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ARTIGO

Diversity and body condition of wild birds in a reforestation area in the Atlantic Forest of Southeastern Brazil

Diversidade e condição corporal de aves silvestres em área de reflorestamento na Mata Atlântica do Sudeste do Brasil

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ABSTRACT: The Atlantic Forest has priority areas for conservation, especially in the Médio Paraíba Region in southeastern Brazil, which was widely deforested during the coffee cycle. In this sense, some methods of environmental assessment as the evaluation of the body condition of wild animals have been widely applied and related to a variety of biological and environmental factors. The current work aimed to evaluate the diversity and body condition of wild birds, and their relationship to biological, ecological and environmental factors, in a reforestation area in the municipality of Pinheiral in the Médio Paraíba Region in southeastern Brazil. A total of 195 were captured with mist nets and identified. Body condition was calculated using simple linear regression between body mass and body length. Linear regression and analysis of variance were used to determine the relationship of body condition with the biological and environmental data. The Shannon-wiener diversity index (H'), Simpson dominance index (λ‘) and Pielou evenness index (J') were calculated from the abundance of bird species. The order Passeriformes was the most representative among the captured birds. Among all the biological and ecological data evaluated, body condition was significantly related only to rain and temperature, where it was observed that the body condition indexes decrease with the increase of the rains and temperature, that is, with the wet season. The Shannon-wiener, Simpson and Pielou indexes showed greater diversity and less dominance in the wet season compared to the dry season, although there is a predominance of birds with greater forest dependencies in the dry season. This work highlights the importance of the maintenance of this reforestation area in the Atlantic Forest of Southeastern Brazil for the conservation of the birds and of the ecosystem of the region, besides showing that the wet season is unfavorable for the body condition of birds.

Keywords: ecological descriptors; fitness; seasonality; conservation; Médio Paraíba Region; birds

RESUMO: A Mata Atlântica tem áreas prioritárias para conservação, especialmente na Região do Médio Paraíba, sudeste do Brasil, que foi amplamente desmatada durante o ciclo do café. Nesse sentido, alguns métodos de avaliação ambiental, como a avaliação da condição corporal de animais silvestres, têm sido amplamente aplicados e relacionados a uma variedade de fatores biológicos e ambientais. O objetivo deste trabalho foi avaliar a diversidade e condição corporal de aves silvestres, e sua relação com fatores biológicos, ecológicos e ambientais, em uma área de reflorestamento no município de Pinheiral na Região do Médio Paraíba, sudeste do Brasil. Um total de 195 foram capturados com redes de neblina e identificados. A condição corporal foi calculada por regressão linear simples entre massa corporal e comprimento corporal. Regressão linear e análise de variância foram usadas para determinar a relação da condição corporal com dados biológicos e ambientais. O índice de diversidade de Shannon-wiener (H'), o índice de dominância de Simpson (λ') e o índice de uniformidade de Pielou (J') foram calculados a partir da abundância de espécies de aves. A ordem Passeriformes foi a mais representativa entre as aves capturadas. Dentre todos os dados biológicos e ecológicos avaliados, a condição corporal foi significativamente relacionada apenas com a pluviosidade e temperatura, onde foi observado que os índices de condição corporal diminuem com o aumento da precipitação e da temperatura, ou seja, com o período chuvoso. Os índices de Shannon-wiener, Simpson e Pielou mostraram maior diversidade e menor prevalência na estação chuvosa em relação à seca, embora haja predominância de aves com maior dependência de florestas na estação seca. Este trabalho destaca a importância da manutenção desta área de reflorestamento na Mata Atlântica do Sudeste do Brasil para a conservação das aves e do ecossistema da região, além de mostrar que o período chuvoso é desfavorável para a condição corporal das aves.
Palavras-chave: descritores ecológicos; condição corporal ; sazonalidade; conservação; Região do Médio Paraíba; aves

INTRODUCTION

The Atlantic Forest is recognized as a global hotspot for having one of the highest rates of endemism and biodiversity, but also for its history of constant threats suffered over centuries (Pinto et al., 2006; Tabarelli et al., 2005). Currently, the Atlantic Forest is reduced to just 12.5% of its original distribution, where it is estimated that about 891 species of wild birds occur, 213 of which are endemic (Silva et al., 2017). Among the several priority areas for conservation of the Atlantic Forest, the Médio Paraíba Region in southeastern Brazil can be highlighted. The region was extensively modified and anthropized, being one of the most deforested areas during the coffee cycle in Brazil (Devide et al., 2014).

Among the various methods of environmental assessment, checking the body condition of animals in a locality or ecosystem has been widely applied in recent decades (Schulte-Hostedde et al., 2005; Labocha & Hayes, 2012). Body condition has been related to a wide variety of individual attributes, such as: survival, productivity, habitat use, behavior, etc. in several wild animals, including birds. Many studies have related body condition of birds to their survival in preserved and urbanized environments (Blums et al., 2005; Stevenson & Woods, 2006; Bókony et al., 2012) and its variation may be indicate environmental stress (Peig & Green, 2010).

In this context, the aim of the current work was to evaluate diversity, equitability and dominance, in addition to the body condition of wild birds, relating them to the different biological, ecological and environmental conditions in a reforestation area in the Municipality of Pinheiral in the Médio Paraiba Region, State of the Rio de Janeiro, Southeastern Brazil.

MATERIALS AND METHODS

Study site: This study was carried out in a reforestation area of 37 ha within the campus Pinheiral of the Instituto Federal de Educação, Ciência e Tecnologia do Rio de Janeiro – IFRJ, which is identified as Espaço Ecológico Educativo – EEcoE (Educational Ecological Space), at the municipality of Pinheiral in the Médio Paraíba Region in the State of the Rio de Janeiro, Southeastern Brazil. This study area is part of the Atlantic Forest biome, whose original vegetation comprises the Submontane Semideciduous Seasonal Forest, characteristic of areas at altitudes between 300 and 800 meters (IBGE, 2012). According to the system proposed by Koppen and Geiger (1936), the climate of the region is Subtropical Humid with dry winter and hot summer (Cwa), with an average annual temperature of 21 ºC (Alvares et al., 2013). The wet season is from October to March and the dry season is from April to September. The mean temperature and rainfall vary between seasons (dry: 17-21°C and 22–62 mm; wet: 21-24°C and 125–270 mm), with 50% of the annual rainfall (700 mm) concentrated from December to February (INMET 2020).

Bird sampling: Six expeditions were conducted in the EEcoE/IFRJ (22°31'37"S, 43°59'45"W), in August, September, October and November 2018; January and February 2019. Average weather data of temperature (°C), humidity (%), dew (°C), pressure (hPa), wind (m/s), radiation (kJ/m²) and rain (mm) over a previous 30-days period of each expedition were obtained from INMET (2019), using data from the Meteorological Station of the Municipality of Rio Claro, in the State of Rio de Janeiro, which is about 20 km from the study area. Birds were caught with mist nets, being 5 nets of 18 × 3 m and 10 nets of 9 × 3 m, and all with mesh size of 20 mm. After capture, the birds were identified, photographed, ringed with numbered metal rings provided by the Brazilian bird-ringing agency (Centro Nacional de Pesquisa e Conservação de Aves Silvestres – CEMAVE) and

evaluated for ecological, biological and biometric data, which were: (1) body mass; (2) body length, (3) wing length; (4) tarsus length; (5) bill length; (6) bill width; (7) bill height; (8) tail length; (9) stage of skull pneumatization; (10) subcutaneous fat level; (11) stage of incubation patch; (12) stage of feather wear; (13) molting stage; and (14) presence of ectoparasites, such as ticks, lice, etc. (Nascimento et al. 1994).

Data analysis: Body condition was calculated by means of a simple linear regression between the log-transformed (log10) values of body mass (dependent variable) and the body length (independent variable), for each species/genus (minimum of 10 individuals). The residuals was used as body condition indices, or the relative mass index (RMI). The RMI with a negative value indicates poor body condition, or poor fitness, when compared to positive values (Labocha & Hayes, 2012). Linear regression was used to determine the relationship of RMI with the biological data of stage of skull pneumatization, subcutaneous fat level, stage of incubation patch, stage of feather wear, quantity of ectoparasites on the birds, in addition to environmental data of temperature, humidity, dew, pressure, wind, radiation and rain. The graphs and coefficient of regression line were obtained using the software Microsoft Excel 2007® (Microsoft, Redmond, Washington). The analysis of variance (ANOVA) verified if the RMI varied among the dry season and wet season, and among birds in molting stage or with incubation patch, or not. The statistical package Bioestat 5.0 was used to calculate the mean, variance, degrees of freedom and P-value (Ayres et al., 2007). The Shannon-wiener diversity index (H'), Simpson dominance index (λ‘) and Pielou evenness index (J') were calculated from the abundance of bird species, in total, and in the comparison between the dry and wet seasons (Odum et al., 1988).

RESULTS

A total of 195 birds of five orders and 17 distinct families were caught and identified (Table 1).

Table 1. Diversity of wild birds captured at Pinheiral, State of Rio de Janeiro, organized by order, family and species and with their respective Shannon-wiener diversity index (H'), Pielou evenness index (J') and Simpson dominance index (λ‘), in totality and in the comparison between dry and wet seasons. (continue)

Orders/ Families/ Species	Seasons		Total	Forest dependence
	Wet	Dry		
Caprimulgiformes: Caprimulgidae				
Nyctidromus albicollis (Gmelin, 1789)	2	0	2	medium
Subtotals:	**2**	**0**	**2**	
Columbiformes: Columbidae				
Columbina talpacoti (Temminck, 1811)	0	6	6	not occur*
Leptotila rufaxilla (Richard & Bernard, 1792)	0	2	2	medium
Leptotila verreauxi Bonaparte, 1855	0	2	2	medium
Subtotals:	**0**	**10**	**10**	
Cuculiformes: Cuculidae: Cuculinae				
Piaya cayana (Linnaeus, 1766)	0	1	1	medium
Subtotals:	**0**	**1**	**1**	
Passeriformes: Cardinalidae				
Cyanoloxia brissonii (Lichtenstein, 1823)	2	3	5	not occur
Subtotals:	**2**	**2**	**5**	
Passeriformes: Dendrocolaptidae: Dendrocolaptinae				
Campylorhamphus falcularius (Vieillot, 1822)	1	1	2	medium
Xiphorhynchus fuscus (Vieillot, 1818)	3	0	3	medium
Subtotals:	**4**	**1**	**5**	
Passeriformes: Dendrocolaptidae: Sittasominae				
Dendrocincla turdina (Lichtenstein, 1820)	0	1	1	medium
Subtotals:	**0**	**1**	**1**	
Passeriformes: Furnariidae: Furnariinae				
Furnarius figulus (Lichtenstein, 1823)	1	0	1	low
Subtotals:	**1**	**0**	**1**	
Passeriformes: Furnariidae: Synallaxiinae				
Phacellodomus erythrophthalmus (Wied, 1821)	2	1	3	high
Phacellodomus rufifrons (Wied, 1821)	0	2	2	low
Subtotals:	**2**	**3**	**5**	
Passeriformes: Parulidae				
Basileuterus culicivorus (Deppe, 1830)	0	1	1	medium
Subtotals:	**0**	**1**	**1**	
Passeriformes: Pipridae: Piprinae				
Manacus manacus (Linnaeus, 1766)	26	19	45	medium
Subtotals:	**26**	**19**	**45**	
Passeriformes: Rhynchocyclidae: Pipromorphinae				
Corythopis delalandi (Lesson, 1830)	3	0	3	high
Leptopogon amaurocephalus Tschudi, 1846	0	1	1	medium
Subtotals:	**3**	**1**	**4**	
Passeriformes: Thamnophilidae: Thamnophilinae				
Thamnophilus caerulescens Vieillot, 1816	7	2	9	medium
Subtotals:	**7**	**2**	**9**	
Passeriformes: Thraupidae: Coerebinae				
Coereba flaveola (Linnaeus, 1758)	1	0	1	low
Subtotals:	**1**	**0**	**1**	
Passeriformes: Thraupidae: Dacninae				
Dacnis cayana (Linnaeus, 1766)	1	0	1	medium
Subtotals:	**1**	**0**	**1**	
Passeriformes: Thraupidae: Diglossinae				
Haplospiza unicolor Cabanis, 1851	1	1	2	high
Subtotals:	**1**	**1**	**2**	

Passeriformes: Thraupidae: Poospizinae				
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	1	1	2	medium
Subtotals:	**1**	**1**	**2**	
Passeriformes: Thraupidae: Tachyphoninae				
Coryphospingus pileatus (Wied, 1821)	3	0	2	low
Ramphocelus bresilia (Linnaeus, 1766)	1	1	2	low
Tachyphonus coronatus (Vieillot, 1822)	2	0	11	medium
Volatinia jacarina (Linnaeus, 1766)	5	6	3	not occur
Subtotals:	**11**	**7**	**18**	
Passeriformes: Thraupidae: Thraupinae				
Stilpnia cayana (Linnaeus, 1766)	0	2	2	low
Thraupis palmarum (Wied, 1821)	1	2	2	medium
Thraupis sayaca (Linnaeus, 1766)	1	1	3	low
Subtotals:	**2**	**5**	**7**	
Passeriformes: Tityridae: Tityrinae				
Pachyramphus polychopterus (Vieillot, 1818)	1	1	2	medium
Subtotals:	**1**	**1**	**2**	
Passeriformes: Troglodytidae				
Cantorchilus longirostris (Vieillot, 1819)	1	0	2	medium
Troglodytes musculus Naumann, 1823	0	2	1	low
Subtotals:	**1**	**2**	**3**	
Passeriformes: Turdidae				
Turdus amaurochalinus Cabanis, 1850	3	10	13	low
Turdus leucomelas Vieillot, 1818	4	3	3	medium
Turdus rufiventris Vieillot, 1818	1	2	7	low
Subtotals:	**8**	**15**	**23**	
Passeriformes: Tyrannidae: Elaeniinae				
Elaenia flavogaster (Thunberg, 1822)	1	2	3	not occur
Subtotals:	**1**	**2**	**3**	
Passeriformes: Tyrannidae: Fluvicolinae				
Cnemotriccus fuscatus (Wied, 1831)	2	0	2	medium
Lathrotriccus euleri (Cabanis, 1868)	2	4	6	medium
Subtotals:	**4**	**4**	**8**	
Passeriformes: Tyrannidae: Tyranninae				
Empidonomus varius (Vieillot, 1818)	0	1	3	medium
Myiarchus ferox (Gmelin, 1789)	1	3	7	medium
Myiodynastes maculatus (Statius Muller, 1776)	0	4	2	medium
Myiozetetes similis (Spix, 1825)	0	3	1	low
Pitangus sulphuratus (Linnaeus, 1766)	2	5	4	low
Tyrannus melancholicus Vieillot, 1819	0	2	4	low
Subtotals:	**3**	**18**	**21**	
Passeriformes: Vireonidae				
Cyclarhis gujanensis (Gmelin, 1789)	0	3	1	medium
Hylophilus poicilotis Temminck, 1822	2	0	1	medium
Hylophilus thoracicus Temminck, 1822	1	0	2	medium
Vireo chivi (Vieillot, 1817)	3	0	5	high
Subtotals:	**6**	**3**	**9**	
Piciformes: Picidae				
Picumnus cirratus Temminck, 1825	2	4	6	medium
Subtotals:	**2**	**4**	**6**	
Total:	**105**	**90**	**195**	
Species richness	**33**	**34**	**48**	
Shannon-wiener diversity index (H')	**3.17**	**2.99**	**3.33**	
Maximum Diversity (H'max)	**3.91**	**3.91**	**3.91**	
Pielou evenness index (J')	**0.81**	**0.76**	**0.85**	
Simpson dominance index (λ')	**0.94**	**0.90**	**0.93**	

*Species that does not normally occur in forest

As expected, the order Passeriformes was the most representative in terms of the numbers of species (86%; 43/50) and specimens (88%; 171/195). The family with the largest number of species caught was the Thraupidae (22%; 11/50), followed by the families Tyrannidae (18%; 9/50) and Vireonidae (10%; 5/50). Pipridae (23%; 45/195), which was only represented by the white-bearded manakin *Manacus manacus* (Linnaeus, 1766), was the most representative family in terms of the number of specimens caught, followed by the families Tyrannidae (16%; 32/195), Thraupidae (16%; 31/195) and Turdidae (12%; 23/195).

Among the 195 individuals caught, white-bearded manakins *M. manacus* (n = 45), thrushes *Turdus amaurochalinus* Cabanis, 1850, *Turdus leucomelas* Vieillot, 1818 and *Turdus rufiventris* Vieillot, 1818 (n = 23), and ruby-crowned tanagers *Tachyphonus coronatus* (Vieillot, 1822) (n = 10) were used in the RMI analyses. Among all the biological and ecological data evaluated by linear regressions, RMI was significantly related only to rain and temperature, where it is observed that the indexes decrease with the increase of the rains and temperature (that is, the wet season) (Fig. 1, 2). These results were confirmed by ANOVA, where highly significant differences ($p<0.01$) were obtained between the dry and rainy seasons, as Figure 3 which shows the RMI means in each season of the three groups of birds evaluated. No differences were observed between the RMI of birds in molting stage or with incubation patch, or not.

The Shannon-wiener, Simpson and Pielou indexes showed greater diversity and less dominance in the wet season compared to the dry season. In contrast, birds with greater forest dependencies were predominantly observed in the dry season, which apparently has better environmental conditions for birds.

DISCUSSION

The EEcoE/IFRJ represents a locality in reforestation in the biome of Atlantic Forest in the in the Médio Paraíba Region, which should be a reference for other localities in reforestation or conservation, in addition to being a study model for the environmental students at IFRJ. In this context, the study of the diversity and conditions of animals and plants in this locality is important for the disclosure of the importance of nature conservation. In addition, studies of birds in reforestation localities become even more important due to the ecological functions of ornithochory and ornithophily, which are essential in the maintenance and growth of forests (Sick, 1997).

In the present study, the RMI were obtained from the linear regression of the values of body mass on body length of birds. The other biometric aspects, mainly tarsus length, are also used for the RMI; however, the values of body length generated better results of linear regression, that is, with the highest values of R^2 (coefficient of determination) in each evaluation. In addition, this option is supported by many authors who obtain RMI from the regression of body mass on body length (Labocha & Hayes, 2012).

The environmental conditions associated with the dry and rainy seasons were the only factors significantly related to the birds' RMI. Evaluating the linear regressions in Figure 1A and 1B, it can be observed that the RMI decreased with increasing temperature and rain, tending to become negative (low body condition) from ~ 110 mm of accumulated rain and ~ 22 ºC of monthly mean temperature.

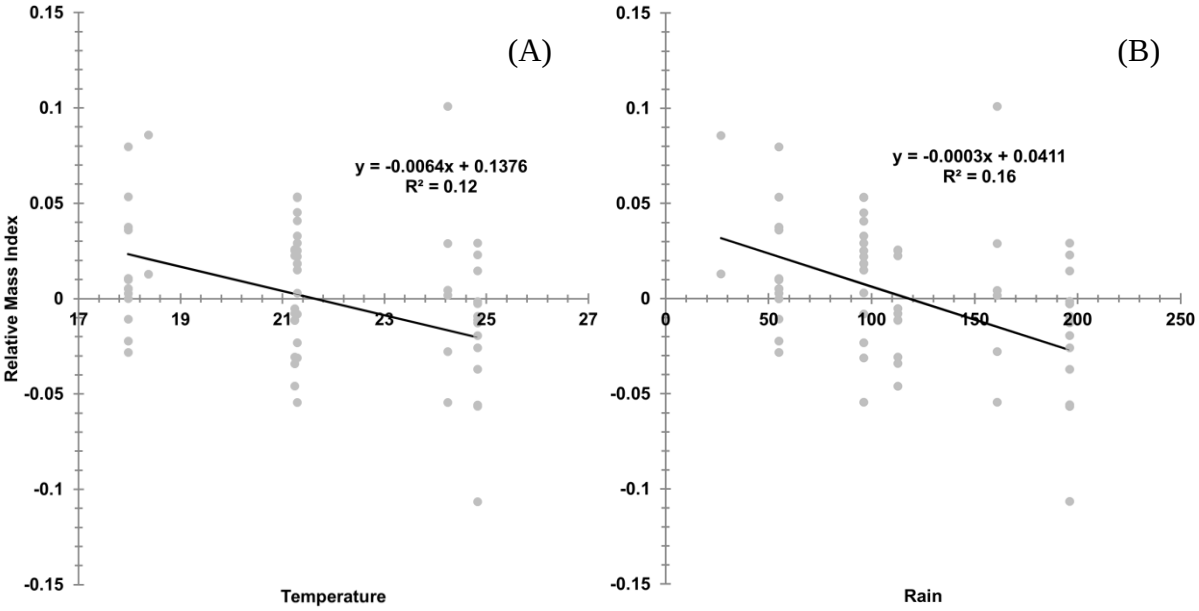

Figure 1. Relationship by linear regression between the relative mass index (RMI) of *Turdus* spp., *Manacus manacus* and *Tachyphonus coronatus* and (A) the accumulated rain (mm) and (B) the mean temperature (°C) over a previous 30-days period of each expedition at Pinheiral, State of Rio de Janeiro, between August 2018 and February 2019.

These results were supported by means comparisons (ANOVA) of RMI, which were significantly different (Fig. 2).

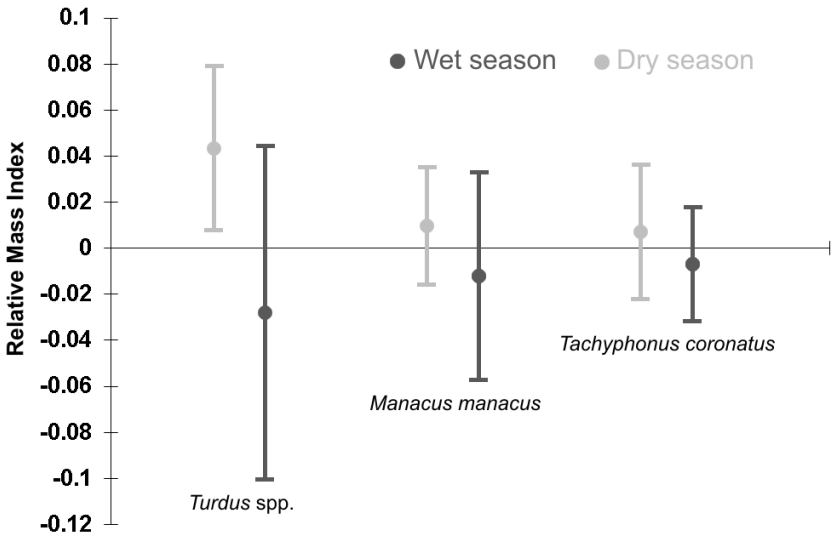

Figure 2. Means and standard deviations of the relative mass index (RMI) by wet and dry seasons of *Turdus* spp., *Manacus manacus* and *Tachyphonus coronatus*, captured at Pinheiral, State of Rio de Janeiro, between August 2018 and February 2019.

Teles et al. (2017) have different results for populations of helmeted manakins *Antilophia galeata* (Lichtenstein, 1823) from a forest fragment of the Biome Cerrado in the State of Minas Gerais, Brazil. In this work differences in RMI of *A. galeata* were observed between the dry and wet seasons; however, the highest RMI were associated with the wet season. The other populations of saffron-billed sparrows *Arremon flavirostris* Swainson 1838; golden-crowned Warblers *Basileuterus culicivorus* (Deppe, 1830), white-striped warblers *Myiothlypis leucophrys* (Pelzeln, 1868) and gray-headed tanagers *Eucometis penicillata* (Spix, 1825), which were also evaluated in Teles et al. (2017), did not have significant differences in RMI between dry and wet seasons. The main differences in body condition observed by Teles et al. (2017) were associated with food habits of birds. In this case, exclusively insectivorous birds had the lowest RMI when compared to frugivorous and omnivorous birds. In the current work, this evaluation was not possible because *Turdus* spp., *M. manacus* and *T. coronatus* have similar food habits eating insects and fruits in greater or lesser proportions (Sick, 1997).

The lowest RMI associated with the wet season were constant for the three groups of birds evaluated, in total and by group (Fig. 1).

The months of January and February in the municipality of Pinheiral and in the nearby regions, which were the main months associated with the lowest RMI of birds, can be extreme in heat and rain, with temperatures close to 40ºC and days with more than 50 mm of rain, as on January 4, 2019, which rained 71 mm in just one hour (INMET, 2020).

Therefore, it is supposed that these extreme conditions may be associated with greater physical wear on the birds, which resulted in lower RMI in these months. A second assumption would be based on the fact that the wet season partly coincides with the breeding periods of the birds, thus pre-breeding stress and nest care, possibly would also be associated with a reduction in the body condition of the birds during this period (Sick, 1997). However, there was no relationship in linear regression or significant differences between the RMI and the incubation levels. Finally, it is assumed that the better body conditions of the birds during the dry season can be related to the availability of food. In this sense, Nwaogu et al. (2016) observed an increase in body mass of females of common bulbuls *Pycnonotus barbatus* (Desfontaine, 1789) in the dry season, which was related to an accumulation of fat, or energy reserve, for future poor foraging conditions. This assumption is based on the fact that the diet and the feeding behavior of birds can be influenced by the seasonality of resources (Manhães, 2003); however, there are no studies on the seasonal variation of food resources for birds in the EEcoE/IFRJ, such as fruiting period or abundance of insects.

Diversity and dominance were respectively higher and lower in the wet season, compared to the dry season (Table 1). This result is not consistent with the RMI results, which suggests that the dry season is more favorable for birds. In this reasoning, greater diversity and less dominance in the dry season was expected. Anyway, it can be observed that despite the greater diversity in the wet season, the species predominant caught in this season had low forest dependence (30% in the wet season and 17% in the dry season, of specimens with low forest dependence); while, in the dry season, the predominant species had high forest dependence (5% in the wet season and 11% in the dry season, of specimens with high forest dependence). This observation can be exemplified with the southern antpipits *Corythopis delalandi* (Lesson, 1830) and sooretama slaty-antshrikes *Thamnophilus ambiguus* Swainson 1825, which have high forest dependence and were only captured in the dry season. In this sense, it can be concluded that despite the greater diversity observed in the wet season, birds with high forest dependence, which have more specialized and narrow ecological niches, were predominantly observed in the dry season, which was associated with better body conditions of birds.

Finally, the current work records for the first time the diversity of birds in the EEcoE/IFRJ in the Municipality of Pinheiral, in the State of Rio de Janeiro, Brazil, highlighting the importance of maintaining the reforestation of this locality for the conservation of the birds and of the ecosystem of the region. In addition, this work shows

that the dry season is more favorable for the fitness of birds in the EEcoE/IFRJ, at least for the populations of *Turdus* spp., *M. manacus* and *T. coronatus*.

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Competing interests

The authors declare no conflict of interest.

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