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ARTICLE

Using MacKinnon lists and mist-netting simultaneously: maximizing the efficiency of rapid surveys of bird populations in the Atlantic Forest of northeastern Brazil

Helon Simões Oliveira[1,4], Mônica Aparecido Pedroso[1], José Weverton Santos[1], Arivania Santos Pereira[1], Juan Ruiz-Esparza[2], Patrício Adriano da Rocha[3], Raone Beltrão-Mendes[1] & Stephen Francis Ferrari[1]

[1] Department of Ecology, Federal University of Sergipe. Av. Marechal Rondon, s/n, 49100-000, São Cristóvão, SE, Brazil.
[2] Nucleus of Education and Agrarian Sciences, Federal University of Sergipe, Campus do Sertão, Rodovia Engenheiro Jorge Neto, km 3, Silos, 49680-000, Nossa Senhora da Glória, SE, Brazil.
[3] Postgraduate Program in Biological Sciences (Zoology), Department of Systematics and Ecology, Federal University of Paraíba, Cidade Universitária, 58051-900, João Pessoa, PB, Brazil.
[4] Corresponding author: helonbio@hotmail.com

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ABSTRACT: The Brazilian Atlantic Forest has been transformed into a mosaic of forest fragments that impacts local populations of vertebrates, in particular birds. In the state of Sergipe, Brazil, while only approximately 10% of the original forest remains, ornithological research is still incipient, and basic data are still lacking. In this context, the present study investigated the bird community of a remnant of Atlantic Forest in the municipality of Japoatã using complementary methods in a rapid survey approach. The composition of the community and its trophic guilds was defined and compared with other localities in Sergipe, and Atlantic Forest sites in other Brazilian states. Data were collected in October 2016, by mist-netting and the compilation of MacKinnon lists. A total of 118 bird species were recorded during 1088 net-h and in 60 MacKinnon lists. Four of these species are under some risk of extinction, and one of these is endemic to the region. The most diverse families were Thraupidae, Tyrannidae, Trochilidae, and Thamnophilidae, with the relative contribution of each family varying according to the the sampling method used. The most common species were *Manacus manacus* (Linnaeus, 1766) and *Coereba flaveola* (Linnaeus, 1758). The omnivores were the largest guild (n = 301 individuals), followed by the insectivores (n = 236) and the frugivores n = 146). The combined survey approach proved effective, increasing the number of bird species known to occur in the study area to 165, with an increase of more than 40% in comparison with previous surveys in the same area. Overall, the results of the present study reinforce the need for further ornithological surveys in the region, and the value of combining complementary approaches for a more comprehensive inventory during rapid surveys.

KEY-WORDS: avifauna, bird conservation, MacKinnon lists, mist-netting, trophic guilds.

INTRODUCTION

The Atlantic Forest originally covered more than 1.3 million square kilometers of the eastern coast of Brazil (Fundação SOS Mata Atlântica & INEP 2016), and is now considered to be one of the world's 35 biodiversity conservation hotspots (Williams *et al.* 2011). The Atlantic Forest extends over more than 20 degrees of latitude, ranging from equatorial to subtropical regions, which generates a considerable diversity of habitats and ecosystems (Tabarelli *et al.* 2005) that contributes to its considerable biodiversity (Myers *et al.* 2000, Faria *et al.* 2006, Pereira & Alves 2007). This biome has suffered extensive deforestation, and ongoing impacts have reduced its cover to no more than 15% of its original area (Fundação SOS Mata Atlântica & INEP 2016). In the Brazilian state of Sergipe, the Atlantic Forest, which originally covered almost half of the state, has been reduced to approximately 10% of its original area. The municipality of Japoatã, location of the present study, was the state's third most degraded in 2000–2014, and currently has only 9.6% of its original forest cover (Fundação SOS Mata Atlântica & INEP 2015).

The expansion of farmland and urban development typically transforms forests into a mosaic of habitats (Gascon *et al.* 2000, Guerra *et al.* 2015), with forest fragments persisting within a matrix of agricultural land. In Sergipe, this matrix is often composed of plantations of sugarcane (*Saccharum* sp.) and eucalypt (*Eucalyptus* sp.). The fragmentation of the forest has a number of negative impacts, including an increase in edge effects, and exposure to fires and chemical substances, such as herbicides, applied to the surrounding matrix (Gascon *et al.* 2000, Piratelli *et al.* 2005, Pereira &

Alves 2007). Dário *et al.* (2002) concluded that habitat fragmentation is especially problematic where dispersal is interrupted, the habitat is of poor quality or the fragments are too small to support viable populations. Dislich *et al.* (2001) emphasize the need for inventories for the understanding of the dynamics of these impacted environments.

Birds are an important component of tropical forest ecosystems (Ortega *et al.* 2003), and almost two thousand different species are found in Brazil (Piacentini *et al.* 2015). A total of 891 species are found in the Atlantic Forest (Moreira-Lima 2013), of which, 213 are endemic, and 147 are considered to be under some risk of extinction. Forest-dwelling birds are especially vulnerable to habitat fragmentation, whereas the populations of more generalist species may increase in response to the expansion of the agricultural matrix and edge effects (Piratelli *et al.* 2005).

The variation in the ecological characteristics of birds, such as their life history and behavior, and the relatively ease of collecting reliable field data make these animals useful indicators of environmental impacts, and they are often the principal focus in studies of environmental monitoring (Uezu *et al.* 2005). In Brazil, a number of studies have demonstrated the impacts of environmental degradation on the diversity of bird communities (Anjos & Boçon 1999, Gimenes & Anjos 2000, Dário *et al.* 2002, Piratelli *et al.* 2005, Faria *et al.* 2006, Paglia 2007, Franz *et al.* 2010), although few data are available on the bird fauna of the state of Sergipe (Sousa 2009, Ruiz-Esparza *et al.* 2015).

Ecological research in the Neotropical region is often hampered by both the complexity of the ecosystems and the scarcity of resources and trained personnel (MacLeod *et al.* 2011). In this context, a rapid survey approach can be extremely lucrative, especially when a relatively large volume of data can be obtained during a short period of time (MacLeod *et al.* 2011, Cavarzere *et al.* 2012, Ruiz-Esparza *et al.* 2016). The present study evaluated the effectiveness of combining complementary approaches, specifically mist-netting and MacKinnon lists (Bibby *et al.* 1998, Ribon 2010), for the collection of data during rapid surveys, in the Atlantic Forest of eastern Sergipe. While both methods provide relatively robust samples of bird diversity, mist-netting tends to provide records of more cryptic, understory species rarely recorded in MacKinnon lists, whereas these lists provide records of many, typically larger, high-flying species, that are almost never captured in mist-nets. The two methods were evaluated separately, and as a combined approach for the inventory of the bird fauna of the Fazenda Santana, a large sugarcane plantation in the municipalities of Japoatã and Pacatuba.

METHODS

Study area

Data were collected between 20–29 October 2016, in remnants of seasonal semi-deciduous Atlantic Forest in eastern Sergipe, Brazil. The study site is located on the Fazenda Santana (10°32'S; 36°45'W), a sugarcane plantation administered by the Brazilian Sugar and Alcohol Company (CBAA), in the municipalities of Japoatã and Pacatuba (Fig. 1).

The local climate is humid coastal, with annual

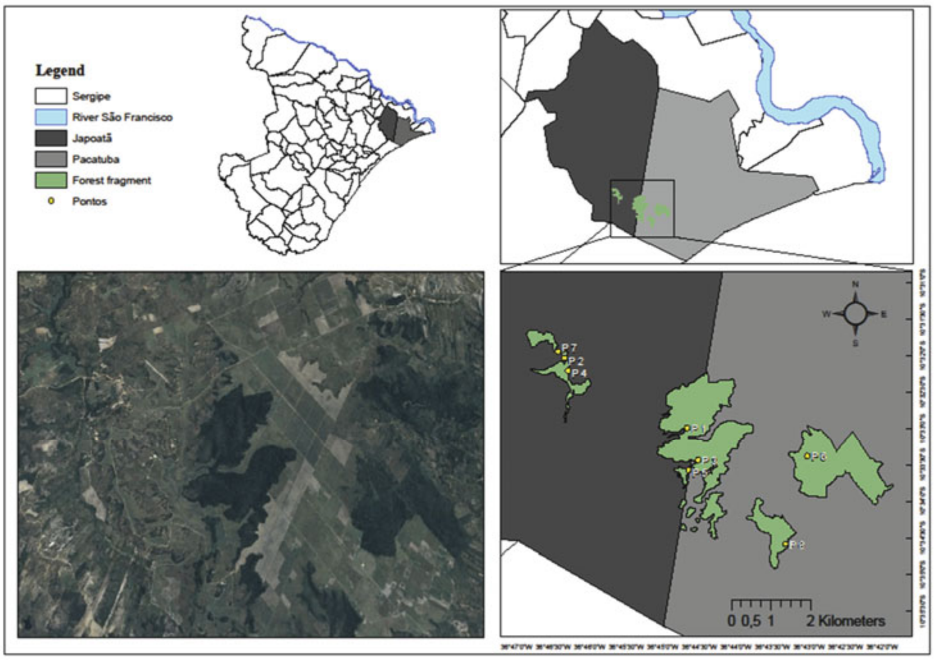

Figure 1. Location of the sampling points on the Fazenda Santana, in the municipalities of Japoatã and Japaratuba, in Sergipe, Brazil.

precipitation of between 1000 mm and 1400 mm (Santos 2009, Aragão *et al.* 2013). The forest patches of the Fazenda Santana straddle the border between the municipalities of Japoatã and Pacatuba, with a total area of approximately 700 ha, surrounded by a matrix of sugarcane. Most of the forest is secondary, having suffered repeated impacts from deforestation and successive sugarcane harvests, which involve the burning off of the plantations prior to harvesting the cane (Sousa 2009).

Data collection

Two complementary techniques were used simultaneously to collect data on the avian fauna of the study area – mist-netting and MacKinnon lists (MacKinnon & Phillipps 1993). A total of 12 mist-nets (12 m × 2.5 m, total area of 360 m^2) were set at eight different sampling points (Fig. 1) to sample the different habitats found within the study area (fragment edge and interior, open and closed habitats). The nets were set along pre-existing trails in morning (05:00–10:00 h) and afternoon (15:00–19:00 h) sessions, and were monitored every 20 min for the prevention of deaths (Ruiz-Esparza *et al.* 2012). The time of capture of each individual in the mist-nets was recorded, for the analysis of daily activity patterns.

All birds captured were ringed with standardized aluminum bands provided by the Brazilian Center for Avian Research and Conservation, CEMAVE (authorization 3905), processed according to the CEMAVE (1994) protocol, and then released at the capture site. Each bird was removed from the net, and placed in a cotton bag to be weighed using Pesola® spring balances (models 10100 and 41000). Prior to the release of each specimen, fecal samples were collected in eppendorf tubes containing 10% formaldehyde for the analysis of the composition of the diet, used to classify guilds. The collection of all biological material was authorized by the Brazilian Federal Biodiversity Information System (SISBIO), through license number 8286-1.

The MacKinnon lists were collected following the recommendations of Ribon (2010), with lists of 10 species being compiled. The birds were identified by an experienced ornithologist using binoculars (8 × 40) and a field guide (Sigrist 2015), supported by vocalizations, whenever appropriate.

While somewhat limited, the inventory of Sousa (2009) was used as a baseline for the compilation of species occurrences, together with the study of Ruiz-Esparza *et al.* (2015). The taxonomy was based on the Brazilian list of Ornithological Records (Piacentini *et al.* 2015), and the conservation status of the species was obtained from IUCN (2017). Birds that were observed or heard outside the systematic sampling were recorded as present at the study site, but they were not included in the statistical analyses.

Data analysis

The relative frequency (Fr) of each species or guild captured in the mist-nets was determined by $Fr = (n/T)*100$, where n = the number of individuals of the target species/group, and T = the total number of individuals recorded in the sample. For the MacKinnon lists, the relative frequency (*IFL*: Index of Frequency in the Lists) was determined by $IFL = (l/Lt)*100$, where l = the number of lists in which the species appears, and Lt = the total number of MacKinnon lists obtained during the study period.

The Jackknife I estimator was used to estimate the total species richness of the study area. This procedure was run in EstimateS 9.1.0 (Colwell *et al.* 2012). Rarefaction curves were also plotted in PAST (Hammer *et al.* 2001) to verify the relative effectiveness of the different survey methods. A cluster analysis based on the Jaccard coefficient was also run in PAST to compare the results of the present study with those of previous surveys in Sergipe (Sousa 2009, Ruiz-Esparza *et al.* 2015).

The species were classified in trophic guilds based on the available data (Wilman *et al.* 2014), together with foraging observations in the field and fecal analyses recorded during the present study. The species were classified in eight guilds: Carnivore (C), Frugivore (F), Granivore (G), Insectivore (I), Nectarivore (N), Scavengers (S), Omnivore (O), and Piscivore (P). The relative abundance of each guild was calculated as above, and the biomass of each group was also determined.

RESULTS

The mist-netting resulted in a total of 1088 net-h of sampling, during which a total of 280 individuals were captured, representing 61 species belonging to 23 families. The Thraupidae was the most diverse family, with 13 species, followed by the Tyrannidae (6 species), and the Trochilidae (5 species). These three families together accounted for 39.3% of the species captured in mist-nets. The Jackknife 1 analysis estimated a total of 89 species for the study area based on these data (Fig. 2), which was statistically different from the number actually recorded (t = -8.35; P = 0.0001).

A total of 599 individuals were recorded in 60 MacKinnon lists, representing 97 species in 33 families. Once again, the Thraupidae was the most diverse family (15 species), followed by the Tyrannidae (10 species), Trochilidae (8 species), and Thamnophilidae (6 species), which together contributed 40.2% of all sightings. The Jackknife 1 analysis of the data estimated a total of 120 species for the study area (Fig. 3), significantly different from the number actually observed (t = -8.69; P = 0.0001). The reduced number of MacKinnon lists is a result of

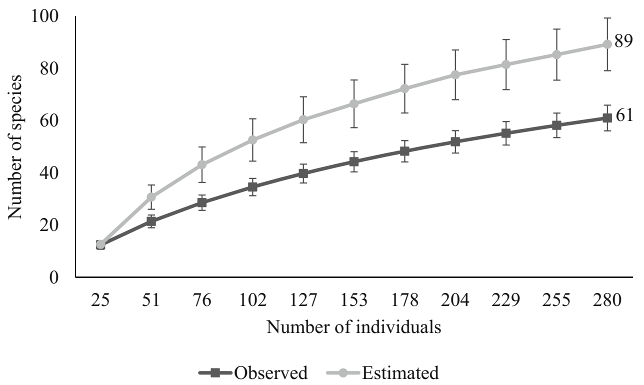

Figure 2. Bird species richness observed and estimated according to the Jackknife 1 procedure, based on the records collected during mist-netting at Fazenda Santana in Japoatã and Pacatuba, Sergipe, Brazil. The records are based on a total of 1080 net-h of sampling effort.

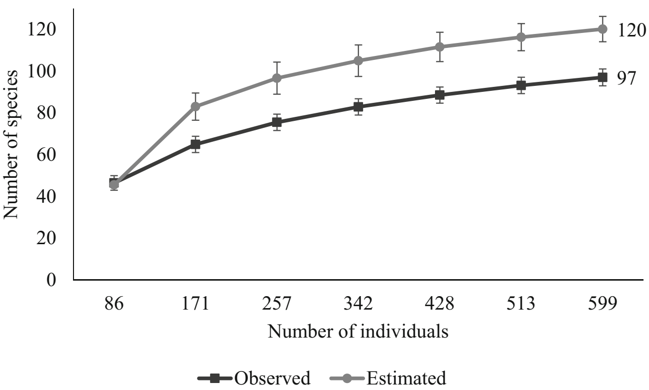

Figure 3. Bird species richness observed and estimated according to the Jackknife 1 procedure, based on the records collected in the MacKinnon lists at Fazenda Santana in Japoatã and Pacatuba, Sergipe, Brazil. Each sample point consists of six lists.

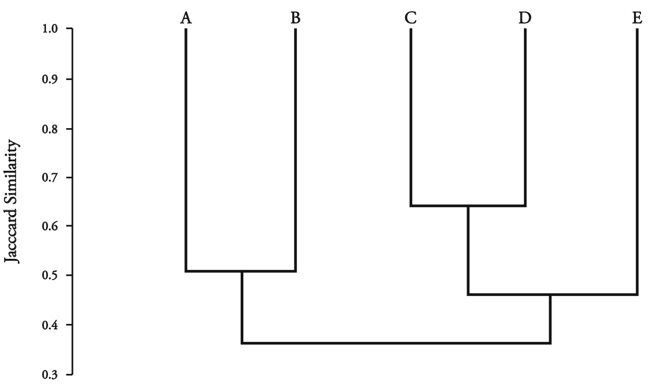

Figure 4. Cluster plot based on the Jaccard similarity index. A = Fazenda Santana (present study); B = Mata do Junco (Ruiz-Esparza *et al.* 2015); C = Mata da Santana (Sousa 2009); D = Mata do Junco (Sousa 2009); E = Mata do Crasto (Sousa 2009).

the low species richness of the study site. However, the number of lists compiled during the present study was more than proportional to the study period, given that approximately 200 lists have been compiled during six other, more recent excursions to the study area (unpub. data).

The cluster analysis (Fig. 4) indicated a relatively high degree of similarity between the results of the present study and those of Ruiz-Esparza *et al.* (2015) at the Mata do Junco reserve (Jaccard index J' = 0.506), located in the municipality of Capela, which borders Japoatã (Fig. 4B). All other studies returned indices of less than 0.4 for the comparison with the present study, and Mata do Crasto, located in the southern extreme of Sergipe, was the least similar (J' = 0.319), which is consistent with its geographic distance from the present study site (Fig. 4). The rarefaction curves plotted for the two methods used in the present study (MacKinnon lists and mist-netting) indicated that the MacKinnon lists provided a more effective inventory of the local avifauna, with an additional 36 species being recorded during the course of the study period (Fig. 5).

A further six species – *Aramides cajaneus* (Statius-Muller, 1776), *Crypturellus noctivagus* (Wied, 1820), *Euscarthmus meloryphus* Wied, 1831, *Nyctibius griseus* (Gmelin, 1789), *Pseudastur polionotus* (Kaup, 1847), and *Pyriglena atra* (Swainson, 1825) – were recorded only during non-systematic observations. Of the total of 118 species recorded at the Fazenda Santana during the present study, only four are listed by the IUCN (2017), two (*C. noctivagus* and *P. polionotus*) are listed as "Near Threatened", one (*Herpsilochmus pectoralis* Sclater, 1857) as "Vulnerable", and one (*P. atra*) as "Endangered".

The most abundant species captured in the mist-nets were *Manacus manacus* (Linnaeus, 1766) (*n* = 60 records; 21.4% of the total), *Dacnis cayana* (Linnaeus, 1766) (n

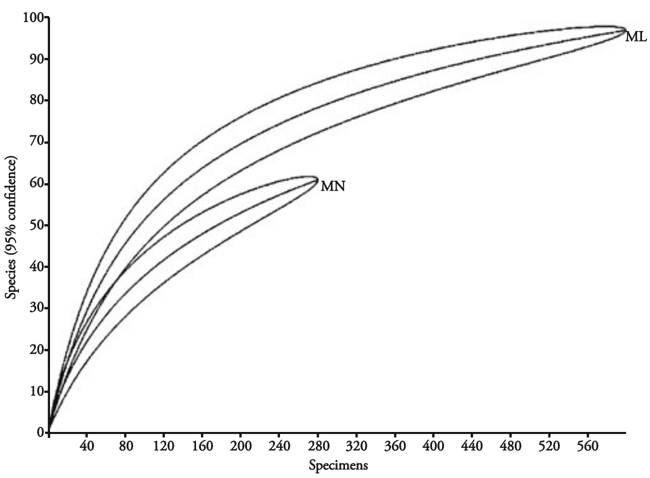

Figure 5. Rarefaction curves comparing the two survey methods used in the present study. ML = MacKinnon lists; MN = Mist-nets.

= 25; 8.9%), *Tangara cayana* (Linnaeus, 1766) (*n* = 17; 6.1%), *Turdus leucomelas* Vieillot, 1818 (*n* = 14; 5.0%), *Hydropsalis albicollis* (Gmelin, 1789) (*n* = 12; 4.3%) and *Tachyphonus rufus* (Boddaert, 1783) (*n* = 12; 4.3%). Together, these six species contributed almost half of all the individuals captured (Table 1).

The most common species recorded in the MacKinnon lists were *Coereba flaveola* (Linnaeus, 1758) (IFL = 46.7%), *Amazona aestiva* (Linnaeus, 1758) (IFL = 41.7%), *Cyclarhis gujanensis* (Gmelin, 1789) (IFL = 36.7%), *Tangara palmarum* (Wied, 1821) (IFL = 33.3%), *Columbina talpacoti* (Temminck, 1810) (IFL = 31.7%), and *D. cayana* (IFL= 31.7%). All other species were recorded less frequently (Table 1).

Based on the timing of the captures in the mist-nets, the birds were most active during the early morning (5:00–10:00 h), when 73.9% of the captures were recorded (during 55.5% of the sampling effort). During the afternoon sessions (15:00–19:00 h), 26.1% of the individuals were captured. After sunset (18:00 h), only birds with nocturnal habits were captured in the mist-nets (Fig. 6).

Considering all records (mist-net captures and MacKinnon lists), the largest guild was that of the omnivores, with 301 individuals (34.2% of the total), followed by the insectivores (*n* = 236; 26.8%), frugivores (*n* = 146; 16.6%), granivores (*n* = 94; 10.6%), nectarivores (*n* = 68; 7.7%), carnivores (*n* = 24; 2.7%), scavengers (*n* = 9; 1.0%), and piscivores (*n* = 1 or 0.1%) (Fig. 7). A similar pattern was recorded in terms of biomass (Fig. 8), although the predominance of the omnivores increased even further, whereas the nectarivores were relegated to penultimate position due to their exceptionally small individual body size.

DISCUSSION

The 118 bird species recorded in the present study represent approximately 43% of the 276 species known to occur in the Atlantic Forest of the state of Sergipe (Ruiz-Esparza *et al.* 2015), and in particular, add 45 species to Sousa (2009) original inventory of the study site. This indicates that the rapid survey approach adopted in the present study provided a reliable sample of the local avian fauna, and represents an important advance in the data available for the study area (Sousa 2009, Moreira-Lima 2013).

Jaccard's index analysis reflected a low similarity (38.9%) between the findings of the present study and the inventory of Sousa (2009). This may be related to the different sampling methods used in the two studies. Sousa (2009) recorded 114 species during 12 visits to the study area between 2001 and 2007, but did not apply a standardized sampling protocol, and included surveys of non-forested areas. This contrasts with the more systematic, complementary approach adopted in the present study. In a similar comparative study, O'Dea *et al.* (2004) found that MacKinnon lists provided much more

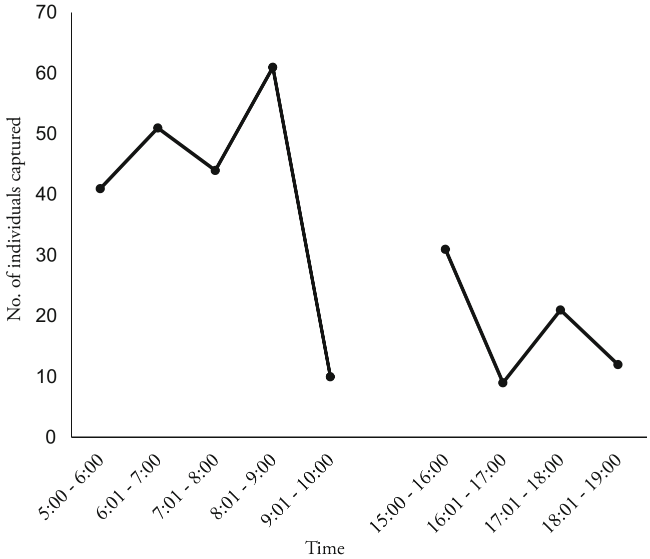

Figure 6. Number of individuals captured in the mist-nets at different times of day.

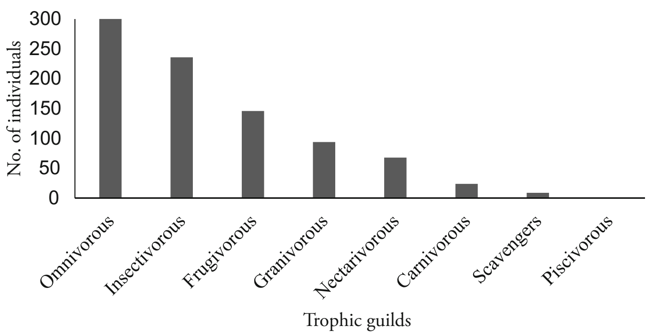

Figure 7. Number of individuals recorded in the present study by trophic guild.

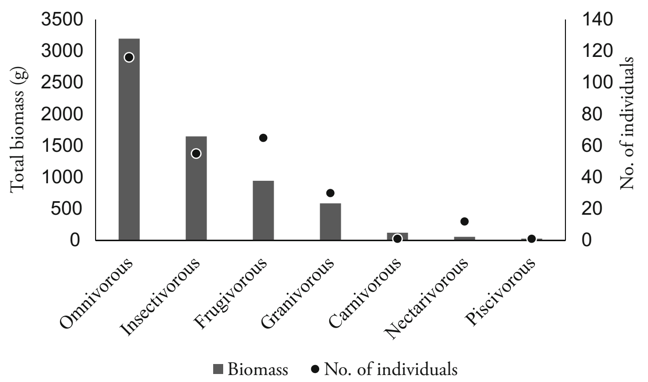

Figure 8. Abundance of individuals, and accumulated biomass by trophic category, collected during the mist-netting.

Table 1. Bird species recorded between 20–29 October at the Fazenda Santana, Japoatã, Sergipe, Brazil. The classification and nomenclature follow the Brazilian Ornithological Records Committee (Piacentini *et al.* 2015). Method: mist-net (MN), MacKinnon list (ML), occasional records (OR). Guild: carnivorous (C), scavengers (S), frugivorous (F), granivorous (G), insectivorous (I), nectarivorous (N), omnivorous (O), piscivorous (P). Number in MacKinnon lists (nML), number in mist-net (nMN), number in occasional records (nOR), total number (*n*), index of frequency in lists (IFL), relative frequency (RF).

Family / Species	Common name	Method	Guild	nML	nMN	nOR	*n*	IFL	RF
Accipitriformes									
Accipitridae									
Geranospiza caerulescens (Vieillot, 1817)	Crane Hawk	MN	C	2	0	0	2	0.03	–
Pseudastur polionotus (Kaup, 1847)	Mantled Hawk	OR	C	0	0	1	1	–	–
Rupornis magnirostris (Gmelin, 1788)	Roadside Hawk	MN	C	6	0	0	6	0.10	–
Apodiformes									
Trochilidae									
Anthracothorax nigricollis (Vieillot, 1817)	Black-throated Mango	MN	N	1	0	0	1	0.02	–
Chlorostilbon lucidus (Shaw, 1812)	Glittering-bellied Emerald	MN–ML	N	9	1	0	10	0.15	0.36
Chlorostilbon notatus (Reich, 1793)	Blue-chinned Sapphire	MN–ML	N	4	2	0	6	0.07	0.71
Chrysolampis mosquitus (Linnaeus, 1758)	Ruby-topaz Hummingbird	MN	N	1	0	0	1	0.02	–
Eupetomena macroura (Gmelin, 1788)	Swallow-tailed Hummingbird	MN	N	4	0	0	4	0.07	–
Hylocharis cyanus (Vieillot, 1818)	White-chinned Sapphire	MN	N	3	0	0	3	0.05	–
Phaethornis pretrei (Lesson & Delattre, 1839)	Planalto Hermit	ML	N	0	2	0	2	–	0.71
Phaethornis ruber (Linnaeus, 1758)	Reddish Hermit	MN–ML	N	2	1	0	3	0.03	0.36
Thalurania glaucopis (Gmelin, 1788)	Violet-capped Woodnymph	MN–ML	N	4	2	0	6	0.07	0.71
Caprimulgiformes									
Caprimulgidae									
Antrostomus rufus (Boddaert, 1783)	Rufous Nightjar	ML	I	0	1	0	1	–	0.36
Chordeiles pusillus (Gould, 1861)	Least Nighthawk	ML	I	0	1	0	1	–	0.36
Hydropsalis albicollis (Gmelin, 1789)	Common Pauraque	MN–ML	I	2	12	0	14	0.03	4.29
Hydropsalis torquata (Gmelin, 1789)	Scissor-tailed Nightjar	ML	I	0	1	0	1	–	0.36
Cariamiformes									
Cariamidae									
Cariama cristata (Linnaeus, 1766)	Red-legged Seriema	MN	C	1	0	0	1	0.02	–
Cathartiformes									
Cathartidae									
Cathartes aura (Linnaeus, 1758)	Turkey Vulture	MN	S	5	0	0	5	0.08	–
Cathartes burrovianus Cassin, 1845	Lesser Yellow-headed Vulture	MN	S	2	0	0	2	0.03	–
Coragyps atratus (Bechstein, 1793)	Black Vulture	MN	S	2	0	0	2	0.03	–
Charadriiformes									
Charadriidae									
Vanellus chilensis (Molina, 1782)	Southern Lapwing	MN	O	3	0	0	3	0.05	–
Columbiformes									
Columbidae									
Columbina squammata (Lesson, 1831)	Scaled Dove	MN–ML	G	5	1	0	6	0.08	0.36
Columbina talpacoti (Temminck, 1810)	Ruddy Ground-Dove	MN–ML	G	19	4	0	23	0.32	1.43
Leptotila verreauxi Bonaparte, 1855	White-tipped Dove	MN–ML	G	16	1	0	17	0.27	0.36
Patagioenas cayennensis (Bonnaterre, 1792)	Pale-vented Pigeon	MN	F	5	0	0	5	0.08	–
Patagioenas picazuro (Temminck, 1813)	Picazuro Pigeon	MN	G	5	0	0	5	0.08	–

Family / Species	Common name	Method	Guild	nML	nMN	nOR	*n*	IFL	RF
Coraciiformes									
Alcedinidae									
Chloroceryle americana (Gmelin, 1788)	Green Kingfisher	ML	P	0	1	0	1	–	0.36
Cuculiformes									
Cuculidae									
Crotophaga ani Linnaeus, 1758	Smooth-billed Ani	MN–ML	O	7	1	0	8	0.12	0.36
Guira guira (Gmelin, 1788)	Guira Cuckoo	MN	O	1	0	0	1	0.02	–
Piaya cayana (Linnaeus, 1766)	Squirrel Cuckoo	MN–ML	O	3	1	0	4	0.05	0.36
Falconiformes									
Falconidae									
Caracara plancus (Miller, 1777)	Southern Caracara	MN	C	7	0	0	7	0.12	–
Herpetotheres cachinnans (Linnaeus, 1758)	Laughing Falcon	MN	C	2	0	0	2	0.03	–
Milvago chimachima (Vieillot, 1816)	Yellow-headed Caracara	MN	C	5	0	0	5	0.08	–
Galbuliformes									
Galbulidae									
Galbula ruficauda Cuvier, 1816	Rufous-tailed Jacamar	MN–ML	I	6	5	0	11	0.10	1.79
Galliformes									
Cracidae									
Ortalis araucuan (Spix, 1825)	East Brazilian Chachalaca	MN	F	2	0	0	2	0.03	–
Penelope superciliaris Temminck, 1815	Rusty-margined Guan	MN	F	1	0	0	1	0.02	–
Passeriformes									
Dendrocolaptidae									
Xiphorhynchus fuscus (Vieillot, 1818)	Lesser Woodcreeper	ML	I	0	1	0	1	–	0.36
Xiphorhynchus guttatus (Lichtenstein, 1820)	Buff-throated Woodcreeper	MN	I	3	0	0	3	0.05	–
Fringillidae									
Euphonia chlorotica (Linnaeus, 1766)	Purple-throated Euphonia	MN	F	8	0	0	8	0.13	–
Euphonia violacea (Linnaeus, 1758)	Violaceous Euphonia	ML	F	0	2	0	2	–	0.71
Furnariidae									
Furnarius figulus (Lichtenstein, 1823)	Wing-banded Hornero	MN	I	2	0	0	2	0.03	–
Furnarius rufus (Gmelin, 1788)	Rufous Hornero	ML	O	0	2	0	2	–	0.71
Synallaxis albescens Temminck, 1823	Pale-breasted Spinetail	MN	I	2	0	0	2	0.03	–
Synallaxis frontalis Pelzeln, 1859	Sooty-fronted Spinetail	MN–ML	I	1	1	0	2	0.02	0.36
Hirundinidae									
Progne chalybea (Gmelin, 1789)	Gray-breasted Martin	MN	I	3	0	0	3	0.05	–
Stelgidopteryx ruficollis (Vieillot, 1817)	Southern Rough-winged Swallow	MN	I	1	0	0	1	0.02	–
Icteridae									
Icterus cayanensis (Linnaeus, 1766)	Epaulet Oriole	ML	O	0	1	0	1	–	0.36
Icterus pyrrhopterus tibialis Swainson, 1838	Variable Oriole	MN	O	1	0	0	1	0.02	–
Molothrus bonariensis (Gmelin, 1789)	Shiny Cowbird	MN	O	1	0	0	1	0.02	–
Nyctibiidae									
Nyctibius griseus (Gmelin, 1789)	Common Potoo	OR	I	0	0	1	1	–	–
Parulidae									
Myiothlypis flaveola Baird, 1865	Flavescent Warbler	MN	I	10	0	0	10	0.17	–

Family / Species	**Common name**	**Method**	**Guild**	**nML**	**nMN**	**nOR**	***n***	**IFL**	**RF**
Passerellidae									
Arremon taciturnus (Hermann, 1783)	Pectoral Sparrow	MN–ML	O	13	8	0	21	0.22	2.86
Pipridae									
Chiroxiphia pareola (Linnaeus, 1766)	Blue-backed Manakin	MN–ML	F	7	2	0	9	0.12	0.71
Manacus manacus (Linnaeus, 1766)	White-bearded Manakin	MN–ML	F	12	60	0	72	0.20	21.43
Neopelma pallescens (Lafresnaye, 1853)	Pale-bellied Tyrant-Manakin	MN–ML	O	1	5	0	6	0.02	1.79
Platyrinchidae									
Platyrinchus mystaceus Vieillot, 1818	White-throated Spadebill	MN–ML	I	1	2	0	3	0.02	0.71
Polioptilidae									
Polioptila plumbea (Gmelin, 1788)	Tropical Gnatcatcher	MN	I	12	0	0	12	0.20	–
Rallidae									
Aramides cajaneus (Statius Muller, 1776)	Gray-necked Wood-Rail	OR	O	0	0	1	1	–	–
Rhynchocyclidae									
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837)	Pearly-vented Tody-tyrant	MN	I	8	0	0	8	0.13	–
Hemitriccus nidipendulus (Wied, 1831)	Hangnest Tody-Tyrant	MN–ML	I	1	3	0	4	0.02	1.07
Leptopogon amaurocephalus Tschudi, 1846	Sepia-capped Flycatcher	MN–ML	I	1	2	0	3	0.02	0.71
Todirostrum cinereum (Linnaeus, 1766)	Common Tody-Flycatcher	MN–ML	I	4	1	0	5	0.07	0.36
Tolmomyias flaviventris (Wied, 1831)	Yellow-breasted Flycatcher	MN–ML	I	10	2	0	12	0.17	0.71
Thamnophilidae									
Formicivora grisea (Boddaert, 1783)	White-fringed Antwren	ML	I	0	1	0	1	–	0.36
Formicivora melanogaster Pelzeln, 1868	Black-bellied Antwren	MN	I	2	0	0	2	0.03	–
Formicivora rufa (Wied, 1831)	Rusty-backed Antwren	MN	I	2	0	0	2	0.03	–
Herpsilochmus pectoralis Sclater, 1857	Pectoral Antwren	MN–ML	I	14	1	0	15	0.23	0.36
Pyriglena atra(Swainson, 1825)	Fringe-backed Fire-eye	OR	I	0	0	1	1	–	–
Taraba major (Vieillot, 1816)	Great Antshrike	MN–ML	I	6	5	0	11	0.10	1.79
Thamnophilus caerulescens Vieillot, 1816	Variable Antshrike	MN	I	1	0	0	1	0.02	–
Thamnophilus pelzelni Hellmayr, 1924	Planalto Slaty-Antshrike	MN–ML	I	11	2	0	13	0.18	0.71
Thraupidae									
Coereba flaveola (Linnaeus, 1758)	Bananaquit	MN–ML	N	28	4	0	32	0.47	1.43
Conirostrum speciosum (Temminck, 1824)	Chestnut-vented Conebill	MN–ML	O	1	1	0	2	0.02	0.36
Dacnis cayana (Linnaeus, 1766)	Blue Dacnis	MN–ML	O	19	25	0	44	0.32	8.93
Hemithraupis guira (Linnaeus, 1766)	Guira Tanager	MN	O	1	0	0	1	0.02	–
Lanio cristatus (Linnaeus, 1766)	Flame-crested Tanager	MN	O	2	0	0	2	0.03	–
Nemosia pileata (Boddaert, 1783)	Hooded Tanager	MN	O	3	0	0	3	0.05	–
Ramphocelus bresilius (Linnaeus, 1766)	Brazilian Tanager	ML	O	0	4	0	4	–	1.43
Saltator maximus (Statius Muller, 1776)	Buff-throated Saltator	MN–ML	O	4	5	0	9	0.07	1.79
Schistochlamys ruficapillus (Vieillot, 1817)	Cinnamon Tanager	MN–ML	G	1	1	0	2	0.02	0.36
Sporophila bouvreuil (Statius Muller, 1776)	Copper Seedeater	MN	G	1	0	0	1	0.02	–
Sporophila leucoptera (Vieillot, 1817)	White-bellied Seedeater	ML	G	0	5	0	5	–	1.79
Sporophila lineola (Linnaeus, 1758)	Lined Seedeater	ML	G	0	6	0	6	–	2.14
Sporophila nigricollis (Vieillot, 1823)	Yellow-bellied Seedeater	MN–ML	G	3	5	0	8	0.05	1.79
Tachyphonus rufus (Boddaert, 1783)	White-lined Tanager	MN–ML	O	14	12	0	26	0.23	4.29
Tangara cayana (Linnaeus, 1766)	Burnished-buff Tanager	MN–ML	O	8	17	0	25	0.13	6.07

Family / Species	Common name	Method	Guild	nML	nMN	nOR	*n*	IFL	RF
Tangara palmarum (Wied, 1821)	Palm Tanager	MN–ML	O	20	2	0	22	0.33	0.71
Tangara sayaca (Linnaeus, 1766)	Sayaca Tanager	MN	O	7	0	0	7	0.12	–
Volatinia jacarina (Linnaeus, 1766)	Blue-black Grassquit	MN–ML	G	14	7	0	21	0.23	2.50
Tinamidae									
Crypturellus noctivagus (Wied, 1820)	Yellow-legged Tinamou	OR	O	0	0	1	1	–	–
Tityridae									
Pachyramphus polychopterus (Vieillot, 1818)	White-winged Becard	MN–ML	I	4	2	0	6	0.07	0.71
Troglodytidae									
Pheugopedius genibarbis (Swainson, 1838)	Moustached Wren	MN–ML	O	13	1	0	14	0.22	0.36
Troglodytes musculus Naumann, 1823	Southern House Wren	MN–ML	I	3	1	0	4	0.05	0.36
Turdidae									
Turdus leucomelas Vieillot, 1818	Pale-breasted Thrush	MN–ML	O	15	14	0	29	0.25	5.00
Tyrannidae									
Camptostoma obsoletum (Temminck, 1824)	Southern Beardless-Tyrannulet	MN–ML	I	6	4	0	10	0.10	1.43
Elaenia cristata Pelzeln, 1868	Plain-crested Elaenia	MN–ML	O	14	3	0	17	0.23	1.07
Elaenia flavogaster (Thunberg, 1822)	Yellow-bellied Elaenia	ML	O	0	6	0	6	–	2.14
Elaenia spectabilis Pelzeln, 1868	Large Elaenia	MN	O	1	0	0	1	0.02	–
Euscarthmus meloryphus Wied, 1831	Tawny-crowned Pygmy-Tyrant	OR	I	0	0	1	1	–	–
Megarynchus pitangua (Linnaeus, 1766)	Boat-billed Flycatcher	MN	O	6	0	0	6	0.10	–
Myiarchus ferox (Gmelin, 1789)	Short-crested Flycatcher	MN–ML	I	5	2	0	7	0.08	0.71
Myiarchus swainsoni Cabanis & Heine, 1859	Swainson's Flycatcher	MN	I	3	0	0	3	0.05	–
Myiophobus fasciatus (Statius Muller, 1776)	Bran-colored Flycatcher	MN–ML	I	1	1	0	2	0.02	0.36
Myiozetetes similis (Spix, 1825)	Social Flycatcher	MN–ML	O	4	8	0	12	0.07	2.86
Pitangus sulphuratus (Linnaeus, 1766)	Great Kiskadee	MN	O	15	0	0	15	0.25	–
Tyrannus melancholicus Vieillot, 1819	Tropical Kingbird	MN	I	15	0	0	15	0.25	–
Vireonidae									
Cyclarhis gujanensis (Gmelin, 1789)	Rufous-browed Peppershrike	MN–ML	I	22	2	0	24	0.37	0.71
Vireo chivi (Vieillot, 1817)	Chivi Vireo	MN–ML	I	12	2	0	14	0.20	0.71
Piciformes									
Picidae									
Campephilus melanoleucos (Gmelin, 1788)	Crimson-crested Woodpecker	MN	I	1	0	0	1	0.02	–
Colaptes melanochloros (Gmelin, 1788)	Green-barred Woodpecker	MN	I	1	0	0	1	0.02	–
Picumnus exilis (Lichtenstein, 1823)	Bahia Piculet	MN	I	2	0	0	2	0.03	–
Veniliornis passerinus (Linnaeus, 1766)	Little Woodpecker	MN	I	2	0	0	2	0.03	–
Psittaciformes									
Psittacidae									
Amazona aestiva (Linnaeus, 1758)	Turquoise-fronted Parrot	MN	F	25	0	0	25	0.42	–
Eupsittula aurea (Gmelin, 1788)	Peach-fronted Parakeet	MN	F	12	0	0	12	0.20	–
Forpus xanthopterygius (Spix, 1824)	Blue-winged Parrotlet	MN–ML	F	9	1	0	10	0.15	0.36
Strigiformes									
Strigidae									
Megascops choliba (Vieillot, 1817)	Tropical Screech-Owl	ML	C	0	1	0	1	–	0.36
Tinamiformes									
Tinamidae									

Family / Species	Common name	Method	Guild	nML	nMN	nOR	*n*	IFL	RF
Nothura maculosa (Temminck, 1815)	Spotted Nothura	MN	I	1	0	0	1	0.02	–
Trogoniformes									
Trogonidae									
Trogon curucui Linnaeus, 1766	Blue-crowned Trogon	MN	O	8	0	0	8	0.13	–

reliable species counts than those obtained at listening points in highland forest in Ecuador, which they attributed to the more comprehensive, active nature of the searches used to compile the MacKinnon lists. The lists do not record abundance data, however, although relative species abundance can be inferred through the IFL (Bibby *et al.* 1998, Ribon 2010). The greater similarity (J' = 50.6%) found between the results of the present study and those of the survey of Ruiz-Esparza *et al.* (2015) may be related to the use of a similar, complementary approach by these authors.

The rarefaction curves further reinforce the effectiveness of the complementary methods for bird inventories in a rapid survey approach, as recommended by Ribon (2010). In the Mata do Junco, Ruiz-Esparza *et al.* (2015) recorded a bird community dominated by Tyrannidae and Thraupidae, as observed in the present study, and in other studies in the Atlantic Forest (Dário *et al.* 2002, Faria *et al.* 2006, Almeida *et al.* 2012, Crestani *et al.* 2015). This reflects the overall diversity of the Thraupidae (157 species) and Tyrannidae (114 species) in the Neotropics (Sick 1997, Piacentini *et al.* 2015), and may reflect the adaptability of both groups to a range of environments, including anthropogenic habitats (Telino-Júnior *et al.* 2005).

The local bird community was dominated by omnivores and insectivores, as observed at other Atlantic Forest sites in the region (Magalhães *et al.* 2007, Ruiz-Esparza *et al.* 2015). At many other sites, however, insectivores predominate over omnivores (Matarazzo-Neuberger 1995, Silveira *et al.* 2003, Telino-Júnior *et al.* 2005, Ruiz-Esparza *et al.* 2016), which may reflect variations in local habitats. Anjos (1998) concluded that omnivorous birds may be more tolerant to habitat fragmentation, due to their greater ecological flexibility, allowing these species to predominate in impacted environments. It is, nevertheless, important to note that while omnivores were more abundant in the present study, the insectivore species richness was higher. The granivores, in turn, may have been favored by the abundance of open habitats within the general study area, which may favor these species (Telino-Júnior *et al.* 2005).

Overall, results of the present study indicate that the combination of complementary sampling techniques provided a more reliable inventory of the bird fauna of the study area than either method on its own, and was especially effective in the context of the rapid survey approach, when compared with the existing data for the study area. Despite these findings, analyses indicate that further research will confirm the occurrence of additional species at the site, using both techniques, which was expected, given the limited perspective of the rapid survey approach.

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REFERENCES

Almeida B.J.M., Almeida B.A., Souza, A.G., Ruiz-Esparza J.M. & Ferrari S.F. 2012. Avifauna dos remanescentes das restingas ao longo da zona de expanção urbana de Aracaju, Sergipe. *Scientia Plena* 8: 129902.

Anjos L. 1998. Conseqüências biológicas da fragmentação no norte do Paraná. *Série Técnica IPEF* 12: 87–94.

Anjos L. & Boçon R. 1999. Bird communities in natural forest patches in southern Brazil. *Wilson Bulletin* 111: 397–414.

Aragão R., Santana G.R., Costa C.E.F.F., Cruz M.A.S., Figueiredo E.E. & Srinivasan V.S. 2013. Chuvas intensas para o estado de Sergipe com base em dados desagregados de chuva diária. *Resvista Brasileira de Engenharia Agrícola e Ambiental* 17: 243–252.

Bibby C., Jones M. & Stuart M. 1998. *Bird surveys, v 1.* London: Expedition Advisory Centre.

Cavarzere V., Costa T.V.V. & Silveira L.F. 2012. On the use of 10-minute point counts and 10-species lists for surveying birds in lowland Atlantic Forests in southeastern Brazil. *Papéis Avulsos de Zoologia* 52: 333–340.

CEMAVE. 1994. *Manual de anilhamento de aves silvestres, 2nd edn.* Brasília: Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis.

Colwell R.K., Chao A., Gotelli N.J., Lin S., Mao C.X., Chazdon R.L. & Longino J.T. 2012. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemblages. *Journal of Plant Ecology* 5: 3–21.

Crestani A.C., Serrano L.S. & Mota J.V.L. 2015. Efeitos do tamanho e geometria dos remanescentes florestais sobre a estrutura da avifauna em uma paisagem fragmentada no nordeste do Brasil. *Atualidades Ornitológicas* 168: 41–46.

Dário F.R., Vincenzo M.C.V. & Almeida Á.F. 2002. Avifauna em fragmentos da Mata Atlântica. *Ciência Rural* 32: 989–996.

Dislich R., Cersósimo L. & Mantovani W. 2001. Análise da estrutura de fragmentos florestais no Planalto Paulistano - SP. *Revista Brasileira de Botânica* 24: 321–332.

Faria C.M.A., Rodrigues M., Amaral F.Q., Módena É. & Fernandes A.M. 2006. Aves de um fragmento de Mata Atlântica no alto Rio Doce, Minas Gerais: colonização e extinção. *Revista Brasileira de Zoologia* 23: 1217–1230.

Franz I., Cappelatti L. & Barros M.P. 2010. Bird community in a forest patch isolated by the urban matrix at the Sinos River Basin, Rio Grande do Sul state, Brazil, with comments on the possible local defaunation. *Brazilian Journal of Biology* 70: 1137–1148.

Fundação SOS Mata Atlântica & INEP. 2015. *Atlas da Mata Atlântica mostra situação do desmatamento em Sergipe*. São Paulo: Máquina Public Relations.

Fundação SOS Mata Atlântica & INEP. 2016. *Atlas dos remanescentes florestais da Mata Atlântica período 2014–2015*. São Paulo: Máquina Public Relations.

Gascon C., Williamson G.B. & Fonseca G.A.B. 2000. Receding forest edges and vanishing reserves. *Science* 288: 1356–1358.

Gimenes M.R. & Anjos L. 2000. Distribuição espacial de aves em um fragmento florestal do campus da Universidade Estadual de Londrina, norte do Paraná, Brasil. *Revista Brasileira de Zoologia* 17: 263–271.

Guerra M.P., Rocha F.S. & Nodari R.O. 2015. Biodiversidade, recursos genéticos vegetais e segurança alimentar em cenário de ameaças e mudanças, p. 39–52. In: Veiga R.F.A. & Queiroz M.A. (eds.). *Recursos fitogenéticos: a base da agricultura sustentável no Brasil. v 1.* Viçosa: UFV.

Hammer Ø., Harper D.A.T. & Ryan P.D. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4: 1–9.

IUCN (International Union for Conservation of Nature). 2017. *The IUCN red list of threatened species*. Version 2017-2. http://www.iucnredlist.org (Access on 17 December 2017).

MacKinnon J. & Phillipps K. 1993. *A field guide to the birds of Borneo, Sumatra, Java, and Bali: the Greater Sunda Islands*, *v 1.* Oxford: Oxford University Press.

MacLeod R., Herzog S.K., Maccormick A., Ewing S.R., Bryce R. & Evans K.L. 2011. Rapid monitoring of species abundance for biodiversity conservation: consistency and reliability of the MacKinnon lists technique. *Biological Conservation* 144: 1374–1381.

Magalhães V.S., Azevedo-Júnior S.M., Lyra-Neves R.M., Telino-Júnior W.R. & Souza D.P. 2007. Biologia de aves capturadas em um fragmento de Mata Atlântica, Igarassu, Pernambuco, Brasil. *Revista Brasileira de Zoologia* 24: 950–964.

Matarazzo-Neuberger W.M. 1995. Comunidade de aves de cinco parques e praças da grande São Paulo, estado de São Paulo. *Ararajuba* 3: 13–19.

Moreira-Lima L. 2013. *Aves da Mata Atlântica: riqueza, composição, status, endemismo e conservação.* MSc. Dissertation, Universidade de São Paulo.

Myers N., Mittermeier R.A., Mittermeier C.G., Fonseca G.A.B. & Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Ortega M.A.A.G., Hernández J.G., Gómez M.F.M. & Velázquez L.E.D. 2003. Un método para la selección de aves bioindicadoras con base en sus posibilidades de monitoreo. *Huitzil* 4: 10–16.

Paglia A.P. 2007. *Espécies ameaçadas da fauna brasileira: análise dos padões e dos fatores de ameaça.* Ph.D. Thesis, Universidade Federal de Minas Gerais.

Pereira M.S. & Alves R.R.N. 2007. Composição florística de um remanescente de Mata Atlântica na área de proteção ambiental Barra do Rio Mamanguape, Paraíba, Brasil. *Revista de Biologia e Ciências da Terra* 7: 1–10.

Piacentini V.Q., Aleixo A., Agne C.E., Maurício G.N., Pacheco J.F., Bravo G.A., Brito G.R.R., Naka L.N., Olmos F., Posso S., Silveira L.F., Betini G.S., Carrano E., Franz I., Lees A.C., Lima L.M., Pioli D., Schunck F., Amaral F.R., Bencke G.A., Cohn-Haft M., Figueiredo L.F.A., Straube F.C. & Cesari E. 2015. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee. *Revista Brasileira de Ornitologia* 23: 91–298.

Piratelli A., Andrade V.A. & Lima-Filho M. 2005. Aves de fragmentos florestais em área de cultivo de cana-de-açúcar no sudeste do Brasil. *Iheringia, Série Zoologia* 95: 217–222.

Ribon R. 2010. Amostragem de aves pelo método de listas de MacKinnon, p. 33–43. In: von Matter S., Straube F.C., Accordi I., Piacentini V. & Cândido-Junior J.F. (eds.). *Ornitologia e conservação: ciência aplicada, técnicas de pesquisa e levantamento, v. 1.* Rio de Janeiro: Technical Books.

Ruiz-Esparza J., Rocha P.A., Ribeiro A.S. & Ferrari S.F. 2012. The birds of the Serra da Guia in the Caatinga of northern Sergipe. *Revista Brasileira de Ornitologia* 20: 290–301.

Ruiz-Esparza J., Santos C.S., Cunha M.A., Ruiz-Esparza D.P.B., Rocha P.A., Beltrão-Mendes R. & Ferrari S.F. 2015. Diversity of birds in the Mata do Junco State Wildlife Refuge, a remnant of the Atlantic Forest of northeastern Brazil. *Check List* 11: 1647.

Ruiz-Esparza J., Silvestre S.M., Moura V.S., Albuquerque N.M., Terra R.F.C., Mendonça L.M.C., Dias D.M., Beltrão-Mendes R., Rocha P.A. & Ferrari S.F. 2016. Inventory of birds in the coastal restinga of a Private Natural Heritage Reserve in northeastern Brazil. *Neotropical Biology and Conservation* 11: 51–61.

Santos A.L.C. 2009. *Diagnóstico dos fragmentos de Mata Atlântica de Sergipe através de sensoriamento remoto.* MSc. Dissertation, Universidade Federal de Sergipe.

Sick H. 1997. *Ornitologia brasileira.* Rio de Janeiro: Nova Fronteira.

Sigrist T. 2015. *Aves do Brasil oriental - guia de bolso*, *v 1.* Vinhedo: Avis Brasilis.

Silveira L.F., Olmos F. & Long A.J. 2003. Birds in Atlantic Forest fragments in north-east Brazil. *Cotinga* 20: 32–46.

Sousa M.C. 2009. Aves de oito localidades do estado de Sergipe. *Atualidades Ornitológicas* 149: 33–57.

Tabarelli M., Pinto L.P., Silva J.M.C., Hirota M.M. & Bedê L.C. 2005. Desafios e oportunidades para a conservação da biodiversidade na Mata Atlântica brasileira. *Megadiversidade* 1: 132–138.

Telino-Júnior W.R., Dias M.M., Azevedo-Júnior S.M., Lyra-Neves R.M. & Larrazábal M.E.L. 2005. Estrutura trófica da avifauna na Reserva Estadual de Gurjaú, Zona da Mata Sul, Pernambuco, Brasil. *Revista Brasileira de Zoologia* 22: 962–973.

Uezu A., Metzger J.P. & Vielliard J.M.E. 2005. Effects of structural and functional connectivity and patch size on the abundance of seven Atlantic Forest bird species. *Biological Conservation* 123: 507–519.

Williams K.J., Ford A., Rosauer D.F., Silva N., Mittermeier R., Bruce C., Larsen F.W. & Margules C. 2011. Forests of east Australia: the 35th biodiversity hotspot, p. 295–310. In: Zachos F.E. & Habel J.C. (eds.) *Biodiversity hotspots: distribution and protection of conservation priority areas, v 1.* Berlin: Springer.

Wilman H., Belmaker J., Simpson J., Rosa C., Rivadeneira M.M. & Jetz W. 2014. EltonTraits 1.0: species-level foraging attributes of the world's birds and mammals. *Ecology* 95: 2027–2027.

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