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2 **Urbanization, resources stabilization and the temporal**

3 **persistence of bird species: a review**

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17 Abstract

18 **Background.** A scarcely studied consequence of urbanization is the effect of the temporal
19 stabilization of habitat structure and resources on bird communities. This alteration is
20 thought to dampen environmental variations between day and night, seasons and years,
21 promoting a temporal persistence of bird composition in urban environments. The aim of
22 this study is to review actual evidences of temporal stabilization of habitats and resources in
23 urban environments, and its potential effects of the temporal variation of bird species
24 presence among different temporal scales.

25 **Methods.** Selection of literature was made by searching published articles and book
26 chapters using Google scholar. I only included articles that compared the temporal variation
27 of bird composition or resources between different levels of urbanization.

28 **Results.** In general, there is evidence of temporal stabilization of habitat structure and
29 resources along the three scales considered. At the diurnal scale, the main factor considered
30 was artificial light in the context of light pollution. At the seasonal and interannual scales
31 several case studies found a lesser temporal variation of primary productivity in urban areas
32 compared with natural and rural areas. Bird species composition showed more stabilization
33 in urban environments at the three temporal scales: 1) several case studies reported bird
34 feeding at night, associated with artificial light; 2) studies in urban parks and along
35 urbanization gradients showed lower seasonal variation of bird composition in the more
36 urbanized areas; and 3) in general, case studies along urbanization gradients showed lower
37 interannual variation of bird composition in the more urbanized areas, although some
38 studies showed no relationships or opposed trends than expected.

39 **Discussion.** The published evidence suggests that urban areas dampen the natural cycles at
40 several temporal scales. The stabilization of biotic and abiotic factors, such as light,

temperature, food and habitat structure are desynchronized from natural diurnal, seasonal and interannual cycles. However, there is a dearth of studies that simultaneously analyze the relationship between resources and bird composition stabilization. I also emphasize the need to differentiate spatial and temporal homogenization of avifaunas for a future research agenda. Moreover, the relationship between urbanization and other taxa is also commented. Finally, I propose suggestions for future work at different spatial scales.

Keywords: birds, diurnal, habitat structure, interannual, seasonal, resources, stability, temporal homogenization

51

52 **1. Introduction**

53 Urbanization have many impacts on natural and seminatural environments; his expansion
54 promotes fragmentation of ecosystems, perforation through the creation of different urban
55 areas, alteration of biochemical cycles, the urban heat island phenomenon and pollution
56 (Miller et al., 2001, Grimm et al., 2008; Shanahan et al., 2014). These environmental
57 changes have impacts on the spatial dynamics of bird communities, promoting significant
58 declines of bird diversity in highly urbanized areas and significant changes of bird
59 composition (Faeth et al., 2011; Suarez-Rubio et al., 2011).

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61 A little explored consequence of urbanization is the apparent stabilization of resources and
62 habitat structure, and its impact on bird communities. Many authors have suggested that the
63 dampening of temporal variation in resources may influence bird community composition
64 by favoring the temporal persistence of bird species capable of exploiting such resources,
65 the so called urban exploiters and adapters (see Blair, 1996). On the other hand, the
66 stabilization of habitats and resources may promote the local extinction of those species
67 adapted to temporal changes of resources and natural disturbances (Luniak, 2004; Shochat
68 et al., 2006; Duckworth, 2014; Parris, 2016; Pickens et al., 2017). The ultimate
69 consequences of these changes would be the local dominance and regional expansion of
70 species benefited by the resources stabilization in urban environments (Shochat et al., 2006;
71 Duckworth, 2014; Parris, 2016).

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73 The stability of urban environments needs to be considered in several temporal scales
74 because urbanization may promote the stabilization of environmental conditions between

day and night, seasons and years. From the point of view of human perception, the temporal stabilization of the environment in urban areas may induce a temporal homogenization of bird communities, where humans perceive a similar bird composition any time and can be disconnected from the natural rhythms of nature (Leveau et al., 2015, Leveau and Leveau, 2016). Therefore, the specific aims of this synthesis were: 1) to review evidences of temporal stability in habitat and resources used by birds in urban environments across different temporal scales; 2) to assess the impact of urbanization on the temporal persistence of bird species across different temporal scale; and 3) to suggest future lines of research.

2. Survey methodology

Selection of literature for this review have started with the search for studies on the temporal variation of bird communities and resources used by them using keywords such as “interannual”, “seasonal”, “nocturnal” coupled with “urban” and “bird”, and “interannual”, “seasonal”, “nocturnal” coupled with “fruits”, “insects” “resources” and “vegetation phenology”. I used Google Scholar and reviewed the first 300 returns for each one to include only articles that compare the temporal variation of bird composition or resources between different levels of urbanization.

3. Temporal stabilization of resources and habitats

3.1. Diurnal scale

Undoubtedly, artificial lighting is the most notable factor altering the natural cycle of day and night in urban areas, promoting negative effects on humans and wildlife (Navara and Nelson, 2007), although some bird species may take advantage extending their feeding

times (Deviche and Davies, 2014). Global maps indicate that the most impacted areas by artificial lighting are the most urbanized ones, such as east North America and Europe (Cinzano et al., 2001; Longcore and Rich, 2004). Within cities, artificial lighting increases with urbanization intensity (Kyba et al., 2012) probably with more intensity in commercial areas with showcases.

Another factor promoting the nocturnal activity of diurnal bird species is the food availability at night (Figure 1). Artificial lighting attracts invertebrates, which have higher abundance under street lights than in patches between lights (Davies et al., 2012). By attracting invertebrates, street lights provide potential food resources for insectivorous birds that extend their activity time after sunset (Figure 1). On the other hand, pedestrian traffic after sunset may provide, directly or indirectly, food resources for omnivorous bird species in urban centres. Moreover, diurnal raptors may exploit alternative food resources available at night at sites with artificial light, such as bats (Mikula et al., 2016).

3.2. Seasonal scale

Evidences of altered seasonal patterns of resources came mainly from data obtained concerning flowering phenology and vegetation indices derived from remote sensors, which are mainly indicators of the net primary productivity. Several studies found an extending growing period of vegetation in urban environments, related to the increase in temperature promoted by the urban heat island (Imhoff et al., 2000; Luo et al., 2006; Buyantuyev and Wu, 2012; Zhou et al., 2016). Also, the increased temperature during winter in urban areas may influence directly the presence of birds (Leston and Rodewald, 2006). On the other hand, Davis et al. (2015) found that native trees in Sydney (Australia)

flowered longer in streets than in remnant and continuous forest, providing more food resources to nectarivorous birds. Nectar and fruits may be available during seasons when they would be naturally absent or scarce by the planting of ornamental trees (Williams and Karl, 1996; Corlett, 2005; Leston and Rodewald, 2006; Williams et al., 2006; Montaldo, 1984; Leveau, 2008; Leveau and Leveau, 2011; Davis et al., 2015; Gray and van Heezik, 2016) (Figure 1).

Irrigation, the use of fertilizers and pruning, and the planting of perennial tree species such as *Pinus* sp. and *Eucalyptus* sp. may stabilize the seasonal dynamics of primary productivity in urban areas compared to agricultural and natural areas (González-García and Gómez Sal, 2008; Loram et al., 2011; Buyantuyev and Wu, 2012; Leong and Roderick, 2015) (Figure 2). The longer period of growing and stability of vegetation in cities may impact in other organisms, such as invertebrates, especially if vegetation exerts bottom-up control on them (Leong and Roderick, 2015). Therefore, along the year would be more food resources available to birds.

Arthropod communities may show lower seasonal changes in urbanized areas than in rural or natural areas. For example, Mulieri et al. (2011) found that sarcophagid diptera richness and abundance did not show significant changes through the year in suburban habitats compared with urban and rural habitats of Burzaco (Argentina). Moreover, whereas sarcophagid richness and abundance showed a positive relationship with temperature in urban and rural habitats, it did not show a significant relationship in the suburban habitat. McIntyre et al. (2001) found that arthropod richness responded similarly to temperature in natural, agricultural, residential and industrial areas of Phoenix (USA). However, arthropod abundance did not show a significant response to temperature in industrial and agriculture

areas. In the same city, Andrade et al. (2017) found that aphid abundance had a lower seasonal variation in irrigated residential areas compared to natural and non-irrigated areas which are more synchronized with the seasonal patterns of precipitation in the region.

The provision of bird feeders with grains or nectar is an important stabilizing factor for birds in urban areas, but they are mainly distributed in cities of developed countries (Jones and Reynolds, 2008) (Figure 1). Within each city, the provision of food for birds is related to socioeconomic and demographic factors (Lepczyk et al., 2004; Arizmendi et al., 2008; Fuller et al., 2008; Davies et al., 2012b; Sonne et al., 2016; Ramírez-Segura, 2016). For example, the provision of seeds and artificial nectar is related to high socioeconomic levels (Davies et al., 2012b; Ramírez-Segura, 2016). Moreover, Gaston et al. (2007) showed that the amount of bird feeders was positively related with garden size. Finally, the presence of landfills may constitute a constant source of food through the year for gulls, ibis and raptors (Yorio and Giaccardi 2002, Martin et al. 2010, Marateo et al. 2013).

3.3. Interannual scale

Data from remote sensors suggest that urban areas have a lower interannual variability of primary productivity in comparison to natural areas (Shochat et al., 2004; Leong and Roderick, 2015), suggesting that habitat structure and food for birds may be temporally more stable in urban areas. Activities such as maintaining vegetation or the use of fertilizers and pesticides may stabilize the interannual habitat structure and primary productivity of residential areas (Lepczyk et al., 2004) (Figure 1). Furthermore, the use and sustaining of nest boxes in backyards may stabilize the presence of hole-nesting bird species (Davies et al., 2009; Duckworth, 2014).

171

172 However, several authors argue that urban areas may be unstable in the long term. Physical,
173 social and vegetation changes associated with advances in urban technology, urban decay,
174 urban redevelopment and socioeconomic fluctuations may influence biotic communities
175 (Shaw et al., 2008; Luck et al., 2009; Hulme-Beaman et al., 2016). On the other hand, the
176 use of bird feeders by households may change considerably in the long term, affecting the
177 occurrence of bird species in backyards (Chamberlain et al., 2005).

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179 **4. Temporal stabilization of bird composition**

180 **4.1. Diurnal scale**

181 Besides there are many records of nocturnal feeding by diurnal birds in urban areas (Sick
182 and Teixeira, 1981; Negro et al., 2000; Rejt, 2004; DeCandido and Allen, 2006; Mikula et
183 al., 2013), only a few studies related bird feeding activity with environmental variables or
184 urban attributes (Table 1a). Studies showed that bird activity after sunset was positively
185 related to artificial light (Stracey et al., 2014; Russ et al., 2014). Dominoni et al. (2013)
186 only found a significant extension of activity in the European Blackbirds before dawn in
187 urban parks compared to forests. Other factors such as day length and cloud cover may
188 influence bird activity at night (Russ et al., 2014).

189

190 **4.2. Seasonal scale**

191 Most of studies showed negative effects of urbanization on seasonality of bird composition
192 (Table 1b). The impacts were observed in the dynamics of composition of the entire
193 communities (La Sorte et al., 2014; Leveau et al., 2015; Leveau and Leveau, 2016) or in the
194 analysis of migratory birds affected (Catterall et al., 1998, Juri and Chani, 2009). A study

conducted in an urban area located in the Amazonas showed a positive relationship between urbanization and the amount of migrant species found (Lees and Moura 2017). Most of studies compared the seasonal dynamics between habitat types, except two studies that related seasonal changes of community composition with impervious surface cover and other vegetation characteristics (Leveau et al., 2015; Leveau and Leveau, 2016). Many examples showed the loss of migratory behavior in bird species colonizing urban environments (Figure 3). However, supplementary food during winter has been associated to the northernward winter migration of the Eurasian Blackcap (*Sylvia atricapilla*) in Europe (Plummer et al. 2015).

4.3. Interannual scale

In general, studies showed that urbanization stabilized the interannual variation of community composition (Table 1c). However, two studies that spanned the longer term had null effects of urbanization or opposed trends than expected (Barrett et al., 2008; Catterall et al., 2010). In particular, Catterall et al. (2010) found population declines of urban associated species, such as the House Sparrow or European Starling (*Sturnus vulgaris*) in suburban habitats compared with bushland. Most of studies related community composition stability with urban attributes, such as impervious cover or human density.

5. Possible mechanisms

Studies suggest that nocturnal activity is mainly regulated by artificial light, which alters melatonin secretion (Dominoni et al., 2013a). Melatonin is a hormone related to the biological rhythm in animals (Jones et al., 2015). Daylength may be a significant factor, as birds presented more night activity with shortest days (Russ et al., 2014; Dominoni and

Partecke, 2015). Meteorological factors such as temperature and cloud cover may influence nocturnal activity of birds (Russ et al. 2014; Dominoni et al. 2014). Bird density was positively related to the degree of nocturnal activity, suggesting a role of intraspecific competition (Russ et al., 2014; Dominoni et al., 2013). Alternatively, a greater bird density may promote by chance a greater probability of appearance of nocturnal feeding (Figure 1). Finally, the importance of food availability at night was suggested but it was very little explored (Dominoni et al., 2014).

The lower seasonal variation of bird communities may be related to the extinction of migratory species and the lower seasonal variation of resident species. Migratory species arrive to a site exploiting surplus resources not used by year-round residents (MacArthur, 1959; Hurlbert and Haskell 2003). If urban areas are characterized by a stabilization of resources, the surplus provided to migratory species would be diminished (Figure 1b). Independently of this, urban areas may be characterized by low amount of food resources to migrants, especially those that feed on insects (Faeth et al., 2005, Teglhoj 2017). Moreover, human disturbance such as pedestrian and car traffic, and nest parasitism may be especially negative to migratory birds (Burger and Gochfeld, 1991; Zhou and Chu, 2012; Rodewald and Shustack, 2008) (Figure 1). Constant food availability through the year to omnivorous species may stabilize their temporal variation relative to populations in rural or natural areas. The more stable presence of resident species may affect negatively to migratory species by interspecific competition for food and nesting places (Figure 1). For example, House sparrows may do aerial hawking of insects, depleting resources to migratory species that exploit the same resources. House Sparrows and European Starlings nest in holes of buildings and trees, the same nest substrates of several migratory swallow species in the

Neotropics (Leveau et al., 2015). Finally, supplementary feeding during winter may create a surplus of resources favoring the arrival of winter migrants (Plummer et al. 2015), thus promoting an opposed process to the seasonal homogenization of bird communities.

Interannual composition stability in highly urbanized areas is probably driven by the high densities that some species achieve there, favored by several factors such as a constant food provision, habitat stability and a favorable microclimate during winter (Figure 1). A highly dominance by a few species, typically the House Sparrow and the Rock Dove, may diminish their extinction probabilities at local scales, at least at short and mid-term scales (between 2 and 10 years). However, at larger temporal scales (> 10 years) it may occur biotic instabilities produced by strong competitive interactions between species (DeAngelis and Waterhouse, 1987). Shochat et al. (2010) showed that dominant bird species were highly efficient foragers that leave scarce resources to subordinate species, probably leading to their exclusion in the long term. On the other hand, bird community fluctuations in rural or natural areas are probably more governed by environmental stochasticities, such as natural disturbances or climatic fluctuations, which affect the persistence of rare species leading to a higher temporal variation of bird composition (Collins, 2000; Sasaki and Lauenroth, 2011).

6. Urbanization and temporal stabilization of composition in other taxa

Recent studies showed that urbanization is associated with a lower temporal variation in species composition of invertebrates. For example, Hwang and Turner (2005) found a lower seasonal variation of necrophagous fly composition in urban than in rural areas of London (UK). Stelzer et al. (2010) found that Bumblebees (*Bombus terrestris*) extended their

foraging activity during winter in urban areas of the same city, presumably due to climate warming and the availability of cultivated winter-flowering plants. Moreover, in a comparative study between Montreal and Quebec (Canada), Normandin et al. (2017) found a higher interannual stability of bee composition in the most urbanized city. The constant provision of food in urban areas may promote behavioral changes of mammals. For instance, the Striped field mouse (*Apodemus agrarius*) became active during daytime in urban parks (Gliwicz et al. 1994). Brown bears (*Ursus arctos*) associated to a garbage dump in Turkey remained sedentary year-round, whereas bears that never visited the dump migrated prior hibernation to search food (Cozzi et al. 2016). Finally, Eurasian red squirrels (*Sciurus vulgaris*) showed a seasonal stabilization of antipredator behavior in urban areas compared to rural areas (Uchida et al. 2016).

7. The need to differentiate spatial and temporal homogenization of avifaunas

In my opinion, spatial and temporal homogenization act at different spatial scales and have different underlying processes. On the one hand, spatial homogenization is the increase of taxonomic similarity of two or more biotas over a specified time interval (Olden and Rooney 2006). The main process is the extinction of native species and the colonization of widespread species. On the other hand, temporal homogenization is the increase of taxonomic similarity over time in a given biota. This phenomenon is given at several temporal scales, as mentioned before. Underlying processes are the extinction of migratory or disturbance-dependent species and the colonization of new temporal niches (for example, the night).

Are both processes simultaneous? The spatial homogenization of bird composition promoted by urbanization seems to be scale dependent. Whereas at global scale or when

comparing different biomes, there is a higher taxonomic similarity in urban areas compared to non-urban areas, at the regional scale urban avifaunas seem to be so heterogeneous as non-urban avifaunas (Leveau et al. 2017). On the other hand, the temporal homogenization of avifaunas can be seen at different spatial scales, from the local to the global scale. For example, the seasonal stabilization of bird composition was detected at local scales in Argentina (Leveau et al. 2015, Leveau and Leveau 2016) and among different biomes in North America (La Sorte et al. 2014). The nocturnal activity of Rock Doves in urban centers is a global phenomenon (Luniak 2004, Leveau unpublished data)

8. Conclusions and future directions

The published evidence suggests that urban areas dampen the natural cycles at several temporal scales. The stabilization of biotic and abiotic factors, such as light, temperature, food and habitat structure are desynchronized from natural diurnal, seasonal and interannual cycles. These changes promoted by urbanization are expected to influence the temporal dynamics of bird composition. In fact, the literature reviewed showed that bird composition was temporally more stable in the most urbanized areas, leading to a temporal homogenization of bird communities (Figure 1). On the other hand, a possible consequence of resource and habitat stabilization is the population growth and range expansion of bird species adapted to urban conditions. For instance, a recent study showed that daily nest survival rates of Blackbirds increased with artificial light at night (Russ et al. 2017). On the other hand, clear examples of species with range expansions associated to urban conditions are hummingbirds; for example the Anna's Hummingbird (*Calypte anna*), the Allen's Hummingbird (*Selasphorus sasin sedentarius*) and the White-throated Hummingbird (*Leucochloris albicollis*) have expanded his range sizes and are species highly associated to

residential areas, which provide supplemental food resources such as nectar, year round flowering plants and nesting places (Clark and Russel 2012, Clark 2017, Greig et al. 2017, Weller et al. 2017). Despite these findings, there are many research gaps that need to be addressed.

Studies concerning the nocturnal activity of diurnal species had more analysis of intervening factors and experimentation, but research only was intensive on the European Blackbird. It is noteworthy that other globally distributed species with nocturnal activity such as the Rock Dove were not studied yet (Luniak, 2004). This is an interesting model species to explore environmental conditions affecting nocturnal activity.

Comparisons of seasonal and interannual compositional stability between urbanization levels exist for different countries (Table 1), but studies that relate the compositional stability and the temporal environmental variation in unison are lacking. Moreover, experimental studies controlling or altering the temporal availability of resources and their effect on bird composition stability are needed. A close example is the work of Galbraith et al. (2015), where supplementary food was experimentally added and removed after 18 months in residential areas, promoting a higher temporal variation of bird composition than control sites where food availability was not altered.

Given that wealthier householders may input more resources to habitat management and bird feeding, it is expected that this type of intervention may promote a higher temporal stabilization in bird composition. These socioeconomic contrasts may act at different spatial scales, from the local scale comparing different residential areas within a city, to the global

scale comparing cities of developed and developing countries.

The stabilizing role of urbanization on environmental conditions may be more evident depending on the geographical location of cities. For example, desert biomes are highly variable according to interannual precipitations (Fang et al., 2001) and, therefore, irrigation use of residential areas may promote higher effects on the stability of bird composition than irrigation in urban areas of forested biomes, which may have lower interannual precipitation fluctuations.

As a result of higher environmental and population variability with time and habitat succession, bird communities are expected to show more variability as the time length of studies increases (Bengtsson et al., 1997). In part, our review resulted in patterns of interannual variability opposed as expected for those studies with more than 10 years of observation length (Table 1). Therefore, studies conducted on longer temporal scales are needed. On the other hand, besides bird composition may change greatly from one year to another, it is necessary to explore whether bird communities of urban areas go to directional changes through time (Collins, 2000; Collins et al., 2000).

An overlooked aspect of urban environments is the possible creation of rhythms on bird communities as a response of massive movement of people between working and weekend days. Car traffic may promote weekly cycles of pollutants, wind speed and noise, that may promote changes in bird activity (Shutters and Balling, 2006; Leveau, 2008; Halfwerk et al., 2011). Along a road near Madrid, Bautista et al. (2004) found changes in raptor composition between working and weekend days. On the other hand, Fernández-Juricic et

al. (2003) found that the presence of pedestrians in urban parks of Madrid affected the abundance of House Sparrows. Therefore, we may expect significant changes of bird composition between working and weekend days in urban green spaces, due to generally a massive number of people visit them on weekends.

The dampening of temporal variation in bird composition may be another facet of the so called extinction of experience (Pyle, 1978; Miller, 2005), where humans are disconnected from natural cycles. Several studies showed that most of people liked the change of seasons (Jauhiainen and Mönkkönen, 2005, Soga et al., 2016), and Palang et al. (2005) recommended to put more emphasis to seasonality in landscape planning. Moreover, although little explored, the seasonal variation of vegetation and animal activity may have an aesthetic value and conserve ecosystem services (Dronova 2017). From a point of view of urban design it is a paradox that urban habitats that we ignore, such as vacant lots, have more relation to the particular natural processes of the region in which the city is located than those places designed in a formal way with particular proportions of lawn, shrubs and trees (Hough, 1994). Therefore, a crucial step to restore nature in cities is to pay attention to the natural cycles characteristics of the surroundings of cities.

Recently, a collaborative project that encompassed six metropolitan areas of varied climatic regions of US aimed to elucidate the ecological homogenization of urban areas compared to natural areas, showing convergences of soil moisture, amount of organic matter and microclimate among residential areas (Groffman et al., 2014; Hall et al., 2016). In my opinion, a step forward is to analyze how these ecosystems properties are stabilized in time, and how this affect the temporal persistence of bird species.

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705 **Table 1.** Summary of studies that associate (A) artificial light with bird feeding at night, (B)
706 urbanization with seasonal variation of bird composition and (C) with interannual variation
707 of bird composition.
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A				
Study design	Species	Main result	Location	Source
Urban and rural forest	European Blackbirds (<i>Turdus merula</i>)	+	Munich, Germany	Dominoni et al. 2013
Suburban and natural sites	Northern Mockingbirds (<i>Mimus polyglottos</i>)	+	Gainesville, USA	Stracey et al. 2014
Urban parks	European Blackbirds (<i>Turdus merula</i>)	+	Leipzig, Germany	Russ et al. 2014
B				
Study design	Main result	Location	Source	
Urban-natural	-	Montpellier, France	Caula et al. 2008	
Urban-natural	-	North America	La Sorte et al. 2014	
Urban-rural	-	Mar del Plata, Argentina	Leveau et al. 2015	
Urban green areas	-	Mar del Plata, Argentina	Leveau and Leveau 2016	
C				
Study design	Main result	Location	Study length	Source
Suburban-natural	+	Brisbane, Australia	15 years	Catterall et al. 2010
Urban-natural	-	Kraków, Poland	2 years	Ciach and Fröhlich 2016
Urban-rural	0	South-east North America	25 years	Barret et al. 2008
Urban areas of different sizes	-	Finland	8 years	Suhonen et al. 2009
Suburban- Exurban	-	Rovaniemi, Finland	5 years	Jokimäki et al. 2012
Urban-periurban	-	Mar del Plata, Argentina	3 years	Leveau and Leveau 2012
Urban-rural	-	Mar del Plata, Argentina	3 years	Leveau et al. 2015
Riparian sites along an urbanization gradient	-	Phoenix, USA	12 years	Banville et al. 2016

+Indicates a positive relationship, - indicates negative relationship and 0 indicates no relationship. In B and C, studies compared the temporal variation in bird composition along urbanization gradients or related it with urban attributes.

Figure 1. Schematic representation of intervening factors and possible mechanisms influencing the temporal dynamics of bird composition in urban areas. Urbanization promotes the temporal stabilization of several environmental characteristics, such as light, food, temperature and habitat structure (red boxes and circles). Human disturbance, through the passing of pedestrians may provide food for birds, whereas the passing of cars may increase the urban heat island. Factors in circles may be strongly affected by the socioeconomic characteristics of citizens. The environmental stabilization is produced at different temporal scales (purple boxes), which in turn promote the temporal homogenization of bird communities. Dashed lines and boxes indicate factors and processes that require further research.

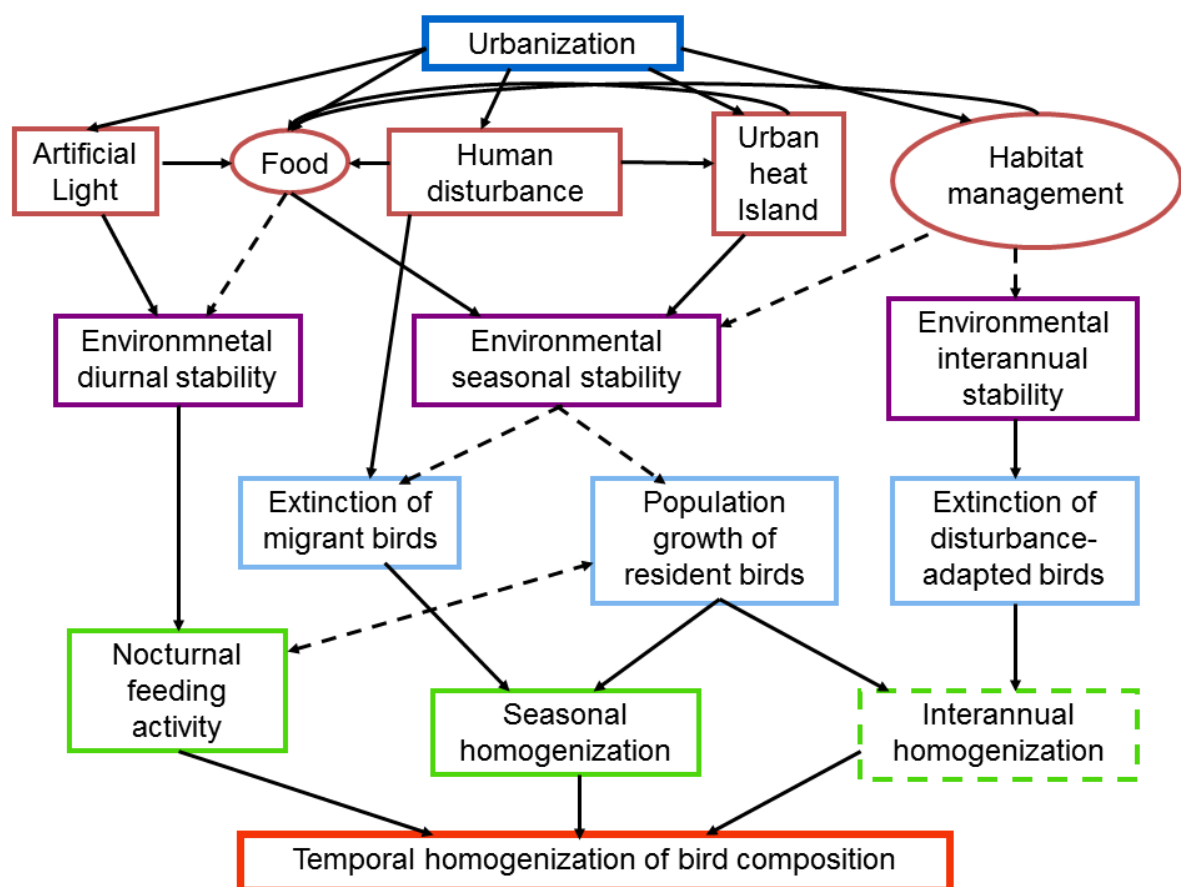
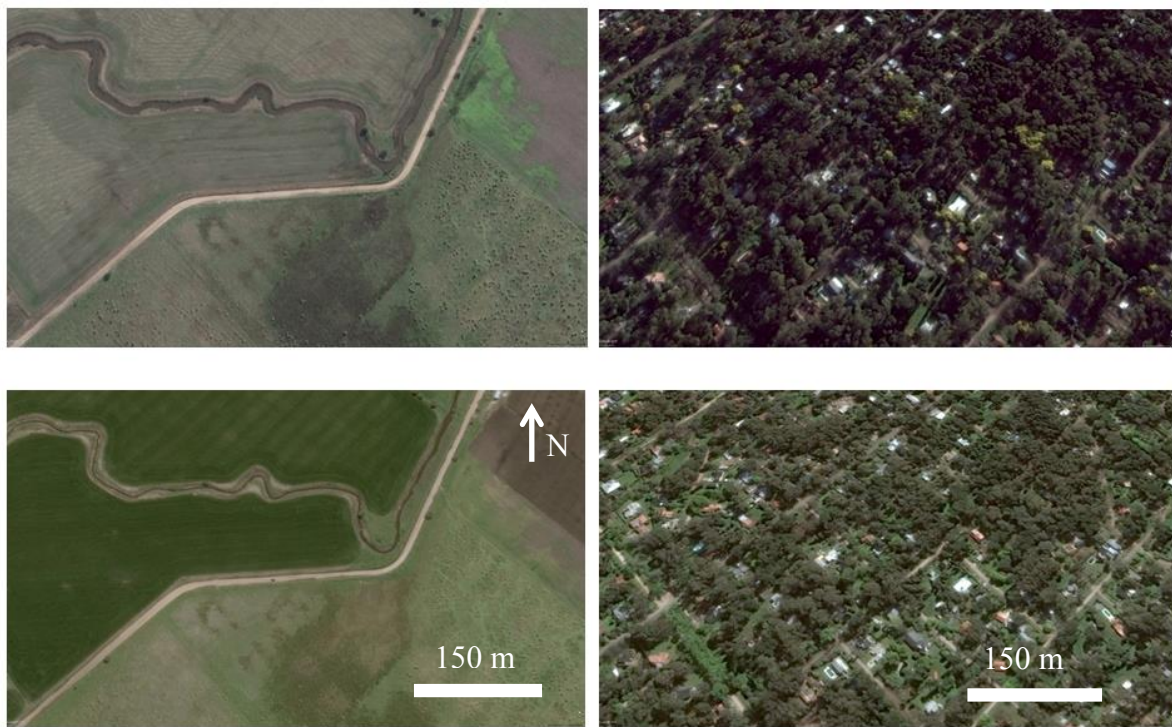


Figure 2. Example of seasonal change of vegetation between a residential periurban area (right) and a rural area (left) of Mar del Plata city, Argentina. Images were obtained through the temporal sequence of Google Earth, selecting images of 15 August 2015 (austral winter, top) and 17 October 2015 (austral spring, bottom). Note the differences in the coloration of vegetation between dates in the rural area compared to the residential area.



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Figure 3. Cases of species that changed from partial migrants to resident species in urban areas. a) Merlin (*Falco columbarius*, Warkentin et al. 1990); b) European Robin (*Erithacus rubecula*, Adriaensen and Dhondt 1990); c) Dark-eyed Junco (*Junco hyemalis*, Yeh 2004); d) House Sparrow (*Passer domesticus*, Anderson 2006); and e) European blackbird (*Turdus merula*, Partecke and Gwinner, 2007; Møller et al., 2014).
 Authors of photos: a) Raj Boora; b) Pierre Selim; c) Peter Wallack; d) Jaap Pol; and e) Malene Thyssen. All pictures under Creative Commons license 4.0.

