

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

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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 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 (CBA), in the municipalities of Japoatã and Pacatuba (Fig. 1).

The local climate is humid coastal, with annual

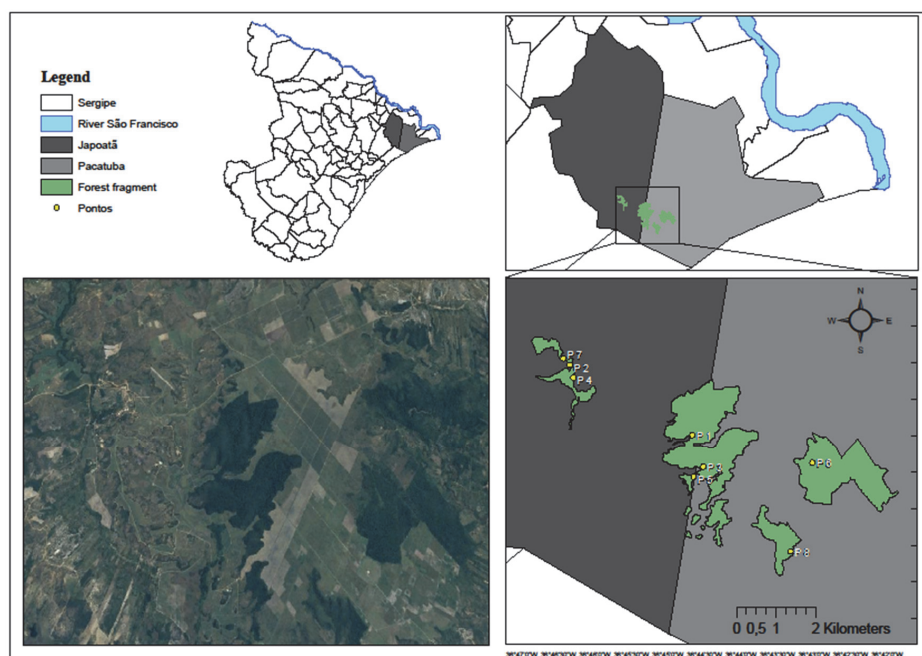


Figure 1. Location of the sampling points on the Fazenda Santana, in the municipalities of Japoatã and Japarutuba, in Sergipe, Brazil.

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 m²) 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 $Fr = (n/T) \times 100$, 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 $IFL = (l/Lt) \times 100$, 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

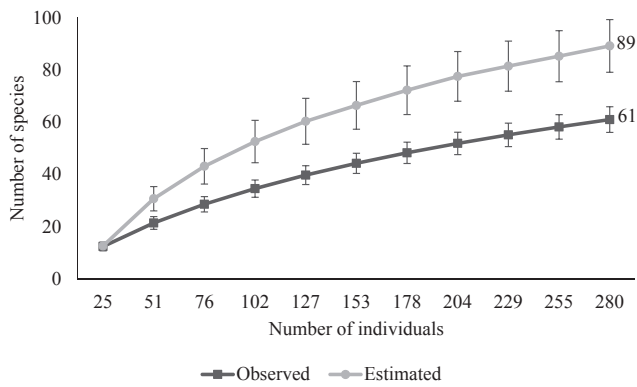


Figure 2. Bird species richness observed and estimated according to the Jackknife 1 procedure, based on the records collected during mist-netting at Fazenda Santana in Japoatã and Pacatuba, Sergipe, Brazil. The records are based on a total of 1080 net-h of sampling effort.

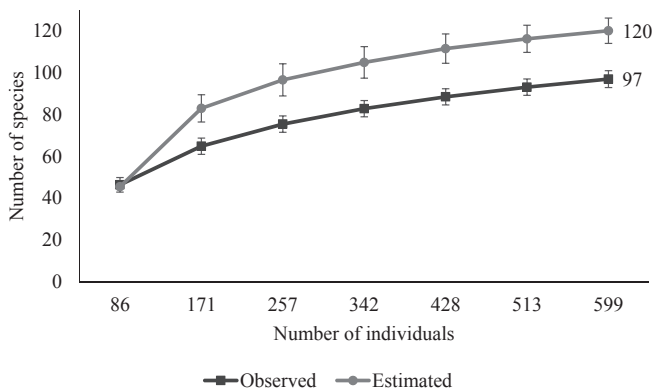


Figure 3. Bird species richness observed and estimated according to the Jackknife 1 procedure, based on the records collected in the MacKinnon lists at Fazenda Santana in Japoatã and Pacatuba, Sergipe, Brazil. Each sample point consists of six lists.

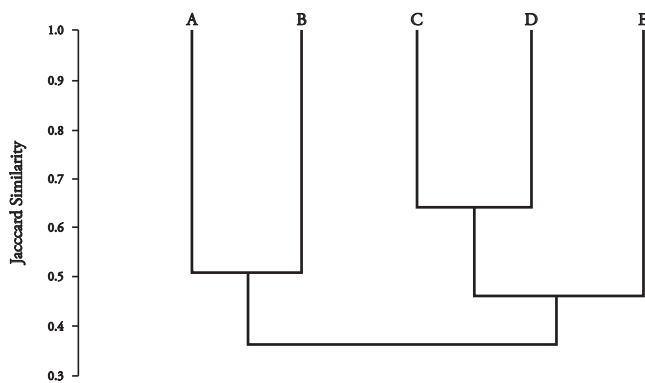


Figure 4. Cluster plot based on the Jaccard similarity index. A = Fazenda Santana (present study); B = Mata do Junco (Ruiz-Esparza *et al.* 2015); C = Mata da Santana (Sousa 2009); D = Mata do Junco (Sousa 2009); E = Mata do Crasto (Sousa 2009).

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

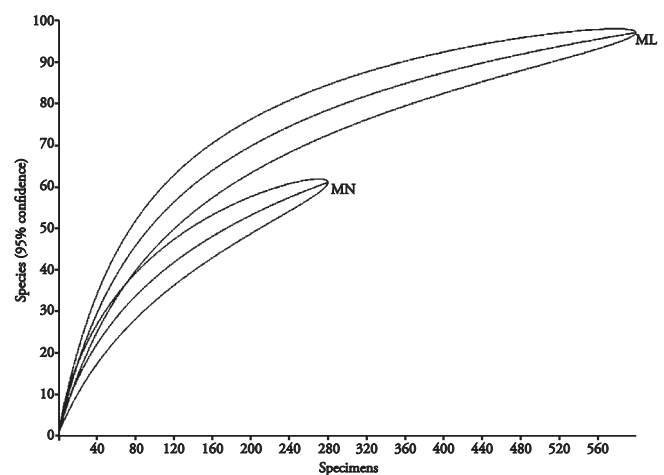


Figure 5. Rarefaction curves comparing the two survey methods used in the present study. ML = MacKinnon lists; MN = Mist-nets.

= 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

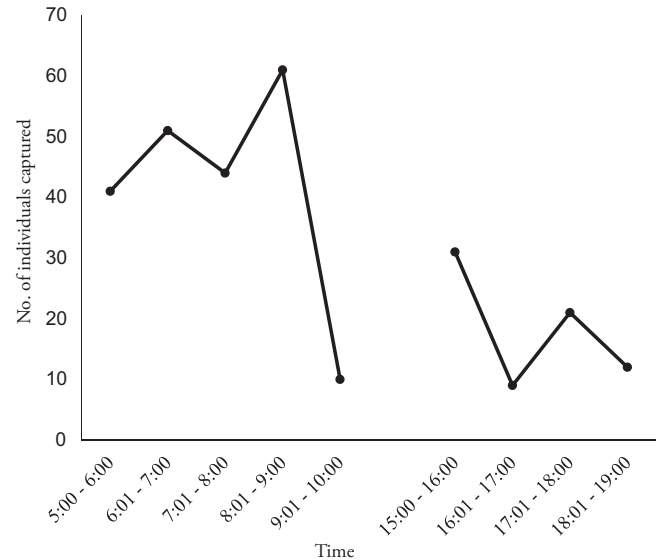


Figure 6. Number of individuals captured in the mist-nets at different times of day.

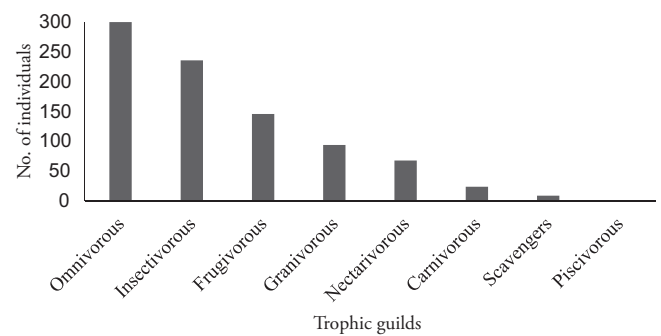


Figure 7. Number of individuals recorded in the present study by trophic guild.

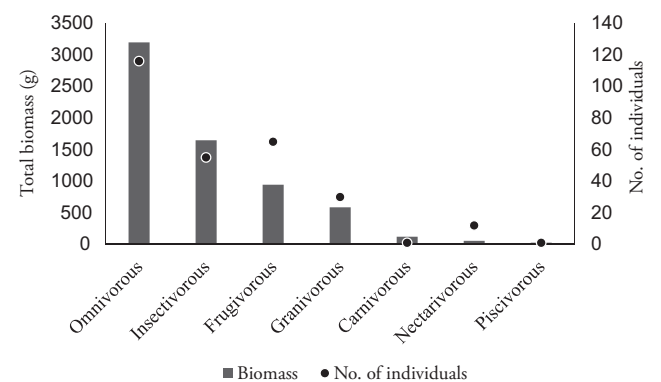


Figure 8. Abundance of individuals, and accumulated biomass by trophic category, collected during the mist-netting.

Table 1. Bird species recorded between 20–29 October at the Fazenda Santana, Japoatá, 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	<i>n</i>	IFL	RF
Accipitriformes									
Accipitridae									
<i>Geranospiza caerulescens</i> (Vieillot, 1817)	Crane Hawk	MN	C	2	0	0	2	0.03	-
<i>Pseudastur polionotus</i> (Kaup, 1847)	Mantled Hawk	OR	C	0	0	1	1	-	-
<i>Rupornis magnirostris</i> (Gmelin, 1788)	Roadside Hawk	MN	C	6	0	0	6	0.10	-
Apodiformes									
Trochilidae									
<i>Anthracothorax nigricollis</i> (Vieillot, 1817)	Black-throated Mango	MN	N	1	0	0	1	0.02	-
<i>Chlorostilbon lucidus</i> (Shaw, 1812)	Glittering-bellied Emerald	MN–ML	N	9	1	0	10	0.15	0.36
<i>Chlorostilbon notatus</i> (Reich, 1793)	Blue-chinned Sapphire	MN–ML	N	4	2	0	6	0.07	0.71
<i>Chrysolampis mosquitus</i> (Linnaeus, 1758)	Ruby-topaz Hummingbird	MN	N	1	0	0	1	0.02	-
<i>Eupetomena macroura</i> (Gmelin, 1788)	Swallow-tailed Hummingbird	MN	N	4	0	0	4	0.07	-
<i>Hylocharis cyanus</i> (Vieillot, 1818)	White-chinned Sapphire	MN	N	3	0	0	3	0.05	-
<i>Phaethornis pretrei</i> (Lesson & Delattre, 1839)	Planalto Hermit	ML	N	0	2	0	2	-	0.71
<i>Phaethornis ruber</i> (Linnaeus, 1758)	Reddish Hermit	MN–ML	N	2	1	0	3	0.03	0.36
<i>Thalurania glaucopis</i> (Gmelin, 1788)	Violet-capped Woodnymph	MN–ML	N	4	2	0	6	0.07	0.71
Caprimulgiformes									
Caprimulgidae									
<i>Antristomus rufus</i> (Boddaert, 1783)	Rufous Nightjar	ML	I	0	1	0	1	-	0.36
<i>Chordeiles pusillus</i> (Gould, 1861)	Least Nighthawk	ML	I	0	1	0	1	-	0.36
<i>Hydropsalis albicollis</i> (Gmelin, 1789)	Common Pauraque	MN–ML	I	2	12	0	14	0.03	4.29
<i>Hydropsalis torquata</i> (Gmelin, 1789)	Scissor-tailed Nightjar	ML	I	0	1	0	1	-	0.36
Cariamiformes									
Cariamidae									
<i>Cariama cristata</i> (Linnaeus, 1766)	Red-legged Seriema	MN	C	1	0	0	1	0.02	-
Cathartiformes									
Cathartidae									
<i>Cathartes aura</i> (Linnaeus, 1758)	Turkey Vulture	MN	S	5	0	0	5	0.08	-
<i>Cathartes burrovianus</i> Cassin, 1845	Lesser Yellow-headed Vulture	MN	S	2	0	0	2	0.03	-
<i>Coragyps atratus</i> (Bechstein, 1793)	Black Vulture	MN	S	2	0	0	2	0.03	-
Charadriiformes									
Charadriidae									
<i>Vanellus chilensis</i> (Molina, 1782)	Southern Lapwing	MN	O	3	0	0	3	0.05	-
Columbiformes									
Columbidae									
<i>Columbina squammata</i> (Lesson, 1831)	Scaled Dove	MN–ML	G	5	1	0	6	0.08	0.36
<i>Columbina talpacoti</i> (Temminck, 1810)	Ruddy Ground-Dove	MN–ML	G	19	4	0	23	0.32	1.43
<i>Leptotila verreauxi</i> Bonaparte, 1855	White-tipped Dove	MN–ML	G	16	1	0	17	0.27	0.36
<i>Patagioenas cayennensis</i> (Bonnaterre, 1792)	Pale-vented Pigeon	MN	F	5	0	0	5	0.08	-
<i>Patagioenas picazuro</i> (Temminck, 1813)	Picazuro Pigeon	MN	G	5	0	0	5	0.08	-

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

Family / Species	Common name	Method	Guild	nML	nMN	nOR	<i>n</i>	IFL	RF
Passerellidae									
<i>Arremon taciturnus</i> (Hermann, 1783)	Pectoral Sparrow	MN–ML	O	13	8	0	21	0.22	2.86
Pipridae									
<i>Chiroxiphia pareola</i> (Linnaeus, 1766)	Blue-backed Manakin	MN–ML	F	7	2	0	9	0.12	0.71
<i>Manacus manacus</i> (Linnaeus, 1766)	White-bearded Manakin	MN–ML	F	12	60	0	72	0.20	21.43
<i>Neopelma pallescens</i> (Lafresnaye, 1853)	Pale-bellied Tyrant-Manakin	MN–ML	O	1	5	0	6	0.02	1.79
Platyrrinchidae									
<i>Platyrinchus mystaceus</i> Vieillot, 1818	White-throated Spadebill	MN–ML	I	1	2	0	3	0.02	0.71
Poliotilidae									
<i>Poliotila plumbea</i> (Gmelin, 1788)	Tropical Gnatcatcher	MN	I	12	0	0	12	0.20	–
Rallidae									
<i>Aramides cajaneus</i> (Statius Muller, 1776)	Gray-necked Wood-Rail	OR	O	0	0	1	1	–	–
Rhynchocyclidae									
<i>Hemitriccus margaritaceiventer</i> (d'Orbigny & Lafresnaye, 1837)	Pearly-vented Tody-tyrant	MN	I	8	0	0	8	0.13	–
<i>Hemitriccus nidipendulus</i> (Wied, 1831)	Hangnest Tody-Tyrant	MN–ML	I	1	3	0	4	0.02	1.07
<i>Leptopogon amaurocephalus</i> Tschudi, 1846	Sepia-capped Flycatcher	MN–ML	I	1	2	0	3	0.02	0.71
<i>Todirostrum cinereum</i> (Linnaeus, 1766)	Common Tody-Flycatcher	MN–ML	I	4	1	0	5	0.07	0.36
<i>Tolmomyias flaviventris</i> (Wied, 1831)	Yellow-breasted Flycatcher	MN–ML	I	10	2	0	12	0.17	0.71
Thamnophilidae									
<i>Formicivora grisea</i> (Boddaert, 1783)	White-fringed Antwren	ML	I	0	1	0	1	–	0.36
<i>Formicivora melanogaster</i> Pelzeln, 1868	Black-bellied Antwren	MN	I	2	0	0	2	0.03	–
<i>Formicivora rufa</i> (Wied, 1831)	Rusty-backed Antwren	MN	I	2	0	0	2	0.03	–
<i>Herpsilochmus pectoralis</i> Sclater, 1857	Pectoral Antwren	MN–ML	I	14	1	0	15	0.23	0.36
<i>Pyriglena atra</i> (Swainson, 1825)	Fringe-backed Fire-eye	OR	I	0	0	1	1	–	–
<i>Taraba major</i> (Vieillot, 1816)	Great Antshrike	MN–ML	I	6	5	0	11	0.10	1.79
<i>Thamnophilus caeruleus</i> Vieillot, 1816	Variable Antshrike	MN	I	1	0	0	1	0.02	–
<i>Thamnophilus pelzelni</i> Hellmayr, 1924	Planalto Slaty-Antshrike	MN–ML	I	11	2	0	13	0.18	0.71
Thraupidae									
<i>Coereba flaveola</i> (Linnaeus, 1758)	Bananaquit	MN–ML	N	28	4	0	32	0.47	1.43
<i>Conirostrum speciosum</i> (Temminck, 1824)	Chestnut-vented Conebill	MN–ML	O	1	1	0	2	0.02	0.36
<i>Dacnis cayana</i> (Linnaeus, 1766)	Blue Dacnis	MN–ML	O	19	25	0	44	0.32	8.93
<i>Hemithraupis guira</i> (Linnaeus, 1766)	Guira Tanager	MN	O	1	0	0	1	0.02	–
<i>Lanio cristatus</i> (Linnaeus, 1766)	Flame-crested Tanager	MN	O	2	0	0	2	0.03	–
<i>Nemosia pileata</i> (Boddaert, 1783)	Hooded Tanager	MN	O	3	0	0	3	0.05	–
<i>Ramphocelus bresilius</i> (Linnaeus, 1766)	Brazilian Tanager	ML	O	0	4	0	4	–	1.43
<i>Saltator maximus</i> (Statius Muller, 1776)	Buff-throated Saltator	MN–ML	O	4	5	0	9	0.07	1.79
<i>Schistochlamys ruficapillus</i> (Vieillot, 1817)	Cinnamon Tanager	MN–ML	G	1	1	0	2	0.02	0.36
<i>Sporophila bouvreuil</i> (Statius Muller, 1776)	Copper Seedeater	MN	G	1	0	0	1	0.02	–
<i>Sporophila leucoptera</i> (Vieillot, 1817)	White-bellied Seedeater	ML	G	0	5	0	5	–	1.79
<i>Sporophila lineola</i> (Linnaeus, 1758)	Lined Seedeater	ML	G	0	6	0	6	–	2.14
<i>Sporophila nigricollis</i> (Vieillot, 1823)	Yellow-bellied Seedeater	MN–ML	G	3	5	0	8	0.05	1.79
<i>Tachyphonus rufus</i> (Boddaert, 1783)	White-lined Tanager	MN–ML	O	14	12	0	26	0.23	4.29
<i>Tangara cayana</i> (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	<i>n</i>	IFL	RF
<i>Tangara palmarum</i> (Wied, 1821)	Palm Tanager	MN–ML	O	20	2	0	22	0.33	0.71
<i>Tangara sayaca</i> (Linnaeus, 1766)	Sayaca Tanager	MN	O	7	0	0	7	0.12	–
<i>Volatinia jacarina</i> (Linnaeus, 1766)	Blue-black Grassquit	MN–ML	G	14	7	0	21	0.23	2.50
Tinamidae									
<i>Crypturellus noctivagus</i> (Wied, 1820)	Yellow-legged Tinamou	OR	O	0	0	1	1	–	–
Tityridae									
<i>Pachyrhamphus polychopterus</i> (Vieillot, 1818)	White-winged Becard	MN–ML	I	4	2	0	6	0.07	0.71
Troglodytidae									
<i>Pheugopedius genibarbis</i> (Swainson, 1838)	Moustached Wren	MN–ML	O	13	1	0	14	0.22	0.36
<i>Troglodytes musculus</i> Naumann, 1823	Southern House Wren	MN–ML	I	3	1	0	4	0.05	0.36
Turdidae									
<i>Turdus leucomelas</i> Vieillot, 1818	Pale-breasted Thrush	MN–ML	O	15	14	0	29	0.25	5.00
Tyrannidae									
<i>Camptostoma obsoletum</i> (Temminck, 1824)	Southern Beardless-Tyrannulet	MN–ML	I	6	4	0	10	0.10	1.43
<i>Elaenia cristata</i> Pelzeln, 1868	Plain-crested Elaenia	MN–ML	O	14	3	0	17	0.23	1.07
<i>Elaenia flavogaster</i> (Thunberg, 1822)	Yellow-bellied Elaenia	ML	O	0	6	0	6	–	2.14
<i>Elaenia spectabilis</i> Pelzeln, 1868	Large Elaenia	MN	O	1	0	0	1	0.02	–
<i>Euscarthmus meloryphus</i> Wied, 1831	Tawny-crowned Pygmy-Tyrant	OR	I	0	0	1	1	–	–
<i>Megarynchus pitangua</i> (Linnaeus, 1766)	Boat-billed Flycatcher	MN	O	6	0	0	6	0.10	–
<i>Myiarchus ferox</i> (Gmelin, 1789)	Short-crested Flycatcher	MN–ML	I	5	2	0	7	0.08	0.71
<i>Myiarchus swainsoni</i> Cabanis & Heine, 1859	Swainson's Flycatcher	MN	I	3	0	0	3	0.05	–
<i>Myiophobus fasciatus</i> (Statius Muller, 1776)	Bran-colored Flycatcher	MN–ML	I	1	1	0	2	0.02	0.36
<i>Myiozetetes similis</i> (Spix, 1825)	Social Flycatcher	MN–ML	O	4	8	0	12	0.07	2.86
<i>Pitangus sulphuratus</i> (Linnaeus, 1766)	Great Kiskadee	MN	O	15	0	0	15	0.25	–
<i>Tyrannus melancholicus</i> Vieillot, 1819	Tropical Kingbird	MN	I	15	0	0	15	0.25	–
Vireonidae									
<i>Cycularbis gujanensis</i> (Gmelin, 1789)	Rufous-browed Peppershrike	MN–ML	I	22	2	0	24	0.37	0.71
<i>Vireo chivi</i> (Vieillot, 1817)	Chivi Vireo	MN–ML	I	12	2	0	14	0.20	0.71
Piciformes									
Picidae									
<i>Campephilus melanoleucos</i> (Gmelin, 1788)	Crimson-crested Woodpecker	MN	I	1	0	0	1	0.02	–
<i>Colaptes melanochloros</i> (Gmelin, 1788)	Green-barred Woodpecker	MN	I	1	0	0	1	0.02	–
<i>Picumnus exilis</i> (Lichtenstein, 1823)	Bahia Piculet	MN	I	2	0	0	2	0.03	–
<i>Veniliornis passerinus</i> (Linnaeus, 1766)	Little Woodpecker	MN	I	2	0	0	2	0.03	–
Psittaciformes									
Psittacidae									
<i>Amazona aestiva</i> (Linnaeus, 1758)	Turquoise-fronted Parrot	MN	F	25	0	0	25	0.42	–
<i>Eupsittula aurea</i> (Gmelin, 1788)	Peach-fronted Parakeet	MN	F	12	0	0	12	0.20	–
<i>Forpus xanthopterygius</i> (Spix, 1824)	Blue-winged Parrotlet	MN–ML	F	9	1	0	10	0.15	0.36
Strigiformes									
Strigidae									
<i>Megascops choliba</i> (Vieillot, 1817)	Tropical Screech-Owl	ML	C	0	1	0	1	–	0.36
Tinamiformes									
Tinamidae									

Family / Species	Common name	Method	Guild	nML	nMN	nOR	<i>n</i>	IFL	RF
<i>Nothura maculosa</i> (Temminck, 1815)	Spotted Nothura	MN	I	1	0	0	1	0.02	-
Trogoniformes									
Trogonidae									
<i>Trogon curucui</i> 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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