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Does urbanization affect the seasonal dynamics of bird communities in urban parks?

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Abstract The environmental factors affecting the spatial dynamics of bird communities in urban parks are well understood, but much less attention has been paid to the seasonal dynamics of bird communities. Since migrant and resident human commensal birds might have contrasting responses to environmental factors of urban parks, we expected different seasonal dynamics among parks. On the other hand, because bird species can have different habitat relationships throughout the year, we also expected different responses of bird richness to environmental variables between breeding and non-breeding seasons. Bird surveys were conducted in 14 small urban parks (1–4 Ha) of Mar del Plata city (Argentina) for one full annual cycle. Bird richness changed between seasons, but bird abundance remained constant. Bird community composition did not vary between seasons, but urban parks near the urban center, with the highest pedestrian traffic and isolation to other green areas had the least seasonal change of composition. During the breeding season, bird richness was negatively affected by the percentage cover of high buildings surrounding the immediate limits of parks, whereas during the non-breeding season bird richness was not related with any environmental variable. Bird composition variation among parks was affected by the distance to the urban center during both seasons. Results showed that urbanization promotes a seasonal homogenization of bird communities in urban parks, probably by affecting the presence of migrant species and promoting the temporal stability of human commensal species.

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Introduction

In addition to their recreational function to humans, urban parks constitute species rich sites among the different land uses of cities (Strohbach et al. 2013; Nielsen et al. 2014). The higher habitat complexity of urban parks compared to other urban habitats promotes higher bird diversity (Fernández-Juricic 2000a; Carbó-Ramírez and Zuria 2011). Moreover, the bird diversity of urban parks may enhance the well-being of humans (Fuller et al. 2007). Therefore, a better knowledge about the environmental factors that determine the bird diversity in urban parks is needed to help urban planners make proper decisions.

Spatial dynamics of bird communities in urban parks are relatively well studied. Bird diversity and composition are related to the distance to other urban parks (Murgui 2007; Carbó-Ramírez and Zuria 2011; Zhou et al. 2012; Charre et al. 2013; Peris and Montelongo 2014), human disturbance (Patón et al. 2012; González-Oreja et al. 2012), habitat structure within parks (Morneau et al. 1999; Pavlík and Pavlík 2000; Faggi and Perepelizin 2006; Croci et al. 2008; Imai and Nakashizuka 2010; Carbó-Ramírez and Zuria 2011; Barbosa de Toledo et al. 2012; Ferenc et al. 2014; Peris and Montelongo 2014), the size of the park (Luniak 1981; Sasvári 1984; Suhonen and Jokimäki 1988; Fernández-Juricic 2000b; Park and Lee 2000; Pavlík and Pavlík 2000; Barbosa de Toledo et al. 2012; Strohbach et al. 2013; Peris and Montelongo 2014), age of the park (Fernández-Juricic 2000b), the level of urbanization surrounding parks (Hudson and Bird 2009; Husté and Boulinier 2011) and the distance to city border (MacGregor-Fors and Ortega-Álvarez 2011). However, seasonal dynamics of bird communities in urban parks were less explored (Sasvári 1984; Murgui 2007; Carbó-Ramírez and Zuria 2011; Charre et al. 2013; Zhou and Chu 2014).

Recent studies conducted along urban–rural gradients proposed that the exclusion of migrant species and the temporal stabilization of habitat and food resources promoted by urbanization cause a seasonal homogenization of bird composition (La Sorte et al. 2014; Leveau et al. 2015). However, this process has not been explored in urban parks yet. Since urban parks can have different levels of isolation from rural areas and human disturbance, and these environmental factors may affect the presence of migrant birds (MacGregor-Fors et al. 2010; Husté and Boulinier 2011; Zhou and Chu 2012), we expect that various environmental variables will affect the seasonal change of bird composition among parks. On the other hand, urban parks surrounded by heavily urbanized areas may have higher densities of human commensal species, such as the House Sparrow (*Passer domesticus*) and the Rock Dove (*Columba livia*), which take advantage of food discarded by humans during winter thus favoring a more stable presence across the year. Therefore, we expect urban parks located in highly urbanized areas will have a lower seasonal change of bird community composition in comparison to urban parks farthest from the urban center.

Most studies of bird communities in urban parks were conducted during the breeding season (Zhou and Chu 2014). However, bird-habitat relationships may change during the year. During the breeding season a more restricted habitat use of birds is expected because of the need to find mates and nest sites, while during the non-breeding season habitat use is more flexible due to birds being mainly influenced by the abundance and distribution of food (Hutto 1985; Sagario and Cueto 2014). Moreover, the high mobility of birds during the non-breeding season due to natal dispersal may promote the use of alternative habitats or habitat patches smaller than the critical breeding home range size of a given species (Murgui 2010). These behavioral changes of birds can decrease the strength of their habitat relationships during the non-breeding season (Murgui 2007, 2010; Zhou and Chu 2014).

In this paper, we examined the temporal change of bird communities in urban parks between the breeding and the non-breeding season in Mar del Plata, a coastal city located in the southeastern part of Buenos Aires province, Argentina. The objectives were: (1) to compare the bird species richness, abundance, and composition between breeding and non-breeding seasons; (2) to relate the change in bird composition observed between seasons in each park with environmental variables that describe park characteristics; and (3) to determine how the relationships between bird community attributes and environmental variables of the urban parks changed between seasons. We expected higher values of bird richness and abundance during the breeding season and a higher bird composition similarity between seasons in the more urbanized parks. Finally, we expected differential responses of community attributes to environmental variables between seasons.

Materials and methods

Study area

The study was conducted in Mar del Plata city (38° 00′ S 57° 33′ W; 618 989 inhabitants). It is a coastal city located in east-central Argentina. It is surrounded by croplands, pastures, woods and small fragments of native grasslands and forests. The average annual temperature is 14.1 °C, the breeding season is the hottest (mean October-March = 17.6 °C) and the non-breeding season the coldest (mean April-September = 10.3 °C). The average annual rainfall is 923.6 mm and the breeding season is the rainiest (542.6 mm), whereas the non-breeding season is the driest (381.0 mm) (Servicio Meteorológico Nacional). Fourteen parks that ranged in size from 1 to 4 ha were selected for study (Fig. 1), located in both downtown and suburban areas of the city. Each park was considered as a separate experimental unit.

Bird census

Bird surveys during the non-breeding season were conducted between July and September 2003, while the breeding season surveys were conducted between November 2003 and March 2004. During each season, four visits were conducted in the first 4 h after dawn on days without rain or strong winds. Following Hutto et al. (1986) we used fixed points of 25 m radii. A single point was located in parks of 1 ha, while in the other larger parks, two points separated by at least 100 m were located. All birds seen or heard during 5 min within 25 m of the point were counted, except for those flying over the top of trees or below that height, but without feeding activity. At each point count, a single observer (LML or CML) conducted the surveys.

Measurement of environmental variables

Eleven environmental variables were considered (Table 1). The size of the park, which is assumed to positively influence the bird richness (Arrhenius 1921; MacArthur and Wilson

Fig. 1 Location of the selected urban parks and his point count sites in this study in Mar del Plata. 1 Plaza Colón, 2 Plaza Mitre, 3 Plaza Peralta Ramos, 4 Plaza Dardo Rocha, 5 Plaza Pueyrredón, 6 Plaza España, 7 Plaza San Martin, 8 Plaza Güemes, 9 Parque Primavesi, 10 Parque San Martin, 11 Plaza Urquiza, 12 Plaza Scarpati, 13 Plaza Espora, 14 Plaza Artigas/Revolución Francesa

1967). The distance to green areas (DGA) was the minimum distance in meters to green areas, such as other urban parks or cemeteries of at least one hectare; this is a measure of connectivity presumed to affect bird richness and composition in urban parks (Fernández-Juricic 2000b; Peris and Montelongo 2014; Chang and Lee 2015). The distance to the city center (DCC) was the minimum distance to the commercial and administrative center of the city, which was considered as the Plaza San Martín (one of the parks included in this study). This variable represents the degree of urbanization surrounding each park. The habitat diversity (H′) was estimated by calculating the Shannon index using the percentage coverage of trees, shrubs, lawns and impervious surfaces estimated visually at the 25 m radius of sampling points. It

Table 1 Description of environmental variables of urban parks in Mar del Plata city, Argentina

Environmental variables	Mean	Standard error	Minimum	Maximum
Distance to green areas (DGA) (m)	528.21	80.09	0.00	1150.00
Distance to the city center (DCC) (m)	2322.86	551.04	0.00	6650.00
Size (Ha)	3.04	0.37	1.00	4.00
Habitat diversity (H′)	0.43	0.02	0.25	0.53
Car traffic (CARS) (cars / min)	5.29	1.54	0.20	23.40
Pedestrian traffic (people / min)	1.80	0.63	0.06	8.07
Tree cover (%)	32.36	5.38	0.00	63.00
Shrub cover (%)	2.65	0.71	0.00	8.00
Lawn cover (%)	63.18	4.67	29.00	96.00
Impervious cover (%)	25.43	3.70	0.00	43.00
High buildings surrounding parks (%)	24.71	8.22	0.00	81.00

represents the habitat complexity and is assumed to positively affect the bird richness within parks (MacArthur and MacArthur 1961; Tews et al. 2004). Pedestrian traffic was defined as the average number of people that passed within 25 m of the observer while they were conducting simultaneously the bird surveys. Car traffic was also simultaneously measured during bird surveys, counting cars moving on the nearest street to the counting point. In general, point counts locations within parks were at a similar distance from streets. Data from the four visits was averaged. Due to the fact that a value of car traffic was considerably higher than the others, this variable was log transformed. Finally, the percentage cover of high buildings was the proportion of buildings with more than two stories surrounding the immediate limits of each park. In the case of parks with two sampling points, the values of the environmental variables of two points were averaged. The size of parks, DCC and DGA were measured by using Google earth.

The environmental variables were only measured during the non-breeding season, and it was assumed that habitat structure did not change significantly between seasons. However, given that Mar del Plata is a tourist destination city that receives people during the summer, human disturbance between parks located in the urban center and those located near the urban fringe could be higher in the breeding than during the non-breeding season.

Data analysis

We explored the correlation between variables and found collinearity among them (Electronic supplementary material 1). For example, DCC was negatively correlated with car traffic, pedestrian traffic, percentage cover of impervious surfaces within parks and the proportion of high buildings surrounding them. Then, we analyzed which of them correlated most with each dependent variable. Therefore, we selected uncorrelated environmental variables for the predictive models.

The difference in bird composition among seasons was analyzed by the adonis function of the vegan package (Oksanen et al. 2007) in R (R Development Core Team 2011) by using the Bray-Curtis dissimilarity index. The composition of birds in parks during each season was analyzed using Non-metric multidimensional scaling (NMDS). Again, the Bray-Curtis dissimilarity index between park bird assemblages was used. Species seen only once were removed from the analysis. The abundances were log $(x+1)$ transformed to avoid the effect of the abundant species (Oksanen 2014). The relationship between axes of the NMDS and environmental variables was explored by the envfit function (Oksanen et al. 2007) by using the vegan package. The arrow shows the direction of the environmental gradient, and the length of the arrow is proportional to the correlation between the environmental variable and the ordering of the NMDS (Oksanen 2015).

The change in bird composition between seasons in each park was analyzed by calculating the Bray-Curtis similarity index. In addition, the abundance-based Sorensen index that takes into account unobserved shared species between seasons was calculated (Chao et al. 2006). These similarity indexes were estimated with SPADE program (Chao and Shen 2010).

Bird richness in each season was calculated using a capture-recapture approach which assumes heterogeneity in detection probability among species and parks (Burnham and Overton 1979; Boulinier et al. 1998). This procedure uses a jackknife estimator associated with model M(h) (Burnham and Overton 1978, 1979; Otis et al. 1978), which estimates bird species richness and species detection probability. Therefore, we took into account possible differences in detectability among species within a park and possible differences in detectability among parks. These estimates were computed using COMDYN software (Hines et al. 1999), with presense-absence data of species in the four visits to each park. In the case of parks with two point counts, we used the cumulative number of species of each visit. On the other hand, the abundance was the average number of birds observed per point count in the four visits to each park (mean number of birds / point / 5 min).

The difference in bird richness and abundance by park among seasons was analyzed by paired Student's t tests. The relationship between dependent and environmental variables was determined using generalized linear models with a Gaussian error structure and identity-link function due to the continuous data (Crawley 2012). Data of bird richness were log-transformed to improve residuals distribution. Models were evaluated with information-theoretic procedures (Burnham and Anderson 2002). Models with all possible combinations of predictor variables were considered. Given the small sample size, Akaike's Information criterion corrected for small sample size (AICc) was calculated for each model (Burnham and Anderson 2002). Model comparisons were made with ΔAICc, which is the difference between the lowest AICc value (i.e., best of suitable models) and AICc from all other models. The best model was selected according to the AICc weight of the model (w_i), which indicates the relative likelihood that the specific model is the best of the suite of all models. For each predictor variable, w_i was summed across all models that contained that variable to estimate the relative variable importance. In addition, 95 % confidence interval limits were estimated for each predictor variable. The analyses were performed with the MuMIn package (Bartoń 2015) in R (R Development Core Team 2011). Plots of the regression models were constructed with the visreg package (Breheny and Burchett 2013).

Results

A total of 37 species were recorded (Table 2), including 24 during the non-breeding season and 32 during the breeding season. The average species detection probability was good in both seasons (breeding season, $\overline{X}=0.80$, Standard error = 0.03; non-breeding season, $\overline{X}=0.83$, SE = 0.03), and did not change between seasons ($t=0.76$, $P=0.463$). However, the detection probability varied considerably between parks in both seasons (breeding season, from 0.60 to 0.97; non-breeding season, from 0.60 to 0.99). This variation highlights the importance of taking into account the heterogeneity in species detectability when estimating bird richness, in comparison to the simple count of species detected which can induce biases in the estimation of bird richness.

Average bird species richness estimated per park was higher during the breeding season ($\overline{X}=17.43$, SE = 1.44) than during the non-breeding season ($\overline{X}=13.36$, SE = 1.25) ($t=3.08$, $P=0.009$). However, bird abundance per park did not change between seasons (breeding, $\overline{X}=16.47$, SE = 0.80; non-breeding, $\overline{X}=16.48$, SE = 1.01; $t=0.02$, $P=0.99$).

The House Sparrow (*Passer domesticus*), the Eared Dove (*Zenaida auriculata*) and the Picazuro Pigeon (*Patagioenas picazuro*) were the most abundant species observed during both seasons (Table 2). However, during the breeding season there were more migrant species than during the non-breeding season (eight versus two species) (Table 2).

Bird community composition did not change between seasons ($F_{(1,\ 26)}=1.66$, $P=0.11$, $r^2=0.06$). The best model explaining the seasonal similarity of composition in parks based on the Bray-Curtis index included the pedestrian traffic and DGA ($w_i=0.63$; see Electronic supplementary material 2). Parks with the highest pedestrian traffic and the highest isolation

Table 2 Percentage of total numbers of birds observed comprised by each bird species during breeding and non-breeding seasons in urban parks of Mar del Plata city, Argentina. R: resident species, SATT: South American Temperate-Tropical migrant, SACT: South American Cool-Temperate migrant (See Joseph 1997). Capital letters in species name's abbreviation indicate migrant species

Species	Abbreviation	Breeding	Non-breeding	Residency status
House Sparrow (*Passer domesticus*)[a]	pado	32.97	29.92	R
Eared Dove (*Zenaida auriculata*)	zeau	19.74	20.11	R
Picazuro Pigeon (*Patagioenas picazuro*)	papi	6.58	10.16	R
Rufous Hornero (*Furnarius rufus*)	furu	6.44	7.78	R
Chalk-browed Mockingbird (*Mimus saturninus*)	misa	5.00	6.24	R
Great Kiskadee (*Pitangus sulphuratus*)	pisu	4.11	4.70	R
Rufous-collared Sparrow (*Zonotrichia capensis*)	zoca	3.22	4.56	R
Shiny Cowbird (*Molothrus bonariensis*)	mobo	3.77	3.85	R
Rufous-bellied Thrush (*Turdus rufiventris*)	turu	3.29	3.29	R
House Wren (*Troglodyes aedon*)	trae	1.51	1.19	R
Hooded Siskin (*Sporagra magellanica*)	spma	0.27	2.42	R
Cattle Tyrant (*Machetornis rixosus*)	mari	1.03	1.05	R
European Greenfinch (*Carduelis chloris*)[a]	cach	1.85	0.21	R
Bay-winged Cowbird (*Agelaioides badius*)	agba	1.71	0.21	R
Chimango Caracara (*Milvago chimango*)	mich	0.69	1.19	R
Tropical Kingbird (*Tyrannus melancholicus*)	TYME	1.78	0	SATT
Vermilion Flycatcher (*Pyrocephalus rubinus*)	PYRU	1.17	0	SATT
White-rumped Swallow (*Tachycineta leucorrhoa*)	TALE	0.96	0	SATT
Blue-and-Yellow Tanager (*Pipraeidea bonariensis*)	pibo	0.14	0.8	R
Glittering-bellied Emerald (*Chlorostilbon lucidus*)	CHLU	0.82	0	SATT
Rock Dove (*Columba livia*)[a]	coli	0.27	0.5	R
Fork-tailed Flycatcher (*Tyrannus savana*)	TYSA	0.48	0	SATT
Monk Parakeet (*Myiopsitta monachus*)	mymo	0.48	0	R
Spot-winged Pigeon (*Patagioenas maculosa*)	pama	0.14	0.28	R
Small-bellied Elaenia (*Elaenia parvirostris*)	ELPA	0.34	0	SATT
White-throated Hummingbird (*Leucochloris albicollis*)	leal	0.14	0.14	R
Buff-winged Cinclodes (*Cinclodes fuscus*)	CIFU	0	0.28	SACT
Green-barred Woodpecker (*Colaptes melanochloros*)	come	0	0.28	R
Whistling Heron (*Syrigma sibilatrix*)	sysi	0.21	0	R
Grey-breasted Martin (*Progne chalybea*)	PRCH	0.21	0	SATT
Southern Lapwing (*Vanellus chilensis*)	vach	0	0.21	R
Tufted Tit-Spinetail (*Lepthastenura platensis*)	lepl	0.14	0	R
Wren-like Rushbird (*Phleocryptes melanops*)	phme	0.14	0	R
Red-crested Cardinal (*Paroaria coronata*)	paco	0	0.14	R
Guira Cuckoo (*Guira guira*)	gugu	0.07	0	R
Brown-chested Martin (*Progne tapera*)	PRTA	0.07	0	SATT
Dark-faced ground tyrant (*Muscisaxicola maclovianus*)	MUMA	0	0.07	SACT

[a] Exotic species

to other green areas had the lowest seasonality in bird composition (Table 3; Fig. 2a, b). On the other hand, the best model explaining the seasonal similarity of bird composition in parks according to the Abundance-based Sorensen index included the distance to the city center ($w_i = 0.67$, respectively; see Electronic supplementary material 3). Parks located furthest from the urban center had the highest seasonality in bird composition (Table 3; Fig. 2c).

NMDS axes were significantly related to the distance to the urban center during both seasons (Table 4). During the breeding season, the presence of the White-rumped Swallow (*Tachycineta leucorrhoa*), the Small-bellied Elaenia (*Elaenia parvirostris*), the Monk Parakeet (*Myiopsitta monachus*) and the Tufted Tit-Spinetail (*Lepthastenura platensis*) was related to parks far from the urban center, whereas the presence of the Rock Dove, the Spot-winged Pigeon (*Patagioenas maculosa*) and the Wren-like Rushbird (*Phleocryptes melanops*) was related to parks near the urban center (Fig. 3a). During the non-breeding season, the Spot-winged Pigeon, the White-throated Hummingbird (*Leucochloris albicollis*), the Blue-and-Yellow Tanager (*Pipraeidea bonariensis*) and the Hooded Siskin (*Sporagra magellanica*) were related to parks far from the urban center, whereas the presence of the Rock Dove, the House Sparrow and the European Greenfinch (*Carduelis chloris*) was in parks near to the urban center (Fig. 3b).

The best model explaining the bird richness variation among parks during the breeding season included the percentage cover of high buildings surrounding parks as explanatory variable ($w_i = 0.38$, see Electronic supplementary material 4). Parks surrounded by high buildings had the lowest bird richness (Table 5, Fig. 4). During the non-breeding season, the best model explaining bird richness included the percentage cover of high buildings and park size ($w_i = 0.26$, see Electronic supplementary material 5). However, neither percentage cover of buildings or park size considerably affected the bird richness, as both confidence limits encompassed zero (Table 5).

Bird abundance variation among parks during both seasons was best explained by park size (breeding season, $w_i = 0.36$, see Electronic Supplementary material 6; non-breeding season, $w_i = 0.49$, see Electronic supplementary material 7). Park size positively influenced the bird abundance (Table 6, Fig. 5a, b).

Table 3 Relative importance, estimates and 95 % confidence interval limits (CL) for explanatory variables describing the seasonal composition similarity based on the Bray-Curtis index and the abundance-based Sorensen index among urban parks in Mar del Plata city, Argentina. Explanatory variables with CL excluding zero are in bold. See Materials and methods for details

Response variable	Explanatory variable	Relative importance	Estimate ± SE	Confidence interval	
				Lower	Upper
Bray-Curtis index	**Intercept**		**0.516 ± 0.081**	**0.348**	**0.684**
	Pedestrian traffic	**0.96**	**0.040 ± 0.011**	**0.015**	**0.064**
	DGA	**0.74**	**2.0E-4 ± 8.4E-5**	**2.0E-05**	**4.0E-04**
	Park size	0.14	0.018 ± 0.026	−0.037	0.073
Abundance-based Sorensen index	**Intercept**		**0.979 ± 0.034**	**0.906**	**1.052**
	DCC	**1.00**	**−2.6E-5 ± 5.4E-6**	**−3.8E-05**	**−1.4E-05**
	Park size	0.13	−0.006 ± 0.009	−0.015	0.026
	H′ habitat	0.12	−0.057 ± 0.136	−0.355	0.242
	DGA	0.11	1.0E-5 ± 4.0E-5	−7.7E-05	9.7E-05

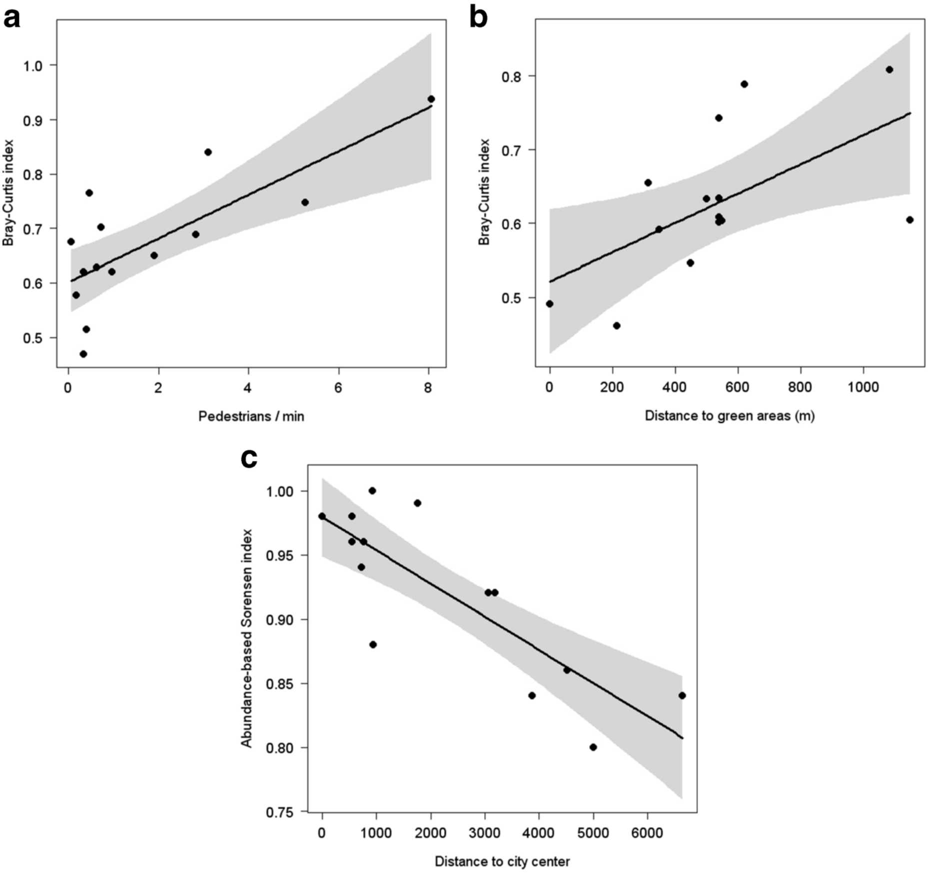


Fig. 2 Responses of the seasonal change in bird community composition, according to the Bray-Curtis similarity index, to pedestrian traffic (**a**) and the minimum distance to other green areas (**b**); and the response of the abundance-based Sorensen index (**c**) to the distance to the urban center in urban parks of Mar del Plata city, Argentina. Gray areas represent the confidence intervals at 95 %

Discussion

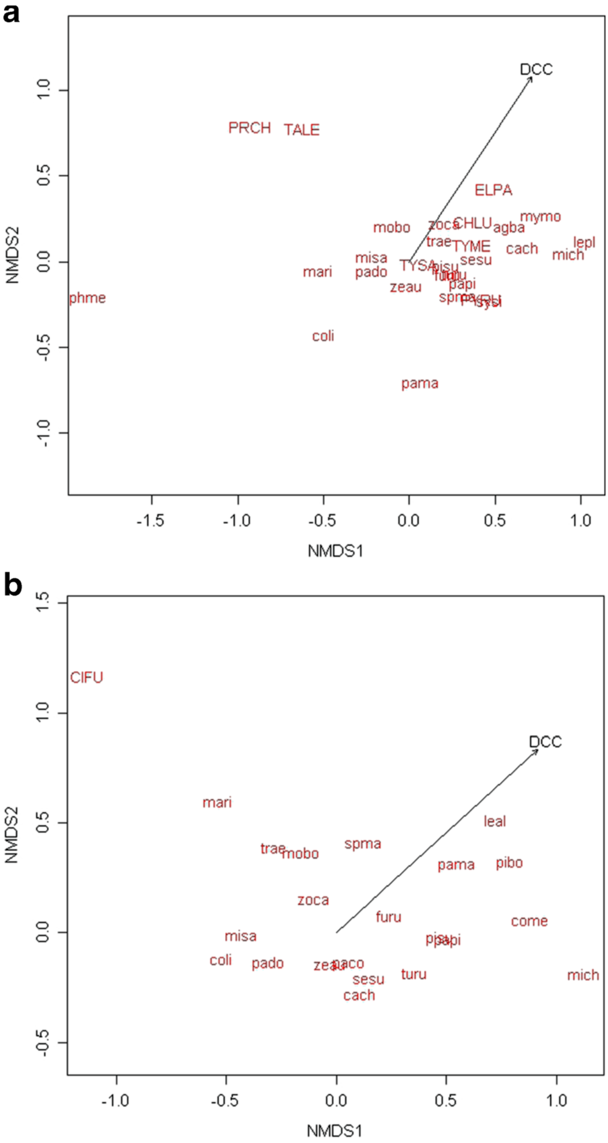
Except for the increased number of migrant species recorded during the breeding season, Adonis analysis did not reveal a significant change in species composition between seasons. However, the stability of species composition between seasons was higher in urban parks

Table 4 R-square values and significance of environmental vectors fitted to the Non-metric Multidimensional Scaling ordination

Environmental variables	Breeding season	Non-breeding season
Distance to green areas (DGA)	0.04	0.15
Distance to the urban center (DCC)	0.64**	0.44*
Park size	0.11	0.10
H′ habitat	0.41	0.18

$^{*}P < 0.05$, $^{**}P < 0.01$

Fig. 3 Plots of Non-metric Multidimensional Scaling for species and the environmental vectors fitted to ordination during breeding (Stress = 0.075) (**a**) and non-breeding seasons (Stress = 0.092) (**b**) in urban parks of Mar del Plata city. The vector shows the direction of linear correlation of the environmental variable with ordination scores. For species names see Table 2; capital letters indicate migrant species. DCC is the distance to city center



located near the urban center, with higher pedestrian traffic and more isolated from other green areas. This lower seasonal variation in species composition may be related to: 1) a higher stability of food resources provided by humans in parks nearer the urban center, which would allow the continuous presence of commensal bird species such as the Rock dove, the Eared dove and the House sparrow; and 2) a lack of suitable habitat for migratory bird species such as the Glittering-bellied Emerald (*Chlorostilbon lucidus*), the White-rumped Swallow, the Tropical Kingbird (*Tyrannus melancholicus*) and the Small-bellied Elaenia (Fig. 3a), which would decrease the seasonal variation in bird composition. Moreover, migrant species seem to be more affected by pedestrian traffic than resident species (Burger and Gochfeld 1991; Zhou and Chu 2012). On the other hand, both the degree of isolation from other green areas and

Table 5 Relative importance, estimates and 95 % confidence interval limits (CL) for explanatory variables describing the bird richness variation among urban parks in Mar del Plata city, Argentina, during the breeding and non-breeding seasons. Explanatory variables with CL excluding zero are in bold. See Materials and methods for details

Response variable	Explanatory variable	Relative importance	Estimate ± SE	Confidence interval	
				Lower	Upper
	Intercept		**1.289 ± 0.106**	**1.065**	**1.513**
Breeding bird richness (log)	**High buildings**	**0.92**	**−0.003 ± 0.001**	**−0.006**	**−0.001**
	Size	0.33	0.039 ± 0.026	−0.018	0.096
	DGA	0.21	−1.3E-4 ± 1.1E-4	−3.6E-4	1.1E-4
	H′ habitat	0.15	−0.280 ± 0.373	−1.099	0.539
	Intercept		**1.005 ± 0.183**	**0.624**	**1.386**
Non-breeding bird richness (log)	High buildings	0.62	−0.004 ± 0.002	−0.007	1.2E-4
	Park size	0.43	0.066 ± 0.038	−0.017	0.149
	H′ habitat	0.23	0.616 ± 0.519	−0.522	1.754
	DGA	0.12	−7.4E-5 ± 1.8E-4	−4.6E-4	3.1E-4

other variables correlated to the distance to city center, such as the percentage cover of impervious surfaces within parks and the proportion of high buildings can negatively affect the presence of migrant species by reducing the amount of vegetation cover, which constitutes a source of food resources for them. Overall, our result agrees with that of La Sorte et al. (2014) and Leveau et al. (2015), who found a lower seasonal turnover of bird communities in urban areas compared to natural and rural areas. These authors postulated that urbanization promotes a seasonal homogenization of bird communities. Our data also show a seasonal homogenization of bird communities at a smaller scale, focusing on urban parks.

Fig. 4 Relationship between breeding bird richness (species / park) and percentage cover of high buildings surrounding each park in Mar del Plata city, Argentina. Gray areas represent the confidence intervals at 95 %

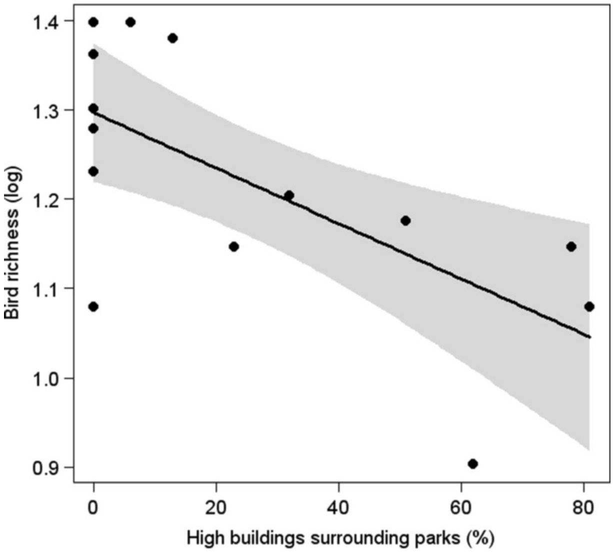


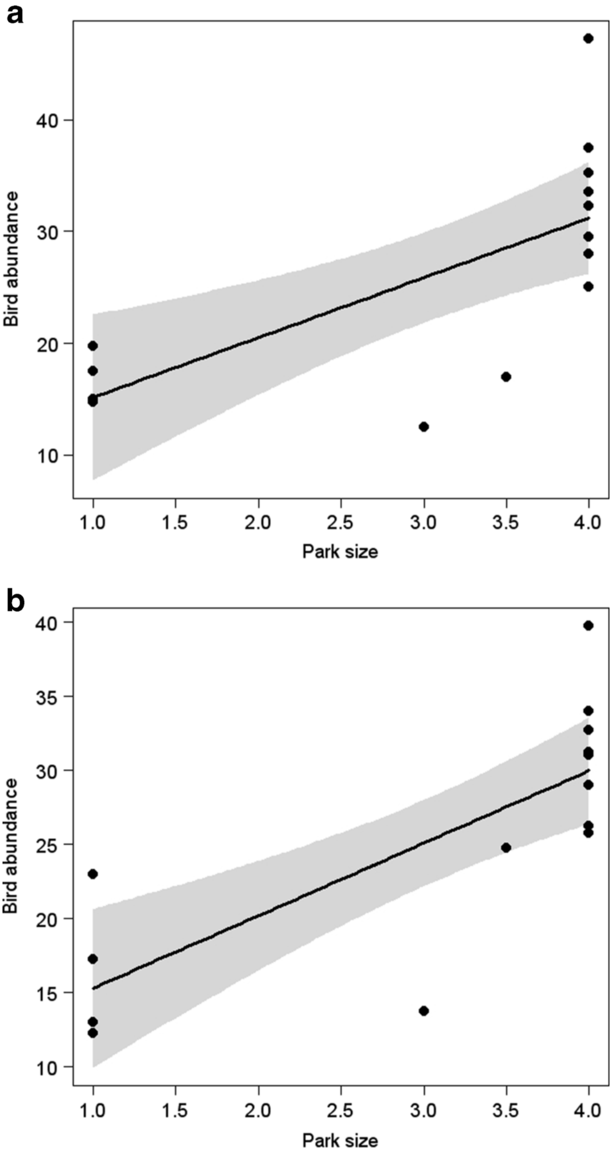
Table 6 Relative importance, estimates and 95 % confidence interval limits (CL) for explanatory variables describing the bird abundance variation among urban parks in Mar del Plata city, Argentina, during the breeding and non-breeding seasons. Explanatory variables with CL excluding zero are in bold. See Materials and methods for details

Response variable	Explanatory variable	Relative importance	Estimate ± SE	Confidence interval	
				Lower	Upper
	Intercept		9.234 ± 8.688	−9.068	27.535
Breeding bird abundance	**Park size**	**0.95**	**5.814 ± 1.774**	**1.988**	**9.640**
	High buildings	0.42	−0.130 ± 0.074	−0.292	0.032
	DGA	0.19	−0.008 ± 0.009	−0.027	0.010
	H′ habitat	0.16	26.845 ± 24.721	−27.386	81.075
	Intercept		6.663 ± 7.446	−9.906	22.233
Non-breeding bird abundance	**Park size**	**0.99**	**4.785 ± 1.158**	**2.253**	**7.317**
	H′ habitat	0.36	26.875 ± 16.441	−9.344	63.094
	DGA	0.10	0.001 ± 0.006	−0.012	0.015
	High buildings	0.10	−0.007 ± 0.061	−0.141	0.126

In our study, bird species richness in urban parks was higher during the breeding season. This result agrees with several studies conducted in natural and agricultural habitats of central Argentina (Cueto and Lopez de Casenave 2000; Isacch and Martínez 2001; Codesido et al. 2008; Leveau and Leveau 2011). The increase of bird richness in urban parks may be partially explained by the arrival of migrants. In fact, during the breeding season eight species of migrants were observed whereas during the non-breeding season we saw only two such species. Migrant species observed during the breeding season belong to the South American Temperate-Tropical group, species that breed in central-east Argentina and migrate to northern South America during autumn-winter (Joseph 1997). Several species recorded in our study such as the Glittering-bellied Emerald, the Gray-breasted Martin (*Progne chalybea*), the White-rumped Swallow, the Tropical kingbird and the Fork-tailed flycatcher (*Tyrannus savana*) also were recorded during the breeding season in urban parks of Buenos Aires city, Argentina (Faggi and Perepelizin 2006). On the other hand, migrant species recorded during the non-breeding season in the urban parks of Mar del Plata, such as the Buff-winged Cinclodes (*Cinclodes fuscus*) and the Dark-faced ground Tyrant (*Muscisaxicola maclovianus*), belong to the South American Cool-Temperate migrants, species that breed in Patagonia and migrate during autumn- winter to central and north Argentina, Bolivia, Perú and Uruguay (Joseph 1997). Due to the scarcity of South American Cool-Temperate migrants in our study, results suggest that urban parks in Mar del Plata are mainly suitable for the South American Temperate-Tropical migrants.

Most of the bird species recorded in our study also were reported along streets in urban and suburban areas of Mar del Plata (Leveau and Leveau 2004). However, the abundances of the Fork-tailed Flycatcher, the Vermilion Flycatcher (*Pyrocephalus rubinus*) and the Cattle Tyrant (*Machetornis rixosus*) were higher in urban parks than in the least urbanized sites of Mar del Plata (Leveau and Leveau 2004), suggesting that urban parks are relevant habitats for these species.

Fig. 5 Relationship between bird abundance (birds / point count / 5 min) per park and park size during the breeding season (**a**) and the non-breeding season (**b**) among urban parks of Mar del Plata city, Argentina. Gray areas represent the confidence intervals at 95 %



According to our results, bird abundance did not change between seasons in the urban parks of Mar del Plata. In contrast, other studies conducted in natural and agricultural habitats showed an increase in bird abundance during the breeding season (Cueto and Lopez de Casenave 2000; Isacch and Martínez 2001; Codesido et al. 2008; Leveau and Leveau 2011). Generally, this seasonal variation of bird abundance in natural and semi-natural areas is related to seasonal fluctuation in food resources during the year. But urban parks often receive the provision of supplementary food by visitors, such as breads and grains (Zhou and Chu 2012). During the non-breeding season, the supplementary food may benefit omnivorous and granivorous species such as the Rock dove, the Eared dove, the Spot-Winged Pigeon, the

Picazuro Pigeon, the House sparrow and the Shiny Cowbird (*Molothrus bonariensis*). Therefore, the supplementary food provided by humans may stabilize bird abundance throughout the year.

During the breeding season the percentage cover of high buildings surrounding each park negatively affected bird richness. This finding is consistent with previous studies on urban parks (Jokimäki 1999; Husté et al. 2006; Latta et al. 2013). Parks surrounded by heavily urbanized areas may provide fewer resources to birds in comparison with parks surrounded by detached houses with yards, which have a greater cover of vegetation (Leveau 2013). On the other hand, the percentage cover of high buildings was positively correlated to pedestrian and car traffic. Previous studies showed that pedestrian traffic negatively affects the presence and the feeding activity of birds (Fernández-Juricic and Tellería 2000; Fernández-Juricic 2001). Increased car traffic is associated with more noise, which may negatively affect the presence of several bird species (Patón et al. 2012; Francis 2015). The noise pollution caused by the car traffic may constrain acoustic intraspecific communication of birds (González-Oreja et al. 2012).

Contrary to the results found elsewhere (Jokimäki 1999; Natuhara and Imai 1999; Fernández-Juricic 2000b; Garitano-Zavala and Gismondi 2003; Husté et al. 2006; Zhou and Chu 2012), our data did not show a significant relationship between bird richness and park size. This could be related to the low range of park size (1 to 4 ha) in our study compared to other studies (Natuhara and Imai 1999: from 0.06 to 43.4 Ha; Fernández-Juricic 2000b: from 1 to 118.2 Ha; Zhou and Chu 2012: from 1 to 19.1 Ha). In addition, habitat diversity was not related to bird richness. The relatively homogeneous structure of urban parks selected in this study could be related to the absence of a significant relationship.

The strongest relationship between bird richness and the environmental variables was during the breeding season. This may be related to a more specialized habitat use and spatial constraints related to the reproductive behavior of birds (Delgado and Moreira 2000; Caula et al. 2008). During the breeding season birds need to select habitats with suitable nesting sites, singing spots and shelter (Hildén 1965; Alatalo 1981). During the non-breeding season, habitat use is more relaxed because individuals increase movements to alternative habitats in the process of dispersal (Tellería and Santos 1997; Murgui 2007). Alternatively, the increase in car traffic during the breeding season due to the arrival of tourists to Mar del Plata could affect bird richness more during the breeding season.

Park size was a strong positive predictor of bird abundance during both seasons. Larger parks could contain more food resources and more interior habitat farther from human disturbances and traffic noise at the edge of parks (Zanette et al. 2000). Car and pedestrian traffic at the edge of urban parks can be higher than in interior areas, negatively affecting bird abundance (Fernández-Juricic 2001). Finally, more edge habitats in smaller urban parks can increase the exposure to nest predation (Jokimäki and Huhta 2000).

Urban parks constitute an essential part of cities for their role in human health and biodiversity conservation (Fuller et al. 2007; Bowler et al. 2010; Nielsen et al. 2014). Since Mar del Plata will continue to expand in the future, the creation of new urban parks is imperative, mainly in neighborhoods at the urban fringe. We suggest that urban planners should take into account the urbanization level surrounding parks and the levels of pedestrian and car traffic to promote higher bird diversity in urban parks. More specifically, traffic calming measures on streets surrounding parks can not only increase the diversity of bird species, but also the health of human beings (Morrison et al. 2004). Moreover, more attention must be paid to mitigate the temporal homogenization of bird composition. There is evidence that people can have a positive attitude to the seasonal change in nature. In a study conducted in Oulunsalo (Finland) most of the people enjoyed the change of seasons (Jauhiainen and Mönkkönen 2005). Therefore, management and planning of urban parks should emphasize the variation of seasons (Palang et al. 2005). Our study showed that more urbanized parks, with higher pedestrian traffic, cover of impervious surfaces within parks and presence of high buildings surrounding parks, were related to a reduction in the seasonal change of bird composition. The design of new urban parks with less impervious surface cover and surrounded by areas of low population density may allow the presence of a higher proportion of migrant species. However, more studies about the effect of urbanization on the seasonal dynamics of bird communities and its impact on humans are needed.

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