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# Avian biotic homogenization driven by airport-affected environments

Renata D. Alquezar[1] · Graziela Tolesano-Pascoli[1] · Diego Gil[2] · Regina H. Macedo[1,3]



## Abstract

Building and operating airports are human activities associated with adverse changes in the natural environment, resulting in threats to the biodiversity in airport surroundings. As urban ecosystems are becoming more prevalent in the world and biotic homogenization is a concern, our aim here was to understand how environments near airports (hereafter "airport-affected" sites) were affected, to assess possible changes in bird community structure. We used mist-nets and sound automatic recording units to catalog bird species in natural sites influenced by three Brazilian airports and in three quiet control sites. We characterized study sites by their landscape structure, noise and light levels, and evaluated avian community structure using species richness, abundance and β diversity indexes. Avian communities presented slightly higher species richness in quiet control than in airport-affected sites. Of 22 widespread species, we identified 10 airport adapters responsible for 38.7% of total abundance in airport-affected sites and 17.2% in quiet control sites. We also identified 11 airport avoiders, presenting opposite trends (8.1% and 30.9% respectively). The β diversity results indicate that the regional pool is an important driver in defining species presence within the studied airports. However, taking a wider view, the prevalence of airport adapter species over airport avoider species in the avian communities of airport-affected environments reveals signs of an on-going process of biotic homogenization. Our study provides evidence of the impact of aircrafts and airports on avian communities, a seldom studied anthropogenic change that may affect conservation-worthy areas worldwide.

**Keywords** Aircraft noise · Automatic recording units (ARU) · Beta diversity · Birds · Brazil · Conservation

## Introduction

Building and operating airports are human activities associated with adverse changes in the natural environment, resulting in threats to the biodiversity in airport surroundings. Here we define "airport-affected environment" as a fragment of natural habitat affected both by habitat degradation and extreme noise levels associated with airport activity. One possible airport-induced effect is that of biotic homogenization, which has become an issue in the last 20 years, as city development and environmental changes have dramatically increased worldwide (Mckinney and Lockwood 1999; Olden 2006). Biotic homogenization occurs due to the geographic expansion of a few species (winners) and the geographic reduction of other species (losers), as a result of environmental changes that benefit winners and handicap losers (Mckinney and Lockwood 1999). This process generates a reduction in β diversity among different sites, either by the loss or the increment of species (Olden 2006), but usually by the replacement of geographically restricted species by a few widespread species (Mckinney and Lockwood 1999).

In airport environments, most of the native habitat is replaced by buildings and other structures (urban habitats), while remnant patches (degraded habitats) are usually composed of degraded areas of native vegetation, roads, crops, pastures, farming (Carrete et al. 2009) and invasive grasses and shrubs (MacDougall and Turkington 2005). This combination of factors results in these degraded habitats facing the

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✉ Renata D. Alquezar
renatalquezar@msn.com

[1] Pós-graduação em Ecologia, Instituto de Ciências Biológicas, Universidade de Brasília, 70919-970, Brasília, DF, Brazil

[2] Departamento de Ecología Evolutiva, Museo Nacional de Ciencias Naturales (CSIC), José Gutiérrez Abascal, 2, 28006 Madrid, Spain

[3] Departamento de Zoologia, Instituto de Ciências Biológicas, Universidade de Brasília, 70910-900, Brasília, DF, Brazil

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impacts of both fragmented and urbanized ecosystems (Caley et al. 2001; Shochat et al. 2006; Carrete et al. 2009). While habitat fragmentation leads to significant losses of biodiversity (Saunders et al. 1991; Gaston et al. 2003; Dixo et al. 2009), habitat urbanization favors generalist and opportunist species that thrive in this novel environment, usually presenting increased abundances (Shochat et al. 2010) and generating biotic homogenization (McKinney 2006).

Extreme noise produced by aircraft and other anthropic sources represents a major concern for human and wildlife welfare (Stansfeld and Matheson 2003; Barber et al. 2009). Typical airport noise patterns are characterized by constant high amplitude levels in the low-frequency ranges and sudden peaks of high amplitude in a broad range of frequencies (Smith 1989; Sierro et al. 2017). Extreme noise has been shown to cause reduced bird population densities (Bayne et al. 2008) and species richness, resulting in changes in community structure and even in the disruption of ecological services, such as seed dispersion and pollination (Francis et al. 2009, 2012). Additionally, noise is also known to impact wildlife behavior, physiology and reproduction, resulting in increased levels of alert behavior (Goldstein et al. 2006; Goudie 2006; Meillère et al. 2015), disrupted foraging patterns (Wale et al. 2013; Voellmy et al. 2014; Klett-Mingo et al. 2016), changes in vocal activity and song structure (Slabbekoorn and den Boer-Visser 2006; Nemeth and Brumm 2009; Potvin et al. 2011; Schuster et al. 2012; Gil et al. 2014; Sierro et al. 2017), reduced pairing success (Habib et al. 2007), reduced nest success (Hayward et al. 2011; Schroeder et al. 2012; Crino et al. 2013; Strasser and Heath 2013), and increased stress levels (Anderson et al. 2011; O'Connor et al. 2011; Blickley et al. 2012; Kleist et al. 2018).

Changes in community structure (richness, diversity, abundance, community composition) due to habitat degradation are typically heightened by additional impacts associated with exposure to extreme noise levels. Changes in species composition between different sites (beta-diversity) are shaped by two ecological processes, species loss and species replacement, leading to species nestedness and species turnover, respectively (Baselga 2012). The species nestedness phenomenon implies that the poorest communities represent a subset of the richest communities, as a result of a non-random loss of species (Patterson and Atmar 1986; Wright and Reeves 1992), and is usually associated with habitat fragmentation and island biogeography. In contrast, the species turnover phenomenon implies that some species are replaced by others, without a reduction in the total number of species (Gaston and Blackburn 2008).

As urban ecosystems are becoming more prevalent in the world and biotic homogenization is a concern, our aim here is to understand how airport-affected environments (degraded habitats exposed to extreme noise levels) induce changes in bird community structure. We expected to find (i) high similarity (low β diversity) among avian communities found in airport-affected environments of different regions, and (ii) increased abundance of a few opportunist species and reduced abundance of many sensitive species in airport environments. Both measures would be indicative of biotic homogenization processes (Mckinney and Lockwood 1999; Knop 2016).

## Methods

### Study sites

We selected three Brazilian airports, based on their high aircraft activity and availability of native vegetation around the lanes. For each airport-affected site, we selected a matched quiet control site, with similar vegetation structure, at distances ranging from 8 to 17 km from the corresponding airport (Fig. 1). Most published studies concerning airport environments are limited to grassland areas immediately around flight lanes (e.g. Blackwell and Wright, 2006; Kershner and Bollinger, 1996), whereas our airport-affected sites comprise residual forested areas affected by aircraft noise around airport flight lanes.

The studied airports are Presidente Juscelino Kubitschek International Airport (AIR_Bras: −15.872°, −47.919°) in Brasília (Federal District), Viracopos International Airport (AIR_Camp: −23.006°, −47.141°) in Campinas (São Paulo state), and Luís Eduardo Magalhães International Airport (AIR_Sal: −12.916°, −38.338°) in Salvador (Bahia state). For each of these airports we chose the following quiet control sites: "Parque Nacional de Brasília" (CONT_Bras: −15.728°, −47.951°) in Brasília (Federal District), a private farm named "Fazenda Santa Maria" (CONT_Camp: −23.098°, −47.130°) in Campinas (São Paulo state), and a residential area with large protected areas named "Condomínio Buscavida" (CONT_Sal: −12.859°, −38.270°) in Salvador (Bahia state). Study sites are named according to whether it is an Airport (AIR) or a quiet control (CONT) site, and by the region/city where it is located (Brasília, Campinas or Salvador).

### Bird captures and recordings

We conducted fieldwork from September to December 2014, and from November 2015 to January 2016, periods when birds are more vocally active in the studied regions, due to the breeding season. We used both mist-net captures and automatic recording units (ARU: SONGMETER SM2+; Wildlife Acoustics, 2007) to identify species in each studied site. These are complementary methods, allowing the detection of a higher number of species since both methodologies have limitations. The mist-net methodology is limited in terms of bird size and flying behavior (Bibby et al. 1992), while the

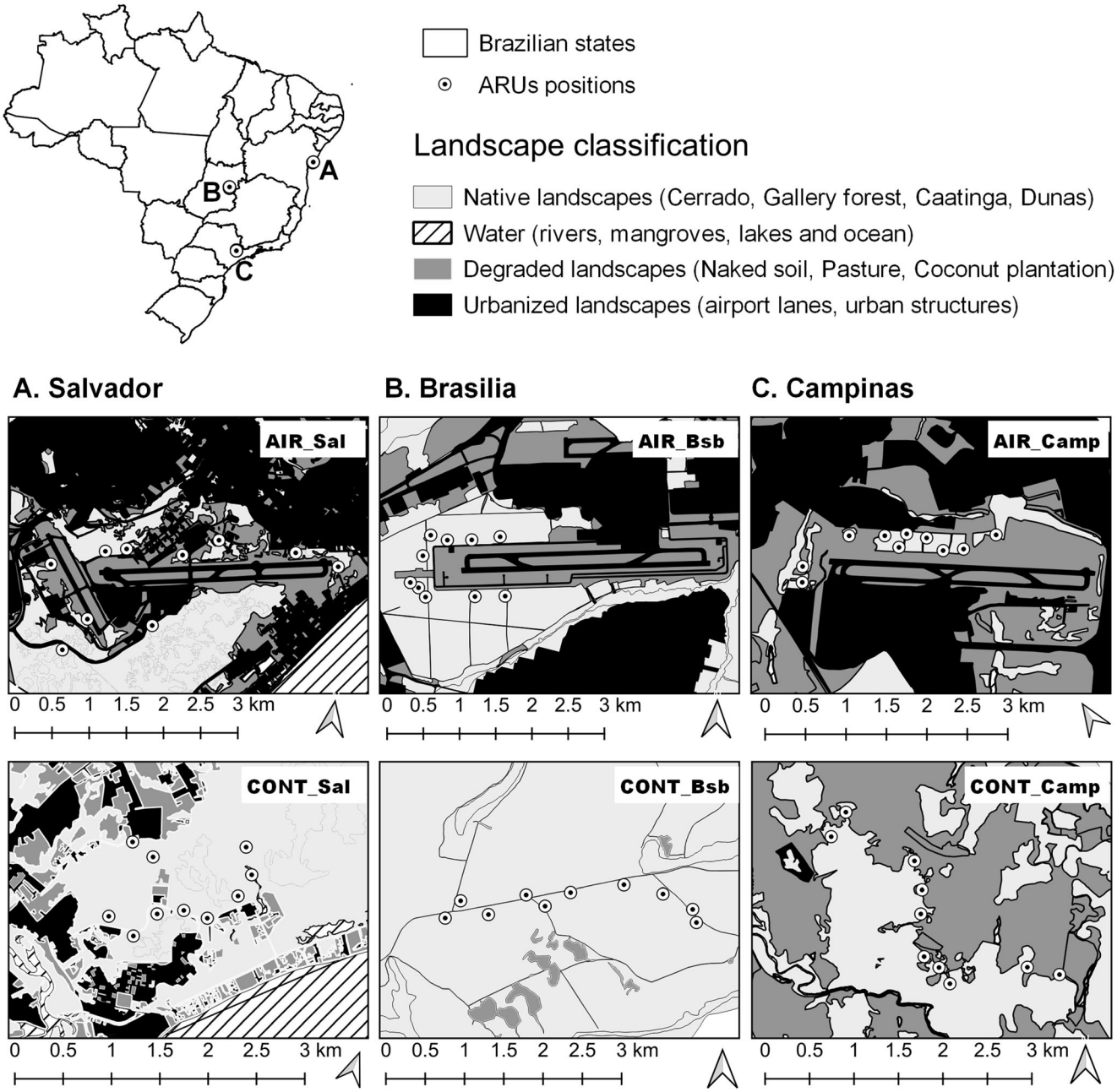


**Fig. 1** Location of study sites in Brazil, including airport-affected (AIR) and quiet control (CONT) sites for each studied region (Sal, Bras and Camp). For each studied site, we present the four major landscape classes and the automatic recorder unit's position

ARU methodology is restricted to vocal species, and requires knowledge of bird vocalizations. The use of ARUs for monitoring avian diversity is a developing technology, proven to be efficient in open areas and as effective as point counts in several habitats (Celis-Murillo et al. 2012; Zwart et al. 2014; Alquezar and Machado 2015).

Using mist-nets, we sampled ten mornings at each airport-affected site and each quiet control site. Each sampling day corresponds to a set of ten mist-nets, opened for 5 h per morning. The effort represents 500 h/site. The mist-nets were monitored at 20 min intervals and all captured birds were identified and banded with numbered metal bands provided by the Brazilian bird-banding agency (CEMAVE-ICMBio). See Online Resource 1 for geographic coordinates and sampling period of each mist-net.

ARUs were placed in 10 points in each airport-affected and quiet control site (total 60 points) and remained at the same spots for two consecutive days, attached to tree branches approximately 2–4 m from the ground. Recorders were programmed to work at dawn between 120 min (−120) before civil twilight until 60 min (+60) after civil twilight (civil twilight: the time when sun center is 6 degrees below the horizon;

www.timeanddate.com). Recordings were conducted in bouts of one minute followed by one inactive minute, totaling 91 min per morning. Recorders sampled at a rate of 44.1 kHz and 16 bits in stereo mode. We listened to a total of 10,920 min of recordings (182 h) to "manually" identify all species by their vocalization. See Online Resource 2 for ARUs geographic coordinates.

## Characterization of sites

**Landscape structure** We classified landscape types within an area of 200 m radius around each ARU point and each mist-net line. Landscape classification was conducted manually, using Google Earth Pro (Google 2019) and Qgis Software v.3.4.7. (Qgis Developmental Team 2019). We classified landscapes as: (1) Native landscapes, including several vegetation types such as *Cerrado* (tropical savanna), gallery forest, *vereda* (marshes), *Caatinga* (dry forest) and sand dunes; (2) Degraded landscapes, including naked soil, pasture, crop and coconut plantation; (3) Urbanized landscapes, including urban structures (e.g. houses, buildings and roads) and airport lanes; and (4) Water, including rivers, mangroves, lakes and ocean. See Fig. 1 for simplified map and Online Resource 3 for detailed colored map.

According to this classification, including only the area of 200 m around sampled points, airport-affected sites present higher proportions of degraded (23–51%) and urbanized landscapes (7–20%) than quiet control sites (5–53% and 0–10% respectively), while the latter had higher proportions of native landscape (Table 1) ($p < 0.001$ for all comparisons, see Online Resource 4 for statistics). Unavoidably, airport-affected sites are intrinsically associated with higher proportions of urbanized landscapes, while quiet sites are associated with higher proportions of native landscapes.

**Noise levels** We estimated noise levels from a subset of the ARU recordings. See Online Resource 4 for detailed methodology. Noise levels were compared within pairs of sites using a LMM and considering mean noise amplitude in a frequency range of 1–2 kHz. This particular band was selected as it better represents aircraft noise (technophony: Towsey et al., 2014, i.e. concentrated below 2 kHz). Mean noise amplitude within pairs of sites in the same region was higher in airport-affected than in quiet control sites, for all regions: Brasília: LMM estimate = −0.297, $X^2 = 173.1$, df = 1, $p < 0.001$; Campinas: LMM estimate = −0.253, $X^2 = 94.34$, df = 1, $p < 0.001$; and Salvador: LMM estimate = −0.167, $X^2 = 15.43$, $p < 0.001$ (Table 1).

**Light levels** We installed *Sky Quality Meters* LU-DL (Unihedron Canada) in five points within each study site to measure mean sky light intensity (i.e. sky darkness). The device remained at the same spots for two consecutive days to measure sky darkness, allowing us to determine light pollution levels during the night. See Online Resource 4 for details in methodology. The general pattern was of higher luminosity levels in airport-affected sites (BRAS: LMM estimate = −0.718, df = 86.9, t.ratio = −2.93, $p = 0.003$; CAMP: LMM estimate = −1.469, df = 84.5, t.ratio = −5.78, $p < 0.001$; SAL: LMM estimate = −0.311, df = 86.7, t.ratio = −1.19, $p = 0.03$) (Table 1).

## Analyses

**Richness estimator** We used richness estimators to evaluate the expected species richness of each studied site, allowing us to compare data obtained using different methods (Magurran 2004). Here, we used the nonparametric estimator Chao 2, based upon presence/absence data, which is an adaptation from Chao 1 (Chao 1987), based on abundance data. Chao 2 uses the number of species that occurs in a single sample, and those that occur in two samples (Magurran 2004). Values were obtained using the *fossil* package (Vavrek 2015) in R 3.3.2. (R Development Core Team 2019). Here we considered each mist-net day and each recording day as a sample.

**Beta (β) diversity** We used the Sorensen-based multiple-site index to evaluate differences in species composition between sites (Whittaker 1972; Baselga 2010). This analysis of dissimilarity provides an indication of two different aspects of diversity: species spatial turnover and nestedness of communities ($\beta_{SOR} = \beta_{SIM} + \beta_{NES}$) (Baselga 2010). Species turnover ($\beta_{SIM}$) is the replacement of some species by others, due to differences in habitat characteristics, geographic and historical aspects (Qian et al. 2005; Baselga et al. 2007). Nestedness ($\beta_{NES}$), on the other hand, represents the tendency of less diverse communities to contain a subset of species from species-richest communities in the same region (Wright and Reeves 1992), and is considered a non-random effect. Values were obtained using the *betapart* package (Baselga et al. 2017), and a cluster was constructed using *stats* package (method Ward D) in R 3.3.2. Here we considered each mist-net day and each recording day as a sample.

**Species composition and relative abundance (VAR index)** Species composition was first analyzed in an explorative manner in order to present a summary of each studied community. Further, we defined species shared among regions, selecting those present in all airports and/or all control sites, presenting at least 30 records in one of the group sites (widespread species).

Inferring abundance from ARU data is challenging but is badly needed, given the increase in ARU methodology use in bird surveys. The VAR index measures the number of songs per unit of time and has been shown to increase with

**Table 1** Characterization of study sites. *Landscape structure*: percentage of landscape classes within each study site; *Noise levels*: values of minimum, mean and maximum amplitudes (dB = decibels) for each study site, between −100 before and 90 min according to civil sunrise time, in frequency range of 1–2 kHz (technophony); *Light levels*: values of minimum, mean and maximum darkness (mag/arcseg$^2$) for each study site, between −120 before and − 60 min according to civil sunrise time (lower values indicate more light)

| | SALVADOR | | BRASILIA | | CAMPINAS | |
|---|---|---|---|---|---|---|
| | Airport | Control | Airport | Control | Airport | Control |
| **Landscape structure** | | | | | | |
| % Native landscape | 37.60 | 82.18 | 73.60 | 94.35 | 36.60 | 47.82 |
| % Degraded landscape | 42.70 | 7.40 | 23.46 | 5.65 | 50.86 | 51.97 |
| % Urbanized landscape | 19.70 | 9.50 | 2.94 | 0 | 11.92 | 0 |
| % Water | 0 | 0.92 | 0 | 0 | 0.62 | 0.21 |
| **Noise levels** | | | | | | |
| Minimum amplitude (dB) | 37 | 36 | 38 | 35 | 40 | 36 |
| Mean amplitude (dB) ± sd | 51 ± 8 | 43 ± 3 | 52 ± 8 | 38 ± 2 | 54 ± 8 | 41 ± 3 |
| Maximum amplitude (dB) | 92 | 70 | 86 | 54 | 92 | 60 |
| **Light levels** | | | | | | |
| Minimum darkness (mag/arcseg$^2$) | 17.11 | 17.49 | 16.34 | 17.79 | 16.16 | 18.18 |
| Mean darkness ± sd | 18.93 ± 0.82 | 19.45 ± 1.06 | 18.29 ± 0.93 | 19.21 ± 0.77 | 18.79 ± 1.36 | 21.00 ± 1.32 |
| Maximum darkness (mag/arcseg$^2$) | 21.07 | 21.36 | 19.66 | 20.57 | 22.94 | 23.19 |

population density (Pérez-Granados et al. 2019). Vocal activity has been shown to be positively related to density estimates of nocturnal migrant bird species (Farnsworth et al. 2004), to population size of colonially-breeding seabirds (Borker et al. 2014; Oppel et al. 2014), and to abundance of two terrestrial bird species (Pérez-Granados et al. 2019).

Here, abundance was inferred adapting the Vocal Activity Rate Index (VAR) proposed for ARU methodology (Pérez-Granados et al. 2019), as the number of files (1 min) in which a species was detected (records). For a restricted pool of widespread species, we compared abundances in airport-affected vs. quiet control sites with a binomial proportion test, using 'species abundance' and 'total abundance' values. We estimated each 'species abundance' in airport-affected and in quiet control sites by summing all records belonging to that species in each site type. We also estimated the 'total abundance' of each site type by summing all species records. Results were obtained using the *stats* package in R 3.3.2.

## Results

Pooling all studied sites and using data from both mist-net captures and ARU methodology, we catalogued a total of 142 species, belonging to 18 bird orders. For the Passeriformes order, 20 families were represented. The mist-net technique yielded 90 species, while the ARU methodology yielded 114 species, with 62 species in common for the two methods (species list available in Online Resource 5). Species name and classification are based on the Brazilian Ornithological Records Comittee (Piacentini et al. 2015).

Airport-affected sites presented lower species richness (53–68) than quiet control sites (75–78) within the three studied regions (Table 2). According to richness values estimated by Chao 2, this pattern would be maintained with an increase of sampling effort.

The hierarchical clustering analysis based on the Sorensen-based multiple-site index of dissimilarity ($\beta_{SOR} = \beta_{SIM} + \beta_{NES}$) yielded three different clusters (Fig. 2). The first cluster (Fig. 2A), based on $\beta_{SOR}$ values, shows higher similarity among sites belonging to the same region, as airport-affected and silent control sites from same regions share a high number of species. The $\beta_{SOR}$ values ranged from 0.28 in Salvador and Campinas to 0.24 in Brasilia region. The second cluster (Fig. 2B), based on $\beta_{SIM}$ values, shows the same pattern as the first cluster, with $\beta_{SIM}$ values equal to 0.13 in Salvador, 0.14 in Campinas, and 0.19 in Brasilia region. The third cluster (Fig. 2C), based on $\beta_{NES}$ values, presents different patterns of community similarity, clustering airport-affected sites and quiet control sites separately, although the separation was not perfect. The AIR_Sal and AIR_Camp communities are more dissimilar to all the other sites and the three control sites are more similar among them. The contribution of this component ($\beta_{NES}$) to $\beta_{SOR}$ was lower than the contribution of $\beta_{SIM}$, with values ranging from 0.003 (CONT_Sal vs. CONT_Camp) to 0.008 (AIR_Sal vs. AIR_Camp). The β values for all pairwise combinations of sites are provided in Online Resource 6.

The Salvador region presented 82 regional species, 23 (28%) of which are exclusive to this pool and 46 (56%) of which are shared between studied sites of the region (Fig. 3).

**Table 2** Data summary of species richness for each site according to each methodology (Both/Total, Mist-nets, and ARU), number of individuals captured in mist-nets, number of sampling units in each methodology, and estimated species richness with Chao 2 estimator ± standard deviation

| Site | Method | Observed richness | No. of individuals | No. of samples | Estimated richness |
|---|---|---|---|---|---|
| AIR_Sal | **Total** | **53** | | **20** | **60.6 ± 3.0** |
| | Net | 28 | 188 | 10 | |
| | ARU | 45 | | 10 | |
| CONT_Sal | **Total** | **75** | | **20** | **83.9 ± 3.3** |
| | Net | 38 | 181 | 10 | |
| | ARU | 60 | | 10 | |
| AIR_Bras | **Total** | **68** | | **20** | **80.4 ± 4.0** |
| | Net | 33 | 175 | 10 | |
| | ARU | 53 | | 10 | |
| CONT_Bras | **Total** | **78** | | **20** | **131.3 ± 12.5** |
| | Net | 35 | 216 | 10 | |
| | ARU | 60 | | 10 | |
| AIR_Camp | **Total** | **55** | | **20** | **77.5 ± 7.5** |
| | Net | 22 | 142 | 10 | |
| | ARU | 48 | | 10 | |
| CONT_Camp | **Total** | **76** | | **20** | **116.3 ± 11.3** |
| | Net | 34 | 134 | 10 | |
| | ARU | 63 | | 10 | |

The Brasília region presented 91 regional species, 23 (25%) of which are exclusive to this pool and 55 (60%) of which are shared between its studied sites. Finally, the Campinas region presented 84 regional species, 12 (14%) of which are exclusive to the region, and 47 (56%) of which are shared between its studied sites (Fig. 3).

The three airport-affected sites together accounted for 114 species (8205 records), of which 15 were found in all airports. The quiet control sites together accounted for 135 species (11,534 records), 24 of which were found in all control sites. Among the widespread species, 11 were found in all studied sites, four were found in all airport-affected sites, and 13 species were found in all quiet control sites. From this pool of 28 widespread species, we excluded 6 species that did not achieve the minimum of 30 records in at least one of the site types (airport or control).

Of the 22 analyzed species, we had a total of 4551 records in airport-affected sites and 6069 records in quiet control sites ('total abundances'). The binomial proportion test shows significant higher abundances of ten

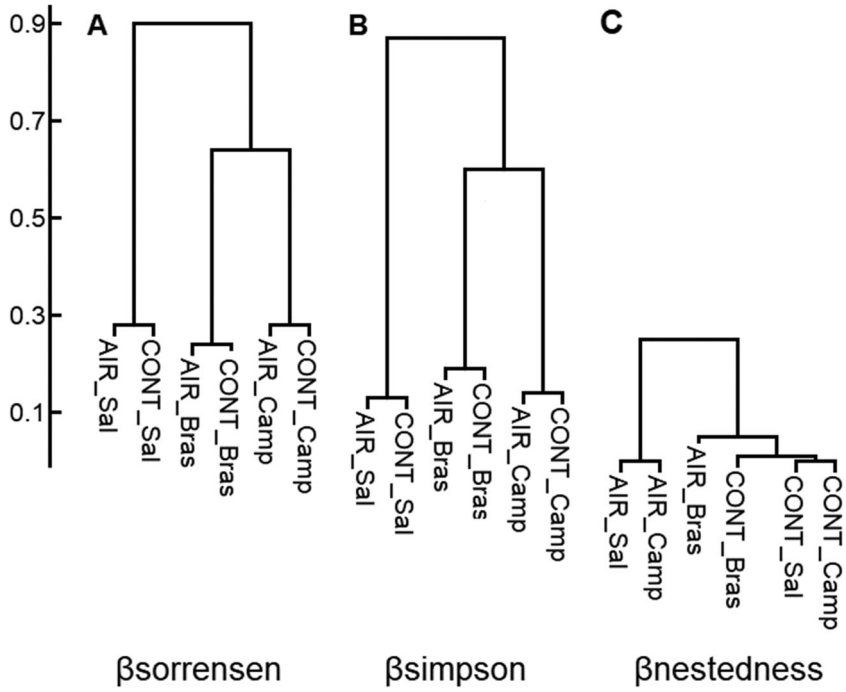


**Fig. 2** Sites clustered by (A) β Sorrensen, (B) β Simpson and (C) β Nestedness indexes of dissimilarity, based on Ward D criteria

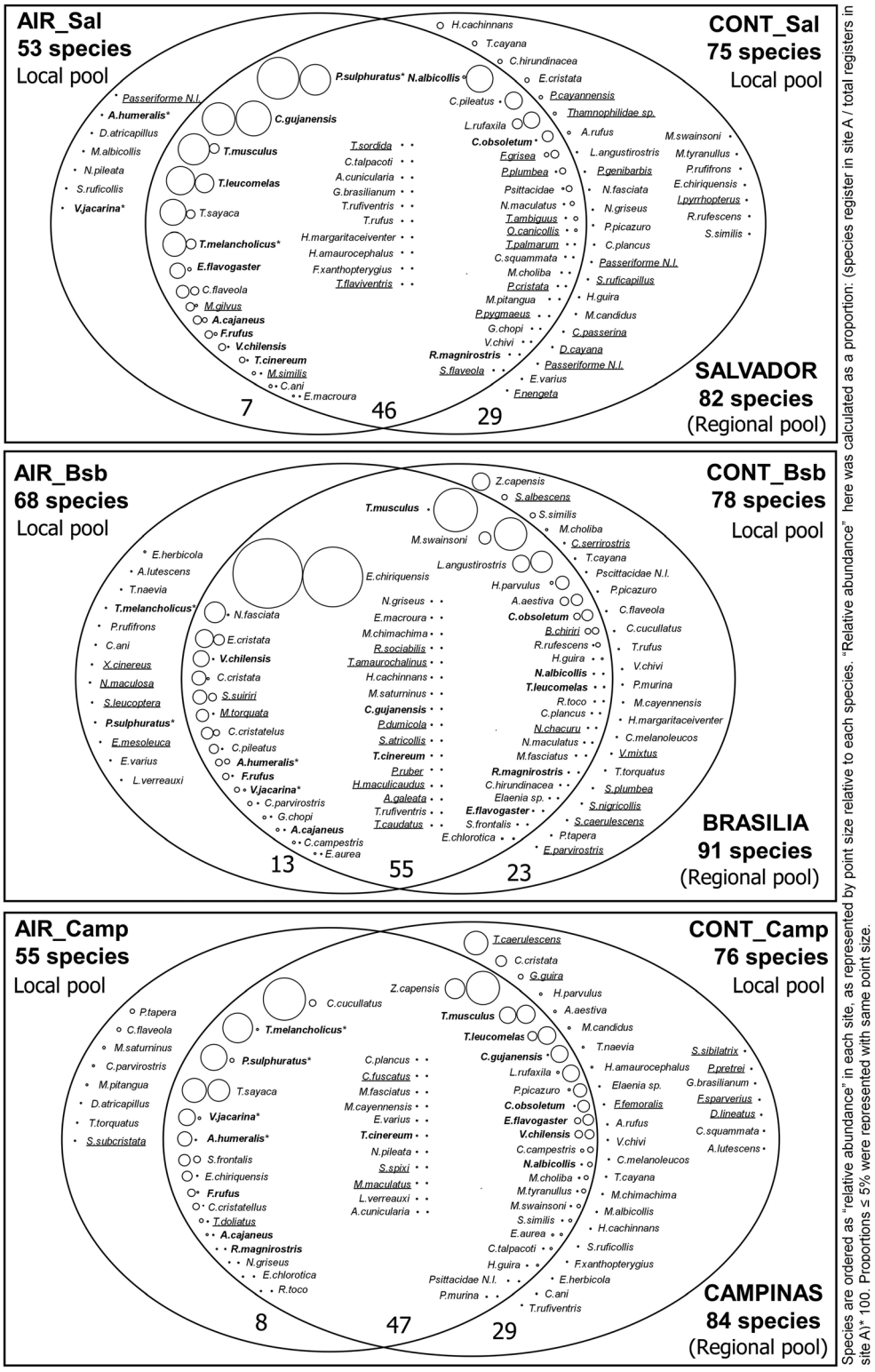


**Fig. 3** Species composition of each studied site, including information on shared and non-shared species among pairs of sites within each region. Species relative abundance (VAR index) in each site is represented by point size. Species that were uniquely found in one region are underlined, species that were found in all sampled sites are in bold, and species that were not found in all sites but were found in all airports are bold plus *

Species are ordered as "relative abundance" in each site, as represented by point size relative to each species. "Relative abundance" here was calculated as a proportion: (species register in site A / total registers in site A)* 100. Proportions ≤ 5% were represented with same point size.

species within the airport-affected sites (airport adapters), significant lower abundances of 11 species within the quiet control sites (airport avoiders), and no significant changes for 1 species (Fig. 4). Additional information is available in Online Resource 7.

The ten widespread airport adapters represented 8.7% of the total richness and 38.2% of the total abundance found in airport-affected sites, and represents 7.4% of the total richness and 17.2% of the total abundance in quiet control sites. The eleven widespread airport avoiders accounted for 9.6% of the

total richness and 12.8% of the total abundance found in airport-affected sites, and represents 8.1% of the total richness and 30.9% of the total abundance in quiet control sites.

## Discussion

Here, we present evidence for avian community homogenization associated with airport-affected environments (characterized by habitat disturbance and extreme noise). Specifically, our findings indicate a slight decrease in species richness in airport-affected sites when compared to quiet control sites. We expected to find higher similarity among airport-affected environments than among regions, but this prediction was not met by the results. On the contrary, we found higher dissimilarity ($\beta_{SOR}$) among regions than among airport-affected sites. Nevertheless, this analysis indicated a higher contribution of a turnover process in communities' dissimilarities rather than effects of a nestedness process, which characterizes biotic homogenization processes. Our second prediction (i.e. increased abundance of a few opportunistic species) was confirmed, as we identified 10 widespread species that, together, compose 38.2% of airport-affected community abundances (as measured by the Vocal Activity Rate Index (VAR)), while their expected values should represent around 12.8% of total community activity, as found in quiet control sites.

The higher species richness values found in quiet control sites represents a small effect, but is typically found in other studies, where the more preserved areas sustain a higher number of species, including sensitive and unique species, while degraded, urbanized and noisy sites present lower species richness (Newbold et al. 2014; Perillo et al. 2017). Due to the urbanization process, disturbed sites occasionally also have the potential to sustain a high number of specific species (Brawn et al. 2001; Møller 2013), usually resulting in communities composed of more generalist and opportunistic species (Blair et al. 1996; Bonier et al. 2007; Patón et al. 2012).

Our results show that species composition found in airport-affected sites is strongly influenced by the available regional species pool, as we found lower $\beta_{SOR}$ and $\beta_{SIM}$ diversity values for sites within the same region. Although contrary to our expectations, this pattern can be explained due to the

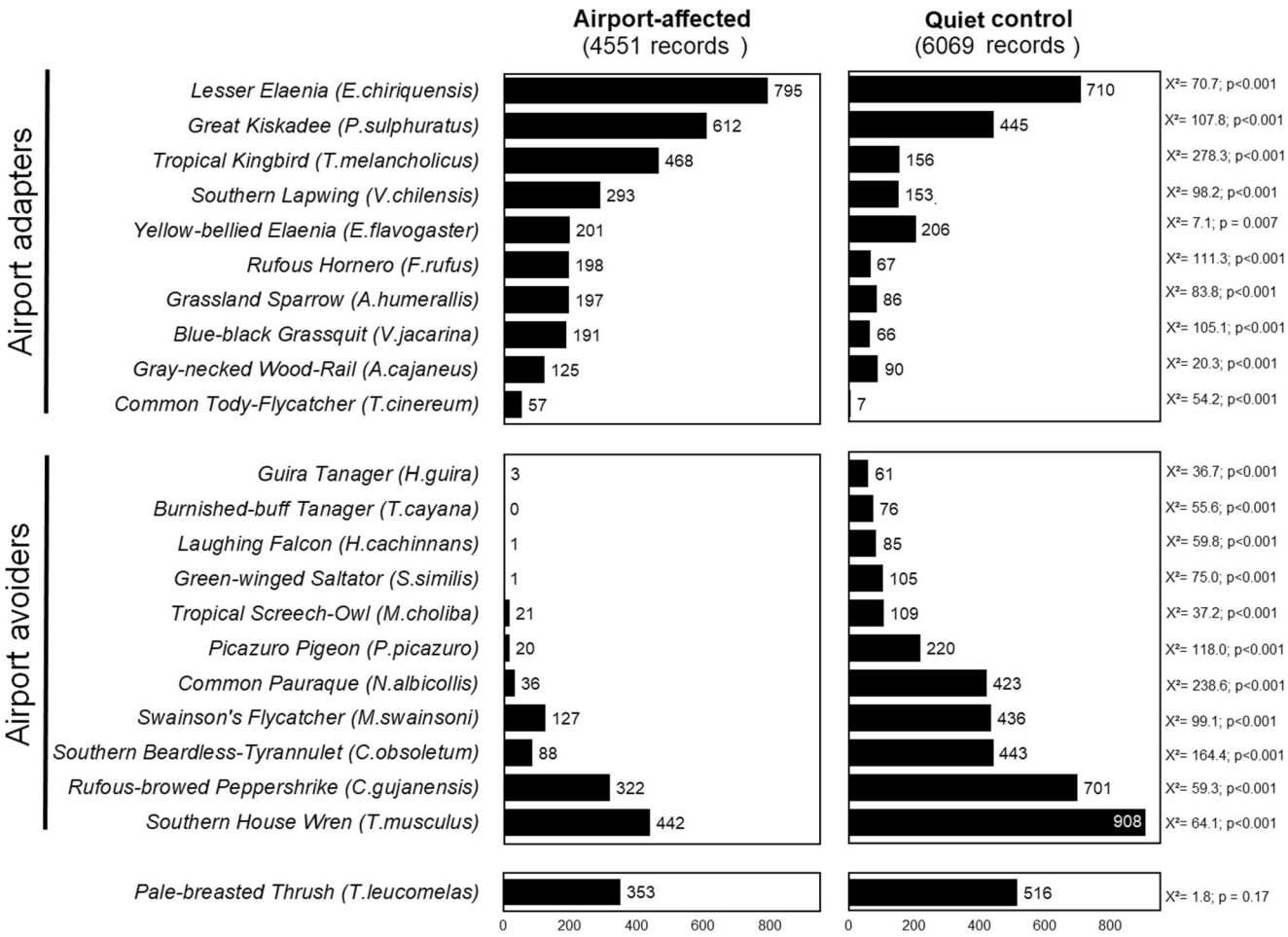


**Fig. 4** Number of records of widespread species in airport-affected and quiet control sites. The *Chi-squared* and *p* values are relative to the Binomial Proportion test and all degrees of freedom equal 1

higher vegetational similarity among areas within the same region (McKinney 2006), in particular in the biogeographically diverse Brazilian region that we studied. On the other hand, $\beta_{NES}$ values were consistently low among sites, indicating that species composition dissimilarities among studied sites are more influenced by the replacement of species (loss and gain) in the community (turnover), than by exclusive loss of species (nestedness). This is an important finding to support our hypothesis, since turnover is the most commonly described process leading to the biotic homogenization (Olden 2006), while nestedness would be more related to habitat fragmentation itself (Lees and Peres 2006).

Species presence or absence is not the only important element to be considered since changes in species abundance in noisy and disturbed places have also been observed in several studies (McKinney 2006; Proppe et al. 2013; Francis 2015). Across the 22 widespread species found, our results point to the decreasing abundance of 11 species in airport-affected sites, which we labeled as airport avoiders, following a similar nomenclature applied in past studies (i.e. urban avoiders and adapters; Blair et al., 1996; Croci et al., 2008). Although present in airports, this subset of airport avoider species seems to be presenting the first signs of intolerance to airport-affected environments. Some of them are large bodied species, such as falcons, owls, pigeons, and pauraques, and are expected to be vulnerable to habitat degradation (Henle et al. 2004). However, this group also includes smaller passerines, some of them easily found in degraded habitats, farms, and cities (e.g. Southern house wren and Rufous-browed Peppershrike). We suggest that, in contrast to those challenges that are found in degraded habitats only, these species might be facing the impact of extreme noise pollution, which can cause challenges for breeding and maintenance of population size (Habib et al. 2007; Hayward et al. 2011; Schroeder et al. 2012; Crino et al. 2013; Strasser and Heath 2013).

Our results also identify species that have larger populations in airport-affected sites. We can call them airport adapters: species that seem to benefit from this novel environment. Note that we do not use the term 'exploiters', which refers to species that are dependent upon urban resources (McKinney, 2006; e.g. house sparrows). The airport adapters are mostly passerines feeding on insects (*E. chiriquensis*, *E. flavogaster, F. rufus, P. sulphuratus*, *T. melancholicus,* and *T. cinereum*) and seeds (*A. humerallis* and *V. jacarina*), but also include two larger-bodied species, that may benefit from their generalist feeding habit (*V. chilensis* and *A. cajaneus*). Although representing a small proportion of the total species richness found in airport-affected sites (114 species), these 10 species comprise almost 40% of total community composition of these sites, suggesting a process of biotic homogenization of the avifauna at the airport-affected environments. The high abundance of insectivorous relative to other feeding groups can also be an indication of a communities' functional homogenization (McKinney 2006), which can jeopardize ecosystem structure by the loss of other important functional groups, such as that of frugivores. On the other hand, among the airport avoiders we can find a more functionally diverse group, including passerines feeding mostly on insects (*M. swainsoni*, *C. obsoletum* and *T. musculus*), on seeds and fruits (*S. similis*, *H. guira*, *T. cayana* and *C. gujanensis*), and also some large-bodied birds feeding on seeds (*P. picazuro*), nocturnal insects (*M. choliba* and *N. albicollis*), and other prey (*H. chachinnans*).

The biotic homogenization process has been more frequently studied in limnological than in avian research. However, the few available bird studies show a positive association of functional, taxonomic and phylogenetic homogenization of bird communities with landscape disturbance, fragmentation and urbanization in several areas around the world (Devictor et al. 2008; van Rensburg et al. 2009; Liang et al. 2019). As pointed out in Francis and Barber's (2013) review, multi-species studies are critical to understand community-level consequences of noise. Here, by coupling information on species richness, beta-diversity, community composition, and abundance (VAR index), we were able to evaluate a broad scenario, showing an on-going process of biotic homogenization among airport environments in Brazil. We expect that this study will generate further discussion about the impacts of aircraft and airports on conservation areas worldwide, as distinctiveness of biotas plays an important role in biodiversity maintenance across the globe.

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