Neotropical Biology and Conservation
12(2):91-99, may-august 2017
Unisinos - doi: 10.4013/nbc.2017.122.02

Rapid surveys as a key tool for the inventory of the bat fauna of Brazil: New records for the coastal restinga

Levantamentos rápidos como ferramenta-chave para o inventário da fauna de morcegos do Brasil: novos registros na restinga costeira

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Abstract

The restingas present a considerable variation in the floristic structure and composition along their latitudinal and morphoclimatic gradients. This variation may have a direct influence on the set of conditions and resources available for their biological communities, including mammals. The present study is the first to assess the bat fauna of a coastal restinga habitat in northeastern Brazil. The study site was the RPPN Caju in the municipality of Itaporanga D'Ajuda, Sergipe. We collected data on 10 consecutive days in 2014, using mist nets set at ground level, sampling a different point on each day. We captured 191 bats (16 species, 14 genera and 5 families), including the first records of *Saccopteryx leptura*, *Molossops temminckii* and *Eptesicus brasiliensis* for the coastal restinga. The latter two species were recorded for Sergipe for the first time. The recorded species richness is one of the highest yet recorded for Brazilian restinga. We increased the number of records of bat species in the Brazilian restinga from 38 to 41, and the number of species known to occur in Sergipe from 48 to 50. We recommend the "wandering" placement of mist nets as an effective strategy for the rapid assessment of bat communities.

Keywords: Chiroptera, *Eptesicus brasiliensis, Molossops temminckii, Saccopteryx leptura,* Sergipe.

Resumo

As restingas apresentam considerável variação na composição e estrutura florística ao longo do seu gradiente latitudinal e morfoclimático. Essa variação pode ter influência direta no conjunto de condições e recursos disponíveis para suas comunidades biológicas, incluindo os mamíferos. O presente estudo é o primeiro a avaliar a quiropterofauna da restinga do nordeste brasileiro. O local de estudo foi a RPPN Caju, no município de Itaporanga D'Ajuda, Sergipe. Foram realizados 10 dias consecutivos de amostragem, em 2014, usando redes de neblina no nível do solo. Em cada dia, foram amostrados pontos diferentes. Foram capturados 191 morcegos (16 espécies, 14 gêneros e 5 famílias), com destaque para os primeiros registros de *Saccopteryx leptura, Molossops temminckii* e *Eptesicus brasiliensis* para a restinga. As duas últimas espécies são registradas pela primeira vez para Sergipe. A riqueza registrada na RPPN representa uma das mais altas registradas na literatura para a restinga. Ampliamos o número de registros de espécies de morcegos para a restinga de 38 para 41, e o número de espécies conhecidas para Sergipe de 48 para 50. Recomenda-se a instalação errante de redes de neblina para avaliações rápidas das comunidades de morcegos.

Palavras-chave: Chiroptera, *Eptesicus brasiliensis, Molossops temminckii, Saccopteryx leptura*, Sergipe.

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Introduction

The Brazilian Atlantic Forest, known for its diversity and species endemism (Myers *et al.*, 2000), originally occupied the entire eastern coast of Brazil. In the present day, however, this biome has less than 15% of its original area (Ribeiro *et al.,* 2009). The Atlantic Forest is a coastal formation, influenced profoundly by marine and fluvial forces, resulting in the establishment of distinct plant communities, such as mangroves and coastal restinga. The restinga is associated with sandy coastal plains and dune fields (CONAMA, 1996). The composition of its plant communities vary according to the limitations imposed by the type of soil, ranging from strictly herbaceous or shrubby vegetation to forest (CONAMA, 1996).

The restinga vegetation can be considered a subset of the adjacent ecosystems, with few endemic species (Rizzini, 1997), resulting in considerable variation in the floristic structure and composition along the latitudinal and morphoclimatic gradients in which this ecosystem occurs (Gonzatti, 2015). This variation presumably has a direct influence on the set of conditions and resources available for the local animal communities, including mammals.

Similarly, only a subset of the bat species typically found in the Atlantic Forest are also encountered in neighboring areas of restinga (Nogueira *et al.,* 2010). In this case, while 115 bat species have been recorded in the Atlantic Forest (Paglia *et al*., 2012; Nogueira *et al*., 2014), only 38 species (26 genera from five families) are confirmed to date for the restinga (see Fogaça and Reis, 2008; Nogueira *et al.,* 2010; Luz *et al.,* 2011). However, all bat inventories in restinga habitats were carried on the southern Atlantic Forest.

The lack of knowledge about bat diversity extends to all Brazilian biomes throughout the country and makes it difficult to decide on priority areas for bat conservation efforts (Bernard *et al.*, 2010). In this sense, rapid inventories of bat diversity may contribute to the fulfillment of the gaps and provide high quality information in a short time (Martins *et al.*, 2006; Lourenço *et al.*, 2010).

Given this background, the present study is the first to assess the bat fauna of a coastal restinga habitat in the northern Atlantic Forest, in northeastern Brazil. We present new records of bat species for this ecosystem, and discuss the observed variation in the richness and composition of bat species along the Brazilian coast.

Methods

Study site

We conducted the present study in the Caju Private Natural Heritage Reserve (RPPN Caju; 11°6'10.12" S, 37°11'4.59" W; 763.37 ha), a protected area in the municipality of Itaporanga D'Ajuda, Sergipe, northeastern Brazil (Figure 1). The reserve, created in 2011, is part of the experimental campus of the local unit of the Brazilian Agri-

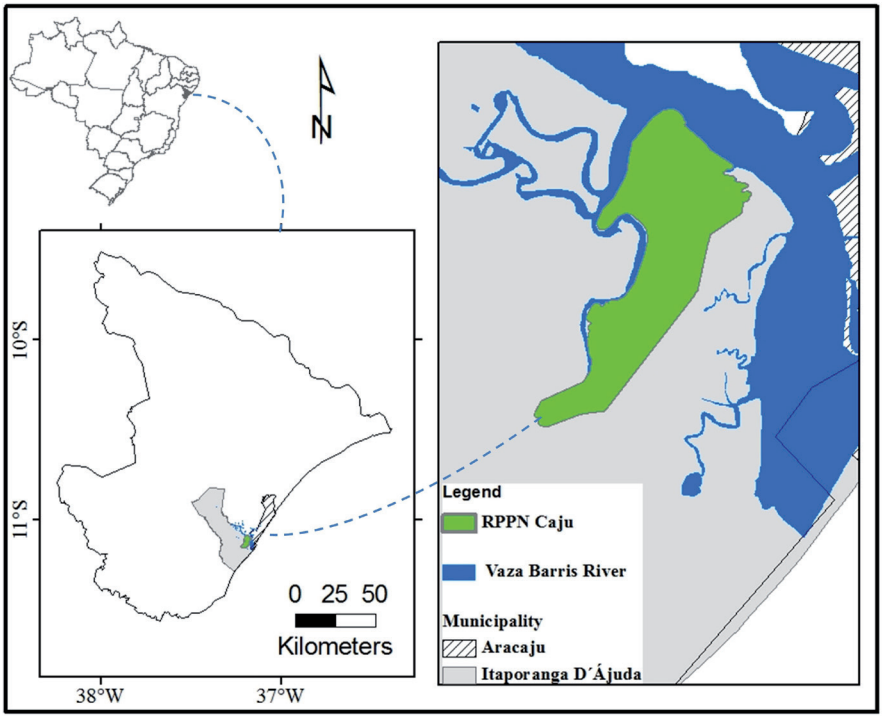

Figure 1. Location of the Caju Private Natural Heritage Reserve, in the municipality of Itaporanga D'Ajuda, Sergipe, northeastern Brazil.

cultural Research Company (EMBRAPA). The RPPN Caju comprises a variety of habitats associated with the Atlantic Forest biome, such as coastal restingas, mangroves, and salt flats, a typical profile of the coastal lowlands of Sergipe, and much of the northeastern Brazil (Silva *et al*., 2000).

The local soil is sandy and has a natural low fertility (Silva *et al*., 2000; Araujo Filho *et al*., 1999). The relief is predominantly flat or slightly undulating, while the mangroves are tidal (EMBRAPA, 2013). The climate is tropical megathermal with dry season in the summer, *As* in Köppen's classification (Alvares *et al*., 2013). The rainy season occurs typically between May and August.

Sampling

We conducted the bat survey on 10 consecutive days between October 21st and 31st, 2014 using mist net trapping (n = 10; 12 m x 2.5 m). We opened the mist nets at ground level from 5 p.m.h to midnight and checked them every 20 minutes. On each day, we also searched different points of the RPPN actively. When choosing the sampling points, we prioritized areas near flowering or fruiting plants, and water sources. We also searched for potential shelters, both to set up the mist nets at night or for active searches during the day.

We placed the captured bats in cotton bags and released most individuals after identification (based on Gardner, 2007), noting gender, age category, reproductive phase, forearm length and body mass. Before release, each individual was marked with a numbered metal band. Voucher specimens of each species were fixed with 10% formalin solution and preserved in wet medium (70% alcohol), before being deposited in the Mammal Collection of the Federal University of Sergipe (Appendix 1).

Data analysis

We calculated the sampling effort by multiplying the total area of the mist-nets by the number of hours they were kept open (Straube and Bianconi, 2002). Species were considered dominant if their relative abundance was higher than 1/S, where S = species richness (Uramoto *et al.,* 2005). We calculated the Jackknife1 species richness and plotted the cumulative species curves (observed and estimated) based on 1000 iterations (see Colwell and Coddington, 1994) in EstimateS 8.0 (Colwell, 2005). Finally, we classified the recorded species according to their trophic guild, based on Kalko *et al.* (1996), as insectivorous, frugivorous, nectarivorous, piscivorous or hematophagous.

Results

Total effort of mist-netting was 16.200 h.m^2, with an additional 30 hours of active search. We captured 191 bats (no recaptures) of 16 species (Figure 2), 14 genera and 5 families (Table 1). Active searches were unsuccessful. The richness estimated by Jackknife 1 was 21.33, with a significant difference (t = -16.68, df = 16, p = 0.0001) between the observed and expected richness, which reinforces the need to increase the sample effort (Figure 3).

Phyllostomidae was the most common family, with 179 captures (92.6% of total), followed by Molossidae (3.66%; n = 7), Vespertilionidae (1.57%; n = 3), Emballonuridae (01.05%; n = 2), and Noctilionidae (1.05%; n = 2). *Artibeus planirostris* (Spix 1823) was the most abundant species, with 29.8% of the captures (n = 57), followed by *Carollia perspicillata* (Linnaeus 1758) (28.2%; n = 54), *Platyrrhinus lineatus* (É. Geoffroy 1810) (7.8%; n = 15), *A. lituratus* (Olfers 1818) (7.3%; n = 14), and *Sturnira lilium* (É. Geoffroy 1810) (6.8%; n = 13). Together, these five species comprise 80.1% of captured individuals (Figure 4). On the other hand, nine species (56.2% of the total) were represented by five or less individuals. *Saccopteryx leptura* (Schreber 1774), *Molossops temminckii* (Burmeister 1854) and *Eptesicus brasiliensis* (Desmarest 1819) were recorded in the restinga for the first time, and the latter two species are also new records for the state of Sergipe.

Given the set of dominant species, frugivory was the most common trophic guild, representing 88.48% of the captured individuals (n = 169). The next most common habit was insectivory (7.85%; n = 15), followed by nectarivory (2.62%; n = 5) and piscivory (1.05%; n = 2).

Discussion

The bat species richness recorded in the present study (16 spp.) is one of the highest recorded for restinga habitats to date. The species richness recorded in previous restinga inventories ranges from two species – in the Maricá Environmental Protection Area (Cerqueira *et al.,* 1990) and in the municipality of Quissamã (Pessôa *et al.,* 2010), both in the state of Rio de Janeiro – to 16 species at Praia das Neves in Presidente Kennedy, Espírito Santo (Luz *et al.,* 2009). Mean species richness in all restinga inventories done in Brazil (n = 18) is 9.05 (SD ± 4.83) species, although sampling effort varies considerably among fieldworks, ranging from 350 h.m² (Pessôa *et al.,* 2010) to 127,500 h.m² (Rosa, 2004). In the present study, we placed mist-nets purposely in the largest possible number of habitats, in order to maximize the sampling of different microenvironments, and a larger number of habitat-dependent species. The efficiency of this strategy was reflected in the high species richness recorded, even though most species were represented by only one or a few (5 or less) specimens.

The present study confirms the predominance of phyllostomids in inventories with mist nets in the Neotropi-

Table 1. Bat species recorded in the Caju Private Natural Heritage Reserve (RPPN Caju) in Itaporanga D'Ajuda, Sergipe, northeastern Brazil, abundance and trophic guilds.

Taxon	Individuals	%	Trophic guild
Emballonuridae			
Peropteryx macrotis (Wagner 1843)	1	0.52	Insectivorous
Saccopteryx leptura (Schreber 1774)[1]	1	0.52	Insectivorous
Phyllostomidae			
Phyllostominae			
Lophostoma brasiliense Peters 1866	3	1.57	Insectivorous
Glossophaginae			
Glossophaga soricina (Pallas 1766)	5	2.62	Nectarivorous
Carolliinae			
Carollia perspicillata (Linnaeus 1758)	54	28.27	Frugivorous
Stenodermatinae			
Artibeus lituratus (Olfers 1818)	14	7.33	Frugivorous
Artibeus obscurus (Schinz 1821)	9	4.71	Frugivorous
Artibeus planirostris (Spix 1823)	57	29.84	Frugivorous
Dermanura cinerea Gervais 1856	7	3.66	Frugivorous
Platyrrhinus lineatus (É. Geoffroy 1810)	15	7.85	Frugivorous
Sturnira lilium (É. Geoffroy 1810)	13	6.81	Frugivorous
Noctilionidae			
Noctilio leporinus (Linnaeus 1758)	2	1.05	Piscivorous
Molossidae			
Molossops temminckii (Burmeister 1854)[1*]	2	1.05	Insectivorous
Molossus molossus (Pallas 1766)	5	2.62	Insectivorous
Vespertilionidae			
Vespertilioninae			
Eptesicus brasiliensis (Desmarest 1819)[1*]	2	1.05	Insectivorous
Myotinae			
Myotis nigricans (Schinz 1821)	1	0.52	Insectivorous
Total	191		

Notes: (1) New record for the coastal restinga ecosystem; (*) New record for the Brazilian state of Sergipe.

cal region, as well as those previously conducted in the restinga (Nogueira *et al.,* 2010). The Phyllostomidae is the most diverse family of Neotropical bats (Gardner, 2007) and capture is favored by placing mist nets at ground level, while emballonurids, molossids and vespertilionids have a more sophisticated echolocation system, which permits better detection of the nets (Fenton *et al.*, 1992; Simmons and Voss, 1998).

Despite the bias associated with the use of mist nets, the presence of emballonurids, represented by *Peropteryx macrotis* (Wagner 1843) and *Saccopteryx leptura*, appears to be unusual in the restinga. *Peropteryx macrotis* had been recorded previously at only one location, the Rio da Onça State Park in Paraná (Fogaça and Reis, 2008), while this is the first record of *S. leptura* in this type of environment.

Seven of the 16 species listed here (41.1%) appear to be common in restinga habitats. *Artibeus lituratus* has been recorded in 83.3% of previous inventories (n = 18), followed by *Glossophaga soricina* (Pallas 1766) (72.2%), *Myotis nigricans* (Schinz 1821) (72.2*%)*, *A. obscurus* (Schinz 1821) (55.6%) and *P. lineatus*, *S. lilium* and *C. perspicillata* (50.0%). Remarkably, we did not capture *A. fimbriatus* Gray 1838 in the RPPN Caju, despite the fact that this species has records for half of all previous inventories. In contrast, *A. planirostris* – the most abundant species in the present study – has records only for two other restinga locations, the Superagui National Park (n = 2) and the Rio da Onça State Park (n = 1), both in the state of Paraná (Fogaça and Reis, 2008). This contrast is related to the distribution of these species within the Atlantic Forest. While *A. fimbriatus* is common in the southern Atlantic Forest and rare in northeastern Brazil, *A. planirostris* has the opposite distributional pattern (Gardner, 2007).

Frugivorous species dominated (species richness and abundance) in the present study area, probably at least partly because of the sampling method (mist-netting) as mentioned above, which is typical of the Atlantic Forest (e.g.: Carvalho *et al.*, 2009; Gomes *et al.*, 2016; Luz *et al.*, 2009). *Noctilio leporinus* is the only piscivorous species

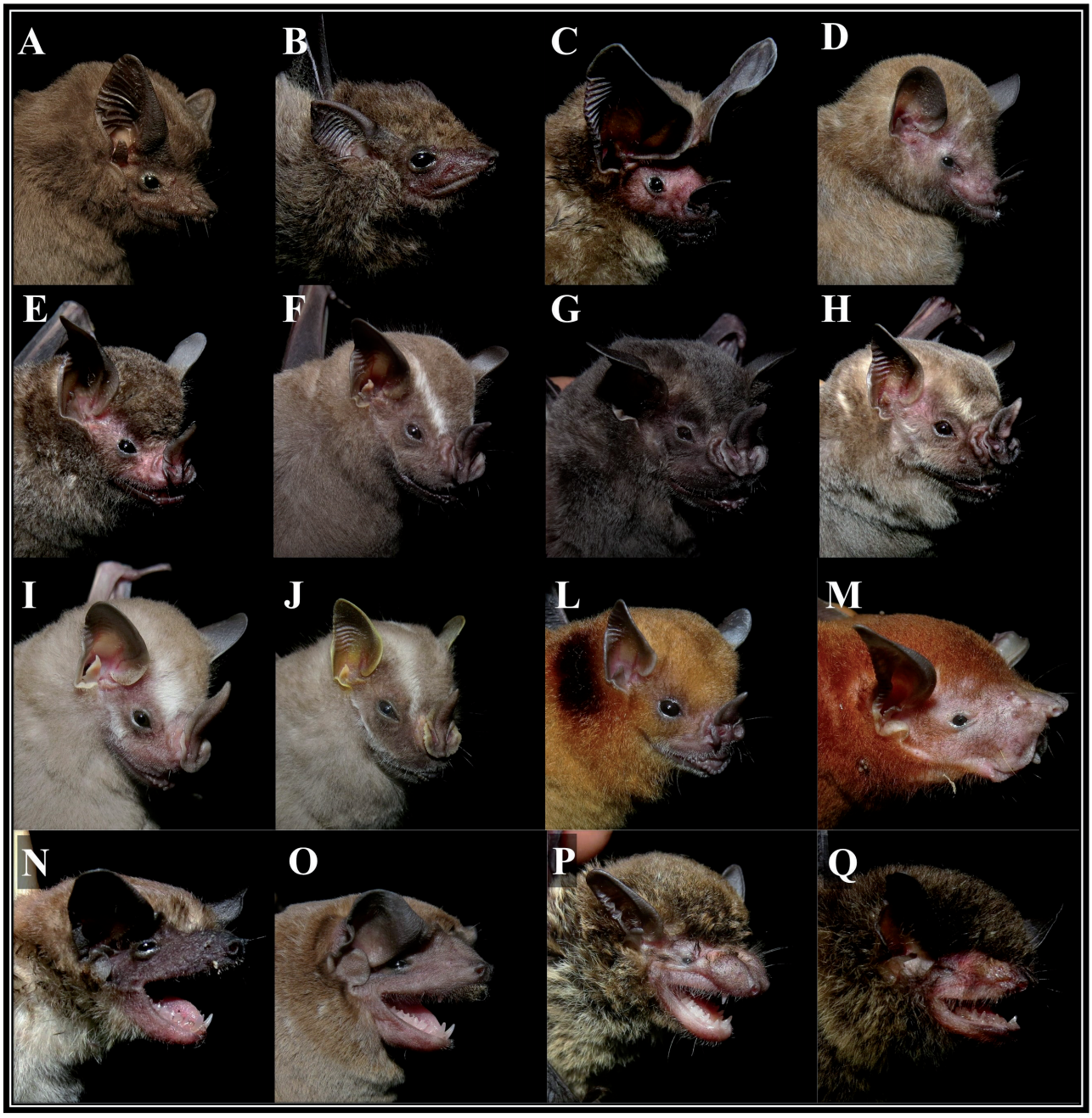

Figure 2. Bats recorded at the Caju Private Natural Heritage Reserve (RPPN Caju), at Itaporanga D'Ajuda, Sergipe, northeastern Brasil. (A) *Peropteryx macrotis*; (B) *Saccopteryx leptura*; (C) *Lophostoma brasiliense*; (D) *Glossophaga soricina*; (E) *Carollia perspicillata*; (F) *Artibeus lituratus*; (G) *Artibeus obscurus*; (H) *Artibeus planirostris*; (I) *Dermanura cinerea*; (J) *Platyrrhinus lineatus*; (L) *Sturnira lilium*; (M) *Noctilio leporinus*; (N) *Molossops temminckii*; (O) *Molossus molossus*; (P) *Eptesicus brasiliensis*; (Q) *Myotis nigricans*.

known to occur in the restinga and, despite being expected to occur in fluvial and marine environments, it has been recorded previously at only five locations (Oprea *et al.,* 2009; Luz *et al.,* 2009; Luz *et al.,* 2011).

The three new species recorded for the restinga (*S. leptura*, *M. temminckii* and *E. brasiliensis*) are rare in general, even in other Atlantic Forest systems, especially when sampled by mist-netting. These characteristics are similar to the other species that have been captured at only one restinga site, i.e., *Carollia brevicauda* (Schinz 1821) (Pessôa *et al.,* 2010), *Diaemus youngi* (Jentink 1893) (Luz *et al.,* 2011), *Diphylla ecaudata* Spix, 1823 (Fazzolari-Corrêa, 1995), *Lasiurus ega* (Gervais 1856) (Marques, 2000), *Myotis levis* (I. Geoffroy 1824) (Fazzolari-Corrêa, 1995),

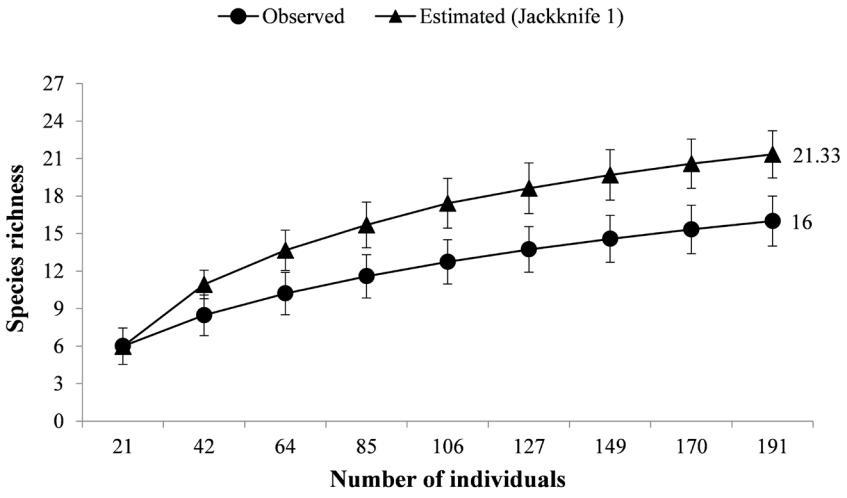

Figure 3. Observed and estimated (Jackknife 1) cumulative species curves (vertical lines = standard deviation) recorded in the Caju Private Natural Heritage Reserve in Itaporanga D'Ajuda, Sergipe, northeastern Brazil.

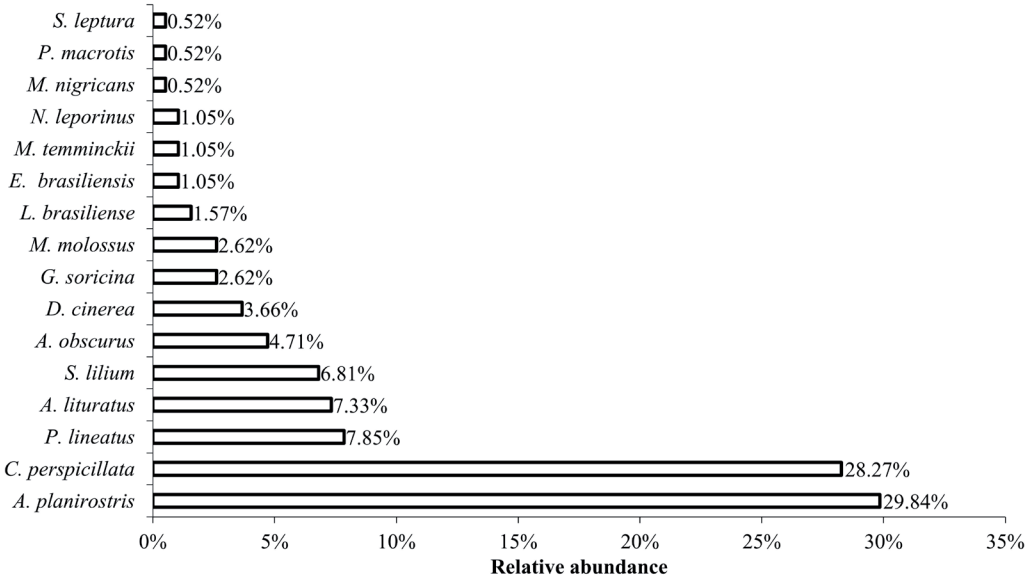

Figure 4. Relative abundances of the bat species recorded in the Caju Private Natural Heritage Reserve, in Itaporanga D'Ajuda, Sergipe, northeastern Brazil.

Tonatia saurophila Koopman & Williams 1951 (Luz *et al.,* 2009), *Tonatia bidens* (Spix 1823) (Martuscelli, 1995), and *Nyctinomops laticaudatus* (E. Geoffroy 1805) (Pacheco and Freitas, 2003).

All previous bat inventories in coastal restinga habitats have focused on sites in southern Brazil. The present study, at RPPN Caju, is the first for the Northeast. With the new records presented here, the total number of bat species known to occur in the restinga has increased to 41, and the number of genera to 28 genera (including *Saccopteryx* and *Molossops*). The records of *Molossops temminckii* and *Eptesicus brasiliensis* also increase the number of bat species known to occur in the state of Sergipe to 50 (Mikalauskas, 2005; Mikalauskas *et al.,* 2006, 2011, 2014; Ástua and Guerra, 2008; Feijó and Nunes, 2010; Rocha *et al.,* 2010, 2011, 2014a, 2014b, 2013, 2015, *in press*; Donato *et al.,* 2012; Brito and Bocchiglieri, 2012; Bocchiglieri *et al.,* 2016; Souza *et al.,* 2016; Bomfim *et al*., 2017).

Molossops temminckii is uncommon in inventories, and is known from little more than twenty localities in

Brazil, mostly in the Caatinga and Cerrado domains (Eger 2008; Nunes *et al.*, 2013). This record is nevertheless unexpected, as it is only the second in the northern extreme of the Atlantic Forest, approximately 500 km south of the first record in the Reserva Biológica Guaribas, Paraíba. Nunes *et al.* (2013) captured 16 individuals at this site, all in the canopy, indicating that this species is under-sampled in mist nets set at ground level.

No species of *Eptesicus* has been recorded previously in Sergipe. As in the case of *M. temminckii*, even considering the methodological bias, there are few records of *Eptesicus brasiliensis* from the Atlantic Forest of northeastern Brazil. The current record fills a gap of approximately 900 km between southern Bahia (Faria *et al.*, 2006) and the state of Paraíba (Feijó and Langguth, 2011).

These records indicate that rapid surveys can be an important inventory tool, especially in Brazil, where less than 10% of the country was minimally surveyed, and there are no records of bats at all from almost 60% of its territory (Bernard *et al.*, 2010). We also found that the "wandering" placement of mist nets, which were set at a different point each night, is a relatively effective approach to increase the number of bat species recorded, especially in rapid surveys. This approach was based on the assumption that capture rates tend to decline over time because the bats learn the locations of the nets, and are thus able to avoid capture (Larsen *et al.*, 2007; Marques *et al.*, 2013). The daily relocation of the nets may not only minimize this avoidance effect (Marques *et al.*, 2013), but also guarantee the sampling of new microhabitats, including roosts, bodies of water, and feeding patches, which may lead to an increase in capture rates.

In addition to complement the management plan of the RPPN Caju, which currently includes no data on the local bat diversity, the present study has advanced our understanding of the patterns of occurrence of bat species in restinga habitats, which are closely linked to the bat diversity of the surrounding region.

Acknowledgments

We thank two anonymous reviewers for their valuable comments on an earlier version of the manuscript. We are grateful to Dr. Lauro Rodrigues Nogueira Junior and Dr. Manoel Moacir Costa Macedo, for permission to use the intalations at RPPN Caju, and to Erivaldo Fonseca, for field support. We also thank CAPES, for doctoral and graduate stipends to DMD, SMS, VSM, NMA and LMCM, and CNPq, for post-doctoral fellowships to JR-E (151121/2014-1, 402582/2015-2), RB-M (503372/2014-5), and PAR (501701/2013-3, 150407/2015-7), and a research grant to SFF (303994/2011-8, 483220/2013). We are also grateful to Mohamed bin Zayed Species Conservation Fund (12055114), Primate Action Fund (1001257) and Primate Conservation Inc. (1158), for research support to RB-M and SFF.

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Submitted on August 24, 2016
Accepted on March 31, 2017

Appendix

List of bats from the Caju Private Natural Heritage Reserve (RPPN Caju) in Itaporanga D'Ajuda, Sergipe, northeastern Brazil, deposited in the Mammal Collection of the Conservation Biology Laboratory at the Federal University of Sergipe, and the respective voucher numbers.

Taxon	Individuals collected	Vouchers
Peropteryx macrotis	1	CMUFS283
Saccopteryx leptura	1	CMUFS275
Lophostoma brasiliense	1	CMUFS263
Glossophaga soricina	1	CMUFS268
Artibeus obscurus	1	CMUFS269
Artibeus planirostris	1	CMUFS280
Dermanura cinerea	2	CMUFS265; CMUFS267
Platyrrhinus lineatus	2	CMUFS270; CMUFS271
Noctilio leporinus	1	CMUFS264
Molossops temminckii	2	CMUFS274; CMUFS279
Molossus molossus	1	CMUFS278
Eptesicus brasiliensis	1	CMUFS277
Myotis nigricans	1	CMUFS272