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Long-term directional changes in urban bird communities of Mar del Plata City, Argentina

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Urban environments have been characterized by their temporal stability of resources, which could promote stability in bird composition. Several studies have found that bird communities in urban environments persist over the years, showing a similar species composition in the short term. However, studies analyzing continuous changes in urban communities over the long term are scarce. This study aimed to analyze the stability or directional changes (instability) in bird communities along an urban gradient. Bird counts were conducted in urban, suburban, and periurban areas over 8-10 years in 2002-2019. Changes in species composition were analyzed over periods ranging from one year to the next, to changes from one year to the seventeenth. Urban bird communities were more similar between years than suburban and periurban communities. Compositional changes were greater as time lags increased, indicating directional compositional shifts. The magnitude of these changes was similar across the urban gradient. The Chimango Caracara (*Milvago chimango*), the Picazuro Pigeon (*Patagioenas picazuro*), the Rufous Hornero (*Furnarius rufus*), and the Red-bellied Thrush (*Turdus rufiventris*) significantly increased their abundances during the period, while the House Sparrow (*Passer domesticus*) significantly decreased its abundance. Regional changes in species abundance, urban vegetation succession, and biotic interactions could explain the changes in bird communities.

KEYWORDS

avian, disturbance, composition, persistence, stability, urbanization

Introduction

Analyzing interannual variation in biotic communities is fundamental to understanding community assembly. Temporal dynamics of communities may be related to changes in environmental local conditions or biotic interactions and regional environmental changes that promote species density fluctuations or range distributional changes (Väisänen et al., 1986; Wiens, 1989; Dornelas et al., 2014). In the actual global change scenario, long-term analysis of communities allows us to identify the factors responsible for population changes (Storch et al., 2023).

Urbanization is one of the most drastic anthropogenic land use changes, causing fragmentation, habitat loss, alteration of hydrologic and biogeochemical cycles, and biodiversity loss (Grimm et al., 2008). Several authors have proposed that urbanization promote a temporal stabilization of environmental conditions, ultimately dampening temporal dynamics of biotic communities (Shochat et al., 2006; Leveau, 2018). Urban areas have shown lower interannual fluctuations of primary productivity than natural or rural areas (Shochat et al., 2004; Leong and Roderick, 2015). This dampening of resources in urban areas has been associated with the higher interannual persistence of bird species in urban areas (Suhonen et al., 2009; Leveau and Leveau, 2012). For example, Leveau et al. (2015) have found that urban bird assemblages had a lower interannual dissimilarity than assemblages of rural areas.

Although several long-term studies of avian communities have been carried out in urban areas (Campbell et al., 2022; Echeverry-Galvis et al., 2023; Skjelvik and Dale, 2024; and references in Fidino and Magle, 2017), it is unknown if urbanization is related to the stabilization of bird communities. Collins et al. (2000) have proposed an analytical method to assess community stability by analyzing the relationship between community dissimilarity and different time intervals or time lags (Figure 1). The regression slope between both variables indicates the rate of change in community composition, whereas the regression coefficient indicates the proportion of signal versus noise (Collins et al., 2000). Thus, the increasing dissimilarity with time lag suggests an unstable directional change because species composition changes with time (Figure 1). On the other hand, a negative relationship between composition dissimilarity and time lag would indicate another type of instability, because community composition is converging to the initial community of the time series. The lack of correlation between species dissimilarity and time lag suggests stability.

This study aims to analyze bird community composition change along the urban gradient of Mar del Plata City over 18 years. Specifically, the study aimed to analyze along the urban gradient: 1) the long-term abundance change of bird species; 2) the mean interannual change of bird composition; and 3) the rate of community composition changes with the passing of years. The habitat structure and level of urbanization of the study area were stable during the period, e.g. no change in land use was noticeable. However, the region had an increasing crop cover, climate warming, and increasing precipitations (Baeza and Paruelo, 2020; Ferrelli et al., 2021a, Ferrelli et al., 2021b), presumably causing population increases and distributional range expansions in several bird species (Gavier-Pizarro et al., 2012; Grande et al., 2015; Leveau, 2021; Vazquez et al., 2024). These species, such as doves, raptors, and swallows, can inhabit urban environments (La Sorte et al., 2018). Recently, Skjelvik and Dale (2024) have shown that local bird species population trends in urban parks were positively related to regional population trends. We expect bird assemblages of the most urbanized areas would be more persistent between years, e.g. their mean interannual species composition will be more similar than in less urbanized areas. However, species composition directional changes would occur with increasing time lags along the urban gradient due to the regional population increases of bird species that can invade urban areas.

Materials and methods

Study area

The study was carried out in Mar del Plata City (38°00′S 57°33′W, 15-38 m.a.s.l.), a coastal tourist city in central-east Argentina (Figure 2). The city has a population of 682605 (National Census

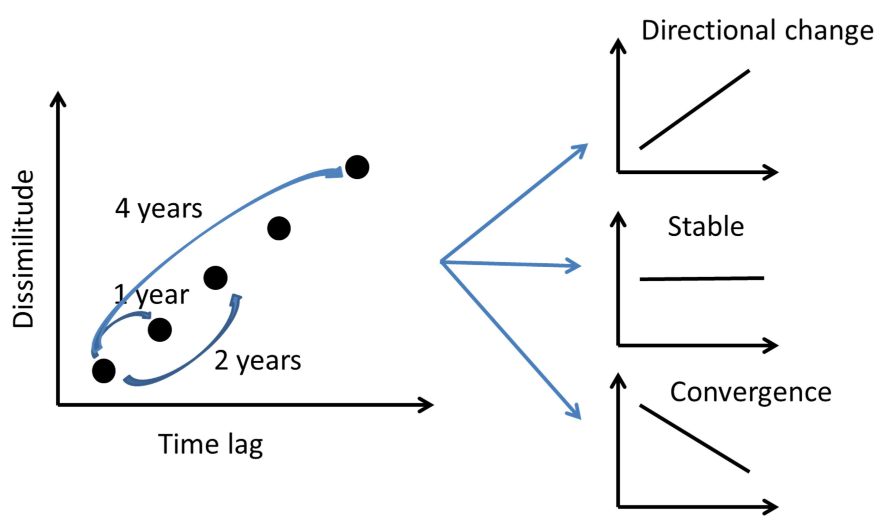

FIGURE 1
Schematic representation of the community stability analysis based on the relation between species composition dissimilarity and different time intervals or time lags. Source: Original figure based on the idea of Collins et al. (2000).

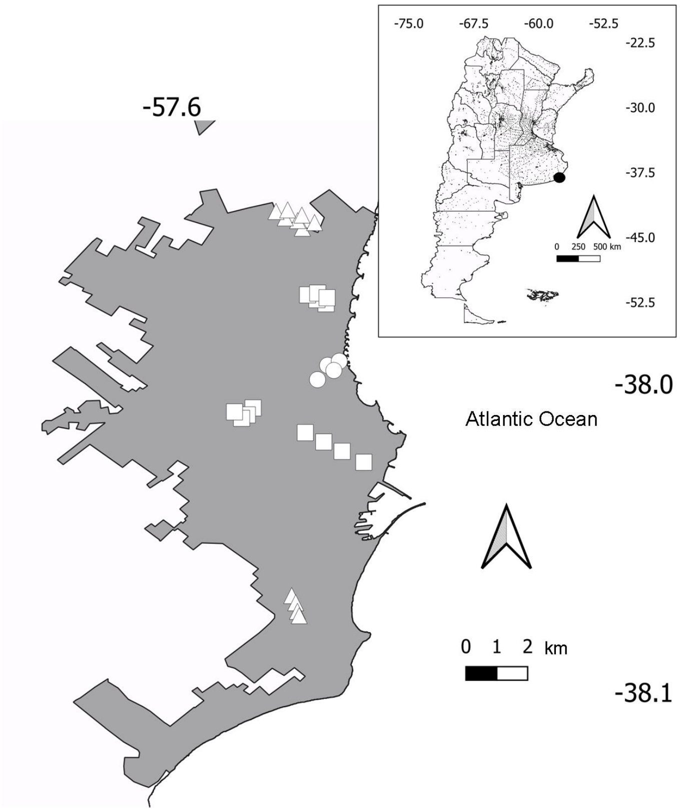

FIGURE 2
Location of Mar del Plata City in Argentina (inset) and urban (circles), suburban (squares), and periurban (triangles) transects in Mar del Plata.

2022), and since 2001 has increased by 21% (National Institute of Statistics and Censuses, https://www.indec.gob.ar/). Mar del Plata has a temperate oceanic climate, with cold winters (July mean temperature = 7.5°C; period 1991-2020) and relatively warm summers (mean January temperature = 20.3°C) (Servicio Meteorológico Nacional, 2023). The mean annual precipitation is 946.1 mm (Servicio Meteorológico Nacional, 2023). The dominant native vegetation of the region is a pseudo-steppe of mesophytes with hill scrub (Oyarzabal et al., 2018). However, the human transformation of the landscape has led to a dominance of crops, grazing lands and exotic tree plantations.

Bird surveys

According to definitions in Marzluff et al. (2001) and MacGregor-Fors (2011), three habitat types were surveyed (see Leveau and Leveau, 2004, Leveau and Leveau, 2012): 1) urban habitat or highly developed was the commercial and administrative center of the city, dominated by buildings and paved streets (mean impervious cover = 95.19%); 2) suburban habitat or moderately developed, composed of detached houses with yards and paved streets (mean impervious cover = 54.45%); and 3) periurban habitat or sparsely developed, composed of detached houses with yards with more vegetation than the suburban habitat and located on the city fringe (mean impervious cover = 17.49%). Bird surveys were carried out during the first four hours after dawn once in December by 100 x 50 m transects, separated at least by 200 m (see more details in Leveau and Leveau, 2012). The period of the year coincided with the bird breeding season (de la Peña, 2013). Bird counts were mainly carried out by LML with the help of Carlos M. Leveau during 2002-2005, while only LML did surveys during the rest of the periods.

The number of transects varied between habitats (Figure 2). The urban habitat had four transects, the suburban habitat 13 transects, and the periurban habitat 11 transects. Transects of the urban habitat were visited during 2002-2005, 2009-2012, and 2018-2019, totaling ten years of surveys. Four suburban and periurban transects were surveyed during the same period. However, nine suburban transects did not have surveys during 2009, whereas seven periurban transects did not have surveys during 2009 and 2010.

Statistical analysis

Species abundance (individuals/transect) was correlated with the years along the urban gradient using Spearman rank (r_s) correlation with the cor function in R (R Core Team, 2019) (Table 1). Only species with three or more records were analyzed. To group the different trends of species abundances through the years, the Spearman rank correlation of each species was grouped using cluster analysis with the function hclust in R (R Core Team, 2019). Dendrograms were obtained using the Euclidean distance between species correlations with single, complete, and average linkage methods. The best linkage method was tested through cophenetic correlations between the Euclidian distance matrix and the cophenetic distance representing the distance of species in the dendrogram (Borcard et al., 2011). Then, the average method had the highest cophenetic correlation and was used to construct the dendrogram.

To test for different interannual species abundance trends along the urban gradient, the species abundance in each transect was related to the interaction between habitat and year, and the number of observers during each year (Table 1). Species trends between habitat types were assessed through generalized linear mixed models (GLMM) using the glmmTMB function of the glmmTMB package (Brooks et al., 2023). A negative binomial (nbinom2) distribution of errors was used. The transect was deemed as a random factor. Models were constructed by backward elimination of non-significant variables ($P > 0.05$) from the full model using the anova function. Final models were contrasted against null models using a likelihood ratio test (LRT test) ($P < 0.05$).

To test for differences of interannual dissimilarity between habitats and directional changes of bird assemblages in the three habitat types (Table 1), the Horn-Morisita dissimilarity index was calculated between years for each transect with the vegdist function in vegan (Oksanen et al., 2022). The Horn-Morisita index is based on differences in the species proportion of two samples and is not biased by differences in sample size (Wolda, 1981). The dissimilarity between years was related to the time lag through a GLMM with the lmer function of the lme4 package (Bates et al., 2015). Time lag was measured at different time intervals (Figure 1, Collins et al., 2000). Time lags were transformed to the square root to avoid the probability that the smaller number of points at larger time lags will bias the analysis (Collins et al., 2000). The mixed model included the interaction between time lag and habitat type, and each transect was deemed as a random factor. Models were constructed by backward elimination of non-significant variables ($P > 0.05$) from the full model using the anova function. Final models were contrasted against null models using a likelihood ratio test (LRT test) ($P < 0.05$). The signal of the community composition change with time was assessed for each habitat type by running a GLMM and calculating the regression coefficient with the function rsquared of the piecewiseSEM package (Lefcheck, 2016). This function allows us to calculate the marginal r^2 due to time lag and the conditional r^2 due to both time lag and the random effects (the transects) (Lefcheck, 2016).

All diagnostic analyses were carried out with the DHARMa package (Hartig, 2022). Final models were plotted using the visreg function of the visreg package (Breheny and Burchett, 2017).

TABLE 1 Summary of statistical approaches used to each study objective along the urban gradient in Mar del Plata City during 2002-2019, Argentina.

Objective	Dependent variable	Explanatory variable	Methods
1-To analyze the long term abundance change of bird species	Bird abundance	Year	Spearman rank correlation
	Bird abundance	Year-Habitat interaction, number of observators	GLMM
2-To analyze the mean interannual change of bird composition	Horn-Morisita dissimilarity index	Habitat	GLMM
3-To analyze the rate of community composition change with the passing years	Horn-Morisita dissimilarity index	Time lag-Habitat interaction	GLMM

Bird species abundance is individuals/transect; the time lag is the difference of years between sampling dates; GLMM is generalized linear mixed model.

Results

A total of 47 bird species and 4408 bird detections were made (Table 2). The total richness was lower in urban than in suburban and periurban habitats. *Columba livia* and *Passer domesticus* were the most common species in the urban habitat, *Passer domesticus* and *Zenaida auriculata* were the most common in the suburban habitat, whereas *Patagioenas picazuro* and *Passer domesticus* were the most common species in the periurban habitat (Table 2).

According to the correlations between species abundances and years along all sites, four groups were obtained (Figure 3). A group of species such as *Tyrannus savana*, *Agelaioides badius* and *Mimus saturninus* had no general correlation between abundances and years. A second group of species such as *Molothrus bonariensis*, *Zonotrichia capensis*, and *Passer domesticus* showed average negative correlations between abundances and years (Figure 3). The other two groups of species showed increases in abundance through the years. Species such as *Leucochloris albicollis*, *Zenaida auriculata*, and *Setophaga pitiayumi* showed moderate increases (mean $r_s = 0.14$), whereas *Sturnus vulgaris* and *Hirundo rustica* showed strongest interannual increases (mean $r_s = 0.36$).

Some species showed different interannual changes of abundances between the three habitats. For example, *Patagioenas picazuro* and *Turdus rufiventris* showed abundances increases in urban and suburban habitats, whereas *Pitangus sulphuratus* only showed increases in the urban habitat (Table 3, Figure 4). *Zenaida auriculata* showed decreasing abundances in suburban habitats, and increasing abundances in urban and periurban habitats (Table 3, Figure 4). Other species, such as *Milvago chimango*, *Spinus magellanica*, and *Passer domesticus* had similar trends along the three habitats (Table 3).

The dissimilarity of bird assemblages was related to the passing of years and habitats (LRT = 51.58, df = 3, $P < 0.001$, Table 4). The interannual dissimilarity of bird assemblages was lower in urban habitats than in suburban and periurban habitats (Figure 5). Therefore, urban habitats had more similar species relative abundances between years compared to suburban and periurban habitats. The dissimilarity of assemblages increased with the passing of years and the rate of increase was similar between habitats (Figure 5). Thus, the relative abundance of species changed continuously through the passing of the years along the three

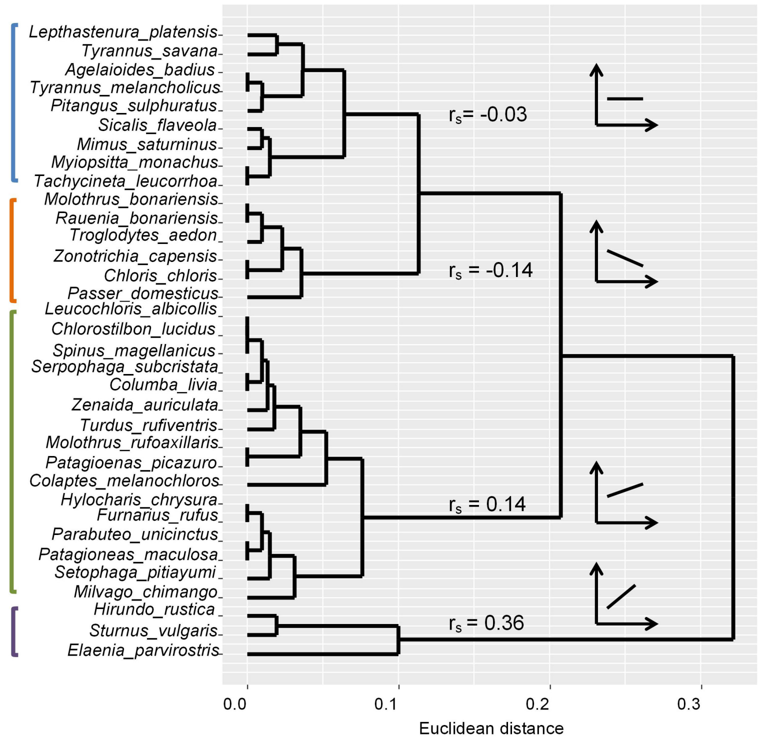

FIGURE 3
Dendrogram showing four groups (cut off 0.10 Euclidian distance) based on species distances of Spearman rank (r_s) correlations between species abundances and years during 2002-2019. Mean correlation values for species in each group are provided.

habitats, showing a pattern of instability of assemblages. However, the signal of these trends was low for the three habitats, and most of the variability was explained by the joint effect of time lag and random effects (Table 5). Therefore, this pattern suggests that there was a significant variation of dissimilarity trends among transects (Figure 6).

Discussion

Our results showed that some species had stable or decreasing interannual abundance trends, but most species showed linear increases. More detailed analyses revealed that some species, such as *Patagioenas picazuro*, *Zenaida auriculata*, and *Pitangus sulphuratus*, had different temporal trends between urban, suburban, and periurban habitats. These changes led to directional changes of avian assemblages which, contrary to what was expected, were of similar rate between the different levels of urbanization.

Bird communities along the urban gradient

The species richness of communities declined in the urban habitat compared to suburban and periurban habitats. The high cover of impervious surfaces in the urban habitat allowed the numerical dominance of *Passer domesticus*, *Columba livia* and *Zenaida auriculata*, which nest on buildings and street trees and can take advantage of discarded food by humans (Leveau and Leveau, 2004; La Sorte et al., 2018). On the other hand, the higher vegetation cover and habitat diversity in suburban and periurban habitats allowed a greater species richness (MacArthur and MacArthur, 1961; Leveau and Leveau, 2004).

Species interannual trends

Some species, such as *Passer domesticus* and *Zonotrichia capensis* showed yearly decreasing trends in their abundances. In the case of *Passer domesticus*, several studies in Argentina and worldwide have found similar results (Shaw et al., 2008; Dandapat et al., 2010; Berigan et al., 2020; Palacio et al., 2018; Campbell et al., 2022). Possible causes of *Passer domesticus* declines are: an increase in pollution; an increase in human socio-economic status; the increase in predation pressure; the decrease in herbaceous vegetation cover; and exposure to diseases (reviewed in Shaw et al., 2008 and Bernat-Ponce et al., 2020). In our study, we found interannual increases in ecological similar species to *Passer domesticus*, such as *Zenaida auriculata* and *Sturnus vulgaris*. These species are omnivorous ground foragers that could compete with *Passer domesticus*. We have seen aggressive exclusion from feeders of individuals of *Passer domesticus* from individuals of *Zenaida auriculata*. On the other hand, potential nest and adult predators of *Passer domesticus*, such as *Milvago chimango*

TABLE 2 List of species recorded along the urban gradient of Mar del Plata City, Argentina, during 2002-2019.

		Habitat		
English name	Scientific name	Urban	Suburban	Periurban
Harris's Hawk	*Parabuteo unicinctus*	0.00	0.05	0.18
Roadside Hawk	*Rupornis magnirostris*	0.00	0.05	0.00
Southern Lapwing	*Vanellus chilensis*	0.00	0.04	0.00
Chimango Caracara	*Milvago chimango*	1.61	1.34	5.69
Rock Dove	*Columba livia*	33.80	0.89	0.54
Picazuro Pigeon	*Patagioenas picazuro*	1.01	11.56	19.93
Spot-winged Pigeon	*Patagioenas maculosa*	0.00	0.67	0.90
Eared Dove	*Zenaida auriculata*	18.71	21.52	10.41
Picui Ground-dove	*Columbina picui*	0.00	0.09	0.00
Burrowing Parakeet	*Cyanoliseus patagonus*	0.00	0.00	0.60
Monk Parakeet	*Myiopsitta monachus*	0.00	1.07	0.36
Dark-billed Cuckoo	*Coccyzus melacoryphus*	0.00	0.00	0.06
Guira Cuckoo	*Guira guira*	0.00	0.05	0.06
Glittering-bellied Emerald	*Chlorostilbon lucidus*	0.00	0.80	0.90
Gilded Sapphire	*Hylocharis chrysura*	0.00	0.09	0.06
White-throated Hummingbird	*Leucochloris albicollis*	0.00	0.58	3.83
Green-barred Woodpecker	*Colaptes melanochloros*	0.00	0.13	0.36
Rufous Hornero	*Furnarius rufus*	0.60	7.19	6.10
Tufted Tit-Spinetail	*Lepthastenura platensis*	0.00	0.09	0.12
Vermilion Flycatcher	*Pyrocephalus rubinus*	0.00	0.05	0.00
White-crested Tyrannulet	*Serpophaga subcristata*	0.00	0.67	0.96
Small-billed Elaenia	*Elaenia parvirostris*	0.00	1.43	1.62
Cattle Tyrant	*Machetornis rixosus*	0.00	0.09	0.00
Great Kiskadee	*Pitangus sulphuratus*	1.41	3.26	4.85
Tropical Kingbird	*Tyrannus melancholicus*	0.00	1.52	1.26
Fork-tailed Flycatcher	*Tyrannus savana*	0.00	0.36	0.06
Rufous-bellied Thrush	*Turdus rufiventris*	0.81	6.25	8.62
Chalk-browed Mockingbird	*Mimus saturninus*	0.00	1.74	1.02
European Starling	*Sturnus vulgaris*	0.00	1.47	0.96
Crested Myna	*Acridotheres cristatellus*	0.00	0.00	0.24
House Wren	*Troglodytes aedon*	0.60	3.84	4.79
Gray-breasted Martin	*Progne chalybea*	0.20	0.00	0.00
White-rumped Swallow	*Tachycineta leucorrhoa*	0.00	0.58	0.00
Barn Swallow	*Hirundo rustica*	1.21	0.80	0.54
House Sparrow	*Passer domesticus*	40.04	24.46	10.47
Hooded Siskin	*Spinus magellanicus*	0.00	0.71	1.56
European Greenfinch	*Chloris chloris*	0.00	0.31	0.96
European Goldfinch	*Carduelis carduelis*	0.00	0.00	0.12

(Continued)

TABLE 2 Continued

		Habitat		
English name	Scientific name	Urban	Suburban	Periurban
Tropical Parula	*Setophaga pitiayumi*	0.00	0.36	1.50
Blue-and-Yellow Tanager	*Rauenia bonariensis*	0.00	0.40	0.18
Double-collared Seedeater	*Sporophila caerulescens*	0.00	0.05	0.00
Yellow Cardinal	*Gubernatrix cristata*	0.00	0.05	0.00
Rufous-collared Sparrow	*Zonotrichia capensis*	0.00	1.83	4.31
Saffron Yellow-Finch	*Sicalis flaveola*	0.00	0.00	0.24
Shiny-Cowbird	*Molothrus bonariensis*	0.00	2.41	1.62
Screaming Cowbird	*Molothrus rufoaxillaris*	0.00	0.18	0.12
Bay-winged Cowbird	*Agelaioides badius*	0.00	0.98	3.95
Total of species		11	41	38

Values are the percentage of abundance in each habitat.

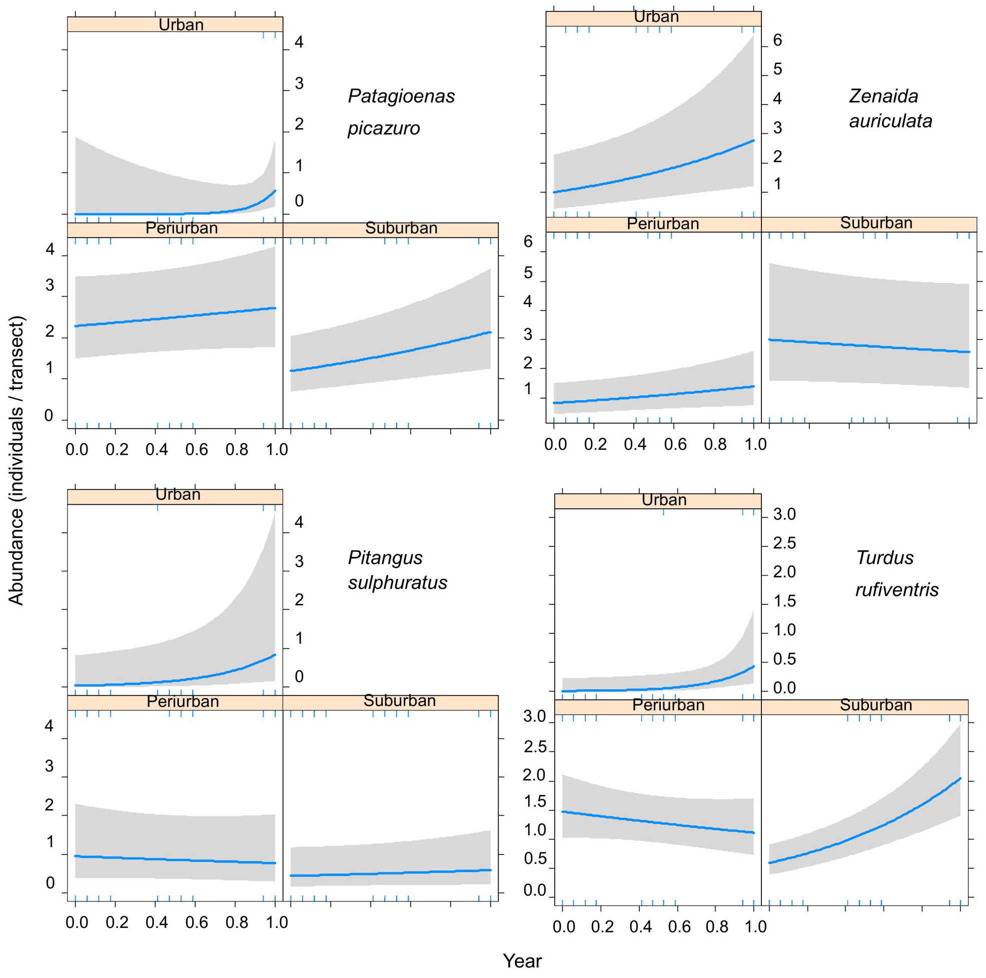

FIGURE 4
Final generalized linear mixed models showing the relationship between bird abundance and years during 2002-2019 in three urban habitats of Mar del Plata City, Argentina. Blue lines indicate the fitted model and grey bands indicate 95% confidence intervals. The year was standardized.

TABLE 3 Final generalized linear mixed models between species abundances, sampling effort (number of observers), habitat, and year along the urban gradient of Mar del Plata City, Argentina.

Species	Variables	Estimate	Std. Error	z value	P
Milvago chimango	Intercept	-0.950	0.289	-3.291	**0.001**
	Suburban	-1.284	0.357	-3.597	**<0.001**
	Urban	-1.603	0.564	-2.843	**0.004**
	Year	1.300	0.310	4.198	**<0.001**
Columba livia	Intercept	-3.633	0.691	-5.260	**<0.001**
	Suburban	0.631	0.711	0.887	0.375
	Urban	4.533	0.869	5.216	**<0.001**
	Year	1.041	0.385	2.702	**0.007**
Patagioenas picazuro	Intercept	1.050	0.159	6.597	**<0.001**
	Suburban	-0.656	0.227	-2.882	**0.004**
	Urban	-10.704	5.360	-1.997	**0.046**
	Year	0.177	0.182	0.975	0.330
	Suburban* Year	0.412	0.267	1.543	0.123
	Urban*Year	9.143	5.539	1.651	0.099
Zenaida auriculata	Intercept	0.093	0.206	0.451	0.652
	Suburban	1.290	0.255	5.062	**<0.001**
	Urban	0.192	0.376	0.509	0.611
	Year	0.526	0.277	1.902	0.057
	Suburban* Year	-0.679	0.333	-2.038	**0.042**
	Urban*Year	0.492	0.495	0.995	0.320
Furnarius rufus	Intercept	-0.046	0.167	-0.275	0.783
	Suburban	-0.110	0.225	-0.490	0.624
	Urban	-14.602	15.015	-0.972	0.331
	Year	0.152	0.292	0.521	0.602
	Suburban* Year	0.756	0.375	2.014	**0.044**
	Urban*Year	13.840	15.310	0.904	0.366
Pitangus sulphuratus	Intercept	0.232	0.264	0.876	0.381
	Suburban	-0.779	0.388	-2.011	**0.044**
	Urban	-3.413	1.627	-2.098	**0.036**
	Year	-0.209	0.378	-0.554	0.579
	Suburban* Year	0.509	0.517	0.983	0.326
	Urban*Year	3.496	1.677	2.085	**0.037**
Turdus rufiventris	Intercept	0.424	0.136	3.112	**0.002**
	Suburban	-0.918	0.216	-4.257	**<0.001**
	Urban	-5.883	2.040	-2.884	**0.004**
	Year	-0.283	0.251	-1.129	0.259
	Suburban* Year	1.531	0.348	4.400	**<0.001**
	Urban*Year	4.934	2.287	2.158	**0.031**
Passer domesticus	Intercept	0.618	0.161	3.837	**<0.001**
	Suburban	1.031	0.196	5.255	**<0.001**
	Urban	1.107	0.268	4.129	**<0.001**
	Year	-0.497	0.144	-3.448	**0.001**
Spinus magellanicus	Intercept	-8.803	2.650	-3.322	**0.001**
	Number of observers	2.903	1.268	2.289	**0.022**
	Year	3.990	1.579	2.527	**0.012**

(Continued)

TABLE 3 Continued

*Denotes interaction between variables. Bold P values are significant (P < 0.05). The periurban habitat is in the intercept.

and *Parabuteo unicinctus*, have also increased their abundance. Thus, we suggest that biotic interactions could be related to the *Passer domesticus* declines in Mar del Plata City.

Zonotrichia capensis is a ground nester species that could be negatively impacted by nest predation (Jokimäki and Huhta, 2000). Therefore, the increase of nest predators such as *Milvago chimango* could be related to the decline of the *Zonotrichia capensis* in Mar del Plata City.

Several species that have been expanding geographically their breeding range in the region during the last three decades, such as *Parabuteo unicinctus*, *Hylocharis chrysura*, *Hirundo rustica*, and *Sturnus vulgaris* (Pinto, 2005; Grande et al., 2015; Winkler et al., 2017; Ojeda et al., 2022; Leveau, 2021), showed strong or moderate interannual increases in their abundances in Mar del Plata City. Regional changes associated with increased crop cover, the construction of paved roads with concrete bridges, and climate warming probably enhanced the availability of food and nesting resources for these species (Pinto, 2005; Winkler et al., 2017; Leveau, 2021). Our results suggest that these species have found suitable habitats in urban areas during their expansion process. For example, *Parabuteo unicinctus* has suitable nesting substrates in wooded residential areas and urban parks, and increased food availability due to the abundance increase of pigeons and doves (Leveau, 2021). In the case of *Hirundo rustica* and *Sturnus vulgaris*, urban areas provide suitable nesting sites in buildings (Leveau, 2021), whereas *Sturnus vulgaris* can benefit from food availability in lawn areas (Ibañez et al., 2023).

Increased crop cover and climate warming in the region probably favored other resident bird species abundance regional increment, thus favoring their population increases in Mar del Plata City. For example, *Milvago chimango*, *Patagioenas picazuro*, *Patagioenas maculosa*, *Zenaida auriculata*, and *Myiopsitta monachus* have been shown to boost their abundances during the period 2002-2012 in the northern part of the pampean region (Gavier-Pizarro et al., 2012; Goijman et al., 2015). Assuming that these population trends

TABLE 4 Final generalized linear mixed model showing the relationship between the site interannual Horn-Morisita dissimilarity of bird species assemblages, time lag, and habitats along the urban gradient of Mar del Plata City, Argentina.

Variables	Estimate	Std. Error	df	t value	P
Intercept	0.371	0.031	40.680	12.027	**<0.001**
Time lag (square root of years)	0.036	0.005	1031.000	6.580	**<0.001**
Suburban	-0.073	0.037	25.170	-1.958	0.061
Urban	-0.153	0.053	24.440	-2.906	**0.008**

Bold values indicate significant differences (P< 0.05). The periurban habitat is in the intercept.

TABLE 5 R-squared values of generalized linear mixed models between bird composition dissimilarity and time lag in urban, suburban, and periurban habitats of Mar del Plata City, Argentina.

	Habitat		
	Urban	Suburban	Periurban
Marginal r^2 (time lag)	0.051	0.035	0.019
Conditional r^2 (time lag + random effects)	0.246	0.212	0.245

remained in the rest of the pampean region, they could have influenced the bird population dynamics in Mar del Plata City. This hypothesis support recent findings of Skjelvik and Dale (2024), who found that local long-term bird trend abundances in urban green spaces of Oslo were correlated with regional bird trends. Therefore, regional and local environmental changes would mold bird population long-term dynamics in urban areas (Skjelvik and Dale, 2024).

Local environmental factors such as vegetation succession may be related to the population trends of bird species (Clements, 1916; Mönkkönen and Helle, 1989). For example, *Zenaida auriculata*, *Turdus rufiventris*, and *Pitangus sulphuratus* increased their abundance in the urban habitat. These species use wooded streets for foraging and nesting (Curzel et al., 2021). Street tree height and crown size are expected to increase with time (Rosenzweig, 1995; Zhao et al., 2016), thus increasing bird resource availability. On the other hand, *Elaenia parvirostris* has been recorded only in suburban and periurban habitats and had a strong abundance increase over time. This species inhabits wooded and residential areas with high habitat diversity (Cueto and Lopez de Casenave, 2000; Leveau, 2013) and was probably favored by increased vegetation complexity promoted by succession.

Interannual changes of species assemblages

The mean dissimilarity among years was lower in the urban habitat than in the suburban and periurban habitats. Therefore, the interannual presence of species was more persistent in the most urbanized areas. This pattern agrees with previous results obtained in the study area over three years (Leveau and Leveau, 2012; Leveau et al., 2015) and elsewhere (Suhonen et al., 2009). In our study area, the urban habitat was composed of a few dominant species, such as *Columba livia, Zenaida auriculata*, and *Passer domestics.* Their high abundances could lower the probability of local extinction due to

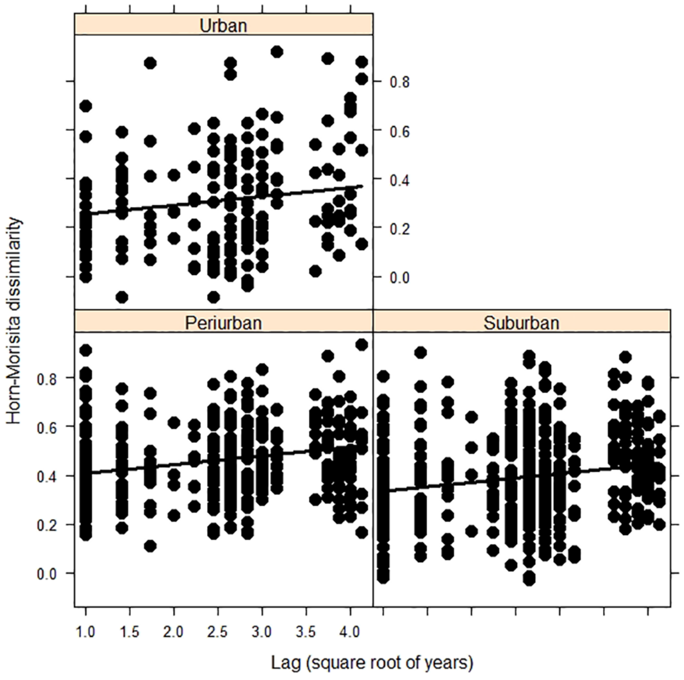

FIGURE 5
Final generalized linear mixed models showing the relationship between bird composition dissimilarity and time lags years during 2002-2019 in three urban habitats of Mar del Plata City, Argentina. Black lines indicate the fitted model.

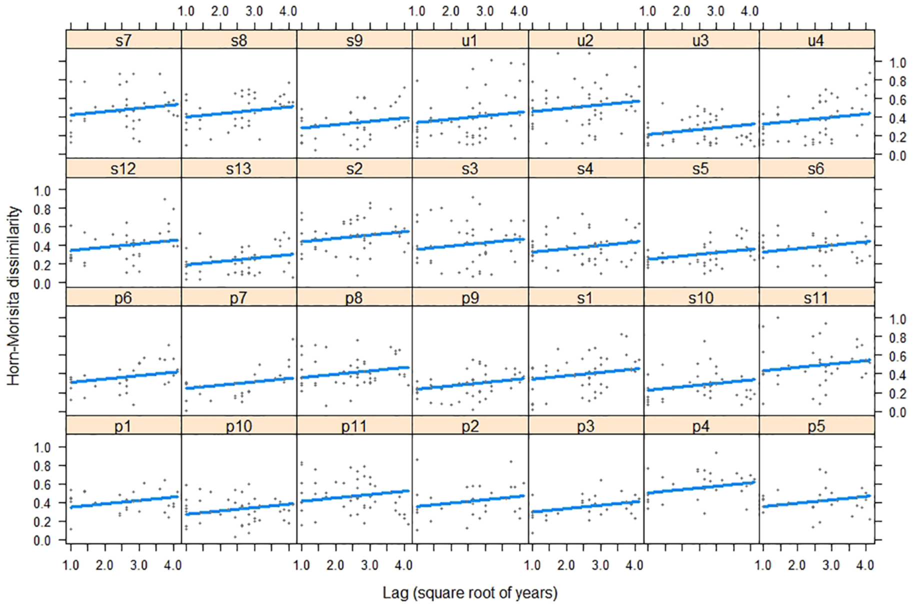

FIGURE 6
Relationship between bird composition dissimilarity and time lags years during 2002-2019 in transects along the urban gradient of Mar del Plata City, Argentina. u: urban habitat (N = 4), s: suburban habitat (N = 13), and p: periurban habitat (N = 11).

environmental stochastic events or individual stochastic variation of birth, death, or offspring production (Vellend, 2010).

Although the change signal was low, the three habitats showed similar rates of compositional changes with time lags. The low signal attributed to the sole effect of time lag, and the greater effect attributed to both time lags and transects suggested that the signal of change varied among transects. This pattern agrees with the hierarchical patch dynamics (Wu and Loucks, 1995), where patches differ in their rates of change over time (see Collins and Xia, 2015). In our case, transects may represent patches with different environmental characteristics that allow species invasions and instability or species persistence over time and stability. For example, the establishment of new populations of *Parabuteo unicinctus* in Mar del Plata city may require sites well connected to other green areas (Leveau, 2021).

Contrary to what was expected, bird assemblages in the three habitat types were similarly unstable. This instability along the gradient could indicate that large-scale disturbances, such as increasing crop cover or climate warming, are directing the local changes in bird assemblages. The local interannual increases of several species that also showed regional increases and distributional expansions support this hypothesis. In turn, the increases in these species are supposed to cause the local population declines of several species by increasing competition and predation. Due to the successional vegetation change correlated with the regional changes in land cover and climate, it is difficult to disentangle their relative roles in the directional changes of bird assemblages.

The increased human population in Mar del Plata City during the study period could have negatively impacted bird communities by increased pedestrian traffic and noise (Fernández-Juricic, 2000; Carral-Murrieta et al., 2020). In addition, increased noise could have decreased bird species detectability (Rodríguez Arancibia et al., 2022). However, most species in our study showed increased abundance or were stable over time, suggesting that human population increase had a negligible effect on the analyzed bird communities.

Conclusions

The results obtained showed that bird assemblages along the urban gradient of Mar del Plata City had increasing dissimilarity with the passing of years. Therefore, bird assemblages were unstable with continuous changes in species abundances. Due to the rate of changes being similar between the urban habitats, the interannual changes in species abundances were probably influenced by regional changes in land uses and climate which promoted population increases of some bird species, such as pigeons and doves. However, species declines along the urban gradient, such as those of House Sparrows, are thought to be related to increased competition with doves. The results highlight the importance of long-term studies in urban areas to get more insights into assemblage dynamics.

Data availability statement

The original contributions presented in the study are publicly available. This data can be found here: https://www.researchgate.

net/publication/383603275_Data_from_Leveau_2024_Frontiers_in_Ecology_and_Evolution.

Author contributions

LL: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Baeza, S., and Paruelo, J. M. (2020). Land use/land cover chang [amp]]ndash;2014) in the Rio de la Plata grasslands: an analysis based on MODIS NDVI time series. *Remote Sens.* 12, 381. doi: 10.3390/rs12030381

Bates, D., Mächler, M., Bolker, B. M., and Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Software* 67, 1–48. doi: 10.18637/jss.v067.i01

Berigan, L. A., Greig, E. I., and Bonter, D. N. (2020). Urban house sparrow (Passer domesticus) populations decline in North America. *Wilson J. Ornithology* 132, 248–258. doi: 10.1676/1559-4491-132.2.248

Bernat-Ponce, E., Gil-Delgado, J. A., and López-Iborra, G. M. (2020). Replacement of semi-natural cover with artificial substrates in urban parks causes a decline of house sparrows Passer domesticus in Mediterranean towns. *Urban Ecosyst.* 23, 471–481. doi: 10.1007/s11252-020-00940-4

Borcard, D., Gillet, F., and Legendre, P. (2011). *Numerical ecology with R* (New York: springer).

Breheny, P., and Burchett, W. (2017). Visualization of regression models using visreg. *R J.* 9, 56–71. doi: 10.32614/RJ-2017-046

Brooks, M., Bolker, B., Kristensen, K., Maechler, M., Magnusson, A., and McGillycuddy, M. (2023). Package 'glmmtmb'. *R Packag Vers* 1, 7.

Campbell, C. E., Jones, D. N., Awasthy, M., Castley, J. G., and Chauvenet, A. L. (2022). Big changes in backyard birds: An analysis of long-term changes in bird communities in Australia's most populous urban regions. *Biol. Conserv.* 272, 109671. doi: 10.1016/j.biocon.2022.109671

Carral-Murrieta, C. O., García-Arroyo, M., Marín-Gómez, O. H., Sosa-López, J. R., and MacGregor-Fors, I. (2020). Noisy environments: untangling the role of anthropogenic noise on bird species richness in a Neotropical city. *Avian Res.* 11, 1–7. doi: 10.1186/s40657-020-00218-5

Clements, F. E. (1916). Plant succession: an analysis of the development of vegetation (No. 242). *Carnegie institution of Washington.*

Collins, S. L., Micheli, F., and Hartt, L. (2000). A method to determine rates and patterns of variability in ecological communities. *Oikos* 91, 285–293. doi: 10.1034/j.1600-0706.2000.910209.x

Collins, S. L., and Xia, Y. (2015). Long-term dynamics and hotspots of change in a desert grassland plant community. *Am. Nat.* 185, E30–E43. doi: 10.1086/679315

Cueto, V. R., and Lopez de Casenave, J. N. (2000). Bird assemblages of protected and exploited coastal woodlands in east-central Argentina. *Wilson Bull.* 112, 395–402. doi: 10.1676/0043-5643(2000)112[0395:BAOPAE]2.0.CO;2

Curzel, F. E., Bellocq, M. I., and Leveau, L. M. (2021). Local and landscape features of wooded streets influenced bird taxonomic and functional diversity. *Urban Forestry Urban Greening* 66, 127369. doi: 10.1016/j.ufug.2021.127369

Dandapat, A., Banerjee, D., and Chakraborty, D. (2010). The case of the Disappearing House Sparrow (Passer domesticus indicus). *Veterinary World* 3, 97.

de la Peña, M. R. (2013). *Nidos y Reproducción de las Aves Argentinas; Ediciones Biológica* (Santa Fe, Argentina: Ediciones Biologica).

Dornelas, M., Gotelli, N. J., McGill, B., Shimadzu, H., Moyes, F., Sievers, C., et al. (2014). Assemblage time series reveal biodiversity change but not systematic loss. *Science* 344, 296–299. doi: 10.1126/science.1248484

Echeverry-Galvis, M. A., Lozano Ramírez, P., and Amaya-Espinel, J. D. (2023). Long-term Christmas Bird Counts describe neotropical urban bird diversity. *PloS One* 18, e0272754. doi: 10.1371/journal.pone.0272754

Fernández-Juricic, E. (2000). Local and regional effects of pedestrians on forest birds in a fragmented landscape. *Condor* 102, 247–255. doi: 10.1093/condor/102.2.247

Ferrelli, F., Brendel, A. S., Perillo, G. M. E., and Piccolo, M. C. (2021b). Warming signals emerging from the analysis of daily changes in extreme temperature events over Pampas (Argentina). *Environ. Earth Sci.* 80, 422. doi: 10.1007/s12665-021-09721-4

Ferrelli, F., Brendel, A. S., Piccolo, M. C., and Perillo, G. M. E. (2021a). Evaluación de la tendencia de la precipitación en la región pampeana (Argentina) durante el período 1960-2018. *Ra'e Ga* 51, 41–57. doi: 10.5380/raega.v51i0

Fidino, M., and Magle, S. B. (2017). "Trends in long-term urban bird research," in *Ecology and conservation of birds in urban environments.* Eds. E. Murgui and M. Hedblom (Springer, Cham, Switzerland), 161–184. doi: 10.1007/978-3-319-43314-1

Gavier-Pizarro, G. I., Calamari, N. C., Thompson, J. J., Canavelli, S. B., Solari, L. M., Decarre, J., et al. (2012). Expansion and intensification of row crop agriculture in the Pampas and Espinal of Argentina can reduce ecosystem service provision by changing avian density. *Agriculture Ecosyst. Environ.* 154, 44–55. doi: 10.1016/j.agee.2011.08.013

Goijman, A. P., Conroy, M. J., Bernardos, J. N., and Zaccagnini, M. E. (2015). Multi-season regional analysis of multi-species occupancy: implications for bird conservation in agricultural lands in east-central Argentina. *PloS One* 10, e0130874. doi: 10.1371/journal.pone.0130874

Grande, J. M., Santillán, M. A., Orozco, P. M., Liébana, M. S., Reyes, M. M., Galmes, M. A., et al. (2015). Barn Swallows keep expanding their breeding range in South America. *Emu* 115, 256–260. doi: 10.1071/MU14097

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., et al. (2008). Global change and the ecology of cities. *Science*, 319 (5864), 756-760.

Hartig, F. (2022).DHARMa: residual diagnostics for hierarchical (Multi-level/mixed) regression models. In: *R package version 0.4.6.* Available online at: https://CRAN.Rproject.org/package=DHARMa (Accessed 22 December 2022).

Ibañez, L., Palacio, F. X., Maragliano, R. E., and Montalti, D. (2023). The presence of an invasive bird, the Common Starling, in an urban landscape: habitat use and relationships with other bird species. *J. Ornithology* 164, 537–546. doi: 10.1007/s10336-023-02047-x

Jokimäki, J., and Huhta, E. (2000). Artificial nest predation and abundance of birds along an urban gradient. *Condor* 102, 838–847. doi: 10.1093/condor/102.4.838

La Sorte, F. A., Lepczyk, C. A., Aronson, M. F., Goddard, M. A., Hedblom, M., Katti, M., et al. (2018). The phylogenetic and functional diversity of regional breeding bird assemblages is reduced and constricted through urbanization. *Diversity Distributions* 24, 928–938. doi: 10.1111/ddi.12738

Lefcheck, J. S. (2016). piecewiseSEM: Piecewise structural equation modelling in r for ecology, evolution, and systematics. *Methods in Ecology and Evolution* 7 (5), 573-579.

Leong, M., and Roderick, G. K. (2015). Remote sensing captures varying temporal patterns of vegetation between human-altered and natural landscapes. *PeerJ* 3, e1141. doi: 10.7717/peerj.1141

Leveau, L. M. (2013). Relaciones aves–habitat en el sector suburbano de mar del plata, Argentina. *Ornitología Neotropical* 24, 201–212.

Leveau, L. M. (2018). Urbanization, environmental stabilization and temporal persistence of bird species: a view from Latin America. *PeerJ* 6, e6056. doi: 10.7717/peerj.6056

Leveau, L. M. (2021). The Harris Hawk (*Parabuteo unicinctus*) in urban areas of Argentina: arrival in Mar Del Plata City and green area use in Buenos Aires City. *Animals* 11, 1023. doi: 10.3390/ani11041023

Leveau, L. M., Isla, F. I., and Bellocq, M. I. (2015). Urbanization and the temporal homogenization of bird communities: a case study in central Argentina. *Urban Ecosyst.* 18, 1461–1476. doi: 10.1007/s11252-015-0469-1

Leveau, L. M., and Leveau, C. M. (2004). Comunidades de aves en un gradiente urbano de la ciudad de Mar del Plata, Argentina. *El Hornero* 19, 13–21. doi: 10.56178/eh.v19i1

Leveau, L. M., and Leveau, C. M. (2012). The role of urbanization and seasonality on the temporal variability of bird communities. *Landscape Urban Plann.* 106, 271–276. doi: 10.1016/j.landurbplan.2012.03.008

MacArthur, R. H., and MacArthur, J. W. (1961). On bird species diversity. *Ecology* 42, 594–598. doi: 10.2307/1932254

MacGregor-Fors, I. (2011). Misconceptions or misunderstandings? *On standardization basic terms definitions urban ecology. Landscape Urban Plann.* 100, 347–349. doi: 10.1016/j.landurbplan.2011.01.013

Marzluff, J. M., Bowman, R., and Donnelly, R. (2001). “A historical perspective on urban bird research: trends, terms, and approaches,” in *Avian ecology and conservation in an urbanizing world*, 1–17. Springer Science+Business Media, New York.

Mönkkönen, M., and Helle, P. (1989). Migratory habits of birds breeding in different stages of forest succession: a comparison between the Palaearctic and the Nearctic. *Annales Zoologici Fennici* 26, 323–330.

Ojeda, V., Chazarreta, M. L., Masello, J. F., Buglione-Rodríguez, F., and Failla, M. (2022). European starlings expand into Patagonia. *Time action. Global Ecol. Conserv.* 39, e02295. doi: 10.1016/j.gecco.2022.e02295

Oksanen, J., Simpson, G., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., et al. (2022).Vegan: community ecology package. In: *R package version 2.6-2.* Available online at: https://CRAN.R-project.org/package=vegan (Accessed 22 December 2022).

Oyarzabal, M., Clavijo, J., Oakley, L., Biganzoli, F., Tognetti, P., Barberis, I., et al. (2018). Unidades de vegetación de la Argentina. *Ecología Austral* 28, 40–63. doi: 10.25260/EA.18.28.1.0.399

Palacio, F. X., Ibañez, L. M., Maragliano, R. E., and Montalti, D. (2018). Urbanization as a driver of taxonomic, functional, and phylogenetic diversity losses in bird communities. *Can. J. Zoology* 96, 1114–1121. doi: 10.1139/cjz-2018-0008

Pinto, E. D. E. (2005). Range expansion of the European Starling *Sturnus vulgaris* in Argentina. *Ardeola* 52, 359–364.

R Core Team (2019). “R: a language and environment for statistical computing,” in *R foundation for statistical computing, version 3.6.1.* Vienna.

Rodríguez Arancibia, J., Escobar, M. A., and Villaseñor, N. R. (2022). Efecto del ruido, cobertura arbórea y hora del día sobre la detectabilidad de aves en ecosistemas urbanos. *El Hornero* 37, 12–12. doi: 10.56178/eh.v37i2.406

Rosenzweig, M. L. (1995). *Species diversity in space and time* (Cambridge: Cambridge University Press).

Servicio Meteorológico Nacional (2023). *Estadísticas climatológicas normales: república Argentina - período 1991-2020* (SMN), 847.

Shaw, L. M., Chamberlain, D., and Evans, M. (2008). The House Sparrow *Passer domesticus* in urban areas: reviewing a possible link between post-decline distribution and human socioeconomic status. *J. Ornithology* 149, 293–299. doi: 10.1007/s10336-008-0285-y

Shochat, E., Stefanov, W. L., Whitehouse, M. E. A., and Faeth, S. H. (2004). Urbanization and spider diversity: Influences of human modification of habitat structure and productivity. *Ecol. Appl.* 14, 268–280. doi: 10.1890/02-5341

Shochat, E., Warren, P. S., Faeth, S. H., McIntyre, N. E., and Hope, D. (2006). From patterns to emerging processes in mechanistic urban ecology. *Trends Ecol. Evol.* 21, 186–191. doi: 10.1016/j.tree.2005.11.019

Skjelvik, C. E., and Dale, S. (2024). Bird population changes in urban green spaces explained by regional population trends. *Urban Ecosyst.*, 1339–1347. doi: 10.1007/s11252-024-01527-z

Storch, D., Koleček, J., Keil, P., Vermouzek, Z., Voříšek, P., and Reif, J. (2023). Decomposing trends in bird populations: Climate, life histories and habitat affect different aspects of population change. *Diversity Distributions* 29, 572–585. doi: 10.1111/ddi.13682

Suhonen, J., Jokimäki, J., Kaisanlahti-Jokimäki, M. L., Hakkarainen, H., Huhta, E., Inki, K., et al. (2009). Urbanization and stability of a bird community in winter. *Ecoscience* 16, 502–507. doi: 10.2980/16-4-3280

Väisänen, R. A., Järvinen, O., and Rauhala, P. (1986). How are extensive, human-caused habitat alterations expressed on the scale of local bird populations in boreal forests? *Ornis Scandinavica* 17, 282–292. doi: 10.2307/3676839

Vazquez, M. S., Scorolli, A. L., and Zalba, S. M. (2024). Range expansion of native thrushes in South America. *Ornithology Res.*, 1–11. doi: 10.1007/s43388-024-00195-z

Vellend, M. (2010). Conceptual synthesis in community ecology. *Q. Rev. Biol.* 85, 183–206. doi: 10.1086/652373

Wiens, J. A. (1989). *The ecology of bird communities (Vol. 2)* (Cambridge: Cambridge University Press).

Winkler, D. W., Gandoy, F. A., Areta, J. I., Iliff, M. J., Rakhimberdiev, E., Kardynal, K. J., et al. (2017). Long-distance range expansion and rapid adjustment of migration in a newly established population of barn swallows breeding in Argentina. *Curr. Biol.* 27, 1080–1084. doi: 10.1016/j.cub.2017.03.006

Wolda, H. (1981). Similarity indices, sample size and diversity. *Oecologia* 50, 296–302. doi: 10.1007/BF00344966

Wu, J., and Loucks, O. L. (1995). From balance of nature to hierarchical patch dynamics: a paradigm shift in ecology. *Q. Rev. Biol.* 70, 439–466. doi: 10.1086/419172

Zhao, S., Liu, S., and Zhou, D. (2016). Prevalent vegetation growth enhancement in urban environment. *Proc. Natl. Acad. Sci.* 113, 6313–6318. doi: 10.1073/pnas.1602312113