Chapter 2
What's New? An Updated Review of Avian Ecology in Urban Latin America

Juan F. Escobar-Ibáñez and Ian MacGregor-Fors

Abstract Among human activities, urbanization represents one of the most worrisome for biodiversity due to the intensity and long-term effects in the place where a city develops, as well as their indirect effect in its area of influence. Birds are one of the most studied groups to assess the impacts that urbanization has on biodiversity, but there is a lag in the knowledge of highly biodiverse regions like Latin America. This region is the most diverse in avian species, but at the same time is one of the most affected by poverty, social inequality, and population growth, representing a priority for studying urban bird responses to urbanization. In this chapter, we compare results of studies of urban birds in Latin American cities published in recent years with an earlier regional review. We found more than one-third of publications in the last six years than in the previous 35 years; however, there is still a bias in the knowledge toward most populated countries, while urban Central America remains understudied. Although there is a lack of information on the mechanistic processes molding urban avian communities, there are important advances in ecological topics, as novel resource use, urban noise, and urban avian diseases. We urge scientists of Latin American latitudes to join efforts in the understanding of avian communities in urban areas. Results of evidence-based studies ought to be communicated to decision-makers to generate strategies that improve urban management and planning.

Keywords Bird diversity • Literature • Tropics • Urban ecology • Urban gradients

2.1 Urbanization, Birds, and Latin America

As highlighted in Chap. 1, human activities are leading ecosystem changes throughout the world, causing unprecedented impacts on biodiversity and human well-being (Mittermeier et al. 2011; Venter et al. 2016). Among human-related ecological

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disturbances, urbanization has been identified as one of the most worrisome due to the intensive and long-term modifications that occur where it takes place, as well as the effects beyond its limits (Kennedy et al. 2011). In fact, urbanization has been related to several components of global change (e.g., climate change, biological invasions; Grimm et al. 2008). Thus, it is not surprising that it has been identified as a major driver of species endangerment (Czech et al. 2000; Maxwell et al. 2016).

For the past decades, ecologists have assessed anthropogenic impacts through measurements of biodiversity (Magurran and McGill 2011). Given the high variability and nature among wildlife groups, it has been suggested to follow a 'biodiversity indicator' approach (also known as 'bioindicator') to assess such ecological effects (Moreno et al. 2007). Among 'bioindicators', birds have been widely used because they have high taxonomic diversity (Jetz et al. 2012), represent one of the best known wildlife groups (Schulze et al. 2004), are relatively easily to survey (Ralph et al. 1996), and quickly respond to modifications in their habitats (Marzluff et al. 2001; Aronson et al. 2014). It is not surprising that, based on all of the above factors, birds have been the most studied group in urban centers (McKinney 2006, 2008; Marzluff 2016). Results of studies focused on urban birds, which are heavily biased toward temperate northern developed regions (e.g., United States, Western Europe; Marzluff 2001; Evans et al. 2009; Ortega-Álvarez and MacGregor-Fors 2011a; Hedblom and Murgui 2017), have established some generalizable and consistent patterns. Yet, differences have been reported in understudied regions, including the tropics and subtropics (Ortega-Álvarez and MacGregor-Fors 2011a).

Among tropical and subtropical regions, Latin America has recently gained presence in the urban bird literature (Ortega-Álvarez and MacGregor-Fors 2011a, b). It is noteworthy to underline that this region shelters an important proportion of global avifauna (BirdLife International 2013), encompassing important hotspots for birds (Mittermeier et al. 2011), which is currently exposed to high urbanization rates (United Nations 2015). This makes Latin America a particularly interesting region to further study avian patterns and processes related to urbanization. Insights from this region would not only strengthen our level of comprehension of the response of birds to this complex human disturbance, but will also provide evidence-based information that could create a solid foundation of urban ecology as well as to endorse and promote novel public policies and strategies in our journey of creating biodiverse, sustainable, and livable cities (McDonnell and MacGregor-Fors 2016).

Taking Fonaroff's (1974) pioneer study of avian ecology in northwestern Trinidad as a starting point of bird knowledge in urban Latin America, studies have risen importantly in the last decades. In this chapter, we consider two previous reviews focused on the development of avian studies in urban Latin America as groundwork (González-Urrutia 2009; Ortega-Álvarez and MacGregor-Fors 2011b), and performed an update of the related literature to set a general state-of-the-art on the topic. Finally, we pinpoint some general research gaps and future directions for the discipline, which are refined by topic in each thematic chapter of this book (Chaps. 3–8) and synthesized in the final one (Chap. 9).

2.2 What's New? An Updated Review on Bird Studies in Urban Latin America

To gather as many studies as possible that were published after those considered by previous reviews (González-Urrutia 2009; Ortega-Álvarez and MacGregor-Fors 2011b), we performed an intensive search in Google Scholar (www.scholar.google.com) and all Web of Science (www.webofknowledge.com) databases included in our institutional subscription (i.e., Web of Science Core Collection, Derwent Innovations Index, KCI-Korean Journal Database, Russian Science Citation Index, SciELO Citation Index) seeking for publications from 2009 to 2015, the time period since the last review. In our searches, we used keyword combinations including 'urban' AND 'bird,' followed by the names of 47 Latin American countries (i.e., Anguilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guadeloupe, Guatemala, Guiana, French Guiana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Barthélemy, Saint Kitts and Nevis, Saint Lucia, Saint Martin, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, and Venezuela).

After carefully reviewing the retrieved set of publications from all used search engines and selecting those that focused on bird studies in urban Latin America, 128 remained (see Appendix 2.1 for references of the publications that were not cited within the chapter). Taking the exhaustive review of 2011 as baseline, which gathered a total of 84 publications in a period of 35 years, the retrieved set of studies represents ~ 9 times higher average annual publication rate. Regarding the geographical distribution of the assessed publications, four countries accounted for ~87% of the articles. Although the same four countries were the best represented in the 2011 review and our update, with Brazil heading the list, Mexico outnumbered the studies from Argentina, and Colombia remained in the same position (Fig. 2.1). It is noteworthy that some countries in which studies were found for previous reviews were absent in our search (French Guiana, Trinidad and Tobago, Panama), while countries as Barbados, Guatemala, Bolivia, and Uruguay recently joined, adding knowledge to our comprehension of avian response to urbanization.

To have a comparable dataset of publications, we used a slightly modified set of categories to those used by Ortega-Álvarez and MacGregor-Fors (2011b) to group the reviewed publications: ecology, species lists, and new records. We did not include a conservation category due to the general lack of conservation-oriented studies in our search (~2%). For further information on the conservation topic, Piratelli et al. (Chap. 8) consider the related literature focused on the reported conservation implications and actions in urban Latin America, as well as the future directions in generating bird-friendly cities. After assigning categories to the set of assessed publications, it was evident that those focused on ecological patterns were still dominant in the literature, represented by ~79% of the retrieved studies, followed by species lists/new records (~19%; Fig. 2.2).

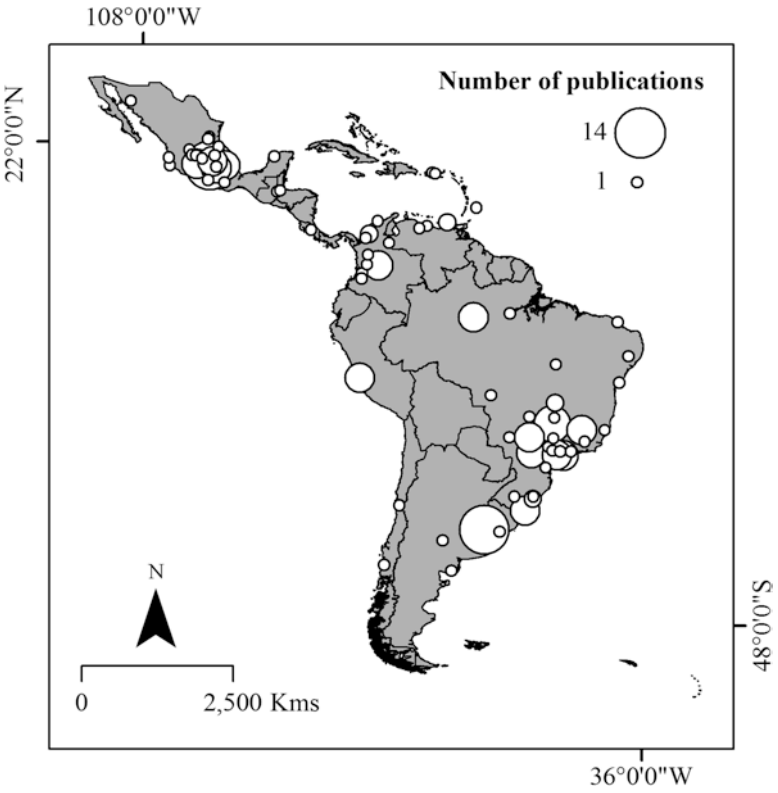

Fig. 2.1 Number of urban bird studies in Latin America by city

2.2.1 Ecological Patterns and Processes

Ecological studies have long represented the majority of urban bird studies in Latin America (Ortega-Álvarez and MacGregor-Fors 2011b); yet, in our updated review, we found a proportional increase in relation to the total retrieved studies, passing from 63% to 78%. Along with such an increase, we identified some specific topics that, as far as we know, had not been previously assessed in the region, including urban bird bioacoustics and parasitism (see Chap. 7). To analyze the retrieved publications, we grouped them in eight main topics that describe their framework and/or aims, as follows: urban gradients, comparisons among different environmental conditions, local traits, regional traits, novel resource use, bird–plant interactions, behavior, noise, and urban avian diseases.

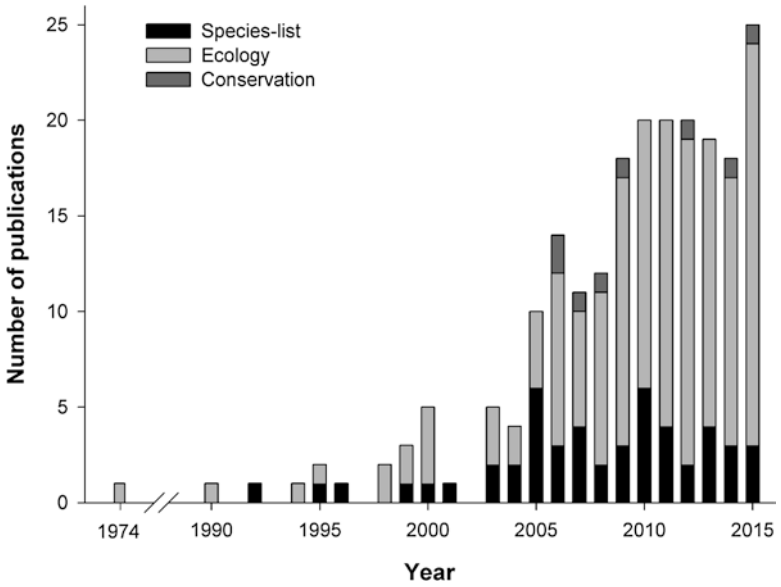

Fig. 2.2 Number of urban bird studies in Latin America by topic and year

2.2.1.1 Urban Gradients

The use of urban gradients is still widely used in the region (Chaps. 3 and 4; also see Chap. 9 for a detailed discussion on the methodological assessment of urban gradients). Some of the general ecological patterns that are consistent with those identified across the globe (Chace and Walsh 2006; Evans et al. 2009) are: (i) decrease in species richness and increase in abundance with urbanization (MacGregor-Fors and Schondube 2012; Toledo et al. 2012; MacGregor-Fors et al. 2015; Silva et al. 2015); (ii) increase in the abundance of a few species that mold the abundance distribution of urban bird communities (Fontana et al. 2011; Toledo et al. 2012); and (iii) increase of compositional similarity in highly urbanized areas (Filloy et al. 2015; Sanz and Caula 2015). One interesting pattern that falls outside of those previously reported was found in La Paz, Bolivia, where bird abundance decreased in highly urbanized areas (Villegas and Garitano-Zavala 2010). Although this pattern was previously reported in City of Olongapo (Philippines; Posa and Sodhi 2006), the study from Bolivia adds evidence for the occurrence of this pattern in tropical areas. Regarding urban to nonurban comparisons, which should not be considered a gradient, but a comparison between different conditions (see Sect. 2.2.1.2, this chapter, as well as Chap. 9 for a detailed discussion), new noticeable results are: the presence of higher concentrations of heavy metals in the feathers of birds from urban areas (Nava-Diaz et al. 2015) and dietary shifts of the Barn Owl (*Tyto alba*) in urban areas when compared to nonurban ones (Teta et al. 2012).

2.2.1.2 Comparisons Among Different Environmental Conditions

Another commonly used approach to assess the response of avian communities to urbanization in Latin America is contrasting urban and surrounding areas. Despite the studied nonurban environments being diverse (e.g., shrublands, grasslands, croplands, woodlands, riparian systems), results are highly consistent with those from the other regions of the globe. For instance, urban avian communities differ importantly in relation to those from surrounding systems, suggesting a 'semipermeability' process of species filtering (MacGregor-Fors 2010; MacGregor-Fors et al. 2011b; Ramírez-Albores 2013; Domínguez-López and Ortega-Álvarez 2014; Puga-Caballero et al. 2014; Filloy et al. 2015; Sanz and Caula 2015; Chap. 6). However, we found some results that are not in agreement with previous ones, such as the absence of differences in bird species richness of an urban area and surrounding forests in Porto Alegre, Brazil (Fontana et al. 2011), as well as the absence of a clear influence of the landscape context on the urban bird communities of periurban Mexico City (Puga-Caballero et al. 2014). This result, although counterintuitive, has also been found in other parts of the world (e.g., western France, northern Finland, eastern Canada; Clergeau et al. 2001).

2.2.1.3 Local Environmental Predictors

At the local scale, most studies report effects of some key environmental characteristics on bird species richness, including vegetation diversity, structure, and composition, as well as proxies of urbanization intensity (see Chaps. 3, 5, and 9 for further methodological discussions). Results of many studies carried out in urban Latin America are in agreement with those from across the globe, finding positive relationships between vegetation complexity (e.g., Toledo et al. 2012; Leveau 2013) and vegetation cover (e.g., Villegas and Garitano-Zavala 2010; Nolazco 2012), and negative relationships with percentage of impervious surface (e.g., Villegas and Garitano-Zavala 2010; Reis et al. 2012; Sanz and Caula 2015), noise (e.g., Fontana et al. 2011), and bird species richness (see Chap. 3 for further details on this topic). However, avian groups have been shown to respond differently to urbanization depending on their specific requirements (Blair 1996; Rebolo and Fiorini 2010; MacGregor-Fors and Schondube 2011; Toledo et al. 2012; see Chap. 6 for a behavioral perspective). Surprisingly, one study found negative relationships between native bird species richness and vegetation richness (Silva et al. 2015), although the authors warn about the low explanatory power of the model (16%).

2.2.1.4 Regional Scale Predictors

Regional scale drivers of species richness, such as species–area relationships, are again similar to those identified in global studies. Positive relationships have been recorded in Mexican urban areas between size of human settlements and bird

species richness (MacGregor-Fors et al. 2011a), as well as with the size of urban greenspaces (Carbó-Ramírez and Zuria 2011; Charre et al. 2013). Interestingly, a study comparing several urbanized settlements of west-central Mexico found that, on a regional scale, settlement size can override the contributions of built cover, human population density, tree cover, and plant diversity (MacGregor-Fors et al. 2011a). On the other hand, considering another island biogeography concept, 'distance from the source' or 'distance to the city border' has been reported to be negatively related to bird species richness (MacGregor-Fors and Ortega-Álvarez 2011; Silva et al. 2015), but this relationship occurs differently for particular bird groups (e.g., native, exotic, migrants; MacGregor-Fors and Ortega-Álvarez 2011; Charre et al. 2013).

2.2.1.5 Novel Resource Use

The ability of organisms to use new resources in urban areas can determine their prevalence in such novel environments (Chap. 6). We found records of the use of resources like thermal power plants by Black (*Coragyps atratus*) and Turkey Vultures in Brazil (*Cathartes aura*; Freire et al. 2015), as well as open garbage containers by some bird species (e.g., Black Vulture; Novaes and Cintra 2013). Similarly, there are interactions not previously recorded in the literature, either in natural and/or modified environments, such as the consumption of bats and rats by Harris's Hawks (*Parabuteo unicinctus*; Ortega-Álvarez and Calderón-Parra 2014) and Channel-billed Toucans (*Ramphastos vitelinus*; da Silva and Azevedo 2013), respectively. Novel nesting sites have also been recorded in urban Latin America, such as Azure-crowned Hummingbirds (*Amazilia cyanocephala*) nesting in open sky wires (Escobar-Ibáñez and MacGregor-Fors 2016) and Kelp Gulls (*Larus dominicanus*) nesting in fuel tanks (Villavicencio 2014). Also, regarding urban nesting, one study from Mexico City found the use of cigarette butts in the nests of House Sparrows (*Passer domesticus*) and House Finches (*Haemorhous mexicanus*) that reduce parasite loads in the nests (Suárez-Rodríguez et al. 2012), and thus could act as repellent (although recent research suggests that incorporating cigarette butts could increase breeding costs; Suárez-Rodríguez et al. 2017). Another interesting study shows that the threatened Burrowing Parrot (*Cyanoliseus patagonus*) reproduces successfully at highly disturbed sites, such as locations in which waterholes are established and construction materials are extracted in Argentina (Tella et al. 2014).

2.2.1.6 Bird-Plant Interactions

As discussed above, urban vegetation has been shown to be tightly related with urban avian diversity. Bird-plant interaction studies have been increasingly present in the urban ecology literature from Latin America, focused both in 'green' and 'gray' areas (Chap. 5), with an important bias toward nectar and fruit consumption (Gómez-Aíza and Zuria 2010; Leveau and Leveau 2011; Rodrigues and Araujo

2011; Maruyama et al. 2012; Andrade et al. 2013; Ferreira and Consolaro 2013; Santos and Ragusa-Netto 2014). One pioneer study evaluated the relationship between the spectral properties of flowers and their visitors in northeastern São Paulo (Toledo and Donatelli 2010), finding more visitor species in those flowers with long wavelengths, although further studies are needed to fully understand the complex network of interactions in which nectar-flowering plants, birds, and other wildlife groups are implied. Although not necessarily novel, several studies have highlighted the importance of exotic trees providing alternative food resources year-round (Oliveira et al. 2013; Previatto et al. 2013). Remarkably, even large-sized frugivores have been recorded to take advantage of such resources in urban Latin America (e.g., Toco Toucan—*Ramphastos toco*, and Blue-and-yellow Macaw—*Ara ararauna*; Santos and Ragusa-Netto 2013, 2014). Studies have suggested considering this in urban ecological management plans, since large frugivores are one of the most susceptible avian groups to human disturbances (Franz et al. 2010; Lessi et al. 2016). Yet, there is evidence that such a positive effect does not always occur, with exotic plant density also being negatively related with urban avian species richness (Reis et al. 2012).

2.2.1.7 Behavior

Behavioral plasticity is one of the most important factors determining the arrival and establishment of birds in urban areas (see Chap. 6 for a thorough revision on this topic). Recent studies have added to our knowledge on avian responses to urbanization from an ethological perspective, such as urban-related resource use by flycatchers (e.g., Great Kiskadee—*Pitangus sulphuratus*, Tropical Kingbird—*Tyrannus melancholicus*; Martins-Oliveira et al. 2012), the flight initiation distance of Burrowing Owl (*Athene cunicularia*; Rebolo-Ifrán et al. 2015), and bolder and better problem-solving urban wild-caught Barbados Bullfinches (*Loxigilla barbadensis*) when compared to individuals captured in nonurban areas (Audet et al. 2016). Additional intriguing avian behavioral responses have been recently reported in urban Latin American sites, including the commensal association of egrets, kingfishers, and herons foraging with otters in an urban greenspace of southeastern Brazil (D'Angelo and Sazima 2014).

2.2.1.8 Noise

Environmental noise seems to play a major role on the establishment of bird species within urban systems (González-Oreja et al. 2012; Chap. 7). This topic has gained important presence in recent years, with studies identifying urban-related bird species (e.g., House Finch, Vermilion Flycatcher—*Pyrocephalus rubinus*) adjusting their vocalizations to avoid noise interference (Bermúdez-Cuamatzin et al. 2009). We found a binational study focused on Mexican and Brazilian birds testing the vocal flexibility of oscine (songbirds that learn to sing) and suboscine birds (those

that lack song learning) in urban systems. Results of the study show that song transmission capacity and ambient acoustics are related for oscines but not for suboscines, suggesting that song learning can be an important mechanism for adaptation in urban areas (Ríos-Chelén et al. 2012).

2.2.1.9 Urban Avian Diseases

Viruses, parasites, bacteria, and fungus are vectors of diverse diseases of ecological and public health concerns (Oliveira et al. 2012; Kading et al. 2013; see Chap. 7 for a thorough review on the topic). There has been an important increase in the number of studies focused on this topic, going from one study identified in the 2011 review (i.e., Monnerat-Nogueira et al. 2005) to 17 studies published in the time frame considered in this review. Interestingly, ~70% of the gathered studies were conducted in Brazil. The vast majority of publications focused on exotic bird diseases, mainly Rock Pigeons—*Columba livia* (de Sousa et al. 2010; de Lima et al. 2011; Caballero et al. 2015; Pérez-García et al. 2015) and House Sparrows (Gondim et al. 2010; Komar et al. 2012), finding *Escherichia coli* in 86% of Rock Pigeon samples (Silva et al. 2009), as well as viruses (e.g., West Nile virus) and fungi (*Cryptococcus* and *Candida* spp.) in 95% of Rock Pigeon samples (Costa et al. 2010). A more ecological study performed in southeastern Mexico shows that urbanization can play a crucial role in the frequency and severity of avian malaria infections for the Chestnut-capped Brushfinch (*Arremon brunneinucha*; Hernández-Lara et al. 2017). Other studies recorded new bacteria in bird species (e.g., *Neospora caninum* in house sparrows, *Dispharynx nasuta* in Picui Ground-Doves, Poxvirus in Barn Owls; Coimbra et al. 2009; Vargas et al. 2011), and even new pathogen genotypes in Eared Doves—*Zenaida auriculata* (i.e., *Toxoplasma gondii* #182; Barros et al. 2014). Of the few publications addressing ecological questions, the main conclusions are: (i) parasite richness and abundance decrease with urbanization (Calegaro-Marques and Amato 2014); (ii) avian host abundance of the West Nile virus increases with urbanization (Morales-Betoulle et al. 2013); and (iii) higher prevalence of parasites in native species when compared to exotics (Lima et al. 2010).

2.2.2 Species Lists and New Records

Urban-related species lists and new records continue to be the second most common topic in the urban bird literature from Latin America. Yet, compared with the 2011 review, there has been a reduction in the proportion of publications (from ~32% in 2011 to ~18.5% to 2015). A decrease in this kind of publications and the increase in ecological studies are parts of a transition toward a more comprehensive approach in the region (Table 2.1). As pointed out in the 2011 review, one of the main differences between species lists of temperate urban areas and those from Latin America is the high level of reported avian diversity (Table 2.2). There is an example of a

Table 2.1 New records for birds in urban Latin America between 2009 and 2015

Species name	Common name	City (Country)	Reference
Dendrocygna bicolor	Fulvous Whistling-Duck	Cúcuta (Colombia)	Armesto et al. (2013)
Streptopelia decaocto	Eurasian Collared-Dove	Querétaro (Mexico)	Pineda-López and Malagamba (2011)
Columbina inca	Inca Dove	Ciudad Victoria (Mexico), Jaumave (Mexico)	Rodríguez-Ruiz et al. (2015)
Coccyzus americanus	Yellow-billed Cuckoo	Cúcuta (Colombia)	Armesto et al. (2013)
Pelecanus occidentalis	Brown Pelican	Santarém (Brazil)	Almeida-Santos et al. (2016)
Myiopsitta monachus	Monk Parakeet	Mexico (country), La Plata (Argentina), Pampas grassland ecoregion (Argentina), Buenos Aires (Argentina)	MacGregor-Fors et al. (2011a), Pineda-López and Malagamba (2011), Volpe and Aramburú (2011), Pineda-López et al. (2013), Bucher and Aramburú (2014), Romero et al. (2015)
Forpus conspicillatus	Spectacled Parrotlet	Cúcuta (Colombia)	Armesto et al. (2013)
Vireo philadelphicus	Philadelphia Vireo	Mexico City (Mexico)	Aguilar-Gómez et al. (2015)
Turdus rufopalliatus	Rufous-backed Robin	León (Mexico); Querétaro (Mexico), Central Mexico	Pineda-López and Malagamba (2009), Martínez-Morales et al. (2010), Pineda-López et al. (2013)
Sturnus vulgaris	European Starling	Buenos Aires (Argentina), León (Mexico), Querétaro (Mexico)	Rebolo and Fiorini (2010), Pineda-López and Malagamba (2011), Pineda-López et al. (2013)
Protonotaria citrea	Prothonotary Warbler	Cúcuta (Colombia)	Armesto et al. (2013)
Paroaria nigrogenis	Masked Cardinal	Cúcuta (Colombia)	Armesto et al. (2013)
Zonotrichia leucophrys	White-crowned Sparrow	Mexico City (Mexico)	Aguilar-Gómez et al. (2015)
Quiscalus mexicanus	Great-tailed Grackle	Ciudad Victoria (Mexico), Jaumave (Mexico)	Rodríguez-Ruiz et al. (2015)

Table 2.2 Bird species lists from urban Latin America between 2009 and 2015

City/country	Species richness	Reference
Caracas (Venezuela)	40	Sainz-Borgo (2015)
Puebla (Mexico)	46	Almazán-Núñez and Hinterholzer-Rodríguez (2010)
Universidad Nacional Agraria la Molina, lima (Peru)	48	Castillo-Palacios et al. (2014)
Sorocaba (Brazil)	65	Cruz and Piratelli (2011)
Universidad Autónoma de Guerrero campus Sur, Chilpancingo (Mexico)	76	Castro-Torreblanca and Blancas-Calva (2009)
Pelotas (Brazil)	84	Sacco et al. (2013)
Universidad del Cauca, Popayán (Colombia)	114	Ramírez-Cháves et al. (2010)
Pelotas (Brazil)	114	Franz et al. (2010)
Belo-Horizonte (Brazil)	123	Vasconcelos et al. (2013)
Puerto Vallarta (Mexico)	160	Molina et al. (2012)
Universidad de Magdalena, Santa Marta (Colombia)	186	Strewe et al. (2009)
Pereira (Colombia)	207	Londoño-Betancourth (2011)
Xalapa (Mexico)	242	Ruelas Inzunza and Aguilar Rodríguez (2010)
Xalapa (Mexico)	341	González-García et al. (2016)

neotropical ctiy for which more than 340 bird species have been recorded in the last three decades (i.e., Xalapa, Mexico, ~64 km^2; González-García et al. 2016). Aside from the study of Xalapa and that of the campus of the Pontifícia Universidade Católica de Minas Gerais (performed along three decades; Vasconcelos et al. 2013), most species lists are based on short time windows or comparisons through time (Franz et al. 2010; Sanz et al. 2010; Biamonte et al. 2011; Vasconcelos et al. 2013; Castillo-Palacios et al. 2014). One of the most dramatic results regarding temporal comparisons was that reported by Biamonte et al. (2011) in relation to the urban sprawl of San José, Costa Rica, finding: (i) the local extinction of 32 resident and 34 latitudinal migratory bird species; (ii) decrease in the abundance of resident and migratory species; (iii) increase of species related to open areas; and (iv) decrease of forest-dependent species.

Regarding the identity of species reported in the species lists, we found both similarities and remarkable differences when compared to the 2011 review. There is a general agreement that the best represented groups throughout Latin American cities are flycatchers (e.g., Strewe et al. 2009; Almazán-Núñez and Hinterholzer-Rodríguez 2010; Cruz and Piratelli 2011; Toledo et al. 2012), although sometimes these groups are underrepresented when compared to adjacent nonurban systems (Fontana et al. 2011). While the 2011 review identified emberizids (e.g., sparrow, buntings) as one of the best represented families, we found that warblers and tana-

gers are often the most represented groups after flycatchers, followed by icterids (e.g., orioles, grackles), emberizids, and hummingbirds (e.g., Caula et al. 2010; Carbó-Ramírez and Zuria 2011; Nolazco 2012; Charre et al. 2013). Detailed analyses focused by country show evident geographical variations. For example, warblers are the best represented group in urban Mexico, followed by flycatchers (Almazán-Núñez and Hinterholzer-Rodríguez 2010; Carbó-Ramírez and Zuria 2011; Molina et al. 2012; Charre et al. 2013; González-García et al. 2014), while flycatchers are the best represented group in Brazil, Colombia, Peru, Venezuela, and Bolivia, followed by tanagers (Castro-Torreblanca and Blancas-Calva 2009; Caula et al. 2010; Ramírez-Cháves et al. 2010; Villegas and Garitano-Zavala 2010; Biamonte et al. 2011; Londoño-Betancourth 2011; Reis et al. 2012; Toledo et al. 2012; Sainz-Borgo 2015).

2.3 Conclusions

Bird studies in urban Latin America have noticeably increased in the last years, providing significant knowledge advances in both well-studied and new topics, including those from countries for which no publications had been identified in previous reviews (i.e., Guatemala, Barbados, Uruguay, Bolivia). Yet, there are some countries that have not continued to contribute with knowledge since the 2011 review (e.g., Trinidad and Tobago, Panama), and many other countries that, as far as we know, have not developed urban avian studies. In this concluding section, we briefly provide a general perspective of the main advances and the future research directions for the study of birds in urban Latin America (see the thematic chapters for specific topic-related advances and future directions; Chaps. 3, 4, 5, 6, 7, and 8).

Our updated review shows that urban avian ecology in Latin America is currently in a transition phase that is moving forward to describe ecological patterns, and even starting to dive into some of the mechanistic processes behind them. Yet, one interesting and worrisome pattern found through our review was a decrease in the proportion of publications of species lists and new records in comparison with the 2011 review. Although it is crucial to generate information regarding the patterns and processes to understand the way in which birds are responding, acclimatizing, and adapting to urbanization in Latin America, basic information is fundamental for further studies. Thus, we recognize the importance of intensifying efforts to keep the generation of basic natural history studies, as well as new records, and species lists together with ecological, genetic, conservation, management, and planning-oriented studies.

Regarding general patterns, few followed a comparative urban–nonurban contrast, finding bird richness decreases with urbanization (e.g., MacGregor-Fors et al. 2011b; Sanz and Caula 2015). However, the kind of ecotone can influence the magnitude of these effects (Puga-Caballero et al. 2014). It is imperative that studies adopt a comparative approach to understand the way in which birds respond to urbanization in the widely diverse set of environmental conditions and bird diversity present throughout Latin America.

We found several studies suggesting that their results show both taxonomic and functional homogenization (e.g., Ortega-Álvarez and MacGregor-Fors 2009; Filloy et al. 2015). However, there are some methodological and conceptual aspects that have not been considered, and we highly recommend interpreting them cautiously (see Chap. 9 for a detailed analysis). Regarding local and regional predictors of bird species richness, we found several similarities to what has been previously reported for the region and others across the globe. For example, vegetation components mold bird diversity within cities at several spatial scales. Although many typical vegetation measures have been assessed (e.g., tree, shrub, and herb cover, DBH, and height; origin, phenology), there are other variables for which we have little information, such as greenspace connectivity, the role of private gardens, green roofs (although scarce in the region), and the bird use of dead trees.

Fortunately, studies focused on some processes of the reported urban bird patterns have started to gain presence in the Latin American bird literature. It is clear that these studies have contributed with pioneer findings, often dealing with acclimatory responses to urbanization that broaden our comprehension of the mechanisms related to some of the described patterns. Yet, these types of studies are scarce and biased toward specific topics. For example, recent studies have assessed the novel use of resources, such as the ability of birds to survive in urban conditions (e.g., Tella et al. 2014), song adjustments to urban noise (e.g., Ríos-Chelén et al. 2012), avian disease diversity related to urbanization (Calegaro-Marques and Amato 2014), spectral properties of flowers with avian feeding visiting rate (Toledo and Donatelli 2010), and the use of artificial resources for nesting (e.g., Suárez-Rodríguez et al. 2012). Interestingly, follow-ups of these studies have untangled important details regarding the main findings. For example, a study assessing the use of cigarette butts by urban birds in Mexico City concluded that while smoked cigarette butts act as ectoparasite repellents, they are also genotoxic, which could represent a negative breeding cost (Suárez-Rodríguez et al. 2017).

Based on our literature review, we identified some general knowledge gaps in relation to our understanding of the effect that urbanization has on birds in Latin America. Such gaps are not only conceptual, but also related with temporal and spatial biases. For example, the time-window of studies is often short, limiting our understanding on the long term, although some studies have addressed temporal changes through decadal comparisons to evaluate avian changes caused by urbanization through time (e.g., Biamonte et al. 2011). Also, the common focus on specific cities, often from the same countries, as well as the use of single-city designs and city comparisons within but not among countries, limits our understanding of the specific factors related with urban bird diversity along the diverse array of urban conditions embedded in a highly diverse cultural region.

Despite the myriad of urban management and planning recommendations based on the assessment of how birds, a well recognized bioindicator, respond to urbanization, many Latin American cities continue to sprawl and be managed without including such knowledge (Silva et al. 2015). Due to the complexity of urban ecosystems, there is an urgent need to include evidence-based ecological knowledge in the urban management, planning, and conservation agendas of the region (Miller and Hobbs 2002; Cestari 2015). Willingness from all the involved stakeholders, from house-

holders to governmental institutions, is key in bridging the gap between evidence-based knowledge and its application (MacGregor-Fors 2015). Undoubtedly, the more we understand the history of our cities, as well as the physical, ecological and social patterns, and related processes, we will be closer to setting balance between our modern urban way of life and the drastic ecological effects it triggers.

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Appendix 2.1 List of Retrieved Publications in the Search that Were Not Cited in the Chapter

Andery D de A, Ferreira Junior FC, de Araújo AV et al (2013) Health assessment of raptors in triage in Belo Horizonte, MG, Brazil. Rev Bras Ciênc Avíc 15:247–256

Azevedo CS, Silva KS, Ferraz JB et al (2012) Does people's knowledge about an endangered bird species differ between rural and urban communities? The case of the Greater Rhea (*Rhea americana*, Rheidae) in Minas Gerais, Brazil. Rev Bras Ornitol 20:8–18

Boogert NJ, Monceau K, Lefebvre L (2010) A field test of behavioural flexibility in Zenaida Doves (*Zenaida aurita*). Behav Process 85:135–141

Carbó-Ramírez P, González-Arrieta RA, Zuria I (2015) Breeding biology of the Rufous-backed Robin (*Turdus rufopalliatus*) in an urban area outside its original distribution range. Wilson J Ornithol 127:515–521

Carrete M, Tella JL (2011) Inter-individual variability in fear of humans and relative brain size of the species are related to contemporary urban invasion in birds. PLoS One 6:e18859

Carrete M, Tella JL (2013) High individual consistency in fear of humans throughout the adult lifespan of rural and urban burrowing owls. Sci Rep 3:3524

Chávez-Zichinelli CA, MacGregor-Fors I, Rohana PT et al (2010) Stress responses of the House Sparrow (*Passer domesticus*) to different urban land uses. Landsc Urban Plan 98:183–189

Fontoura PM, Orsi ML (2013) Ecological partitioning of three Columbidae species in Northern Paraná, Southern Brazil. Biota Neotrop 13:44–49

González-Oreja JA (2011) Birds of different biogeographic origins respond in contrasting ways to urbanization. Biol Conserv 144:234–242

Jebai GT, Arakaki BR, Silva CAP et al (2013) Análise comparativa da densidade de onze passeriformes em duas áreas urbanas em Londrina, norte do Paraná, Brasil. Rev Bras Ornitol 17:183–186

Johnston López K, Macías Duarte A, Castillo Gámez RA (2015) Urban birds in the Sonoran Desert: Estimating population density from point counts. Huitzil 16:37–47

Laiolo P (2011) Homogenisation of birdsong along a natural–urban gradient in Argentina. Ethol Ecol Evol 23:274–287

Leveau LM, Isla FI, Bellocq MI (2015) Urbanization and the temporal homogenization of bird communities: A case study in central Argentina. Urban Ecosyst 18:1461–1476

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Rosselli L, Stiles FG (2012b) Local and landscape environmental factors are important for the conservation of endangered wetland birds in a high Andean Plateau. Waterbirds 35:453–469
Sazima I (2009) Insect cornucopia: Various bird types prey on the season's first giant cicadas in an urban park in southeastern Brazil. Biota Neotrop 9:259–262
Sazima I, D'Angelo GB (2012) Agonistic interactions between two foraging Anhinga females in Southeastern Brazil. Wilson J Ornithol 124:403–405
Solaro C, Sarasola JH (2015) Nest-spacing, not human presence, influences the breeding of Chimango Caracaras (*Milvago chimango*) in a peri-urban reserve. Emu 115:72–75
Zaldúa N, Hernández D, Rodríguez-Tricot L (2013) Evaluación del uso de cajas nido por parte de aves urbanas. Bol Soc Zool Uruguay 22:39–45

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Almazán-Núñez RC, Hinterholzer-Rodríguez A (2010) Dinámica temporal de la avifauna en un parque urbano de la ciudad de Puebla, México. Huitzil 11:26–32
Almeida-Santos DA, Ferreira GS, Lopes EV (2016) New record of the Brown Pelican *Pelecanus occidentalis* in continental waters of the Brazilian Eastern Amazon. Rev Bras Ornitol 23:351–353
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