Sazima *et al*., 1994), which benefits from urban forestry (Bredt & Uieda, 1996). Landscape architects of large cities use fast-growing tree species and prefer exotic species (Santos *et al*., 2009). Species such as the sea almond (*Terminalia cattapa*, family Combretaceae) are typical; it is found in several cities and provides food for *Artibeus* bats all year long (Galetti & Morelato, 1994; Sazima *et al*., 1994).

In QBV, *C. perspicillata* represented only 0.20% of the captures. This is totally different from what has been reported for forests in the state of Rio de Janeiro, where this species predominates (see Baptista & Mello, 2001; Esbérard *et al*., 2006; Dias & Peracchi, 2008; Esbérard & Bergallo, 2008; Esbérard, 2009), or at least occurs at high density (e.g., Esbérard, 2003a). Similar results were obtained by Reis & Muller (1995), who sampled the university campus and the urban area of Londrina, southern Brazil, and found a low capture rate for this species in city. This species adapts well to disturbed environments because they consume fruits of pioneer plant species present in the understory (Faria, 2006), but absent in urban areas.

Desmodus rotundus was only collected in nets set up close to zoo animals. However, its capture could be expected in other areas of QBV, since this species is common in the city of Rio de Janeiro, where it attacks pets and even humans (Esbérard *et al*., 1998 and 2001). No roost of this species was located in the study area, but a male specimen, which had been previously marked in Grajaú State Park in Maciço da Tijuca, was captured; it moved over a very large and highly urbanized area. This species of hematophagous bat has been found in other Brazilian urban areas, where it preys on domestic dogs (Esbérard *et al*., 2001; Uieda, 1995; Carneiro *et al*., 2005;

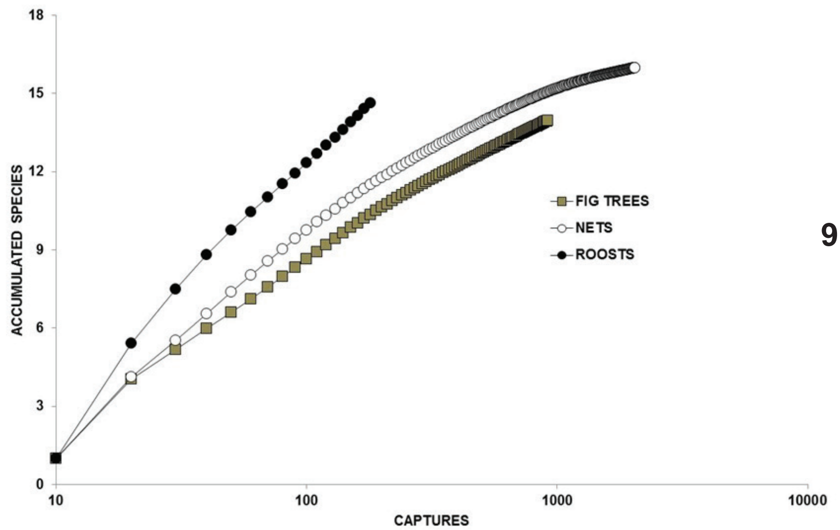


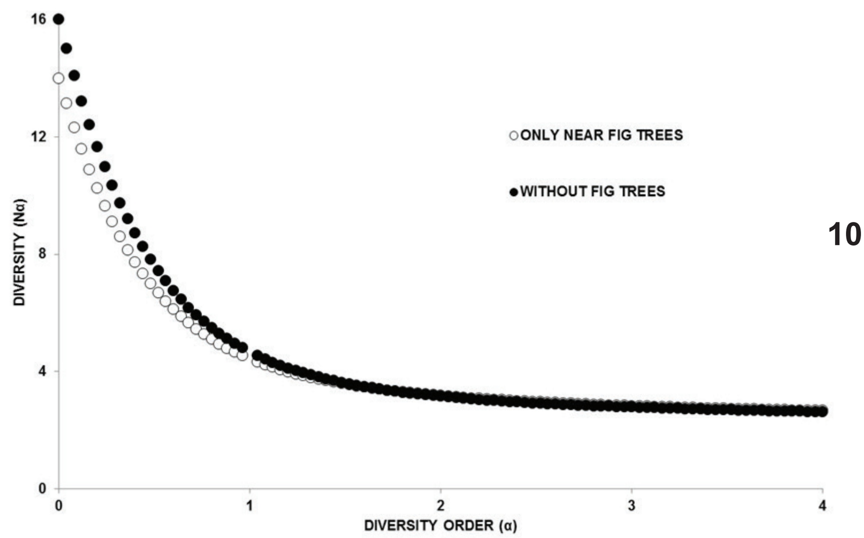
Figs 7-8: 7, abundance rankings for sampling carried out near fig trees; 8, and far from fig trees.

Ferraz *et al*., 2007).

In Brazil there are so far no long-term surveys in urban parks that allow detailed comparisons of richness and abundance, but the capture efficiency observed in QBV can be considered as high compared with surrounding forest areas (0.04 bats/h-net – see Esbérard, 2003a). Sampling nights close to fig trees resulted in very high efficiency in QBV, surpassing 1.0 bats/h-net (Nunes *et al*., 2007; Pereira & Esbérard, 2009).

Fruit tree species, mainly of *Ficus*, are an important food source for frugivorous bats (Morrison, 1980; Kalko *et al*., 1996), and the fig trees of QBV represent a constant source of nutrients. In QBV there are more than 35 adult fig trees. In a small forest fragment in Campinas, Figueiredo (1996) found 11 fig trees that produced figs during the whole year. However, the high density of fig trees in QBV did not result in high richness of frugivorous bats. Sampling near fruiting fig trees did not result in higher richness than sampling far from these trees or out of the fruiting period, as already observed in forest areas (Kalko *et al*., 1996).





Figs 9, 10: 9, Rarefaction for captures in roosts, in nets far from fruiting fig trees, and in nets near fruiting fig trees; 10, Rényi series for diversity comparison between sampling with nets far from fruiting fig trees and near fruiting fig trees.

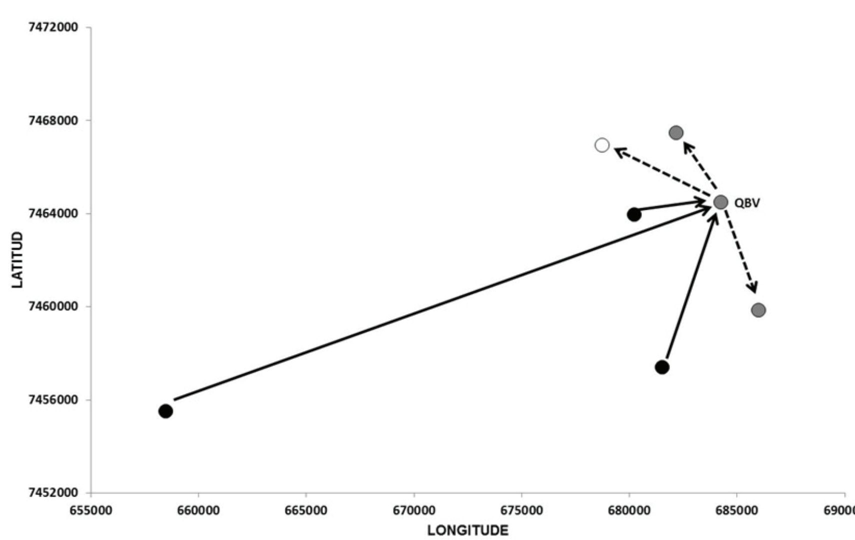


Fig. 11. Movements of bats marked or recaptured in Quinta da Boa Vista. Black dots represent reserves, grey dots represent urban parks, and the white dot represents the residential area. Arrows represent the direction of each movement.

Therefore, a high density of frugivores may be maintained in urban areas, but species that depend on forests do not enter urban areas, and are not attracted by urban fruiting fig trees.

The recapture of bats marked in surrounding forest fragments and in QBV shows the importance of urban parks for the maintenance of bat diversity (Ávila-Flores & Fenton, 2005; Oprea *et al*., 2009). Such movements show that *A. lituratus* *A. fimbriatus*, and *D. rotundus* use QBV (and probably other parks) to survive in urban areas. Considering movement distances already recorded for *Artibeus* bats in southeastern Brazil, which can be larger than 30 km (Costa *et al*., 2006; Menezes-Júnior *et al*., 2008; Mendes *et al*., 2009), we may suppose that *A. fimbriatus* and *A. lituratus* move around the whole urban area and surroundings, flying between all urban parks and remaining forest areas, and feeding on trees (see Estrada & Coates-Estrada, 2001; Oprea *et al*., 2009).

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