

Chapter 3

Urbanization and Bird Communities: Spatial and Temporal Patterns Emerging from Southern South America

M.I. Bellocq, L.M. Leveau, and J. Filloy

Abstract Urbanization is an expanding process worldwide, and South America seems to follow the general pattern observed in more urbanized regions of the world. Most conceptual models on the response of biodiversity to urbanization, however, are based on the experience in developed economies. In this chapter, we summarize patterns of bird communities found at different spatial and temporal scales in southern South America. Along a 1400-km latitudinal gradient, we found that urbanization (1) obscured the latitudinal pattern of bird species richness, (2) had a stronger negative effect on bird richness in tropical than in temperate or arid regions, and (3) resulted in more similar communities than the seminatural or rural areas, suggesting a process of biotic homogenization. The analysis of urban centers of different sizes indicated that bird richness and abundance were negatively affected by urbanization only in cities above 7000 and 13,000 inhabitants, respectively. In the Pampean region, urbanization affected negatively birds that nest on the ground, with insectivorous and carnivorous diets, feeding on the air and on vegetation and with solitary and migratory behaviors. Urbanization decreased the seasonal and interannual variability of bird species composition. We suggest future directions of research on the influence of latitude on temporal dynamics of bird communities in urban areas, comparison of bird responses to urbanization among biogeographical regions using a mechanistic approach, and including functional and phylogenetic diversity as response variables in the analyses.

Keywords Argentina • Biotic homogenization • Community similarity • Neotropics • Species richness

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3.1 Introduction

Human land use changes native ecosystems and, when globally expanded, contributes to biodiversity loss, climate change, and environmental degradation (Lambin et al. 2001). From the perspective of biodiversity conservation, urbanization is considered a major cause of species extinction (i.e., Czech et al. 2000). It promotes the replacement or impoverishment of native communities and the arrival of cosmopolitan species (loss of beta diversity); consequently, it is expected that taxonomic similarity between communities increases in this process of biotic homogenization (McKinney 2006). Furthermore, given that species able to exploit human-modified habitats tend to be ecologically redundant and/or phylogenetically close related, functional and phylogenetic diversities would also be lost (Olden et al. 2004).

Urbanization is an expanding process worldwide (see Lepczyk et al. 2016; Chen and Wang 2016), and South America seems to follow the general pattern observed in developed economies (Pimentel et al. 1998). In Europe and the United States (to a less extent), however, landscape is highly fragmented by urbanization, whereas in South America, urban centers are still growing over rural or seminatural areas (McGranahan and Satterthwaite 2003; Pauchard et al. 2006; Garaffa et al. 2009). The great majority of the studies on bird assemblages in urban areas were conducted in Europe and the United States where urbanization is most developed, and much less were conducted in South America, Africa, and Asia (i.e., in most of the Earth). For example, the geographical distribution of bird surveys used by Pautasso et al. (2011) to describe the global macroecology of bird assemblages in urbanized ecosystems accounts for that spatially unbalance number of studies.

In this chapter, we analyze some spatial and temporal patterns of bird assemblages that emerged from urban areas developed in southern South America. First, we examine changes in species richness and composition similarity along a latitudinal gradient, relating variations to environmental variables (associated with causal hypothesis) and comparing the patterns between urban and nonurban areas. Second, we analyze the response of bird species richness to urbanization gradients from the core-urban area to the rural zone, in urban centers located in the Pampean region of Argentina. Third, we analyze the influence of town size on the response of bird species richness and total abundance to urbanization gradients. Fourth, we compared bird functional groups between urban and nonurban areas in several cities of the Pampean region. Fifth, we show seasonal and year-to-year variability in bird community attributes recorded in a coastal city. Finally, we suggest directions for future research.

3.2 Spatial Patterns of Diversity

Patterns of community attributes, such as species composition, richness, and diversity, occurring at large geographical scales are explained by factors acting at large scales, such as climatic factors. Similarly, local diversity patterns are usually explained by the variation of local environmental factors such as habitat heterogeneity. There is evidence that bird communities responded to urbanization along both climatic and land cover gradients in the southern Neotropics.

3.2.1 *Latitudinal Patterns and Diversity–Environment Relationships*

Species richness in general and bird richness in particular decline from the equator to the poles (Hawkins et al. 2006). It is widely accepted that broad-scale latitudinal changes in bird richness are explained by the flow of energy and water showing a positive association between richness and temperature or rainfall (Mittelbach et al. 2001; Hawkins et al. 2003), a pattern also observed in the southern Neotropics (Rabinovich and Rapoport 1975; Bellocq and Gómez-Insausti 2005). Studies conducted in Argentina, however, showed that urbanization obscured the latitudinal pattern of bird species richness from 26° to 38°S and 59° to 61°W that includes subtropical forests, shrublands, and grasslands (Fig. 3.1). Bird richness declined with increasing latitude in rural areas but remained relatively constant in urban centers; in rural areas, mean annual temperature and mean annual precipitation accounted for the latitudinal pattern (Filloy et al. 2015). That indicates urban centers held a constant number of species independently of town climatic location, probably due to changes in temperature and water inputs and to sustained resource availability (compared to the surroundings) as a consequence of human management of urban areas. In contrast to the pattern observed in southern South America, along a latitudinal gradient in Europe (from 41° to 53°N, a similar length to our study), there were significant positive correlations between latitude and bird species richness in urban areas (Ferenc et al. 2014); that is, species richness surprisingly increased with latitude (that the authors hypothesized due to climatic variability promoting generalist species). The latitudinal patterns observed in nonurban areas also differed between southern South America (richness declined with increasing latitude, explained by temperature and precipitation) and Europe (richness peaked at intermediate latitudes within the study range, explained by potential sampling biases and patterns occurring at larger scales). The contrasting results between South America and Europe alert that broad studies including all biogeographic regions should be conducted to understand wildlife responses to urbanization.

Furthermore, the difference we found in species richness between urban centers and rural areas was larger at lower latitudes (Fig. 3.2), indicating that urbanization had a stronger negative impact on bird richness in tropical than in temperate or arid

Fig. 3.1 Location of the 15 towns along the latitudinal gradient of Argentina. With kind permission from Springer Science + Business Media: *Urban Ecosystems, Urbanization altered latitudinal patterns of bird diversity-environment relationships in the southern Neotropics*, 18, 2015, 777–791, J. Filloy, S. Grosso, M.I. Bellocq, Figure 1



regions (Filloy et al. 2015). Previous studies showed that bird richness decline from the rural to the core-urban area (e.g., Faeth et al. 2011), a pattern also observed in cities from the Neotropics (Garaffa et al. 2009; Villegas and Garitano-Zavala 2010; Reis et al. 2012). Processes involving a decline in local habitat productivity and changes in species interactions and resource availability with respect to the surroundings may explain the reduced species richness in urban areas (Shochat et al. 2006). However, the latitudinal variation on the degree of impact of urbanization on bird species richness requires consideration of both local and regional primary productivity and vegetation stratification, because the impact differs with the climatic context in which urbanization develops (Filloy et al. 2015). In towns developed in tropical or subtropical climates, impervious areas reduced primary productivity and vegetation stratification compared to the seminatural forest where more bird species are able to coexist. In contrast, in settlements located in arid or semiarid zones, water irrigation and vegetation management increase primary productivity compared to seminatural adjacent areas, partially compensating the reduction of vegetation due to impervious areas. In some arid environments, bird species richness may even reach higher values in town centers than in rural zones (Mills et al. 1989). The observed latitudinal differences in the degree of urbanization impact on species richness are also related to patterns of variation in

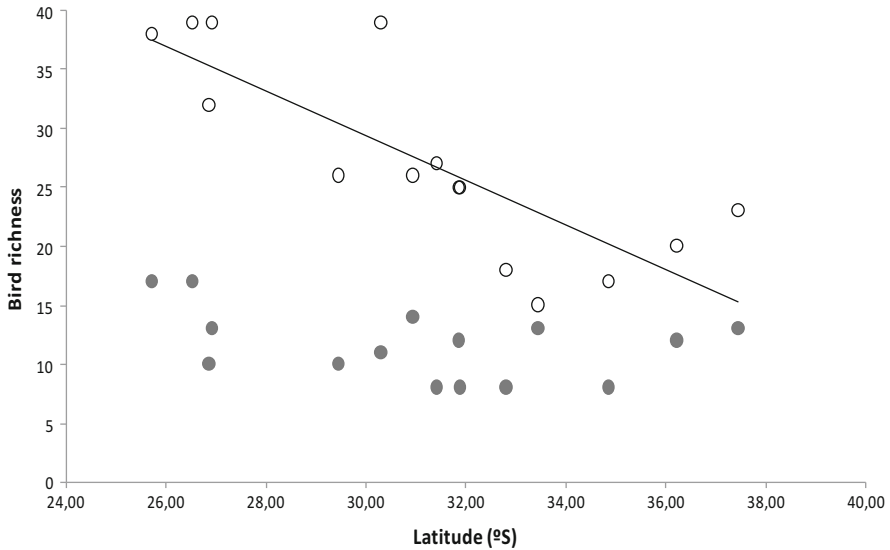


Fig. 3.2 Bird species richness in 15 core-urban areas (*black dots*) and their correspondent rural areas (*white dots*) along a latitudinal gradient from 26° to 38°S in Argentina. *Line* depicts a significant negative linear trend for rural areas, whereas core-urban areas did not show a significant relationship with latitude. With kind permission from Springer Science + Business Media: Urban Ecosystems, Urbanization altered latitudinal patterns of bird diversity-environment relationships in the southern Neotropics, 18, 2015, 777–791, J. Filloy, S. Grosso, M.I. Bellocq, Figure 3

community composition reflecting life history traits. The environmental filter imposed by urbanization results in assemblages composed by a set of species able to exploit or to adapt to urban environments, characterized by broad tolerance to environmental conditions or specific tolerance to built-up environments (McKinney 2006; Kark et al. 2007). Thus, the larger the regional species pool, the larger the impact of urbanization on species richness.

Urbanization worldwide is expected to influence global biota distribution. Physical environmental homogenization due to human activities developed over large extensions of land, such as urbanization, promotes global biotic homogenization (McKinney and Lockwood 1999). Composition of bird communities was more similar between urban centers than between adjacent seminatural areas at any distance along a range of 1400 km in Central Argentina (Fig. 3.3). Similarly, other studies around the world showed that urban bird assemblages had higher similarity in species composition than nonurban assemblages, indicating that urbanization causes biotic homogenization (Clergeau et al. 2006; McKinney 2006; Luck and Smallbone 2011).

Similarity in species composition between communities reflects the spatial turnover in species composition, or beta diversity. Close communities tend to share more species than communities far apart. Similarity in the composition between assemblages declines with increasing geographic distance between them,

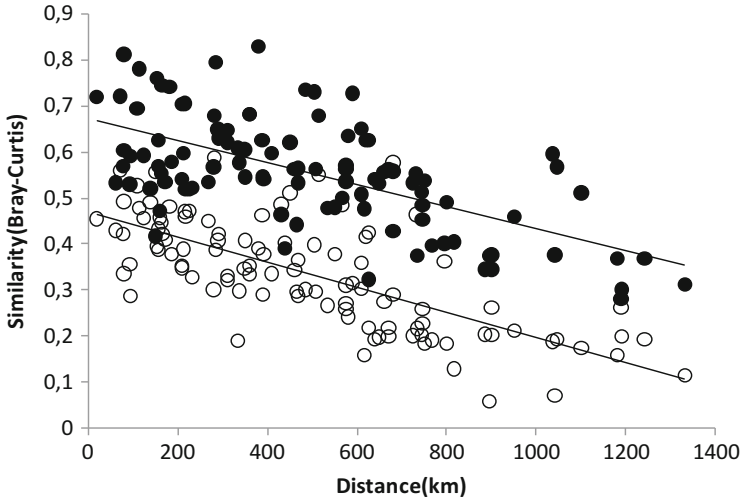


Fig. 3.3 The distance decay in similarity for urban (*black dots*) and rural (*white dots*) bird assemblages along a latitudinal gradient from 26° to 38°S in Argentina. With kind permission from Springer Science+Business Media: *Urban Ecosystems*, Urbanization altered latitudinal patterns of bird diversity-environment relationships in the southern Neotropics, 18, 2015, 777–791, J. Filloy, S. Grosso, M.I. Bellocq, Figure 5

a pattern referred to in the literature as the distance decay in similarity (Nekola and White 1999). Such pattern occurs as a response to gradual spatial changes in environmental conditions, and it has been documented across a wide range of geographic gradients and organisms (Soininen et al. 2007). Distance decay in bird community similarity was also recorded across regions in the southern Neotropics (Fig. 3.3). Because environmental similarity is expected to be higher between urban than between nonurban environments, similarity in species composition is expected to decay with distance at a lower rate in urban centers than in the surrounding areas, a pattern observed in Australia (Luck and Smallbone 2011) and Europe (Clergeau et al. 2006; Ferenc et al. 2014). In contrast, when comparing the pattern between core-urban and rural areas in southern South America, Filloy et al. (2015) found similar rates of decay indicating that urbanization had no effect on the rate at which bird community composition changes with the geographic distance at the interregional scale (Fig. 3.3). The similar rate in distance decay between urban centers and seminatural areas likely reflects that the composition of urban bird assemblages is highly dependent on the regional species pool along the study gradient in South America.

3.2.2 Bird Community Responses to Urbanization Gradients

The empirical evidence consistently indicates that bird communities respond to urbanization. The influence of town size on the spatial patterns of richness along urban–rural gradients and the variation of functional groups have been much less explored.

3.2.2.1 Bird Responses to Urbanization in Temperate Agrosystems

Spatial variations in bird taxonomic richness along gradients of urbanizations have long been described. The general pattern indicates that richness declines from rural or seminatural areas to the core-urban area (Chace and Walsh 2006; Faeth et al. 2011), although unimodal relationships may also occur (Marzluff 2001).

Spatial patterns of bird species richness were studied along urban–rural gradients in 15 cities ranging 18,000–25,000 inhabitants in the Pampean region of Argentina, where the original grasslands were intensively modified by agriculture. There was consistency in the decline of species richness from the rural zone to the core-urban area (i.e., city of Suipacha, Fig. 3.4a), associated to the increase in impervious areas (Fig. 3.4b).

3.2.2.2 Influence of Town Size on Bird Community Responses

Evidence from temperate agrosystems of the Pampean region indicates that bird community responses to urban–rural gradients depend on town size. To test whether spatial patterns in community attributes along urban–rural gradients change with town size, Garaffa et al. (2009) surveyed birds in nine urban centers ranging 472 to 520,000 inhabitants and 0.9–10.0-km gradient extend at similar latitude (between 34 and 35°S) in the Pampean region of Argentina (Fig. 3.5). Bird species richness responded to urbanization along urban–rural gradients longer than 1.4 km and human population size of the settlement over 7000 inhabitants (Fig. 3.6). That indicates a threshold below which bird richness showed no response to urbanization. The existence of a threshold was also reported for wintering birds in Finland (Jokimäki and Kaisanlahti-Jokimäki 2003) and breeding birds in west–central Mexico (MacGregor-Fors et al. 2011). Values of the threshold, however, differed among study regions indicating that factors beyond town size are influencing responses of bird species richness to urbanization.

There is evidence from the Pampean region that patterns of bird abundance along urban–rural gradients were also affected by town size. Garaffa et al. (2009) plotted bird abundance against the first factor scores obtained from environmental variables in principal component analysis for settlements of varied size (Fig. 3.7). In villages and most small towns, abundance of native species was similar along the gradients (Fig. 3.7a–d); but in settlements over 13,000 inhabitants, abundance of

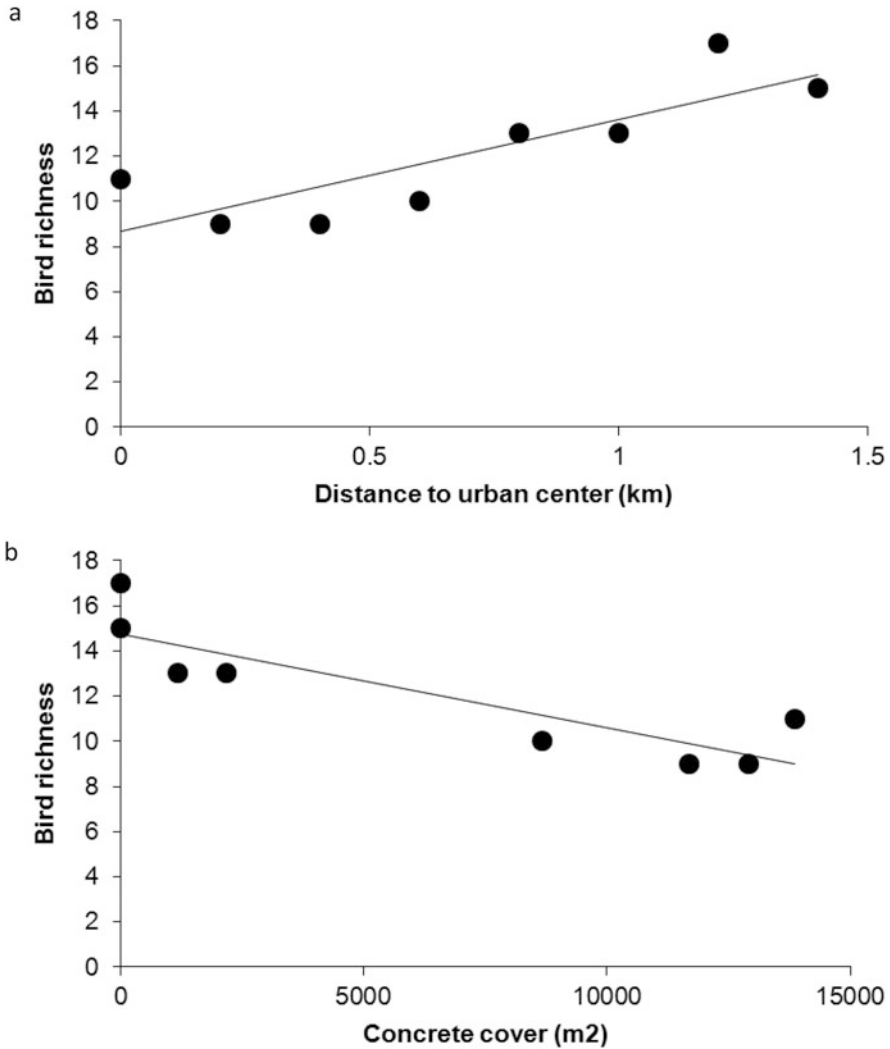


Fig. 3.4 Number of bird species recorded in observation points located at different distances from the core-urban area (a) and in relation to cover of impervious areas (b) in the city of Suipacha (7149 inhab.), a typical human settlement of the Pampean region, Argentina

native species decreased from the rural zone to the core-urban area (Fig. 3.7e–g and i). When exotic species were included, three different patterns of bird abundance were found: increased (Fig. 3.7a and h), decreased (Fig. 3.7e and g), or remained constant (Fig. 3.7f and i) from the rural zone to the core-urban area. Villages and towns below 13,000 inhabitants showed no response in the abundance of both native and total birds along gradients (Fig. 3.7b–d).

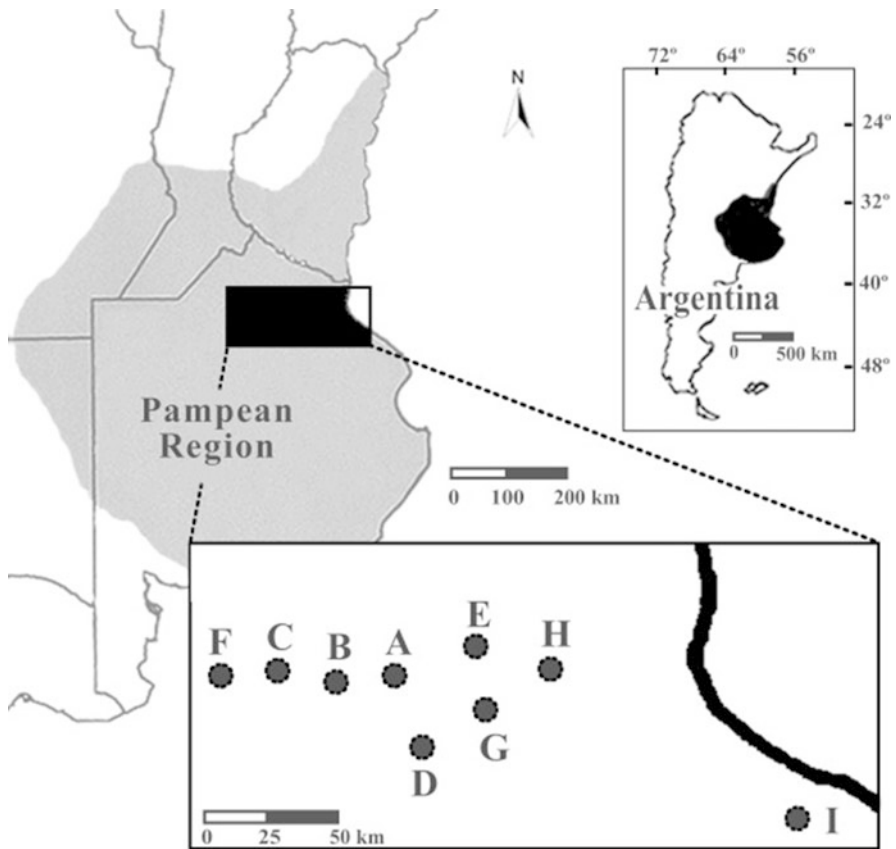
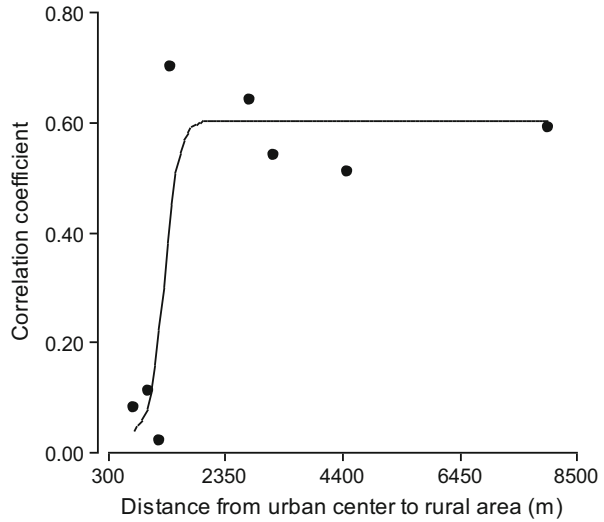


Fig. 3.5 Location of the nine urban–rural gradients in the Pampean region, Argentina. Ascending alphabetic order indicates increasing urbanized area size. (A) Rivas, (B) Castilla, (C) Rawson, (D) Suipacha, (E) SA Giles, (F) Chacabuco, (G) Mercedes, (H) Lujan, (I) La Plata. Reprinted from *Landscape and Urban Planning*, 90 (1), P. Garaffa, J. Filloy, M.I. Belloq, Bird community responses along urban–rural gradients: Does the size of the urbanized area matter?, 33–41, Copyright (2009), with permission from Elsevier

3.2.2.3 Variation of Functional Groups Between Urban and Rural Areas

Knowledge of the relationships between bird species traits and urbanization may improve our understanding of which bird species will become part of the urban avifauna in the future (Conole and Kirkpatrick 2011; Ikin et al. 2012). To gain more insights on the effects of urbanization on life history traits of birds, we analyzed data from seven urban centers (ranging 20,000 to 30,000 inhabitants) in the Pampean region (Cañada de Gómez, Firmat, Lincoln, Coronel Suárez, Bolivar, Balcarce, and Miramar). Habitats considered were urban (>50% cover of impervious areas) and rural (no cover of impervious areas). Bird surveys were conducted

Fig. 3.6 Correlation coefficient between bird species richness and the distance to the core-urban area for nine cities of the Pampean region as a function of the length of the urban–rural gradient



once during the breeding season by either point or transect counts. In Cañada de Gómez, Firmat, Lincoln, Coronel Suárez, and Bolivar City, seven 50-m-radius point counts were conducted in each habitat type, whereas in Balcarce and Miramar, five strip transects (100 × 50 m) were surveyed in each habitat type. Density of each species was calculated for each habitat and city, for a total of 14 sites. Species were classified according to five life history traits (following Narosky and DiGiacomo 1993; De la Peña 2010a, b): (1) nest substrate (ground, trees and shrubs, buildings, or parasite), (2) diet (omnivorous, granivorous, insectivorous, or carnivorous), (3) residency status (migratory or resident), (4) gregarious behavior (solitary or gregarious), and (5) foraging habit (ground, vegetation, or air). Then, we created a matrix of sites ($n = 14$) by density (individuals/hectare) of traits ($n = 11$). Given that traits can be related to each other, exploratory factor analysis was performed to obtain the underlying factors representing functional groups (Leveau 2013). A maximum likelihood factor extraction method was used, and factors were rotated using the varimax normalized method. Site scores of factors were compared between urban and rural sites with a Mann–Whitney test.

Exploratory factor analysis explained 78 % of the variance and produced three factors or functional groups (Table 3.1). Functional group 1 had higher value scores in urban habitats ($U = 4.00$, $P = 0.009$) (Fig. 3.8) and was related to traits that allow success in highly urbanized areas: nesting in buildings, omnivorous diet, resident, and gregarious. Functional group 2 had higher value scores in rural habitats ($U = 7.00$, $P = 0.025$) and was related to nesting on the ground, insectivorous, and carnivorous diets, feeding on the air and vegetation, and a solitary and migrant behavior. Finally, functional group 3 had similar value scores between habitats ($U = 17.00$, $P = 0.338$) and was negatively related to a granivorous diet and nesting on trees.

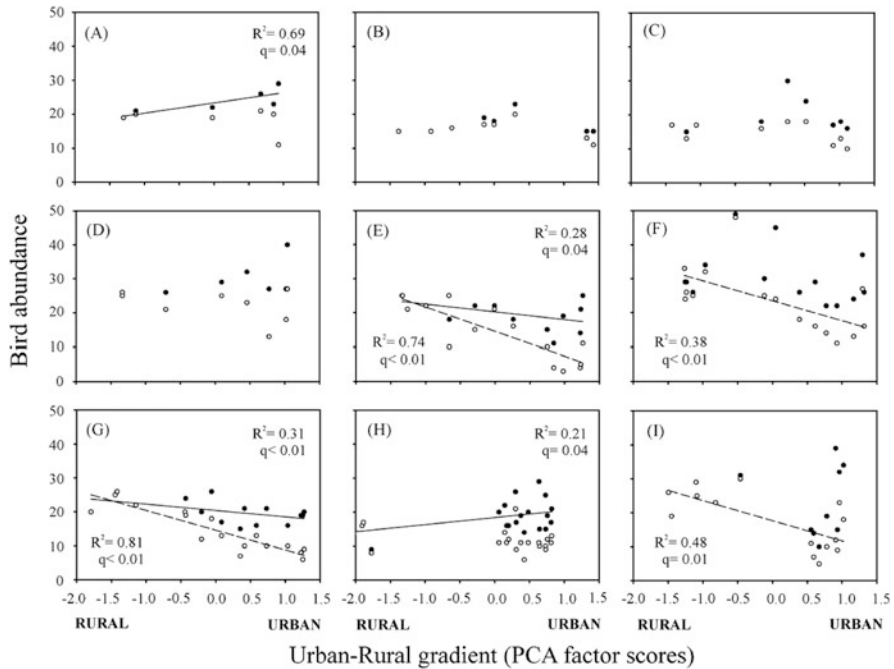


Fig. 3.7 Bird abundance (individuals/point count) arranged across the first factor scores resulted from principal component analysis. Native species: *dashed lines, white dots*. Both native and exotic species: *solid lines, black dots*. Coefficient of determination and significance are represented for native (*bottom left*) and both native and exotic species (*top right*) in each square figure. Ascending alphabetic order indicates increasing urbanized area size. (A) Rivas; (B) Castilla; (C) Rawson; (D) Stuipacha; (E) SA Giles; (F) Chacabuco; (G) Mercedes; (H) Lujan; (I) La Plata. Reprinted from *Landscape and Urban Planning*, 90 (1), P. Garaffa, J. Filloy, M.I. Bellocq, Bird community responses along urban–rural gradients: Does the size of the urbanized area matter?, 33–41, Copyright (2009), with permission from Elsevier

Results from our analysis in the Pampean region showed that birds nesting on the ground, having insectivorous and carnivorous diet, feeding on vegetation and in air, and having a migratory status were negatively impacted by urbanization, which is consistent with patterns found in other studies (Kark et al. 2007; Blair and Johnson 2008; Croci et al. 2008; MacGregors Fors et al. 2010; Leveau 2013; Jokimäki et al. 2014). However, in our analysis, traits related to nesting in trees and granivorous diet were not affected by urbanization; tree abundance in our urban centers may be higher than that of rural areas because cities are set in a grassland biome (e.g., Leveau 2013). Therefore, trees probably were not a limiting substrate for nesting in urban habitats.

Table 3.1 Loadings of the three factors produced from the trait-site matrix of birds in urban and rural habitats of Central Argentina. Higher trait-factor loadings are highlighted in bold

Traits	Factor 1	Factor 2	Factor 3
Nest build	0.90	-0.38	0.03
Omnivorous	0.91	-0.32	-0.06
Resident	0.85	0.01	-0.47
Gregarious	0.87	-0.25	-0.34
Feed ground	0.87	-0.08	-0.44
Nest ground	-0.51	0.77	0.05
Insectivorous	-0.38	0.81	0.14
Carnivorous	-0.37	0.75	0.22
Migrant	-0.09	0.81	0.12
Solitary	-0.45	0.80	-0.08
Feed air	-0.06	0.77	0.19
Feed veget	-0.51	0.58	0.02
Granivorous	0.15	0.00	-0.91
Nest tree	0.28	-0.18	-0.83
Brood parasite	0.03	0.28	-0.07
Eigenvalues	7.07	2.82	1.57
% Variance	33.2	29.8	14.5

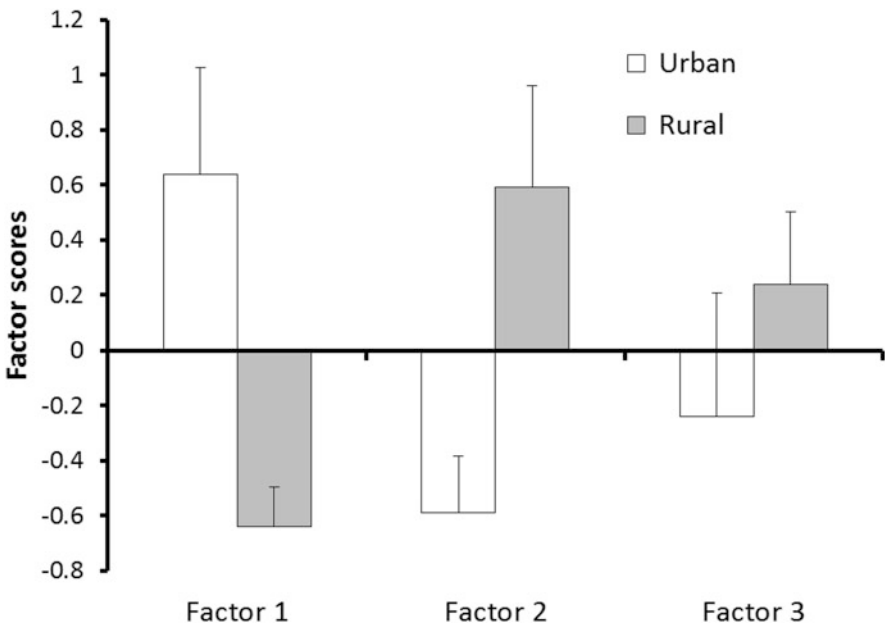


Fig. 3.8 Mean score values and standard errors of factors from the bird traits in urban and rural habitats of seven cities in Central Argentina

3.3 Temporal Variability in Community Attributes

In several cities, urbanization was associated to a dampening of the temporal fluctuation in habitat structure and the availability of food and water (see Shochat et al. 2006). This stabilization of resources may influence the seasonal and interannual bird community dynamics.

3.3.1 Seasonal Variability in Community Attributes

Seasonality, or the predictable change in environmental conditions of a site throughout the year, is expected to determine the proportion of resident and migratory species in a community (Herrera 1978a; Hurlbert and Haskell 2003). Increasing resource availability between the winter and the summer will be associated to an increase in the proportion of migrant species in the community. However, evidence from several studies showed that at least two factors of the urban environment may reduce seasonality of bird communities (see Macías-García et al. 2016). First, seasonal environmental variability may be reduced in urban centers relative to nonurban areas because of vegetation management and water irrigation (White et al. 2002; Shochat et al. 2006; Faeth et al. 2011; Buyantuyev and Wu 2012). Second, migrant birds may be excluded from urban areas due to a lack of tree cover and a lack of herbaceous vegetation and food supply (Blair and Johnson 2008; MacGregors Fors et al. 2010; Leveau 2013).

We compared the seasonal change in bird community attributes in two levels of urbanization in the coastal city of Mar del Plata (38° 00' S 57° 33' W, 600,000 inhabitants). Birds were surveyed during three breeding (spring–summer) and nonbreeding (autumn–winter) seasons in 100 × 50 m strip transects, during 2002–2005. Fifteen transects were located in urban areas (>50 % building cover) and 14 in peri-urban areas (5–20 % building cover) at the city fringe. Seasonal change in bird richness and abundance was determined by the coefficient of variation (CV), comparing bird richness and abundance of each strip transect between the nonbreeding and the breeding season. The change in community composition between seasons was calculated with the Jaccard index (for more details in methods, see Leveau and Leveau 2012), comparing bird composition in each strip transect between the nonbreeding and the breeding season.

Seasonal similarity in community composition was higher in the urban (mean = 0.72, SE = 0.05) than in the peri-urban (mean = 0.58, SE = 0.03; Student test, $t = 2.18$, $P = 0.038$) area. In contrast, the seasonal change of bird richness was similar between urban (mean = 0.20, SE = 0.04) and peri-urban (mean = 0.23, SE = 0.03; $t = 0.55$, $P = 0.586$) areas. Furthermore, the seasonal change of bird abundance tended to be significantly higher in the peri-urban area (mean = 0.29, SE = 0.04; urban area, mean = 0.18, SE = 0.04; $t = 1.88$, $P = 0.070$). The literature indicates that seasonal dynamics of bird communities depends on the arrival of

migratory species in Central Argentina (Cueto and Lopez de Casenave 2000; Isacch and Martinez 2001; Isacch et al. 2003; Codesido et al. 2008; Leveau and Leveau 2011; Apellaniz et al. 2012). However, those migrant species are mostly excluded from highly urbanized areas. In our study, the presence of migrant species in the urban area was only occasional, whereas in the peri-urban area, four species were recorded [glittering-bellied emerald (*Chlorostilbon lucidus*), fork-tailed flycatcher (*Tyrannus savana*), tropical kingbird (*Tyrannus melancholicus*), and small-billed elaenia (*Elaenia parvirostris*)]. Those migrant species nest in trees and feed on insects and, in the case of glittering-bellied emerald, on nectar. Therefore, the lack of tree cover and food resources in highly urbanized areas compared to low urbanized areas may be the cause of low numbers of migrant species and the lack of seasonality in bird community composition. Our findings of lower seasonality in bird community composition and richness in highly urbanized areas agree with patterns found in Europe (Clergeau et al. 1998; Caula et al. 2008), North America (Clergeau et al. 1998; La Sorte et al. 2014), Australia (Catterall et al. 1998), and Argentina (Leveau et al. 2015; Cid and Caviedes-Vidal 2014). On the other hand, the lower seasonal variability of bird abundance in the urban area could be related to a constant supply of resources between seasons (Shochat et al. 2006).

3.3.2 Year-to-Year Variability in Community Attributes

Interannual variability in climate, resources, and habitat structure is thought to influence the interannual dynamics of bird communities (Järvinen 1979; Theriault and Kolasa 2000). However, urban environments may have a reduced interannual variability in resource availability and habitat structure relative to the nonurban areas (Shochat et al. 2006). The constant supply of food resources provided by humans may stabilize the temporal dynamics of bird communities in highly urbanized areas (Suhonen and Jokimäki 1988). Moreover, highly urbanized areas generally are dominated by a few cosmopolitan species, such as the house sparrow (*Passer domesticus*) and the rock dove (*Columba livia*), promoting interannual stability of bird communities (Collins 2000; Sasaki and Lauenroth 2011). Highly abundant species are usually more persistent because they have lower extinction risk than rare species (Collins 2000). Conversely, bird communities dominated by less abundant species and having more rare species are expected to show deeper fluctuations among years.

Recent studies in Mar del Plata City showed little year-to-year variation in community composition in the core-urban area compared to peri-urban (Fig. 3.9) and rural areas that was related to the abundance of the dominant species in the most urbanized areas (Leveau and Leveau 2012; Leveau et al. 2015). In fact, the house sparrow and the rock dove represented each one between 20 and 29% of the individuals recorded in the most urbanized sites (Leveau and Leveau 2012). Moreover, these species were the two most temporally persistent in that sites,

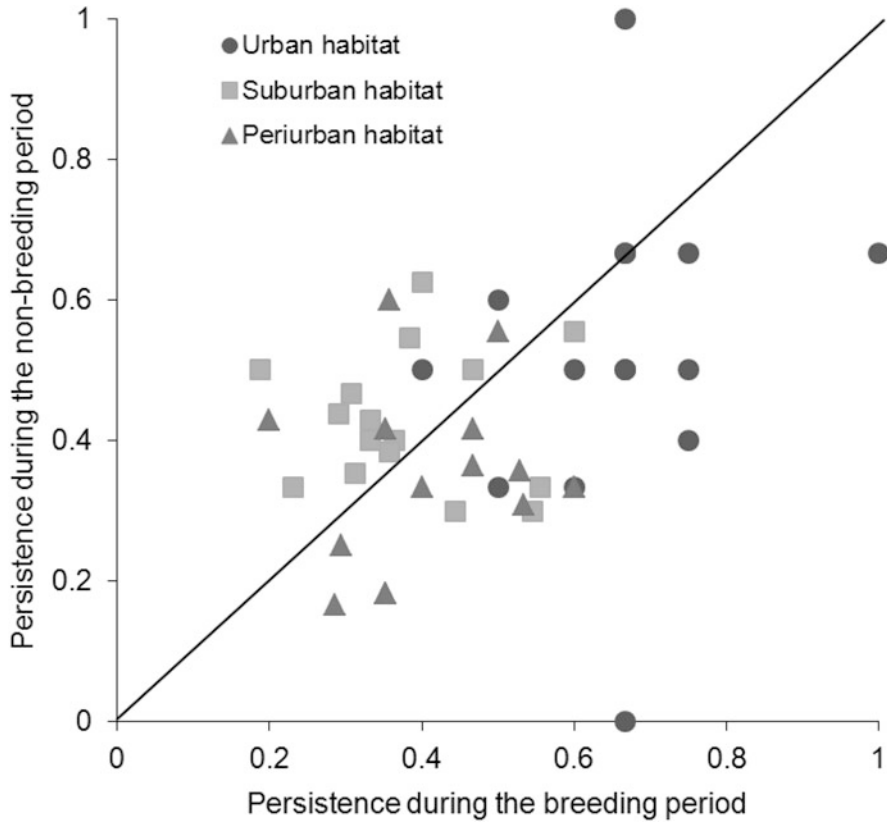


Fig. 3.9 Interannual variability of bird community composition along the urban gradient of Mar del Plata city, showing the values of persistence during the breeding and nonbreeding seasons. Persistence values vary from 0 (no species were recorded in all 3 years) to 1 (all species were recorded all 3 years). The *continuous line* indicates that the level of persistence was the same in both periods. Adapted from Leveau and Leveau (2012)

being recorded every year. On the other hand, the two most persistent species in suburban and peri-urban sites only represented the 11 % of the species recorded. A higher proportion of rare species in these suburban and peri-urban areas may be related to a lower stability of community composition. Furthermore, a constant food supply provided directly or indirectly by humans in the most urbanized sites may contribute to the high abundances and, therefore, higher temporal stability.

Interannual variability in bird community composition in the core-urban area was higher during the breeding than during the nonbreeding season (Fig. 3.9). This pattern is consistent with the hypothesis that bird communities are more stable during the breeding season, because species have stricter habitat affinities at this time (Rice et al. 1983; Tellería and Santos 1997).

Our results obtained in Mar del Plata (Leveau and Leveau 2012; Leveau et al. 2015) of a lower interannual variability in community composition agree

with those found in Finland by Suhonen et al. (2009). However, Barrett et al. (2008) did not find differences in the long-term dynamics of bird assemblages in areas of high and low human population densities. The differences in the temporal and spatial scales used in studies may be related to their contrasting results.

3.4 Future Directions

Studies conducted in the Northern Hemisphere, Australia, and Argentina showed that urbanization altered the seasonal dynamics of bird communities. Given that seasonal variation of climate and, consequently, of bird communities in natural areas increases with latitude (Herrera 1978b; Newton and Dale 1996a, b), we expect that the impact of urbanization on the seasonal dynamics of bird communities also increases toward the poles. Future studies should explore the interaction between latitude and urbanization in affecting the seasonal dynamics of bird communities. On the other hand, results from Finland and Argentina showed that urbanization stabilizes the interannual variation of community composition. Therefore, in a recent article, we proposed that urbanization promotes a temporal homogenization of bird communities, lowering the seasonal and interannual variations of bird composition (Leveau et al. 2015). However, further research is needed to understand to what extent urbanization reduces the temporal dynamics of bird communities.

Most conceptual models on the response of biodiversity to urbanization are based on the experience in developed economies. The evidence from studies conducted in southern South America indicates that latitudinal patterns of bird assemblages in urban areas differed between South America and Europe and that the negative impact of urbanization on species richness is the strongest in highly rich regions such as the tropics. Given the environmental, historical, and socioeconomic scenarios of the different regions of the world, a comparison of bird response to urbanization among biogeographical regions should be conducted to better understand global patterns; certainly, efforts should be made for filling information gaps. Such comparison should use a mechanistic approach to allow explaining the observed patterns and help to develop a unified heuristic framework.

The inclusion of complementary components to the traditional taxonomic local diversity (alpha diversity) is only recently being incorporated in the study of urban biodiversity, and it is virtually unexplored in South America and in most other regions of the world. Future studies should incorporate the turnover of species along urbanization gradients (beta diversity), the functional and phylogenetic facets of biodiversity, and ecosystem processes and functions (i.e., predation, pollination). Birds are good biological models to increase our understanding of the responses of biodiversity to urbanization because they proved to be sensitive to urbanization and are relatively well known and easy to survey worldwide.

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