Biodiversidade Brasileira Revista Científica

ARTIGO CIENTÍFICO

Avifauna in the urban area of Teresina municipality, state of Piauí, Brazil

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Como citar:
Madella-Auricchio CR, Silva MV, Auricchio P. Avifauna in the urban area of Teresina municipality, state of Piauí, Brazil. Biodivers. Bras. [Internet]. 2026; 16(2): e2857. doi:10.37002/biodiversidadebrasileira.v16i2.2857

Recebido em 22/09/2025 – Aceito em 12/05/2026

ABSTRACT – Here we present, for the first time, the distribution and ecological attributes of the avifauna in an urban area of Piauí.We evaluated the bird assemblage in sites with different degrees of anthropization in the Teresina municipality. The bird assemblage was evaluated to the richness, evenness, abundance, seasonal variation, taxonomic diversity, functional diversity, functional traits, and similarity in species composition. Were registered 12,505 specimens, comprising 115 species, 42 families, and 100 genera. The most representative families were: Tyrannidae, Thraupidae, and Icteridae. The first occurrence of *Spizaetus tyrannus* (Wied, 1820) and *Attila spadiceus* (Gmelin, 1789) was recorded in Piauí. Also, were recorded the migratory species *Pandion haliaetus* (Linnaeus, 1758) and *Falco peregrinus* Tunstall, 1771. Results showed that the bird richness in Teresina is similar to other anthropized areas in Piauí, and to other Brazilian cities. The most abundant species were those associated with anthropized areas, and the downtown sampling sites have showed low richness, diversity, and differed in species composition compared to green areas. The urban parks keep the greatest species richness, and the functional trait analysis indicates that these areas are very important in the maintenance of the local bird diversity. The analysis showed that vegetation is the most important element for the species to use as *habitat*, foraging, and nesting substrate. As conservation strategies, we suggest that it is imperative the maintenance of the existing urban parks and the use of the native tree species of the surrounding area for urban afforestation to prevent decline of bird species in Teresina.
Keywords: Anthropization; bird assemblage; functional traits; *habitat* loss; urbanization.

Avifauna na área urbana do município de Teresina, estado do Piauí, Brasil

RESUMO – Neste estudo, apresentamos pela primeira vez a distribuição e os atributos ecológicos da avifauna em uma área urbana no Piauí. Nós avaliamos a assembleia de aves em locais com diferentes graus de antropização no município de Teresina. Foram avaliadas riqueza, equitabilidade, abundância, variação sazonal, diversidade taxonômica, diversidade funcional, traços funcionais e a similaridade na composição de espécies. Foram registrados 12.505 espécimes, compreendendo 115 espécies, 42 famílias e 100 gêneros. As famílias mais representativas foram: Tyrannidae, Thraupidae e Icteridae. Registramos pela primeira vez no Piauí as espécies *Spizaetus tyrannus* (Wied, 1820) e *Attila spadiceus* (Gmelin, 1789). Também foram registradas as espécies migratórias *Pandion haliaetus* (Linnaeus, 1758) e *Falco peregrinus* Tunstall, 1771. Os resultados mostraram que a riqueza de aves em Teresina é similar a outras áreas antropizadas no Piauí e de outras cidades brasileiras. A maior abundância esteve associada a locais antropizados, mas o centro da cidade apresentou baixa riqueza, diversidade e diferente composição de espécies comparado a áreas verdes. Os parques urbanos tiveram a maior riqueza de espécies e traços funcionais indicando que estes locais são muito importantes para a manutenção da diversidade de avifauna local. As análises mostraram que a vegetação é o elemento mais importante para as espécies para uso como *habitat*, forrageamento e substrato para nidificação. Como estratégia de conservação sugerimos que é imperativa a manutenção dos parques urbanos e uso de árvores nativas na área urbana para prevenir o declínio das espécies de aves em Teresina.

Palavras-chave: Assembleia de aves; traços funcionais; perda de *habitat*; urbanização.

Avifauna en el área urbana del município de Teresina, estado do Piauí, Brasil

RESUMEN - En este estudio presentamos por primera vez la distribución y los atributos ecológicos de la avifauna en un área urbana de Piauí. Evaluamos el ensamblaje de aves en localidades con diferentes grados de antropización en el municipio de Teresina. Evaluamos la riqueza, equitatividad, abundancia, variación estacional, diversidad taxonómica, diversidad funcional, rasgos funcionales y similitud en la composición de especies. Se registraron 12.505 especímenes, que abarcan 115 especies, 42 Familias y 100 Géneros. Las familias representativas fueron: Tyrannidae, Thraupidae e Icteridae. Registramos por primera vez en Piauí las especies *Spizaetus tyrannus* (Wied, 1820) e *Attila spadiceus* (Gmelin, 1789). También registramos las especies migratorias *Pandion haliaetus* (Linnaeus, 1758) e *Falco peregrinus* Tunstall, 1771. Los resultados mostraron que la riqueza de aves en Teresina es similar a otras áreas antropizadas en Piauí y otras ciudades brasileñas. La mayor abundancia de especies se asoció con los sitios antropizados, pero el centro de la ciudad presentó poca riqueza, diversidad y una composición de especies diferente en comparación con las áreas verdes. Los parques urbanos tuvieron mayor riqueza de especies y rasgos funcionales, lo que indica que estos lugares son muy importantes para mantener la diversidad de aves locales. La vegetación fue el elemento más importante para las especies, ya que sirve como hábitat, sustrato por la alimentación y la anidación. Como estrategia de conservación, sugerimos que el mantenimiento de los parques urbanos y el uso de árboles nativos en las zonas urbanas es imperativo para prevenir la disminución de las especies de aves en Teresina.

Palabras clave: Ensamblaje de aves; rasgos funcionales; pérdida de *habitat*; urbanización.

Introduction

Urbanization is a major global driver of species decline, primarily through the destruction of natural *habitat* and ecological pathways; however, cities are devoid of biodiversity, as some species are able to adapt to urban environments and may even exploit urban structures that provide resources for breeding, feeding, and protection from predators, including native species [1] [2] [3] [4] [5].

The effects of urbanization should be studied at a local scale because each geographic area has a unique ecological community, climate, ecosystem, different levels of urbanization, alien species, and many others variables [6] [7]. Thus, accessing the local species richness, distribution, abundance, the most vulnerable species to disappear, and how communities assemble across the urban areas, is an important approach to understand the effects of *habitat* changes on species, and is the first step to support biodiversity conservation policies and decision-making in sustainable urban infrastructures, especially in developing countries [8] [9].

After Colombia and Peru, Brazil has the highest bird species richness with 1971 species, which are included in 33 orders, 102 families and 732 genera, with 293 endemic species, according to the Brazilian Ornithological Records Committee [10]. Among vertebrates, birds are the most studied taxa in urban areas as they are easy to monitor, identify, and because many species indicate the *habitat* integrity [8]. Despite urban ornithology research has increased in Latin America, many areas remain poorly studied [9] [11], highlighting the need for studies across diverse urban matrices beyond green areas and for the integration of functional trait approaches in ecological community analyses to better understand species differences and assess the magnitude of biodiversity loss [3] [6].

Studies on avifauna of Piauí have been focused only in protected areas, as Parque Nacional Serra da Capivara [19] [20], Parque Nacional Serra das Confusões [21], Parque Nacional de Sete Cidades [22]; remnants of native vegetation [23] [24], or in specific surveys made in some areas of the coast [25] [26] [27]. In this context, here we present the first study on bird assemblage of the Teresina municipality, State of Piauí, Northeast Brazil. Our objective was evaluate species richness, abundance, species composition, taxonomic and functional diversity, and the seasonal variation of the avifauna at sites with different levels of urbanization in the municipality of Teresina. In addition, we present a preliminary list of bird species for this municipality and indicate the most vulnerable species to urbanization.

Material and Methods

Study area

This research was carried out in the municipality of Teresina (05°05´20´´ S, 42°48´07´´ W), north of the State of Piauí, Northeast region of Brazil. This municipality is located at 343 km from the coast, between the Parnaíba and Poti rivers, at 74 m a.s.l., and its population is approximately 900,000 inhabitants [28] (Fig. 1A). The total urban area is 133 km^2, with 119 km^2 (89.5%) of continuous constructions with little spacing between buildings, and 14 km^2 (10.5%) with a more spaced occupation model, mainly occupied by condominiums or allotments [28]. The climate is tropical hot sub-humid (AW´) according to the Köppen´s classification, with an average annual temperature of 28.6 °C with a rainy period from December to May and a dry period from June to November [29] [30]. The region has a mosaic of phytophysiognomies of subcaducifolia forest, Cerrado and Caatinga [31].

Sample design and data collection

Ten sampling sites (S1 to S10) were chosen in the urban area (Fig. 1B; Table 1). These sites were in areas with different degrees of urbanization: S1 and S2 in downtown, a very urbanized area with little vegetation cover; S5, S6, S7, S8 and S10 in semi-urbanized areas with tree cover and sparse urban constructions; and the S3, S4, and S9 in urban parks. A one-kilometer-long transect was demarcated at each sampling site with five fixed counting points, 200 m between each one to avoid double counting of individuals. At each counting-point, a radius of 50 m was established around the observer who stayed for 10 minutes for bird recording, using the counting method [32] [33]. The specimens were counted through visual detections, using a 10x25 mm Nautika Bird binocular, and photographed whenever possible.

Data collection took place monthly from March to October 2018. In each monthly collection, observations were made during the morning, from 06h00-07h00, and when public security allowed, sampling was also conduct at night from 19h00-20h00, at sites 4, 8, and 9. A total of 80 observations were made in the morning and 24 at night, totalling 104 hours of observations.

Nomenclature and taxonomic classification followed the Annotated Lists of Birds of Brazil, published by the Brazilian Ornithological Records Committee [10] [34].

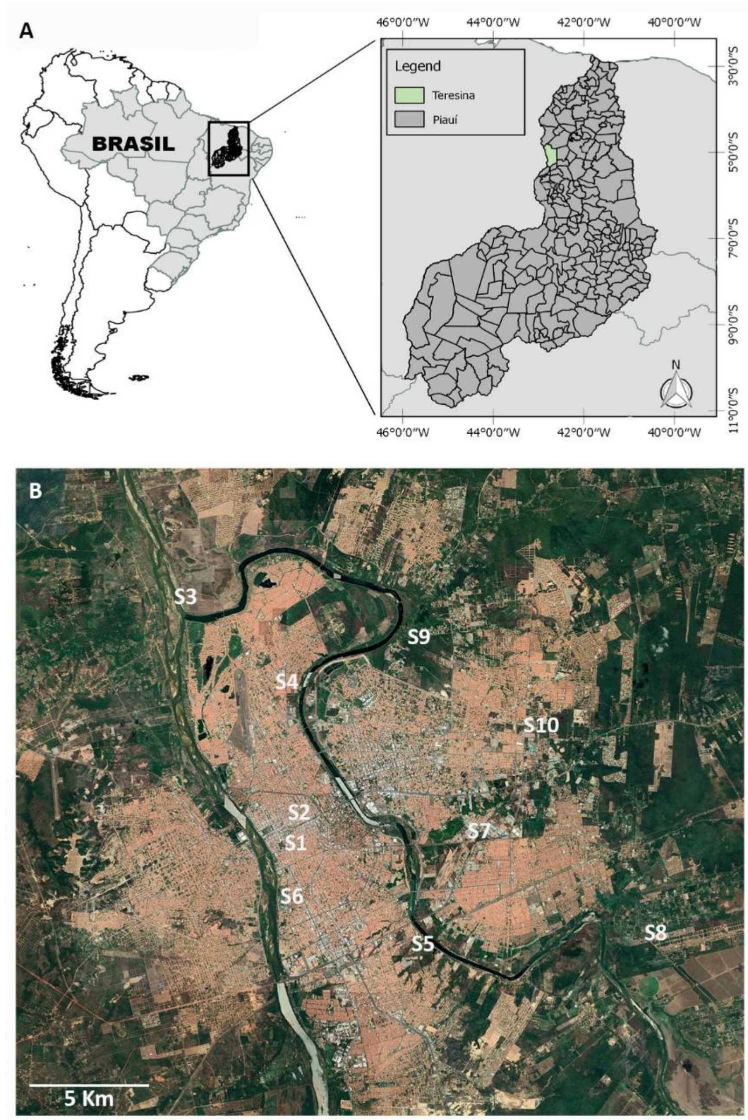

Figure 1 – (A) Study area; the municipality of Teresina, State of Piauí, northeast region of Brazil; **(B)** Sampling sites in the urban area.

Table 1 – Information on the study sites located in the municipality of Teresina, Piauí, Brazil.

Site	Adress	Geographical coordenates	Urban área	Arborization: Low (<10 trees)	Arborization: Medium (10-30 trees)	Arborization: High (>30 trees)	Description of the aquatic environment in the site
S1	**7 de Setembro street**	**05°05´50.37´´S, 42°48´35.7´´W**	**Downtown**	**X**			
S2	**Frei Serafim avenue**	**05°05´19.44´´S, 42°48´28.7´´W**	**Downtown**		**X**		
S3	**Encontro dos Rios Park**	**05°02´06.9´´S, 42°50´21´´W**	**North**			**X**	**At the margins of the Parnaíba and Poti rivers**
S4	**Park of the city**	**05°03´22.5´´S, 42°48´38.3´´W**	**North**			**X**	**At the margins of the Poti River**

https://doi.org/10.37002/biodiversidadebrasileira.v16i2.2857

S5	**Celso Pinheiro avenue**	**05°07´20.4´´S, 42°46´19´´W**	**South**			**X**	**At the margins of the Poti River**
S6	**Administrative center**	**05°´06´30.6´´S, 42°48´48.6´´W**	**South**			**X**	**At the margins of the Parnaíba; and has a lake with 40 m diameter, approximately**
S7	**Deputado Paulo Ferraz avenue**	**05°05´59´´S, 42°45´49.4´´W**	**Southeast**			**X**	
S8	**Camilo Filho avenue**	**05°7´18.7´´S, 42°42´50.3´´W**	**Southeast**			**X**	
S9	**Zoobotanical Park**	**05°02´29.2´´S, 42°46´31.5´´W**	**East**			**X**	**Has an artificial lake with 60 m diameter, approximately**
S10	**São Leonardo street**	**05°04´2.15´´S, 42°44´45.12´´W**	**East**			**X**	

Data analysis

Species accumulation curves were calculated for each sampling site to assess sample sufficiency, based on the number of samples, the observed species richness (S_{obs}, applying the Mao Tau statistic), and the first-order Jackknife richness estimator, based on 1000 randomizations, using the software EstimateS version 9.1 [35] [36].

The avifauna was evaluated for the species richness (S), abundance, number of individuals, evenness using the Pielou´s evenness index (J´), taxonomic diversity using the Hill N1 diversity index (eH´), and functional diversity (FD) using the RAO index [37] [38]. The seasonal variation in each sampling site was evaluated comparing the richness and the number of individuals between dry and rainy periods, significant differences ($p<0.05$) between arithmetic means were tested using a *t*-test. To assess the functional diversity, each species was categorized using functional traits for diet (omnivorous, ichthyophagous, carnivorous, insectivorous, necrophagous, malacophagous, granivorous, frugivorous, herbivorous, nectarivorous), foraging substrate (soil, water, air, vegetation), nesting substrate (cavity, vegetation, soil, on aquatic vegetation, urban construction), and *habitat* (aquatic, anthropic, arboreal, herbaceous) (Appendix 1). The functional traits information of each species was obtained from the literature [39] [40] [41]. To calculate the Rao index, each functional trait was quantified [37]. The Rao index assigns values ranges from 0 (maximum similarity between functional traits) to 1 (the maximum difference between functional traits) [42] [37].

The frequency of occurrence (FO) of each species was also calculated according to [43], where days of record of each species are multiplied by 100 and divided by the total collection campaigns (n=8). Thus, the percentage of FO of the species in the samples was classified as: *very common* (M), percentage equal to or greater than 75% ($X\geq75\%$); *common* (C), between 50% and 74% ($50< X< 74\%$); *uncommon* (I), between 15% and 49% ($15< X< 49\%$); *rare* (R), below 14% ($X\leq14\%$); and *occasional* (O) if recorded only once during the study.

To evaluate the similarity in species composition between the sampling sites, a dendrogram was built using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) algorithm, using a presence-absence matrix, and the Jaccard coefficient in the software R version 3.5.0, Vegan package [44]. We consider that the Jaccard coefficient is more appropriate to similarity analysis because the abundances in study sites may variate among dry/rainy periods, breeding seasons, and from year to year [45]. Furthermore, because water birds were sampled mainly in aquatic environments, water birds were excluded from the similarity analysis, as well as night birds, which were recorded only at night observations in sites S4, S8, and S9.

Results

Were registered 12,505 specimens of 115 species, representing 19 orders, 42 families, and 100 genera. The order Passeriformes was dominant (S = 54; 47%), with the Tyrannidae (S = 13), Thraupidae (S = 10) and Icteridae (S = 7) being the most representative families. Among the non-Passeriform orders, Ardeidae - Pelecaniformes (S = 5; 4.35%), and Psittacidae - Psittaciformes (S = 5; 4.35%) stood out (Table 2). The species accumulation curves showed stabilization for all sites, and comparing the observed richness (S_{obs} Mau Tau) with the estimated (Jackknife 1) between 85 to 93% of the species were recorded, indicating sample sufficiency (Fig. 2). Moreover, the presence of *uncommon* and *rare* species such as, *Pandion haliaetus* (Linnaeus, 1758), *Spizaetus tyrannus* (Wied, 1820), and *Falco peregrinus* Tunstall, 1771, also indicates efficiency in the methodology.

A total of 113 species were classified as residents according to the Brazilian Ornithological Records Committee [10], including six endemic to Brazil – *Furnarius figulus* (Lichtenstein, 1823), *Cyanocorax cyanopogon* (Wied, 1821), *Icterus jamacaii* (Gmelin, 1788), *Paroaria dominicana* (Linnaeus, 1758), *Veniliornis passerinus* (Linnaeus, 1766), and *Celeus ochraceus* (Spix, 1824) (Appendix 1) – and the most abundant species recorded were, in decreasing order, *Columbina squammata* (Lesson, 1831) (889 individuals), *Progne chalybea* (Gmelin, 1789) (869 individuals), *Coragyps atratus* (Bechstein, 1793) (662 individuals), and *Passer domesticus* (Linnaeus, 1758) (616 individuals) (Fig. 3A).

Regarding the diet, most species were insectivorous (S = 64; 55%) and frugivorous (S = 23; 20%), with four necrophagous species *Cathartes aura* (Linnaeus, 1758), *Cathartes burrovianus* Cassin, 1845, *Coragyps atratus*, and *Caracara plancus* (Miller, 1777); four nectarivorous species *Eupetomena macroura* (Gmelin, 1788), *Chlorostilbon lucidus* (Shaw, 1812), *Chionomesa fimbriata* (Gmelin, 1788), and *Coereba flaveola* (Linnaeus, 1758); and two malacophagous species *Rostrhamus sociabilis* (Viellot, 1817) and *Aramus guarauna* (Linnaeus, 1766) (Fig. 3B; Appendix 1). Most species (S = 91; 79%) use vegetation as a nesting substrate, with only 10 species (8.7%) able to nest in urban construction (Fig. 3C). Vegetation is the place where the most species forage (S = 80; 69.5%) (Fig. 3D), and usually use as *habitat* (S = 85, 73.9%) (Fig. 3E). The results of functional traits analysis also showed that 29 species (25%) are associated with aquatic *habitat* (Fig. 3E).

Among the sites, site 2 showed the lowest richness (S = 29) and the lowest number of individuals (n = 692), and the site 9 housed 91.3% (S = 105) of the total listed species and also had the highest number of individuals (n = 2224) (Fig. 4A, Fig. 4B). The Pielou´s evenness index (J´) values varied between 0.72 (site 6) and 0.9 (site 3) (Fig. 4C). The site 2 had the lowest diversity value (eH´ = 13.7) and the site 9 the highest value (eH´ = 60.34) (Fig. 4D). The functional diversity analysis showed that all sites housed species with differences in functional traits, with Rao index values varying between 0.56 (site 1) and 0.65 (site 5) (Fig. 4E). Richness and the number of individuals varied between the dry and rainy periods, significant differences ($p < 0.05$) were observed for the number of individuals at sites 4 ($p = 0.03$), 5 ($p = 0.01$), and 6 ($p = 0.001$), and for richness only at site 3 ($p = 0.02$) (Fig. 4F).The similarity dendrogram identified four main groups (S1–S2, S6–S10, S3–S9, and S5–S7), while S4 and S8 were the most dissimilar sites (Fig. 5); according to the FO classification, 99 species (86%) were considered *very common* (M), seven *common* (C), eight *uncommon* (I), one *rare* species (*Pandion haliaetus*), and none *occasional* (Table 2).

Table 2 – Taxonomy list of bird species recorded from March to October 2018, in the urban area of Teresina, State of Piauí, Brazil. Nomenclature and taxonomic order according to the Brazilian Ornithological Records Committee [10]. Legend: Ab = abundance; FO% = frequency of occurrence; R = resident; E = endemic.

Species	Sampled sites										Total Ab	FO %	Status
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10			
ANSERIFORMES Linnaeus, 1758													
Anatidae Leach, 1820													
Dendrocygna bicolor (Vieillot, 1816)	0	0	0	0	0	25	0	0	0	0	25	62.5	R
Dendrocygna viduata (Linnaeus, 1766)	0	0	0	0	0	426	0	0	0	0	426	100	R
Dendrocygna autumnalis (Linnaeus, 1758)	0	0	0	0	12	374	0	0	0	0	386	100	R
Amazonetta brasiliensis (Gmelin, 1789)	0	0	0	0	0	15	0	0	0	0	15	50	R
SULIFORMES Sharpe, 1891													
Phalacrocoracidae Reichenbach, 1849													
Nannopterum brasilianum (Gmelin, 1789)	0	0	5	0	13	0	0	0	6	0	24	37.5	R
PELECANIFORMES Sharpe, 1891													
Ardeidae Leach, 1820													
Tigrisoma lineatum (Boddaert, 1783)	0	0	5	0	0	0	1	0	5	0	11	75	R
Butorides striata (Linnaeus, 1758)	0	0	9	0	5	0	0	0	9	0	23	100	R
Bubulcus ibis (Linnaeus, 1758)	0	0	0	0	17	0	0	10	15	0	42	75	R
Ardea alba (Linnaeus, 1758)	0	0	30	0	9	0	0	0	6	0	45	100	R
Egretta thula (Molina, 1782)	0	0	60	0	25	0	0	0	32	0	117	100	R
CATHARTIFORMES Seebohm, 1890													
Cathartidae Lafresnaye, 1839													
Cathartes aura (Linnaeus, 1758)	0	2	18	10	22	11	15	11	9	8	106	100	R
Cathartes burrovianus Cassin, 1845	1	2	10	7	16	5	11	19	13	16	100	100	R
Coragyps atratus (Bechstein, 1793)	14	20	76	36	107	53	124	75	61	96	662	100	R
ACCIPITRIFORMES Bonaparte, 1831													
Pandionidae Bonaparte, 1854													
Pandion haliaetus (Linnaeus, 1758)	0	0	1	0	1	0	0	0	0	0	2	12.5	
Accipitridae Vigors, 1824													
Rostrhamus sociabilis (Vieillot, 1817)	0	0	6	0	4	0	6	0	9	0	25	100	R
Geranospiza caerulescens (Vieillot, 1817)	0	0	1	1	1	0	7	3	1	1	15	87.5	R
Rupornis magnirostris (Gmelin, 1788)	12	3	12	12	17	10	8	11	19	10	114	100	R

Species	Sampled sites										Total Ab	FO %	Status
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10			
Spizaetus tyrannus (Wied, 1820)	0	0	0	0	0	3	0	0	0	0	3	37.5	R
GRUIFORMES Bonaparte, 1854													
Aramidae Bonaparte, 1852													
Aramus guarauna (Linnaeus, 1766)	0	0	4	0	1	0	0	0	9	0	14	100	R
Rallidae Rafinesque, 1815													
Aramides cajaneus (Statius Muller, 1776)	0	0	2	0	0	0	0	0	14	0	16	75	R
Gallinula galeata (Lichtenstein, 1818)	0	0	10	0	10	0	0	0	8	0	28	87.5	R
Porphyrio martinica (Linnaeus, 1766)	0	0	15	0	13	0	22	0	16	0	66	100	R
CHARADRIIFORMES Huxley, 1867													
Charadriidae Leach, 1820													
Vanellus chilensis (Molina, 1782)	0	0	29	7	22	3	27	34	36	10	168	100	R
Jacanidae Chenu & Des Murs, 1854													
Jacana jacana (Linnaeus, 1766)	0	0	29	0	59	0	26	0	26	0	140	100	R
Sternidae Vigors, 1825													
Phaetusa simplex (Gmelin, 1789)	0	0	25	0	0	0	0	0	0	0	25	100	R
COLUMBIFORMES Latham, 1790													
Columbidae Leach, 1820													
Columbina talpacoti (Temminck, 1810)	20	15	43	72	32	28	30	54	41	36	371	100	R
Columbina squammata (Lesson, 1831)	74	78	58	175	58	86	56	88	105	111	889	100	R
Columba livia Gmelin, 1789	106	98	12	38	67	61	45	28	16	48	519	100	R
Leptotila rufaxilla (Richard & Bernard, 1792)	0	0	3	14	2	0	3	5	12	0	39	100	R
CUCULIFORMES Wagler, 1830													
Cuculidae Leach, 1820													
Piaya cayana (Linnaeus, 1766)	0	0	1	6	0	0	0	0	6	0	13	87.5	R
Crotophaga major Gmelin, 1788	0	0	25	0	3	0	0	0	30	0	58	87.5	R
Crotophaga ani Linnaeus, 1758	6	0	40	50	31	38	24	42	58	40	329	100	R
Guira guira (Gmelin, 1788)	4	0	0	33	7	9	28	0	41	11	133	100	R
STRIGIFORMES Wagler, 1830													
Tytonidae Mathews, 1912													
Tyto furcata (Temminck, 1827)	0	0	0	6	0	0	0	10	7	0	23	87.5	R

Species	Sampled sites S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total Ab	FO %	Status
Strigidae Leach, 1820													
Megascops choliba (Vieillot, 1817)	0	0	0	11	0	0	0	7	20	0	38	100	R
Glaucidium brasilianum (Gmelin, 1788)	0	0	0	11	1	0	0	7	13	0	32	100	R
CAPRIMULGIFORMES Ridgway, 1881													
Caprimulgidae Vigors, 1825													
Nyctidromus albicollis (Gmelin, 1789)	0	0	0	14	0	0	0	16	21	0	51	100	R
Hydropsalis parvula (Gould, 1837)	0	0	0	12	0	0	0	1	19	0	32	87.5	R
APODIFORMES Peters, 1940													
Apodidae Olphe-Galliard, 1887													
Tachornis squamata (Cassin, 1853)	102	58	32	40	42	98	34	44	126	33	609	100	R
Trochilidae Vigors, 1825													
Eupetomena macroura (Gmelin, 1788)	3	2	1	3	0	4	5	1	9	2	30	100	R
Chlorostilbon lucidus (Shaw, 1812)	1	0	6	7	1	0	2	2	5	0	24	100	R
Chionomesa fimbriata (Gmelin, 1788)	7	4	12	21	5	11	12	7	19	6	104	100	R
TROGONIFORMES A. O. U., 1886													
Trogonidae Lesson, 1828													
Trogon curucui Linnaeus, 1766	0	0	0	8	0	0	0	0	12	0	20	100	R
CORACIIFORMES Forbes, 1844													
Alcedinidae Rafinesque, 1815													
Megaceryle torquata (Linnaeus, 1766)	0	0	6	0	0	2	0	0	3	0	11	100	R
Chloroceryle amazona (Latham, 1790)	0	0	7	0	0	7	0	0	4	0	18	100	R
Chloroceryle americana (Gmelin, 1788)	0	0	5	0	0	4	0	0	3	0	12	75	R
GALBULIFORMES Fürbringer, 1888													
Galbulidae Vigors, 1825													
Galbula ruficauda Cuvier, 1816	0	0	5	3	0	0	0	0	7	0	15	87.5	
PICIFORMES Meyer & Wolf, 1810													
Ramphastidae Vigors, 1825													
Pteroglossus inscriptus Swainson, 1822	0	0	0	0	0	0	0	0	28	0	28	87.5	R
Pteroglossus aracari (Linnaeus, 1758)	0	0	0	0	0	0	0	0	15	0	15	75	R

	Sampled sites												
Species	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**Total Ab**	**FO %**	**Status**
Picidae Leach, 1820													
Veniliornis passerinus (Linnaeus, 1766)	7	0	10	14	10	4	10	8	11	2	76	100	R, E
Celeus ochraceus (Spix, 1824)	0	0	0	0	0	0	0	0	8	0	8	62.5	R, E
Campephilus melanoleucos (Gmelin, 1788)	0	0	2	8	1	0	1	2	21	1	36	100	R
FALCONIFORMES Bonaparte, 1831													
Falconidae Leach, 1820													
Caracara plancus (Miller, 1777)	3	2	9	1	13	19	6	3	14	11	81	100	R
Milvago chimachima (Vieillot, 1816)	0	0	6	3	5	2	4	6	11	1	38	100	R
Herpetotheres cachinnans (Linnaeus, 1758)	0	0	0	0	0	0	0	5	2	0	7	62.5	R
Falco peregrinus Tunstall, 1771	4	6	0	0	0	1	0	0	0	0	11	37.5	
PSITTACIFORMES Wagler, 1830													
Psittacidae Rafinesque, 1815													
Psittacara leucophthalmus (Statius Muller, 1776)	0	0	21	0	0	5	21	36	7	2	92	100	R
Aratinga jandaya (Gmelin, 1788)	0	0	0	0	0	0	13	0	29	0	42	100	R
Eupsittula aurea (Gmelin, 1788)	0	0	6	9	4	5	3	0	7	10	44	100	R
Forpus xanthopterygius (Spix, 1824)	0	0	0	0	0	0	0	0	5	0	5	50	R
Brotogeris chiriri (Vieillot, 1818)	23	9	25	25	15	24	14	27	37	20	219	100	R
PASSERIFORMES Linnaeus, 1758													
Thamnophilidae Swainson, 1824													
Thamnophilus doliatus (Linnaeus, 1764)	0	0	11	15	1	0	9	8	17	2	63	100	R
Taraba major (Vieillot, 1816)	0	0	2	4	0	0	0	0	10	0	16	87.5	R
Dendrocolaptidae Gray, 1840													
Dendroplex picus (Gmelin, 1788)	0	0	7	10	1	2	0	5	6	0	31	100	R
Furnariidae Gray, 1840													
Furnarius figulus (Lichtenstein, 1823)	0	0	15	0	2	0	0	0	10	0	27	87.5	R, E
Furnarius leucopus Swainson, 1838	0	0	15	13	16	5	14	16	24	4	107	100	R
Certhiaxis cinnamomeus (Gmelin, 1788)	0	0	25	0	16	0	0	0	23	0	64	100	R
Rhynchocyclidae Berlepsch, 1907													
Tolmomyias flaviventris (Wied, 1831)	9	8	17	32	10	5	13	12	28	3	137	100	R
Todirostrum cinereum (Linnaeus, 1766)	33	33	35	37	24	27	33	34	36	21	313	100	R

https://doi.org/10.37002/biodiversidadebrasileira.v16i2.2857

Species	Sampled sites										Total Ab	FO %	Status
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10			
Tyrannidae Vigors, 1825													
Attila spadiceus (Gmelin, 1789)	0	0	0	4	0	0	1	0	6	0	11	75	R
Myiarchus ferox (Gmelin, 1789)	0	0	0	1	0	0	1	0	1	0	3	37.5	R
Pitangus sulphuratus (Linnaeus, 1766)	51	23	47	52	21	30	39	37	37	25	362	100	R
Philohydor lictor (Lichtenstein, 1823)	0	0	10	0	3	0	8	2	11	0	34	100	R
Machetornis rixosa (Vieillot, 1819)	12	16	6	0	8	12	3	8	13	14	92	100	R
Myiodynastes maculatus (Statius Muller, 1776)	0	0	3	4	0	0	2	0	4	0	13	75	R
Megarynchus pitangua (Linnaeus, 1766)	0	0	2	12	2	0	5	4	5	1	31	100	R
Myiozetetes cayanensis (Linnaeus, 1766)	5	0	7	5	6	6	5	2	7	0	43	100	R
Myiozetetes similis (Spix, 1825)	0	0	0	7	3	3	6	4	8	0	31	100	R
Tyrannus melancholicus Vieillot, 1819	12	13	7	16	18	22	10	0	26	7	131	100	R
Fluvicola albiventer (Spix, 1825)	0	0	0	0	12	0	9	0	0	0	21	87.5	R
Fluvicola nengeta (Linnaeus, 1766)	12	0	24	0	20	22	28	21	33	14	174	100	R
Arundinicola leucocephala (Linnaeus, 1764)	0	0	5	0	14	0	15	0	5	0	39	100	R
Vireonidae Swainson, 1837													
Cyclarhis gujanensis (Gmelin, 1789)	0	0	0	8	1	0	1	2	5	0	17	100	R
Corvidae Leach, 1820													
Cyanocorax cyanopogon (Wied, 1821)	0	0	0	5	0	0	0	0	18	0	23	87.5	R, E
Hirundinidae Rafinesque, 1815													
Progne tapera (Vieillot, 1817)	0	0	4	0	12	0	6	6	24	0	52	100	R
Progne chalybea (Gmelin, 1789)	268	189	43	90	53	65	63	24	12	62	869	100	R
Tachycineta albiventer (Boddaert, 1783)	0	0	15	0	0	2	0	0	2	0	19	87.5	R
Troglodytidae Swainson, 1831													
Troglodytes musculus Naumann, 1823	22	10	22	39	16	19	15	20	35	14	212	100	R
Pheugopedius genibarbis (Swainson, 1838)	0	0	3	4	2	0	1	0	7	0	17	100	R
Cantorchilus longirostris (Vieillot, 1819)	0	0	7	5	4	0	3	0	7	0	26	100	R, E
Donacobiidae Aleixo & Pacheco, 2006													
Donacobius atricapilla (Linnaeus, 1766)	0	0	0	0	0	0	0	0	11	0	11	75	R
Polioptidae Baird, 1858													
Polioptila atricapilla (Gmelin, 1788)	3	6	14	16	4	8	5	7	17	0	80	100	R

Species	Sampled sites S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total Ab	FO %	Status
Turdidae Rafinesque, 1815													
Turdus rufiventris Vieillot, 1818	0	0	0	0	0	0	0	0	3	0	3	37.5	R
Turdus leucomelas Vieillot, 1818	0	0	9	16	0	2	7	8	14	6	62	100	R
Turdus amaurochalinus Cabanis, 1850	0	0	1	2	0	0	1	1	2	0	7	62.5	R
Icteridae Vigors, 1825													
Psarocolius decumanus (Pallas, 1769)	5	0	35	33	13	11	17	57	44	8	223	100	R
Cacicus cela (Linnaeus, 1758)	0	0	1	4	0	0	0	0	5	0	10	75	R
Icterus jamacaii (Gmelin, 1788)	0	0	0	0	0	0	0	0	5	0	5	37.5	R, E
Gnorimopsar chopi (Vieillot, 1819)	0	0	0	0	0	0	0	0	2	0	2	25	R
Chrysomus ruficapillus (Vieillot, 1819)	0	0	0	0	0	0	0	0	116	0	116	100	R
Molothrus oryzivorus (Gmelin, 1788)	0	0	0	0	0	0	0	0	4	0	4	37.5	R
Molothrus bonariensis (Gmelin, 1789)	0	0	6	3	75	22	0	0	133	8	247	100	R
Thraupidae Cabanis, 1847													
Paroaria dominicana (Linnaeus, 1758)	0	0	0	0	0	0	0	0	13	0	13	75	R, E
Thraupis sayaca (Linnaeus, 1766)	0	0	5	2	7	5	12	0	0	0	31	87.5	R
Thraupis palmarum (Wied, 1821)	11	8	16	14	16	19	17	15	32	9	157	100	R
Nemosia pileata (Boddaert, 1783)	2	1	16	15	12	17	1	6	27	0	97	100	R
Conirostrum speciosum (Temminck, 1824)	0	2	7	4	6	0	4	1	12	0	36	87.5	R
Sicalis flaveola (Linnaeus, 1766)	13	16	10	14	10	20	17	9	23	14	146	87.5	R
Hemithraupis guira (Linnaeus, 1766)	4	0	21	4	8	11	7	12	4	0	71	100	R
Volatinia jacarina (Linnaeus, 1766)	0	0	18	9	14	4	10	11	7	19	92	50	R
Coereba flaveola (Linnaeus, 1758)	20	25	18	27	18	12	11	23	25	17	196	100	R
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	2	2	2	5	10	2	1	2	1	2	29	87.5	R
Fringillidae Leach, 1820													
Euphonia chlorotica (Linnaeus, 1766)	0	0	1	10	2	0	6	5	6	0	30	100	R
Estrildidae Bonaparte, 1850													
Estrilda astrild (Linnaeus, 1758)	16	7	53	68	62	30	52	39	177	69	573	100	R
Passeridae Rafinesque, 1815													
Passer domesticus (Linnaeus, 1758)	51	34	62	46	30	74	31	74	55	159	616	100	R
Richness	35	29	82	68	73	55	67	59	105	42			
Number of individuals	938	692	1309	1312	1203	1790	1047	1037	2224	953	12,505		

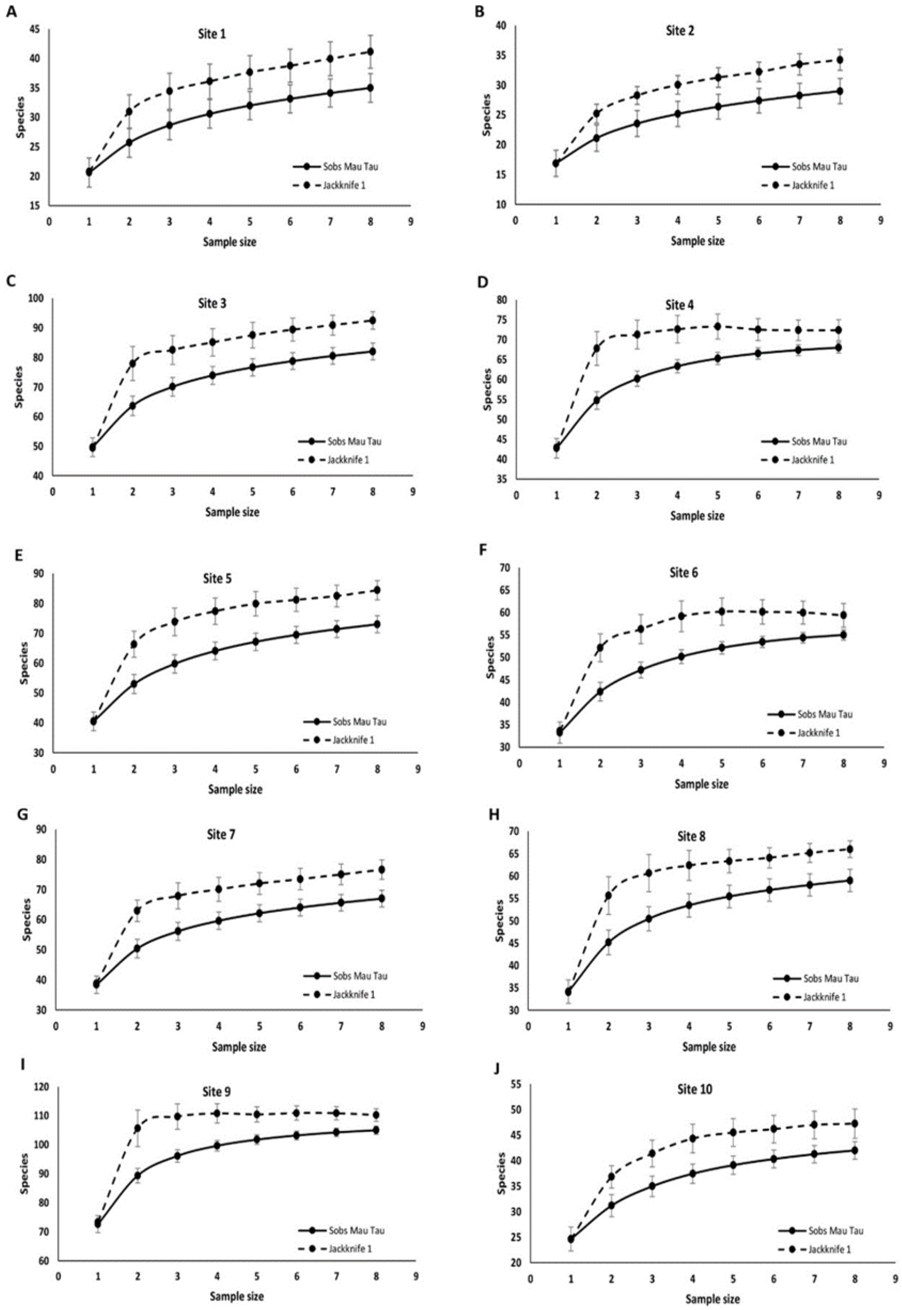

Figure 2 – Species accumulation curves representing the species richness observed (solid lines) and estimated by Jackknife 1 estimator (dashed lines) based on eight sampling campaigns conducted from March to October 2018. The vertical bars indicate the standard deviations of species richness observed and estimated.

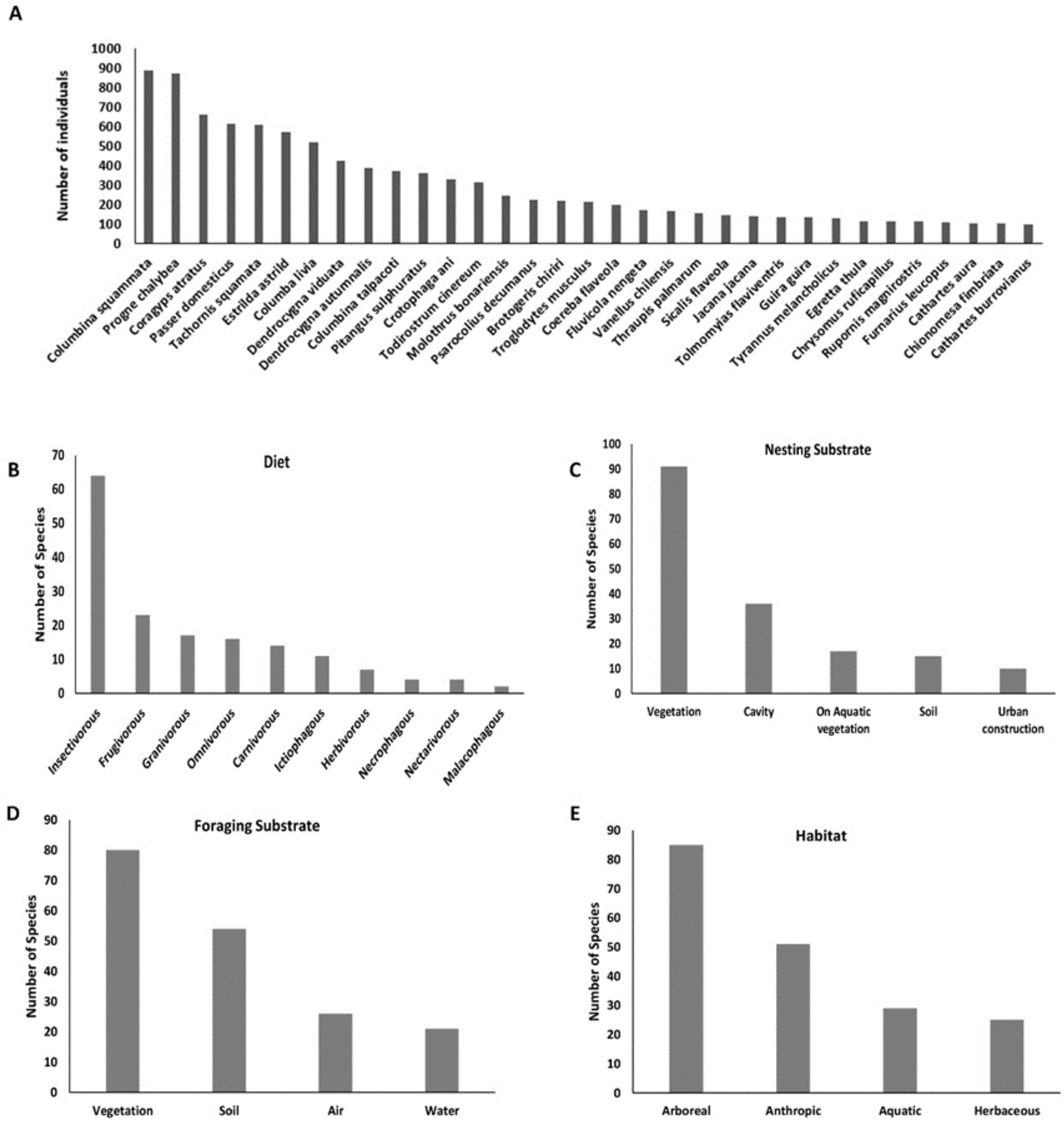

Figure 3 – The most abundant species in decreasing order (A). The number of bird species classified according to functional traits to diet (B), nesting substrate (C), foraging substrate (D), and habitat (E).

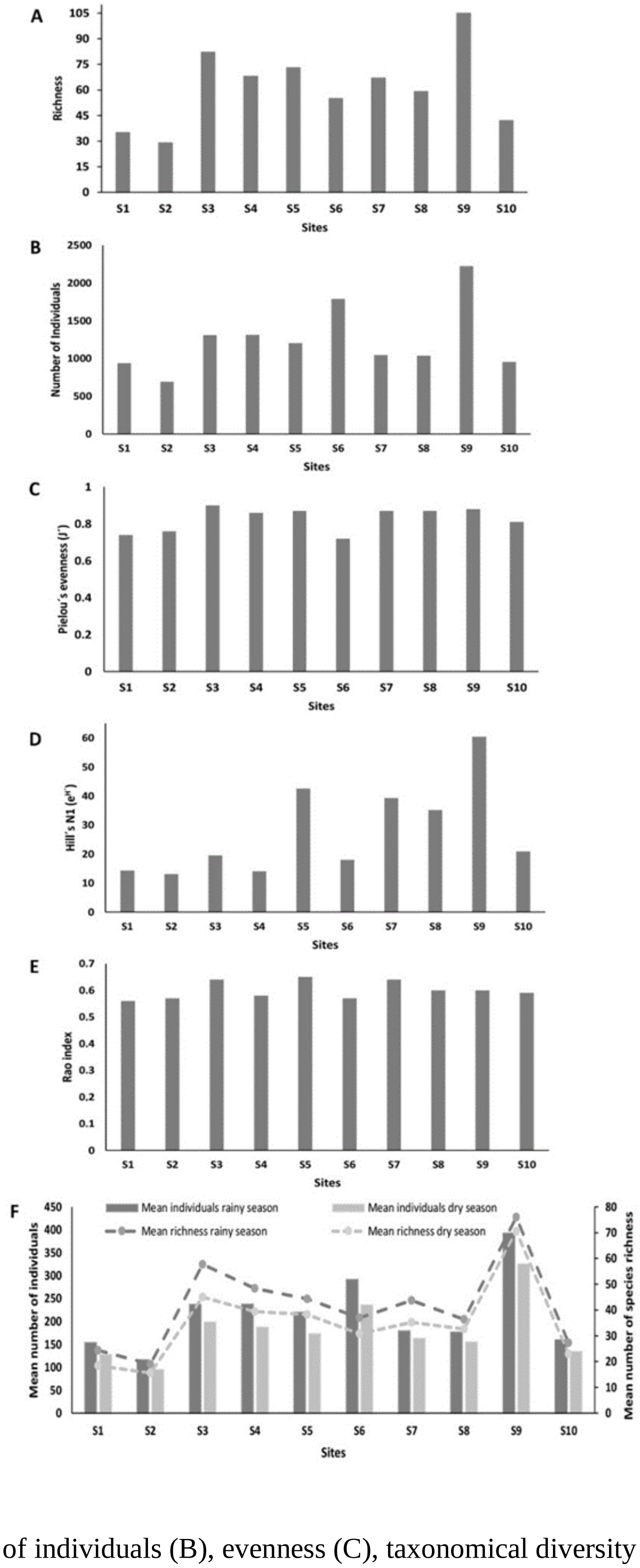

Figure 4 – Richness (A), number of individuals (B), evenness (C), taxonomical diversity (D), functional diversity (E), and seasonal variation between dry and rainy periods found in each sampling sites (F).

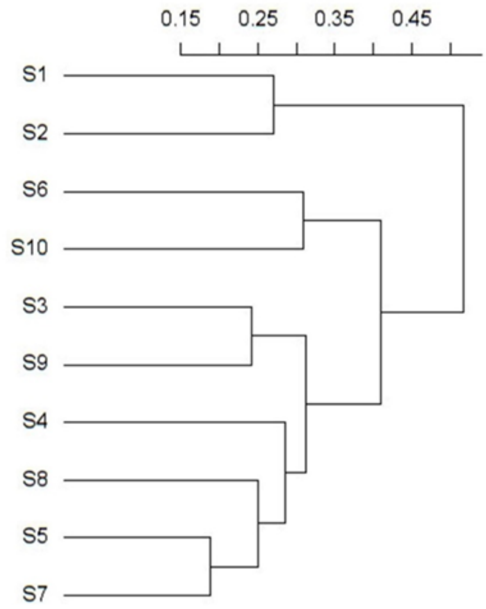

Figure 5 – Dendrogram for similarity of bird species compositions in ten sampling sites in the Teresina municipality, Piauí, Brazil. The scale bar shows the Jaccard coefficient.

Discussion

The total of 115 bird species recorded in Teresina is only between 34.2% to 42.2% of the richness described in inventories carried out in protected native vegetation remnants, such as national parks [19] [20] [21] [22], and environments little anthropized in the State of Piauí [23] [24] [25]. When compared to other inventories performed in highly anthropized areas, such as in a carnaubal area [46] and at the international airport of Parnaíba [27], the species richness of Teresina is more similar to these areas, varying from 69.4% to 79.6%, respectively. We consider the species richness in Teresina to be low, indicating species loss due to the urbanization process.

The comparison of the richness between different areas evidently requires care and sometimes must not be done, because the species have different responses to environmental changes, differences in latitude, altitude and climate can affect the geographical distribution, and the differences in the sampling methods [47] [48] [49]. However, considering that this is the first study on the assembly of birds in the municipality of Teresina, and there are no other studies throughout urban areas in Piauí, the comparison of the richness with other inventories carried out in the region, helped us to assess the impact of urbanization on avifauna.

Teresina is classified as a city with a moderate degree of urban construction [28], however, the richness of birds recorded is similar to those cities with an intense degree of urbanization, such as Porto Alegre, in Rio Grande do Sul, with 135 species, and Uberlândia, in Minas Gerais, with 149 species [50] [51]. Richness values lower than this were found in the cities of Uruguaiana (Rio Grande do Sul) with 34 species [52], Ipatinga (Minas Gerais) with 57 species [53], and Iporá (Goiás) with 70 species [54].

Among the 10 sampling sites throughout the city, the low richness, the similarity in species composition, the low abundance and low taxonomic and functional diversity in the most central sites (1, 2, 6, and 10) can be attributed to the intense degree of urbanization. Similar results were also found by [55] in the central and urbanized area of the city of Uberlândia, in Minas Gerais, where they registered only 66 species.

Abundance values indicated no dominant species at any collecting sites; consequently, evenness values were high and consistent among species commonly found in urban environments. The most abundant species were those usually found in urban areas, such as the exotic *Columba livia* (Gmelin, 1789), *Estrilda astrild* (Linnaeus, 1758) and *Passer domesticus* (Linnaeus, 1758) [56] [16]. The greater abundance of *P. domesticus* at site 10, for example, was possibly due to a high concentration of residences and vacant lands at this site, what offer suitable conditions for nesting and feeding. An interesting fact is that the counting of *P. domesticus* was possible here, as large flocks were not seen, as it is often observed in other cities [18].

Estrilda astrild was predominantly seen in Site 9, as this site has a large amount of grasses, its main source of food. *Columba livia* was more abundant in the urban centre (sites 1 and 2) because these places provide remains of food discarded by people. *Columba livia* was not registered in any conservation unit in Piauí, which confirms the association of this species with anthropic activity [20] [25] [22] [21]. *Columbina squammata*, the most abundant species in Teresina, could be observed almost everywhere, mainly in backyards, where they use roof eaves for nesting, indicating that this species benefit from urban constructions (personal observation). Other species that also benefits from urban constructions or are tolerant to urbanization are: *Progne chalybea*, *Pitangus sulphuratus*, *Troglodytes musculus* [57] [18].

Although the aforementioned species are granivorous, the greater richness of insectivorous species (Fig. 3B) was already expected, as there is a tendency to find a predominance of insectivorous birds in disturbed environments [58] [27]. In addition, the large number of the insectivorous Tyrannidae can also be justified, as the species of this family shows resilience in inhabiting different environments including disturbed areas [59]. Furthermore, the presence of Tytonidae, Accipitridae (except *Rostrhamus sociabilis*) and Falconidae (except *Milvago chimachima*) can be justified by the proliferation of rodents in the urban environment [60] [61].

Among the notable species registered, there were some migratory from the Northern Hemisphere [62]: *Pandion haliaetus*, also recorded by Olmos and Brito [24] at Boa Esperança Dam (border between Maranhão and Piauí); and *Falco peregrinus* Tunstall, 1771, a species that also occurs in the Environmental Protection Area of the Delta do Parnaíba (PI) [26]. Additionally, it was notable the presence of 14 species usually found in illegal bird trafficking and pet trade in Piauí [63], such as *Gnorimopsar chopi*, *Sicalis flaveola*, *Icterus jamacaii*, and *Psarocolius decumanus*. In some regions in Northeast Brazil, *G. chopi*, for example, was extinct by this activity [57].

Overall, differences between the dry and rainy seasons were not observed in most sites. However, significant differences in species richness were detected at site 3 due to the presence of 11 species recorded only in the dry period: *Pandion haliaetus, Geranospiza caerulescens, Aramides cajaneus, Piaya cayana, Eupetomena macroura, Taraba major, Megarynchus pitangua, Arundinicola leucocephala, Turdus amaurochalinus, Thraupis sayaca*, and *Euphonia chlorotica*. The increase of records of some species during the rainy season at site 4 (*Cathartes burrovianus, Tachornis squammata, Progne Chalybea, Estrilda astrild, Columbina squammata*), site 5 (*Dendrocygna viduata, Rupornis magnirostris, Porphyrio martinica, Vanellus chilensis, Progne chalybea, Molothrus bonariensis*), and site 6 (*Coragyps atratus, Tachornis squammata, Progne chalybea, Estrilda astrild, Passer domesticus*), was responsible for the significant differences in these sites. This possibly matches the reproduction period or more food resources seasonally available to these species.

The presence of artificial lakes and rivers that surround the city is essential because they are mandatory environments for Anatidae (*Dendrocygna bicolor*, *D. viduata*, *D. autumnalis* and *Amazonetta brasiliensis*), in sites 5 and 6, and riparian species such as *Egretta thula* (Molina, 1782), *Rostrhamus sociabilis* (Vieillot, 1817) and *Aramus guarauna* (Linnaeus, 1766) which depend on these environments to feed and live. Olmos et al. [57] also highlighted the importance of aquatic environments for the permanence of these species in a study conducted in Petrolina, Pernambuco.

Although urbanization has been shown to have a negative impact on avifauna, the most important finding in our results was the evidence that the green areas as the urban parks were responsible for the permanence and maintenance of most bird species, indicated by the highest values of richness, diversity, abundance, and similarity in species composition in these sites. Analysis of functional traits revealed that most species are dependent on vegetation to nest, forage and inhabit (Fig. 3C-E). In this way, the Site 9 (at Zoobotanical Park) was the most diverse, harboring 105 (91.35%) of the total 115 species. Similar results were found in parks and green areas in other cities such as Porto Alegre, with 170 species [64]; Caxias do Sul also with 170 species [65], Maringá (Paraná) with 144 species [14], Vitória (Espírito Santo) with 120 species and Uberlândia (Minas Gerais) with 149 species [50], which reinforces the importance of these green places for the maintenance of birds in urban areas.

Some of the species are typically from forest systems, such as *Psarocolius decumanus*, *Pteroglossus inscriptus* (species with predominant Amazonian distribution), *Thamnophilus doliatus* (Linnaeus, 1764) and *Spizaetus tyrannus* [57] [24]. The record of *Spizaetus tyrannus*, was the first record for the State of Piauí, and this species is associated with the edges of primary and secondary forests and has already been extinct in other regions in Brazil by the anthropization and removal of native forest vegetation [66]. We also report the first record of *Attila spadiceus* for Piauí. Little is known about its *habitat* in Brazil, but the species appears to be associated with forest systems, as it has been recorded in bamboo forests in Acre [67] and in secondary forests in Colombia [68]. We also recorded species commonly found in the Caatinga biome such as *Cyanocorax cyanopogon*, *Tolmomyias flaviventris* (Wied, 1831), *Paroaria dominicana* and *Icterus jamacaii*, the two latter considered endemic to this biome [23]. Species in Cerrado phytophysiognomies or deciduous forests, as *Hemithraupis guira*, *Crotophaga ani* and *Guira guira* were recorded. Some of these species (such as *P. dominicana* and *Guira guira*) benefit from abandoned fields and live in open areas, previously forested, showing resilience to the degradation of the natural environment [20]. These results agree with the phytophysiognomies surrounding Teresina, which consists of a mosaic of Cerrado, Caatinga, and subcaducifolia forest [31]. However, a survey on afforestation revealed that 47.8% of the plant species used for afforestation in the city are exotic, with the species *Azadirachta indica* (Meliaceae) being the most used in avenues and sidewalks [69]. That is a matter to worry because this percentage is much higher than that found in a global analysis carried out in urban areas, where the average of exotic plants was 28% [70].

To prevent the decline of species in Teresina, we suggest that it should be planting in the urban area the same native species found in the surrounding area. An example of the importance of native plant for bird species was the abundance and the registry of *Tachornis squamata* (Cassin, 1853) in all sampling sites, which can be attributed to the presence of buriti palms (*Mauritia flexuosa*), a very abundant species throughout Teresina, including avenues (personal observation). The *M. flexuosa* palm is considered a key species for obtaining resources by many species, and *T. squamata* illustrates its importance very well, since they build their nests in the crown of these palm trees and nowhere else [71]. This indicates that *T. squamata*, as well as the other species of birds recorded here that are associated with forest vegetation, can disappear from the urban area due to intensive deforestation of the surroundings and the replacement of native plants by exotic ones.

Conclusion

The Teresina municipality has low species richness compared to preserved natural remnants in the region, and the most abundant species were those usually found in urban areas, even exotics. Among the sampling sites, the urban parks showed high richness and diversity values, which indicates its importance in the maintenance of bird species in the urban area, mainly for those which depend on vegetation to nest, feed, and inhabit. We also recorded two new records for Piauí: *Spizaetus tyrannus* and *Attila spadiceus*.

As a conservation strategy, it is imperative to plan the city expansion avoiding the intensification of deforestation of its surroundings, prioritize native species in urban afforestation, the creation of new parks, and maintenance of the existing ones to prevent species decline or extinction of the local bird species.

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Biodiversidade Brasileira
Fluxo Contínuo
v. 16 n.2, 2026
https://revistaeletronica.icmbio.gov.br/index.php/BioBR/
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ISSN: 2236-2886