Revista Brasileira de Ornitologia 25(1): 31–39.
March 2017

ARTICLE

Effects of urbanization on the avian community in a southern Brazilian city

Vinícius Abilhoa[1,2,3] & Rafael Amorin[1,2]

[1] Museu de História Natural Capão da Imbuia. Rua Professor Benedito Conceição, 407, CEP 82810080, Curitiba, Paraná, Brazil.
[2] Programa de Pós-graduação em Zoologia, Universidade Federal do Paraná. Avenida Cel. Francisco H. dos Santos, S/N, Jardim das Américas, Caixa Postal 19020, CEP 81531-980, Curitiba, PR, Brazil.
[3] Corresponding author: vabilhoa@uol.com.br

Received on 14 April 2016. Accepted on 10 May 2017.

ABSTRACT: This paper compares the proportion of urban tolerant birds in the urban avian community and the amount of built-up areas, mostly impervious surface, as indicators of urbanization on patterns of bird species richness in a southern Brazilian city. From September to December 2013 (breeding season), bird surveys were conducted in 120 squares of 100 ha randomly select within Curitiba, Paraná, Brazil. All bird species seen or heard during the sample timeframe were recorded. The extent of urban modification and disturbance was estimated directly from urban landscape data analyses through a geographic information system. Linear regressions were graphed and Spearman rank correlations were calculated to assess the relationship of overall species richness and the percentage of urban tolerant birds against the percentage of built-up areas as the predictor variable. Kruskal-Wallis non-parametric analyses of variance were performed to test if the total richness or the percentage of urban tolerant birds on the assemblages differed between categories of urbanization (low, intermediate and high). We recorded 102 bird species, including 13 urban tolerant species. As expected, urbanization significantly reduced species richness, but urban tolerant species were less affected to changes on land modifications associated to urban growth. The increase in representativeness of "urban-adaptable" species on the bird assemblages of intermediate and high-urbanized areas in Curitiba was probably favored by their broad environmental tolerance. Most urban tolerant species registered are ground foraging resident birds, use a diverse array of anthropogenic resources, and can be found occupying various types of habitat in several human-modified ecosystems.

KEY-WORDS: avian community, nonnatives, synanthropic, urban exploiters, urban landscape.

INTRODUCTION

Urban development exerts negative impacts on biodiversity because of habitat loss and ecosystems fragmentation (McKinney 2002). In urban landscapes, the disruption of ecosystem processes (Thom *et al.* 2001), predator proliferation (Baker *et al.* 2008, Fischer *et al.* 2012), elevated noise levels (Proppe *et al.* 2013), and the fragmentation of remaining forests (Zipperer *et al.* 2012) significantly impact the richness (Marzluff 2001) and consequently the composition and functional structure of bird communities (*e.g.* Blair 1996, Marzluff 2001, Lim & Sodhi 2004, Ferenc *et al.* 2013).

The composition and distribution of urban birds are influenced by habitat structure and urban development in Australia (Garden *et al.* 2006), Europe (Ferenc *et al.* 2013), Asia (Sodhi *et al.* 1999), North America (Donnelly & Marzluff 2006), South Africa (van Rensburg *et al.* 2009) and Neotropics (Leveau & Leveau 2005, 2012, Pauchard *et al.* 2006, Fontana *et al.* 2011, Reis *et al.* 2012, Toledo *et al.* 2012, Silva *et al.* 2015). The lowest values of species richness are usually registered in the most intensively built-up areas, such as the city center (Blair 1996).While there is general consensus in the literature regarding the point of lowest diversity, usually urban core areas (Seress & Liker 2015), species richness is higher in areas of intermediate levels of urbanization (Marzluff 2001, Chace & Walsh 2006).

Patterns of avian community composition within the urban landscape are mediated by species tolerance and ability to exploit urbanized areas. Species sensitive to habitat disturbances have been categorized as "urban avoiders" (McKinney 2002) or "urban-sensitive" (Garden *et al.* 2007), while species that are common in urbanized areas have been categorized as "urban exploiters" (McKinney 2002) or "synanthropes" (Marzluff *et al.* 2001). Birds in urban ecosystems are usually opportunistic species with wide dispersal ability, whereas species with poor dispersal ability, slow reproduction or specialized diets disappear from urban assemblages as urbanization increases (McKinney & Lockwood 1999). The increase in the "urban-adaptable" species and the formation of similar urban communities in many regions all over the world has been promoting the biotic homogenization process (McKinney 2006).

Several studies examined the composition of urban avian communities and stated that these communities comprise native and nonnatives species, well adapted to human-dominated landscapes, which are tolerant to urban constraints and able to maintain populations in urbanized areas (Manhães & Loures-Ribeiro 2005, Pinheiro *et al.* 2008, Shochat 2010, Fontana *et al.* 2011). Lower levels of urbanization seem to increase richness because of the coexistence of species associated with original and new habitat, whereas higher levels would lead to lower species richness (Blair 1996, Marzluff 2001).

This study aims to assess changes in the species richness and also in the representativeness of urban tolerant birds across a range of sample areas embedded in a southern Brazilian city. We hypothesized that the overall species richness, as opposed to the representativeness of urban tolerant birds, will decline with increasing urbanization. As urban tolerant species generally thrive in urban ecosystems, their richness and presence should be less affected to changes on land modifications associated to urban growth.

METHODS

Study area

Curitiba (25°25'S; 49°16'W), a 324-year-old city occupies 432.2 km^2 and is located in the Subtropical Zone of southern Brazil. The average altitude is 934 m a.s.l., ranging between 900 and 1000 m. The city has a subtropical highland climate where the temperature ranges from 21 to 32°C during the rainy summer and from 0 to 13°C in the winter, when rainfall is less abundant. The average annual precipitation is 1413 mm with little variation throughout the year. The population has grown exponentially over the last decades, and reach almost 1.8 million people and an average density of 4062 inhabitants km^{-2}, becoming the eighth most populous city in the country in 2014 (ICLEI 2008, Curitiba 2016).

The City's territory has 77,786,020.60 m^2 of forests remnants (20% of the city surface), comprising nowadays more than 50 conservation units, mostly municipal parks. The arborisation of streets, recreational parks and private green areas are dominated by nonnative species, such as the Crape Myrtle (*Lagerstroemia indica*), Chinese Privet (*Ligustrum lucidum*), Rosewood (*Tipuana tipu*), Box Elder (*Acer negundo*), Vilca (*Anadenanthera colubrina*) and the Brazilian Firetree (*Schizolobium parahyba*).

Historical bird records identified 387 native species in Curitiba, along with 30 species considered introduced, exotic or accidental (Straube *et al.* 2014). The urban resident avian community comprises more than 100 aquatic and terrestrial species, as well as migratory birds. The most common native species found in the city are Rufous Hornero (*Furnarius rufus*), Eared Dove (*Zenaida auriculata*), Rufous-collared Sparrow (*Zonotrichia capensis*), House Wren (*Troglodytes aedon*), and Great Kiskadee (*Pitangus sulphuratus*), along with the nonnatives House Sparrow (*Passer domesticus*), Rock Dove (*Columba livia*) and the Common Waxbill (*Estrilda astrild*).

Sampling and data analysis

Curitiba's territory was divided into 490 equal squares of 100 ha (1000 × 1000 m) to standardize samples and to ensure independence from urban form. At the periphery of the study area, there were 85 irregularly bounded squares that were eliminated due to their irregular size and smaller areas, yielding 405 squares (Fig. 1). For the bird survey, we randomly selected sample sites (squares) within Curitiba using '*sample*' function in R software (R Development Core Team 2013). Such random selection ensured that sites with different levels of urbanization (amount of built-up areas) were surveyed. Sample-based rarefaction method was performed to evaluate the adequate sampling effort (number of squares surveyed) (Colwell *et al.* 2004).This measuring of species richness preserves the spatial structure of the data, reflecting processes such as spatial aggregation or segregation of species (Gotelli & Colwell 2011). Sample-base rarefaction curves were calculated (*Mao Tau* estimator, 500 randomizations) in the software EcoSim, version 7.72 (Gotelli & Entsminger 2000).

Fieldwork was carried out during the breeding season (spring), between September and early December of 2013, when most birds establish breeding territories and exhibit strong site fidelity (Sogge 2000). Choosing this period of the year also avoid the temporal fluctuation caused by the presence of migratory birds. Each square was surveyed by walking along public rights-of-way (*e.g.* streets, unpaved roads, grasslands with scattered trees and shrubs, ornamental gardens, parks, non-municipal green spaces, built-up areas) in the period with maximum bird activity (between 6:30 and 10:00 h) on sunny or scattered clouds days. No surveys were performed during periods of rain or high wind. One hour was spent in each 100 ha square, thereby standardizing sampling effort across all sites. This period of time was considered satisfactory for sampling two non-adjoining squares for each day. Adjacent squares were not surveyed during the same day in order to avoid overlapping observations of birds. Birds were detected visually and/ or by vocalizations, and all species were assumed to have equal detection probabilities due to the large-scale urban landscape. This assumption is common to studies of urban bird communities (Chapa-Vargas & Robinson 2006, Donnelly & Marzluff 2006). We recorded the presence of all bird species seen or heard during the sample timeframe in the surroundings at unlimited distances, excluding high-flying individuals and night-active species. Bird taxonomy and nomenclature follow Piacentini *et al.* (2015).

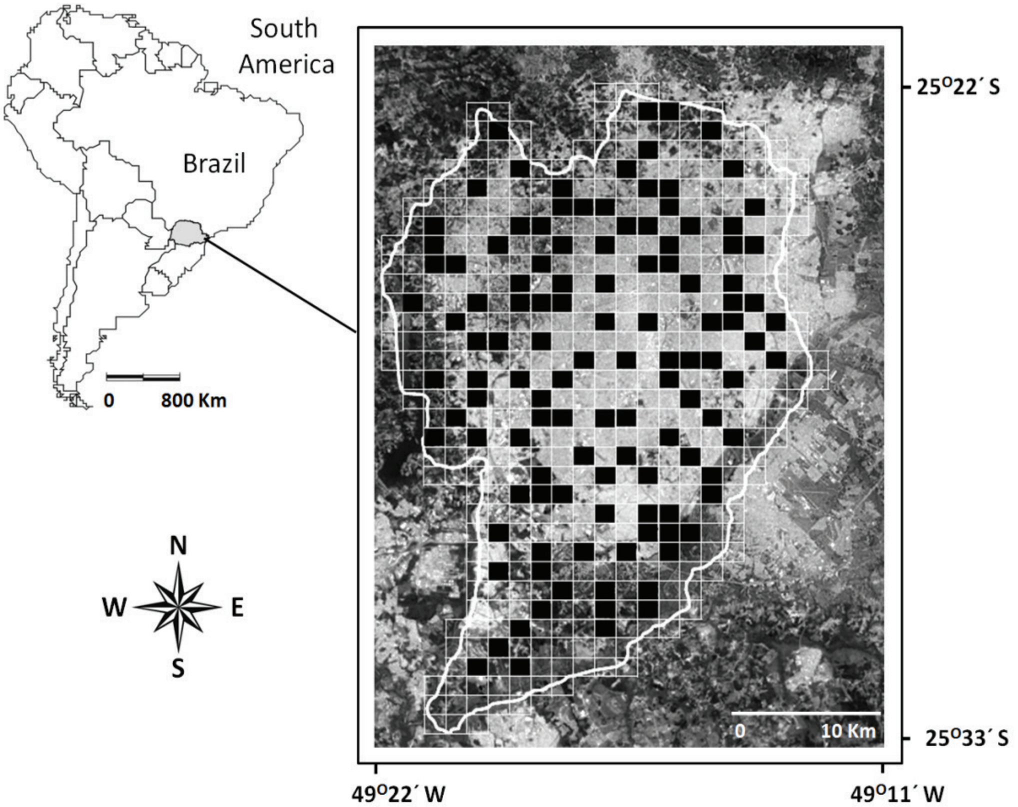

Figure 1. Map of the Curitiba municipality in southern Brazil, showing the distribution of the 120 sample sites (black squares). The small South America map depicts the location of the state of Paraná (shaded) and the city of Curitiba.

We divided the community registered into two groups based upon their life history characteristics and ability to thrive and exploit urbanized ecosystems (Blair 1996). Thirteen species were assigned to the synanthropic guild according to Litteral & Wu (2012), and were therefore considered urban tolerant birds. Besides urban invaders (*i.e.* House Sparrow, Rock Dove, and Common Waxbill), most species that thrive in urban environments are remnant native species, some of which are synanthropic generalists, urban commensals and/or urban-resource dependent (Marzluff 2001).

The extent of urban modification and disturbance was estimated directly from urban landscape data analysis rather than indirect inference or *a priori* assignment. A geographic information system (GIS) was used, built by means of ArcView GIS 3.2 software and geographical databases of the city of Curitiba, provided by Curitiba's Institute of Research and Public Planning (IPPUC). For each sample point (100 ha square), the amount of built-up areas (*e.g.* buildings, roads, industrial areas, paved-over soil, compacted/near-impervious open spaces) was measured. We used the amount of built-up areas as a proxy to evaluate the proportion of impervious surface. Land-surface impermeabilization is one of the most important landscape modification produced by urbanization, and such anthropogenic habitat fragmentation and disturbance are known to influence avian community (Marzluff *et al.* 2001). Modification of land cover in urban areas has also been shown to cause the urban heat island effect, which leads to higher temperature in urbanized areas than surroundings (*e.g.* Streutker 2003), causing differences in timing of arrival of migratory birds in cities (Tryjanowski *et al.* 2013).

Linear regressions were graphed and Spearman rank correlations were calculated on the total number of species and the percentage of urban tolerant birds as the dependent variables against the percentage of built-up areas as the predictor variable. Non-parametric rank correlations were used because species richness and the proportion of urban tolerant birds could not be successfully normalized to meet assumptions of parametric tests. We used the proportion of impervious surface to indicate the level of urbanization and to determine whether this important modification on the urban landscape affected species richness and the percentage of urban tolerant birds on the assemblages.

To summarize the relative influence of the level of urbanization on bird species richness and composition, sample units (squares) were categorized into one of the following classes (levels) of urbanization: low (<50% of built-up areas), intermediate (50–75% of built-up areas), and high (>75% of built-up areas). We examined the effect of the urbanization level on avian composition through Kruskal-Wallis non-parametric analyses of variance, as initial examination of the data revealed they do not meet assumptions of parametric tests (Zar 1999). Kruskal-Wallis tests were performed to evaluate if the number of overall species or the percentage of urban tolerant birds on the assemblages differed between different levels of urbanization. Boxplots on both assemblages were constructed.

RESULTS

A total of 102 bird species, representing 43 families of 29 orders were observed. Species richness estimated using the sample-based rarefaction technique tended to stabilize after 120 squares were sampled. The greatest recorded richness concerned Thraupidae (11 species), Tyrannidae (9 species), and Columbidae (6 species). The families Icteridae and Picidae can also be highlighted because of their representativeness (5 species each) in the surveys. Among the 102 birds identified, 13 were considered urban tolerant species, including three nonnatives (Rock Dove, Common Waxbill, and House Sparrow) (Table 1).

Table 1. Common names, scientific names, families, origin (native or exotic), and tolerance to exploit urbanized areas (according to Litteral & Wu 2012) of birds observed during the study period in Curitiba city, southern Brazil.

Common name	Species	Family	Origin	Urban tolerant
Brown Tinamou	*Crypturellus obsoletus*	Tinamidae	Native	No
White-faced Whistling-Duck	*Dendrocygna viduata*	Anatidae	Native	No
Brazilian Teal	*Amazonetta brasiliensis*	Anatidae	Native	No
White-cheeked Pintail	*Anas bahamensis*	Anatidae	Native	No
Dusky-legged Guan	*Penelope obscura*	Cracidae	Native	No
Neotropic Cormorant	*Nannopterum brasilianus*	Phalacrocoracidae	Native	No
Black-crowned Night-Heron	*Nycticorax nycticorax*	Ardeidae	Native	No
Striated Heron	*Butorides striata*	Ardeidae	Native	No
Great Egret	*Ardea alba*	Ardeidae	Native	No
Whistling Heron	*Syrigma sibilatrix*	Ardeidae	Native	No
Buff-necked Ibis	*Theristicus caudatus*	Threskiornithidae	Native	No
Black Vulture	*Coragyps atratus*	Cathartidae	Native	No
White-tailed Kite	*Elanus leucurus*	Accipitridae	Native	No
Roadside Hawk	*Rupornis magnirostris*	Accipitridae	Native	No
Slaty-breasted Wood-Rail	*Aramides saracura*	Rallidae	Native	No
Common Gallinule	*Gallinula galeata*	Rallidae	Native	No
Southern Lapwing	*Vanellus chilensis*	Charadriidae	Native	Yes
White-backed Stilt	*Himantopus melanurus*	Recurvirostridae	Native	No
Solitary Sandpiper	*Tringa solitaria*	Scolopacidae	Native	No
Wattled Jacana	*Jacana jacana*	Jacanidae	Native	No
RuddyGround Dove	*Columbina talpacoti*	Columbidae	Native	Yes
Rock Pigeon	*Columba livia*	Columbidae	Exotic	Yes
Picazuro Pigeon	*Patagioenas picazuro*	Columbidae	Native	No
Eared Dove	*Zenaida auriculata*	Columbidae	Native	Yes
White-tipped Dove	*Leptotila verreauxi*	Columbidae	Native	No
Gray-fronted Dove	*Leptotila rufaxilla*	Columbidae	Native	No
Squirrel Cuckoo	*Piaya cayana*	Cuculidae	Native	No
Smooth-billed Ani	*Crotophaga ani*	Cuculidae	Native	No
Guira Cuckoo	*Guira guira*	Cuculidae	Native	No
Burrowing Owl	*Athene cunicularia*	Strigidae	Native	No
White-collared Swift	*Streptoprocne zonaris*	Apodidae	Native	No
Swallow-tailed Hummingbird	*Eupetomena macroura*	Trochilidae	Native	No
White-vented Violetear	*Colibri serrirostris*	Trochilidae	Native	No
Glittering-bellied Emerald	*Chlorostilbon lucidus*	Trochilidae	Native	No
White-throated Hummingbird	*Leucochloris albicollis*	Trochilidae	Native	No
Surucua Trogon	*Trogon surrucura*	Trogonidae	Native	No
Ringed Kingfisher	*Megaceryle torquata*	Alcedinidae	Native	No
Red-breasted Toucan	*Ramphastos dicolorus*	Ramphastidae	Native	No
White Woodpecker	*Melanerpes candidus*	Picidae	Native	No
Yellow-fronted Woodpecker	*Melanerpes flavifrons*	Picidae	Native	No
White-spotted Woodpecker	*Veniliornis spilogaster*	Picidae	Native	No
Green-barred Woodpecker	*Colaptes melanochloros*	Picidae	Native	No

Common name	Species	Family	Origin	Urban tolerant
Campo Flicker	*Colaptes campestris*	Picidae	Native	No
Southern Caracara	*Caracara plancus*	Falconidae	Native	No
Yellow-headed Caracara	*Milvago chimachima*	Falconidae	Native	No
American Kestrel	*Falco sparverius*	Falconidae	Native	No
Aplomado Falcon	*Falco femoralis*	Falconidae	Native	No
Plain Parakeet	*Brotogeris tirica*	Psittacidae	Native	Yes
Pileated Parrot	*Pionopsitta pileata*	Psittacidae	Native	No
Scaly-headed Parrot	*Pionus maximiliani*	Psittacidae	Native	No
Variable Antshrike	*Thamnophilus caerulescens*	Thamnophilidae	Native	No
Olivaceous Woodcreeper	*Sittasomus griseicapillus*	Dendrocolaptidae	Native	No
Planalto Woodcreeper	*Dendrocolaptes platyrostris*	Dendrocolaptidae	Native	No
Rufous Hornero	*Furnarius rufus*	Furnariidae	Native	Yes
Araucaria Tit-Spinetail	*Leptasthenura setaria*	Furnariidae	Native	No
Spix's Spinetail	*Synallaxis spixi*	Furnariidae	Native	No
Swallow-tailed Manakin	*Chiroxiphia caudata*	Pipridae	Native	No
Southern Beardless-Tyrannulet	*Camptostoma obsoletum*	Tyrannidae	Native	No
Yellow-bellied Elaenia	*Elaenia flavogaster*	Tyrannidae	Native	No
White-crested Tyrannulet	*Serpophaga subcristata*	Tyrannidae	Native	No
Great Kiskadee	*Pitangus sulphuratus*	Tyrannidae	Native	Yes
Cattle Tyrant	*Machetornis rixosa*	Tyrannidae	Native	No
Tropical Kingbird	*Tyrannus melancholicus*	Tyrannidae	Native	No
Fork-tailed Flycatcher	*Tyrannus savana*	Tyrannidae	Native	No
Long-tailed Tyrant	*Colonia colonus*	Tyrannidae	Native	No
Euler's Flycatcher	*Lathrotriccus euleri*	Tyrannidae	Native	No
Rufous-browed Peppershrike	*Cyclarhis gujanensis*	Vireonidae	Native	No
Chivi Vireo	*Vireo chivi*	Vireonidae	Native	No
Plush-crested Jay	*Cyanocorax chrysops*	Corvidae	Native	No
Blue-and-white Swallow	*Pygochelidon cyanoleuca*	Hirundinidae	Native	Yes
Brown-chested Martin	*Progne tapera*	Hirundinidae	Native	No
Gray-breasted Martin	*Progne chalybea*	Hirundinidae	Native	No
Southern House Wren	*Troglodytes musculus*	Troglodytidae	Native	Yes
Rufous-belliedThrush	*Turdus rufiventris*	Turdidae	Native	Yes
Creamy-bellied Thrush	*Turdus amaurochalinus*	Turdidae	Native	No
White-neckedThrush	*Turdus albicollis*	Turdidae	Native	No
Chalk-browed Mockingbird	*Mimus saturninus*	Mimidae	Native	No
Rufous-collared Sparrow	*Zonotrichia capensis*	Passerellidae	Native	No
Tropical Parula	*Setophaga pitiayumi*	Parulidae	Native	No
Masked Yellowthroat	*Geothlypis aequinoctialis*	Parulidae	Native	No
Golden-crowned Warbler	*Basileuterus culicivorus*	Parulidae	Native	No
White-browed Warbler	*Myiothlypis leucoblepharus*	Parulidae	Native	No
Red-rumped Cacique	*Cacicus haemorrhous*	Icteridae	Native	No
Chopi Blackbird	*Gnorimopsar chopi*	Icteridae	Native	No
Chestnut-capped Blackbird	*Chrysomus ruficapillus*	Icteridae	Native	No
Yellow-rumped Marshbird	*Pseudoleistes guirahuro*	Icteridae	Native	No
Shiny Cowbird	*Molothrus bonariensis*	Icteridae	Native	Yes
Fawn-breasted Tanager	*Pipraeidea melanonota*	Thraupidae	Native	No
Blue-and-yellow Tanager	*Pipraeidea bonariensis*	Thraupidae	Native	No
Diademed Tanager	*Stephanophorus diadematus*	Thraupidae	Native	No
Sayaca Tanager	*Tangara sayaca*	Thraupidae	Native	Yes
Saffron Finch	*Sicalis flaveola*	Thraupidae	Native	Yes
Blue-black Grassquit	*Volatinia jacarina*	Thraupidae	Native	No
Black-goggled Tanager	*Trichothraupis melanops*	Thraupidae	Native	No
Red-crested Finch	*Coryphospingus cucullatus*	Thraupidae	Native	No
Swallow Tanager	*Tersina viridis*	Thraupidae	Native	No
Double-collared Seedeater	*Sporophila caerulescens*	Thraupidae	Native	No
Green-winged Saltator	*Saltator similis*	Thraupidae	Native	No
Hooded Siskin	*Spinus magellanicus*	Fringillidae	Native	No
Violaceous Euphonia	*Euphonia violacea*	Fringillidae	Native	No
Common Waxbill	*Estrilda astrild*	Estrildidae	Exotic	Yes
House Sparrow	*Passer domesticus*	Passeridae	Exotic	Yes

The most common and widespread species of birds, with a frequency of occurrence of more than 80% in the surveys, were the natives Rufous Hornero, Eared Dove, Great Kiskadee, and Rufous-bellied Thrush (*Turdus rufiventris*), along with the nonnative House Sparrow. Rock Dove and House Sparrow were registered in all sites assessed in high urbanized areas, whereas the Eared Dove and the House Sparrow were the most persistent species in the low to intermediate urbanized sites.

The effect of the urbanization level on avian richness was significant (Kruskal-Wallis $H_{2,120}$ = 47.817, P = 0.001, Fig. 2), however the avian richness was not statistical different between low and intermediate urbanized sites (P > 0.05). Despite the high-variability in data, total richness was lower in sites were the amount of built-up areas was higher (Spearman r_s = -0.69, P = 0.01, Fig. 3).

The effect of the urbanization level on the amount of urban tolerant birds on avian composition was also significant (Kruskal-Wallis $H_{2,120}$ = 50.065, P = 0.001, Fig. 4), except between low and intermediate urbanized sites (P > 0.05). The proportion of urban tolerant birds on avian composition was higher in high urbanized sites (Spearman r = 0.71, P = 0.001, Fig. 5).

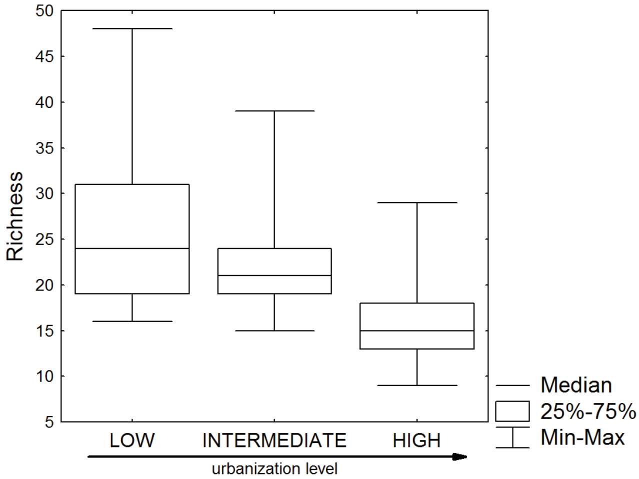

Figure 2. Box-plot on avian total richness of Curitiba, southern Brazil, considering the effect of the proportion of built-up areas (urbanization levels). Low (<50% of built-up areas), intermediate (50–75% of built-up areas), and high (>75% of built-up areas).

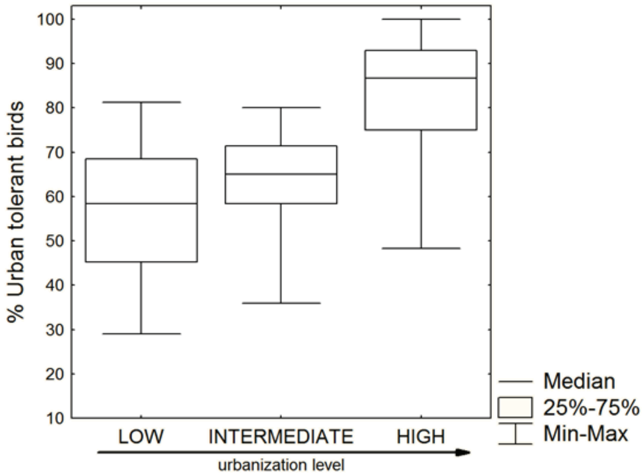

Figure 4. Box-plot on the amount of tolerant birds in avian assemblages of Curitiba, southern Brazil, considering the effect of the proportion of built-up areas (urbanization levels). Low (<50% of built-up areas), intermediate (50–75% of built-up areas), and high (>75% of built-up areas).

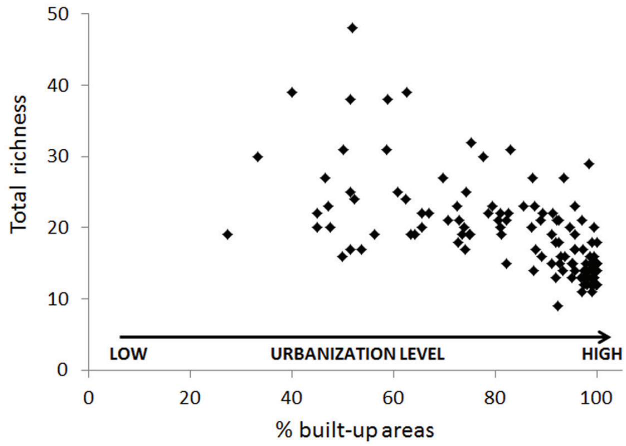

Figure 3. Regression on avian total richness in Curitiba, southern Brazil, considering the effect of the proportion of built-up areas (urbanization levels).

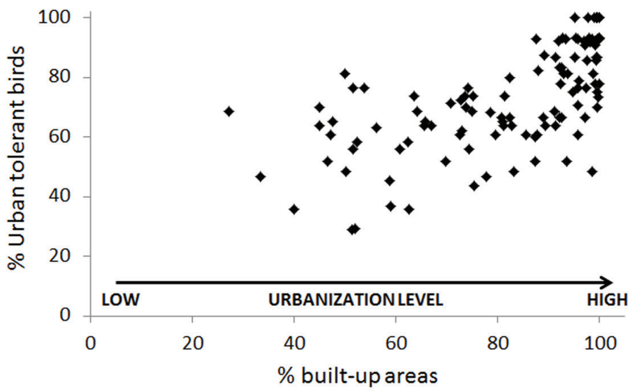

Figure 5. Regression on the amount of tolerant birds in avian assemblages of Curitiba, southern Brazil, considering the effect of the proportion of built-up areas (urbanization levels).

DISCUSSION

This study examined trends in bird richness and the representativeness of urban tolerant birds across a range of sampled areas embedded in a southern Brazilian city. The assemblage recorded consisted of a high frequency of a relatively few species of birds, including both natives species (*e.g.* Ruddy Ground Dove *Columbina talpacoti*, Eared Dove, Great Kiskadee, Rufous-bellied Thrush, Rufous Hornero) and nonnatives (Rock Dove, Common Waxbill, and House Sparrow). The bird assemblages detected are typical of others South American's urban landscapes (*e.g.* Reynaud & Thioulouse 2000, Leveau & Leveau 2005, 2012, Manhães *et al.* 2005, Pauchard *et al.*

2006, Pinheiro *et al*. 2008, Fontana *et al*. 2011, Reis *et al*. 2012, Toledo *et al*. 2012).

As expected, we found that urbanization plays an important role in shaping spatial distribution of urban bird assemblages. Our analysis supported recent reviews of Hansen *et al.* (2005) and Faeth *et al.* (2011), which have found that for the overall bird community, species richness declines with increasing urban development, and also that the representativeness of species that are ecologically associated with humans increase in sites with high amounts of built-up areas (Sandström *et al*. 2006, DeVictor *et al*. 2007, Kark *et al*. 2007, Conole & Kirkpatrick 2011).

The number of species recorded in areas with high urbanization levels was significantly lower than at the low and intermediate urbanized areas. High (>75% of built-up areas) urbanized sites were found not only in central districts of Curitiba, but also in the surroundings of the urban core. In such sites, the urbanization process decreased the taxonomic and functional characteristics of avian communities through the loss of rare and specialist species, and by the increase of generalist urban birds, a biological phenomenon called biotic homogenization (McKinney & Lockwood 1999). Our results indicated that urbanization changes bird species richness, both by decreasing native species diversity and by the addition of widely distributed synanthropic species, such as Ruddy Ground Dove, Eared Dove, Great Kiskadee, Rufous-bellied Thrush, Rufous Hornero, Rock Dove, Common Waxbill, and House Sparrow. These species appear to benefit from the greater availability of resources that occur in urban areas.

According to Kark *et al.* (2007) and Møller (2009), urban birds share certain life history traits, including being resident (as opposed to migrant), nesting above ground (*i.e.* cavity and canopy nesters), and having a behavioral plasticity that allows a species to have a broad environmental tolerance. The 12 urban tolerant birds identified in Curitiba shared these traits, and they included both native and nonnative species. Even though urbanization and associated modifications negatively affect native species (Blair 1996, Hodgson *et al.* 2007, Kark *et al*. 2007, Evans *et al*. 2011), leading to an increase in invasive ones usually exotics (Blair 2001, Sol *et al.* 2012), Curitiba's highly urbanized environments were not dominated by exotic species. The most widespread and commonly registered species were the natives Rufous Hornero, Eared Dove, Great Kiskadee, and Rufous-bellied Thrush, along with the nonnative House Sparrow. However, our personal observations indicate that the abundance of individuals of exotic species seems to outnumbered native ones. Factors like the higher temperature in urban environments (Roth *et al.* 1989), the greater availability of nest sites (Murgui 2009), and the greater availability of anthropogenic food (Suhonen & Jokimäki 1988, Leveau & Leveau 2005) may contribute to the higher densities of these exotic species in urban areas (DeVictor *et al*. 2007).

The ground foraging birds was by far the most abundant in terms of the number of species observed, and were represented by granivorous, omnivorous, and insectivorous birds. The dominant trophic guild (granivorous) were represented by Ruddy Ground Dove, Rock Pigeon, Eared Dove, Saffron Finch (*Sicalis flaveola*), and Common Waxbill. Omnivorous were represented by Plain Parakeet (*Brotogeris tirica*), Great Kiskadee, Rufous-bellied Thrush, and House Sparrow, and insectivorous species, represented by Rufous Hornero, Southern Lapwing and Blue-and-white Swallow (*Pygochelidon cyanoleuca*). Such trophic guilds are usually benefited from habitat modification (Willis 1979) and from an increase in built-up areas (Jokimäki & Suhonen 1998).

Our results show that most avian species were negatively affected by urban disturbance, except urban tolerant birds. These observations were consistent with other studies which have found that certain functional groups tend to thrive in urban communities (Blair 1996, Kark *et al.* 2007, Conole & Kirkpatrick 2011), such as sedentary species (Croci *et al.* 2008) and birds with larger ranges and broader environmental tolerances (Blackburn *et al.* 2009). On the other hand, the exact ecological mechanisms driving urban bird composition according to different levels of anthropogenic disturbances still need further investigation. Most urban tolerant species registered in Curitiba are ground foraging resident birds, which use a diverse array of anthropogenic resources and can be found occupying various types of habitat in the city. The ability to exploit a wide variety of resources, which is useful when resources are scarce or when individuals colonize new environments, contribute to urban bird's ecological flexibility, predisposing them to succeed in human-disturbed habitats (Bonier *et al*. 2007).

ACKNOWLEDGEMENTS

We thank Antenor Silva (*Museu de História Natural Capão da Imbuia*) for helping with the geographic information system (GIS) and anonymous referees for helpful comments on a previous version of this manuscript. *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)* provided grant to R.A.

REFERENCES

Baker P.J., Molony S.E., Stone E., Cuthill I.C. & Harris S. 2008. Cats about town: is predation by free-ranging pet cats *Felis catus* likely to affect urban bird populations? *Ibis* 150: 86–99.

Blackburn T.M., Lockwood J.L. & Cassey P. 2009. *Avian invasions: the ecology and evolution of exotic birds*. New York: Oxford University Press.

Blair R.B. 1996. Land use and avian species diversity along an urban gradient. *Ecological Applications* 6: 506–519.

Blair R.B. 2001. Creating a homogeneous avifauna, p. 459–486. In: Marzluff J.M., Bowman R. & Donelly R. (eds.). *Avian ecology and conservation in an urbanizing world*. Boston: Kluwer Academic.

Bonier F., Martin P.R. & Wingfield J.C. 2007. Urban birds have broader environmental tolerance. *Biology Letters* 3: 670–673.

Chace J.F. & Walsh J.J. 2006. Urban effects on native avifauna: a review. *Landscape and Urban Planning* 74: 46–69.

Chapa-Vargas L. & Robinson S.K. 2006. Nesting success of a songbird in a complex floodplain forest landscape in Illinois, USA: local fragmentation *vs.* vegetation structure. *Landscape Ecology* 21:525–537.

Colwell R.K., Mao C.X. & Chang J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. *Ecology* 85: 2717–2727.

Conole L.E. & Kirkpatrick J.B. 2011. Functional and spatial differentiation of urban bird assemblages at the landscape scale. *Landscape and Urban Planning* 100: 11–23.

Croci S., Butet A. & Clergeau P. 2008. Does urbanization filter birds on the basis of their biological traits? *Condor* 110: 223–240.

Curitiba – Prefeitura Municipal de Curitiba. 2016. *Portal da Prefeitura de Curitiba*. http://www.curitiba.pr.gov.br (access on 23 October 2016).

DeVictor V., Julliard R., Couvet D., Lee A. & Jiguet F. 2007. Functional homogenization effect of urbanization on bird communities. *Conservation Biology* 21: 741–751.

Donnelly R. & Marzluff J.M. 2006. Relative importance of habitat quantity, structure, and spatial pattern to birds in urbanizing environments. *Urban Ecosystems* 9: 99–117.

Evans K.L., Chamberlain D.E., Hatchwell B.J., Gregory R.D. & Gaston K.J. 2011. What makes an urban bird? *Global Change Biology* 17: 32–44.

Faeth S.H., Bang C. & Saari S. 2011. Urban biodiversity: patterns and mechanisms. *Annals of the New York Academy of Sciences* 1223: 69–81.

Ferenc M., Sedláček O., Fuchs R., Dinetti M., Fraissinet M. & Storch D. 2013. Are cities different? Patterns of species richness and beta diversity of urban bird communities and regional species assemblages in Europe. *Global Ecology and Biogeography* 23: 479–489.

Fischer J.D., Cleeton S.H., Lyons T.P. & Miller J.R. 2012. Urbanization and the predation paradox: the role of trophic dynamics in structuring vertebrate communities. *BioScience* 62: 809–818.

Fontana C.S., Burger M.I. & Magnusson W.E. 2011. Bird diversity in a subtropical South-American city: effects of noise levels, arborisation and human population density. *Urban Ecosystems* 14: 341–360.

Garden J., Mcalpine C., Peterson A.N.N., Jones D. & Possingham H. 2006. Review of the ecology of Australian urban fauna: a focus on spatially explicit processes. *Austral Ecology* 31: 126–148.

Garden J.G., McAlpine C.A., Possingham H.P. & Jones D.N. 2007. Habitat structure is more important than vegetation composition for local-level management of native terrestrial reptile and small mammal species living in urban remnants: a case study from Brisbane, Australia. *Austral Ecology* 32: 669–685.

Gotelli N.J. & Colwell R.K. 2011. Estimating species richness, p. 39–54. In: Magurran A.E. & McGill B.J. (eds.). *Frontiers in measuring biodiversity.* New York: Oxford University Press.

Gotelli N.J. & Entsminger G.L. 2000. *EcoSim: null models software for ecology*. v. 5.0. Acquired Intelligence Inc. and Kesey-Bear. http://homepages.together.net/~gentsmin/ecosim.htm (access on 20 June 2014)

Hansen A.J., Knight R.L., Marzluff J.M., Powell S., Brown K., Gude P.H. & Jones K. 2005. Effects of exurban development on biodiversity: patterns, mechanisms, and research needs. *Ecological Applications* 15: 1893–1905.

Hodgson P., French K. & Major R.E. 2007. Avian movement across abrupt ecological edges: differential responses to housing density in an urban matrix. *Landscape and Urban Planning* 79: 266–272.

ICLEI (International Council for Local Environmental Initiatives Local Governments for Sustainability). 2008. *Local action for biodiversity report*. http://archive.iclei.org/index.php?id=7910 (access on 04 July 2015).

Jokimäki J. & Suhonen J. 1998. Distribution and habitat selection of wintering birds in urban environments. *Landscape and Urban Planning* 39: 253–263.

Kark S., Iwaniuk A., Schalimtzek A. & Banker E. 2007. Living in the city: can anyone become an urban exploiter? *Journal of Biogeography* 34: 638–651.

Leveau C.M. & Leveau L.M. 2005. Avian community response to urbanization in the Pampean region, Argentina. *Ornitología Neotropical* 16: 503–510.

Leveau L.M. & Leveau C.M. 2012. The role of urbanization and seasonality on the temporal variability of bird communities. *Landscape and Urban Planning* 106: 271–276.

Lim H.C. & Sodhi N.S. 2004. Responses of avian guilds to urbanisation in a tropical city. *Landscape and Urban Planning* 66: 199–215.

Litteral J. & Wu J. 2012. Urban landscape matrix affects avian diversity in remnant vegetation fragments: evidence from the Phoenix metropolitan region, USA. *Urban Ecosystems* 15: 939–954.

Manhães M.A. & Loures-Ribeiro A. 2005. Spatial distribution and diversity of bird community in an urban area of southeast Brazil. *Brazilian Archives of Biology and Technology* 48: 285–294.

Marzluff J.M. 2001. Worldwide urbanization and its effects on birds, p. 331–364. In: Marzluff J.M., Bowman R. & Donnelly R. (eds.). *An urbanizing world*. Boston: Kluwer Academic.

Marzluff J.M., Bowman R. & Donnelly R. 2001. A historical perspective on urban bird research: trends, terms, and approaches, p. 1–17. In: Marzluff J.M., Bowman R. & Donnelly R. (eds.). *Avian ecology and conservation in an urbanizing world*. Boston: Kluwer Academic.

McKinney M.L. 2002. Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *BioScience* 52: 883–890.

McKinney M.L. 2006. Urbanization as a major cause of biotic homogenization. *Biological Conservation* 127: 247–260.

McKinney M.L. & Lockwood J.L. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends in Ecology & Evolution* 14: 450–453.

Møller A.P. 2009. Successful city dwellers: a comparative study of the ecological characteristics of urban birds in the Western Palearctic. *Oecologia* 159: 849–858.

Murgui E. 2009. Seasonal patterns of habitat selection of the House Sparrow *Passer domesticus* in the urban landscape of Valencia (Spain). *Journal of Ornithology* 150: 85–94.

Pauchard A., Aguayo M., Peña E. & Urrutia R. 2006. Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepción, Chile). *Biological Conservation* 127: 272–281.

Piacentini V.Q., Aleixo A., Agne C.E., Mauricio G.N., Pacheco J.F., Bravo G.A., Brito G.R.R., Naka L.N., Olmos F., Posso S., Silveira L.F., Betini G.S., Carrano E., Franz I., Lees A.C., Lima L.M., Pioli D., Schunck F., Amaral F.R., Bencke G.A., Cohn-Haft M., Figueiredo L.F.A., Straube F.C. & Cesari E. 2015. Annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee. *Revista Brasileira de Ornitologia* 23: 91–298.

Pinheiro R.T., Dornas T., Reis E.S., Barbosa M.O. & Rodello D. 2008. Birds of the urban area of Palmas, TO: composition and conservation. *Revista Brasileira de Ornitologia* 16: 339–347.

Proppe D.S., Sturdy C.B. & St Clair C.C. 2013. Anthropogenic noise decreases urban songbird diversity and may contribute to homogenization. *Global Change Biology* 19: 1075–1084.

R Development Core Team. 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org. (access on 23 October 2013).

Reis E., López-Iborra G.M. & Pinheiro R.T. 2012. Changes in bird species richness through different levels of urbanization: implications for biodiversity conservation and garden design in central Brazil. *Landscape and Urban Planning* 107: 31–42.

Reynaud P.A. & Thioulouse J. 2000. Identification of birds as biological markers along a Neotropical urban–rural gradient (Cayenne, French Guiana), using co-inertia analysis. *Journal of Environmental Management* 59: 121–140.

Roth M., Oke T.R. & Emery W.J. 1989. Satellite-derived urban heat islands from three coastal cities and the utilization of such data in urban climatology. *International Journal of Remote Sensing* 10: 1699–1720.

Sandström U.G., Angelstam P. & Mikusiński G. 2006. Ecological diversity of birds in relation to the structure of urban green space. *Landscape and Urban Planning* 77: 39–53.

Seress G. & Liker A. 2015. Habitat urbanization and its effects on birds. *Acta Zoologica Academiae Scientiarum Hungaricae* 61: 373–408.

Shochat E., Lerman S. & Fernández-Juricic E. 2010. Birds in urban ecosystems: population dynamics, community structure, biodiversity, and conservation, p. 75–86. In: Aitkenhead-Peterson J. & Volder A. (eds.). *Urban ecosystem ecology*. Madison: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America.

Silva C.P., García C.E., Estay S.A. & Barbosa O. 2015. Bird richness and abundance in response to urban form in a Latin American city: Valdivia, Chile as a case study. *PLoS ONE* 10: e0138120.

Sodhi N.S., Briffett C., Kong L. & Yuen B. 1999. Bird use of linear areas of a tropical city: implications for park connector design and management. *Landscape and Urban Planning* 45: 123–130.

Sogge M.K. 2000. Breeding season ecology, p. 57–70. In: Finch D.M. & Stoleson S.H. (eds.). *Status, ecology and conservation of the southwestern Willow Flycatcher.* Ogden: Department of Agriculture Forest Service, Rocky Mountain Research Station.

Sol D., Bartomeus I. & Griffin A.S. 2012. The paradox of invasion in birds: competitive superiority or ecological opportunism? *Oecologia* 169: 553–564.

Straube F.C., Carrano E., Santos R.E.F., Scherer-Neto P., Ribas C.F., Meijer A.A.R., Vallejos M.A.V., Lanzer M., Klemann-Júnior L., Aurélio-Silva M., Urben-Filho A., Arzua M., Lima A.M.X., Sobânia R.L.M., Deconto L.R., Bispo A.Â., Jesus S. & Abilhoa V. 2014. *Aves de Curitiba: coletânea de registros, v. 2.* Curitiba: Hori Consultoria Ambiental e Prefeitura Municipal de Curitiba.

Streutker D.R. 2003. Satellite-measured growth of the urban heat island of Houston, Texas. *Remote Sensing of Environment* 85: 282–289.

Suhonen J. & Jokimäki J. 1988. A biogeographical comparison of the breeding bird species assemblages in twenty Finnish urban parks. *Ornis Fennica* 65: 76–83.

Thom R.M., Borde A.B., Richter K.O. & Hibler L.F. 2001. *Influence of urbanization on ecological processes in wetlands. Land use and watersheds: human influence on hydrology and geomorphology in urban and forest areas, v. 1.* Washington: American Geophysical Union.

Toledo M.C.B., Donatelli R.J. & Batista G.T. 2012. Relation between green spaces and bird community structure in an urban area in southeast Brazil. *Urban Ecosystems* 15: 111–131.

Tryjanowski P., Sparks T.H., Kuźniak S., Czechowski P. & Jerzak L. 2013. Bird migration advances more strongly in urban environments. *PLoS ONE* 8: e63482.

van Rensburg B.J., Peacock D.S. & Robertson M.P. 2009. Biotic homogenization and alien bird species along an urban gradient in South Africa. *Landscape and Urban Planning* 92: 233–241.

Willis E.O. 1979. The composition of avian communities in remanescent woodlots in southern Brazil. *Papéis Avulsos de Zoologia, São Paulo* 33: 1–25.

Zar J.H. 1999. *Biostatistical analysis*. New Jersey: Prentice Hall.

Zipperer W.C., Foresman T.W., Walker S.P. & Daniel C.T. 2012. Ecological consequences of fragmentation and deforestation in an urban landscape: a case study. *Urban Ecosystems* 15: 533–544.

Associate Editor: Carla S. Fontana.