

Roberto Leonan M. Novaes*, Renan F. Souza, Saulo Felix, André C. Siqueira, Rafael S. Laurindo, Luis Fernando Menezes Jr. and Julie T. Shapiro

Seasonality and habitat influence on bat assemblage structure in an urban Atlantic Forest remnant from Southeastern Brazil

DOI 10.1515/mammalia-2015-0115

Received July 3, 2015; accepted April 13, 2016

Abstract: The Brazilian Atlantic Forest is a severely threatened biodiversity hotspot and many remnants exist only as fragments. In order to understand how bat assemblage structure within a forest fragment surrounded by an urban matrix might respond to seasonality and different habitats, we sampled bats over 39 nights in the forest fragment of Gericinó-Mendanha Massif, Rio de Janeiro State. From February 2006 to January 2010, we captured 874 bats, belonging to 25 species and eight different feeding guilds. Frugivorous species were the most abundant, representing 83.33% of captures, and the gleaning insectivores were the least abundant (1.47%). We did not find changes in bat species composition between seasons, although capture rate was higher in the rainy season. However, we did find significant differences in species abundance between seasons. The habitat influence did not significantly differentiate the assemblages, but species richness was higher in the mature ombrophilous forest. The

community composition indicates that this conservation unit is an important remaining fragment for maintaining the diversity and richness of bats, although it is possible that historical processes of environmental exploitation have already resulted in a loss of species.

Keywords: bat community; Chiroptera; Neotropics; seasonal variation; trophic guild.

Introduction

The Brazilian Atlantic Forest, which stretches north to south along the Brazilian coast, is one of the most threatened biomes on the planet and includes one of the most biodiverse terrestrial ecosystems known. Currently, only 11% of its original area still exists and the remaining areas are largely comprised of highly fragmented secondary vegetation (Ribeiro et al. 2009). The diversity of mammals in the Atlantic Rainforest is one of the highest on the planet (Costa et al. 2005). However, a large number of these species are threatened by the severe fragmentation and habitat destruction (Chiarello 1999). This emphasizes the necessity of urgent conservation planning for the mammals of this biome. However, such plans require reliable information about species occurrence and geographic distribution of specific taxa, which is essential for conserve remaining natural environments (Soulé and Wilcox 1980).

In some Neotropical areas, the bat community may comprise more than 50% of mammalian diversity, representing a great diversity of species, feeding habits, and abundance (Wilson 1973, Timm 1994). The study of bat communities contributes to our knowledge of the factors influencing the dynamics of species occurrence in natural and disturbed landscapes (Meyer et al. 2008), providing data which can be used for the effective management of remaining forest fragments and optimizing species conservation efforts (Novaes et al. 2010).

Data regarding bats are still preliminary for much of Brazil (Bernard et al. 2011). The Atlantic Rainforest is arguably the best studied region of Brazil for bats, where

*Corresponding author: Roberto Leonan M. Novaes, Fundação Oswaldo Cruz, Fiocruz Mata Atlântica, Estrada Rodrigues Caldas, 3400, 22713-375, Rio de Janeiro, RJ, Brazil, e-mail: robertoleonan@gmail.com

Renan F. Souza: Programa de Pós-Graduação em Ecologia e Evolução, Universidade do Estado do Rio de Janeiro, Av. São Francisco Xavier, 524, 20550-013, Rio de Janeiro, RJ, Brazil

Saulo Felix: Departamento de Zoologia, Universidade Federal do Estado do Rio de Janeiro, Av. Pasteur, 458, 22290-240, Rio de Janeiro, RJ, Brazil

André C. Siqueira: Faculdade de Formação de Professores, Universidade do Estado do Rio de Janeiro, Rua Dr. Francisco Portela, 1470, 24434-005, São Gonçalo, RJ, Brazil

Rafael S. Laurindo: Departamento de Biologia, Universidade Federal de Lavras, Campus Universitário, CEP 37200-000, Lavras, MG, Brazil

Luis Fernando Menezes Jr.: Instituto de Biologia, Universidade Federal Rural do Rio de Janeiro, BR 465, km 47, CEP 23890-000, Seropédica, RJ, Brazil

Julie T. Shapiro: School of Natural Resources and the Environment, Department of Wildlife Ecology and Conservation, University of Florida, 110 Newins-Ziegler Hall, Gainesville, FL 32611, USA

113 species, 65% of Brazil's total, have been recorded (Bernard et al. 2011, Paglia et al. 2012). Even so, new species of bats are still being described in the Atlantic Rainforest, including areas with extensive surveys, such as the southeast portion (Nogueira et al. 2012, Dias et al. 2013, Velazco et al. 2014), indicating the necessity of continued inventories (Varzinczak et al. 2016). The bats of Rio de Janeiro are particularly well-studied, and the remaining large forest fragments within metropolitan Rio de Janeiro have been the site of various studies (Dias et al. 2002, Esbérard 2003, Dias et al. 2008), although this is the first study of bats carried out in Gericinó-Mendanha Massif (GMM).

We studied the bats in GMM in order to understand how bat communities in an isolated forest fragment within an urban matrix might vary across a gradient of anthropogenic disturbance and across seasons. Our hypotheses were that (i) the assemblage structure would not change with seasonality, although there would be differences in abundance of species; and (ii) that there would be differences in the assemblage structure according to the type of habitat.

Materials and methods

Study area

The Gericinó-Mendanha Massif (hereafter GMM) has been recognized as a State Environmental Protection Area since 2005 and includes three conservation units, the Natural Municipal Park of Nova Iguaçu, the Natural Municipal Park of Mendanha, and the recently established Serra do Mendanha State Park (Decreto Estadual n° 44.342, of August 22, 2013). GMM is comprised of approximately 8000 ha of continuous Atlantic Rainforest classified as ombrophilous dense tropical forest (IBGE 2012), of which almost 4400 ha are protected as a conservation unit. This area is geographically isolated from other forest fragments as it is completely surrounded by the urban matrix of the Rio de Janeiro, Nova Iguaçu, and Mesquita municipalities within the metropolitan region of the state of Rio de Janeiro in southeast Brazil (Figure 1). There are two primary seasons: a cold and dry season (April–September), and a warm rainy season (October–March).

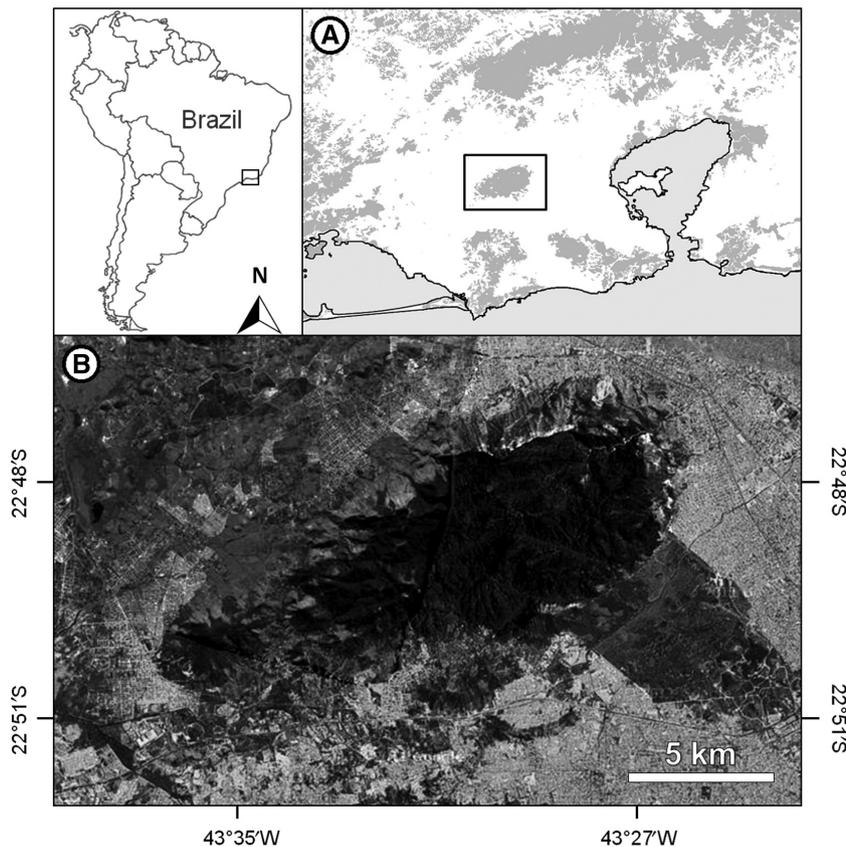


Figure 1: (A) Gericinó-Mendanha Massif (in rectangle) isolated of the others Atlantic Forest remnants (in gray), and (B) surrounded by the urban matrix in metropolitan region of Rio de Janeiro State, Brazil.

Temperatures vary between 12 and 35°C and precipitation between 1100–2000 mm per year. Elevation varies from 60 to 800 m a.s.l. (SEMUAM 2001).

Historically, the area of GMM has been used for harvesting timber and deforested for making pastures, monocultures of coffee, sugarcane, and more recently, banana. However, after a long process of vegetative recuperation, beginning nearly 100 years ago, the area is currently a mosaic consisting of approximately 60% mature forest, while the remaining 40% of the fragments are comprised of secondary forest in regeneration, banana plantations, agricultural fields, and pastures (SEMUAM 2001). The best-preserved fragments are located in the deep valleys at the headwaters of rivers, areas that are difficult access, and at higher elevations. In these areas, patches of primary forest can still be found (Santos et al. 2007). These primary forest remnants give great conservation importance to this massif, which is considered a priority area for biodiversity conservation and hydrological supply for the metropolitan region of Rio de Janeiro. The GMM region was declared an Atlantic Rainforest Biosphere Reserve in 1992.

Sampling

We sampled bats from February 2006 to January 2010, sampling two habitats per night, totaling 39 nights using eight mist-nets (Zootech® 6- 9- and 12×3 m, 20 mm mesh) placed at ground level along the trails, over water bodies and clearings in forests. Nets were kept open for approximately 12 h each night, from sunset to sunrise. All sampling sites were between 100 and 480 m a.s.l., reducing the possibility that changes in community would be due to altitudinal variation (e.g. Stevens 1992, Dias et al. 2008). Sampling effort was equal in all nights, in the two seasons (dry and rainy) and among the habitats. The sampling nights were independent of the lunar cycle and climatic conditions. The four habitats we sampled are described below:

1. Banana [(BAN) 22°50'08"S, 43°29'28"W, and 22°50'19"S, 43°31'00"W]: area characterized by banana plantations surrounded by early or late secondary forest. Here, we placed mist nets exclusively on trails in the interior of the banana plantations.
2. Initial secondary forest [(ISF) 22°46'45"S, 43°27'23"W]: area characterized by herbaceous and shrubby vegetation, predominately ruderal, invasive, and native pioneer species, in the process of ecological succession. The highest level of vegetation does not pass 10 m. Bromeliads and orchids are absent due to high levels of solar radiation and low humidity.

3. Late secondary forest [(LSF) 22°46'58"S, 43°28'11"W, and 22°50'08"S, 43°29'56"W]: area characterized by three strata of vegetation which are not well defined. The first stratum has a maximum height of approximately 6 m, predominately palm trees, especially young individuals of *Astrocaryum aculeatissimum* (Schott) Burret., *Geonoma* spp., and *Euterpe edulis* Mart. The two upper strata are more difficult to define, with an average height of 12–15 m and a large diversity of species, particularly adult individuals of *Spondias lutea* L., *Pterocarpus rohrii* Vahl., *Cecropia hololeuca* Miq., *Inga edulis* Mart. and *Jacaratia spinosa* (Aubl.).
4. Mature ombrophilous forest [(MOF) 22°47'45"S, 43°28'37"W, and 22°49'29"S, 43°29'25"W]: area characterized by three well-defined strata, the highest of which trees may reach a height of 18 m, with some emergent individuals that may be higher. The flora is very diverse, and largely shaded in the interior with a marked presence of bromeliad epiphytes, orchids, and adult palms.

Individual bats were marked with numbered plastic collars (Esbérard and Daemon 1999) and released in the same location as capture. Some individuals were collected (removed from the environment) and deposited in the bat collection Adriano Lucio Peracchi (ALP) of the Institute of Biology of the Universidade Federal Rural do Rio de Janeiro–UFRRJ (see Appendix 1), following the ethics norms established by Sikes et al. (2011), under SISBIO/IBAMA license 1896-1/15809.

Data analysis

The bats were classified in trophic guild according to Kalko et al. (1996). We used an analysis of similarity (ANOSIM – one way) to compare the differences in composition and species abundance during the rainy and dry seasons with Jaccard similarity index, which uses only presence/absence data for species and the Bray-Curtis index, which also considers abundance. The analysis produces values of R between -1 and +1. Values of R closer to +1 indicate higher dissimilarity between groups (Clarke 1993). We also used the method SIMPER (percent similarity), which defines the contribution of each species to the dissimilarity between seasons.

We calculated sampling effort (following Straube and Bianconi 2002) and estimated capture efficiency by dividing the total number of captures by the calculated sampling effort. We estimated maximum species richness using the Jackknife-1 (Shao and Tu 1995) in the software SigmaPlot

12.0. For each sampled habitat, we created a species accumulation curve with a 95% confidence interval using the software EstimateS 9.0 (Colwell 2013). We used one-way analysis of variance (ANOVA) to determine differences among the assemblages composition for seasons as well for the entire period of fieldwork. All statistics were carried out in the program PAST, version 3.0 (Hammer et al. 2001).

Results

We captured 874 individual bats over the course of 81,738 m² mist-net hours (approximately 20,434 m² mist

net hours per habitat). Capture efficiency varied for each habitat, being higher in habitats with a greater degree of conservation (BAN 0.007 bats/m².h; ISF 0.006 bats/m².h; LSF 0.015 bats/m².h; MOF 0.013 bats/m².h). We recorded 25 species of bat distributed in four families: Phyllostomidae (20 species), Vespertilionidae (3), Molossidae (1) and Noctilionidae (1). The results are summarized in Table 1. Individuals of *Noctilio leporinus* were observed foraging above lake Epaminondas Ramos. However, no individual of this species was captured; therefore, we have not included *N. leporinus* in quantitative analyses.

The family Phyllostomidae represented 91.2% of total captures, while Molossidae accounted for 6.8%

Table 1: Bats from Gericinó-Mendanha Massif, including trophic guild, number of captures (N) and abundance ratios (%).

Taxa	Trophic guild	N	%
Phyllostomidae			
Desmodontinae			
<i>Desmodus rotundus</i> (E. Geoffroy, 1810)	Sanguivore	20	2.3
Glossophaginae			
<i>Anoura caudifer</i> (É. Geoffroy, 1818)	Nectarivore	23	2.6
<i>Anoura geoffroyi</i> Gray, 1838	Nectarivore	15	1.7
<i>Glossophaga soricina</i> (Pallas, 1766)	Nectarivore	19	2.2
Lonchophyllinae			
<i>Lonchophylla peracchii</i> Dias, Esbérard & Moratelli, 2013	Nectarivore	3	0.3
"Micronycterinae"			
<i>Micronycteris microtis</i> Miller, 1898	Gleaning insectivore	1	0.1
<i>Micronycteris minuta</i> (Gervais, 1856)	Gleaning insectivore	1	0.1
Phyllostominae			
<i>Phyllostomus hastatus</i> (Pallas, 1767)	Omnivore	4	0.6
<i>Tonatia bidens</i> (Spix, 1823)	Gleaning insectivore	11	1.3
Carollinae			
<i>Carollia perspicillata</i> (Linnaeus, 1758)	Frugivore	186	21.2
Stenodermatinae			
<i>Artibeus fimbriatus</i> Gray, 1838	Frugivore	51	5.9
<i>Artibeus lituratus</i> (Olfers, 1818)	Frugivore	370	42.3
<i>Artibeus obscurus</i> (Schinz, 1821)	Frugivore	13	1.5
<i>Chiroderma doriae</i> Thomas, 1891	Frugivore	3	0.3
<i>Platyrrhinus lineatus</i> (E. Geoffroy, 1810)	Frugivore	39	4.7
<i>Platyrrhinus recifinus</i> (Thomas, 1901)	Frugivore	9	1.0
<i>Pygoderma bilabiatum</i> (Wagner, 1843)	Frugivore	6	0.7
<i>Sturnira lilium</i> (E. Geoffroy, 1810)	Frugivore	19	2.1
<i>Sturnira tildae</i> de la Torre, 1959	Frugivore	1	0.1
<i>Vampyressa pusilla</i> (Wagner, 1843)	Frugivore	4	0.6
Noctilionidae			
<i>Noctilio leporinus</i> (Linnaeus, 1758)	Piscivore	–	–
Molossidae			
<i>Molossus molossus</i> (Pallas, 1766)	Uncluttered aerial insectivore	60	6.6
Vespertilionidae			
Vespertilioninae			
<i>Eptesicus brasiliensis</i> (Desmarest, 1819)	Background aerial insectivore	1	0.1
Myotinae			
<i>Myotis nigricans</i> (Schinz, 1821)	Background aerial insectivore	10	1.1
<i>Myotis riparius</i> Handley, 1960	Background aerial insectivore	5	0.6
Total		874	100

and Vespertilionidae 1.8%. The most abundant species were *Artibeus lituratus* and *Carollia perspicillata*, which together accounted for more than half of the total captures (63.6%). The Jackknife-1 estimated the richness of GMM at 30 (± 4) species, indicating that the observed richness represents approximately 80% of the estimated richness for this area (Figure 2). The species accumulation curve did not reach an asymptote for any of the sampled habitats, suggesting that continued surveys will result in additional species (Figure 3).

In the dry season, the number of captures per night ranged from 2 to 33 (average 15 captures), while during the rainy season captures ranged from 10 to 53 bats per night, with an average of 29 bats per night (Table 2). The Jaccard index did not show changes in bat species composition

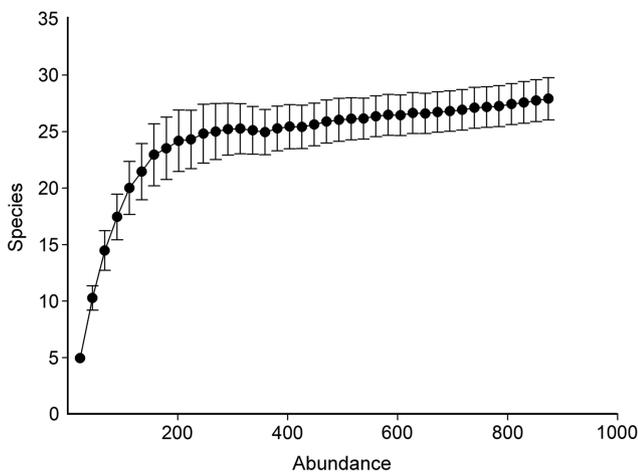


Figure 2: Richness estimator curve (Jackknife-1) of the bat assemblage from Gericinó-Mendanha Massif, Rio de Janeiro, Brazil.

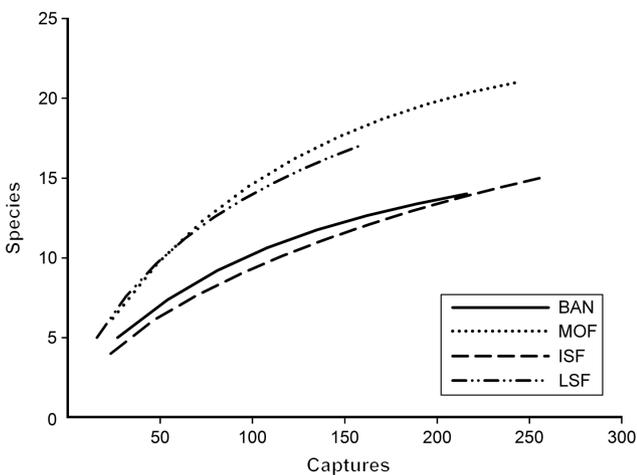


Figure 3: Species accumulation curves of bat assemblage in four habitats of Gericinó-Mendanha Massif, Rio de Janeiro, Brazil. BAN: banana plantations, ISF: initial secondary forest, LSF: late secondary forest, MOF: mature ombrophilous forest.

between the dry and rainy seasons (ANOSIM: $R=0.014$, $p=0.370$). However, the Bray-Curtis index showed a significant difference in species abundance (ANOSIM: $R=0.260$, $p<0.001$), with increased captures in rainy season (Figure 4). Frugivores and nectarivores had a marked drop in abundance during the dry season, while insectivores were more abundant during this season. *Artibeus lituratus* (35.0%) was the species that contributed most to the dissimilarity between the seasons, followed by *Carollia perspicillata* (19.4%).

We registered bats of eight trophic guilds, with a markedly high abundance of frugivorous bats, which accounted for 80% of captures. The least abundant guild was gleaning insectivores, accounting for 1.47% of captures, and represented by only three species (*Micronycteris microtis*, *Micronycteris minuta*, and *Tonatia bidens*) captured exclusively in MOF.

The four sampled habitats showed differences in species richness. The habitat with the least number of species was BAN (14 species), followed by the ISF (15 species), and LSF (17 species). The MOF had the highest richness at 21 species (Table 2). However, we found no significant difference among assemblage composition ($F_{3,67}=0.15$; $p>0.05$) for the entire sampled period, nor for dry season ($F_{3,43}=0.18$; $p>0.90$) or rainy season ($F_{3,57}=0.20$; $p>0.05$).

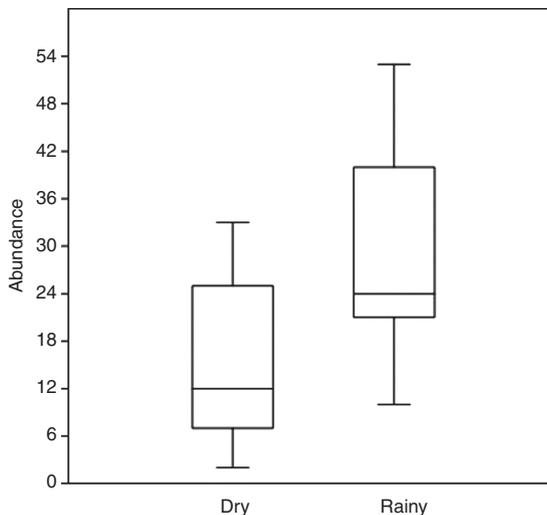
Discussion

The richness and abundance of species in GMM is comparable to other studies in the Atlantic Rainforest with similar sampling efforts (e.g. Dias et al. 2002, Dias et al. 2008, Esbérard et al. 2010). Currently, other similar-sized fragments within Rio de Janeiro, such as Pedra Branca Massif and Tijuca Massif, have registered more species in a greater number of families, but as a result of long-term or multiple studies, employing a variety of techniques such as active roost searches (Dias et al. 2002, Esbérard 2003).

There was a greater number of captures during the rainy season. Studies in the Atlantic Forest have shown that the availability of fruit and flowers is higher during this season (Talora and Morellato 2000), which could drive this pattern, especially considering that more than 90% of captures were frugivorous and nectarivorous bats. Complementarily, we saw a marked drop in the number of captures during the dry season, as reported in other studies in the Atlantic Forest (Gomes et al. 2014, Ortêncio-Filho et al. 2014). In addition, in the Atlantic Forest, the rainy season favors reproduction (and births) of phytophagous species, resulting

Table 2: Bats from Gericinó-Mendanha Massif, including number of captures for each habitat and total (Σ) in the dry and rainy seasons. Habitats: banana plantations (BAN), initial secondary forest (ISF), late secondary forest (LSF), mature ombrophilous forest (MOF).

Species	Dry					Rainy				
	BAN	ISF	LSF	MOF	Σ	BAN	ISF	LSF	MOF	Σ
<i>Anoura caudifer</i>	0	4	2	2	8	5	6	3	1	15
<i>Anoura geoffroyi</i>	0	0	3	2	5	0	0	2	8	10
<i>Glossophaga soricina</i>	0	3	2	2	7	6	5	0	1	12
<i>Lonchophylla peracchii</i>	0	0	0	0	0	1	0	1	1	3
<i>Desmodus rotundus</i>	1	0	0	10	11	3	2	1	3	9
<i>Carollia perspicillata</i>	12	7	14	15	48	31	9	35	63	138
<i>Artibeus fimbriatus</i>	3	0	3	9	15	1	24	2	9	36
<i>Artibeus lituratus</i>	51	35	28	12	126	59	86	42	57	244
<i>Artibeus obscurus</i>	5	1	0	1	7	2	0	2	2	6
<i>Chiroderma doriae</i>	0	2	0	0	2	0	0	0	1	1
<i>Platyrrhinus lineatus</i>	7	3	0	1	11	22	1	1	4	28
<i>Platyrrhinus recifinus</i>	1	3	0	0	4	0	0	3	2	5
<i>Pygoderma bilabiatum</i>	0	0	0	0	0	0	0	1	5	6
<i>Sturnira lilium</i>	1	0	2	1	4	1	1	2	11	15
<i>Sturnira tildae</i>	1	0	0	0	1	0	0	0	0	0
<i>Vampyressa pusilla</i>	0	0	0	0	0	2	0	1	1	4
<i>Micronycteris microtis</i>	0	0	0	1	1	0	0	0	0	0
<i>Micronycteris minuta</i>	0	0	0	0	0	0	0	0	1	1
<i>Phyllostomus hastatus</i>	0	0	2	0	2	0	0	0	2	2
<i>Tonatia bidens</i>	0	0	0	8	8	0	0	0	3	3
<i>Molossus molossus</i>	0	38	0	0	28	0	22	0	0	22
<i>Eptesicus brasiliensis</i>	0	1	0	0	1	0	0	0	0	0
<i>Myotis nigricans</i>	0	1	1	3	5	0	1	3	1	5
<i>Myotis riparius</i>	0	0	2	0	2	1	1	0	1	3
Total	82	98	59	67	306	134	158	99	177	568

**Figure 4:** Seasonal variation in bat abundance from Gericinó-Mendanha Massif, Rio de Janeiro, Brazil.

in a population increase (higher input of individuals in the assemblage), higher activity and, consequently, higher capture rate (Costa et al. 2007, Mello et al. 2009, Godoy et al. 2014).

Aerial insectivores were captured in equal proportions in both seasons. However, the low number of captures overall prevents a more robust comparison. According to Marques et al. (2015), mist nets are inefficient to capture aerial insectivores. Therefore, studies that only use mist nets are not able to evaluate the effect of seasonality and the influence of habitat on the structuring of the community of these bats.

Although species richness was greater in the MOF than any other habitats, we did not find significant differences in the assemblages among habitats. This may indicate homogenization of the bat fauna in urban fragments due to a history of environmental exploitation. This is another indicator that even within a forest fragment, some species of bats are sensitive to the anthropogenic changes to habitats, which has been documented by many authors (Schulze et al. 2000, Estrada and Coates-Estrada 2002, Gorresen and Willig 2004, Meyer and Kalko 2008).

Gleaning insectivorous bats were captured exclusively in MOF, with only three species in GMM. Species of this trophic guild are edge-sensitive, occur at low natural abundances and have limited mobility (Gorresen and Willig 2004, Meyer et al. 2008). The presence of these

three species points to the importance of this habitat for conservation and demonstrates the range of disturbance in the GMM, with the mature forest showing less disturbance than other areas.

According to Meyer et al. (2008), animalivorous bats are especially sensitive to forest fragmentation, and their occurrence is related to the size and isolation of a given fragment. Despite its extensive area, the GMM is a forest fragment isolated by an urban matrix, which can make it difficult to maintain the diversity of bats, by not allowing the flow of certain species from other forest areas towards this remnant. In addition, much of the forest covering the GMM are recovering from decades of reforestation, which may have caused impoverishment of the vegetation compared to primary Atlantic Forest, consequently leading to the loss of the most sensitive bat species.

Areas that are less well preserved, such as the ISF and BAN, had lower species richness and a greater abundance of frugivores when compared to the more conserved areas. Schulze et al. (2000) suggests the markedly high abundance of generalist frugivores could be a strong indicator of disturbance in forests. According to Reis et al. (2006), anthropogenic modification in forests changes resource availability, which could favor the predominance of generalist species that are able to consume a variety of native and invasive species (Sazima and Fischer 1994, Aguiar and Marinho-Filho 2007, Novaes and Nobre 2009). Secondary forests in regeneration generally have high productivity, including increased vegetation growth and production of fruits (Murcia 1995, Asbjornsen et al. 2004), allowing high populations of generalist frugivorous species in these habitats.

The high prevalence of *Carollia perspicillata* and *Artibeus lituratus* is common and has been reported in other studies throughout the Atlantic Forest, including forest remnants in metropolitan Rio de Janeiro (e.g. Dias et al. 2002, Esbérard 2003, Dias et al. 2008). These two species have a primarily frugivorous, highly flexible diet, although they prefer fruits of *Piper* (Piperaceae), *Cecropia* (Cecropiaceae), and *Ficus* (Moraceae) and other species that are common in regenerating secondary forest, habitat edges, and anthropogenic landscapes (Wilson et al. 1996, Andrade et al. 2013). In addition, these two species are particularly able to adapt to environmental change, such as habitat disruption (Gorresen and Willig 2004).

Currently, GMM is still under intense pressure, due to urban expansion, as its original vegetation has been systematically removed to make space for houses and the growth of 'favelas' (=urban sprawl) within the massif. It is possible that this process of exploitation and isolation of GMM has resulted in a loss of species. Even so, the GMM

still conserves significant richness of species and trophic guilds important for the conservation of forest areas, including species of Phyllostominae. This massif could be one of the most important natural resources of the area that can conserve wildlife populations and their ecological functions.

GMM is geographically isolated from other forest remnants, <10 km from Pedra Branca Massif; 15 km from the Reserva Biológica do Tinguá; 20 km from Tijuca Massif and approximately 30 km from the mosaic of forest remnants of Costa Verde, in southern Rio de Janeiro. However, this may not represent isolation for some species of bats. For example, in 2008 an individual of *Artibeus lituratus* marked in Itacuruça Island was recaptured in GMM, representing a movement of 35 km (Menezes et al. 2008). Some bat species have large movement capability (Bernard and Fenton 2002, Costa et al. 2006, Mello et al. 2008, Esbérard et al. 2011), which enhances the importance of this fragment as an ecological corridor for other urban forest remnants of the metropolitan area of Rio de Janeiro. As pointed out by Ribeiro et al. (2009), in the Atlantic Forest even small fragments have value as "connection areas" and decrease the distances between fragments.

This study of bats in GMM included the capture of *Lonchophylla peracchii*, a species endemic to a small area of Atlantic Forest in the Serra do Mar. Its range is one of the most restricted known for bats anywhere in the world (Teixeira et al. 2014). With its fascinating appearance and charismatic appeal, *L. peracchii* has awakened new interest in ecological research and conservation in Rio de Janeiro (Novaes et al. 2010, Teixeira et al. 2014). The presence of *L. peracchii* in GMM represents an opportunity to pursue funding for the management of local conservation units, which is located in a generally poor, neglected area with limited resources. The use of *L. peracchii* as a flagship species could provide a point of local pride (Bowen-Jones and Entwistle 2002), serve as an educational tool for students, and galvanize local interest in conservation and ecological research.

Conclusion

We did not find changes in bat species composition between seasons but in species abundance, corroborating our first hypothesis. However, we suggest that a longer period to study seasonal variation in order to determine changes in bat communities is necessary, especially in a new century with intense climate change. Although species richness was higher in the mature ombrophilous

forest, the habitat type did not significantly differentiate the assemblages, contrary to our second hypothesis. We suggest there may be a homogenization of the local bat fauna due to the historical process of environmental exploitation of the Gericinó-Mendanha Massif.

Acknowledgments: We are grateful to Ana C. Façanha, Flávio A.P. Mello, Luiz Fernando Dias-de-Oliveira, Luzianne Gomes, Mariana A.S. Louro, Mariana V.P. Aguiar, Paula C. Andrade, Raphael Silveiras, Rogério Guedes, Tatiane S. Cardoso, Tiago Lobo and Vinícius de Bruycker for the fieldwork assistance; to SEMUAM/Nova Iguaçu for the research license in the Parque Natural Municipal de Nova Iguaçu (N001/2010). This project was also carried out with the support of Zootech®.

Appendix 1

Bats from Gericinó-Mendanha Massif deposited in the collection of bats Adriano Lucio Peracchi (ALP) of the Institute of Biology, Universidade Federal Rural do Rio de Janeiro, Brazil.

Phyllostomidae: *Artibeus fimbriatus* (ALP6791, ALP9470); *Artibeus lituratus* (ALP6790, ALP9471, ALP9472, ALP9473, ALP9474); *Artibeus obscurus* (ALP9475); *Chiroderma doriae* (ALP6785); *Platyrrhinus lineatus* (ALP9476); *Platyrrhinus recifinus* (ALP6792, ALP9477, ALP9478); *Pygoderma bilabiatum* (ALP9479, ALP9480); *Sturnira lilium* (ALP6789, ALP9481, ALP9482); *Vampyressa pusilla* (ALP6787, ALP9483); *Desmodus rotundus* (ALP6793, ALP9484, ALP9485); *Anoura caudifer* (ALP6786, ALP9486); *Anoura geoffroyi* (ALP9487); *Glossophaga soricina* (ALP6794, ALP9488); *Lonchophylla peracchii* (ALP9489, ALP9490); *Carollia perspicillata* (ALP6788, ALP9491, ALP9492, ALP9493, ALP9494); *Micronycteris microtis* (ALP9495); *Micronycteris minuta* (ALP9496); *Phyllostomus hastatus* (ALP6784, ALP9497); *Tonatia bidens* (ALP9498, ALP9499); **Molossidae:** *Molossus molossus* (ALP6795, ALP6796, ALP9500, ALP9501); **Vespertilionidae:** *Eptesicus brasiliensis* (ALP6821), *Myotis nigricans* (ALP6797, ALP9502, ALP9503, ALP9504, ALP9505, ALP9506, ALP9507); *Myotis riparius* (ALP9508, ALP9509, ALP9510).

References

Aguiar, L.M.S. and J.S. Marinho-Filho. 2007. Bat frugivory in a remnant of Southeastern Brazilian Atlantic Forest. *Acta Chiropterol.* 9: 251–260.

- Andrade, T.Y., W. Thies, P.K. Rogeri, E.K.V. Kalko and M.A.R. Mello. 2013. Hierarchical fruit selection by Neotropical leaf-nosed bats (Chiroptera: Phyllostomidae). *J. Mammal.* 94: 1094–1101.
- Asbjornsen H., M.S. Ashton, D.J. Voigt and S. Palacios. 2004. Effects of habitat fragmentation on the buffering capacity of edge environments in a seasonally dry tropical oak forest ecosystem in Oaxaca, Mexico. *Agric. Ecosyst. Environ.* 103: 481–495.
- Bernard, E. and M.B. Fenton. 2002. Bat mobility and roosts in a fragmented landscape in Central Amazonia, Brazil. *Biotrop.* 35: 262–277.
- Bernard, E., L.M.S. Aguiar and R.B. Machado. 2011. Discovering the Brazilian bat fauna: a task for two centuries? *Mammal Rev.* 41: 23–39.
- Bowen-Jones, E. and A. Entwistle. 2002. Identifying appropriate flagship species: the importance of culture and local contexts. *Oryx* 36: 189–195.
- Chiarello, A.G. 1999. Effects of fragmentation of the Atlantic Forest on mammal communities in South-eastern Brazil. *Biol. Cons.* 89: 71–82.
- Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Austral Ecol.* 18: 117–143.
- Colwell, R.K. 2013. EstimateS: statistical estimation of species richness and shared species from samples. Version 9.0. User's guide and application published at: <http://purl.oclc.org/estimates>.
- Costa, L.O., Y.L.R. Leite, S.L. Mendes and A.D. Ditchfield. 2005. Mammal conservation in Brazil. *Conserv. Biol.* 19: 672–679.
- Costa, L.M., A.F.D. Prata, D. Moraes, C.F.V. Conde, T. Jordão-Nogueira and C.E.L. Esbérard. 2006. Deslocamento de *Artibeus fimbriatus* sobre o mar. *Chiropterol. Neotrop.* 12: 289–290.
- Costa, L.M., J. Almeida and C.E.L. Esbérard. 2007. Dados de reprodução de *Platyrrhinus lineatus* em estudo de longo prazo no Estado do Rio de Janeiro (Mammalia, Chiroptera, Phyllostomidae). *Iheringia. Ser. Zool.* 97: 152–156.
- Dias, D., A.L. Peracchi and S.S.P. Silva. 2002. Quirópteros do Parque Estadual da Pedra Branca, Rio de Janeiro, Brasil (Mammalia, Chiroptera). *Rev. bras. Zool.* 19: 113–140.
- Dias, D., C.E.L. Esbérard and A.L. Peracchi. 2008. Riqueza, diversidade de espécies e variação altitudinal de morcegos na Reserva Biológica do Tinguá, estado do Rio de Janeiro, Brasil (Mammalia, Chiroptera). In: (N.R. Reis, A.L. Peracchi and G.A.S. Santos, eds.) *Ecologia de Morcegos*. Editora Technical Books, Rio de Janeiro, Brazil. pp. 97–108.
- Dias, D., C.E.L. Esbérard and R. Moratelli. 2013. A new species of *Lonchophylla* (Chiroptera, Phyllostomidae) from the Atlantic Forest of southeastern Brazil, with comments on *L. boker-manni*. *Zootaxa* 3722: 347–360.
- Esbérard, C.E.L. 2003. Diversidade de morcegos em área de Mata Atlântica regenerada no sudeste do Brasil. *Rev. bras. Zool.* 5: 189–204.
- Esbérard, C.E.L. and C. Daemon. 1999. Um novo método para marcação de morcegos. *Chiropterol. Neotrop.* 5: 116–117.
- Esbérard, C.E.L., M. Baptista, L.M. Costa, J.L. Luz and E.C. Lourenço. 2010. Morcegos de Paraíso do Tobias, Miracema, Rio de Janeiro. *Biota Neotrop.* 10: 249–255.
- Esbérard, C.E.L., G.P. Freitas, J.L. Luz, K.M. Costa and L.N. Freitas. 2011. Intervalos máximos entre captura e recaptura de morcegos no estado do Rio de Janeiro, sudeste do Brasil. *Chiropterol. Neotrop.* 17: 957–962.

- Estrada, A. and R. Coates-Estrada. 2002. Bats in continuous forest, forest fragments and in an agricultural mosaic habitat-island at Los Tuxtlas, Mexico. *Biol. Conserv.* 103: 237–245.
- Godoy, M.S., W.D. Carvalho and C.E.L. Esbérard. 2014. Reproductive biology of the bat *Sturnira lilium* (Chiroptera, Phyllostomidae) in the Atlantic Forest of Rio de Janeiro, southeastern Brazil. *Braz. J. Biol.* 74: 913–922.
- Gomes, L.A.C., A.S. Pires, M.A. Martins, E.C. Lourenço and A.L. Peracchi. 2014. Species composition and seasonal variation in abundance of Phyllostomidae bats (Chiroptera) in an Atlantic Forest remnant, southeastern Brazil. *Mammalia* 79: 1564–1547.
- Gorresen, P.M. and M.R. Willig. 2004. Landscape responses of bats to habitat fragmentation in Atlantic Forest of Paraguay. *J. Mammal.* 85: 688–697.
- Hammer, Ø., D.A.T. Harper and P.D. Ryan. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontol. Elect.* 4: 1–9.
- IBGE (Instituto Brasileiro de Geografia e Estatística). 2012. Manual técnico da vegetação brasileira, 2ª ed. IBGE, Rio de Janeiro, Brazil. pp. 271.
- Kalko, E.K.V., CO. Handley Jr. and D. Handley. 1996. Organization, diversity, and long-term dynamics of a neotropical bat community. In (M.L. Cody and J.A. Smallwood, eds.) Long-term studies of vertebrate communities. Academic Press, New York, NY. pp. 503–553.
- Marques, J.T., M.J. Ramos-Pereira and J.M. Palmeirim. 2015. Patterns in the use of rainforest vertical space by Neotropical aerial insectivorous bats: all the action is up in the canopy. *Ecography* 38: 1–11.
- Mello, M.A.R., W.R. Silva and E.K.V. Kalko. 2008. Movements of the bat *Sturnira lilium* and its role as a seed disperser of Solanaceae in the Brazilian Atlantic forest. *J. Trop. Ecol.* 24: 225–228.
- Mello, M.A.R., E.K.V. Kalko and W.R. Silva. 2009. Ambient temperature is more important than food availability in explaining reproductive timing of the bat *Sturnira lilium* (Mammalia: Chiroptera) in a montane Atlantic Forest. *Can. J. Zool.* 87: 239–245.
- Menezes, Jr., L.F., A.C. Duarte, R.L.M. Novaes, A.C. Façanha, A.L. Peracchi, L.M. Costa, A.F.P. Fernandes and C.E.L. Esbérard. 2008. Deslocamento de *Artibeus lituratus* (Olfers, 1818) (Mammalia, Chiroptera) entre ilha e continente no Estado do Rio de Janeiro, Brasil. *Biota Neotrop.* 8: 243–245.
- Meyer, C.F.J. and E.K.V. Kalko. 2008. Assemblage-level responses of phyllostomid bats to tropical forest fragmentation: land-bridge islands as a model system. *J. Biogeogr.* 35: 1711–1726.
- Meyer, C.F.J., J. Fründ, W.P. Lizano and E.K.V. Kalko. 2008. Ecological correlates of vulnerability to fragmentation in Neotropical bats. *J. appl. Ecol.* 45: 281–391.
- Murcia, C. 1995. Edge effects in fragmented forests: Implications for conservation. *Trends Ecol. Evol.* 10: 50–56.
- Nogueira, M.R., I.P. Lima, A.L. Peracchi and N.B. Simmons. 2012. New genus and species of nectar-feeding bat from the Atlantic Forest of southeastern Brazil (Chiroptera, Phyllostomidae, Glossophaginae). *Am. Mus. Novit.* 3747: 1–30.
- Novaes, R.L.M. and C.C. Nobre. 2009. Dieta de *Artibeus lituratus* (Olfers, 1818) em área urbana na cidade do Rio de Janeiro: frugivoria e novo registro de folivoria. *Chiróp. Neotrop.* 15: 487–493.
- Novaes, R.L.M., F.A.P. Mello, S. Felix, R. Silveiras, A.C.S. Façanha, T.S. Cardoso, M.A.S. Louro, R.F. Souza, M.V.P. Aguiar, A.C. Siqueira and C.E.L. Esbérard. 2010. *Lonchophylla bokermanni* na Floresta Atlântica: distribuição, conservação e nova localidade de ocorrência para uma espécie ameaçada de extinção. *Chiróp. Neotrop.* 16: 710–714.
- Ortêncio-Filho, H., T.E. Lacher and L.C. Rodrigues. 2014. Seasonal patterns in community composition of bats in forest fragments of the Alto Rio Paraná, southern Brazil. *Stud. Neotrop. Fauna Environ.* 49: 1–11.
- Paglia, A.P., G.A.B. Fonseca, A.B. Rylands, G. Herrmann, L.M.S. Aguiar, A.G. Chiarello, Y.L.R. Leite, L.P. Costa, S. Siciliano, M.C.M. Kierulff, S.L. Mendes, V.C. Tavares, R.A. Mittermeier and J.L. Patton. 2012. Lista anotada dos Mamíferos do Brasil, 2ª ed. *Occ. Pap. Conserv. Biol.* 6: 1–76.
- Reis, N.R., A.L. Peracchi, I.P. Lima and W.A. Pedro. 2006. Riqueza de espécies de morcegos (Mammalia, Chiroptera) em dois diferentes habitats na região centro-sul do Paraná, sul do Brasil. *Rev. bras. Zool.* 23: 813–816.
- Ribeiro, M.C., J.P. Metzger, A.C. Martensen, J.C. Ponzoni and M.M. Hirota. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biol. Conserv.* 142: 1141–1153.
- Santos, M.C.F., R.L. Moura and A.A. Valente. 2007. Bromeliaceae no Maciço do Geracimó-Mendanha, Rio de Janeiro, Brasil. *Rev. Bras. Biociên.* 5: 63–65.
- Sazima, I. and E.A. Fischer. 1994. The fruit bat *Artibeus lituratus* as a forest and city dweller. *Ciênc. Cult.* 46: 164–168.
- Schulze, M.D., N.E. Seavy and D.F. Whitacre. 2000. A comparison of the phyllostomid bat assemblage in undisturbed Neotropical forest and in forest fragments of a Slash-and-Burn farming mosaic in Petén, Guatemala. *Biotrop.* 32: 174–184.
- SEMURAM (Secretaria Municipal de Urbanismo e Meio Ambiente da Cidade de Nova Iguaçu). 2001. Plano de manejo do Parque Natural Municipal de Nova Iguaçu. Prefeitura de Nova Iguaçu, Fundo Nacional do Ambiente, Instituto Estadual de Florestas do Rio de Janeiro, Nova Iguaçu, Brazil. pp. 101.
- Shao, J. and D. Tu. 1995. The jackknife and bootstrap. Springer, New York, NY. pp. 517.
- Sikes, R.S., W.L. Gannon and The Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. *J. Mammal.* 92: 235–253.
- Soulé, M.E. and B.A. Wilcox. 1980. Conservation biology: an evolutionary-ecological perspective. Sinauer and Associates, Sunderland, UK. pp. 395.
- Stevens, G.C. 1992. The elevational gradient in altitudinal range: an of rapport's latitudinal rule to altitude. *Am. Nat.* 140: 893–911.
- Straube, F.C. and G.V. Bianconi. 2002. Sobre a grandeza e a unidade utilizada para estimar esforço de captura com utilização de redes-de-neblina. *Chiróp. Neotrop.* 8: 150–152.
- Talora, D.C. and L.P.C. Morellato. 2000. Fenologia de espécies arbóreas em floresta de planície litorânea do sudeste do Brasil. *Rev. bras. Bot.* 23: 13–26.
- Teixeira, T.S.M., M.M. Weber, D. Dias, M.L. Lorini, C.E.L. Esbérard, R.L.M. Novaes, R. Cerqueira and M.M. Vale. 2014. Combining environmental suitability and habitat connectivity to map rare or Data Deficient species in the Tropics. *J. Nat. Conserv.* 22: 384–390.
- Timm, R.M. 1994. The mammals fauna. In: (L.A. McDade, K.S. Bawa, H.A. Hespenheide and G.S. Hartshorn, eds.) *La Selva: ecology*

- and natural history of a Neotropical rainforest. University of Chicago Press, Chicago and London, IL and UK. pp. 229–237.
- Varzinczak, L.H., I.P. Bernardi and F.C. Passos. 2016. Is the knowledge of bat distribution in the Atlantic Rainforest sufficient? Comments about new findings and a case study in the Paraná State coastal area, Brazil. *Mammalia* 80: 263–269.
- Velazco, P.M., R. Gregorin, R.S. Voss and N.B. Simmons. 2014. Extraordinary local diversity of disk-winged bats (*Thyropteridae*: *Thyroptera*) in northeastern Peru, with the description of a new species and comments on roosting behavior. *Am. Mus. Novit.* 3795: 1–28.
- Wilson, D.E. 1973. Bat faunas: a trophic comparison. *Syst. Zool.* 22: 14–29.
- Wilson, D.E., C.F. Ascorra and S.T. Solari. 1996. Bats as indicators of habitat disturbance. In: (D.E. Wilson and S.A. Sandoval, eds.) *Manu: the biodiversity of southeastern Peru*. Smithsonian Institution Press, Washington, DC. pp. 613–525.