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Bird trophic guilds in distinct phytophysiognomies associated with the Atlantic forest in the Ibura National Forest, Northeastern Brazil

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Abstract - The fragmentation process of the Atlantic Forest can lead to the decline of many species, however, it can benefit generalist species better adapted to open environments. The present study investigated the influence of three phytophysiognomies (semi-deciduous seasonal Atlantic Forest, eucalypt plantations, and open fields) on the trophic guilds of birds in the Ibura National Forest (Sergipe, northeastern Brazil). Data were collected between August 2012 and May 2013 using MacKinnon lists, in biweekly three-day samples. A total of 91 species were recorded, being the most common omnivore, insectivore, and carnivore guilds. The Atlantic Forest area had a lower richness of bird species in the trophic guilds. Frugivores were not associated with the native forest, which may be related to local anthropogenic impacts associated with the exploitation of natural resources, resulting in higher species richness in the eucalyptus plantations and open fields. The results of the present study reinforce the potential of the Ibura National Forest for the conservation of the region's avian fauna. However, it highlights the need to implement measures for managing the natural vegetation and concrete efforts for the conservation of birds.

Keywords: Avian fauna. Eucalypt plantation. Food ecology. MacKinnon lists. Semi-deciduous seasonal Atlantic forest. Protected areas.

Guildas tróficas de aves em fitofisionomias distintas associadas à Mata Atlântica na Floresta Nacional de Ibura, Nordeste do Brasil

Resumo - O processo de fragmentação da Mata Atlântica pode levar ao declínio de muitas espécies, porém, pode beneficiar espécies generalistas que se adaptem melhor a ambientes abertos. O presente estudo investigou a influência de três fitofisionomias (Mata Atlântica sazonal semidecídua, plantações de eucalipto e campos abertos) nas guildas tróficas de aves da Floresta Nacional de Ibura (Sergipe, nordeste do Brasil). Os dados foram coletados entre agosto de 2012 e maio de 2013, usando listas

de MacKinnon, em amostragens quinzenais de três dias. Foram registradas 91 espécies, sendo as guildas dos onívoros, insetívoros e carnívoros as mais comuns. A área de Mata Atlântica teve menor riqueza de espécies de aves nas guildas tróficas. Os frugívoros não se associaram à floresta nativa, o que pode estar relacionado a impactos antropogênicos locais associados à exploração de recursos naturais, resultando em maior riqueza de espécies no plantio de eucalipto e em campo aberto. Os resultados do presente estudo reforçam o potencial da Floresta Nacional de Ibura para a conservação da avifauna local. No entanto, destaca a necessidade da implementação de medidas de manejo da vegetação natural e esforços concretos para a conservação da avifauna.

Palavras-chave: Avifauna. Plantação de eucalipto. Ecologia trófica. Listas MacKinnon. Floresta Atlântica sazonal semidecídua. **Á**reas protegidas.

Gremios tróficos de aves en distintas fitofisionomías asociadas con el Bosque Atlántico en el Bosque Nacional Ibura, noroeste de Brasil

Resumen - El proceso de fragmentación del Bosque Atlántico puede llevar al declinio de muchas especies, sin embargo, puede beneficiar a especies generalistas mejor adaptadas a ambientes abiertos. El presente estudio investigó la influencia de tres fitofisionomías (bosque atlántico estacional semi-caducifolio, plantación de eucaliptos y campos abiertos) en los gremios tróficos de aves en el Bosque Nacional Ibura (Sergipe, noroeste de Brasil). Los datos se recopilaron entre agosto de 2012 y mayo de 2013, utilizando Listas de MacKinnon en muestras quincenales de tres días. Se registraron 91 especies, siendo más los comunes los gremios omnívoros, insectívoros y carnívoros. En el bosque Atlántico encontramos los valores más bajos de riqueza de especies de aves. Los frugívoros no se asociaron con el bosque Atlántico, lo que puede explicarse por los impactos antropogénicos locales de la explotación de los recursos naturales, lo que ocasiona que la plantación de eucalipto y el campo abierto sean más ricos en especies. Los resultados del presente estudio sugieren el potencial del Bosque Nacional Ibura para la conservación de la avifauna en la región. Sin embargo, destaca la necesidad de implementar medidas para el manejo de la vegetación nativa y esfuerzos concretos para la conservación de las aves.

Palabras-clave: Avifauna. Plantación de eucaliptos. Ecología alimentar. Listas de MacKinnon. Bosque Atlántico estacional semi-caducifolio. Áreas naturales protegidas.

Introduction

The Atlantic Forest is a global biodiversity conservation hotspot (Rezende et al. 2018). Originally covering some 1.3 million square kilometers (SOS Mata Atlântica and Instituto Nacional de Pesquisas Espaciais 2018), this domain on the eastern seaboard of Brazil has suffered five centuries of deforestation and urban and agricultural development, which has led many species to the brink of extinction (Uezu and Metzger 2016). The fragmentation of the continuous habitat into a series of isolated patches surrounded by an anthropogenic matrix has several negative consequences for the resident fauna (Fahrig 2017). This process accentuates extinction risk through the isolation of breeding populations and associated impacts, such as an increase in edge effect (Laurance 2008). The permeability of the matrix surrounding the fragments also determines which species can survive in a given landscape (Barros et al. 2019), with some species

actually being benefited, as seen in the case of the granivorous birds that inhabit the sugarcane plantations of southeastern Brazil (Piratelli et al. 2005).

Birds are among the vertebrates most impacted by deforestation and habitat fragmentation, with canopy frugivores and understory insectivores disappearing first under advancing deforestation (Luck et al. 2013; Burivalova et al. 2015). These guilds, which are relatively dependent on forest habitats, tend to disappear from the smaller fragments, given the exponential growth of edge effects, which favors generalist species better adapted to open areas and the forest edge (Anjos 1998).

A fundamental strategy to mediate the impacts of deforestation on ecosystems is the creation of protected areas. The first Brazilian protected area, the Itatiaia National Park, was created only in 1937 (Rylands and Brandon 2005), and while many other protected areas were established throughout the country in the subsequent decades, deforestation and hunting pressure continue to have a fundamental impact on Brazilian wildlife, even within these areas (Tabarelli et al. 2005). By 2015, only 163,762 km^2 of the Atlantic Forest remained intact, representing 12.5% of the original area of the domain (SOS Mata Atlântica and Instituto Nacional de Pesquisas Espaciais 2018). With the Brazilian state of Sergipe having a similar scenario, where only 724 km^2 of the original 10,189 km^2 of Atlantic Forest remain (Vasconcelos and Nery 2013; Fundação SOS Mata Atlântica and INPE 2015).

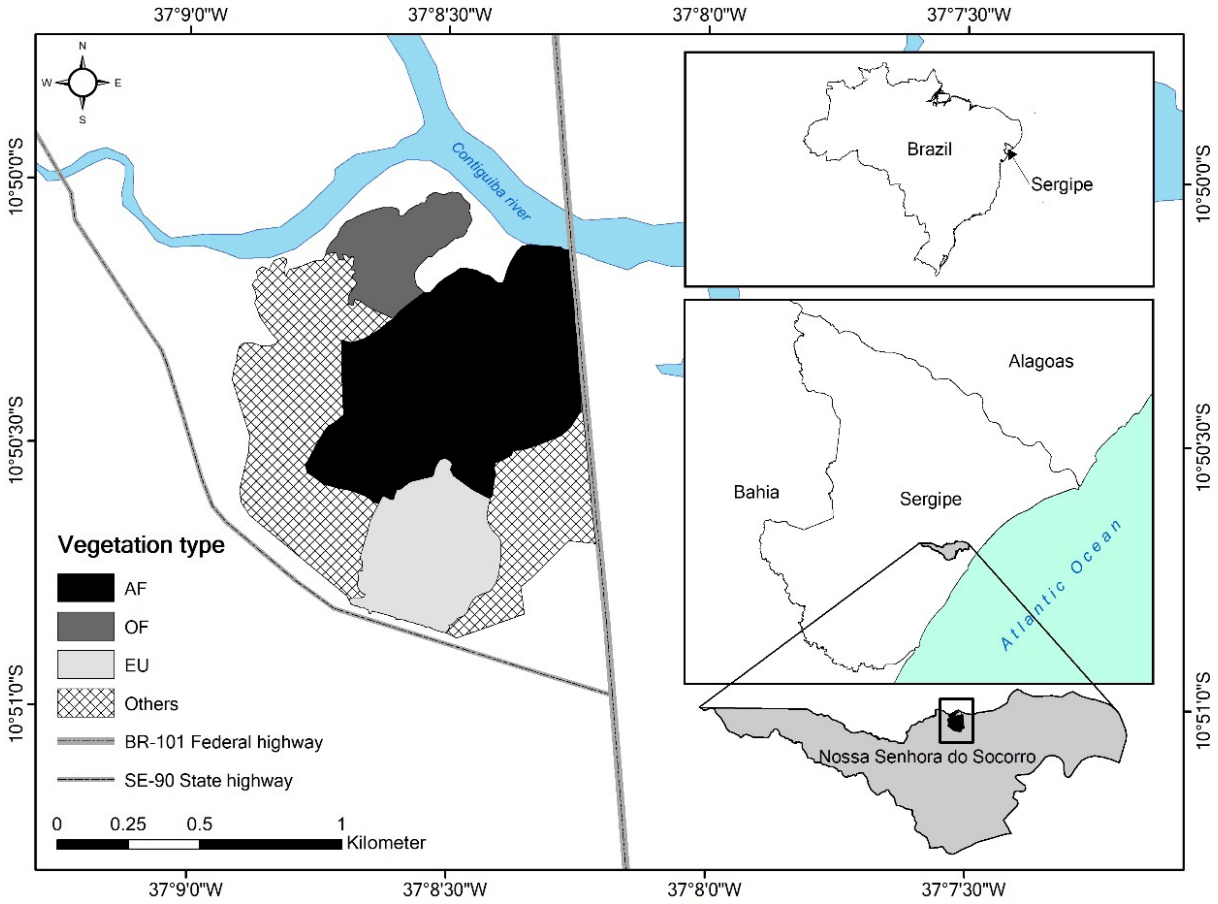
Relatively few ornithological studies have focused on the Atlantic Forest bird communities of Sergipe (D'Horta et al. 2005; Sousa 2009; Ruiz-Esparza et al. 2015; Ruiz-Esparza et al. 2016; Oliveira et al. 2018). While these studies provide an important database for the understanding of the region's avian fauna, it is especially necessary to better comprehend how this fauna responds to local anthropogenic impacts. The present study thus focuses on the birds of the Ibura National Forest, in Sergipe, providing not only a species inventory but also an analysis of the structure of the trophic guilds found in the three distinct phytophysiognomies found within this protected area.

Methods

Study area

The present study was conducted in the Ibura National Forest (FLONA do Ibura), located at kilometer 85 of the BR-101 federal highway (10°50'38.43" S, 37°8'25.23" W) in the municipality of Nossa Senhora do Socorro, Sergipe, Brazil (Figure 1). This 145 ha protected area was created by federal decree on September 19th, 2005, to conciliate the conservation of natural habitats with the sustainable exploitation of natural resources and scientific research (Brasil 2005).

Figure 1. Location of the Ibura National Forest in the municipality of Nossa Senhora do Socorro, Sergipe, Brazil. AF = Atlantic Forest, OF = Open Field, EU = Eucalypt plantation.



The local climate, according to Köppen-Geiger classification, is *Aw* (tropical), with dry summers, annual precipitation of 1000–1400 mm, and mean temperatures of 22.7–26.5ºC (Kottek et al. 2006). The local soil is red-yellow podzolic, with a narrow band of indiscriminate mangrove soil on the margin of the Contiguiba River. The terrain is flat, with a mean altitude of 22 m *a.s.l.* (Jacomine et al. 1975). The natural local vegetation is semi-deciduous seasonal Atlantic Forest at different stages of regeneration, in addition to unmanaged stands of eucalypt (*Eucalyptus torelliana* and *Eucalyptus citriodora*) planted approximately 40 years ago (Santana et al. 2017). The third phytophysiognomy is open fields, composed of patches of exotic grasses, with some trees and shrubs, and mangrove forest on the margin of the river. Santana et al. (2017) considered the area of the Atlantic Forest to be well preserved, due to the presence of many native and endemic tree species.

Data collection

The local bird fauna was surveyed every fortnight between August 2012 and May 2013. Each survey lasted three days, with each of the three phytophysiognomies (Atlantic Forest, eucalypt plantation, and open fields) being sampled on one day per campaign. Areas under regeneration, buildings, and mangroves were not sampled (Others in Fig. 1) due to logistic difficulties, in

particular, the lack of a vessel for aquatic surveys. Data were collected using MacKinnon lists (MacKinnon and Phillipps 1993; Bibby et al. 1998).

The MacKinnon List method consisted of surveying birds using lists of 10 species, which were compiled by the same observer in all the samples. To compile a list, the observer walks along a pre-established trail, in either the morning (05:00–10:00 h) or the afternoon (15:00–19:00 h), and when a bird species is sighted or heard, it is added to the list until 10 different species have been recorded. A species cannot be repeated on the same list, nor can the same individual be included in two consecutive lists. At the end of each list, there was a 10-minute interval before starting a new list, in an attempt to guarantee that the same individuals were not recorded in consecutive lists. As there is no formal limit on the number of lists that can be collected during a study (Bibby et al. 1998), the maximum possible number of lists was compiled during each sampling session. The birds were identified using binoculars (Eagle Optics 10 x 42) and the nomenclature follows the Comitê Brasileiro De Registros Ornitológicos (Piacentini et al. 2015).

Data analysis

The bird species recorded during the study were classified into eight different trophic guilds: Carnivore (Car), Scavenger (Sca), Granivore (Gra), Insectivore (Ins), Nectarivore (Nec), Omnivore (Oni), Frugivore (Fru), and Piscivore (Pis), based on the arrangements suggested by Sick (2001), Piratelli et al. (2005), Scherer et al. (2005), Toledo-Lima et al. (2014), Wilman et al. (2014), and Crestani et al. (2015). To verify the sampling efficiency, total bird species richness was estimated using the Jackknife 1 procedure, run in EstimateS 9.1.0 (Colwell 2013). The relative abundance of each species was obtained using the Index of Frequency in the Lists (IFL), which is given by IFL = l_i/L, where l_i = the number of lists in which species *i* was recorded, and L = the total number of lists compiled (Bibby et al. 1998).

Two classical indices – Shannon-Wiener's diversity index (H') and Pielou's evenness (E') – were applied to describe the diversity of birds in the study areas, using the IFL as a measure of abundance. The similarity in the composition and abundance of the different phytophysiognomies was also evaluated using a cluster analysis, based on the Bray-Curtis coefficient of similarity (Legendre and Legendre 2012).

The Kruskal-Wallis nonparametric analysis of variance was used to verify the variation in species richness among the trophic guilds in the different phytophysiognomies. This nonparametric test was used because the variances of species richness were not homoscedastic. Dunn's multiple comparison test was used to identify the phytophysiognomies with significantly different species richness. The p values were adjusted by the Holm method (Dunn 1964; Legendre and Legendre 2012). All these analyses were run in the R software (R Core Team 2018).

Results

During the present study, a total of 100 MacKinnon lists were compiled, providing 1000 records of the birds that occur within the study area. A total of 91 species were recorded, representing 33 families (Table 1). The highest species richness (S = 77) was recorded in the eucalypt plantation, followed by the open field (S = 72), and the Atlantic Forest (S = 44). Overall, the most diverse families

were the Thraupidae (15 species), Tyrannidae (9 species), and Ardeidae (5 species). Together, these three families contributed almost one third of the bird species recorded in the Ibura National Forest. The most common species were *Tangara palmarum* (Wied 1821) (*n* = 43 records; IFL = 0.43), *Coragyps atratus* (Bechstein 1793) (*n* = 41; IFL = 0.41), *Troglodytes musculus* Naumann, 1823 (*n* = 40; 0.40), *Columbina talpacoti* (*n* = 39; IFL = 0.39), and *Turdus leucomelas* (*n* = 37; IFL = 0.37).

Table 1. Bird species recorded in the Ibura National Forest, in the municipality of Nossa Senhora do Socorro, Sergipe, Brazil during the present study period (August 2012 through May 2013). IFL = Index of Frequency in the Lists. Phytophysiognomies: AF = Atlantic Forest; EU = Eucalypt plantation; OF = Open Field. Trophic guilds: Car = Carnivore; Sca = Scavenger; Fru = Frugivore; Gra = Granivore; Ins = Insectivore; Nec = Nectarivore; Omn = Omnivore; Pis = Piscivore.

Family/Species	English name	IFL	Phytophysiognomy	Guild
Accipitridae				
Buteo brachyurus	Short-tailed Hawk	0.13	OF/EU	Car
Elanus leucurus	White-tailed Kite	0.01	EU	Car
Rupornis magnirostris	Roadside Hawk	0.18	OF/EU/AF	Car
Alcedinidae				
Megaceryle torquata	Ringed Kingfisher	0.08	OF/EU/AF	Pis
Ardeidae				
Ardea alba	Great Egret	0.09	OF/EU	Pis
Bubulcus ibis	Cattle Egret	0.07	OF/EU	Ins
Butorides striata	Striated Heron	0.02	OF/EU	Pis
Egretta caerulea	Little Blue Heron	0.02	OF	Pis
Nycticorax nycticorax	Black-crowned Night-Heron	0.01	EU	Pis
Caprimulgidae				
Nyctidromus albicollis	Common Pauraque	0.1	OF/EU/AF	Ins
Cathartidae				
Cathartes aura	Turkey Vulture	0.23	OF/EU/AF	Sca
Cathartes burrovianus	Lesser Yellow-headed Vulture	0.01		Sca
Coragyps atratus	Black Vulture	0.41	OF/EU/AF	Sca
Charadriidae				
Vanellus chilensis	Southern Lapwing	0.03	OF/EU/AF	Omn
Columbidae				
Columbina squammata	Scaled Dove	0.02	OF	Gra
Columbina talpacoti	Ruddy Ground Dove	0.39	OF/EU/AF	Gra
Leptotila verreauxi	White-tipped Dove	0,09	OF/EU/AF	Gra
Cuculidae				
Crotophaga ani	Smooth-billed Ani	0.14	OF/EU/AF	Omn
Piaya cayana	Squirrel Cuckoo	0.11	OF/EU/AF	Omn
Dendrocolaptidae				
Dendroplex picus	Straight-billed Woodcreeper	0.01	EU	Ins
Falconidae				
Caracara plancus	Southern Caracara	0.11	OF/EU	Car
Falco sparverius	American Kestrel	0.01	OF	Car

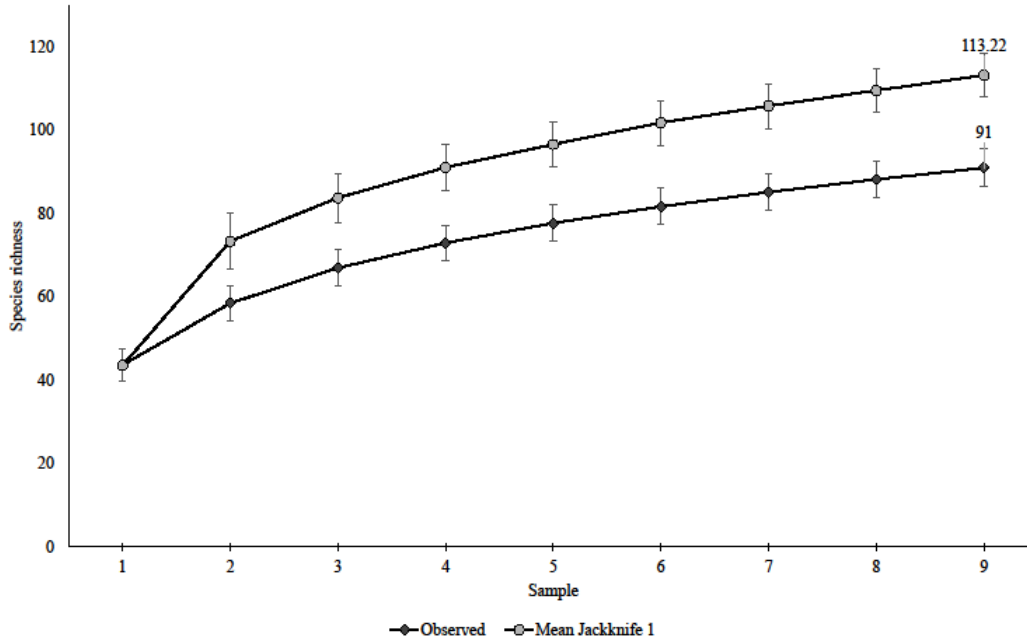
Family/Species	English name	IFL	Phytophysiognomy	Guild
Herpetotheres cachinnans	Laughing Falcon	0.19	OF/EU/AF	Car
Milvago chimachima	Yellow-headed Caracara	0.13	OF/EU/AF	Car
Fringillidae				
Euphonia chlorotica	Purple-throated Euphonia	0.36	OF/EU/AF	Fru
Euphonia violacea	Violaceous Euphonia	0.23	OF/EU/AF	Fru
Galbulidae				
Galbula ruficauda	Rufous-tailed Jacamar	0.34	OF/EU/AF	Ins
Hirundinidae				
Progne tapera	Brown-chested Martin	0.03	OF/EU	Ins
Stelgidopteryx ruficollis	Southern Rough-winged Swallow	0.03	OF/EU	Ins
Tachycineta albiventer	White-winged Swallow	0.01	EU	Ins
Icteridae				
Icterus pyrrhopterus	Epaulet Oriole	0.01	EU	Omn
Molothrus bonariensis	Shiny Cowbird	0.01	EU	Omn
Nyctibiidae				
Nyctibius griseus	Common Potoo	0.02	OF	Ins
Parulidae				
Myiothlypis flaveola	Flavescent Warbler	0.01	EU	Ins
Passerellidae				
Arremon taciturnus	Pectoral Sparrow	0.25	OF/EU/AF	Omn
Passeridae				
Passer domesticus	House Sparrow	0.01	EU	Omn
Picidae				
Celeus ochraceus	Ochre-backed Woodpecker	0.06	OF/EU/AF	Ins
Dryocopus lineatus	Lineated Woodpecker	0.01	EU	Ins
Veniliornis passerinus	Little Woodpecker	0.06	OF/EU	Ins
Pipridae				
Chiroxiphia pareola	Blue-backed Manakin	0.04	EU	Fru
Manacus manacus	White-bearded Manakin	0.07	EU/AF	Fru
Polioptilidae				
Polioptila plumbea	Tropical Gnatcatcher	0.14	OF/EU/AF	Ins
Psittacidae				
Brotogeris tirica	Plain Parakeet	0.03	OF/EU	Fru
Eupsittula aurea	Peach-fronted Parakeet	0.17	OF/EU	Fru
Forpus xanthopterygius	Blue-winged Parrotlet	0.27	OF/EU	Fru
Rallidae				
Aramides cajaneus	Gray-cowled Wood-Rail	0.17	OF/EU/AF	Omn
Laterallus viridis	Russet-crowned Crake	0.01	EU	Omn
Rallus longirostris	Mangrove Rail	0.01	AF	Omn
Rhynchocyclidae				
Leptopogon amaurocephalus	Sepia-capped Flycatcher	0.01	OF	Ins
Todirostrum cinereum	Common Tody-Flycatcher	0.06	EU	Ins

Family/Species	English name	IFL	Phytophysiognomy	Guild
Tolmomyias flaviventris	Yellow-breasted Flycatcher	0.02	OF/EU	Ins
Strigidae				
Megascops choliba	Tropical Screech-Owl	0.04	OF/EU/AF	Car
Thamnophilidae				
Formicivora grisea	White-fringed Antwren	0.15	OF/EU	Ins
Formicivora melanogaster	Black-bellied Antwren	0.01	AF	Ins
Taraba major	Great Antshrike	0.02	OF/EU	Ins
Thamnophilus pelzelni	Planalto Slaty-Antshrike	0.15	OF/EU/AF	Ins
Thraupidae				
Chlorophanes spiza	Green Honeycreeper	0.01	OF	Fru
Coereba flaveola	Bananaquit	0.2	OF/EU/AF	Nec
Conirostrum speciosum	Chestnut-vented Conebill	0.02	OF/EU	Omn
Dacnis cayana	Blue Dacnis	0.05	OF/EU/AF	Omn
Hemithraupis guira	Guira Tanager	0.01	EU	Omn
Nemosia pileata	Hooded Tanager	0.06	OF/EU	Omn
Saltator maximus	Buff-throated Saltator	0.03	OF/EU	Omn
Sporophila albogularis	White-throated Seedeater	0.01	OF	Gra
Sporophila bouvreuil	Copper Seedeater	0.01	EU	Gra
Tachyphonus rufus	White-lined Tanager	0.06	OF/EU/AF	Omn
Tangara cayana	Burnished-buff Tanager	0.1	OF/EU	Omn
Tangara palmarum	Palm Tanager	0.43	OF/EU/AF	Omn
Tangara sayaca	Sayaca Tanager	0.2	OF/EU/AF	Omn
Tersina viridis	Swallow Tanager	0.02	OF	Omn
Volatinia jacarina	Blue-black Grassquit	0.12	OF/EU	Gra
Trochilidae				
Chrysolampis mosquitus	Ruby-topaz Hummingbird	0.02	OF	Nec
Eupetomena macroura	Swallow-tailed Hummingbird	0.14	OF/EU/AF	Nec
Phaethornis ruber	Reddish Hermit	0.04	OF/AF	Nec
Thalurania glaucopis	Violet-capped Woodnymph	0.04	OF/EU/AF	Nec
Troglodytidae				
Pheugopedius genibarbis	Moustached Wren	0.05	OF/EU	Omn
Troglodytes musculus	House Wren	0.4	OF/EU/AF	Ins
Trogonidae				
Trogon curucui	Blue-crowned Trogon	0.02	EU/AF	Omn
Turdidae				
Turdus leucomelas	Pale-breasted Thrush	0.37	OF/EU/AF	Omn
Turdus rufiventris	Rufous-bellied Thrush	0.09	OF/EU/AF	Omn
Tyrannidae				
Camptostoma obsoletum	Southern Beardless-Tyrannulet	0.2	OF/EU/AF	Ins
Elaenia cristata	Plain-crested Elaenia	0.02	OF/EU	Omn
Elaenia flavogaster	Yellow-bellied Elaenia	0.12	OF/EU	Omn
Fluvicola nengeta	Masked Water-Tyrant	0.04	EU/AF	Ins

Family/Species	English name	IFL	Phytophysiognomy	Guild
Megarynchus pitangua	Boat-billed Flycatcher	0.22	OF/EU/AF	Omn
Myiarchus tyrannulus	Brown-crested Flycatcher	0.01	OF	Ins
Myiozetetes similis	Social Flycatcher	0.27	OF/EU/AF	Omn
Pitangus sulphuratus	Great Kiskadee	0.31	OF/EU/AF	Omn
Tyrannus melancholicus	Tropical Kingbird	0.33	OF/EU/AF	Ins
Vireonidae				
Cyclarhis gujanensis	Rufous-browed Peppershrike	0.31	OF/EU/AF	Ins
Vireo chivi	Red-eyed Vireo	0.27	OF/EU/AF	Ins

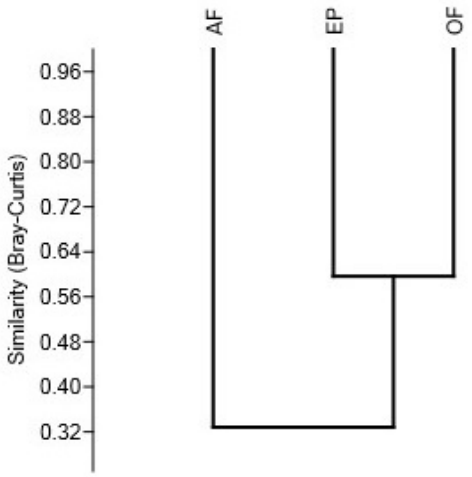
The total species richness sampled in the Ibura National Forest corresponded to approximately 80% of the richness estimated by the Jackknife 1 procedure, which indicated a total of 113.22 species (± SD 5.3), based on the data from the MacKinnon lists (Figure 2).

Figure 2. Species accumulation curves for the records obtained (observed) and the Jackknife 1 estimator of the bird diversity of the Ibura National Forest in Nossa Senhora do Socorro, Sergipe, Brazil. Data collected between August 2012 and May 2013.



The Shannon-Wiener diversity (H') was 3.96 for the open field, 3.85 for the eucalypt plantation, and 3.45 for the Atlantic Forest. Evenness (J') was 0.73 for the open field, 0.61 for the eucalypt plantation, and 0.72 for the Atlantic Forest. The cluster analysis indicated that the bird assemblages of the open field and eucalypt plantation were more similar to one another than either was to the Atlantic Forest (Figure 3).

Figure 3. Cluster analysis, based on the Bray-Curtis index, for the matrix of bird species abundance in the three phytophysiognomies sampled (AF = Atlantic Forest; EP= eucalypt plantation; OF = open field) in the Ibura National Forest, Nossa Senhora do Socorro, Sergipe (Brazil).



The omnivore, insectivore, and carnivore guilds were the most common in all three study areas, although the frugivores had the same species richness as the carnivores (n = 7) in the eucalyptus plantation and the nectarivores had the same species richness as the carnivores (n = 4) in the native Atlantic Forest (Figure 4). Significant variation (Kruskal-Wallis, $p < 0.05$) was found among habitats in the diversity of almost all trophic guilds (Figure 5) except the nectarivores ($p > 0.07$). Dunn's test revealed significant differences between at least one pair of guilds in most physiognomies. In general, bird species richness was lowest in the Atlantic Forest, in all guilds, except the nectarivores.

Figure 4. Species richness of the different bird trophic guilds recorded in the three phytophysiognomies of the Ibura National Forest, in Sergipe, Brazil, between August 2012 and May 2013. Phytophysiognomies: AF = Atlantic Forest; EP= eucalypt plantation; OF = open field.

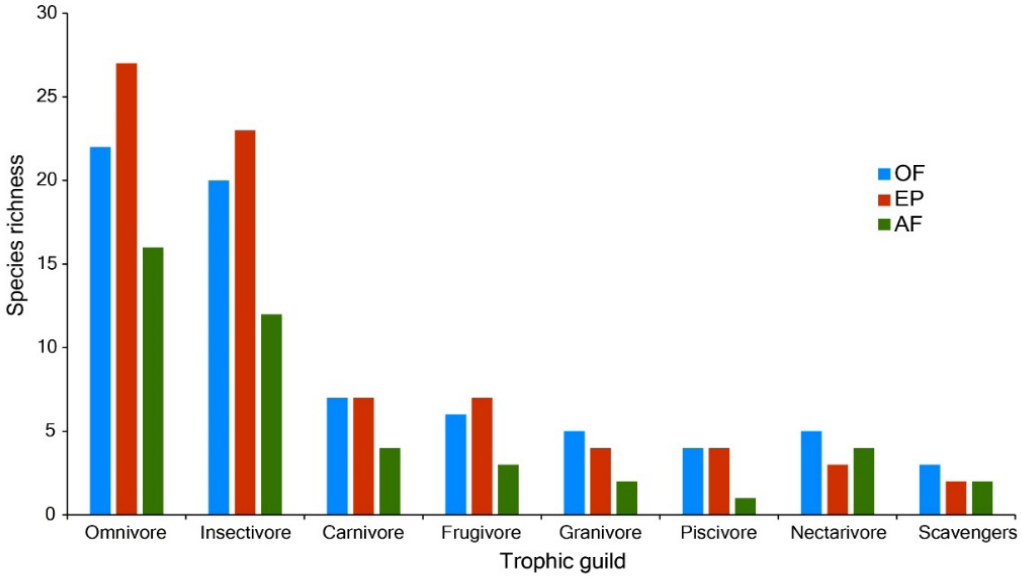
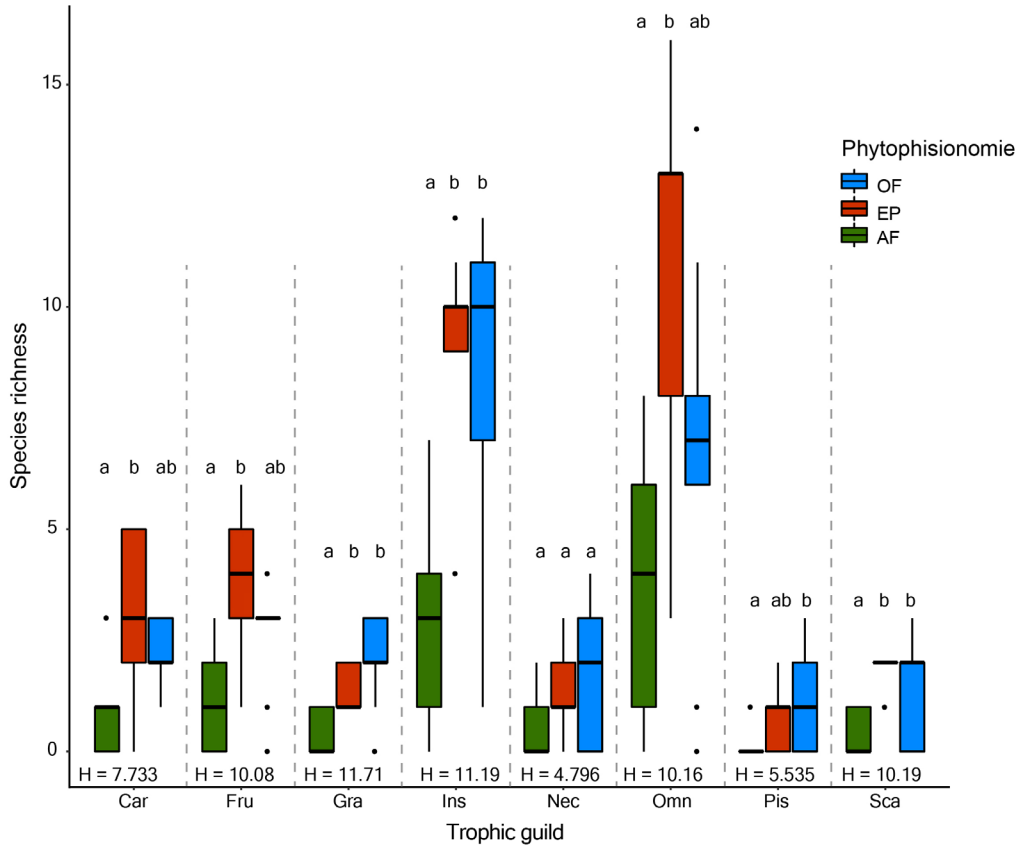


Figure 5. Box plots of variance distribution and index H from the Kruskal-Wallis analysis and the results of Dunn's test for the pairwise differences in the number of bird species per guild in each phytophysiognomy (AF = Atlantic Forest; EP = eucalypt plantation; OF = open field) sampled in the Ibura National Forest, Sergipe, Brazil. The columns with different letters are significantly different from one another (Dunn's test, $p < 0.05$, P adjusted by Holm's method). Car = Carnivore; Fru = Frugivore; Gra = Granivore; Ins = Insectivore; Nec = Nectarivore; Omn = Omnivore; Pis = Piscivore; Sca = Scavenger.



Discussion

The bird species richness and composition recorded in the Ibura National Forest were similar to those recorded at other Atlantic Forest sites in Sergipe, such as the Mata do Junco State Wildlife Refuge, with 129 species (Ruiz-Esparza et al. 2015), the Serra de Itabaiana National Park, with 123 species (D'Horta et al. 2005), and the Caju Private Natural Heritage Reserve, with a slightly lower total of 89 species (Ruiz-Esparza et al. 2016). At Mata do Crasto, however, in the municipality of Santa Luzia do Itanhy, Sousa (2009) recorded a total of 204 species, possibly reflecting the much better conservation status of this site in comparison with the other forests surveyed in the state of Sergipe.

A similar spread of results has been obtained at other Atlantic Forest sites in northeastern Brazil. Relatively rich bird faunas have been recorded at some sites, such as the Charles Darwin Ecological Refuge, in the state of Pernambuco, where Magalhães et al. (2007) recorded 151 bird species, and Usina São José, also in Pernambuco, where Farias et al. (2007) recorded 184 species. By contrast, Silva et al. (2015) recorded only 52 species in forest fragments around the Viçosa campus

of the Federal University of Alagoas, while at other sites in the state of Alagoas, Silveira et al. (2003) recorded as few as 20–46 species.

This considerable variation among sites in bird species richness may be related to several factors, including the size of the forest fragment (Matthews et al. 2016), its conservation status, the quality of the habitat, and sampling effort (Cure et al. 1991; Schilling and Batista 2008). The lack of standardization in sampling methods also hinders more conclusive comparisons among studies. Despite this, it is clear from the results of the present study that the Ibura National Forest is an important site for the conservation of Atlantic Forest birds in Sergipe, in particular, and in northeastern Brazil, in general. One of the species recorded in the present study, *Herpsilochmus pectoralis* Sclater 1857, which is classified as Vulnerable by the IUCN (BirdLife International 2017) is of special interest.

The tyrant flycatchers (Tyrannidae) and tanagers (Thraupidae) are among the most predominant groups in most Brazilian avian communities (Piacentini et al. 2015). In addition to their natural species richness, many flycatchers and tanagers are tolerant of habitat disturbance and human impacts (Franco and Prado 2012; Silveira and Machado 2012; Toledo-Lima et al. 2014; Crestani et al. 2015). Habitat degradation typically impacts the more specialized species, such as the large canopy frugivores and understory insectivores (Luck et al. 2013; Burivalova et al. 2015), which are often replaced by more generalist species (Ricklefs and Relyea 2016).

Habitat degradation results in shifts in microclimatic parameters, creating an environment that may be inappropriate for many species, which may become locally extinct (Laurance 2008). The human populations adjacent to the Ibura National Forest can exacerbate habitat degradation within this protected area, given that many local residents exploit its resources illegally (Gomes et al. 2006).

The predominance of the omnivore and insectivore guilds is also typical of Atlantic Forest sites in the Brazilian Northeast, such as the campus of the Federal University of Alagoas (Silva et al. 2015), Fazenda Nossa Senhora da Paz in the municipality of Mata de São João (Crestani et al. 2015), and Fazenda Santa Fé, in the municipality of Tanque d'Arca, in the state of Alagoas

(Toledo-Lima et al. 2014). In the present study, the carnivore guild was represented by birds of the families Strigidae, Accipitridae, and Falconidae, including *Buteo brachyurus* Vieillot 1816 and *Caracara plancus* (Miller 1777) that fly at high levels in search of prey, including insects and small vertebrates (Ogden 1974; Sick 2001), which favors their occurrence in eucalypt plantation and open areas, as confirmed by the analyses.

In the case of the frugivore guild, only species of the genera *Manacus* and *Euphonia* were recorded in the Atlantic Forest, although they were also present in the other habitats, reflecting their ecological plasticity (Sick 2001; Gonçalves and Vitorino 2014). All the other frugivores recorded in the present study were cardinals, parrots, and tanagers, birds that feed on small palm nuts and fruit (Sick 2001), and while the open field has less of these resources, many frugivores were recorded in this habitat in transit between areas of forest.

Granivorous and scavengers were more common in open field. Vultures (Cathartidae), the only representatives of the scavenger guild, typically fly high over open areas in search of animal carcasses, which means that they are rare in denser habitats, such as the forest, either because of the relative lack of feeding resources or their reduced visibility in this environment (Sick 2001; Olmos et al. 2006). The distribution of the granivores is also consistent with their feeding ecology, given

that they are favored by the abundance of seed produced by the grasses found in open fields (Anjos 1998; Sick 2001).

The only insectivore found exclusively in the Atlantic Forest zone was *Formicivora melanogaster* Pelzeln 1868, and the only omnivore was *Rallus longirostris* Boddaert 1783. Understory insectivores, which are more dependent on the forest nucleus, tend to disappear following fragmentation and the reduction of the fragments (Aleixo 1999). As a relatively small and highly degraded forest remnant (Santana et al. 2017), the Ibura National Forest has likely already lost its more sensitive insectivores. Species such as *Platyrinchus mystaceus* Vieillot 1818 and *Sittasomus griseicapillus* (Vieillot, 1818), which are found in better-preserved forests in Sergipe (Sousa 2009; Ruiz-Esparza et al. 2015), can now be extinct at Ibura, where only the most tolerant and generalist species remain. By contrast, as omnivory reflects more generalist feeding thus, omnivores may be better adapted to degraded habitats in comparison with more specialized feeders (Morante-Filho and Silveira 2012; Crestani et al. 2015). This may account for the reduced diversity of both insectivores and omnivores in the Atlantic Forest in comparison with the other phytophysiognomies.

Five species of piscivorous birds were recorded in the present study, including four herons and one kingfisher. Except for *Megaceryle torquata* (Linnaeus 1766), these species were recorded at the margins of the local bodies of water. While significant differences between habitats were found in this guild, it seems likely that this variation was either related to the greater visibility of the more open habitats (and other, random factors), rather than any intrinsic feature of these environments.

No significant variation in the nectarivore guild was found among phytophysiognomies. All but one of the nectarivores recorded during the present study were hummingbirds. While some 25 trochilid species are known to occur in Sergipe (Sousa 2009; Ruiz-Esparza et al. 2011; Ruiz-Esparza et al. 2012; Ruiz-Esparza et al. 2015; Ruiz-Esparza et al. 2016), the five species recorded at Ibura National Forest were all generalists, such as *Thalurania glaucopis* (Gmelin 1788), *Eupetomena macroura* (Gmelin 1788), and *Phaethornis ruber* (Linnaeus 1758), which are commonly found in urban environments (Matarazzo-Neuberger 1992; Straube et al. 2006; Pereira and Silva 2009). The other nectarivore was the bananaquit, *Coereba flaveola* (Linnaeus 1758), a species distributed widely in the Neotropical region (Bellemain et al. 2008), in both rural and urban environments (Ribeiro and Silva 2005; Cristofoli et al. 2008).

Differences between insectivores and omnivores can be explained by an increase in omnivores in anthropized areas, such as areas of secondary or exotic vegetation, and a more varied diet is favored in disturbed environments, omnivores can benefit when variations in food supply occur (Telino-Júnior et al. 2005). In fragments with reduced size, in areas with secondary vegetation, the omnivorous birds may be in a higher percentage than the frugivorous (Motta-Júnior 1990).

In this work, no guans or chachalacas were found that can help in seed dispersal, for example *Ortalis araucuan* and *Penelope superciliaris*, which are present in more conserved forests such as Junco (Ruiz-Esparza et al. 2015). Also toucans, for example, *Ramphastus vitellinus* present in Itabaiana or Crasto (Sousa 2009). Some of these species may present local extinctions due to several factors, having an increase during the last years by anthropogenic actions such as hunting or deforestation, compromising the interactions in the essential forests for the functioning of ecosystems (Emer et al. 2019).

Frugivores play a fundamental role in forests, as they maintain the dispersion of seeds from local to regional scale, contributing to the regeneration of plants in situ. Thus, the greatest richness of this trophic guild was found in the eucalyptus plantation and open areas, which can contribute to the ecosystem services of these birds, there will be greater interaction between plant-bird, where factors body mass and seed diameter, present a close relationship in the process of seed dispersal (Emer et al. 2018).

Wild birds respond positively or negatively to changes in the environment in different forms (Andrade et al. 2011). The results found can be used to determine indicators of environmental sustainability and can be expressed in terms of Pressure/State/Impact/Response (Kristensen 2004). Such sustainability indicators help in the weighting of changes positively or negatively according to the level of sustainability of the analyzed site, when negative, they reflect some type of disturbance caused by human activities.

An important negative indicator found in our study is the absence of large body mass species (Peres 2001; Develey and Martensen 2006; Pinheiro and Dornas 2009), which may be related to hunting pressure on species such as the Tynamidae and Cracidae families, which are constant targets of hunters due to their size. On the other hand, and corroborating the impacted state of the study area is the absence of large frugivores, for example, of the genera *Ortalis*, *Penelope* or *Amazona* (Aleixo and Vielliard 1995), since birds of this type are very demanding concerning their diet, requiring a high density of fruit in the forest to compose their diet.

Conclusions

Bird trophic guilds can be useful indicators of the ecological variation among different environments (Stotz et al. 1996) and the absence of more specialist species from the Atlantic Forest may be related to the anthropogenic impacts within the area of the Ibura National Forest. While this protected area is relatively small, its bird fauna is similar in diversity to many other areas of Atlantic Forest in the Brazilian Northeast. Its conservation value is further reinforced by the presence of a vulnerable bird species. The recuperation of degraded areas (eucalypt plantation and open field), may further reinforce the value of this protected area in a region with a relative paucity of conservation units.

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