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RESEARCH ARTICLE

Community of diurnal birds of prey in an urban area in southeastern Brazil

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Abstract

As urban areas expand, some species of diurnal birds of prey occupy these habitats, and many establish viable populations. The objectives of this study were to: (1) survey the species of birds of prey in the urban area located in the interior of the São Paulo state, Brazil, (2) to verify the proportion of generalist and specialist species in terms of habitat and diet, (3) determine the period that the species are more active during the time period of the point counts, and (4) to evaluate if there is a pattern of seasonality. Samples were collected monthly between October 2014 and September 2016 using the point counts method (four points; 4 hr duration each). We analyzed species richness, habitat and diet, number of contacts and frequency of occurrence, period of greatest activity, and seasonality. We recorded 19 species of birds of prey through 2555 contacts. Most of the registered species (61%) were habitat and diet generalists, and the same percentage of species classified as uncommon or rare. In relation to the period of greatest activity, falconids were more active in the first hour while accipitrids and cathartids were more active in the fourth hour. In addition, we did not observe a seasonal pattern in this community, but *Gampsonyx swainsonii* showed a seasonal trend. We verified that the urban area of the municipality of Pirajuí has a significant diversity of birds of prey, including specialist species of habitat and diet. This information obtained evidence the importance of urban environments for birds of prey and showed the ability of these species to use this environment. From our results, we suggest that future studies should evaluate the effects of urban areas of different sizes and degrees of urbanization on bird of prey communities.

PENSOFT

Keywords
neotropical region, point counts, raptors, sazonality, urban ecology

Introduction

The term 'diurnal birds of prey' is used to classify 313 species of birds currently distributed in three orders: Cathartiformes, Accipitriformes and Falconiformes (Ferguson-Lees and Christie 2001). Brazil hosts 76 species, six of which are Cathartiformes, 49 Accipitriformes, and 21 Falconiformes (Piacentini et al. 2015). Of these, 52 species occur in the São Paulo state, four of which are Cathartiformes, 37 Accipitriformes, and 11 Falconiformes (Figueiredo 2016).

It is well known that the growth of urban areas can negatively affect local biodiversity either through loss or degradation of habitats, alteration to the landscape with anthropic constructions, introduction of exotic species, or indirect effects, such as climate change, interference in ecological interactions, and availability of food, in addition to human disturbances (Marzluff 2001; Chace and Walsh 2006; Ortega-Álvarez and MacGregor-Fors 2011; Barth et al. 2015).

Birds are abundant in urban environments, being one of the groups most surveyed in these environments (Toledo et al. 2012). Many studies have shown that urbanization alters the richness, composition, and abundance of bird communities (Blair 1996; Clergeau et al. 1998; Ortega-Álvarez and MacGregor-Fors 2009). However, different birds of prey species may be affected differently (Carvalho and Marini 2007). Some are highly sensitive to changes in the natural environment and negatively affected by urbanization (Savard et al. 2000; Hager 2009). However, some small and medium-sized raptors have successfully colonized these environments (Newton 1986; Rutz 2008; Stout and Rosenfield 2010; Altwegg et al. 2014), maybe because they find food, nesting, and roosting places (Mörtberg 2001).

In recent decades, the use of urban environments by birds of prey has increased, and a great number of species might establish populations in urban areas (Newton 1979; Sick 1997; Wheeler 2003a, 2003b; Lynch 2007; Carvalho and Marini 2007; Filloy and Bellocq 2007). However, studies that address the community of bird of prey in urban areas are scarce, especially in Brazil, where we have not found previous studies carried out in small cities.

Our study aimed to: (1) survey the species of birds of prey in the urban area located in the interior of the São Paulo state, Brazil; (2) to verify the proportion of generalist and specialist species in terms of habitat and diet based on the literature and field observations; (3) to verify the time period in which each species is more frequent during the time period established for the realization of the point counts; and (4) to evaluate whether there is a pattern of seasonality in the occurrence of the species that comprise this community.

Material and methods

Study area

The study site is located in an ecotone area between Atlantic Forest and Cerrado (savannah) Biomes. Around the urban area, there are currently small fragments of native vegetation with most of the territory occupied by plantations such as sugar cane, orange and *Eucalyptus* sp., as well as large areas of cattle pasture. Occupying about 11 km^2, the urban area of the municipality of Pirajuí (21°59'55"S, 49°27'26"W), in the São Paulo state, Brazil, represents a small portion of the municipal territory (Fig. 1) that has an area of 823,350 km^2 (IBGE 2000) and population of 22,704 inhabitants (IBGE 2010). Its afforestation consists mainly of trees (mainly *Leucaena leucocephala* (Lam.) De Wit. (Fabaceae: Mimosoideae)) located around the river that crosses the city (which still suffers from sewage dump) and of native and exotic trees planted in the residences by the population. Regarding the structure, the town is formed mostly by residential neighborhoods without high-rise construc-

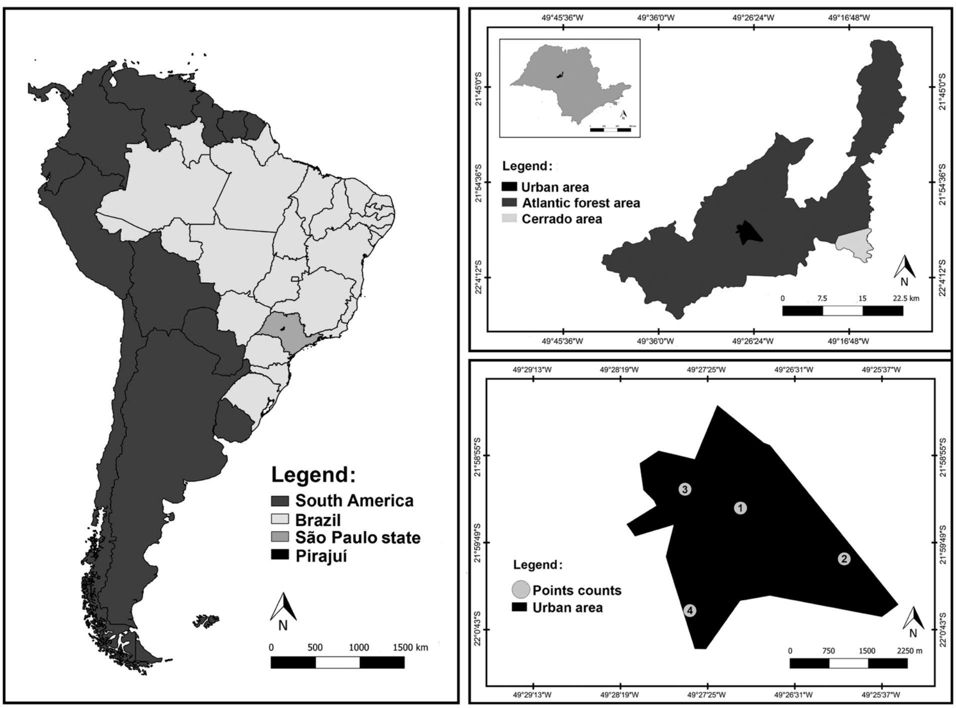

Figure 1. Location of the municipality of Pirajuí in the São Paulo state, in the Brazilian southeastern region, delimitation of the urban area and location of the points counts.

tions (with the highest points being churches and phone towers). In addition, there are small properties with pastures on the periphery of the city. The local climate is humid subtropical with hot summer (Cfa). In the dry season, which is from April to September, the temperature is on average between 16.33 °C to 27.33 °C and an average precipitation of 50.33 mm. In the rainy season, which is from October to March, the temperature is on average between 20.5 °C to 30.16 °C and an average precipitation of 170.33 mm (Alvares et al. 2013; CLIMATEMPO 2020).

Point Count method

We adopted the point count methodology for studies of birds of prey according to Mañosa et al. (2003), Loures-Ribeiro and Anjos (2006), Carvalho and Marini (2007), and Granzinolli and Motta-Junior (2010). We selected four point counts, located in neighborhoods near the edge of the city but with wide view over the urban area, with a minimum distance of 1 km between each other (detection radius of each point was approximately 500 m). These points included places that allowed a broad view of the urban area and the area of vision of such points did not overlap. Between October 2014 and September 2016, we carried out monthly surveys at these four points during the first 4 hours in the morning (0600–0630 H to 1000–1030 H). Each point count was surveyed on a different day (we avoided adverse weather conditions such as wind and rain). We performed a monthly visit at each sampling point, totaling 384 h of sample effort, and 96 h at each point. The field worksheet was divided into four one-hour periods to relate which species is more frequent during the time period established for the realization of the point counts. Point counts were surveyed using 10 × 42 binoculars. A pilot study was carried out in order to test this methodology for six months.

Analyses

Species richness estimation

Species richness was estimated using the nonparametric estimator Jackknife 1 with the software EstimateS (Colwell 2009). A species accumulation curve was obtained to evaluate species richness and the efficiency of the sample effort. The nomenclature and taxonomic sequence of the list of registered species followed that of the BirdLife International (HBW and BirdLife International 2018).

Habitat and diet

We classified the species registered as generalists or specialists according to the habitats in which they occur (generalists being those occur in different types of habitat and specialists being those that preferred specific habitats). Regarding the diet, specialists were considered those species that fed only a certain type of prey and generalists those that consumed a wide range of prey. We performed both classifications according to information contained in specialized literature (Sick 1997; Ferguson-Lees and Christie 2001) and field observations.

Number of contacts and frequency of occurrence

We considered the number of contacts for each species in each 1-h period. Thus, the data do not reflect the real abundance, but they represent the frequency with which each species used the urban environment along the gradient of pre-established schedules. According to Aleixo and Vielliard (1995) "contact is defined as the occupation of territory or presence of an individual or group of individuals of a species within the detection radius of the point count". We considered vocal activity as a contact on occasions where, later, it was possible to detect where the individual was. For *Coragyps atratus* (Bechstein, 1793), the number of contacts was defined as the number of individuals of the largest flock found in each time period to avoid overestimation. The frequency of occurrence (F.O.%) was calculated for each species following Vielliard and Silva (1990). Species were classified as rare to very common according to their frequency of occurrence as follows: F.O. = 0.1–24.9% was rare (R), between 25% and 49.9% was uncommon (UN), between 50% and 74.9% was common (C), and between 75% and 100% was very common (VC).

Period of greater activity

The field worksheet was divided into four 1-hr periods to relate each period to the highest activity schedule of each species during the time period established for the realization of the point counts, which is the period in which a particular species is most likely to be detected, by either increased flight or vocal activity.

Seasonality

To check the seasonality of the bird of prey community, the data of species richness and number of contacts were analyzed using circular statistical analysis (Zar 2010a) in order to verify if there was a seasonal pattern in each year. To carry out the analysis, the months of the year were converted to angles at 30° intervals (360° of the circumference divided by the 12 months of the year), and starting from 0° in October, 30° in November to 330° in September. The existence of seasonality in the occurrence of species was tested using the same parameters as Maffei (2014): 1. The mean angle (μ): point of the greatest concentration, is the angle in the circumference that represents a greater concentration of the data used in the analysis and can be interpreted as the month when the data obtained the highest value. It is also the position of the arrow represented in the circular histogram; 2. The angular standard deviation: is the standard deviation of the values of the previous parameter; 3. The mean length of the vector (r): is a measure of data concentration and varies between 0 (indicates that the data have a dispersed distribution in the annual cycle) and 1 (indicates that the data is concentrated in the same direction, or that is, there is a greater concentration of data in a specific month or more). This parameter in the circular histogram is represented by the size of the arrow, the value being zero when the arrow is close to the center of the circle and as it moves towards the extremity, its value approaches 1, which is the maximum value. Afterwards, we used the Rayleigh uniformity test (z), this test ($p < 0.05$) verifies that the data is not evenly distributed around the circular distribution cycle (Zar 2010b). When $p < 0.05$ it means that the data have a concentration, that is, seasonality. The analyses were performed separately for the first (Oct 2014 to Sep 2015) and for the second year (Oct 2015 to Sep 2016) of sampling.

After this analysis, we used the species contact number data to verify whether any particular species showed a seasonal pattern in their occurrence. However, we excluded species classified as rare according to their frequency of occurrence from this analysis, as this low occurrence could negatively influence the analysis, showing a seasonality that is not real. This is because as the circular statistical analysis analyzes the distribution of the occurrence of the species throughout the annual cycle, the inclusion of rare species, such as *Circus buffoni*, which was recorded only once in February, could induce the wrong idea that the species has a tendency to occur in that month.

The data of number of contacts of each species were used as a frequency, and the contact numbers of the months were added (Oct 2014 to Oct 2015; Nov 2014 to Nov 2015 to Sep 2015 to Sep 2016) in order to avoid the influence of natural fluctuations in the occurrence of some species that are common in the Neotropical region (Hayes 1991; Jaksié et al. 1992; Rivera-Milán 1995). In this way, the result of this sum was inserted as frequency and the months as angles with an interval of 30° (360° of the circumference divided by the 12 months of the year) and we use the same parameters as the analysis performed for species richness and number of contacts.

For both analysis, circular statistical analysis was used (Zar 2010a) using the Oriana software, version 4.02 (Kovach 2013), which also generated the circular data histograms.

Results

Richness

A total of 19 species of birds of prey (Table 1) were recorded, with Accipitridae being the dominant family (11 species, 58%), followed by Falconidae (six species, 32%), and Cathartidae (two species, ~10%). Of the 19 species, 18 were recorded during the sampling period and one species, *Falco peregrinus* Tunstall, 1771, was recorded only in the pilot study.

The species accumulation curve (Fig. 2) did not show complete stabilization but instead showed a tendency to asymptote. According to the estimator Jackknife 1, ~95% of the estimated species were sampled in the studied area.

Table 1. Diurnal birds of prey registered in the urban area of Pirajuí, São Paulo state, Brazil. F.O%: Frequency of Occurrence. Status: R – rare, UN – uncommon, C – common, VC – very common. Period of higher activity and classification of habitat / diet.

Species	English name	Number of contacts				F.O%	Status	Period of greater activity	Habitat / Diet
		Chuvosa 2014/15	Seca 2015	Chuvosa 2015/16	Seca 2016				
Cathartiformes Seebohm, 1890									
Cathartidae Lafresnaye, 1839									
Cathartes aura (Linnaeus, 1758)	Turkey Vulture	0	1	6	11	12.50	R	4th hour	generalist / generalist
Coragyps atratus (Bechstein, 1793)	American Black Vulture	366	380	387	379	100	VC	4th hour	generalist / generalist
Accipitriformes Bonaparte, 1831									
Accipitridae Vigors, 1824									
Chondrohierax uncinatus (Temminck, 1822)	Hook-billed Kite	4	4	12	7	50	C	4th hour	specialist / specialist
Gampsonyx swainsonii Vigors, 1825	Pearl Kite	7	1	7	4	41.66	UN	4th hour	generalist / generalist
Circus buffoni (Gmelin, 1788)	Long-winged Harrier	0	0	1	0	4.16	R	4th hour	specialist / generalist
Accipiter striatus Vieillot, 1808	Sharp-shinned Hawk	0	0	0	2	8.33	R	1st and 4th hour	specialist / generalist
Ictinia plumbea (Gmelin, 1788)	Plumbeous Kite	3	1	7	1	29.16	UN	4th hour	generalist / specialist
Rostrhamus sociabilis (Vieillot, 1817)	Snail Kite	18	0	0	0	8.33	R	3rd hour	specialist / specialist
Geranospiza caerulescens (Vieillot, 1817)	Crane Hawk	4	5	0	2	37.50	UN	1st hour	generalist / generalist
Buteogallus meridionalis (Latham, 1790)	Savanna Hawk	1	1	3	3	20.83	R	4th hour	generalist / generalist
Rupornis magnirostris (Gmelin, 1788)	Roadside Hawk	31	40	37	46	100	VC	4th hour	generalist / generalist
Geranoaetus albicaudatus (Vieillot, 1816)	White-tailed Hawk	4	2	2	1	33.33	UN	4th hour	generalist / generalist
Buteo brachyurus Vieillot, 1816	Short-tailed Hawk	1	9	2	3	37.50	UN	4th hour	generalist / specialist
Falconiformes Bonaparte, 1831									
Falconidae Leach, 1820									
Caracara plancus (Miller, 1777)	Southern Caracara	144	194	82	141	100	VC	1st hour	generalist / generalist
Milvago chimachima (Vieillot, 1816)	Yellow-headed Caracara	11	29	21	30	91.66	VC	1st hour	generalist / generalist
Herpetotheres cachinnans (Linnaeus, 1758)	Laughing Falcon	0	0	3	2	16.66	R	1st hour	generalist / specialist
Falco sparverius Linnaeus, 1758	American Kestrel	17	8	8	12	91.66	VC	4th hour	generalist / generalist
Falco femoralis Temminck, 1822	Aplomado Falcon	20	9	5	13	83.33	VC	1st and 2nd hour	generalist / generalist
Falco peregrinus Tunstall, 1771	Peregrine Falcon					recorded in the period prior to the study			

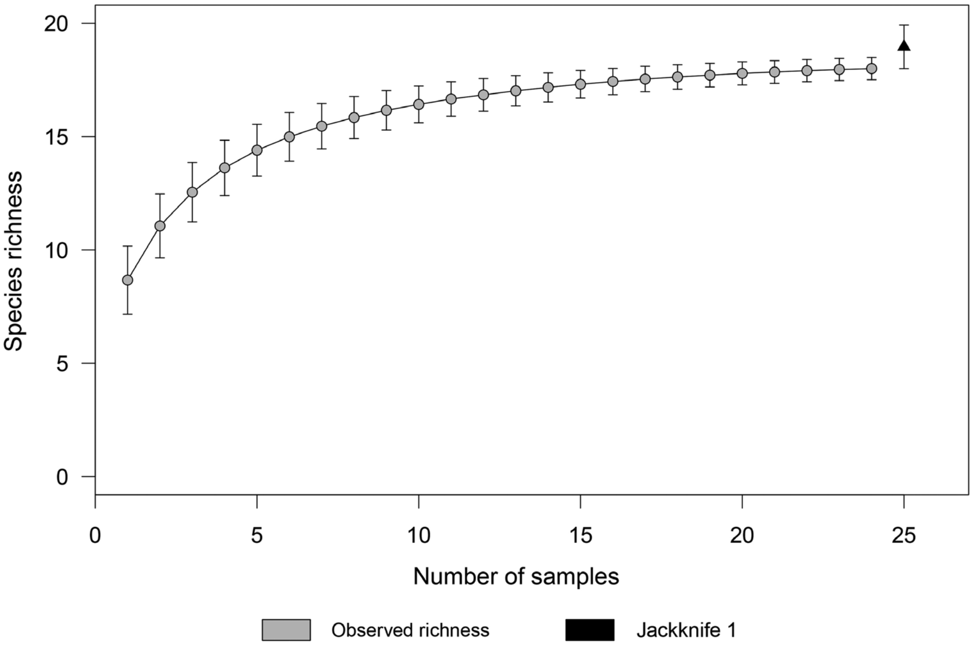

Figure 2. Species accumulation curve (100 times randomized) and Jackknife 1 of urban diurnal birds of prey in the municipality of Pirajuí, São Paulo state, Brazil.

Habitat and diet

In relation to the habitats in which species can occur, 14 species (78%) were classified as habitat generalists and four species (22%) as specialists. Among the specialists, two species live in forest environments (*Chondrohierax uncinatus* (Temminck, 1822) and *Accipiter striatus* Vieillot, 1808); one lives in wetland and open fields (*Circus buffoni* (Gmelin, 1788)); and one lives exclusively in water bodies (*Rostrhamus sociabilis* (Vieillot, 1817)). Regarding the type of diet, 13 species (72%) were classified as generalists and five species (28%) as specialists. *Chondrohierax uncinatus* is specialized to feed on gastropods (arboreal, terrestrial, and aquatic), *Ictinia plumbea* (Gmelin, 1788) has insectivorous habits, *R. sociabilis* is specialized in feeding on aquatic snails (mainly of the genus *Pomacea* (Perry, 1810)), *Buteo brachyurus* Vieillot, 1816 is specialized in feeding on birds, and *Herpetotheres cachinnans* (Linnaeus, 1758) on snakes (Table 1). Eleven species (61%) were considered generalists for both habitat and diet, and two species (11%) were considered specialists in terms of habitat and diet. Three species (17%) were classified as habitat generalists and diet specialists, and two species (11%) were considered habitat specialists and diet generalists.

Number of contacts and frequency of occurrence

2555 contacts were made with diurnal birds of prey (Table 1). The species with the highest number of contacts were *Coragyps atratus* (1512 contacts, 59% of total), *Caracara plancus* (Miller, 1777) (561 contacts, 22%), and *Rupornis magnirostris* (Gmelin, 1788) with 154 contacts (6%). The less contacted species were *Circus buffoni* (one contact, 0.04%), *Accipiter striatus* (two contacts, 0.08%), and *Herpetotheres cachinnans* (five contacts, 0.19%). As for the frequency of occurrence, the same pattern regarding the number of contacts was observed, in which *C. atratus*, *C. plancus*, and *R. magnirostris* presented a 100% frequency of occurrence. *Circus buffoni* had the lowest frequency of occurrence (4%), followed by *A. striatus* and *Rostrhamus sociabilis* (8%) and *H. cachinnans* (17%). Regarding status, six species (33.33%) were classified as rare, five (27.77%) were considered uncommon, one (5.55%) common, and six (33.33%) were very common.

Period of greater activity

In relation to the period of the greatest activity, in general a well-defined pattern was found among families. The majority of species in the Falconidae family (four species, 80% of the total) were more active during the first hour, while 73% of Accipitridae species (eight species) and all Cathartidae species were more active during the fourth hour (Table 1).

Seasonality

Species richness and number of contacts did not show a defined pattern, with fluctuations in these parameters occurring during the months and between the years.

The results of the circular statistical analysis (Table 2) revealed that the species richness, both in the first and in the second year, does not present a seasonality pattern (Figure 3). The average length value of the vector (r) was close to zero for both years ($r = 0.062$ and $r = 0.064$, respectively), indicating that the data were dispersed around the circumference, with no concentration of these (which would indicate seasonality). The Rayleigh test confirmed the absence of a seasonal pattern ($p = 0.699$ and $p = 0.654$, respectively).

Regarding the number of contacts, the circular statistics revealed that there was also no seasonal pattern in the two years analyzed. Although the Rayleigh test showed values that would indicate possible seasonality in the second year ($p < 0.001$), values close to zero ($r = 0.041$ and $r = 0.091$, respectively) of the average length of the vector (r) in both years show that the data are scattered around the circumference, similar to that found for species richness.

Seasonality analyzes were performed using circular statistics for 12 species, the data obtained are in Table 3 and the circular histograms in Fig. 4.

Of these species, 10 did not show seasonality in their pattern of occurrence, presenting values of the mean length of the vector (r) closer to zero, the length of the arrows represented in the circular histogram are closer to the center (values close to 0) than to the extremity (values close to 1), which shows that the data are distributed in a non-concentrated manner during the annual cycle.

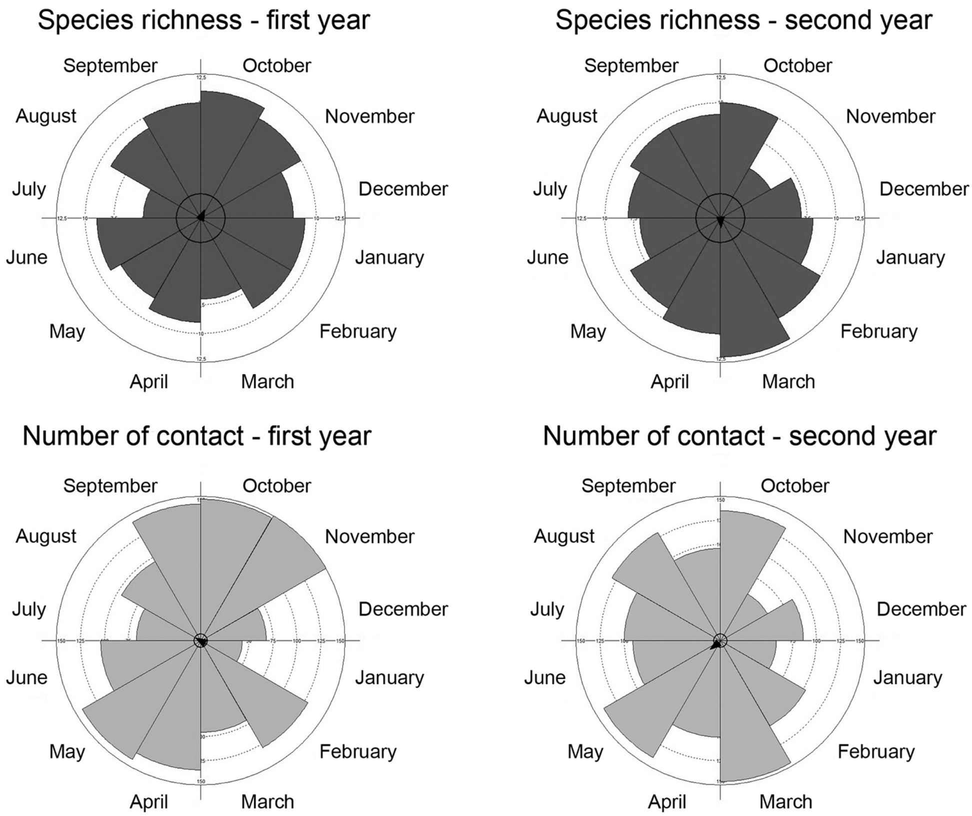

Figure 3. Histograms of the circular statistical analysis of each year of species richness and number of contact of diurnal birds of prey of Pirajuí, São Paulo state, Brazil.

Table 2. Result of circular statistical analysis to verify the occurrence or not of a seasonal pattern in species richness and number of contact during each sampling year of diurnal birds of prey of Pirajuí, São Paulo state, Brazil.

	Mean angle (μ)	Angular standard deviation	Mean length of the vector (r)	Rayleigh test (p)
Species richness – first year	24.313°	135.029°	0.062	0.669
Species richness – second year	176.807°	134.372°	0.064	0.654
Number of contact – first year	299.547°	144.949°	0.041	0.113
Number of contact – second year	231.546°	125.382°	0.091	< 0.001

Of the remaining two species, *Gampsonyx swainsonii*, despite having been recorded during most months of the year, according to the circular statistical analysis showed a seasonal trend, presenting an intermediate value of mean length of the vector (r) but closer to one ($r = 0.567$) than zero; it also presented a value of 127.369° for the mean angle (μ), indicating a greater concentration of contacts in the month of February. The Rayleigh test also showed a value that reinforces the existence of a seasonal pattern ($P = 0.001$).

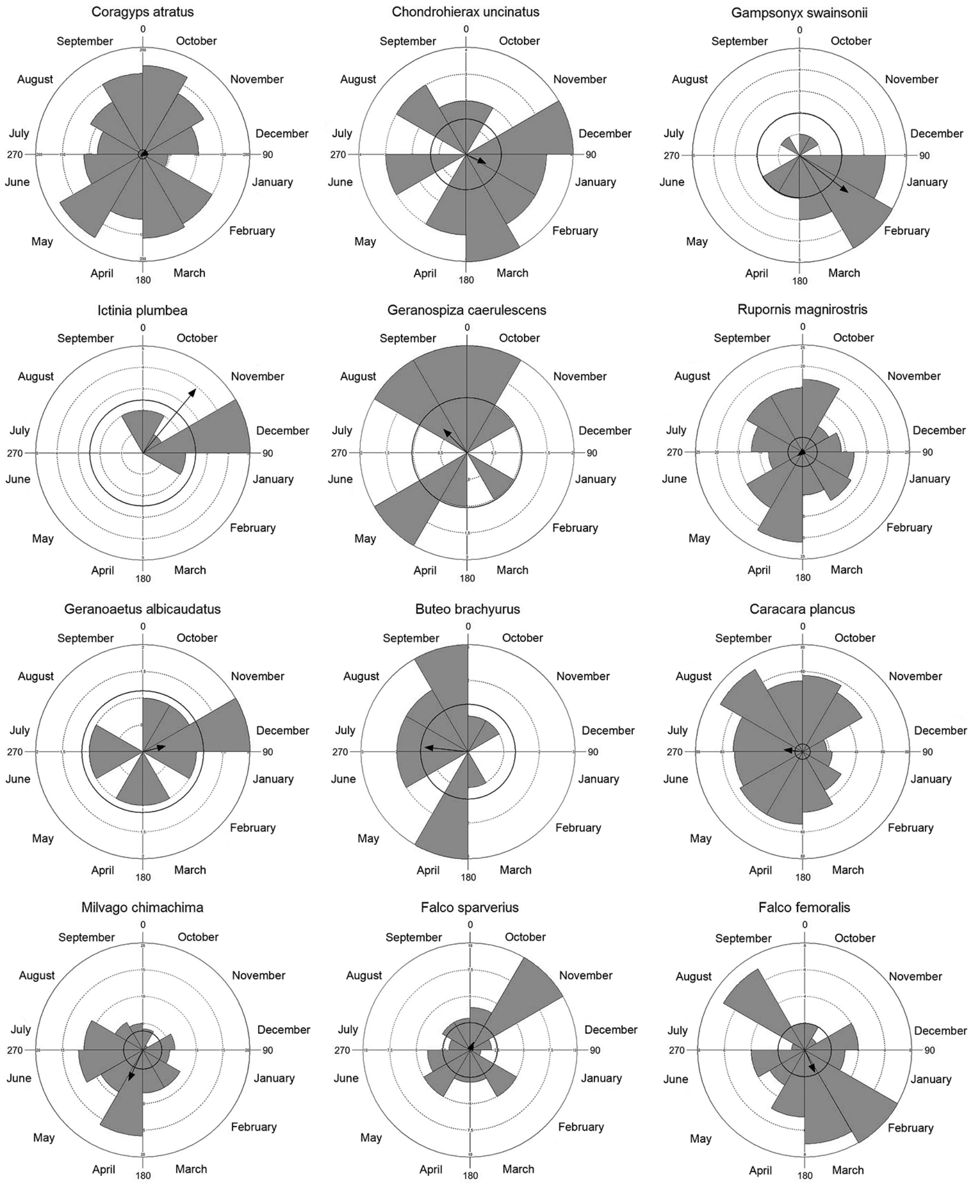

Figure 4. Histograms of the circular statistical analysis of each species of diurnal birds of prey of Pirajuí, São Paulo state, Brazil.

As for *Ictinia plumbea*, which is a known migratory species, as expected, it presented a seasonal pattern in its occurrence, presenting a value of the mean length of the vector (r) close to one (r = 0.774) and the mean angle (μ) of 39.399°, indicating a greater concentration of contacts in the month of November. The Rayleigh test also showed a value that reinforces the existence of a seasonal pattern (P < 0.001).

Table 3. Result of circular statistical analysis to verify the occurrence or not of a seasonal pattern in the occurrence of each species of diurnal birds of prey of Pirajuí, São Paulo state, Brazil.

Species	Mean angle (μ)	Angular standard deviation	Mean length of the vector (r)	Rayleigh test (p)
Cathartiformes Seebohm, 1890				
Cathartidae Lafresnaye, 1839				
Coragyps atratus (Bechstein, 1793)	236.842	154.165	0.027	0.338
Accipitriformes Bonaparte, 1831				
Accipitridae Vigors, 1824				
Chondrohierax uncinatus (Temminck, 1822)	114.641	102.706	0.201	0.341
Gampsonyx swainsonii Vigors, 1825	127.369	61.036	0.567	0.001
Ictinia plumbea (Gmelin, 1788)	39.399	40.984	0.774	< 0.001
Geranospiza caerulescens (Vieillot, 1817)	315	87.969	0.308	0.361
Rupornis magnirostris (Gmelin, 1788)	235.313	136.382	0.059	0.587
Geranoaetus albicaudatus (Vieillot, 1816)	75	100.138	0.217	0.667
Buteo brachyurus Vieillot, 1816	275.726	77.119	0.404	0.085
Falconiformes Bonaparte, 1831				
Falconidae Leach, 1820				
Caracara plancus (Miller, 1777)	275.787	106.84	0.176	< 0.001
Milvago chimachima (Vieillot, 1816)	205.112	87.286	0.313	< 0.001
Falco sparverius Linnaeus, 1758	24.248	128.113	0.082	0.74
Falco femoralis Temminck, 1822	155.459	98.782	0.226	0.09

Discussion

The richness of diurnal birds of prey registered represented approximately 37% of the species that occur in the São Paulo state (according to Figueiredo 2016) and 25% of those occurring in Brazil (see Piacentini et al. 2015). This richness was considered to be relatively high, although the study sampled only the urban area. Other previous studies in Brazil have reported similar levels of richness but, in addition to urban areas, these studies also sampled the semi-natural areas around cities (Carvalho and Marini 2007; Silva and Machado 2016).

As mentioned earlier in the introduction, there is a scarcity of studies conducted with birds of prey in urban areas in Brazil, especially in small cities. This study sought to fill this gap. However, for comparing the results, the options are limited, since other studies have been carried out in different biomes, where the species composition tends to be naturally different. The only study carried out in a similar biome (ecotone Atlantic Forest and Cerrado) is that of Belo Horizonte (Carvalho and Marini 2007), which is a Brazilian metropolis.

In Belo Horizonte municipality (2.5 million inhabitants), 21 species of birds of prey were recorded, 14 within the urban area (Carvalho and Marini 2007) being nine species common to our census. Among these species these authors registered four forest specialists at forest fragments within the city: *Micrastur semitorquatus* (Vieillot, 1817), *Micrastur ruficollis* (Vieillot, 1817), *Leptodon cayanensis* (Latham, 1790), and *Accipiter bicolor* (Vieillot, 1817); also, the field specialist species *Geranoaetus melanoleucus* (Vieillot, 1819). Moreover, in semi-natural areas around the city, species with more specialist habitat requirements were recorded, such as forest species: *Falco rufigularis* Daudin, 1800, *Buteogallus lacernulatus* (Temminck, 1827), and *Harpagus diodon* (Temminck, 1823); in and open fields: *Buteogallus coronatus* (Vieillot, 1817) and *Falco deiroleucus* Temminck, 1825 (Carvalho and Marini 2007).

Although richness was also similar to studies performed in natural areas, species composition shows that this parameter is not indicative of good environmental quality. In studies carried out in areas of the Atlantic Forest, species with greater sensitivity to environmental changes and species that are naturally rare were recorded, such as: *Buteogallus lacernulatus* (Zorzin 2011), *Pseudastur polionotus* (Kaup, 1847) (Mañosa et al. 2003), *Geranoaetus melanoleucus* (Salvador-Jr and Silva 2009), *Spizaetus melanoleucus* (Vieillot, 1816) (Salvador-Jr and Silva 2009), *Spizaetus tyrannus* (Wied, 1820) (Mañosa et al. 2003; Azevedo et al. 2003; Zorzin 2011; Salvador-Jr and Silva 2009), *Spizaetus ornatus* (Daudin, 1800) (Mañosa et al. 2003) and *Micrastur ruficollis* (Zorzin 2011). The same was observed in studies conducted in Cerrado areas where one species with high sensitivity and naturally rare was recorded, *Buteogallus coronatus* (Baumgarten 2007; Benfica 2013; Granzinolli 2009). Species like *Sarcoramphus papa* (Linnaeus, 1758) (Baumgarten 2007; Loures-Ribeiro and Anjos 2006), *Leptodon cayanensis* (Benfica 2013; Granzinolli 2009; Zorzin 2011; Salvador-Jr and Silva 2009), *Accipiter bicolor* (Benfica 2013; Zorzin 2011; Salvador-Jr and Silva 2009), *Accipiter superciliosus* (Linnaeus, 1766) (Mañosa et al. 2003; Granzinolli 2009), *Buteo albonotatus* Kaup, 1847 (Baumgarten 2007; Granzinolli 2009; Zorzin 2011) and *Micrastur semitorquatus* (Baumgarten 2007; Benfica 2013; Zorzin 2011; Salvador-Jr and Silva 2009) were recorded in both biomes. It is likely that some of these species occurred in the study area in the past, when it still contained larger areas of native vegetation, and the current absence of these species is a consequence of the process of occupation of the region, either by urbanization or by the suppression of natural areas for the use of plantation and livestock land in rural areas.

Although birds of prey are generally sensitive to changes in their habitat and high levels of urbanization (Savard et al. 2000; Hager 2009), the high species richness of the study area may be due to urban landscapes providing the basic requirements for the occurrence of birds of prey, such as a food source, due to the high densities of birds and rodents, and nesting sites (Emlen 1974; Newton 1979; Beissinger and Osborne 1982; Tomialojc and Gehlbach 1988; Bird et al. 1996; Love and Bird 2000).

In addition, birds of prey may have territories that extend beyond the urban boundary, and thus, urban areas do not necessarily have to meet all of their ecological demands (Chace and Walsh 2006). This hypothesis is evidenced by our finding that, among the 19 species recorded in this study, only *Chondrohierax uncinatus*, *Circus buffoni*, and *Accipiter striatus* were not detected in the rural or semi-natural areas around Pirajuí urban area (Martins 2018). In Belo Horizonte, Carvalho and Marini (2007) recorded all species within the urban area at natural areas outside the urban boundary.

Although the raptor community in the urban area of Pirajuí comprised mostly generalist species (61% generalists for habitat and diet), we can highlight some specialist species: *Chondrohierax uncinatus*, a forest species with a gastropod-specialized diet (Ferguson-Lees and Christie 2001) which was reported. Its common occurrence in the study area is probably due to the availability of the exotic snail

Achatina fulica Bowdich, 1822 (Martins and Donatelli 2014). Our observations suggest that the species is established in the city of Pirajuí with indications that it reproduces in the place, since it was observed on some occasions that a young member of the species was flying with an adult member of the species. Moreover, *Circus buffoni* is more associated with natural areas of wetlands and open fields (Ferguson-Lees and Christie 2001). This species was recorded once in our study, a female foraging in an area of the city with grasses. Finally, *Accipiter striatus* was associated with forest areas (Sick 1997) and might occur in urban parks. The low abundance of this species observed during the present study can be attributed to its low population density or due to a discrete behavior typical of some *Accipiter* sp.

One of the recorded species is on the bird list of endangered fauna in the São Paulo state (São Paulo 2018): *Circus buffoni* is classified as vulnerable. Additionally, none of the recorded species are on either the national list of endangered species (MMA – Ministério do Meio Ambiente 2016) or on the global list of the International Union for the Conservation of Nature (IUCN – International Union for the Conservation of Nature 2020).

Most of the species recorded in the present study (61%) had relatively low contact numbers and frequency of occurrence. This might be because birds of prey (particularly accipitrids) usually occur at low densities in the natural environment (Newton 1979). In relation to the period of the greatest activity of the species sampled, the morning period according to the studies by Benfica (2013), Canuto (2009) and Robbins (1981) presented a higher concentration of records. Our results showed that those accipitrids and falconids that feed on small mammals and birds were more active in the early morning to synchronize with the peak activity of their prey (Vieira and Baumgarten 1995; Halle 1995; Granzinolli and Motta-Junior 2010). Moreover, species such as cathartids and some accipitrids that require thermals to glide find it difficult to fly early in the morning, and are generally more active from mid-morning (Fuller and Mosher 1981; Granzinolli and Motta-Junior 2010).

We did not use it in our study, but it would be important to consider the application in later studies, mainly in larger cities, of the imperfect detection model (MacKenzie et al. 2002). The method proposed by MacKenzie et al. (2002) allows for estimating the probability of occupation when the probability of detecting the species is < 1. One requirement of this method is that the data be collected multiple times in the sampled location to detect the target species (MacKenzie et al. 2002; Costa 2014). In this way it is possible to obtain information and unbiased estimates regarding the probability of detection and the probability of occupation of the species (MacKenzie and Bailey 2004). This is because we cannot overlook the false absence of species in ecological studies, since the non-detection of a species in a locality does not mean its absence (Wintle et al. 2005; Kajin and Grelle 2012; Costa 2014).

Although raptor species exhibit different behaviors and consequently use habitats differently (Granzinolli and Motta-Junior 2010), our results did not suggest seasonal patterns in species richness or number contacts. However, a single migratory species was recorded during the sampling period, *Ictinia plumbea*, which remained in the region from September to January. *Rostrhamus sociabilis* is a partial migrant in most of South America (Bildstein 2004) and was recorded on two occasions, one of which was a flock of 16 individuals flying over the city, probably performing some seasonal movement. *Gampsonyx swainsonii*, despite being a resident species (Ferguson-Lees and Christie 2001; Bildstein 2004), showed a statistically seasonal tendency with its detectability being higher during the first months of the year. We did not find information about migration in the species; our data suggest that the species has a local movement or a partial migration in the study area. *Falco peregrinus* is also a migratory species but was recorded only during the pilot study.

Despite the absence of a seasonal pattern, it was evident that there were fluctuations in species richness and the number of contacts between the months and between the years during the sampling period. Seasonal fluctuations in the abundance of non-migratory raptors appear to be common in the Neotropical region (Hayes 1991; Jaksié et al. 1992; Rivera-Milán 1995), although their causes have not been explored (Baumgarten 1998). These fluctuations seem to be influenced by the particular characteristics of each species and factors such as recruitment, mortality, dispersion, regional movements and food availability (Newton 1979; Grant et al. 1991; Jaksié et al. 1992; Del Hoyo et al. 1994; Hayes 1995). Regarding the availability of resources, these tend to be more stable in the urban than in natural environments. This justifies the absence of seasonal patterns found in the urban birds of prey community of Pirajuí.

Our hypothesis to try to explain these fluctuations in the study area is that the species of birds of prey are resident in their territory. However, because this territory has a large area, which can extend beyond urban boundaries, these birds explore different portions of it throughout the annual cycle. Hence, perhaps a certain species was not present in the study area during the sampling period or possibly it simply has a low population density.

Contrary to what was observed in the present study, Carvalho and Marini (2007) found a seasonal pattern and observed that the species richness fluctuated between 14 and 16 species, being slightly higher between January and May compared to other months. Benfica (2013) observed that raptors were more abundant in the rainy season, while species richness values were higher in September, March and May (Benfica 2013). Zilio et al. (2014) found a greater abundance of raptors in spring/summer than in autumn/winter, but found no difference between the sampled years. This pattern, according to the authors, was expected due to the presence of migratory species that are present in the study area during spring/summer. Also, they found variations in species considered to be residents, suggesting that some of them are partial or local migrants, or nomadic in the region.

We verified that the urban area of the municipality of Pirajuí has a significant diversity of birds of prey. Nineteen species of diurnal birds of prey were found, including specialist species of habitat and/or diet. This information furnished evidence of the importance of urban environments for birds of prey and showed the ability of these species to use the urban environment. From our results, we suggest that future studies should evaluate the effects of urban areas of different sizes and degrees of urbanization on bird of prey communities.

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