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CLARISSA DE OLIVEIRA SANTOS

EFFECTS OF LOCAL AND LANDSCAPE ENVIRONMENTAL VARIABLES ON AVIFAUNA ABUNDANCE IN FOREST FRAGMENTS OF ATLANTIC FOREST IN SOUTHEASTERN BRAZIL

Dissertação apresentada ao Programa
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Effects of local and landscape environmental variables on avifauna abundance in forest fragments of Atlantic Forest in southeastern Brazil

Orientação: Prof. Dr. Augusto João Piratelli
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ÍNDICE

RESUMO GERAL

A conversão de florestas neotropicais em terras agrícolas tem como consequências alterações na estrutura interna e pressões externas sobre remanescentes florestais, que afetam a abundância de aves em diferentes escalas espaciais. Neste estudo, verificamos a contribuição relativa de três escalas espaciais (local, imediato e de paisagem) sobre a abundância de aves em fragmentos de mata atlântica no sudeste do Brasil. Nós testamos se as espécies que responderam de maneira semelhante às variáveis ambientais estão na mesma guilda de forrageamento. Realizamos este estudo através de 44 pontos fixos em 18 fragmentos, na zona de amortecimento de uma unidade de conservação. Foram amostradas 15 variáveis ambientais em três escalas espaciais; seis locais específicos, três nos arredores imediatos (raio de amortecimento de 100m) e seis na paisagem). Foram registrados 1724 indivíduos de 108 espécies entre abril de 2017 e fevereiro de 2018. Classificamos as espécies amostradas em 15 grupos de forrageamento. As frações únicas de local e de paisagem afetaram a abundância de aves, mas os arredores imediatos e exclusivos não influenciaram significativamente essa variável. Identificamos um padrão relacionado aos efeitos da escala local apenas para aves insetívoras, mas nenhum padrão para as outras guildas de forrageamento associadas a quaisquer outras escalas. Nosso estudo pode subsidiar práticas de manejo nos locais avaliados, incrementando principalmente a densidade do sub-bosque e a altura do dossel remanescente das florestas nativas.

Palavras-chave: aves, fragmentos florestais, grupos tróficos, zona de amortecimento

Artigo Produzido

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Effects of local and landscape environmental variables on avifauna abundance in forest fragments of the Atlantic Forest in southeastern Brazil

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ABSTRACT

Pristine Neotropical forests have been converted into agricultural lands. Shifts in the internal structure and external pressures on forest remnants affect bird assemblages that require specific resources for survival at different spatial scales. In this study, we verified the relative contribution of three spatial scales (local, immediate surroundings and landscape) on the abundance of birds in Atlantic forest fragments in south-eastern Brazil. We tested whether species that responded in a similar way to environmental variables are in the same foraging guild. We carried out this study through 44 fixed points in 18 fragments, in the buffer zone of a protected area. We sampled 15 environmental variables in three spatial scales; six site-specific, three at the immediate surrounds (buffer radius of 100m), and six at the landscape). We recorded 1724 individuals from 108 species between April 2017 and February 2018. We classified sampled species in 15 foraging groups. The unique fractions of local and landscape have affected bird abundance, but the exclusive immediate surroundings have not significantly influenced this variable. We have identified a pattern related to the effects of local scale only for insectivorous birds, but no pattern for the other foraging guilds linked to any other scales. Our study may support management practices in the studied sites, practices mainly improving the understory density and canopy height of the remaining patches of native forest.

Keywords: Birds, buffer zone, forest patches, trophic groups

Introduction

Forest fragmentation resultant of anthropogenic activities has been cited as one of the major causes of global biodiversity decline (D´Eon *et al.* 2002; Gardner *et al.* 2009; Barlow *et al.* 2016). The habitat loss exposes organisms to several stresses, which occur at different spatial scales (Blaustein *et al.* 2011; Chase and Knight 2013; Bartlett *et al.* 2016) and may vary in intensity among taxa and ecological groups (Leibold *et al.* 2004; Ewers and Didham 2006). Thus, recent research has been increasingly investigating the effects of fragmentation at different scales on several groups of organisms (Kennedy *et al*. 2013; Sarthou *et al.* 2014; Lafage and Pétillon 2016; Morante-Filho *et al.* 2016).one of the major causes of global biodiversity decline (D´Eon *et al.* 2002; Gardner *et al.* 2009; Barlow *et al.* 2016). The habitat loss exposes organisms to several stresses, which occur at different spatial scales (Blaustein *et al.* 2011; Chase and Knight 2013; Bartlett *et al.* 2016) and may vary in intensity among taxa and ecological groups (Leibold *et al.* 2004; Ewers and Didham 2006). Thus, recent research has been increasingly investigating the effects of fragmentation at different scales on several groups of organisms (Kennedy *et al*. 2013; Sarthou *et al.* 2014; Lafage and Pétillon 2016; Morante-Filho *et al.* 2016).

The sensitivity of bird species to fragmentation is variable and depends on several factors, such as habitat and diet specialization, population size, body size, mobility and nesting (Murphy 2012; Neuschulz *et al*. 2013; Newbold 2013; Bregman 2014; Pavlacky *et al.* 2015; Alexandrino *et al.* 2016). More specifically, the analysis of bird guilds response to habitat conditions in fragmented areas, at different spatial scales, is a recurrent approach (Pearson 1975; Altshuler 2006; Gray *et al.* 2007; Hasui *et al.* 2007; Piacentini and Varassin 2007; Boscolo and Metzger 2009; Galitsky 2015).

Guild is a term coined to refer to a set of species that explore a given resource in similar patterns (Root 1967; Blondel 2003) e.g. habitat structure, food and others. Nevertheless, the classification of species into guilds is useful since fragmentation causes changes to the habitat structure, limiting access to specific resources, such as foraging and nesting grounds (Lamanna and Martin 2016; Verga *et al.* 2017). Additionally, such categorization allows going beyond community composition and evaluating possible losses of ecosystem functions (Gray *et al.* 2007; Bovo *et al.* 2018).

However, a priori species allocation in different guilds based on *e.g.* expert knowledge and general empirical observations may bring some limitations. More specifically, species have been reported to present different responses within a given guild; therefore, generalizations at the guild level may not fit the ecological reality. For instance, the effects of fragmentation on the abundance of understory insectivorous birds vary considerably among species; imposing limitations to determine the influence of different spatial scales on species of the same foraging guild (Banks-Leite *et al.* 2013; Edwards *et al.* 2013). A similar conflict arises for large frugivores. This foraging guild would theoretically be more susceptible to regional effects; since most species need to move across patches of native vegetation in search of fruits, which are often scarce in small fragments (Mueller *et al.* 2014; Santos-Junior *et al*. 2016). Yet, some species often included in this guild (*e.g. Patagioenas picazuro*; Athiê and Dias, 2010; Cruz and Piratelli, 2011; Vitorino *et al.* 2018), may have low sensitivity to anthropic alterations, being abundant even in disturbed areas (Franz *et. al.* 2010; Cruz and Piratelli 2011; Alexandrino *et. al.* 2013; Alexandrino *et. al.* 2016). Moreover, although guilds have been identified as useful indicators, the sensitivity patterns may be context specific (Sigel *et al.* 2010, Thornton *et al.* 2011, Vetter *et al*. 2011).

Birds respond to habitat alterations by either increasing or reducing species abundance. Thus, the likelihood of detecting biodiversity responses to habitat alterations increases by monitoring such ecological variables (Mazaris et al. 2013; Aebischer et al. 2016). Ultimately, such analysis becomes a valuable tool for suggesting priorities in conservation efforts and illustrating the representativeness of protected areas (Horn and Koford 2006; Johnston 2015).

Here, we studied forest fragments of semi-deciduous seasonal Atlantic forest and tested the relative contribution of environmental variables of three spatial scales - local, immediate surrounding (100-m radius buffer) and landscape - on bird species abundance. Considering that species formally grouped in foraging guilds often vary in ecological and morphological characteristics, we expect to find no homogeneous pattern of responses in abundance within each guild.

Methods

Study area

We carried out this study in an area of ~.2,350ha, representing nearly 10% of the boundaries of the city of Araçoiaba da Serra, state of São Paulo, Brazil (23 ° 30 '16' 'S, 47 ° 36' 52"W) (Figure 1), which lies in a transition region between Atlantic Forest and Cerrado. The mean annual local temperature and rainfall are 20.8 ° C and 1248.5 mm, respectively (CEPAGRI, 2017). The city is part of the buffer zone of Floresta Nacional de Ipanema, a 5,069ha federal protected area

(ICMBio, 2017). Forest fragments occupy 9.4% of the city area, and the predominant vegetation is semi-deciduous seasonal forest, being 1.18% of woodlands and 8.25% of “capoeiras” (Albuquerque and Rodrigues 2000, SIFESP, 2001; IBGE 2015). Land use is characterized by pasturelands and agriculture, mainly of sugarcane crops (Sales *et al.* 2016).

Avifauna

To test the influence of local and landscape factors on avifauna, we set 44 points in 18 fragments (Figure 2). To ensure the independence of the bird data, the points were established with a minimum distance of 200m (Blake 1992; Vielliard *et al.* 2010). We conducted 50-m fixed-radius point-count surveys during 10 minutes at the 44 points twice, both in dry and wet season, in the morning and afternoon (6:00 a.m. to 9:00 a.m. and 4:30p.m. to 6:30 p.m.) (Becker *et al.* 2013, Alexandrino *et al.* 2016, Uezu and Metzger 2016). We used a Bushnell Natureview 8x42 binocular, a Sony ICD-PX440 Digital Audio Recorder, and specific literature (Ridgely *et al.* 2015) for species identification. The species nomenclature followed the classification of Handobook (HBW) and BirdLife International (2016). For each species, we calculated the index of point abundance (IPA) dividing the number of contacts (i.e. birds that were heard or seen) by the number of sampled point counts.

We classified the trophic/foraging guilds according to the diet, morphological and foraging characteristics (*e.g.* substrate and strategy of foraging). Species were split into fifteen categories according to Wilman et al. 2014, Del Hoyo et al. 2016 and Santos-Junior et al. 2016: foliage insectivores (Fi); omnivores (Om); understory insectivores (Ui); insectivores trunk-climbers (Ti); large frugivores (Lf); forest edge granivores (Eg); aerial insectivores (Ai); canopy insectivores (Ci); nectarivores (Ne); small frugivores (Sf); open area granivores (Ag); open area insectivores (Ia); detritivores (De); carnivores (Ca) and piscivores (Pi).

Environmental variables

We assessed the environmental condition at three spatial scales most likely to influence the avifauna (Pearson 1975; Hasiu et al. 2007; Piacentini and Varassin 2007). The first scale represents the local variables, sampled in 10x10m plots around the center of each of the 44 points. Six environmental variables were assessed at each of the avifauna data collecting points, from March to August 2017. The variables were (a) richness of arboreal morphospecies; (b) number of standing dead trees; (c) average canopy height (using a laser rangefinder, by readings at the four cardinal points in the center of each plot); (d) canopy cover (by averaging four densitometer readings at the in four cardinal points in the center of the plot); (e) understory density (by counting the regenerating and shrub individuals between 50 cm and 2 m); and (f) average of the soil temperature of the four days that each point was sampled (measured with a digital thermometer in the center of the plot).

The second variable set was the immediate surrounding environment, which we sampled using a 100-m radius buffer around each point. In each buffer we calculated the forest cover area; average NDVI (normalized difference vegetation index), as a green biomass indicator (Rouse *et al.* 1973; Freitas *et al.* 2005); and the area of five classes of declivity, 1) 0º to 5°; 2) 5 to 12°; 3) 12 to 30°; 4) 30 to 45° and 5) > 45°. The last variable group was of the landscape variables, related to distance metrics. For this, we measured the distance from each point to the nearest forest patch, pond, stream and headwater, and the areas of each of these landscape features. These two last variable groups was obtained from Landsat 8 a 30-m resolution land-cover layer with 74.6% overall fuzzy accuracy in ArcGis v.10.5 (ESRI, 2016).

Data analyses

We performed a redundancy analysis (RDA) with all variables and used the Ordistep function to first, exclude the ones that were strongly correlated and second, select those that best explained the bird data variation. With the selected variables in each set, we partitioned the data variance into seven independent fractions: (a) exclusive local effects; (b) exclusive immediate surrounding; (c) exclusive landscape effects (100-m radius buffer) effects; (d) shared effects between local and immediate surrounding; (e) shared effects between landscape and immediate surrounding; (f) shared effects between local and landscape; (g) shared effects between the three set variables. Species were clustered by the *k-mean* method according to their coordinates on the

RDA axes. The distribution of the species in the RDA axes was divided into seven clusters (Fig.6), however, only species at the five clusters that presented greater variation in the RDA axes were analyzed.

In order to meet the assumptions of linearity of the RDA analysis, we standardized both the variable and bird data, using the Hellinger transformation for the later. We considered a level of significance equal to or less than 0.05. All analyzes were performed in R (R Development Core Team 2014) with the Vegan package (Oksanen et al. 2013).

Results

We recorded 1724 bird contacts from 108 species. The most abundant species were *Basileuterus culicivorus* (IPA=4.068) and *Turdus leucomelas* (IPA=2.363) (Table S1) whereas the most abundant foraging guild were foliage Insectivores and Omnivores (Fig.3).

The variance fractions related to local, immediate surroundings (100m radius buffer) and landscape together (a+b+c+d+e+f) explained 13.7% of the variation in bird abundance (Fig. 2). The unique fractions of each set of explanatory variables, i.e. local (a) and landscape (c) were significant (p=0.0039 and p=0.00099, respectively), but the exclusive immediate surroundings (b) did not significantly influence bird abundances (p= 0.187) (Table 1). The ordistep function kept the environmental variables (a) canopy height and understory density, for local scale; (b) declivity 1 (0-5º) for the immediate surroundings; and (c) nearest pond distance, for the landscape scale (Fig. 5). The first RDA axis explained 39.4% of the variance and was influenced by the understory density and the nearest pond distance. The second RDA axis explained 27.9% and was associated with canopy height and declivity between 0 and 5º.

The five species groups selected according to the clusters were: (a) positively related to canopy height and understory density; (b) positively related to understory density; (c) positively related to declivity between 0-5º; (d) positively related to nearest pond distance; (e) negatively related to nearest pond distance (Table 3).

Discussion

In our study, we found that landscape and local environmental characteristics have influenced the abundance of birds in semideciduous seasonal forest fragments. According to the variance partitioning, the variables of these two scales present similar pattern of influence, with the total and the unique effect of landscape characteristics (8.7% and 4.4%, respectively) showing larger influence than local scale (5.75% and 3.1%) (Fig. 4; Table 1). These results agree with previous studies, in which both spatial scales, i.e. the plot structure (here presented as local characteristics) and the landscape characteristics, influence bird richness and abundance, whereas a higher influence is observed at the landscape scale (Carrara, 2015; Galitsky 2015; Buffa et. al, 2018).

Regarding the local environmental variables, ten species were positively influenced by understory density and canopy height. Ten were insectivores with different foraging substrates. *Basileuterus culicivorus, Thamnophilus caerulescens* and *Vireo olivaceus* are foliage-gleaners. *Corythopis delalandi, Myiothlypis flaveola* and *Tapera naevia* are understory insectivores. *Conirostrum speciosum* forages on the canopy; and *Sittasomus griseicapillus* is a trunk-insectivore (Table 3 A-B). Understory density are intimately related to insect's availability (Streby *et al.* 2011; Powell *et al.* 2015) and canopy height with patch structure and conservation (Peña-Claros 2003).

The declivity between 0-5º has positively influenced eleven species. The most abundant species were the omnivores *Turdus leucomelas* and *Pitangus sulphuratus*, and the large frugivore *Patagioenas picazuro* (Table 3C); all widely common in human-modified environments (Pereira and Brito, 2005; Franz et. al., 2010; Cruz and Piratelli, 2011; Alexandrino et. al., 2013; Alexandrino et. al. 2016). Although some of these species belong to more specialized foraging guilds (*e.g.,* trunk-twig insectivores and nectarivores; Heyman 2010), their representatives are mostly generalists, also known to be abundant in anthropogenic environments, i.e. *Colaptes campestris* and *Coereba flaveola* (Dario 2017, Del Hoyo et al., 2018). The slope of the terrain may be related to patterns of occupation and land use in agricultural fields, since the difficulty of access to steeper areas might translate into higher deforestation of lowlands (Silva et al., 2007; et al., 2010). Thus, an inverse relationship between the declivity of the terrain and the abundance of generalist species is expected, since these species are able of be benefited from anthropogenic disturbances (Laurance et al., 2002, Le Viol et al. 2012).

We identified a pattern among the effects of local scale on insectivorous birds, as in Bregman et al. (2015). However, this was restricted to birds' diet, not to the foraging guild (Table 3A-B). There was no pattern for foraging guilds linked to the other two scales (i.e. landscape and immediate surroundings). Our results agree with Ulrich et al. (2017), who tested a series of functional traits more liable of explaining part of the spatial segregation of birds in fragments of the Atlantic forest and found no influence related to foraging traits.

In conclusion, as a buffer zone of a protected area, our area of study still support several forest dweller species. However, its current fragmentation and conversion into intensive crop and livestock farming can jeopardize the persistence of several species, especially the more specialized in their ecological requirements. Thus, considering the trends of influence observed in our analyzed environmental variables, we propose the introduction of management practices that improve the understory density and canopy height of the remaining patches of native forest.

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References

Aebischer, N.J., Bailey, C.M., Gibbons, D.W., Morris, A.J., Peach, W.J., and Stoate, C. (2016). Twenty years of local farmland bird conservation: the effects of management on avian abundance at two UK demonstration sites. *Bird Study* **63**, 10–30. doi:10.1080/00063657.2015.1090391

Albuquerque, G.B. and Rodrigues, R.R. (2000). A vegetação do Morro de Araçoiaba, Floresta Nacional de Iperó (SP). *Scientia Forestalis* **58**, 145-159.

Alexandrino, E.R., Bovo, Luz, A.A.A., Costa, D.T.A., Betini, J.C., Ferraz, G.S., and Couto, H.T.Z., (2013). Aves do campus Luiz de Queiroz (Piracicaba/SP) da Universidade de São Paulo: mais de 10 anos de observações neste ambiente antrópico. *Atualidades Ornitologicas*. **173**, 40L 52.

Alexandrino, E. R., E. R. Buechley, A. J. Piratelli, K. M. P. M. B. Ferraz, R. A. Moral, Ç. H. Sekercioglu, W. R. Silva and Couto, H. T. Z. (2016). Bird sensitivity to disturbance as an indicator of forest patch conditions: an issue in environmental assessments. *Ecological Indicators* **66,** 369–381. doi: 10.1016/j.ecolind.2016.02.006

Altshuler, D.L. (2006). Flight performance and competitive displacement of hummingbirds across elevational gradients. *The American Naturalist* **167**, 216–229. doi: 10.1086/498622

Antogiovanni, M. and Metzger J.P. (2005). Influence of matriz habitats on the occurrence of insectivorous birds species in Amazônia Forest fragments. *Biological Conservation, Kidlington* **122**, 441-451. doi: 10.1016/j.biocon.2004.09.005

ARAÇOIABA DA SERRA, HISTÓRICO. Available at https://cidades.ibge.gov.br/ [Verified November 21 2016]

Athiê, S., and Dias, M. M. (2010) Avian community composition in an urban park in central São Paulo State, southeastern Brazil. *Revista Brasileira de Zoociências*, Juiz de Fora, **12**, 67-73.

Ballarini, Y., Frizzas, M.R. and Marini, M.A. (2013). Stomach contents of Brazilian non-passerine birds. *Revista Brasileira de Ornitologia* **21**, 235–242.

Banks-Leite, C.,Ewers, R.M.and Metzger, J.P. (2013) The confounded effects of habitat disturbance at the local, patch and landscape scale on understory birds of the Atlantic forest. *Ecological Indicators*, **31**, 82–88. doi: 10.1016/j.ecolind.2012.04.015

Bartlett, L.J., Newbold, T., Purves, D.W., Tittensor, D.P., and Harfoot, M.B.J. (2016). Synergistic impacts of habitat loss and fragmentation on model ecosystems. *Proceedings of the Royal Society B*, **283,** 20161027. doi:10.1098/rspb.2016.1027

Barlow, J. (2016). Anthropogenic disturbance in tropical forests can double biodiversity loss from deforestation. *Nature* **535**, 144– 149. doi: 10.1038/nature18326

Becker, R. G., Paise, G., and Pizo, M. A. (2013). The structure of bird communities in areas revegetated after mining in southern Brazil. *Revista Brasileira de Ornitologia* **21**, 221-234.

Bender, D.J., Contreras, T.A. and Fahrig, L. (1998) Habitat loss and population decline: a meta-analysis of the patch size effect. *Ecology*, **79**, 517–529. doi: 10.1890/0012-9658(1998)079[0517:HLAPDA]2.0.CO;2

Blaustein A. R., Han B., Relyea R. A., Johnson P. T. J., Buck J. C., Gervasi S. S., and Kats L. B. (2011) The complexity of amphibian population declines: understanding the role of cofactors in driving amphibian losses. *Annals of New York Academy of Sciences.* **1223**, 108–119. doi: 10.1111/j.1749-6632.2010.05909.x

Blondel, J. (2003). Guilds or functional groups: does it matter? *Oikos* **100**, 223–231. doi: 10.1034/j.1600-0706.2003.12152.x

Bregman, T.P. , Lees, A. C., Seddon, N., MacGregor, H. E. A., Darski, B., Aleixo, A., Bonsall, M. B. and Joseph A. Tobias (2015). Species interactions regulate the collapse of biodiversity and ecosystem function in tropical forest fragments. *Ecology* **96,** 2692-2704. doi: 10.1890/14-1731.1

Bocard, D., Legendre, P. and Drapeau, P. (1992) Partialling out the spatial component of ecological variation. *Ecology,* **73**, 1045–55. doi: 10.2307/1940179

Boscolo, D. and Metzger, J. (2009). Is bird incidence in Atlantic forest fragments influenced by landscape patterns at multiple scales? *Landscape Ecology* **24**, 907–918. doi: 10.1007/s10980-009-9370-8

Borowik, T., Pettorelli, N., Sönnichsen, L. and Jędrzejewska, B. (2013). Normalized difference vegetation index (NDVI) as a explanatory of forage availability for ungulates in forest and field habitats. *European Journal of Wildlife*, **59**, 675-682. doi: 10.1007/s10344-013-0720-0

Bovo, A.A.A., Magioli, M., Percequillo, A. R., Kruszynski, C., Alberici, V., Mello, M. A. R., Correa, L. S., Gebin, J. C. Z., Ribeiro, Y. G. G., Costa, F. B., Ramos, V. N., Benatti, H. R., Lopes, B., Martins, M. Z. A., Camargo, P. B., Labruna, M. B. and Ferraz, K. M. P. M. B (2018). Human-modified landscape acts as refuge for mammals in Atlantic Forest. *Biota Neotropica*, **18**, 2. doi: 10.1590/1676-0611-bn-2017-0395

Carrara, E., Arroyo-Rodríguez, V., Vega-Rivera, J. H., Schondube, J. E., de Freitas, S. M. and Fahrig, L. (2015). Impact of landscape composition and configuration on forest specialist and generalist bird species in the fragmented Lacandona rainforest, Mexico. *Biological Conservation* **184**, 117–126. doi: 10.1016/j.biocon.2015.01.014

CEPAGRI, Available: http://www.cpa.unicamp.br/outrasinformacoes/clima_muni_033.html [Verified: ago16 2017]

Chase, J.M. and Knight, T.M. (2013). Scale-dependent effect sizes of ecological drivers on biodiversity: why standardised sampling is not enough. *Ecology Letters*, **16**, 17–26. doi: 10.1111/ele.12112

Cristiano,P.M., Madanes, N., Campanello, P.I. , Francescantonio, D., Rodriguez, S.A., Zhang, Y.J., Carrasco, L.O. and Goldstein, G. (2014) High NDVI and potential canopy photosynthesis of South American subtropical forests despite seasonal changes in leaf area index and air temperature. *Forests*, **5**, 287-308. doi:10.3390/f5020287

Cruz, B.B., and Piratelli, A.J., (2011). Avifauna associated to an urban extend of the SorocabaRiver, Southeastern Brazil. *Biota Neotropica,* **11**, 255–264. doi:10.1590/S1676060320110004000022

Dario, F. R., (2017). Diversity and trophic structure of birds in forest fragments in the metropolitan area of São Paulo, Brazil. *Scholars Journal of Agriculture and Veterinary Sciences,* **4**, 364-373. doi: 10.21276/sjavs.2017.4.9.7

Del Hoyo, J., A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana. (2018). Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. Available at: http://www.hbw.com. [Verified 03 Feb 2018]

D´Eon, R.G., Glenn, S.M., Parfitt, I., and Fortin, M.J. (2002). Landscape connectivity as a function of scale and organism vagility in a real forested landscape. *Conservation Ecology* **6**, 1-10. doi:10.21276/sjavs.2017.4.9.7

ESRI (2011). ArcGIS Desktop; Release 10. Redlands, CA: Environmental Systems Research Institute.

Ewers, R.M. and Didham, R.K. (2006). Confounding factors in the detection of species responses to habitat fragmentation. *Biological Reviews* **81**, 117–142. doi:10.1017/S1464793105006949

Franz, I., Cappelatti, L., and Barros, M.P., (2010). Bird community in a forest patch isolatedby the urban matrix at the Sinos River basin, Rio Grande do Sul State, Brazil, with comments on the possible local defaunation. *Brazillian Journal Biology.* **70**, 1137–1148. doi:10.1590/S1519-69842010000600002

Freitas, S.R., Mello, M.C.S. and Cruz ,C.B.M. (2005). Relationships between forest structure and vegetation indices in Atlantic Rainforest. *Forest Ecology and Management* **218**: 353–362. doi:10.1016/j.foreco.2005.08.036

Filloy, J., Zurita, G. A., Corbelli, J. M. and Bellocq, M. I. (2010). On the similarity among bird communities: testing the influence of distance and land use. *Acta Oecologica*., **36**, 333–338. doi:10.1016/j.actao.2010.02.007

Galitsky C. and Lawler J.J. (2015). Relative influence of local and landscape factors on bird communities vary by species and functional group. *Landscape Ecology* **30**, 287–299. doi: 10.1007/s10980-014-0138-4

Gardner, T. A.; Barlow, J.; Chazdon, R.; Ewers, R. M.; Harvey, C. A.; Peres, C. A. and Sodhi, N. S. (2009). Prospec*ts for* tropical forests biodiversity in a human-modified world. *Ecology Letters* **12**, 561-582. doi: 10.1111/j.1461-0248.2009.01294.x

Gray M.A., Baldauf S.L., Mayhew P.J. and Hill J.K. (2007) The response of avian feeding guilds to tropical forest disturbance. *Conservation Biology* **2,** 133–141. doi:10.1111/j.1523-1739.2006.00557.x

Hasui, E., Gomes, V.S.D. and Silva, W.R. (2007). Effects of vegetation traits on habitat preferences of frugivorous birds in Atlantic rain forest. *Biotropica* **39**, 502–509. doi: 10.1111/j.1744-7429.2007.00299.x

Hernández-Ruedas, M.A., Arroyo-Rodríguez, V., Meave, J.A., Martínez-Ramos, M., Ibarra-Manríquez, G. and, Martínez, E.(2014). Conserving tropical tree diversity and forest structure: the value of small rainforest patches in moderatelymanaged landscapes. PLoS One 9, e98932. doi: 10.1371/journal.pone.0098931

Horn, D.J. and Koford, R.R. (2006). Could the area-sensitivity of some grassland birds be affected by landscape composition? *In, D. Egan & J.A. harrington (Eds.): Proceedings of the 19th North American prairie conference, University of Wisconsin.* 109-116

IBAMA, Available at: cidades.ibge.gov.br. [Verified: November 14, 2016]

Johnston, Lisa(2016) Indonesia's Forest Fires Reignite, Threatening Protected Areas and Peatlands. *World Resources Institute.* Available at: http://www.wri.org/blog/2015/07/indonesia%E2%80% 99s-forest-fires-reignite-threatening-protected-areas-and-peatlands [Verified March, 23 2018]

Kennedy C.M., (2013). A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems, *Ecology Letters* **16,** 584-599. doi:10.1111/ele.12082

Kindt, R. (2014) BiodiversityR: GUI for biodiversity, suitability and community ecology analysis Package. R package version 2.5- http://cran.rproject.org/web/packages/BiodiversityR/index.html

Lafage, D. and Pétillon, J., (2016). Relative importance of management and natural flooding on spider, carabid and plant assemblages in extensively used grasslands along the Loire. *Basic and Applied Ecology*, **17,** 535–545. doi: 10.1016/j.baae.2016.04.002

LaManna, J.A., and Martin, T.E.(2016). Costs of fear: behavioural and life-history responses to risk and their demographic consequences vary across species. *Ecology Letters*. **19**, 403–413. doi: 10.1111/ele.12573

Laurance, W.F., Lovejoy, T.E., Vasconcelos, H.L., Bruna, E.M., and Didham, R.K., (2002). Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology*. **16**, 605–18. doi: 10.1046/j.1523-1739.2002.01025.x

Le Viol, I., Jiguet, F., Brotons, L., Herrando, S., Lindström, A., Pearce-Higgins, J.W., Reif, J., Van Turnhout C., and Devictor, V., (2012). More and more generalists: two decades of changes in the European avifauna. *Biology Letters*. **8**, 780–782. doi: 10.1098/rsbl.2012.0496

Leibold, M.A., Holyoak, M., Mouquet N., Chase, P.A.J.M., Hoopes, M.F., Holt, R.D., Shurin, J.B., Law, R., D. Tilman, M. Loreau and A. Gonzalez, The metacommunity concept: A framework for multi-scale community ecology, *Ecology Letters*. 7 (2004) 601–613. doi: 10.1111/j.1461-0248.2004.00608.x

Lindell, C.A., Chomentowski W.H, and Zook, J.R. (2004). Characteristics of bird species using forest and agricultural land covers in southern Costa Rica. *Biodiversity and Conservation* **13**, 2419-2441.

Lees, A.C. and Peres C.A. (2009). Gap-crossing movements predict species occupancy in Amazonian forest fragments *Oikos* **118**, 280–290. doi: 10.1111/j.1600-0706.2008.16842.x

Mazaris AD, Papanikolaou AD, Barbet-Massin M, Kallimanis A.S., and Jiguet F (2013) Evaluating the connectivity of a protected areas' network under the prism of global change: the efficiency of the european natura 2000 network for four birds of prey. *PLoS ONE* 8:e50640. doi: 10.1371/journal.pone.0059640

Merler, J. A., Diuk-Wasser and M., and Quintana, R. D. (2001). Winter diet of Dusky-legged Guan (Penelope obscura) at the Paraná River Delta region. *Studies on Neotropical Fauna and Environment*. **36**, 33–38. doi: 10.1076/snfe.36.1.33.8886

Moradi, H.V., Zakaria, M., Mohd, A.B., and Yusof, E. (2009). Insectivorous birds and environmental factors across an edge-interior in tropical rainforest of Malaysia. *International Journal of Zoological Research* **5**, 27-41.

Morante-Filho, J. C., and Arroyo-Rodríguez, V., Faria, D. (2016). Patterns and predictors of β -diversity in the fragmented Brazilian Atlantic forest: A multiscale analysis of forest specialist and generalist birds. *Journal of Animal Ecology* **85,** 240 –250. doi: 10.1111/1365-2656.12448

Mueller, T., Lenz, J., Caprano, T., Fiedler, W., and Böhning-Gaese, K. (2014) Large frugivorous birds facilitate functional connectivity of fragmented landscapes. J. *Apply Ecology*, **51**, 684–692. doi: 10.1111/1365-2664.12247

Murphy G.E.P., and Romanuk T.N. (2012). A meta-analysis of community response predictability to anthropogenic disturbances. *The American Naturalist* **180,** 316–327. doi: 10.1086/666986

Neuschulz E.L., Brown M., and Farwig N. (2013). Frequent bird movements across a highly fragmented landscape: the role of species traits and forest matrix. *Animal Conservation* **16**, 170–179. doi: 10.1111/j.1469-1795.2012.00582.x

Newbold T., Scharlemann J.P.W., Butchart S.H.M., Şekercioğlu Ç.H., Alkemade R., Booth H., and Purves D.W. (2013). Ecological traits affect the response of tropical forest bird species to land-use intensity. *Proceedings of Royal Society B*, **280**. doi: 10.1098/rspb.2012.2131

Pavlacky D.C., Possingham, H.P., and Goldizen A.W. (2015). Integrating life history traits and forest structure to evaluate the vulnerability of rainforest birds along gradients of deforestation and fragmentation in eastern *Australia Biology Conservation* **188**, 89–99. doi: 10.1016/j.biocon.2014.10.020

Pearson, D.L. (1975). The relation of foliage complexity to ecological diversity of three Amazonian bird communities. *Condor* **77**, 453–466. doi: 10.2307/1366092

Peña-Claros, M. (2003). Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon. *Biotropica* **35**,450-461. doi: 10.1646/01078

Piacentini, V. and Varassin, I.G. (2007). Interaction network and the relationships between bromeliads and hummingbirds in an area of secondary Atlantic rain forest in southern Brazil. *Journal of Tropical Ecology* **23**, 663–671. doi: 10.1017/S026646740700449X

Powell, L.L., Cordeiro, N.J., and Stratford, J.A., (2015). Ecology and conservation of avian insectivores of the rainforest understory: a pantropical perspective. *Biological Conservation* **188**, 1-10. doi:10.1016/j.biocon.2015.03.025

R Development Core Team, 2017. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3- 9000051-07-0. URL: http://www.R-project.org.

Ribon, R., Simon, J.E. and De Mattos, G.T., (2003). Bird extinctions in Atlantic Forest fragments of the Vicosa region, southeastern Brazil. *Conservation Biology* **17**, 1827–1839. doi: 10.1111/j.1523- 1739.2003.00377.x

Root, R. B. (1967). The niche exploitation pattern of the blue-gray gnatcatcher. *Ecological Monographs* **37**, 317–350. doi: 10.2307/1942327

Sarthou, J.P., Badoz, A., Vaissière, B., Chevallier, A. and Rusch, A. (2014). Local more than landscape parameters structure natural enemy communities during their overwintering in semi-natural habitats. *Agriculture, Ecosystems and Environment* **194**, 17–28. doi:10.1016/j.agee.2014.04.018

Sekercioglu, C¸. H., Ehrlich, P. R., Daily, G. C., Aygen, D., Goehring, D. and Sandi, R. F. (2002). Disappearance of insectivorous birds from tropical forest fragments, *Proceedings of the National Academy of Sciences* **99**, 263–267. doi: 10.1073/pnas.012616199

Sekercioglu, C., Daily, G. and Ehrlich, P. (2004). Ecosystem consequences of bird declines. *Proceedings of the National Academy of Sciences* **101**, 18042–18047. doi:10.1073/pnas.0408049101

Sigel B.J., Robinson W.D. and Sherry T.W. (2010) Comparing bird community responses to forest fragmentation in two lowland Central America reserves. *Biological Conservation* **143**, 340-350. doi: 10.1016/j.biocon.2009.10.020

Silva, W.G., Metzger, J.P., Bernacci, L.C., Catharino, E.L.M., Durigan, G. and Simões, S.(2008). Relief influence on tree species richness in secondary forest fragments of Atlantic Forest, SE, Brazil. *Acta Botanica Brasilica* **22**, 589–598. doi: 10.1590/S0102-33062008000200026

Streby, H.M., Peterson, S.M., and Anderson, D.E. (2011) Invertebrate availability and vegetation characteristics explain use of nonnesting cover types by mature-forest songbirds during the post-fledging period. *Journal of Field Ornithology* **82,** 406–414. doi: 10.1111/j.1557-9263.2011.00343.x

Thornton, D., Branch, L., and Sunquist, M. (2011). Passive sampling effects and landscape location alter associations between species traits and response to fragmentation. *Ecological Applications* **21**, 817-829. doi: 10.1890/10-0549.1

Uezu, A., and Metzger, J.P. (2016) Time-Lag in Responses of Birds to Atlantic Forest Fragmentation: Restoration Opportunity and Urgency. *PLoS One* **11,** e0147909. doi:10.1371/journal.pone.0147909

Ulrich, W., Banks-Leite, C., De Coster, G., Habel, J.C., Matheve, H., Newmark, W. D., Tobias, J.A. and Lens, L. (2017) Environmentally and behaviourally mediated co-occurrence of functional traits in bird communities of tropical forest fragments. *Oikos*, 10.1111/ oik.04561. doi:10.1111/oik.04561

Van Rensburg, B.J., Chown, S.L. and Gaston, K.J. (2002). Species richness, environmental correlates, and spatial scale: a test using South African birds. The *American Naturalist*, **159**, 566–577. doi: 10.1086/339464

Vetter, D., Hansbauer, M. M., Vegvári, Z. and Storch, I. (2011) Predictors of forest fragmentation sensitivity in Neotropical vertebrates: a quantitative review. *Ecography*, **34**, 1-8. doi: 10.1111/j.1600-0587.2010.06453.x

Vielliard, J.M.E. and Silva, W.R. (1990). Nova metodologia de levantamento quantitativo da avifauna e primeiros resultados do interior do Estado de São Paulo, Brasil. In: *Anais do IV Encontro Nacional de Anilhadores de Aves*, Recife, 117-151.

Walz, U. and Syrbe R.U. (2013). Linking *la*ndscape structure and biodiversity. *Ecological Indicators* **31.8**, 1-5. doi:10.1016/j.ecolind.2013.01.032

Wilcove, D.S., Mclellan, C.H., Dobson, A.P. (1986). Habitat fragmentationin the temperate zone. Conservation Biology the Science of Scarcity and Diversity In: Soulé, M.E. (Ed.) 237-256.

Wilman, H., Belmaker, J., Simpson, J., De La Rosa, C., Rivadeneira, M.M. and Jetz, W. (2014) EltonTraits 1.0: Species-level foraging attributes of the world's birds and mammals. *Ecology* **95**, 2027–2027. doi: 10.1890/13-1917.1

TABLES

Table 1. Degree of freedom (df), explained variation (R^2), adjusted explained variation ($Adj.R^2$) of the three explanatory scales on the abundance of birds, in a region of the Atlantic Forest in southeastern Brazil. Fractions are as follows: exclusive effects: a= local, b= landscape c = immediate surrounding, and shared effects: d = local and landscape, e= landscape and immediate surrounding, f= local and immediate surrounding, g= local, landscape and immediate surrounding.

Fractions	Df	R.square	Adj.R.square
[a+d+f+g] = Local	3	0,123	0,05722
[b+d+e+g] = Immediate surrounding	2	0,10597	0,06236
[c+e+f+g] = Landsacpe	6	0,21445	0,08707
[a+b+d+e+f+g] = Local + Immediate surrounding	5	0,19837	0,0929
[a+c+d+e+f+g] =Local + Landsacpe	9	0,31203	0,12992
[b+c+d+e+f+g] = Landscape + Immediate surrounding	8	0,27244	0,10613
[a+b+c+d+e+f+g] = All	11	0,35784	0,13709
Individual fractions			
[a] = Exclusively Local	3	0,03096	
[b] = Exclusively Immediate surrounding	6	0,0442	
[c] = Exclusively Landscape	2	0,00717	

Table 2. Degrees of freedom (df), F statistics and p-value for the influence of effects of local, landscape and immediate surroundings on birds abundance in a region of the Atlantic Forest in southeastern Brazil. Significance levels: $p < 0.05$: ∗0,05; ∗∗0,01; ∗∗∗ <0,001.

	Local			
	Df	**Variance**	**F**	**Pr(>F)**
Model	3	0.05094	1.3244	0.00099
Residual	32	0.38304		
	Immediate surrounding			
	Df	**Variance**	**F**	**Pr(>F)**
Model	2	0.02732	1.1413	0.187
Residual	32	0.38304		
	Landsacpe			
	Df	**Variance**	**F**	**Pr(>F)**
Model	6	0.09512	1.3244	0.00099
Residual	32	0.38304		

Table 3. Cluster of species (a) Positively related to Canopy Height and Understory Density; (b)) Positively related to Understory Density; (c) Positively related to Declivity 1 (0-5º); (d) Positively related to Nearest Pond Distance; (e) Negatively related to Nearest pond

	Species	**Acronym**	**IPA**	**Guild**
a) Positively related to “Canopy Height” and “Understorey Density”	*Basileuterus culicivorus*	Bcul	4,068	Fi
	Thamnophilus caerulescens	Tcae	1,364	Fi
	Turdus albicollis	Talb	0,386	Om
	Corythopis delalandi	Cdel	0,818	Ui
	Conirostrum speciosum	Cspe	0,182	Ci
b) Positively related to “Understorey Density”	*Sittasomus griseicapillus*	Sgri	1,205	Ti
	Vireo olivaceus	Voli	1,023	Fi
	Myiothlypis flaveola	Mfla	1,091	Ui
	Tapera naevia	Tnae	0,50	Ui
	Cyclarhis gujanensis	Cguj	2,068	Om
c) Positively related to “Declivity 1 (0-5º)”	*Turdus leucomelas*	Tlcm	2,364	Om
	Colaptes campestris	Ccam	0,114	Ti
	Patagioenas picazuro	*Ppic*	2,25	Lf
	Cyanocorax cristatellus	Ccri	0,091	Om
	Crotophaga ani	Cani	0,182	Oi
	Myiozetetes similis	Msim	0,295	Om
	Coereba flaveola	Cfla	0,295	Ne

	Pitangus sulphuratus	Psul	0,864	Om
	Caracara plancus	Cplan	0,159	Ca
	Ramphastos toco	Rtoc	0,250	Lf
	Hirundinea ferrugínea	Hfer	0,068	Ai
	Turdus leucomelas	Tlcm	2,364	Om
d) Positively related to “Nearest Pond Distance”	*Hylatomus lineatus*	Hlin	0,068	Ti
	Euphonia chlorotica	Echl	0,477	Sf
	Phaethornis pretrei	Ppre	0,182	Ne
	Camptostoma obsoletum	Cobs	0,455	Fi
	Sicalis flaveola	Sfla	0,114	Ag
	Phyllomyias plumbeiceps	Pplum	0,045	Ui
e) Negatively related to “Nearest pond Distance	*Dysithamnus mentalis*	Dmen	1,523	Fi
	Lathrotriccus euleri	Leul	0,523	Ui
	Leptotila verreauxi	Lver	0,705	Eg
	Progne tapera	Ptap	0,159	Ai
	Todirostrum poliocephalum	Tpoli	0,091	Ci
	Synallaxis ruficapilla	Sruf	0,273	Fi
	Piaya cayana	Pcay	0,318	Om
	Aramides saracura	*Asar*	0,114	Om
	Dendrocincla turdina	Dtur	0,50	Ti
	Myiodynastes maculatus	Mmac	0,409	Om
	Sclerurus scansor	Ssca	0,205	Ui
	Thamnophilus doliatus	Tdol	0,455	Fi
	Lochmias nematura	Lnem	0,250	Ui
	Tolmomyias sulphurescens	Tsul	0,795	Fi

FIGURES

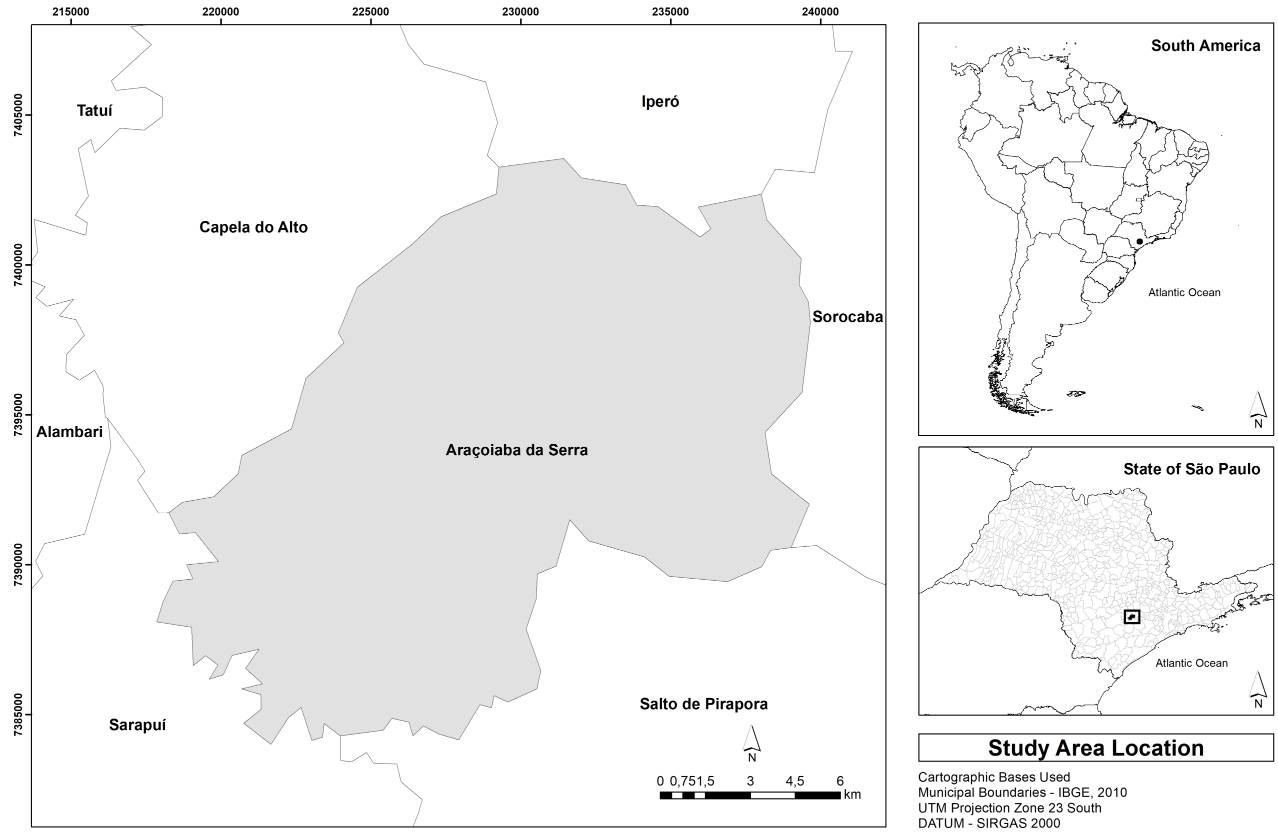


Figure 1. Araçoiaba da Serra, São Paulo, Brazil.

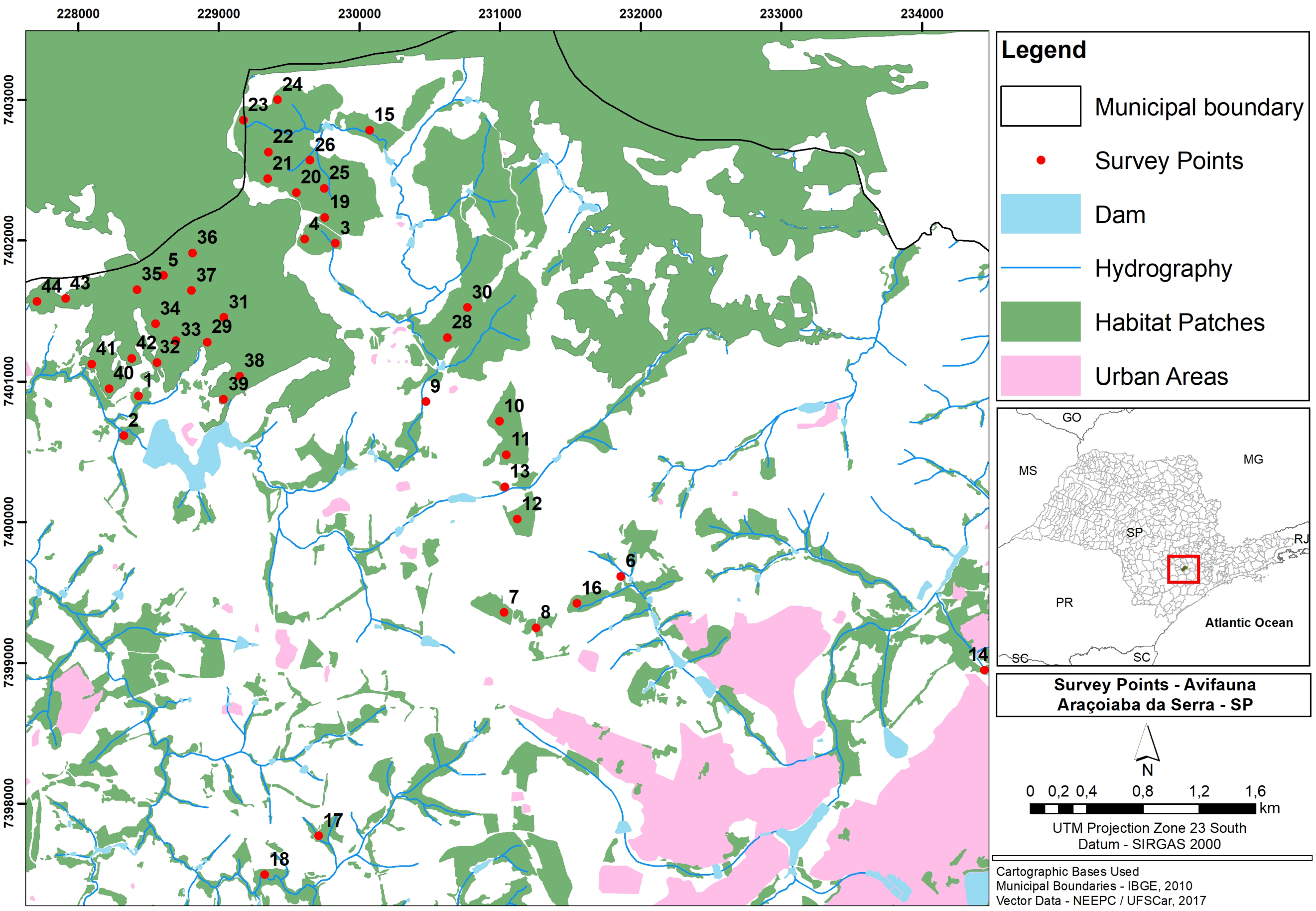


Figure 2. Fixed point counts in Araçoiaba da Serra, São Paulo, Brazil.

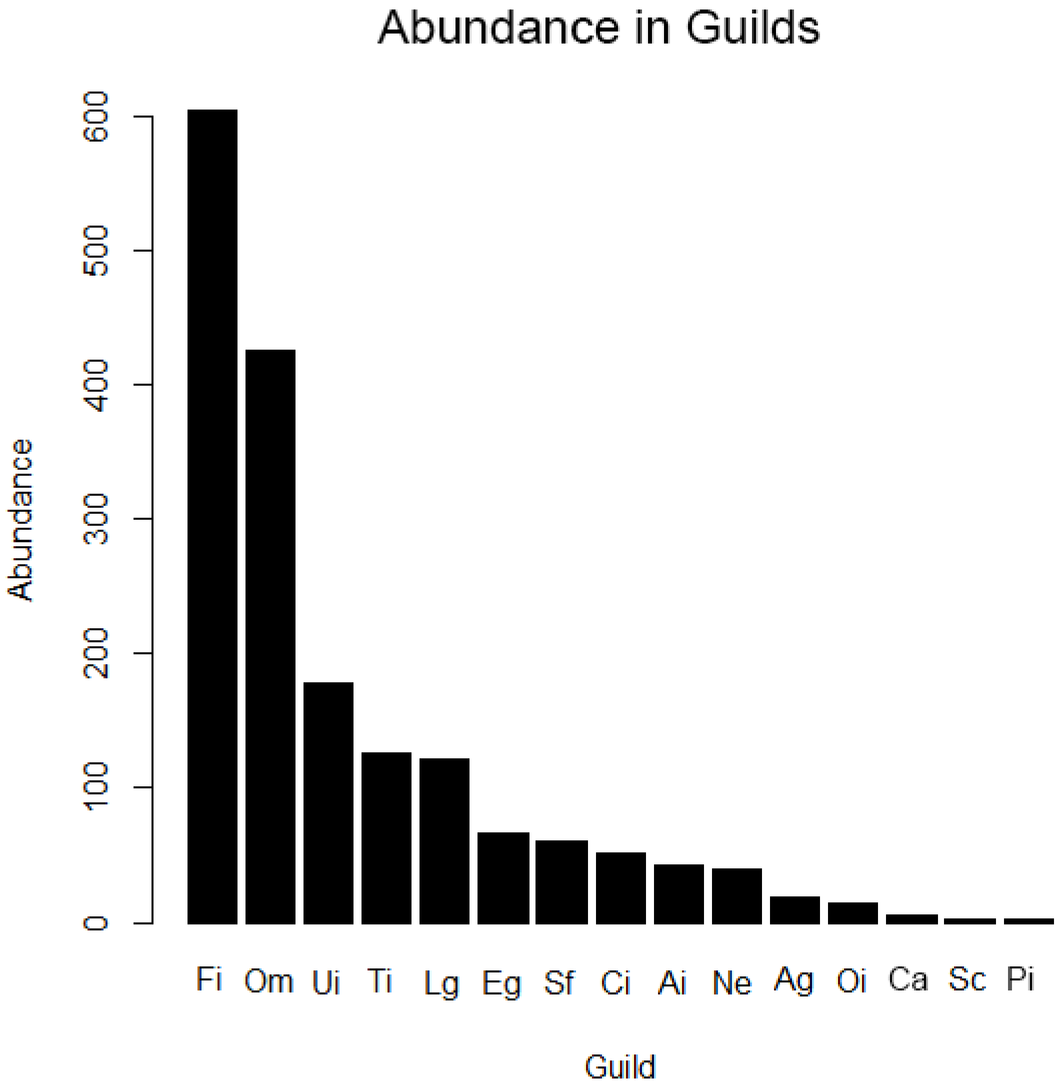


Figure 3. Abundance of birds in each guild foraging in a region of Atlantic Forest in southeastern Brazil. Legend: foliage insectivores (Fi); omnivores (Om); understory insectivores (Ui); trunk climbers insectivorous (Ti); large frugivores (Lg); edge granivores (Eg); aerial insectivorous (Ai); canopy insectivores (Ic); nectarivores (Ne); small frugivores (Sf); open area granivores (Ag); open area insectivores (Oi); scavengers (Sc); carnivores (Ca) and piscivores (Pi).

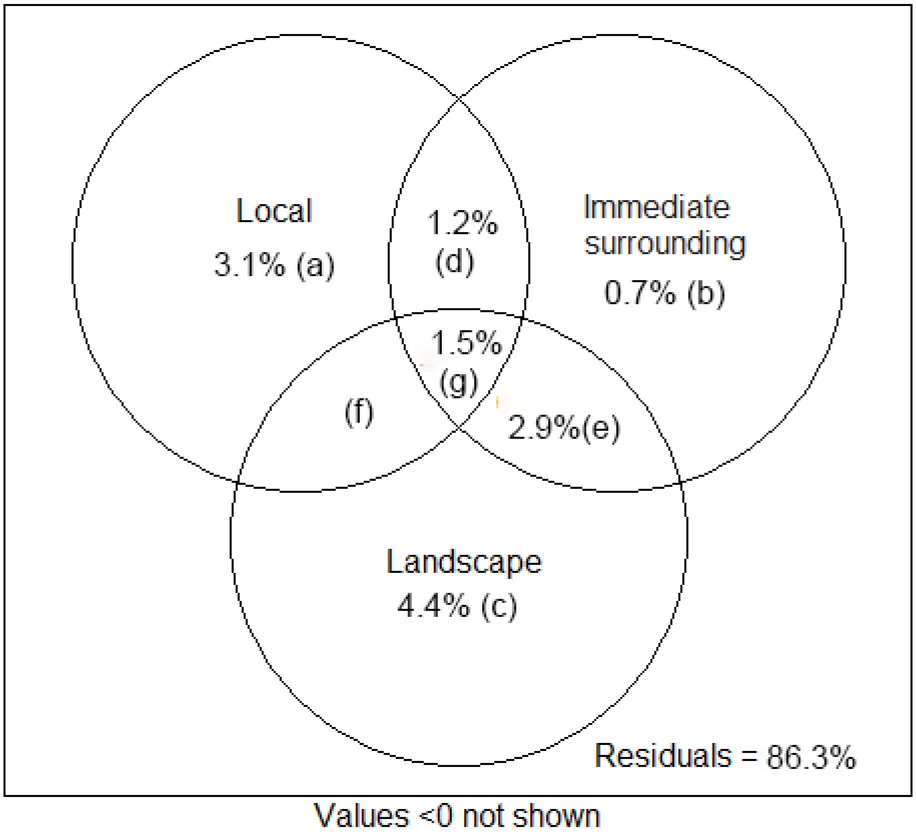
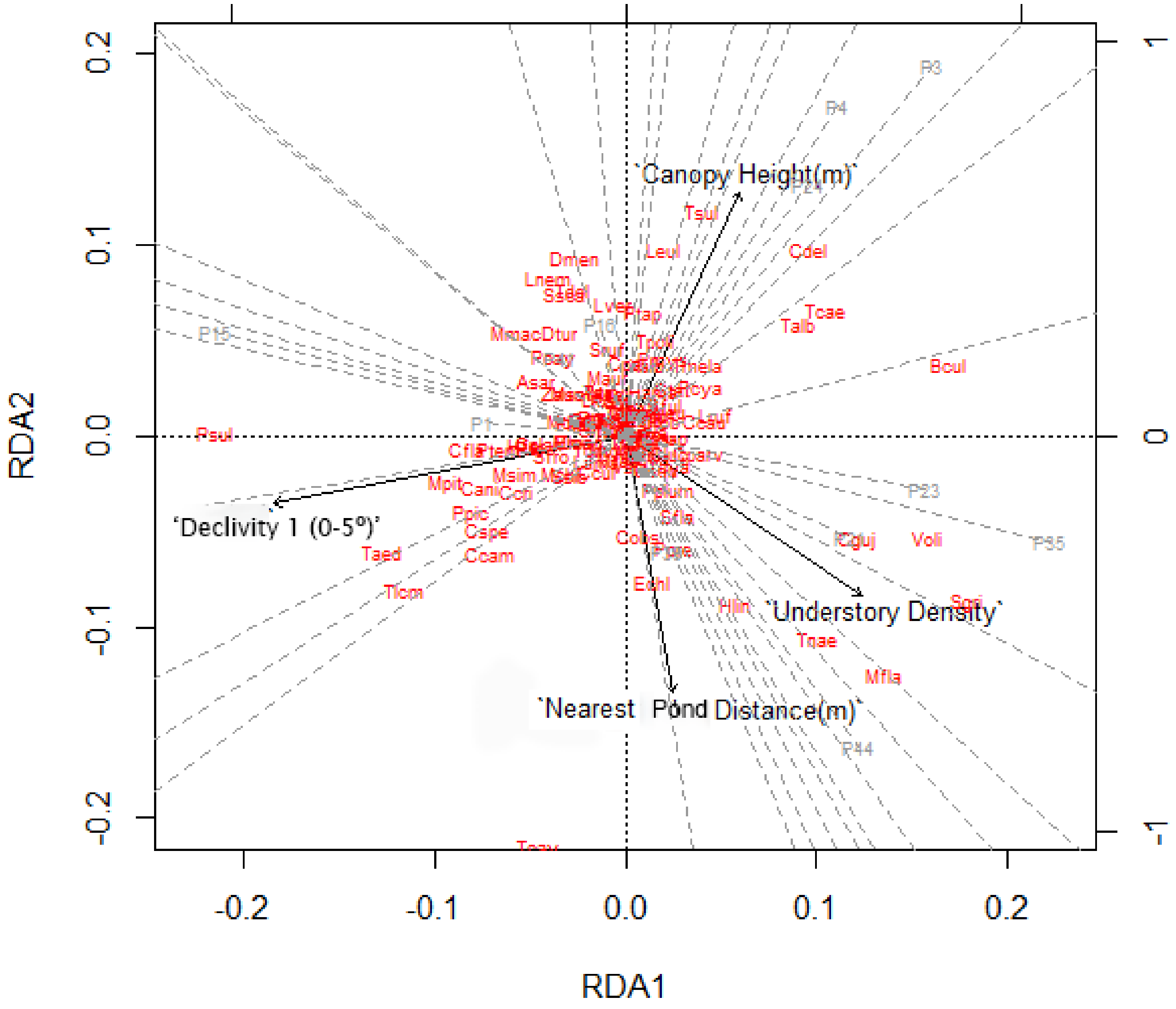


Figure 4. Venn diagram displaying the results of the variation partitioning analysis of the three explanatory scales on the abundance of birds. The explanatory variables were local (X1), landscape (X2) immediate surrounding and (X3) habitat features. The a, b, and c fractions represent the portion of bird abundances variation explained exclusively by local, immediate surrounding and landscape zone, respectively; the intersections indicate the fraction of variability in the response variable accounted for by both explanatory variables sets; and indicates the fraction of the variation that were not explained by the model.



.Figure 5. Ordination plot of the partial RDA analysis with the effects of the explanatory variables that best explain the variation of bird abundances in a region of the Atlantic Forest in south-eastern Brazil.

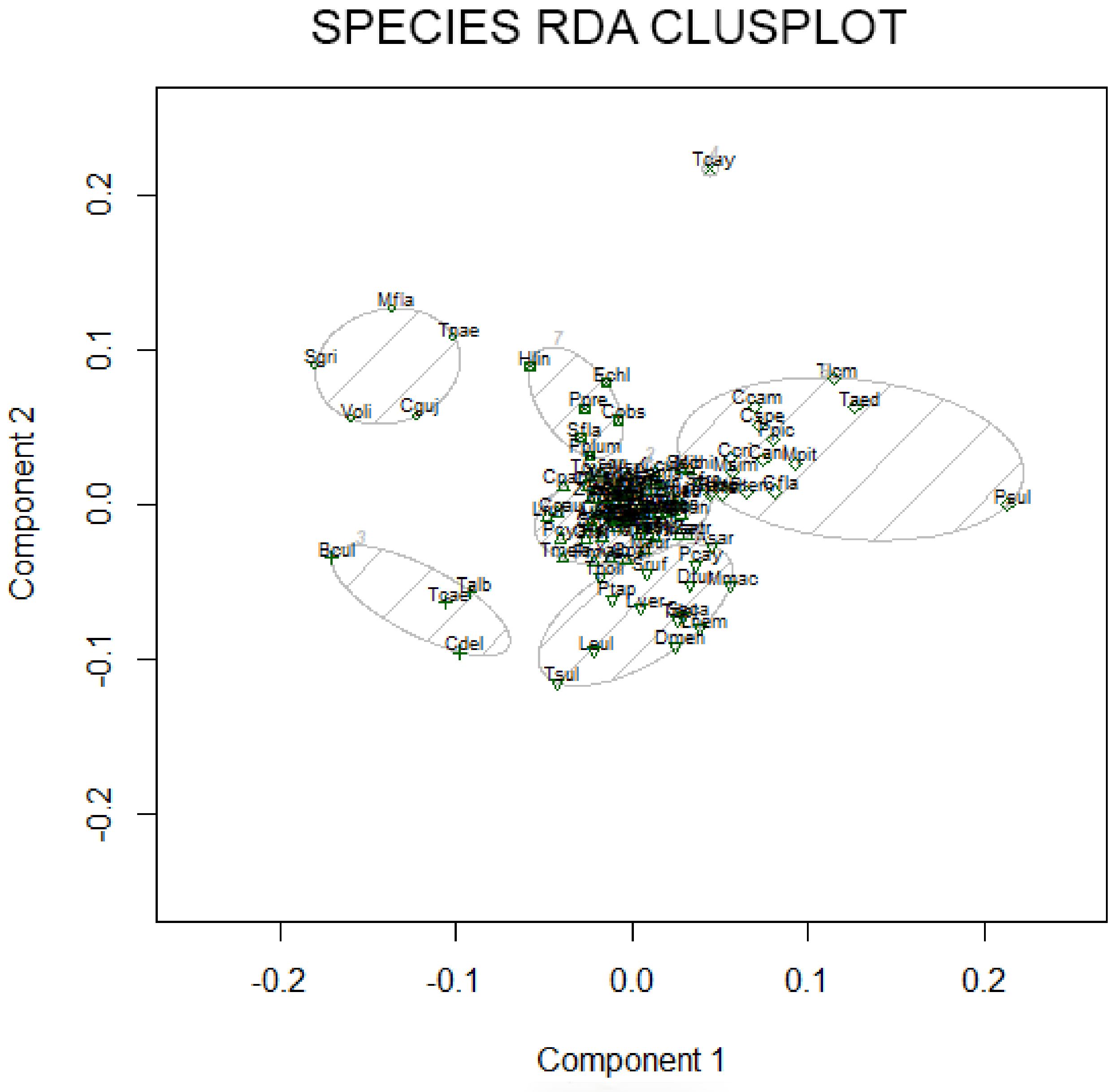


Figure 6. Species clusters according to the axes of the RDA.

Table S1. Bird species recorded by fixed point counts (Jun-Sep 2017 and Oct 2017- Feb 2018). Legend: Index of Punctual Abundance (IPA), foliage insectivores (Fi); omnivores (Om); understory insectivores (Ui); trunk climbers insectivorous (Ti); large frugivores (Lg); edge granivores (Eg); aerial insectivorous (Ai); canopy insectivores (Ic); nectarivores (Ne); small frugivores (Sf); open area granivores (Ag); open area insectivores (Oi); scavengers (Sc); carnivores (Ca) and piscivores (Pi).

Family	**Specie**	**Acronym**	**IPA**	**Guild**
Tinamidae	*Crypturellus parvirostris*	Cparv	0,159	Ag
	Crypturellus tataupa	Ctat	0,091	Fi
Cracidae	*Penelope obscura*	Pobs	0,114	Lg
Cathartidae	*Coragyps atratus*	Catr	0,068	Sc
Accipitridae	*Rupornis magnirostris*	*Rmag*	0,023	Ca
Rallidae	*Aramides saracura*	*Asar*	0,114	Om
Columbidae	*Columbina squammata*	*Csqu*	0,045	Ag
	Patagioenas picazuro	*Ppic*	2,25	Lg
	Patagioenas cayennensis	*Pcaye*	0,273	Lg
	Zenaida auriculata	*Zaur*	0,227	Ag
	Leptotila verreauxi	Lver	0,705	Eg
	Leptotila rufaxilla	Lruf	0,432	Eg
	Geotrygon montana	Gmon	0,045	Eg
Cuculidae	*Piaya cayana*	Pcay	0,318	Om
	Crotophaga ani	Cani	0,182	Oi
	Tapera naevia	Tnae	0,50	Ui
Trochilidae	*Phaethornis pretrei*	Ppre	0,182	Ne
	Eupetomena macroura	Emac	0,136	Ne
	Thalurania glaucopis	Tgla	0,114	Ne
	Leucochloris albicollis	Lalb	0,091	Ne
	Chlorostilbon lucidus	Cluc	0,023	Ne
	Stephanoxis lalandi	Slal	0,068	Ne
Alcedinidae	*Megaceryle torquata*	Mtor	0,023	Pi
Galbulidae	*Galbula ruficauda*	Gruf	0,114	Ai
Ramphastidae	*Ramphastos toco*	Rtoc	0,250	Lg
Picidae	*Picumnus temminckii*	Ptem	0,091	Ti
	Melanerpes candidus	Mcan	0,068	Ti
	Veniliornis spilogaster	Vspi	0,227	Ti
	Colaptes campestris	Ccam	0,114	Ti
	Campephilus robustus	Crob	0,205	Ti
	Hylatomus lineatus	Hlin	0,068	Ti
Falconidae	*Caracara plancus*	Cplan	0,159	Ca
	Milvago chimachima	Mchi	0,045	Ca
Thamnophilidae	*Mackenziaena severa*	Msev	0,114	Fi
	Dysithamnus mentalis	Dmen	1,523	Fi
	Thamnophilus doliatus	Tdol	0,455	Fi
	Thamnophilus caerulescens	Tcae	1,364	Fi
Conopophagidae	*Conopophaga lineata*	Clin	0,091	Fi

Family	**Specie**	**Acronym**	**IPA**	**Guild**
Furnariidae	*Sittasomus griseicapillus*	Sgri	1,205	Ti
	Dendrocincla turdina	Dtur	0,50	Ti
	Xiphocolaptes albicollis	Xalb	0,068	Ti
	Automolus leucophthalmus	Aleu	0,568	Fi
	Sclerurus scansor	Ssca	0,205	Fi
	Lochmias nematura	Lnem	0,250	Ui
	Synallaxis ruficapilla	Sruf	0,273	Fi
	Synallaxis spixi	Sspi	0,023	Fi
	Synallaxis frontalis	Sfro	0,250	Fi
	Cranioleuca pallida	Cpal	0,136	Ti
	Syndactyla rufosuperciliata	Srufo	0,023	Ui
Pipridae	*Chiroxiphia caudata*	Ccau	0,477	Sf
Tyrannidae	*Platyrinchus mystaceus*	Pmys	0,091	Ui
	Leptopogon amaurocephalus	Lama	0,432	Ai
	Corythopis delalandi	Cde	0,818	Ui
	Myiornis auricularis	Maur	0,250	Ui
	Tolmomyias sulphurescens	Tsul	0,795	Fi
	Todirostrum poliocephalum	Tpoli	0,091	Ci
	Phyllomyias plumbeiceps	Pplum	0,045	Ui
	Todirostrum cinereum	Tcin	0,159	Fi
	Hirundinea ferruginea	Hfer	0,068	Ai
	Camptostoma obsoletum	Cobs	0,455	Fi
	Myiarchus swainsoni	Mswa	0,068	Ci
	Myiarchus tuberculifer	Mtub	0,045	Fi
	Myiarchus ferox	Mfer	0,091	Ci
	Myiarchus tyrannulus	Mtyr	0,091	Ci
	Capsiempis flaveola	Cflav	0,182	Ui
	Sirystes sibilator	Ssib	0,250	Ci
	Pitangus sulphuratus	Psul	0,864	Om
	Myiodynastes maculatus	Mmac	0,409	Om
	Megarynchus pitangua	Mpit	0,273	Om
	Myiozetetes similis	Msim	0,295	Om
	Tyrannus melancholicus	Tmel	0,250	Ci
	Myiophobus fasciatus	Mfas	0,159	Ui
	Fluvicola nengeta	Fnen	0,136	Oi
	Lathrotriccus euleri	Leul	0,523	Ui
Vireonidae	*Cyclarhis gujanensis*	Cguj	2,068	Om
	Hylophilus amaurocephalus	Hama	0,091	Ci
	Vireo olivaceus	Voli	1,023	Fi
Corvidae	*Cyanocorax cristatellus*	Ccri	0,091	Om
Cathartidae	*Pygochelidon cyanoleuca*	Pcya	0,295	Ai
	Progne tapera	Ptap	0,159	Ai
Troglodytidae	*Troglodytes aedon*	Taed	0,50	Fi
Turdidae	*Turdus leucomelas*	Tlcm	2,364	Om
	Turdus albicollis	Talb	0,386	Om
	Turdus rufiventris	Truf	0,227	Om
	Turdus amaurochalinus	Tama	0,205	Om

Family	Specie	Acronym	IPA	Guild
Mimidae	*Mimus saturninus*	Msat	0,182	Om
Passerellidae	*Zonotrichia capensis*	Zcap	0,136	Eg
Parulidae	*Setophaga pitiayumi*	Spit	0,409	Fi
	Basileuterus culicivorus	Bcul	4,068	Fi
	Myiothlypis flaveola	Mfla	1,091	Ui
	Myiothlypis leucoblephara	Mleu	0,409	Fi
Thraupidae	*Thraupis sayaca*	Tsay	0,295	Om
	Thraupis cyanoptera	Tcya	0,091	Om
	Tangara palmarum	Tpal	0,068	Om
	Tangara cayana	Tcay	1,114	Om
	Nemosia pileata	Npil	0,045	Ci
	Conirostrum speciosum	Cspe	0,182	Ci
	Sicalis flaveola	Sfla	0,114	Eg
	Coryphospingus cucullatus	Ccul	0,068	Eg
	Tachyphonus coronatus	Tcor	0,068	Om
	Ramphocelus carbo	Rcar	0,182	Om
	Dacnis cayana	Dcay	*0,045*	Sf
	Saltator fuliginosus	Sful	0,045	Om
	Coereba flaveola	Cfla	0,295	Ne
	Trichothraupis melanops	Tmela	0,205	Sf
	Tersina viridis	Tvir	0,159	Sf
	Euphonia chlorotica	Echl	0,477	Sf
	Habia rubica	Hrub	0,114	Ui