Avian species richness in cities: A review of the Spanish-language literature from the Southern Cone of South America

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Abstract
South America sustains an important part of the world’s terrestrial biodiversity and its population is highly urbanized. Global syntheses have revealed a paucity of urban ecological research in the region; however, local research might be overlooked due to language barriers. As a contribution to disseminating local knowledge, we conducted a synthesis of Spanish-language literature on bird species richness in the Southern Cone of South America - an area of high diversity, endemism, and more than half of the world’s terrestrial biome types. In this systematic review, we identified patterns and trends in the literature, and the variables that influence bird species richness. Research has focused on national capital cities and green areas (large urban parks). Most studies covered short periods of time (1 year or less) and involved one season only (reproductive). The most studied biomes were temperate grasslands, savannas and shrublands, and Mediterranean and temperate forests, and no studies were found in mountains or deserts. Bird species richness in cities from the Southern Cone was positively influenced by vegetation cover and plant and habitat diversity; whereas variables associated with urban cover and disturbance exhibited negative effects. Important gaps in knowledge include: research in small and medium size cities, in overlooked biomes (deserts, xeric shrublands, and montane grasslands and shrublands), long-term research comprising different seasons, the inclusion of green spaces other than urban parks, and interdisciplinary studies that consider environmental, social, and economic components of urban ecosystems. By filling these key knowledge gaps, researchers from South America can contribute to the development of science-based actions to preserve nature in an urbanizing world.

Keywords Argentina · Birds · Chile · Species richness · Urban parks · Uruguay

Introduction
Urbanization has dramatically transformed landscapes. Urbanization generates ecosystems that are dominated by impervious surfaces (Garaffa et al. 2009), with profound and long-lasting habitat modification (McKinney 2002). This leads to habitat loss and fragmentation for species that cannot cope with rapid land use change (Grimm et al. 2008). Thus, urbanization is one of the main threats to biodiversity, which leads to the extinction of native species and promotes the establishment of exotic species (McKinney 2006). Given the rapid decline of global biodiversity, promoting urban ecological research is important to provide evidence-based action to help conserve biodiversity in the context of increasing urbanization.

Urban ecological research has experienced a rapid growth in the last few decades. Most of the research has emerged from developed countries, especially in temperate regions of the northern hemisphere (US, Canada and Western Europe; Magle et al. 2012; Escobar-Ibáñez and MacGregor-Fors 2017). However, most future urban growth will occur in Latin America, Africa and Asia, which will experience an important decrease in rural population and a rise in urban population (United Nations 2019). The current paucity of urban ecological research in these continents has led to important knowledge gaps that limit sustainable urban development (Ortega-Álvarez and MacGregor-Fors 2011a; Magle et al. 2012).
Latin America is already one of the most urbanized regions in the world. In the last 70 years, urban population exhibited ca. 8-fold increase (United Nations 2019). Currently, about 80% of the human population live in urban areas, and the population of large cities is expected to further increase a 15% by 2030 (United Nations 2015). In the last 40 years, eight medium-sized cities (1-5 million inhabitants) expanded and now are large cities with more than 5 million inhabitants, including four megacities with more than 10 million inhabitants (Santa Cruz 2012; MacGregor-Fors and Escobar-Ibáñez 2017a). Given that in Latin America most people live in cities, cities offer an important place to restore human connection with nature and encourage conservation efforts (Sanderson and Huron 2011).

Conservation can be challenging in this region as cities commonly threaten biodiversity rich areas (Pauchard and Barbosa 2013; Aronson et al. 2014). Latin America contains more than 40% of the Earth’s biodiversity, including 70% percent of vertebrate species in the world, and more than 25% of the world’s forests (UNDP 2010). It also contains 70% of global terrestrial ecoregion and biome types, comprising a large variety of the world’s plants and animals (Olson et al. 2001). In addition, the region presents five of 35 global biodiversity hotspots where conservation actions should be prioritized as they contain high endemism in plants and animals, but where more than 70% of the original vegetation has been lost (Myers et al. 2000; Mittermeier et al. 2011).

The Southern Cone of South America is characterized by endemic species and evolutionary novelties (Ibarguchi 2014), and exhibits a growing urbanization (more than 75% of its population live in urban land; United Nations 2019). It is comprised of three countries: Argentina, Chile, and Uruguay. Chile exhibits high endemism, where ca. 25% of the species are endemic to the country (MMA 2018). Argentina has three ecological regions with the greatest species diversity in South America (i.e. the Paranaense jungle, the Yungas and the Chaco; SAyDS 2015). Uruguay has identified 35% of native species as priority species, with several populations facing a high level of threat (MVOTMA 2014). In addition to the outstanding proportion of endemic species, the region also maintains an important number of species threatened with extinction according to national determinations. For instance in two ecoregions, the Patagonian Steppe has 38 threatened animal species and the Valdivian Temperate Rainforest contains 40 threatened species (Hoekstra et al. 2010). In addition, this region can contribute to a better understanding of biodiversity responses to urbanization in different climates and geological conditions because it contains more than half of the world’s terrestrial biome types (eight of 15 biomes; Henwood 1998).

Previous syntheses of urban ecological literature have either found no studies or a few studies from Chile and Uruguay, whereas Argentina has contributed an important proportion of studies from Latin America (Ortega-Álvarez and MacGregor-Fors 2011a; Beninde et al. 2015; Escobar-Ibáñez and MacGregor-Fors 2017). However, these results might be limited by the search language, where languages other than English are commonly overlooked in scientific reviews. Spanish is the second most widely spoken native language on the planet (after Mandarin Chinese; Lewis et al. 2014). Spanish is important for disseminating local knowledge because it is the main language spoken in the region and several Latin American journals publish articles in Spanish, including ca. 40 Web of Science indexed journals in the fields of ecology and zoology (Neira et al. 2011). In addition, people from countries where the official language is not English are less likely to read and publish in English (Nuñez et al. 2019).

To help disseminate findings from urban ecological research from Latin America, we synthesized the state of knowledge on bird species richness in the Southern Cone (Chile, Argentina and Uruguay). We focused on birds because they are one of the most studied animal groups and are commonly used to study biodiversity patterns in urban ecosystems (McKinney 2008), because they are diverse, form complex communities, respond to changes in habitat conditions, and can be used as bioindicators (Chace and Walsh 2006; MacGregor-Fors and Escobar-Ibáñez 2017a).

We focused on the Spanish-language literature, as this information has been commonly excluded from both global and regional reviews. We evaluated: (1) publication trends and geographical patterns, (2) study design, (3) the origin of the species considered in analyses of bird species richness, and (4) effects of predictive variables on bird species richness. We discuss our findings in the context of urban ecological research and identify knowledge gaps to encourage the development of the field in the region and its global impact.

Methods

Search strategy

We searched for articles that evaluated bird species richness in cities of the Southern Cone of South America on Google Scholar (https://www.scholar.google.com), with help of Publish or Perish software (a software that helps conduct literature reviews and exports search results in different formats; Harzing 2010). We used Google Scholar for our search because it contains papers from any language and a larger number of documents in Spanish than other search engines (e.g. Web of Science or Scopus; Martín-Martin et al. 2018). In addition, it contains peer-reviewed articles in indexed journals as well as grey literature (e.g. papers published in...
non-indexed journals, conference papers, thesis, reports; Falagas et al. 2008). We included grey literature because it represents a large body of knowledge recommended to be considered in systematic reviews (Manterola et al. 2013). Grey literature also reduces publication bias because inconclusive results or those that are contrary to common findings are less likely to be published (González et al. 2011).

The search was conducted on July 24th 2020. As recommended by Pullin and Stewart (2006), we aimed for high sensitivity where the search was sufficiently rigorous and broad for most eligible studies to be identified for inclusion in this review. Thus, our search included the following combination of keywords in Spanish: “species richness” (“riqueza de especies” in Spanish) AND birds (aves) AND city (ciudad) AND (Chile OR Argentina OR Uruguay). The word birds (aves) was considered in the title. Titles and abstracts identified in the search were scrutinized and the entire article was retrieved when studies were likely to fulfill the following inclusion criteria: (1) it reported empirical data on bird species richness, (2) was located in cities from the Southern Cone (i.e. Argentina, Chile, Uruguay), and (3) was written in Spanish. For all papers that met the inclusion criteria, references cited in them were considered to add new documents that were not detected with our search criteria. To further complement the review, we assessed the table of contents of six scientific journals from the three countries that were likely to publish studies on bird species richness in cities. The journals considered were: Revista Chilena de Historia Natural, Revista Chilena de Ornitología, Acta Zoológica Lilloana, Ornitología Neotropical, Revista Achará and Anales del Museo de Historia Natural de Montevideo.

Data extraction and synthesis

We performed a qualitative synthesis and assessment, following the method of other synthesis in urban biodiversity research (e.g. McKinney 2002; Farinha-Marques et al. 2011; Nielsen et al. 2014). For each article that met our inclusion criteria, we extracted information that allowed us to evaluate:

1. Publication trends and geographical patterns: we extracted the year of publication, publication type (e.g. book chapter, journal article, thesis, technical report, conference proceeding; if published in a journal we extracted the journal name), country and city where the investigation took place. To identify the distribution per biome, we located cities on a digital layer (shapefile) of the world’s terrestrial biomes (Albers 2019), and calculated the number of studies per biome. In addition, to see the representation of cities, we calculated the proportion of cities with studies from the total number of provincial capital cities per biome.

2. Study design: we extracted study extent (in years), sampling season, and the land use types where sampling took place. Regarding the land use type, we consider the terminology used in the studies, except for “green area” (land covered by vegetation) that we further separated into: large urban parks (> 2 ha), small parks (< 2 ha), botanical garden, island hills (i.e. hills covered by vegetation that are commonly surrounded by built areas) and vacant lots.

3. Bird species origin: we recorded the origin of bird species included in estimates of species richness (i.e. native, exotic or both). For this, we searched in methods and results whether they calculated species richness separately for native and exotic species or pooled together data independent of species origin. When origin was not declared by the authors, we examined the bird species recorded. This data allowed us to evaluate whether researchers were considering species origin. Since exotic species commonly increase with urbanization, replacing native bird species (McKinney 2008), this is an important factor to consider when aiming to improve the quality of urban lands for local fauna.

4. Effects of predictive variables on species richness: we recorded the independent variables studied and their effects on (or associations with) bird species richness. The effect of independent variables on species richness was classified as positive when a positive coefficient was statistically significant ($P < 0.05$), negative when a negative coefficient was statistically significant ($P < 0.05$), and neutral when no statistical difference was found ($P \geq 0.05$).

Results

We found 497 documents in our search in Google Scholar. Four of these were duplicated records. From the list of references and the targeted search on the table of contents of local journals, another 27 documents were included that were not detected in our original search. After reading the title and abstract of the 520 records, 213 entire documents were assessed. Of these, 37 studies met our inclusion criteria and were considered in our qualitative synthesis (Fig. 1). The other 176 documents were excluded because they did not meet our inclusion criteria: 115 studies did not present empirical data on species richness, 45 were not developed in a city and 16 did not take place in the Southern Cone.

Publication trends and geographical patterns

Among the 37 documents that met our inclusion criteria, only two studies (5% of total) were published between 1980 and 1999, whereas 20 studies (54%) were published between
2000–2009, and 15 studies (41%) were published between 2010–2019 (Fig. 2A). No studies were found in 2020. Most studies (76%) were published in scientific journals, followed by book chapters (11%) and theses (8%. Fig. 2B). Among journals, more studies were published in The Chilean Ornithological Bulletin (25% of total, Boletín Chileno de Ornitología that since 2016 is published under the name of Revista Chilena de Ornitología), followed by El Hornero (18%, published by the Argentinian Birds/La Plata Ornithological Association), and Acta Zoológica Lilloana (18%, published by Fundación Miguel Lillo, also from Argentina, Fig. 2C).

Twenty studies (54% of total) were conducted in Argentina, 15 (41%) in Chile, and two (5%) in Uruguay. They comprised 18 cities, with more studies conducted in the capital cities of Chile (Santiago, seven studies, 19%) and Argentina (Buenos Aires, six studies, 16%, Fig. 3A). All studies comprised a single city, except for two, which included two and three different cities (Díaz et al. 2018; Leveau and Leveau 2006; respectively; Table 1).

Regarding the biomes, 58% of cities studied were in forests and 42% in grasslands (Fig. 3B). No study was found in cities located in montane grasslands and shrublands, nor in desert nor xeric shrublands. Half of studies (50%) were in temperate zones. More studies were performed in temperate grasslands, savannas and shrublands (32%), followed by Mediterranean forests, woodlands and scrub (24%), and temperate broadleaf and mixed forests (18%, Fig. 4A). All biomes the Southern Cone contain cities where research on bird species richness has not yet been conducted. The montane grasslands and shrublands biome contains a single provincial capital city (Putre, Chile), where no study on bird species richness was found (Fig. 4B).

**Study design**

Most studies (25 studies, 68%) were performed in only one year or less, whereas only four studies (11%) comprised surveys longer than two years (Fig. 5A). Sampling was conducted in spring-summer season in 41% of the studies, 16% sampled in autumn-winter season, while 35% included the four seasons (Fig. 5B).

Most studies (60%) focused in one land use type, with green areas being the most frequent (35% of studies focused only in these areas). They were followed by sampling in two land use types (28%) and along an urban gradient (11%, Fig. 5C). Among the studies that surveyed green areas, the most common were large urban parks, followed by small parks and hills. In addition, there was only one study that included vacant lots and another that included a botanical garden (Fig. 5D).

**Bird species origin**

To calculate bird species richness, both native and exotic birds were pooled together in 78% of the studies. Four studies (11%) analyzed species richness for native birds, whereas only three studies (8%) analyzed the species richness of native and exotic birds separately. All studies recorded more species of
native than exotic birds. For instance, Echevarría et al. (2011) recorded 70 native species and two exotic species in Tucumán, Argentina; Chiang (2019) recorded 25 native species and five exotic species in Santiago, Chile; whereas Perepelizin and Faggi (2009) recorded 20 native species and four exotic species in Buenos Aires, Argentina; Fig. 6A).

**Effect of predictive variables on species richness**

Twenty studies evaluated relationships between bird species richness and independent variables. Nearly half studies (55%) investigated environmental variables: ten studies assessed vegetation variables and eight studied land use types (Fig. 6B). Other variables considered were bird attributes (e.g. home range, biological traits, feeding, resting and nesting substrate), season and human-related variables (e.g. vehicle traffic, transit of people, population density and knowledge of birds). Ten studies conducted statistical analyses to evaluate the effect of independent variables on species richness, where we obtained 27 relationships (with reported P-values; Table 2). Most studies found vegetation cover to have a positive influence on bird species richness (e.g. percent cover of different vegetation layers, Normalized Difference Vegetation Index [NDVI]), plant diversity (e.g. diversity of trees and native plants) and habitat diversity (diversity of land cover types; Fig. 6C). In contrast, urban cover (e.g. percent cover of built-up, pavement and residential areas) and urban disturbance (e.g. human and vehicle traffic), exhibited mostly negative effects on bird species richness (Fig. 6C).
Discussion

Publication trends and geographical patterns

In contrast to previous reviews on bird species richness that found no studies from the Southern Cone of South America (e.g. Marzluff et al. 2001; Aronson et al. 2014; Nielsen et al. 2014), we found 37 studies that investigated bird species richness in cities. This difference is undoubtedly due to differences in the language selected (Spanish) and the search criteria used (e.g. the inclusion of grey literature). In fact, literature reviews for Latin America have reported an important increase in the number of studies when they considered documents in Spanish language and grey literature (González-Urrutia 2009; Delgado-Velez and Correa-Hernandez 2013). This finding highlights that local evidence from the Southern Cone has been left out of global reviews, which might lead to important gaps in the global understanding of urban avian ecology.

Only two studies were published before 2000, which is consistent with the time-lag in the development of urban
ecological research in Latin American countries (Ortega-Álvarez and MacGregor-Fors 2011b). Although the number of articles increased in 2000-2009 period, they dropped in the last decade (2010-2019). Ortega-Álvarez and MacGregor-Fors (2011b) found an important increase in publications written in English from Latin American countries since 2005, which might explain the decline of publications in the local language during the last decade. The decline of studies published in Spanish language might be due to growing interest and academic pressures for publishing in international peer-reviewed journals. Academics are commonly assessed by their publications in high-impact international journals because they are perceived to be of greater quality, reach a broader audience, and can lead to networks with international scientists (Guzmán-Valenzuela and Gómez 2019). If publications in international journals continue growing at the expense of publications in Spanish language in local journals, the science-policy gap is likely to increase over time in Latin America. This is because studies that are relevant for local policy and practice commonly need to be written in the local language and published in local

Table 1  Summary table of the 37 publications included in qualitative synthesis (references can be found in Appendix)

| Author         | Year | Country       | City               | Biome                                                   |
|----------------|------|---------------|--------------------|---------------------------------------------------------|
| Feninger       | 1983 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Rossetti and Giraudo | 2003 | Argentina     | Santa Fé           | Flooded grasslands and savannas                         |
| Leveau and Leveau | 2004 | Argentina     | Mar del Plata      | Temperate grasslands, savannas and shrublands           |
| Juri and Chani  | 2005 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Faggi and Perepelizin | 2006 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Gómez          | 2006 | Argentina     | Mendoza            | Temperate grasslands, savannas and shrublands           |
| Krauczek       | 2006 | Argentina     | Posadas            | Flooded grasslands and savannas                         |
| Leveau and Leveau | 2006 | Argentina     | Mar del Plata, Necocoea y Miramar | Temperate grasslands, savannas and shrublands |
| Germain et al. | 2008 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Fernández et al. | 2009 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Juri and Chani  | 2009 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Maraglio et al. | 2009 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Perepelizin and Faggi | 2009 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Haedo et al.   | 2010 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Echevarría et al. | 2011 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Cavicchia and García | 2012 | Argentina     | Buenos Aires       | Temperate grasslands, savannas and shrublands           |
| Leveau         | 2013 | Argentina     | Mar del Plata       | Temperate grasslands, savannas and shrublands           |
| Navarro and Antelo | 2014 | Argentina     | San Miguel de Tucumán | Tropical moist broadleaf forests                        |
| Ramírez et al. | 2016 | Argentina     | Luján              | Temperate grasslands, savannas and shrublands           |
| Figini         | 2019 | Argentina     | Mendoza            | Temperate grasslands, savannas and shrublands           |
| Estades        | 1995 | Chile         | Santiago           | Mediterranean forests, woodlands and scrub              |
| Urquiza and Mella | 2002 | Chile         | Santiago           | Mediterranean forests, woodlands and scrub              |
| Díaz and Armesto | 2003 | Chile         | Santiago           | Mediterranean Forests, Woodlands and Scrub              |
| Hinojosa-Sáez et al. | 2007 | Chile         | Concepción         | Temperate broadleaf and mixed forests                   |
| Mella and Loutit | 2007 | Chile         | Santiago           | Mediterranean forests, woodlands and scrub              |
| Cursach and Rau | 2008 | Chile         | Osorno             | Temperate broadleaf and mixed forests                   |
| Cursach and Rau | 2008 | Chile         | Puerto Montt       | Temperate broadleaf and mixed forests                   |
| Kusch et al.   | 2008 | Chile         | Punta Arenas       | Temperate broadleaf and mixed forests                   |
| Soto           | 2014 | Chile         | Concepción         | Temperate broadleaf and mixed forests                   |
| Rodríguez et al. | 2016 | Chile         | Coquimbo           | Mediterranean forests, woodlands and scrub              |
| Chávez-Villavicencio | 2018 | Chile         | Coquimbo           | Mediterranean forests, woodlands and scrub              |
| Díaz et al.    | 2018 | Chile         | Valdivia y Santiago | Temperate broadleaf and mixed forests; and Mediterranean forests, woodlands and scrub |
| Gallaedo et al. | 2018 | Chile         | Llanquihue         | Temperate broadleaf and mixed forests                   |
| Muñoz et al.   | 2018 | Chile         | Santiago           | Mediterranean forests, woodlands and scrub              |
| Chiang         | 2019 | Chile         | Santiago           | Mediterranean forests, woodlands and scrub              |
| Seguí and Caballero-Sadi | 2013 | Uruguay       | Montevideo         | Tropical grasslands, savannas and shrublands           |
| Sarroca et al. | 2006 | Uruguay       | Montevideo         | Tropical grasslands, savannas and shrublands           |
journals or reports (Guzmán-Valenzuela and Gómez 2019). Therefore, it is important that scientists remain engaged and interested in providing evidence that is locally relevant and available.

Our findings show that most studies were published in locally-based academic journals, where those led by the Ornithological Associations of Chile (*Boletín/Revista Chilena de Ornitología*) and Argentina (*El Hornero*) are important for disseminating knowledge that is accessible to managers, planners, policy makers and citizens – at least the work is available in the national language, free of charge (open-access). Of course, availability and access to empirical evidence is only one step towards informed policy and practice. Transdisciplinary groups and participatory
decision-making where actors from different sectors engage and collaborate, including scientists, planners, politicians and the local community, are needed to allow to progress towards sustainable cities (e.g. Menegat 2002). By bridging the gap between policy/practice and science, local decisions can be informed so that they promote biodiversity conservation and sustainable urban development.

Chile and Argentina contributed with a similar number of publications. This result disagrees with findings from previous reviews focused on urban birds in Latin America, where the number of publications from Argentina commonly outpaces the number of publications from Chile. This has been recorded in many topics, such as bird community diversity, composition and spatial distribution (seven-fold larger in

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**Fig. 5** A. Number of studies according to sampling length (in years). B. Number of studies by sampling season. C. Number of studies according to the environment surveyed. D. Number of publications according to the type of green area sampled.
Argentina than in Chile; Ortega-Álvarez and MacGregor-Fors 2011a), bird studies in general (five-fold; Ortega-Álvarez and MacGregor-Fors 2011b), bird species richness and composition (two-fold; MacGregor-Fors and García-Arroyo 2017b), as well as bird demography and population dynamics (two-fold; Leveau and Zuria 2017). The difference between our findings and previous reviews can be explained by the late development of the discipline of urban ecology in Chile. In fact, only recently urban bird studies from Chile are being published in international journals (e.g. Silva et al. 2015; Celis-Diez et al. 2017; Muñoz-Pedreros et al. 2018; Amaya-Espinell et al. 2019; Villaseñor and Escobar 2019; Villaseñor et al. 2020).

Avian ecological research in Latin America focuses on large cities (Escobar-Ibáñez and MacGregor-Fors 2017). Our review evidences that almost half of bird studies from the Southern Cone of South America focused on national capitals: Santiago de Chile (more than 7 million inhabitants), Buenos Aires (more than 17 million inhabitants) and Montevideo (more than 1 million inhabitants). These cities are characterized by unplanned urban growth that followed a Spanish design (Grau and Foguet 2021). Although it is important to generate scientific evidence in national capital cities, it is also relevant to study medium size and small cities, which are expected to concentrate an important part of future urban growth that is likely to be rapid and unplanned (e.g. Merlott et al. 2012; Barton et al. 2013). Scientific evidence can contribute to planning for a sustainable urban growth by helping to implement intentional early conservation actions, such as
limiting land use change, promoting green space within the city, as well as identifying focal conservation areas (Ortega-Álvarez and MacGregor-Fors 2009; Ikin et al. 2015).

The Southern Cone’s cities provide an excellent opportunity to better understand biodiversity responses to urbanization in a variety of climates and geological conditions. However, the focus on a few large cities has led to a gap of knowledge on different biomes. Most research on bird species richness in cities from the Southern Cone of South America has been conducted in temperate grasslands and Mediterranean forests, woodlands and scrub. Global analyses on urban birds have found that studies in temperate regions dominate the literature, with lack of research from tropical forests (Chace and Walsh 2006), where human population will experience an important growth (McDonald et al. 2013).

That we found no studies in desert and xeric shrublands or montane grasslands and shrublands represents an important knowledge gap. Chile contains the Atacama Desert, the driest desert in the world. Few ecological studies have been performed in deserts and xeric shrublands because they present low productivity and low species richness, although they harbor species adapted to such dry conditions that can enrich our understanding on how urbanization influence these ecosystems. Putre is in the montane grasslands and shrublands biome, at 3,500 m.a.s.l., where despite the proximity to the desert, there are diverse plant and animal communities. Tropical Andes is an area highlighted for global conservation efforts (Myers et al. 2000) and where knowledge is needed to inform sustainable development. Although some biomes exhibited a greater number of studies, they are still very few compared to the large number of provincial capitals they contain. For instance, no studies were found in 93% of provincial capitals in Mediterranean forests, woodlands and scrub, a biome that presents high endemism, has lost about 70% of its natural vegetation (Myers et al. 2000) and concentrates most cities and human population of Chile. No studies were found in 96% of provincial capitals located in tropical grasslands, savannas and shrublands, including areas of high value for birds, such as the extensive grasslands in Uruguay and Argentina that sustain the largest bird species

| Predictive variables type | Response variable | Predictive variable | Effect | p-value | Reference |
|--------------------------|-------------------|--------------------|--------|---------|-----------|
| Vegetation cover         | Diversity index*  | Tree cover         | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Vegetation cover         | Diversity index*  | Green areas surrounding area | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Vegetation cover         | Richness of birds | Percentage of vegetation | Positive < 0.005 | Mella and Loutit (2007) |
| Vegetation cover         | Richness of birds | Park size          | Positive < 0.05 | Muñoz-Pedreros et al. (2018) |
| Vegetation cover         | Richness of birds | Park area          | Positive < 0.05 | Urquiza and Mella (2002) |
| Vegetation cover         | Richness of birds | Native vegetation (%) | Positive < 0.05 | Urquiza and Mella (2002) |
| Vegetation cover         | Richness of birds | Trees and shrubs (%) | Positive < 0.001 | Leveau and Leveau (2004) |
| Vegetation cover         | Richness of birds | Grass (%)          | Positive < 0.001 | Leveau and Leveau (2004) |
| Vegetation cover         | Richness of birds | NDVIr              | Positive < 0.01 | Haedo et al. (2010) |
| Vegetation cover         | Richness of birds | Tree and shrub cover | Positive < 0.001 | Leveau (2013) |
| Vegetation cover         | Richness of birds | Herbaceous cover    | Neutral > 0.05 | Chiang (2019) |
| Plant diversity          | Diversity index*  | Tree Biodiversity Index | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Plant diversity          | Diversity index*  | Native plant biodiversity index | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Plant diversity          | Diversity index** | Plant structure diversity | Positive < 0.05 | Estades (1995) |
| Plant diversity          | Diversity index** | Diversity of plant species | Positive < 0.05 | Estades (1995) |
| Plant diversity          | Richness of birds | Richness native vegetation | Positive < 0.04 | Chiang (2019) |
| Habitat richness         | Diversity index*  | Diversity of habitats in green space | Positive < 0.05 | Faggi and Perepelizin (2006) |
| Bare ground              | Richness of birds | Bare ground cover   | Neutral > 0.06 | Chiang (2019) |
| Urban coverage           | Diversity index*  | Residential use in surrounding area (%) | Negative < 0.05 | Faggi and Perepelizin (2006) |
| Urban coverage           | Diversity index*  | Industrial use in surrounding area | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Urban coverage           | Diversity index*  | Services use in surrounding area | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Urban coverage           | Richness of birds | Buildings (%)       | Negative < 0.001 | Leveau and Leveau (2004) |
| Urban coverage           | Richness of birds | Asphalt (%)         | Negative < 0.001 | Leveau and Leveau (2004) |
| Disturbance              | Diversity index*  | Use of roads in surrounding area | Neutral > 0.05 | Faggi and Perepelizin (2006) |
| Disturbance              | Richness of birds | Automobile traffic (cars/minute) | Negative < 0.01 | Germain et al. (2008) |
| Disturbance              | Richness of birds | Pedestrian circulation (people/minute) | Negative < 0.01 | Germain et al. (2008) |

*Diversity index (bird richness/logarithm of the park area); **Shannon-Weaver diversity index (H)*
diversity in the region (Hoekstra et al. 2010) and contain Important Bird Areas (IBAs; Di Giacomo and Krapovickas 2005). This highlights an important gap in our understanding of urban avian ecology in the region.

**Study design**

Short-term research dominated the literature. The study with the longest duration (six years of surveys, conducted over a decade) examined bird community changes in an urban wetland associated with anthropogenic disturbance (Kusch et al. 2008). It is essential to promote this type of long-term studies in the region to understand the factors driving population, community and ecosystem change, and identifying the actions needed to prevent species extinctions and rescue ecosystems from extinction cascades (Gaiser et al. 2020).

Most urban avian research was conducted in one season (reproductive), providing limited information on seasonal changes and evidence for conservation strategies for a variety of birds (e.g. migratory birds). Studies that evaluated both reproductive and non-reproductive seasons reported changes in species richness of Neotropical birds through the year due to seasonal movements (migrations), as well as cities providing a wintering refuge (e.g. Fernández et al. 2009; Villaseñor and Escobar 2019). Identifying seasonal changes in species richness, as well as changes in community composition, will allow a better understanding of bird interactions and how the urban land is used through the year.

Green areas were the preferred environment to conduct research. This pattern has been reported by authors from Latin America (MacGregor-Fors and García-Arroyo 2017b) and the world (Chamberlain et al. 2009; Nielsen et al. 2014; Beninde et al. 2015). Although, a recent literature review on avian abundance reported a greater number of studies in the wider urban matrix (Leveau and Zuria 2017). Urban parks represent large green areas that support a high variety of birds, allowing researchers to record a greater number of species than built-up areas, which are commonly dominated by a few exotic species (e.g. Díaz and Armesto 2003; Villaseñor et al. 2020). Informal green areas have received limited attention, with only one study reporting greater species richness in vacant lands than in urban parks and residential areas in Santiago de Chile (Chiang 2019). Vacant lands are important to maintain birds in the city (Villaseñor et al. 2020; Zuñiga-Palacios et al. 2020), can support different animals, provide ecosystem services, connect humans with nature and contribute to human health and wellbeing (Riley et al. 2018).

**Bird species origin**

Most studies pooled together native and exotic birds to estimate bird species richness. Few studies separated species by their origin. This deficit can lead to a poor understanding on bird community changes in urban ecosystems. By studying avian responses of native and exotic birds separately researchers can, for example, identify key elements to control exotic species and improve habitat conditions for native birds (Garaffa et al. 2009; Benito et al. 2019).

Given that exotic species commonly rise with increasing urbanization, if researchers only consider total species richness or abundance, exotic species might mask the loss of native species (Van Heezik et al. 2008; Silva et al. 2015). Although, the number of exotic species is lower than the number of native species in cities from the Southern Cone, exotic species commonly dominate the built environment. Thus, the effect of exotic species is likely to be stronger on total bird abundance and species diversity indices than on species richness (Perepelizin and Faggi 2009; Benito et al. 2019; Villaseñor et al. 2020).

Among the pool of studies reviewed, three of them were particularly notable. Regarding species origin, Díaz and Armesto (2003) found that endemic species were more affected by urban development than other native birds. Chiang (2019) found that informal green spaces, which are commonly overlooked in urban ecological research, provided an important habitat for native birds. Echevarría et al. (2011) surveyed birds in the botanical garden of Miguel Lillo Foundation in the city of San Miguel de Tucumán, Argentina. Although it is a small botanical garden (less than 1 ha in size), it presents greater bird species richness than large city parks because of its high structural and compositional diversity of native plants, which contributes to preserving native birds.

**Effect of predictive variables on species richness**

The effect of predictive variables on bird species richness in the Southern Cone agrees with general patterns that have emerged from other continents, providing support for the development of a unified theory. Vegetation cover and plant diversity exhibited mostly positive effects on bird species richness (Estades 1995; Urquiza and Mella 2002; Leveau and Leveau 2004). Vegetation cover and diversity benefit a variety of bird species, as it provides feeding, resting and nesting sites (Chace and Walsh 2006; Evans et al. 2009; Leveau 2013; Nielsen et al. 2014; Beninde et al. 2015; Huang et al. 2015). A few studies did not find significant effects of vegetation nor plant diversity on species richness. Faggi and Perepelizin (2006) considered species richness of terrestrial and aquatic birds (pooled together). In that case, bird species richness was more related to water bodies than vegetation. In addition, not all vegetation variables were found to be relevant, such as in Chiang (2019) where native plants had a significant effect on bird species richness, but did not find a similar effect from plant cover. Urban cover, such as built-up area and impervious surfaces, as well as human-disturbance, such as vehicle traffic,
exhibited mainly negative effects on bird species richness (Germain et al. 2008). This might be due to habitat loss and the dominance of exotic species such as *Passer domesticus* and *Columba livia* in urban land (Leveau and Leveau 2004; Germain et al. 2008). These findings are consistent with other literature reviews (e.g. Marzluff et al. 2001; Chace and Walsh 2006; MacGregor-Fors and García-Arroyo 2017b).

The relationship between bird species richness and environmental variables was commonly explored, but no study considered biological interactions, spatial variables (except one), nor socio-economics. Biological interactions (e.g. predation, pollination, competition) and spatial variables (e.g. distance to the urban limit, spatial aggregation of trees) can influence bird species richness (Natuhara and Imai 1999; Silva et al. 2015; Morelli et al. 2015; Villaseñor et al. 2021). South America is characterized by large social, economic and environmental inequities; thus, it is important to investigate how socio-economics influence urban biodiversity. Urban ecology must be considered as an interdisciplinary field that not only considers biological and environmental components, but rather where natural and social science connect (McIntyre et al. 2008). The latest urban ecology paradigm of “ecology for the city” encourages ecologists to work for a sustainable urban future with a variety of specialists from different backgrounds, as well as with urban dwellers, aiming for environmental integrity, social equity and economic viability (Pickett et al. 2016).

**Future research**

Our review evidences clear knowledge gaps that need to be addressed. Urgently needed research in the Southern Cone of South America includes studies performed in: (1) cities in biomes such as deserts and xeric shrublands, montane grasslands and shrublands, as well as tropical grasslands, savannas and shrublands, and Mediterranean forests, woodlands and scrub; (2) small and medium size cities, especially those that are experiencing rapid and unplanned urban growth; (3) long-term research with seasonality; (4) including green spaces other than urban parks; (5) incorporating spatial, biological interactions and interdisciplinary studies that consider environmental, social and economic components of urban ecosystems.

A problem for the future that we detected from our review is the decline in studies published in the local language, because this is likely to increase the science-policy gap over time. Language barriers faced by Latin American scientists have limited their contribution in international journals, where scientists often declare facing difficulties in English writing, dissatisfaction and anxiety (Hanauer et al. 2019). However, this barrier might be lowering due to greater access to English education, training of scientists overseas and increasing international collaborations (Rodrigues et al. 2016). To ensure scientific evidence is available to local managers, urban planners, policy makers, and local communities, it is important to disseminate findings in the local language. Scientists can contribute by summarizing or synthesizing a compilation of findings from different studies to be published in local journals or magazines, writing books or book chapters, supervising thesis and making them publicly available, as well as contributing to participatory planning and management. Universities should play a leading role, not only in generating local evidence, but also in disseminating the knowledge produced (Martínez 2021), a variable that could be considered when measuring the performance of academics. In our review, open-access journals led by Ornithological Associations of Chile and Argentina have contributed to disseminating knowledge locally and should continue being a platform for urban ecological research. In addition, the development of new mechanisms to inform policy and practice, by promoting transdisciplinary research and participatory decision-making processes will aid sustainable development (Dávalos and Romo-Pérez 2017).

Urban ecology can provide data, principles, concepts, and tools to create livable and sustainable cities (Chace and Walsh 2006). Therefore, it is necessary continue to strengthen our knowledge on the factors influencing biodiversity and implement strategies to better inform management, planning and new public policies for sustainable and biodiverse cities.

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