

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

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Research Article

Keywords: Argentina, birds, Chile, species richness, urban parks, Uruguay.

DOI: <https://doi.org/10.21203/rs.3.rs-157419/v1>

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Abstract

South America sustains an important part of the world's terrestrial biodiversity and presents a high urbanization level. Global syntheses have revealed a paucity of urban ecological research in this region; however, local research might be overlooked due to language barriers. To contribute to disseminate local knowledge, we synthesized the 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 biomes. In this systematic review, we identified patterns and trends in the literature, and the variables that influence bird species richness. Most research was performed in large cities, focused on green areas (large urban parks), short-termed (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 study was 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 of knowledge include research in small and medium size cities, in overlooked biomes (deserts, xeric shrublands, montane grasslands and shrublands), long-term research, comprising different seasons, including green space 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.

Introduction

The field of urban ecology 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 y Western Europe; Magle et al. 2012; Escobar-Ibáñez & MacGregor-Fors 2017). However, the main future urban growth will occur in Latin America, Africa and Asia (United Nations 2019). The paucity of urban ecological research in these continents has led to an important knowledge gap that limits sustainable urban development (Ortega-Álvarez & MacGregor-Fors 2011a; Magle et al. 2012).

Latin America is one of the most urbanized regions in the world. In the last 70 years, human urban population exhibited ca. 8-fold increase (United Nations 2019). Currently, about 80% of the human population live in urban areas, and human population in large cities is expected to further increase a 15% by 2030 (United Nations 2015). Urbanization has dramatically transformed landscapes, creating ecosystems that are dominated by impervious surfaces (Garaffa et al. 2009). This leads to the loss and fragmentation of habitats for different species that cannot cope with the rapid change of land (Grimm et al. 2008). Given the rapid decline of global biodiversity, it is important to promote urban ecological research to provide evidence-based knowledge and help conserve biodiversity under increasing urbanization.

Encouraging urban ecological research in South America will help preserve its large natural capital. This region contains more than 40% of the Earth's biodiversity, including 70% percent of vertebrate species in the world, and more than 25% of forests (UNDP 2010). It contains 70% of global terrestrial ecoregions and biomes, comprising a large variety of the world's plants and animals (Olson et al. 2001). In addition, the region presents five of 35 biodiversity hotspots where conservation actions should be prioritized as they contain high endemism in plants and animals but lost more than 70% of the original vegetation (Mittermeier et al. 2011).

The Southern Cone of South America is characterized by endemic species and evolutionary novelties (Ibarguchi 2014). It comprises 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 environments with the greatest species diversity in South America (the Paranaense jungle, the Yungas and the Chaco) (SAyDS 2015). In Uruguay, 35% of the species have been declared a priority species, with several populations facing a high level of threat (MVOTMA, 2014). The region not only presents many endemic birds, mammals and reptiles, but also maintains several species threatened with extinction. For instance, 38 threatened animal species inhabit in the Patagonian Steppe and 40 threatened animal species inhabit in the Valdivian temperate forests (Hoekstra et al. 2010). In addition, this region can contribute to a better understanding on biodiversity responses to urbanization in different climates and geological conditions because it presents more than half of world's terrestrial biomes (eight of 15 biomes, Henwood 1998).

Previous syntheses of urban ecological research have found either no studies or a few studies from Chile and Uruguay, whereas Argentina contributes with an important proportion of studies from Latin America (Ortega-Álvarez & MacGregor-Fors 2011a; Beninde et al. 2015; Escobar-Ibáñez & 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), and it 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 ISI-indexed journals in the field of ecology and zoology (Neira et al. 2011). In addition, people from countries where the official language is other than 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 y 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). They are diverse, form complex communities, respond to changes in habitat conditions, and can be used as bioindicators (MacGregor-Fors & Escobar-Ibáñez 2017, Chace & Walsh 2006).

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 designs, (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 their global impact.

Methods

Search strategy

We searched for relevant papers on Google Scholar (<https://www.scholar.google.com>), with help of publish or perish software (Harzing 2010). We used Google Scholar because it contains papers from any language and contains a larger number of documents in Spanish than other search engines (e.g. Web of Science or Scopus). 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 and reports) (Falagas et al. 2008). We included grey literature because it represents a large body of knowledge that it is recommended to be considered in systematic reviews (Manterola et al. 2013). Grey literature also reduces publication bias because non-concluding 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. Thus, our search included the following combination of keywords in Spanish: “species richness” AND birds AND city AND (Chile OR Argentina OR Uruguay). The word birds (*aves* in Spanish) was considered in the title. Titles and abstracts identified in the search were scrutinized and the entire article was retrieved when likely to fulfil 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 or Uruguay), and (3) was written in Spanish. For all papers that met the inclusion criteria, the list of references was read searching for new relevant documents (not found by the search engine).

Data extraction and synthesis

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 the study was published, publication type (if published in a scientific journal we extracted the journal name), country and city where the investigation took place. To identify the biomes that have received more and less attention, we located cities on a digital layer (shapefile) of the world's terrestrial biomes (Albers 2019), and calculated the number of cities with and without studies per biome.

(2) Study designs: we extracted study extent (in years), season when sampling was performed, and the environments or land use types where sampling took place.

(3) Bird species richness: we recorded the origin of the species included in analyses of species richness (i.e. native, exotic and both).

(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 (3) neutral when no statistical differences was found ($P > 0.05$).

We performed a qualitative synthesis and assessment, following synthesis in urban biodiversity research (e.g. McKinney 2002; Farinha-Marques et al. 2011, Nielsen et al. 2014).

Results

We found 497 documents in our search in Google Scholar. Four of these were duplicated records. From the list of references, another 20 documents were included that were not detected in our original search. After reading the title and abstract of the 513 records, 206 entire documents were assessed. Of these, 30 studies met our inclusion criteria and were included 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 articles were not in a city (nor town), and 16 did not take place in the Southern Cone.

Publication trends and geographical patterns

Among the 30 documents that met our inclusion criteria, only two studies (7% of total) were published between 1980 and 1999, whereas 16 studies (50%) were published between 2000–2009, and 12 studies (40%) were published between 2010–2019 (Fig. 2A). No studies were found in 2020. Most studies (70%) were published in scientific journals, followed by book Chaps. (10%) and theses (10%, Fig. 2B). Among journals, most studies were published in The Chilean Bulletin of Ornithology (27% 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, Fig. 2C).

Fifteen studies (50% of total) were conducted in Argentina, 14 (47%) in Chile, and one (3%) in Uruguay. They comprised 14 cities, with most of the studies being conducted in the capital city of Chile (Santiago, 7 studies, 23%) and Argentina (Buenos Aires, 6 studies, 20%) (Fig. 3A). All studies comprised a single city, except for one that included two different cities (Díaz et al. 2018 in Table 1).

Table 1

Summary table of the 30 publications included in qualitative synthesis (references can be found in Appendix).

Author	Country	City	Biome
Faggi & Perepelizin, 2006	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Perepelizin & Faggi, 2009	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Díaz & Armesto, 2003	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub
Cursach & Rau, 2008a	Chile	Puerto Montt	Temperate Broadleaf and Mixed Forests
Cavicchia & García, 2012	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Juri & Chani, 2009	Argentina	San Miguel de Tucumán	Tropical Moist Broadleaf Forests
Mella & Loutit, 2007	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub
Soto, 2014	Chile	Concepción	Temperate Broadleaf and Mixed Forests
Krauczuk, 2006	Argentina	Posadas	Flooded Grasslands and Savannas
Muñoz et al. 2018	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub
Figini, 2019	Argentina	Mendoza	Temperate Grasslands, Savannas and Shrublands
Chávez-Villavicencio, 2018	Chile	Coquimbo	Mediterranean Forests, Woodlands and Scrub
Rodríguez et al. 2016	Chile	Coquimbo	Mediterranean Forests, Woodlands and Scrub
Estades, 1995	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub
Urquiza & Mella, 2002	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub
Feninger, 1983	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Leveau & Leveau, 2004	Argentina	Mar del Plata	Temperate Grasslands, Savannas and Shrublands
Díaz et al. 2018	Chile	Valdivia and Santiago	Temperate Broadleaf and Mixed Forests; and Mediterranean Forests, Woodlands and Scrub

Author	Country	City	Biome
Cursach & Rau, 2008b	Chile	Osorno	Temperate Broadleaf and Mixed Forests
Hinojosa-Sáez et al. 2007	Chile	Concepción	Temperate Broadleaf and Mixed Forests
Juri & Chani, 2005	Argentina	San Miguel de Tucumán	Tropical Moist Broadleaf Forests
Kusch et al. 2008	Chile	Punta Arenas	Temperate Broadleaf and Mixed Forests
Fernández et al. 2009	Argentina	San Miguel de Tucumán	Tropical Moist Broadleaf Forests
Leveau & Leveau, 2006	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Germain et al. 2008	Argentina	Buenos Aires	Temperate Grasslands, Savannas and Shrublands
Haedo et al. 2010	Argentina	San Miguel de Tucumán	Tropical Moist Broadleaf Forests
Seguí & Caballero-Sadi, 2013	Uruguay	Montevideo	Tropical Grasslands, Savannas and Shrublands
Leveau, 2012	Argentina	Mar del Plata	Temperate Grasslands, Savannas and Shrublands
Ramírez et al. 2016	Argentina	Luján	Temperate Grasslands, Savannas and Shrublands
Chiang, 2019	Chile	Santiago	Mediterranean Forests, Woodlands and Scrub

Regarding the biomes, 57% of cities studied were in forests and 43% in grasslands (Fig. 3B). No study was found in cities located in montane grasslands and shrublands neither in desert and xeric shrublands. Most studies (51%) were in temperate zones. Most studies were performed in “Temperate Grasslands, Savannas and Shrublands” (32%), “Mediterranean Forests, Woodlands and Scrub” (29%) and “Temperate Broadleaf and Mixed Forests” (19%) (Fig. 4A). All biomes found in the Southern Cone present several cities where research on bird species richness have not been conducted. Only the biome “Montane Grasslands and Shrublands” contains a single city (Putre, Chile), where no study on bird species richness was found (Fig. 4B).

Study design

Regarding the temporal length, 22 studies (71%) were performed in a year or less, whereas only two studies (6%) comprised surveys longer than two years (Fig. 5A). Sampling was conducted in spring-

summer season in 52% of the studies, 16% was performed in autumn-winter season, and 26% included four seasons (Fig. 5B).

Most studies (58%) focused only in one environment, where green areas were the most frequent (39% of studies focused only in these areas). They were followed by sampling in two environments (29%) and along an urban gradient (13%) (Fig. 5C). Among the studies that surveyed green areas, the most common were large urban parks, followed by small parks, hills and only one study in vacant lands (Fig. 5D).

Bird species richness

To calculate bird species richness, both native and exotic birds were pulled together in 77% of the studies. Four studies (13%) analyzed species richness for native birds only; whereas only two studies (7%) analyzed bird species richness of native and exotic birds separately (Perepelizin & Faggi, 2009; Chiang, 2019; Fig. 6A).

Effect of predictive variables on species richness

Twenty studies evaluated relationships between bird species richness and independent variables. Most studies (52%) investigated environmental variables: 10 studies included vegetation variables and 8 included land use (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 on birds), but socioeconomics has not been investigated. Ten studies conducted statistical analyses to evaluate the effect of independent variables on species richness, where we obtained 27 relationships (presented *P*-values). Most studies found a positive influence on bird species richness of vegetation cover (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.

Discussion

Publication trends and geographical patterns

In contrast to reviews on bird species richness that commonly report a null contribution of studies from the Southern Cone of South America (e.g. Marzluff et al. 2001; Aronson et al. 2014; Nielsen et al. 2014), we found thirty studies written in Spanish that investigated bird species richness in cities. Only two studies were published before 2000, which is consistent with the time-lag in the development of urban ecological research experienced by Latin American countries (Ortega-Álvarez & MacGregor-Fors 2011b). Although the number of articles increased in 2000–2009 period, they dropped in the last decade (2010–2019). The decline of studies published in Spanish language might be due to increasing pressures for publishing in English at international peer-reviewed journals among local scientists. For instance, a review

on Ortega-Álvarez & MacGregor-Fors (2011b) found a dramatic increase in the number of publications written in English from Latin American countries since 2005, which might explain the observed recent decline of publications in the local language.

As pressures for publishing in international journals continue in Latin America, the science-policy gap might increase over time. Our findings show that most studies are published in academic journals, where those led by Ornithological Associations of Chile (*Boletín/Revista Chilena de Ornitología*) and Argentina (*El Hornero*) are important in disseminating knowledge that is accessible to managers, planners, policy makers and citizens – at least the work is available in the official language and it is free (open-access). This finding highlights that scientific associations from these countries could play an important role in assist managers and urban planners to 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 outperforms the number of publications from Chile. For instance, in a literature review on bird community diversity, composition and spatial distribution, the number of studies was 7-fold larger in Argentina than in Chile (Ortega-Álvarez & MacGregor-Fors, 2011a). In addition, Ortega-Álvarez & MacGregor-Fors (2011b) found five-fold more bird studies (including bird species lists, ecology and conservation) in Argentina than in Chile. MacGregor-Fors & García-Arroyo (2017), reported that the number of studies on bird species richness and composition in Argentina doubled the number of studies from Chile. Leveau & Zuria (2017) found the double of studies on bird demography and population dynamics in Argentina compared to Chile. The difference between our finding and previous reviews can be explained by the late development of the discipline of urban ecology in Chile, where only recently urban bird studies from Chile are increasing in international peer-reviewed journals (e.g. Silva et al. 2015, Celis-Diez et al. 2017, Muñoz-Pedrerros et al. 2018, Amaya-Espinel et al. 2019, Villaseñor & Escobar 2019, Villaseñor et al. 2020).

Avian ecological research in Latin America focuses on large cities (Escobar-Ibáñez & MacGregor-Fors, 2017). Our review evidence that almost half of bird studies from the Southern Cone of South America are focused on capital cities: Santiago de Chile, Buenos Aires and Montevideo. In fact, the only study found in Uruguay was conducted in its capital (Montevideo). Although it is important to generate scientific evidence in large cities, it is also relevant to study smaller urban areas, which are likely to experience rapid and unplanned urban growth. Scientific evidence can contribute to achieve a sustainable urban growth by helping to implement early conservation actions, such as limiting land use change, promoting green space within the city, as well as identifying focal conservation areas (Ortega-Álvarez & MacGregor-Fors, 2009; Ikin et al. 2015).

Most research on bird species richness in cities from the Southern Cone of South America has been conducted in temperate grasslands and Mediterranean forests. Global analyses on urban birds have found that studies in temperate regions dominate the literature, with lack of research from tropical forest

regions (Chace & Walsh 2006). In the Southern Cone, the focus on a few large cities has led to a gap of knowledge on different biomes. For instance, no studies were found in montane grasslands and shrublands and desert and xeric shrublands. Given that the Southern Cone presents more than half of world terrestrial biomes (eight of 15 biomes, Henwood 1998), their cities provide an excellent opportunity to better understand biodiversity responses to urbanization in a variety of climates and geological conditions.

Study design

Short-term research dominates the literature. Ninety percent of studies lasted for one or two years, whereas only one study presented data for more than three years. The study with the longest duration (6 years of surveys, that comprised an extent of a decade) examined changes in the bird community in an urban wetland, and their possible associations with anthropogenic disturbance (Kusch et al. 2008). The lack of long-term research is common in ecological research and limits our understanding on ecosystems and human impacts in the long term (Turner et al. 2003). Long-term ecological studies are needed to understand the factors driving population, community and ecosystem change, and allow to undertake early actions to prevent species extinctions and rescue ecosystems from extinction cascades (Gaiser et al. 2020).

Most urban avian research was conducted in one season, where the reproductive season (spring and summer seasons) dominated the literature. Fewer studies comprised both reproductive and non-reproductive seasons. Studies that have included reproductive and non-reproductive seasons have found changes in species richness through the year (e.g. Fernández et al. 2009). This might be due to seasonal movements (e.g. migrations) in Neotropical birds as well as cities providing a wintering refuge during environmentally hard seasons (e.g. Fernández et al. 2009; Villaseñor & Escobar, 2019). Given that patterns of species richness can change through the year in a city, it is important to consider these variations and possible changes in the influence of predictive variables on species richness.

Green areas were the preferred environment to conduct research. This pattern has been reported by authors from Latin America (MacGregor-Fors & García-Arroyo 2017), although a recent literature review on avian abundance reported greater number of studies on the urban matrix (Leveau & Zuria, 2017). Urban parks have received greater attention probably because their large area covered by vegetation maintains a high diversity of birds, allowing researchers to record a greater variety of species than built-up areas, which are commonly dominated by a few exotic species (e.g. Díaz & Armesto 2003, Villaseñor et al. 2020). Informal green areas, such as vacant lands, have received limited attention, with only one study (a master science thesis) comparing bird species richness among vacant lands, urban parks and residential areas in Santiago de Chile (Chiang, 2019).

Effect of predictive variables on species richness

The effect of predictive variables on bird species richness in the Southern Cone agrees with common findings from the world. Vegetation cover and plant diversity exhibited mostly positive effects on bird species richness (Estades 1995, Urquiza & Mella 2002, Leveau & Leveau 2004), findings that agree with

global research (Chace & Walsh 2006, Evans et al. 2009, Beninde et al. 2015, Nielsen et al. 2014). 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). These findings are also consistent with previous literature reviews (e.g. Marzluff et al. 2001, Chace & Walsh 2006, Beninde et al. 2015, MacGregor-Fors & García-Arroyo 2017).

Most studies investigated the relationship between bird species richness and environmental variables. There was a clear knowledge gap: no study evaluated how socio-economics influences bird species richness in a city. Urban ecology must be considered as an interdisciplinary field, where social and natural science connect (McIntyre et al. 2008). Different authors have found that variables associated to humans, such as cultural, economic and demographic variables influence biodiversity (Kinzig et al. 2005, Nilon et al. 2011; MacGregor-Fors & Escobar-Ibáñez, 2017). Given the lack of studies exploring socio-economic factors on birds, it is important to highlight that new urban ecology paradigms highlight to not only consider biological and environmental components, but rather a holistic view of urban ecosystems. For instance, the paradigm of “ecology for the city” encourages ecologists to work for a sustainable urban future with a variety of specialists with different backgrounds as well as with urban dwellers by aiming environmental integrity, social equity and economic viability (Pickett et al. 2016).

Future research

Our review evidence clear knowledge gaps that need to be addressed. Research that is urgently needed in the Southern Cone of South America includes studies performed in: (1) cities in biomes such as deserts, xeric shrublands, mountain grasslands and shrublands, flooded grasslands and savannas, and tropical grasslands, savannas and shrublands; (2) small and medium size cities, and urban areas that are experiencing rapid and unplanned urban growth; (3) long-term research as well those comprising different seasons across the year; (4) include green space other than urban parks; (5) interdisciplinary studies that consider environmental, social and economic components of urban ecosystems.

A problem for the future that emerges from our review is the lack of growth 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 to face 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, scientists should also disseminate their findings in their local language. This can be addressed by summarizing or synthesizing a compilation of findings from different studies to be published in local journals or magazines, writing books or book chapters, as well supervising thesis and making them publicly available. In this context, Universities should play an important role not only in generating local evidence but also in disseminate knowledge. Open-access journals led by Ornithological Associations of Chile and Argentina have greatly contributed to disseminating knowledge locally and should continue being a platform for urban ecological research.

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

Declarations

Ethics approval and consent to participate: Not applicable.

Consent for publication: All authors consent to the publication of the manuscript in Urban Ecosystems, should the article be accepted by the Editor-in-Chief upon completion of the refereeing process.

Availability of data and materials: Data will be made available on request.

Competing interests: The authors declare that they have no conflict of interest.

Funding: Master in Wild Lands and Nature Conservation (Faculty of Forestry Sciences and Nature Conservation, Universidad de Chile) granted to CMP. ANID-FONDECYT 11201045 granted to NRV.

Authors' contributions: NRV conceived, designed, and wrote the manuscript. CMP collected and synthesized the data, elaborated graphs and figures and wrote the manuscript.

Acknowledgments: Authors thank scholarship from the Master in Wild Lands and Nature Conservation, from the Faculty of Forestry Sciences and Nature Conservation, Universidad de Chile, granted to CMP. NRV received funding from ANID-FONDECYT 11201045.

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