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Effects of proximity to urban areas on a riparian bird community in remnant Atlantic Forest in southeastern Brazil

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ABSTRACT

The goal of this study was to evaluate the effect of urban activities on the structure and composition of a bird community in riparian forests in the state of São Paulo, Brazil. The study was carried out in seven areas of remnant riparian forest where fixed points have been established to sample bird species. Richness, diversity, abundance, frequency and trophic groups were used as metrics of the bird community. At each point measurements were taken for: (1) habitat characteristics: average height of trees, number of trees above 2m, number of shrubs <2m and the percentage of canopy opening; (2) neighborhood characteristics: closest distance from open areas, highways, urban areas, river and floodplain to the point of observation. The observations resulted in 88 species of birds belonging to 34 families. The most representative families were Tyrannidae, Thraupidae and Picidae. The most predominant trophic groups were insectivorous (54%), omnivorous (11.5%) and frugivorous (10.3%). The results obtained showed that the number of trees explained the variation in abundance, while the mean height of the trees explained variations in richness and frequency. Overall, the bird community was negatively affected by proximity of urban areas and highways. In conclusion, the community of birds in the riparian forest may be affected by the loss of trees above 2m and by urbanization, leading mainly to the replacement of species belonging to specialist trophic groups by generalist species and those more adjusted to human presence.

Keywords: bird community, habitat, landscape, Paraiba do Sul River, urban activities.

Efeito da proximidade de áreas urbanas sobre a comunidade de aves ripárias em remanescentes de Mata Atlântica no Sudeste brasileiro

RESUMO

O objetivo deste estudo foi avaliar o efeito das atividades urbanas na estrutura e composição da comunidade de aves de matas ciliar rio Paraíba do Sul, estado de São Paulo, Brasil. O estudo foi realizado em sete áreas remanescentes de mata ciliar, onde foram estabelecidos pontos fixos para amostragem de espécies de aves. Riqueza, diversidade, abundância, frequência e tróficos foram utilizados como métricas estruturais da comunidade. A partir de cada ponto foram tomadas medidas quanto: (1) Características do habitat: altura média das árvores, número de árvores acima de 2m, número de arbustos <2m e porcentagem de abertura do dossel; (2) Características do bairro: distâncias mais próximas de áreas abertas, rodovias, áreas urbanas, rios e várzeas até o ponto de observação Por meio das observações foram registradas 88 espécies de aves pertencentes a 34 famílias. As famílias mais representativas foram Tyrannidae, Thraupidae e Picidae. Os grupos tróficos mais predominantes foram insetívoro (54%), onívoro (11,5%) e frugívoro (10,3%). Os resultados obtidos mostraram que o número de árvores explicou melhor a variação em abundância, enquanto a altura média das árvores explicou as variações de riqueza e frequência. No geral, a comunidade de aves foi afetada negativamente pela proximidade das áreas urbanas e das rodovias. Concluindo, a comunidade de aves da mata ciliar pode ser afetada pela perda de árvores acima de 2m e pela urbanização, levando principalmente à substituição de espécies pertencentes a grupos tróficos especializados por espécies generalistas e que melhor se ajustam à presença humana.

Palavras-chave: atividades urbanas, comunidade de aves, habitat, paisagem, Rio Paraíba do Sul.

1. INTRODUCTION

Some of the main characteristics of riparian forests are (1) linearity, the formation of corridors that can facilitate movement of individuals, allowing them to spread across the landscape or move from one forest patch to another (Rosenberg *et al.*, 1997; Lidicker Jr., 1999) and that theoretically facilitate gene flow between forest patches and reduces rates of stochastic extinction (Fahrig and Merriam, 1994); (2) heterogeneity of habitat, because the riparian forest is an ecotone between terrestrial and aquatic ecosystems that encompass a diversity of environmental factors and processes; and (3) availability of resources such as water, nutrients, food, shade and others that are not found in adjacent environments (Gregory *et al.,* 1991; Godinho *et al.,* 2010; Mafia 2015). These, among other attributes of riparian forests, explain the occurrence of a high diversity of bird species even when the forest occupies a small area (Gregory *et al.,* 1991; Silva and Vielliard, 2000; Lees and Peres, 2008).

The species that compose bird communities in riparian forests vary according to the biome, region, habitat, and season. For instance, in arid environments the riparian forest becomes a refuge to many resident bird species mainly in times of drought and a wintering place for migratory birds (Smith *et al.,* 2008; Oneal and Rotenberry, 2009). In addition, Silva and Vielliard (2000) stated that the riparian forest bird community located in tropical forests is heterogeneous and can host endemic and migratory species that have generalist and specialist habits, and forest border species, among others. Thereby, it is important to highlight the necessity of preserving this environment for maintenance and conservation of bird communities which depend entirely depend on riparian forests, such as endemic species, or those that partially depend on them, such as migratory species, and those that use the riparian forest to rest, reproduce, eat, or obtain other resources that are available seasonally or occasionally. (Mckinney, 2002; Metzger, 2010; Mello *et al*., 2014).

Human occupation leads to an urbanization process that includes urban, suburban, and rural classes according to the gradient of transformations (Gianotti *et al.,* 2016). However, this process can occur in a disorderly manner, mainly when there is no proper planning and urbanization advances into protected areas. Social inequality and the illegal housing market may lead to occupation of protective areas, such as riparian forests, creating a conflict between urban and agricultural development and the conservation of natural resources (Gonçalves and Souza 2012). Even being protected by law, riparian forests located in the urban – rural gradient are still being degraded, altering the forest structure (McDonnell and Pickett 1990), the flux of energy, nutrients, water quality, and composition and structure of the natural communities (Grimm *et al.,* 2000; Pickett *et al.,* 2011, Hutyra *et al.,* 2014).

Considering that each species is affected differently by human interventions, some bird species are more tolerant to changes and become abundant while others are intolerant and become rare, migrate or are locally extinguished (Marini and Garcia 2005, Luther *et al.*, 2008, Van Rensburg *et al.,* 2009, Toledo *et al.,* 2012). Thus, the decrease in bird species richness and an increase in the abundance and frequency of generalist and exotic species are expected effects associated with riparian forest degradation and being in close proximity to anthropic activities (Smith and Schaefer 1992, Neto and Viadana 2006, Luther *et al.,* 2008, Oneal and Rotenberry 2009, Brummelhaus *et al.,* 2012, Mafia 2015). Our presumption that different types of urban activities at both a local scale, such as habitat degradation, and at a landscape scale, such as agricultural activities, and expansion of cities and roads has negatively influenced the bird community when compare with natural characteristics such as the proximity of rivers and floodland (várzea). Thus, the main goal of this study was to evaluate the influence of urban activities on the composition and structure of a remnant riparian forest bird community.

2. MATERIALS AND METHODS

2.1. Study area

The study was carried out in the riparian forest of the Paraíba do Sul River located in the municipalities of Aparecida, Potim and Guaratinguetá (Table 1), state of São Paulo, Brazil. The climate of the region is classified as rainy subtropical with dry winters (Cwa) according to the KÖPPEN classification system (Rolim et al., 2007). These municipalities are located in the Atlantic Forest domain (Instituto Florestal / SP, 2016).

The Paraíba do Sul River basin is one of the most important in Brazil, as it is located between two major industrial and demographic centers, the municipalities of São Paulo and Rio de Janeiro, and supplies approximately 2,227,872 inhabitants (ANA 2016).

Table 1. Characterization of the urban region of the three counties located in the Paraíba do Sul River basin, São Paulo state, Brazil.

County	Latitude & Longitude	Altitude (M)	Average annual temperature (°C)	Average anual rain (mm)	County
Aparecida	22º50'49" S 45º13'47" W	550	21.8	1350.9	Late successional forest (2.48) Young secondary forest (13)*
Guaratinguetá	22º48'28" S 45º11'39" W	530	21.9	1312	Late successional forest (11.51) Young secondary forest (9.35)*
Potim	22º50'24" S 45º15'19" W	550	21.8	1424.2	Late successional forest (0.54) Young secondary forest (2.27)*

* INSTITUTO FLORESTAL/SP. Resultados. Mapas Municipais. SIFESP. 2016.

Seven riparian forest patches embedded in an urban matrix were chosen (Figure 1, and Table 2). The type of land use contiguous to riparian forest areas was classified as agricultural or urban.

In each area points parallel to the river were plotted with an average distance of 200 m from each other. In total, 35 points were established approximately 10 m from the edge and followed the contour of the patch. The number of points in each patch varied according to its area, shape and accessibility. To obtain the coordinates and distance of the observation points, the application "Andlocation" for Android phone was used.

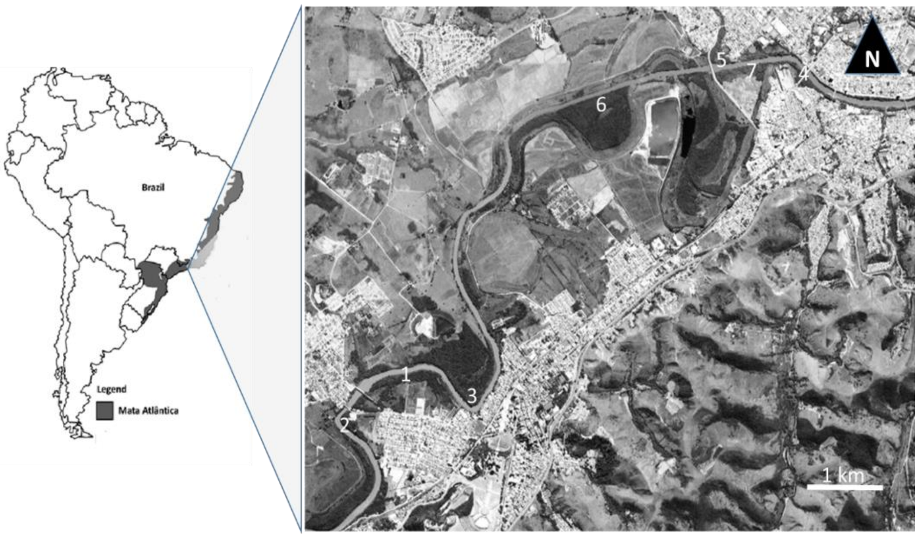

Figure 1. Localization of the study area in the southeast Brazil with presentation of the Atlantic Forest domain and in highlighted the locals where were run the surveys.
Source: Google Earth.

Table 2. Characteristics of the seven studied patches according to location (city and geographic coordinates), area (ha) and contiguous area characterization.

ID	Lat & Long	County	Number of points	Contiguous land use type
1	22º50'30" S 45º14'38" W	Aparecida	8	Degraded floodplain with shrubs and pasture.
2	22º50'23" S 45º14'15" W	Potim	3	Sand mine, pasture and urban area
3	22º50'39" S 45º14'56" W	Aparecida	11	Floodplain
4	22º48'37" S 45º11'49" W	Guaratinguetá	2	Urban area
5	22º48'27" S 45º12'29" W	Guaratinguetá	2	Urban area
6	22º48'51" S 45º13'16" W	Aparecida	6	Pasture and plantation
7	22º48'33" S 45º12'17" W	Guaratinguetá	4	Floodplain and pasture

2.2. Sampling of the bird community

The survey was performed during 4 h beginning immediately after sunrise, in June and July 2016 and June 2017. The field work was run during dry season due to the difficulty of access in the wet periods, when most of the patches are prone to flooding. The bird community was sampled using the point counts method – each point was visited once a month wherein the observer stayed at a point for 15 minutes recording all bird species seen and heard (Develey, 2003).

The observations were made using a 42x zoom semiprofessional camera Nikon Coolpix P510 and an audio recorder Sony ICD-PX240. The identification of the species was done using a field guide and by comparison with available databases on interactive sites such as xeno-canto and Wikiaves (Sigrist 2013, Xeno-Canto 2017, Wikiaves 2017). The list of Brazilian birds regularized by the Brazilian Ornithological Records Committee (Piacentini et al., 2015) was used as basis for scientific nomenclature.

Based on classifications of trophic groups used by Willis (1979), Sick (1997), Belton

(2000), and Scherer et al. (2010), the species of birds were grouped as follows: insectivorous - diet based mainly on the ingestion of insects; carnivorous - a diet composed essentially of live animals, such as vertebrates of various sizes and large invertebrates; frugivorous - diet composed basically of fruits; nectivorous - diet consisting especially of nectar; scavenger - diet composed of dead animals; omnivorous - diet consisting of several types of food, from fruits and arthropods to small vertebrates; granivorous - diet based on the ingestion of seeds; piscivorous - diet consisting mainly of fish; and herbivorous - those who eat plants.

The classification according to habitat use was based on observations of species occurrence in the riparian forest during the period of study, and were divided into arboreal - species with forest habits almost always seen in the crown of the trees; forest edge (strip of 2 m from the open area); open area (pastures and plantations, but was registered inside the patch); wetland (river bank, floodplain or swamp); and canopy (species that were always seen perched on tree tops, mainly in emergent trees).

2.3. Variables analyzed

For the description of bird community structure, richness, absolute abundance (total number of individuals per species), frequency (obtained from number of points that bird was observed by total number of points), Shannon index (H '), evenness, and dominance (Happer 1999) were analyzed.

At each point three visits were made, one in each study month. In order to avoid pseudoreplication, patches and sampling points were randomly chosen, and during this time an average of three points were visited per day. The characterization was done at each point according to two scales: (1) habitat and (2) neighborhood.

Habitat characteristics: in a radius of 5m from the sampling point we quantified average height of trees, number of trees > 2 m high, number of shrubs < 2 m in height and percentage of canopy opening. To estimate the height of the trees a visual parameter was using a 2 m ruler parallel to the trunk of each tree from the ground. The ruler was also used to demarcate, approximately, the radius around the point for quantification of trees and shrubs. Photos using a cellphone and fisheye lens 180º (Daite, model 10x) were taken. Each photo was analyzed with Image J software (Abràmoff et al., 2004) counting area with vegetation by total area to determine the percentage of canopy cover.

Neighborhood characteristics: measurements were taken from the observation point considering the closest distances (from the edge of the patch) in meters to open areas (pasture and agriculture), urban area (cities or built-up areas), highways (paved with asphalt or concrete and with two or more lanes), floodplains and rivers. All distances were obtained through the ruler tool available in Google Earth.

2.4. Data analyses

The D'Agostino test was run before all analyses to check the normal distribution of the data. We classified each point as urban or agriculture according to nearest type of land use. Thus, we compared urban points (n=11) *versus* agricultural (n= 16) ones for richness, total abundance (∑ of the number of individuals of all species observed), total frequency (∑ of the frequency of each species observed at one point; for example, if at one point three species were observed, and one of these occurred at 30 points out of a total of 36 (fr = 30/36 = 0.83), another at 3/36 = 0.083 and the third at 16/36 = 0.36 the frequency value at the point was 1.27). An unpaired t- test was used for comparisons at each point. To analyze the collinearity among explanatory variables (habitat characteristics: average height of trees, number of trees above 2m, number of shrubs <2m and percentage of canopy opening, and neighborhood characteristics: distances in meters from open areas, highways, urban areas, floodplains and rivers) the Pearson's linear correlation was used, and variables with r>0.5 were excluded.

However, the results showed no significant correlation thus eliminating the possibility of collinearity among explanatory variables. Linear regression using R^2 and p-values for model validation was conducted to describe the relationship between dependent (richness, abundance and frequency) and explanatory variables (habitat characteristics: average height of trees, number of trees above 2m, number of shrubs <2m and percentage of canopy opening, and neighborhood characteristics: distances in meters from open areas, highways, urban areas, floodplains and rivers). The correlation and regression analyses were performed in Prism graphpad V, with a significance level of $p < 0.05$.

The aggregate effect of the explanatory variables on the bird species was analyzed using Canonical Correspondence Analysis – CCA, using abundance values of the registered species. Principal Component Analyses – PCA – was used to reduce the number of variables used in the CCA; thus, variables with eigenvalues <0.5 were excluded. All multivariate analyses were run in PAST 3.22.

3. RESULTS AND DISCUSSION

In total, 88 species from 34 different families were inventoried in the study area (Appendix 1). The descriptive indices of the community were: Shannon index (H') = 3.67, evenness = 0.45, and dominance = 0.04. Compared with the Wikiaves website (Wikiaves 2018), our study showed that these bird species in the riparian forest represented 65.7% of the bird community. The families with the highest number of species were Tyrannidae (n = 19), Thraupidae (n = 9), and Picidae (n = 6). The most abundant species during observation periods were *Pygochelidon cyanoleuca* (Vieillot, 1817) (Blue-and-white Swallow), *Coereba flaveola* (Linnaeus, 1758) (Bananaquit), *Pitangus sulphuratus* (Linnaeus, 1766) (Great Kiskadee), and *Troglodytes musculus* Naumann, 1823 (Southern House Wren). A total of 17 species were represented by just one individual. Most species were classified as arboreal and/or endemic to humid areas (observed at the forest edge close to floodplains and river banks), and were more observed at points located in study areas 1 and 6. Four species were observed at most of the sampling points, of which all were native; *Coereba flaveola* (Linnaeus, 1758) and *Pintangus sulphuratus* (Linnaeus, 1766) were detected at 93% of the sampling points; *Troglodytes musculus* (Naumann, 1823) and *Pygochelidon cyanoleuca* (Vieillot, 1817) were detected at 89% and 79% of the sampling points, respectively. These four species are commonly observed in heavily urbanized areas (Toledo et al 2012). During the study period only one exotic *Passer domesticus* (Linnaeus, 1758) (House Sparrow) and one endangered species *Amadonastur lacernulatus* (Temminck, 1827) (White-necked Hawk) were recorded.

The percentage of species registered in each trophic group was insectivores (54%), omnivores (12.6%), frugivores (10.3%), granivores (5.7%), piscivores (5.7%), carnivores (4.6%), nectarivores (4.6%), herbivores (1.1%), and scavengers (1.1%). Tyrannidae represented the family with the highest number of species, which is typical for the Neotropical region, and might explain the predominance of the species in this family, including *Pitangus sulphuratus* (Sigrist 2013). In addition, many Tyrannids are able to adjust to a wide variety of environments, including those affected by urbanization (Aleixo & Vielliard 1995, Sick 1997, Almeida et al. 1999, Anjos et al. 2007). Most of the Tyrannid species detected in our study belonged to insectivorous and omnivorous trophic groups. The prevalence of insectivores and omnivores was expected, because are common in tropical regions where insects are always available (Sick 1997). These groups were also observed in other studies carried out in Brazil, including both forest remnants and protected areas (Blamires et al. 2001, Telino-Júnior et al. 2005, Donatelli et al. 2007). In other cases, where studies were carried out in urban green areas (such as parks), omnivores dominated over other trophic groups (Argel-de-Oliveira 1995, Villanueva & Silva 1996, Valadão et al., 2006, Scherer et al., 2010). This dominance of omnivores was probably due to their lack of food preferences, allowing them to forage on food resources that are not subject to seasonal variations, including human leftovers (Scherer et al., 2010).

For habitat groups, the most recorded species were classified as arboreal (n = 28), followed by wetlands (n = 17). These species are almost exclusively recorded in the canopy of trees and, therefore, are found in riparian forests, which serve as refuges in urbanized environments (Silva & Vielliard, 2000, Luther et al., 2008, Oneal & Rotenberry, 2009). This refuge hypothesis is reinforced by the registered presence of the species *Amadonastur lacernulatus*, which is endemic to the Atlantic Forest and is considered endangered due to the loss of habitat due to human construction and lead contamination (Plaza et al. 2018, Sarasola 2018). *Amadonastur lacernulatus* uses tall trees to build its nest, and is commonly observed in coastal areas, and is rarely observed above 900 m (Sigrist 2013). Thus, riparian forests might be important for species that use wide territories, such as top predators. In addition, most species that were only observed once were edge of forest or species endemic to wetlands, including *Myiarchus swainsoni* (Cabanis & Heine, 1859) and *Nycticorax nycticorax* (Linnaeus, 1758). This finding demonstrates the importance of these environments for conserving species susceptible to change, including the removal of trees for human activities (Silva & Vielliard, 2000, Luther et al., 2008, Oneal & Rotenberry, 2009, Sigrist, 2013).

The results of the comparisons using richness, abundance, and frequency were evaluated in relation to the closest land-use type (agricultural or urban) to the observation point (Figure 2). A non-significant result was obtained for ($t = 0.318$, $p = 0.75285$) between the two land-use types. On the other hand, abundance ($t = 2.7185$; $p = 0.01$) and frequency ($t = 4.4424$; $p = 0.000$) were significantly different and were higher at the points closest to urban areas. These results corroborate our hypothesis that urbanization influences the structure of the bird community. Other works documented that in a rural-urban gradient changes in the structure of the bird community are observed (Clergeau *et al*., 1998; Garaffa *et al*., 2009) such as increase in abundance and frequency of generalist species (McDonnell & Pickett, 1990; Marzluff, 2001; Pickett *et al.*, 2011). We observed that generalist and opportunistic species exhibited high values of abundance, which might be explained by their close proximity to urban environments (Smith & Schaefer 1992, Neto & Viadana 2006, Luther et al., 2008, Oneal & Rotenberry, 2009, Brummelhaus et al., 2012, Kale et al., 2012). For example, *Passer domesticus*, *Pitangus sulphuratus*, and *Thraupis sayaca* are already strongly adjusted to urban environments, and are abundant in cities (Amâncio et al., 2008, Sigrist, 2013).

Linear regression analysis showed that abundance and frequency were the most sensitive parameters to changes in habitat as well as in landscape. Between the habitat and landscape variables, richness, abundance, and frequency showed that the average height of trees explained <15% variation in richness and frequency, while the number of trees explained 22% of abundance. The landscape variables, distance to urban areas and highways, had stronger power in explaining variation in the abundance and frequency of birds. The number of trees, distance to highways, and urban areas were negatively correlated with the abundance and frequency of bird species. In comparison, the average height of trees and number of shrubs <2 m were positively correlated with species richness and frequency (Table 3).

The increase in abundance of a few species is generally observed in highly urbanized environments when compared to natural environments (Gagné & Fahrig 2011). In urbanized environments, native specialist species are replaced by generalist native or exotic species. Consequently, species richness cannot change significantly. In comparison, the abundance and frequency of species may be the better parameters to identify changes in community structure (Marini & Garcia 2005, Luther et al. 2008). The PCA results corroborate those obtained in the regression analysis.

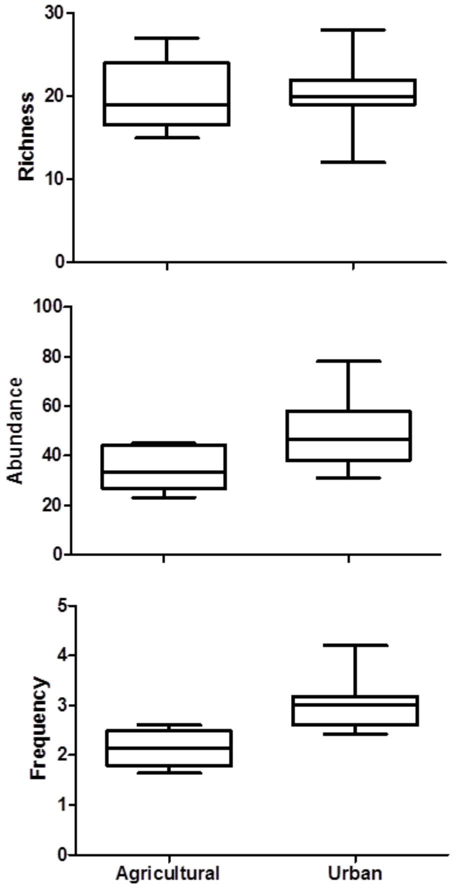

Figure 2. Average, maximum and minimum values, and standard deviation of variation in richness, abundance and frequency between rural and urban land use.

Table 3. Results of linear regression analysis for local and neighborhood variables with abundance, richness, and frequency.

Variables	Richness	Abundance	Frequency
Local			
Number of trees >2m	0.048	-0.22**	-0.055
Number of shrubs <2m	0.172	-0.24	0.135*
Height of trees	-0.14*	-0.091	-0.123*
Canopy opening	0.045	-0.153*	-0.008
Neighborhood			
Distance to open areas	0.001	0.004	0.158*
Distance to floodplain	0.139	-0.129*	0.016
Distance to highways	0.143	-0.260**	-0.257**
Distance to urban area	0.002	-0.173**	-0.398***
Distance to the river	0.027	-0.134*	0.064

*p<0.05 ** p<0.01 ***p<0.001.

PCA analyses showed that the number of trees above 2 m and distance to highways, urban areas, floodplains, and rivers explained more than 50% of the observed variation (eigenvalues > 0.5; Table 4). These parameters were therefore included in the CCA analysis with the PC1 variable and were the variables included in the PCA analysis. The PC1 eigenvalue was 3.118 and explained more than 89.9% of the variation. The CCA analysis showed the relationship between the observation points and PC1 and variables that contributed with greater variation (Figure 3). The closer to the river, the further away from urban areas and highways, and the more trees present at the observation points, the greater the chances of observing the rarest and most forest-dependent species (Figure 4), and the greater the chances of maintaining a better and more conserved community of birds.

Table 4. First and second principal component weight values obtained from Principal Component Analyses – PCA – for local and neighborhood variables.

	Variables	PC 1	PC 2
Local	Number of trees >2m	0.519	-0.289
	Number of shrubs <2m	0.167	0.019
	Height of trees	-0.111	0.283
	Canopy opening	-0.262	-0.248
Neighborhood	Distance to open areas	-0.203	-0.243
	Distance to floodplain	0.542	-0.155
	Distance to highways	0.988	0.080
	Distance to urban area	0.979	-0.149
	Distance to the river	0.648	0.719

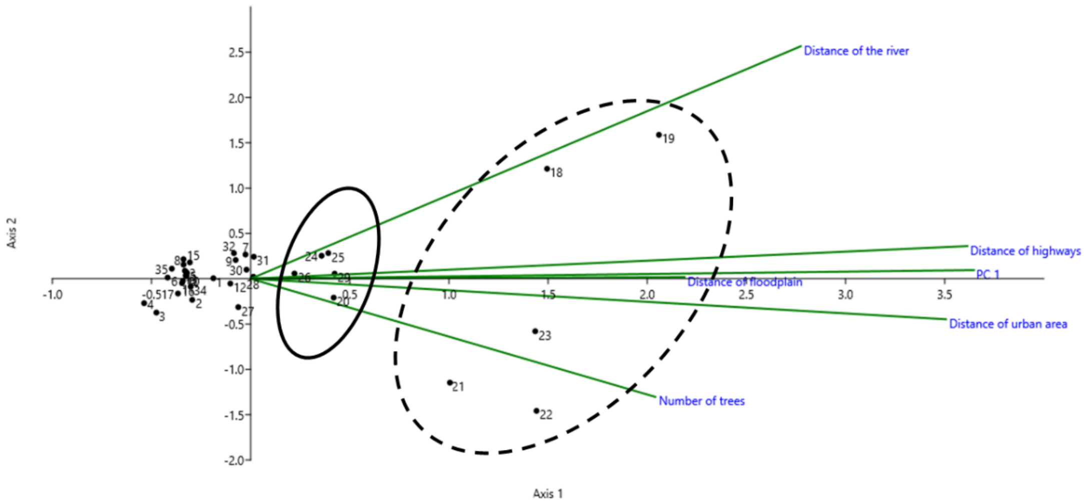

Figure 3. Graphical representation of the canonical correspondence analysis between observation points and the main analyzed variables; namely, distance to the river, distance to urban areas, distance to public roads, distance to the floodplains, and number of trees. Blue circle: observation points in area 3. Blue circle: observation points in area 6.

CCA (Figure 3) also showed that species with forest habits such as *Manacus manacus* and *Florisuga fusca* were present at points furthest away from highways, urban areas and rivers. The opposite trend was obtained for generalist and/or opportunistic habit species such as *Passer* *domesticus* and *Pitangus sulphuratus*, which were negatively correlated to these variables since these species are closely linked to the urban environment. Arboreal species such as *Conirostrum speciosum* were negatively correlated to the percentage of canopy opening. Birds that are always detected close to aquatic environments were negatively correlated (the smaller the distance, the greater the abundance) with distance to the river. Examples of such species included *Furnarius figulus* and *Nannopterum brasilianus*, which were consistently detected in vegetation closest to the river.

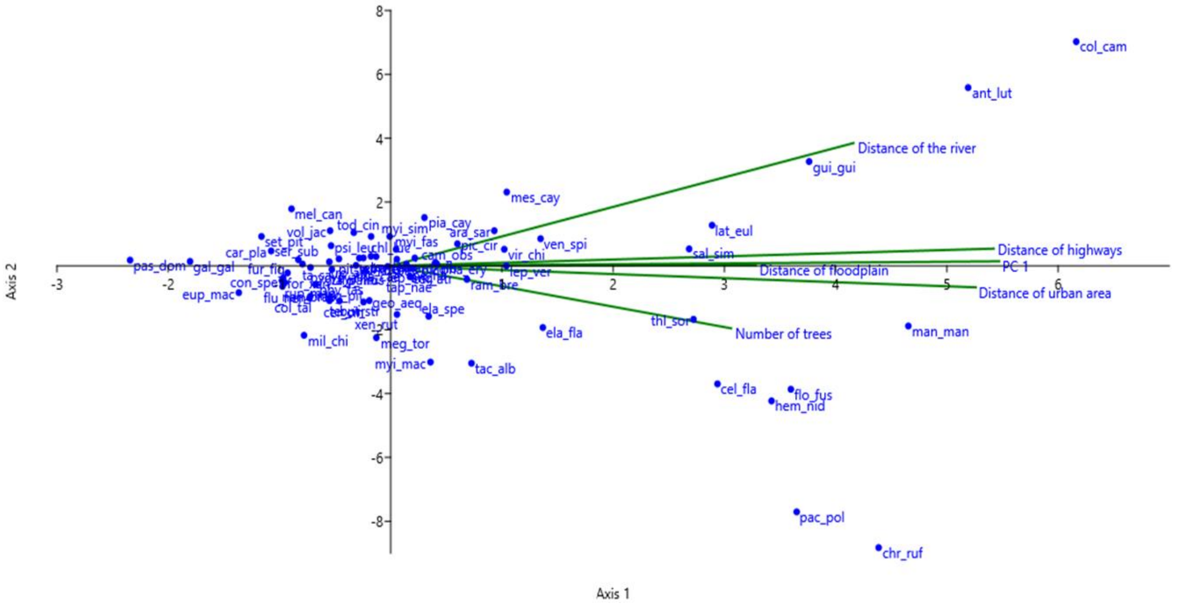

Figure 4. Graphical representation of the canonical correspondence analysis between observed bird species and the main variables analyzed; namely, distance to rivers, distance to urban areas, distance to public roads, distance from the floodplain, and number of trees.

In general, our results provide evidence for the effects of urbanization. For instance, species like *Hemitriccus nidipendulus*, *Manacus manacus*, and *Florisuga fusca* had abundance values that were inversely proportional to the distance of urban areas and/or public roads. In other words, the points closest to urban environments supported a higher abundance of generalist species. That is, abundance and frequency differed between the observation points located near rural and urban environments. Studies carried out by Saab (1999) and Kennedy et al. (2010) in the United States of America (USA) and Jamaica, respectively, showed that neighborhood type had the greatest influence on the bird communities of remaining areas. Saab (1999) showed that the remaining areas close to natural environments had high richness and a greater frequency of specialist species. In comparison, in areas where the surrounding environment had been altered by man, exotic, parasitic, and nest predator species were more common (Saab, 1999). Kennedy et al. (2010) showed that the abundance, richness, and composition of the bird community depends on the type of surrounding environment. For instance, agricultural environments support more conserved bird communities than peri-urban environments (Kennedy et a.,l 2010).

Species for which only one individual was observed were more frequently detected at points located in the largest areas (1 and 6) that had very distinct characteristics (see Table 1). Points located in area 1 were characterized by the typical linear arrangement of the riparian forest, facilitating its use as an ecological corridor (SMA/SP 2014). The 6th area was circular in shape and was surrounded by rural areas, which reduce human interference (McKinney 2002). At intermediate levels (where the natural and anthropic environments had similar proportions), the number of species was higher. At sites, where urbanization is high, species richness declines, with a significant loss of species that are less tolerant to urban environments (Gagné & Fahrig, 2011, Ortega-Álvarez & Macgregor-Fors, 2011, Brummelhaus et al., 2012).

4. CONCLUSIONS

In general, our results show that the effects of surrounding urban activities were more significant than habitat effects, with only the points located in areas greater than 10 ha, far from urban areas, and with emergent trees maintaining a better-conserved and well-structured bird community, in terms of composition, abundance, and frequency. Our results highlight the importance of conserving large areas with more structured vegetation, which provides important habitat diversity for the maintenance of bird communities in riparian forest remnants. Rare and endemic species could be used as a reference to identify these areas that could be considered priority for conservation. Unfortunately, surrounding areas of the riparian forest are constantly being degraded or subjected to various types of anthropic interference, particularly urbanization. Thus, management actions can be proposed to improve conservation of priority areas, for example use of buffer strips to reduce the impacts of border areas.

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Appendix 1. List of species with scientific and common names; origin (native, N, exotic, E); trophic group (G = Granivore; F = Frugivore; H = Herbivore; I = insectivore; N = Nectarivore; P = Piscivore; O = Omnivorous; C = Carnivore; Ne = Scavenger); habitat (A= arboreal; Ef= forest edge; Oa= open area; W= wetland; C=canopy); total abundance, relative abundance and frequency observed in riparian forest fragments in the municipalities of Aparecida, Potim and Guaratinguetá (SP).

Family	Scientific Name/Common English Name	Origin	Trophic groups	Habitat	Total Abundance	Relative abundance
ACCIPITRIDAE	*Amadonastur lacernulatus* (Temminck, 1827) White-necked Hawk	N	C	A	1	0.001
ACCIPITRIDAE	*Rupornis magnirostris* (Gmelin, 1788) Roadside Hawk	N	C	Oc	3	0.002
ALCEDINIDAE	*Megaceryle torquata* (Linnaeus, 1766) Ringed Kingfisher	N	P	W	4	0.003
ANHINGIDAE	*Anhinga anhinga* (Linnaeus, 1766) Anhinga	N	P	W	1	0.001
ARDEIDAE	*Ardea alba* Linnaeus, 1758 Great Egret	N	O	W	2	0.001
ARDEIDAE	*Ardea cocoi* Linnaeus, 1766 Cocoi Heron	N	P	W	1	0.001
ARDEIDAE	*Butorides striata* (Linnaeus, 1758) Striated Heron	N	P	W	2	0.001
ARDEIDAE	*Nycticorax nycticorax* (Linnaeus, 1758) Black-crowned Night-Heron	N	O	W	1	0.001
CATHARTIDAE	*Coragyps atratus* (Bechstein, 1793) Black Vulture	N	S	Oc	9	0.006
COLUMBIDAE	*Columbina talpacoti* (Temminck, 1811) Ruddy Ground-Dove	N	G	Oa/Ef	9	0.006
COLUMBIDAE	*Leptotila verreauxi* Bonaparte, 1855 White-tipped Dove	N	G/F	Ef	30	0.021
COLUMBIDAE	*Patagioenas picazuro* (Temminck, 1813) Picazuro Pigeon	N	G/F	Ef	18	0.013
CUCULIDAE	*Crotophaga ani* Linnaeus, 1758 Smooth-billed Ani	N	C	Oa	20	0.014
CUCULIDAE	*Guira guira* (Gmelin, 1788) Guira Cuckoo	N	C	Oa	5	0.004
CUCULIDAE	*Piaya cayana* (Linnaeus, 1766) Squirrel Cuckoo	N	I	A	14	0.01
CUCULIDAE	*Tapera naevia* (Linnaeus, 1766) Striped Cuckoo	N	I	Ef	8	0.006
DENDROCOLAPTIDAE	*Lepidocolaptes angustirostris* (Vieillot, 1818) Narrow-billed Woodcreeper	N	I	Oa	5	0.004
DONACOBIIDAE	*Donacobius atricapilla* (Linnaeus, 1766) Black-capped Donacobius	N	I	W	1	0.001
FALCONIDAE	*Caracara plancus* (Miller, 1777) Southern Caracara	N	O	Oc/Oa	6	0.004
FALCONIDAE	*Milvago chimachima* (Vieillot, 1816) Yellow-headed Caracara	N	O	Oc	2	0.001
FRINGILLIDAE	*Euphonia chlorotica* (Linnaeus, 1766) Purple-throated Euphonia	N	F	A	24	0.017
FURNARIIDAE	*Certhiaxis cinnamomeus* (Gmelin, 1788) Yellow-chinned Spinetail	N	I	W	33	0.024
FURNARIIDAE	*Furnarius figulus* (Lichtenstein, 1823) Wing-banded Hornero	N	I	W	17	0.012
FURNARIIDAE	*Phacellodomus erythrophthalmus* (Wied, 1821) Orange-eyed Thornbird	N	I	A	10	0.007
FURNARIIDAE	*Synallaxis spixi* Sclater, 1856 Spix's Spinetail	N	I	A	59	0.042
HIRUNDINIDAE	*Alopochelidon fucata* (Temminck, 1822) Tawny-headed Swallow	N	I/F	Oa	1	0.001
HIRUNDINIDAE	*Pygochelidon cyanoleuca* (Vieillot, 1817) Blue-and-white Swallow	N	I	Oc	140	0.1
HIRUNDINIDAE	*Tachycineta albiventer* (Boddaert, 1783) White-winged Swallow	N	I	W	3	0.002
ICTERIDAE	*Chrysomus ruficapillus* (Vieillot, 1819) Chestnut-capped Blackbird	N	G/F	W	2	0.001
MOTACILLIDAE	*Anthus lutescens* Pucheran, 1855 Yellowish Pipit	N	I	Oa	4	0.003
PARULIDAE	*Setophaga pitiayumi* (Vieillot, 1817) Tropical Parula	N	I	A	2	0.001
PARULIDAE	*Geothlypis aequinoctialis* (Gmelin, 1789) Masked Yellowthroat	N	I	A	5	0.004

Continued...

PASSERIDAE	*Passer domesticus* (Linnaeus, 1758) House Sparrow	E	O	Ef	2	0.001
PHALACROCORACIDAE	*Phalacrocorax brasilianus* (Gmelin, 1789) Neotropic Cormorant	N	P	W	5	0.004
PICIDAE	*Celeus flavescens* (Gmelin, 1788) Blond-crested Woodpecker	N	O	A	4	0.003
PICIDAE	*Colaptes campestris* (Vieillot, 1818) Campo Flicker	N	I	Oa	4	0.003
PICIDAE	*Colaptes melanochloros* (Gmelin, 1788) Green-barred Woodpecker	N	I	Ef	1	0.001
PICIDAE	*Melanerpes candidus* (Otto, 1796) White Woodpecker	N	I/F	Oa	3	0.002
PICIDAE	*Picumnus cirratus* Temminck, 1825 White-barred Piculet	N	I	A	38	0.027
PICIDAE	*Veniliornis spilogaster* (Wagler, 1827) White-spotted Woodpecker	N	I	Ef	7	0.005
PIPRIDAE	*Manacus manacus* (Linnaeus, 1766) White-bearded Manakin	N	F/I	A	2	0.001
PSITTACIDAE	*Forpus xanthopterygius* (Spix, 1824) Blue-winged Parrotlet	N	F/G	A	28	0.02
PSITTACIDAE	*Psittacara leucophthalmus* (Statius Muller, 1776) White-eyed Parakeet	N	F/G	Oc	22	0.016
RALLIDAE	*Aramides saracura* (Spix, 1825) Slaty-breasted Wood-Rail	N	O	W	2	0.001
RALLIDAE	*Gallinula galeata* (Lichtenstei, 1818) Common Gallinule	N	H	W	2	0.001
RAMPHASTIDAE	*Ramphastos toco* Statius Muller, 1776 Toco Toucan	N	O	Oc	1	0.001
RHYNCHOCYCLIDAE	*Hemitriccus nidipendulus* (Wied, 1831) Hangnest Tody-Tyrant	N	I	A	5	0.004
RHYNCHOCYCLIDAE	*Todirostrum cinereum* (Linnaeus, 1766) Common Tody-Flycatcher	N	I	A	51	0.036
THAMNOPHILIDAE	*Thamnophilus caerulescens* Vieillot, 1816 Variable Antshrike	N	I	A	6	0.004
THRAUPIDAE	*Coereba flaveola* (Linnaeus, 1758) Bananaquit	N	N /F	A	109	0.078
THRAUPIDAE	*Conirostrum speciosum* (Temminck, 1824) Chestnut-vented Conebill	N	I	A	14	0.01
THRAUPIDAE	*Ramphocelus bresilius* (Linnaeus, 1766) Brazilian Tanager	N	F	A	53	0.038
THRAUPIDAE	*Saltator similis* d'Orbigny & Lafresnaye, 1837 Green-winged Saltator	N	O	Ef	15	0.011
THRAUPIDAE	*Tangara palmarum* (Wied, 1823) Palm Tanager	N	F/I	A	8	0.006
THRAUPIDAE	*Tangara sayaca* (Linnaeus, 1766) Sayaca Tanager	N	F/I	A	54	0.039
THRAUPIDAE	*Tersina viridis* (Illiger, 1811) Swallow Tanager	N	F/I	A	2	0.001
THRAUPIDAE	*Thlypopsis sordida* (d'Orbigny & Lafresnaye, 1837) Orange-headed Tanager	N	F/I	A	29	0.021
THRAUPIDAE	*Volatinia jacarina* (Linnaeus, 1766) Blue-black Grassquit	N	G	Oa	3	0.002
THRESKIORNITHIDAE	*Mesembrinibis cayennensis* (Gmelin, 1789) Green Ibis	N	I	A	6	0.004
TITYRIDAE	*Pachyramphus polychopterus* (Vieillot, 1818) White-winged Becard	N	I	A	2	0.001
TROCHILIDAE	*Eupetomena macroura* (Gmelin, 1788) Swallow-tailed Hummingbird	N	N	Ef	2	0.001
TROCHILIDAE	*Chlorostilbon lucidus* (Shaw, 1812) Glittering-bellied Emerald	N	N	Ef	10	0.007
TROCHILIDAE	*Florisuga fusca* (Vieillot, 1817) Black Jacobin	N	N	Ef	7	0.005
TROGLODYTIDAE	*Troglodytes musculus* Naumann, 1823 Southern House Wren	N	I	Ef	76	0.054
TURDIDAE	*Turdus amaurochalinus* Cabanis, 1850 Creamy-bellied Thrush	N	I/F	A	1	0.001
TURDIDAE	*Turdus leucomelas* Vieillot, 1818 Pale-breasted Thrush	N	I/F	A	38	0.027
TYRANNIDAE	*Arundinicola leucocephala* (Linnaeus, 1764) White-headed Marsh Tyrant	N	I	W	1	0.001
TYRANNIDAE	*Camptostoma obsoletum* (Temminck, 1824) Southern Beardless-Tyrannulet	N	I/F	A	56	0.04
TYRANNIDAE	*Elaenia flavogaster* (Thunberg, 1822) Yellow-bellied Elaenia	N	I/F	A	6	0.004

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TYRANNIDAE	*Elaenia spectabilis* Pelzeln, 1868 Large Elaenia	N	I/F	A	11	0.008
TYRANNIDAE	*Fluvicola nengeta* (Linnaeus, 1766) Masked Water-Tyrant	N	I	W	17	0.012
TYRANNIDAE	*Lathrotriccus euleri* (Cabanis, 1868) Euler's Flycatcher	N	I	A	15	0.011
TYRANNIDAE	*Megarynchus pitangua* (Linnaeus, 1766) Boat-billed Flycatcher	N	O	Oc	21	0.015
TYRANNIDAE	*Myiophobus fasciatus* (Statius Muller, 1776) Bran-colored Flycatcher	N	I	A	38	0.027
TYRANNIDAE	*Myiodynastes maculatus* (Statius Muller, 1776) Streaked Flycatcher	N	I/F	A	7	0.005
TYRANNIDAE	Myiozetetes similis (Spix, 1825) Social Flycatcher	N	I/F	W	21	0.015
TYRANNIDAE	*Myiarchus swainsoni* Cabanis & Heine, 1859 Swainson's Flycatcher	N	I/F	A	1	0.001
TYRANNIDAE	*Phyllomyias fasciatus* (Thunberg, 1822) Planalto Tyrannulet	N	I	A	4	0.003
TYRANNIDAE	*Pitangus sulphuratus* (Linnaeus, 1766) Great Kiskadee	N	O	Oc	92	0.066
TYRANNIDAE	*Satrapa icterophrys* (Vieillot, 1818) Yellow-browed Tyrant	N	I	Oa	1	0.001
TYRANNIDAE	*Serpophaga nigricans* (Vieillot, 1817) Sooty Tyrannulet	N	I	W	1	0.001
TYRANNIDAE	*Serpophaga subcristata* (Vieillot, 1817) White-crested Tyrannulet	N	I	A	15	0.011
TYRANNIDAE	*Sirystes sibilator* (Vieillot, 1818) Sibilant Sirystes	N	I	Ef	1	0.001
TYRANNIDAE	*Tyrannus melancholicus* Vieillot, 1819 Tropical Kingbird	N	I	Ef	12	0.009
TYRANNIDAE	*Tyrannus savana* Vieillot, 1808 Fork-tailed Flycatcher	N	I	Oc/Oa	1	0.001
VIREONIDAE	*Vireo chivi* (Vieillot, 1817) Chivi Vireo	N	I	A	21	0.015
XENOPIDAE	*Xenops rutilans* Temminck, 1821 Streaked Xenops	N	I	A	4	0.003
Total					1,400	