Ilha Grande, one of the locations with the most records of bat species (Mammalia, Chiroptera) in Rio de Janeiro state: results of a long-term ecological study

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Abstract. Faunal inventories provide quantitative and qualitative data for different sites and are relevant sources of information for identifying areas of high species richness and endemism. Biological collections are important in this context for increasing the precision of species identification. The objectives of this study were to update the list of bat species of Ilha Grande by analyzing specimens in zoological collections as well as records obtained in areas where no such studies had been undertaken before; to compare five different studies conducted on Ilha Grande using mist net sampling; and to compare the results of studies on Ilha Grande with sampling results from other areas in Rio de Janeiro state. The occurrence of 36 bat species was confirmed for Ilha Grande. Five studies on Ilha Grande formerly conducted by the authors were compared with 34 fauna inventories in Rio de Janeiro state. The studies on Ilha Grande had distinct objectives and sampling techniques applied to different locations in the same area. Ilha Grande is one of the regions in Rio de Janeiro state with more bat records both in terms of abundance and number of species, as well as one of the areas of highest bat capture effort.

Keywords. Atlantic Forest; Inventory; RAPELD; Richness; Zoological collections.

INTRODUCTION

Knowledge on biological diversity is considered essential for planning conservation actions, as these depend on understanding species distribution and systematics as well as aspects related to community ecology, demography and natural history (Santos, 2003; Silveira et al., 2010). Fauna inventories provide quantitative and qualitative data (Owen, 2000), therefore being relevant sources of information for identifying areas of high richness and endemism (Remsen, 1994; Blackburn & Gaston, 1998; Myers et al., 2000). Species inventories form a substantial part of studies on mammals in Brazil (Brito et al., 2009).

The Order Chiroptera represents the second most studied taxon among mammals in Brazil (Brito et al., 2009). Bats are considered well studied in Atlantic Forest ecosystems (Bernard et al., 2011). There is a long history of scientific inventories in the biome, a larger concentration of researchers and scientific institutions, and more financial resources compared with other regions in Brazil (see Lewinsohn & Prado, 2005; Brito et al., 2009). Although survey gaps remain in several regions in the country, bats may be considered well...
studied in Rio de Janeiro state, in southeastern Brazil (Bergallo et al., 2003; Peracchi & Nogueira, 2010; Stevens, 2013). Secondary studies in this region can therefore be useful to synthesize data in search of new evidence.

Different techniques may be used in chiropterofauna inventories. Capture methods used in inventories must be efficient in capturing the largest number of species. The method most commonly used in the Neotropical region for bat capture is to set mist nets in probable bat flight routes in the forest undergrowth (Kunz & Kurta, 1988; Estrada et al., 2004). Mist nets are efficient for capturing bats in the Phyllostomidae family, especially for frugivore bats (Sipinski & Reis, 1995; Pedro & Taddei, 1997; Kalko, 1998). The efficiency of the method is low for insectivore bats in families Emballonuridae, Thyropteridae, Vespertilionidae, and Molossidae (Voss & Emmons, 1996; Simmons & Voss, 1998), as insectivore species tend to fly higher and avoid the nets by using echolocation (Kunz & Kurta, 1988; Voss & Emmons, 1996).

The selective quality of mist nets can be minimized by sampling design. Alternatives have been used in different studies to increase capture of insectivore bats or of bat species that fly above the forest undergrowth. Mist nets are set in the higher forest strata or above water (e.g., Carvalho & Fabián, 2011; Costa et al., 2012). Sampling design can also influence bat abundance, not only species richness, and be directed at certain species or groups of species. Mist nets set near fruit-bearing trees would increase capture of frugivorous species, for example (Kalko, 1998). Methodological variations can lead to detecting more species or capturing more bats in an area, but total local density may interfere with capture rates (e.g., Fleming, 1988). Capture effort is another relevant variable for increasing the knowledge of species in an area, being strictly related to richness (Bergallo et al., 2003).

Ilha Grande is recognized as one of the areas of highest bat richness and abundance in the state of Rio de Janeiro due to intensive capture efforts in different regions (see Bergallo et al., 2003; Esbérard et al., 2006). The first list of bat species of Ilha Grande, compiled in 1988, included seven species (Fernandez et al., 1988). Later Esbérard et al. (2006) updated these records, listing 36 species. However, some areas on the island, especially in the forest interior and at elevations higher than 250 meters, had not been well studied before 2014 despite high capture efforts in other areas (Esbérard et al., 2006). Additionally, new bat species have been described for Ilha Grande in recent years and taxonomic issues on Chiroptera in Brazil were resolved. For these reasons, a taxonomic review of bats of Ilha Grande was needed to provide a more precise estimate of bat diversity on the island. The objectives of this study were, therefore, to (i) compile an updated list of bat species of Ilha Grande by conducting studies in areas that had not been well studied and reviewing the taxonomic identification of voucher specimens; (ii) compare different studies formerly conducted on Ilha Grande; (iii) compare studies conducted on Ilha Grande with studies in other areas in Rio de Janeiro state.

**MATERIAL AND METHODS**

**Study area**

Ilha Grande is located in Ilha Grande Bay, in the municipality of Angra dos Reis. It is the third largest island in Brazil (INEA, 2020), and the largest in Rio de Janeiro state. The shortest distance to the continent is approximately 2 km (Araújo & Oliveira, 1988). Protected areas are established on 156 km² (81% of the insular surface) of the total 193 km² of Ilha Grande (Ilha Grande State Park and Praia do Sul Biological Reserve, INEA, 2013) in the category of strict protection. The climate is tropical, hot and humid, subject to rainfall all year round, with higher concentration in the summer and lower in winter, and no dry season (INEA, 2013). The variation in average temperature is low throughout the year. July is the coldest month (20.2 °C), and February, the hottest (26.4 °C) (INEA, 2013). The forests on Ilha Grande are classified as Dense Ombrophilous Forest (Atlantic Forest) in the Brazilian Classification System (INEA, 2013). Dense secondary forests in intermediate and advanced stages of succession cover about 80% of the island. The remaining areas are forests in early successional stages, coastal scrub (restinga), vegetation on rock outcrops, and mangroves (INEA, 2013). Ilha Grande contains some of the best preserved remnants of the Atlantic Forest biome in Brazil, being therefore considered an ecological sanctuary. The relevance of local ecosystems led to the inclusion of Ilha Grande in the Atlantic Forest Biosphere Reserve in 1992 (INEA, 2020). It was more recently declared a UNESCO Natural Heritage Site on 05 July, 2019.

**Data collection**

Bat capture and data generation are results of different projects of the Mammal Ecology Lab (Laboratório de Ecologia de Mamíferos – LEMA) of the Rio de Janeiro State University (Universidade do Estado do Rio de Janeiro – UERJ). These five studies on bats conducted on Ilha Grande were not published independently in scientific journals. Some of the data gathered in studies 1, 2, 3, and 4 (described below) were included in the study by Esbérard et al. (2006). While other exclusive results by Esbérard et al. (2006) were not used in the present study, as they are not data from LEMA.

The bats captured in all studies were released on the same site of capture. Bats were initially identified in the field with the use of field guides and identification keys available in the scientific literature (mainly, Emmons & Feer, 1997; Gregorin & Taddei, 2002; Reis et al., 2007; Gardner, 2008; Reis et al., 2013). A few individuals of each species were collected for voucher material (see Table 1). Voucher specimens captured in studies 1, 2, 3, and 4 were deposited in the collection of the old Urban Bats Project (Projeto Morcegos Urbanos), currently the reference collection of the Bat Diversity Lab (Laboratório de Diversidade de Morcegos – LADIM) of the Federal Rural University of Rio de Janeiro (Processos 1785/89-IBAMA.)
Table 1. Updated list of bat species of Ilha Grande, Angra dos Reis, Rio de Janeiro state, Brazil, with reference to voucher specimens. Nomenclature and taxonomic arrangement according to Garbino et al. (2020).

| TAXA | VOUCHER MATERIAL |
|------|-------------------|
| **Family Emballonuridae** | |
| *Peropteryx macrotis* (Wagner, 1843) | LADIM 3836 |
| **Family Phyllostomidae** | |
| *Micronycteris micros* Miller, 1898 | LADIM 3466, 4019; ALP 10843 |
| *Desmodus rotundus* (É. Geoffroy, 1810) | LADIM 10841, 11045 |
| *Chiropterus auritus* (Peters, 1856) | ALP 10842 |
| *Phyllostomus hastatus* (Pallas, 1767) | LADIM 4045 |
| *Tatania bidens* (Spix, 1823) | ALP 10844, 10943 |
| *Trachops cirrhosus* (Spix, 1823) | ALP 10580 |
| *Anoura caudifer* (É. Geoffroy, 1818) | ALP 10939 |
| *Anoura geoffroyi* Gray, 1838 | ALP 11026, 11038 |
| *Glialis bispinis* (Pallas, 1766) | ALP 10937 |
| *Lanchochelys penacchi Dias, Esbrérid e Moratelli, 2013* | ALP 10924 |
| *Carollia perspicillata* (Linnaeus, 1758) | ALP 10845, 11023 |
| *Nyctinomops laticaudata* (Linnaeus, 1758) | ALP 10940 |
| *Nyctophilus nitrignus* (Schinz, 1821) | ALP 10850 |
| *Nycteris watsoni* (Peters, 1860) | ALP 10840, 10841 |
| *Artibeus lituratus* (É. Geoffroy, 1818) | ALP 10842 |
| *Artibeus obscurus* Schinz, 1891 | ALP 10840, 10841 |
| *Chiroderma donoris* Thomas, 1891 | ALP 10844, 10943 |
| *Chiroderma villosus* Peters, 1860 | ALP 10580 |
| *Platyrrhinus lineatus* (É. Geoffroy, 1810) | ALP 10939 |
| *Platyrrhinus recifensis* (Thomas, 1901) | ALP 10845 |
| *Pseudophyllus bilobatus* (Wagner, 1843) | ALP 10928, 10944 |
| *Vampyrodes caraccioli* (Thomas, 1898) | ALP 10841 |
| *Vampyrodes pusilla* | |
| **Family Noctilionidae** | |
| *Nyctinomops laticaudata* (Linnaeus, 1758) | |
| *Nycticeius helicus* (Cuvier, 1822) | |
| **Family Furipteridae** | |
| *Furipterus horrens* | |
| **Family Molossidae** | |
| *Nyctimene irrorata* (Linnaeus, 1758) | |
| **Family Vespertilionidae** | |
| *Lasiusus ege* (Gervais, 1856) | |
| *Myotis albescens* (É. Geoffroy, 1810) | |
| *Myotis nigris* (Schinz, 1821) | |
| *Myotis riparius* Handley, 1960* | |

Fieldwork for study 1 was conducted during three consecutive nights per month between January, 1998, and December, 1999, totaling 72 survey nights. Two to five mist nets were set every night (sizes varying from 6 × 3 meters to 12 × 3 meters) and deployed for a period of six hours. Capture effort was estimated at a minimum of 15,552 h.m² and a maximum of 77,760 h.m² (Straube & Bianco, 2002), with an average of 46,656 h.m². The sampling sites (one per night) were the Caxadaço trail, Parnaioca trail and Dois Rios Village (Fig. 1). Sampling was carried out in well conserved habitats and under varied climatic conditions that included wind and rain, and covered all phases of the lunar cycle. Mist nets were set in areas with higher likelihood of bat capture according to recommendations by Kunz & Kurta (1988), such as close to the entrance of caves, over rivers, along trails, faults, rocky formations, tree hollows, and under flowering or fruit-bearing trees.

Fieldwork for study 2 was conducted between May, 2001, and April, 2002. Six field surveys were carried out, each one during one, three or four nights, totaling 19 survey nights. Two to five mist nets (sizes varying from 7 × 3 meters to 12 × 3 meters) were deployed between four and seven hours from twilight, totaling 17,518 h.m² of capture effort. The sampling sites were located in Dois Rios Village, Parnaioca Village, Abraão Village and on Praia Grande de Palmas (Fig. 1). The position of mist nets was defined using the same criteria as in study 1.

Fieldwork for study 3 was conducted between September, 2002, and August, 2005, with sampling undertaken in three consecutive nights, totaling 33 survey nights. Mist nets were set in the same position during the three nights of the survey. Six mist nets were deployed every night (12 × 3 meters) from twilight to dawn, totaling 85,536 h.m² of capture effort. Eleven areas were covered: Matariz Village, Saco do Céu, Enseada das Estrelas, Abraão Village, Praia Grande de Palmas, Farol dos Castelhanos, Praia de Lopes Mendes, Caxadaço, Dois Rios Village, Dois Rios Village trail – Parnaioca, Parnaioca and SISBIO-10356-1). The voucher material of study 5 was deposited in the reference collection of the Mastozoology Lab (Laboratório de Mastozoologia Dr. Adriano Lúcio Peracchi – ALP) of the Federal Rural University of Rio de Janeiro (Universidade Federal Rural do Rio de Janeiro – UFRJ) (Permanent IBAMA License Nº 12548 and Nº 10361; SISBIO Nº 45702-4; INEA Nº 63/2015; CEUA Nº 008/2018).

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Results

Updated list of bat species and capture results from five different studies of Ilha Grande

We confirmed the occurrence of 36 bat species on Ilha Grande (Table 1). We add five species to the Ilha Grande bat list: Glyphonycteris sylvestris, Platyrrhinus reicipinus, Vampyromos caraccioli, Myotis ikehoshii, and M. riparius. We removed seven species from the previous list: Artibeus planirostris, Lonchophylla mordax, Lonchophylla bokermanni, Micronycteris minutia, Micronycteris mega lotis, Uroderma magnirostrum, and Nyctinomops macrotis.

Considering the five studies together, a total of 2,763 individuals of 32 species in 23 genera and five families were captured. The most abundant species on the island...
were C. perspicillata, with 735 captures, and A. fimbriatus, with 485 captures. Bats of two species were only captured once, P. macrotis and M. izecksohni. Eleven species were common to the five studies: C. perspicillata, A. fimbriatus, Sturnira lilium, A. obscurus, Artibeus lituratus, A. caudifer, T. bidens, Platyrrhinus lineatus, M. nigricans, Lonchophylla peracchii, and C. doriae (Table 2).

Chromologically, 20 species were registered in the first study; two species added from the second study, and only one species from the third study. Four more species were added from study 4, with C. auritus, Artibeus cinereus, and P. recifinus captured exclusively in mist nets in the canopy, and Sturnira tildae only in a mist net at ground level. Five other species were added from study 5. All five studies have therefore contributed species for the bat list of Ilha Grande (Table 2).

The Jaccard Similarity Index between the five studies on Ilha Grande demonstrated a variation of $C_J = 0.48$ to 0.87. Studies 1 and 3 had more similar results (87%), followed by studies 2 and 3 (74%) (Table 3).

### Table 2. Bat abundance in five studies conducted between 1998 and 2018 on Ilha Grande, Angra dos Reis, Rio de Janeiro state, Brazil. In parentheses, number of recaptures in studies that cite this data. Total capture number includes recapture.

| Taxa                                    | Study 1 (1998-1999) | Study 2 (2001-2002) | Study 3 (2002-2005) | Study 4 (2004-2007) | Study 5 (2014-2018) | TOTAL |
|-----------------------------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-------|
| **Family Emballonuridae**               |                     |                     |                     |                     |                     |       |
| Peropteryx macrotis                     | 0                   | 0                   | 1                   | 0                   | 0                   | 1     |
| **Family Phyllostomidae**               |                     |                     |                     |                     |                     |       |
| Micronycteris microtis                  | 2                   | 0                   | 3                   | 0                   | 13                  | 18    |
| Desmodus rotundus                      | 13                  | 2                   | 16                  | 0                   | 3                   | 34    |
| Chiropterus auritus                     | 0                   | 0                   | 0                   | 1                   | 5                   | 6     |
| Phyllostomus hastatus                  | 4                   | 0                   | 25                  | 0                   | 0                   | 29    |
| Tonatia bidens                         | 16                  | 7                   | 9                   | 2                   | 12                  | 46    |
| Trachops cirrhosus                     | 4                   | 3                   | 8                   | 0                   | 16                  | 31    |
| Anoura caudifer                        | 19                  | 6                   | 9                   | 1                   | 6 (1)               | 42    |
| Anoura geoffroyi                       | 0                   | 0                   | 0                   | 0                   | 0                   | 6     |
| Glossophaga soricina                   | 16                  | 0                   | 4                   | 1                   | 4                   | 25    |
| Lonchophylla penacchii                 | 8                   | 2                   | 4                   | 3                   | 7                   | 24    |
| Carollia perspicillata                 | 225                 | 65                  | 161                 | 18                  | 219 (27)            | 735   |
| **Family Phyllostomidae**               |                     |                     |                     |                     |                     |       |
| Micronycteris microtis                  | 0                   | 0                   | 0                   | 0                   | 2                   | 2     |
| Artibeus cinereus                      | 0                   | 0                   | 0                   | 0                   | 4                   | 6     |
| Artibeus fimbriatus                    | 203                 | 25                  | 81                  | 84 (8)              | 80 (4)              | 485   |
| Artibeus lituratus                     | 33                  | 3                   | 31                  | 23 (1)              | 25                  | 116   |
| Artibeus obscurus                      | 139                 | 46                  | 99                  | 32 (3)              | 148 (6)             | 473   |
| Artibeus sp.                           | 41                  | 4                   | 8                   | 17 (1)              | 0                   | 71    |
| Chiroderma doriae                      | 3                   | 1                   | 7                   | 7                   | 4                   | 22    |
| Chiroderma villosum                    | 1                   | 0                   | 2                   | 0                   | 2                   | 5     |
| Phyllostomus lineatus                  | 13                  | 5                   | 9                   | 3                   | 8                   | 38    |
| Phyllostomus recifinus                 | 0                   | 0                   | 0                   | 3                   | 8                   | 11    |
| Pygoderma blabiatum                    | 1                   | 0                   | 1                   | 10                  | 0                   | 12    |
| Sturnira lilium                        | 161                 | 33                  | 76                  | 11                  | 4                   | 285   |
| Sturnira tildae                        | 0                   | 0                   | 0                   | 2                   | 5                   | 7     |
| Vampyressa pusilla                     | 0                   | 4                   | 7                   | 2                   | 4                   | 17    |
| Vampyrophiles caraccioli               | 0                   | 0                   | 0                   | 3                   | 3                   | 3     |
| **Family Noctilionidae**                |                     |                     |                     |                     |                     |       |
| Noctilio leporinus                     | 1                   | 33                  | 42                  | 0                   | 0                   | 76    |
| **Family Molossidae**                  |                     |                     |                     |                     |                     |       |
| Molossus flavipes                      | 0                   | 2                   | 2                   | 0                   | 0                   | 4     |
| Molossus molossus                      | 4                   | 16                  | 42                  | 0                   | 0                   | 62    |
| **Family Vespertilionidae**            |                     |                     |                     |                     |                     |       |
| Myotis izecksohni                      | 0                   | 0                   | 0                   | 0                   | 1                   | 1     |
| Myotis nigricans                       | 12                  | 10                  | 18                  | 4                   | 1                   | 45    |
| Myotis riparius                        | 0                   | 0                   | 0                   | 0                   | 25                  | 25    |
| **Total capture**                      | 919                 | 267                 | 665                 | 226 (13)            | 635 (38)            | 2.763 |
| **Accumulated capture**                | 919                 | 1.186               | 1.851               | 2.090               | 2.763               | —     |
| **Total species**                      | 20                  | 17                  | 23                  | 18                  | 26                  | 32    |
| **Accumulated species**                | 20                  | 22                  | 23                  | 27                  | 32                  | —     |
| **Exclusive species**                  | 0                   | 0                   | 1                   | 0                   | 5                   | —     |
| **Capture effort (h.m²)**              | 46.656              | 17.518              | 85.536              | 82.944              | 257.790             | 490.444 |
| **Capture efficiency**                 | 0.020               | 0.015               | 0.008               | 0.003               | 0.003               | 0.006 |

* = Total capture divided by capture effort.
Table 3. Jaccard Similarity Index between five different studies conducted between 1998 and 2018 on Ilha Grande, Angra dos Reis, Rio de Janeiro state, Brazil.

|       | Study 1 | Study 2 | Study 3 | Study 4 | Study 5 |
|-------|---------|---------|---------|---------|---------|
| Study 1 | 1.00    |         |         |         |         |
| Study 2 | 0.68    | 1.00    |         |         |         |
| Study 3 | 0.87    | 0.74    | 1.00    |         |         |
| Study 4 | 0.52    | 0.52    | 0.52    | 1.00    |         |
| Study 5 | 0.53    | 0.48    | 0.53    | 0.63    | 1.00    |

Comparison between studies on Ilha Grande and other studies in Rio de Janeiro state

A total of 39 studies containing lists of bat species in Rio de Janeiro state were reviewed (Table 4 and Fig. 2). The best studied location was Maciço da Tijuca, with six sampling sites. Five studies conducted on Ilha Grande were assessed. Two studies conducted at different periods in time were found for each of the locations Pedra Branca State Park and Tinguá Biological Reserve. One single inventory was found for each of the other locations.

The highest number of Phyllostomidae bat species was registered in the Tinguá Biological Reserve, with 25 species in the family (Table 4, Figs. 3A and 3B). At the same time, it accounted for the highest capture effort of all studies (268,473 h.m²) (Table 4, Figs. 3A and 3B). Study 5 on Ilha Grande is among the richest in Phyllostomidae, with 23 species (Table 4, Figs. 3A and 3B). The study with the highest capture success was conducted at Quinta da Boa Vista, with 2,994 captures (Table 4, Figs. 3A). The linear regression between capture effort and richness was also significant, as well as positive (r² = 0.648 – Fig. 3A). The linear regression between capture effort and richness was significant (r² = 0.337; F = 4.732; p = 0.036), but the best fit was generated from a quadratic model (r² = 0.648 – Fig. 3A). The linear regression between capture effort and richness was also significant, as well as positive (r² = 0.546; F = 24.078; p < 0.001, Fig. 3B). This confirmed that the higher the number of captures and capture effort, the higher the richness encountered.

DISCUSSION

The confirmation that 36 bat species occur on Ilha Grande implies that the island hosts 18% of the bat species known in Brazil (Garbino et al., 2020), 37% of the species in the Atlantic Forest (Muyllaert et al., 2017), and 46% of the species known in Rio de Janeiro state (Peracchi & Nogueira, 2010; Moratelli et al., 2011; Dias et al., 2013; Delciellos et al., 2018).

Species lists must be regularly updated because new species are continually described and recorded in Brazil due to taxonomic revisions (e.g., Moratelli et al., 2011; Dias et al., 2013; Garbino et al., 2020). In addition, there are species that are difficult to identify and can be confused with other species such as G. sylvestris (Nogueira et al., 2007) and species of the genus Myotis (López-González et al., 2001; Moratelli et al., 2011).

Myotis izecksohni was described after publication of the first list of bat species of Ilha Grande (Esbérrard et al., 2006). Records of M. izecksohni have shown that it occurs between 600 and 1,300 meters a.s.l. (Moratelli et al., 2011; Reis et al., 2013; Dias et al., 2015). Bats of this species were captured during study 5 on Ilha Grande at 408 meters a.s.l., which indicates that it can occur at lower altitudes than formerly stated.

Based on taxonomic reviews of bat voucher material collected in studies by Esbérard et al. (2006), the occurrence of seven species was not confirmed on Ilha Grande. They were therefore removed from our list. Some species, such as A. planirostris, M. minuta, N. macrotis and U. magnoirostrum, are reported for the Costa Verde region, in the municipalities of Mangaratiba or Angra dos Reis (Bozilan et al., 2010; Delciellos et al., 2018). Specimens registered by Esbérard et al. (2006) as M. megalotis correspond to M. microtis. Specimens formerly identified on the island as L. mordax and L. bokermanni correspond to L. peracchi, the only species of Lonchophyllinae registered in the state of Rio de Janeiro (see Dias et al., 2013).

The five studies conducted by the authors on Ilha Grande and described in this paper amount to a total capture effort of 490,444 h.m², one of the largest ever applied to a single area in Rio de Janeiro state. Considering all five studies, the species more often captured were C. perspicillata and A. fimbriatus, which together represented almost half the total captures (44.15%). These two most abundant species on Ilha Grande are also among the most frequent and most captured bat species in the Atlantic Forest domain (Muyllaert et al., 2017). As Esbérard et al. (2006) had already observed, the record of A. fimbriatus as the second most abundant species differs from other locations surveyed in Rio de Janeiro state, where A. lituratus is most often more abundant (e.g., Dias et al., 2002; Luz et al., 2011a; Esbérard et al., 2013; Lourenço et al., 2014; Souza et al., 2015). Although the five studies conducted on the island were based on the use of mist nets, the sampling points and some criteria for defining the location of these points differed. In studies 1 and 2, mist nets were set in probable bat flight routes (Kunz & Kurta, 1988), resulting

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Species lists must be regularly updated because new species are continually described and recorded in Brazil due to taxonomic revisions (e.g., Moratelli et al., 2011; Dias et al., 2013; Garbino et al., 2020). In addition, there are species that are difficult to identify and can be confused with other species such as G. sylvestris (Nogueira et al., 2007) and species of the genus Myotis (López-González et al., 2001; Moratelli et al., 2011).

Myotis izecksohni was described after publication of the first list of bat species of Ilha Grande (Esbérrard et al., 2006). Records of M. izecksohni have shown that it occurs between 600 and 1,300 meters a.s.l. (Moratelli et al., 2011; Reis et al., 2013; Dias et al., 2015). Bats of this species were captured during study 5 on Ilha Grande at 408 meters a.s.l., which indicates that it can occur at lower altitudes than formerly stated.

Based on taxonomic reviews of bat voucher material collected in studies by Esbérard et al. (2006), the occurrence of seven species was not confirmed on Ilha Grande. They were therefore removed from our list. Some species, such as A. planirostris, M. minuta, N. macrotis and U. magnoirostrum, are reported for the Costa Verde region, in the municipalities of Mangaratiba or Angra dos Reis (Bozilan et al., 2010; Delciellos et al., 2018). Specimens registered by Esbérard et al. (2006) as M. megalotis correspond to M. microtis. Specimens formerly identified on the island as L. mordax and L. bokermanni correspond to L. peracchi, the only species of Lonchophyllinae registered in the state of Rio de Janeiro (see Dias et al., 2013).

The five studies conducted by the authors on Ilha Grande and described in this paper amount to a total capture effort of 490,444 h.m², one of the largest ever applied to a single area in Rio de Janeiro state. Considering all five studies, the species more often captured were C. perspicillata and A. fimbriatus, which together represented almost half the total captures (44.15%). These two most abundant species on Ilha Grande are also among the most frequent and most captured bat species in the Atlantic Forest domain (Muyllaert et al., 2017). As Esbérard et al. (2006) had already observed, the record of A. fimbriatus as the second most abundant species differs from other locations surveyed in Rio de Janeiro state, where A. lituratus is most often more abundant (e.g., Dias et al., 2002; Luz et al., 2011a; Esbérard et al., 2013; Lourenço et al., 2014; Souza et al., 2015).

Although the five studies conducted on the island were based on the use of mist nets, the sampling points and some criteria for defining the location of these points differed. In studies 1 and 2, mist nets were set in probable bat flight routes (Kunz & Kurta, 1988), resulting
Figure 3. Relationship between number of species in the Phyllostomidae family (A) and number of captures in the Phyllostomidae family, (B) and capture effort (h.m²) in bat inventories in Rio de Janeiro state. Numbers correspond to locations listed in Table IV. Dots: cross = study 1 on Ilha Grande; square = study 2 on Ilha Grande; star = study 3 on Ilha Grande; triangle = study 4 on Ilha Grande; black circle = study 5 on Ilha Grande; grey circle = other studies in Rio de Janeiro state.
in the surveys with highest capture efficiency. In studies 3, 4, and 5, we did not choose specific points to set the mist nets. In study 3, the nets were set systematically, while in study 5 we used the method of uniform distribution plots. Only study 4 included sampling efforts in the tree canopy.

Comparisons between studies are of high relevance to science, contributing to the understanding of patterns of habitat use or even functioning as parameters of efficiency, especially when different methods are used. Setting mist nets in the forest canopy, the method used in study 4, is an alternative to survey bat species not easily captured in nets set at ground level (e.g., Carvalho & Fabián, 2011). Knowledge on the use of the canopy by bats is still incipient in Brazil (Scultori et al., 2008), where most studies of the kind have been conducted in the Amazon, often leading to the addition of exclusive species only registered when this method is applied (e.g., Kalko & Handley, 2001; Bernard, 2001). Considering the chronology of studies on Ilha Grande, positioning mist nets at canopy height led to the addition of three species. Although the capture rates of C. auritus, A. cinereus and P. recifinus were low, these species are often captured at ground level, as in study 5. Setting mist nets in the canopy increased the capture rate of species that might otherwise have been considered rare if surveys had been restricted to ground level (Esbérard et al., 2006; Bolzan et al., 2010).

Even if capture rate was already high in former years, study 5, the most recent one (from 2014 to 2018),
contributed more species records to the list of Ilha Grande. The RAPELD methodology used in this study (Magnusson et al., 2005) recommends sampling to be carried out in areas away from human settlements or roads (where research is often conducted), removing the bias of where researchers believe capture rate will be higher. Adoption of this methodology directed sampling to be performed in areas not considered in former studies (Esbérard et al., 2006), as well as at higher altitudes.

Areas in the Atlantic Forest where records of bats varied from 20 to 40 species and more than 1,000 Phyllostomidae individuals were captured may be considered well studied (e.g., Esbérard, 2003; Bergallo et al., 2003). By applying these parameters to the studies assessed in this paper, we found that more than 20 species were only registered in nine studies in Rio de Janeiro state, while more than 1,000 Phyllostomidae bats were captured only in three of these nine studies (Lourengo et al., 2014; Souza et al., 2015; Luz et al., 2011a). Capture rate may be related to local bat density, but it can also be influenced by the methods used (Fleming, 1988; Kunz & Kurta, 1988; Esbérard, 2006, 2007, 2009).

Long capture efforts are required to assess the real richness of a location (Voss & Emmons, 1996; Bergallo et al., 2003). A large effort may be represented by the increase of survey nights and/or capture hours, or by the number and surface area of mist nets (Morrison, 1978, 1980; Straube & Bianconi, 2002). The two studies in Rio de Janeiro state that stand out due to a capture effort of more than 200,000 h.m² are among the richest (25 and 23 species) (Lourengo et al., 2014; study 5 on Ilha Grande). Short inventories most often do not include species that are difficult to capture or that are considered rare; such species may be captured in long-term ecological studies or when higher capture efforts than usual are applied (Esbérard, 2009).

So that more consistent data for conservation studies are obtained (see Bernard et al., 2011), it is important that the lists are updated regularly, as new species are being described and registered as a result of taxonomic reviews and new inventories. (e.g., Moratelli et al., 2011; Nogueira et al., 2012; Dias et al., 2013; Nascimento et al., 2013; Delciellos et al., 2018). Lists of species that provide the capture quantity are important, as variation in abundance has been applied in species management and conservation biology (Brown et al., 1995).

CONCLUSIONS

Given the results of our study, we reiterate the relevance of specimen collection for vouchers in zoological collections. The analysis and confirmation of taxonomic identification of specimens a posteriori in the light of current knowledge depends on voucher specimens and is essential to increase the knowledge of species diversity in different areas. Bats captured on Ilha Grande and deposited in zoological collections allowed us to review the identification of specimens as well as to remove species whose identification had not been confirmed from the list of bat species of Ilha Grande.

Complementarily, Ilha Grande is a location with a long history of research with logistical support by the Center for Environmental Studies and Sustainable Development (CEADS, acronym in Portuguese) of the State University of Rio de Janeiro (UERJ, acronym in Portuguese), located in Dois Rios Village. This explains the number of studies conducted by different coordinators with various objectives described in this paper. It has also contributed to the fact that Ilha Grande is one of the areas in the state of Rio de Janeiro with more bat records in terms of abundance and species richness, as well as one of the areas with highest capture effort.

The use of capture effort measures may be considered efficient to compare species richness in the Phyllostomidae family. For comparisons between studies, however, the use of this variable alone may be a problem because the sampling design of the surveys will influence the total richness registered at the sampling site. When studies on Ilha Grande were compared with others in the state, we noticed variations in richness and in abundance due to the methods used, with some species exclusive to certain studies. Besides, several publications do not include capture effort data, or calculate capture effort differently from the recommendation by Straube & Bianconi (2002), used in this study.

Implementation of the RAPELD methodology and taxonomic identification supported by voucher specimens in zoological collections made it possible to add new species records for Ilha Grande. Still, other new species records may be expected for the island, once sampling of bat species not commonly captured in mist nets has not been intensive. A methodology for insectivore bats, such as the use of bioacoustics, may increase the richness of bat species on Ilha Grande even more. In addition to the 36 species confirmed in this study, other four species for which voucher specimens were not available may be considered for Ilha Grande based on spatial distribution data.

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AUTHORS’ CONTRIBUTIONS

Each author made a relevant contribution to the present manuscript, performed a critical revision, and approved the final version. L.M.C.: Fieldwork (in charge of study 5 on Ilha Grande); organization, analysis and data interpretation; manuscript development. E.C.L.: Fieldwork (study 5 on Ilha Grande); organization, data analysis and interpretation; manuscript development. D.A.D.J.: Fieldwork (studies 1 and 2 on Ilha Grande); manuscript development. D.D.: Taxonomic identification of voucher specimens; manuscript development. C.E.L.E.: Fieldwork (studies 1 and 2 on Ilha Grande); manuscript development. T.J.-N.: Fieldwork (study 3 and in charge of study 4 on Ilha Grande); organization of data. G.M.: Fieldwork (in charge of studies 1, 2, and 3 on Ilha Grande); organization of data. H.G.: Fieldwork (studies 1 and 2 on Ilha Grande); data analysis and interpretation; manuscript development.

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