Chapter 9
Trends in Long-Term Urban Bird Research

Mason Fidino and Seth B. Magle

Abstract The vast majority of urban bird research is conducted over relatively short time frames (1–2 years), thereby limiting our ability to understand how temporal processes influence urban bird populations and communities. To further evaluate the importance of and contributions provided by long-term ($\geq$5 years) ecological studies of urban avifauna, we reviewed the published literature for such studies to (1) explore and characterize the focus of long-term urban bird research, (2) identify gaps in our knowledge base, and (3) make suggestions for future research. We identified 85 papers published between 1952 and 2014 for this review. While long-term studies ranged from 5 to 175 years, most were $\leq$30 years in length. Community-level studies predominately quantified how urbanization affects species richness and composition through time, while population-level studies were primarily on single species of larger body size ($\geq$80 g). Almost every study we reviewed was conducted in North America and Europe, a result that is generally unsurprising as temperate zones and wealthier countries are overrepresented in the literature. Overall, long-term studies provide unique insights into how slow and subtle processes, land-use legacies, time-lagged responses, and complex phenomena influence urban birds. To better encourage the inclusion of long-term studies in urban avian ecology, we suggest that ecologists should (1) keep long-term phenomena in mind when constructing short-term studies, (2) make published datasets accessible, and (3) provide adequate metadata regarding how data was collected.

Keywords Conservation • Literature review • Long-term studies • Urban birds • Urban ecology

9.1 Introduction

Ecological systems are largely controlled by two interrelated but fundamental factors, space and time, which influence patterns and processes at multiple scales. When considered individually, many theories (e.g., island biogeography) and

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concepts (e.g., connectivity, edge effects, and spatial autocorrelation) from spatial ecology have greatly influenced the way we shape and address ecological questions (Wolkovich et al. 2014). In the same vein, a multitude of ecological properties that influence species inherently include temporal components (e.g., resource availability, Rey 1995; predator-prey dynamics, Benoit-Bird and Au 2003; and colonization and extinction, Levin 1974). However, space and time must be considered together as they are inherently linked. For example, spatial patterns can change through time, and patterns observed today may be a function of time-lagged responses (Kuussaari et al. 2009; Krauss et al. 2010) or land-use legacies (Foster et al. 2002). Indeed, space and time are two axes of dynamism that influence the landscape in complex and interrelated ways (Delcourt et al. 1982; Wiens 1989; Dunning et al. 1992; Ramalho and Hobbs 2012). Thus, space, time, and their interaction must be accounted for to better understand the myriad ways in which individuals, populations, and communities interact with their environment.

Both spatially and temporally, the human modification of landscapes through processes such as urbanization has significantly altered ecological processes (Booth and Jackson 1997; Vitousek et al. 1997; Baker et al. 2001; Imhoff et al. 2004; Halpern et al. 2008) and the distribution and abundance of wildlife (Marzluff et al. 2001a; McKinney 2002, 2006; Aronson et al. 2014). In the last decade, humanity has transitioned from primarily living in rural to urban areas, and 66 % of the world's population is expected to live in urban environments by 2050 (United Nations 2014). In response, the rate of urbanization continues to accelerate worldwide (Forman 2008; Dearborn and Kark 2010), which has negatively influenced many species (Czech and Krausman 1997; Czech et al. 2000). At least partially as a result, there has been increased interest in the study of urban ecosystems and wildlife (Mcdonald et al. 2008; Mayer 2010), and publication rates of urban wildlife literature continue to rise (Magle et al. 2012).

Birds are by far one of the most studied taxa in urban areas (Magle et al. 2012), and literature focused on their ecology and conservation in cities is growing rapidly (Bird et al. 1996; Marzluff et al. 2001a; Lepczyk and Warren 2012). Because birds are appreciated by people (Turner et al. 2004), are relatively easy to detect and observe (Blair 1999), and respond rapidly to changes in landscape composition (Marzluff 2005), it is not surprising that they represent a significant proportion of published urban wildlife literature. Urban bird studies have significantly contributed to the field of urban ecology, and many of the patterns observed within urban systems are illustrated with birds (Blair 1996; Crooks 2004; Marzluff 2005; Aronson et al. 2014). Yet this research has primarily focused on patterns and processes at varying spatial scales, and most studies are conducted over relatively short time frames (1–2 years; Marzluff 2001). While studies of this nature fit within standard funding cycles or the length of a typical graduate program, longer-term studies are critical to better understand and predict how slow or subtle temporal processes, rare events, and complex phenomena influence urban bird populations and communities (Foster et al. 2002; Turner et al. 2004; Wolkovich et al. 2014).

The importance of long-term studies in ecology is well recognized, and reviews focused on the contribution of such studies in different ecological subdisciplines abound (Strayer et al. 1986; Hobbie 2003; Likens 2004; Jackson and Fuereder 2006; Ducklow et al. 2009; Clutton-Brock and Sheldon 2010; Magurran et al. 2010). Although urban avian ecology is a relatively new and burgeoning field, the necessity for long-term ecological studies has also been recognized. Indeed, the seminal work by Marzluff et al. (2001a) has numerous suggestions for the inclusion of long-term studies in urban bird research including population-level studies that explore how birds respond to urbanization at different points along the urban-rural gradient, linking population demographics to urban bird community composition, and studies of non-synanthropic species. To determine if these suggestions have been addressed since that time, and to further evaluate the importance of and contributions provided by long-term ecological studies of urban avifauna, we reviewed the published literature for such studies to (1) explore and characterize the past and current focus of long-term urban bird research, (2) identify potential gaps in our knowledge base, and (3) make suggestions for future research directions.

9.2 Methods

We searched the published literature with two search engines, ISI Web of Science and Google Scholar, using all unique combinations of the search terms "*urban*," "long-term," "park," "bird*," "avian," "fragmentation," "time," and "temporal" that included at least one word associated with birds (i.e., "bird*" or "avian"). The "*" character was included within the "urban" and "bird" search terms so that iterations of these words such as suburban, ex-urban, urbanization, birds, or birding were also detected in the search. Each publication that resulted from this search was reviewed to determine if it met the criteria for inclusion. Given that most urban bird studies span 1–2 years (Marzluff et al. 2001b), publications were included if they represented original research on urban birds and collected data over at least a 5-year period. We chose a 5-year cutoff because we believe this is a conservative estimate of the length of time needed to represent a range of temporally varying conditions within an urban environment, such as wet or dry years. Furthermore, continuous collection of data over the length of a study was not necessary. For instance, a study would be included if it collected data on only two separate years provided they were at least 5 years apart. Following Marzluff et al. (2001b), we also searched the literature-cited section of each long-term study for additional empirical work on long-term urban bird research; all such studies were included if they met the criteria above.

Throughout this process there was some redundancy between studies as data from sites were used in numerous papers. For example, a series of studies were conducted over a period of about 150 years at the same sites in the Boston Metropolitan area (Brewster 1906; Walcott 1974; Strohbach et al. 2014). When these redundancies occurred, we considered research papers to be independent and original provided the questions asked and analyses performed differed. A total of 85 papers were found for this review (Appendix). We should note that our search technique may be less likely to detect research on temporal trends present in local

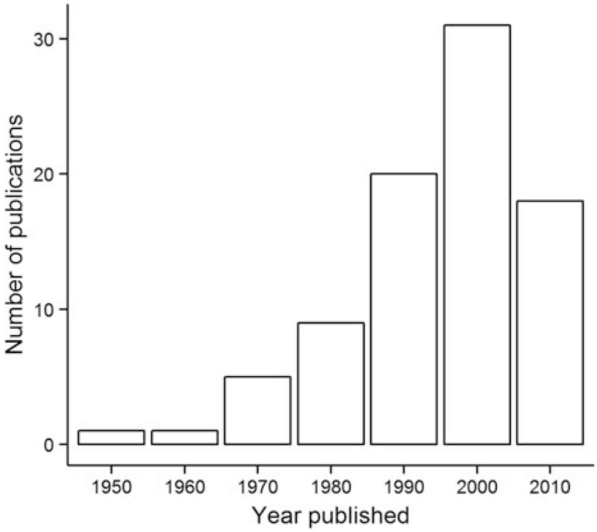


Fig. 9.1 The number of long-term urban bird studies published per decade since 1950

ornithological journals or in urban ornithological atlases (e.g., Luniak 2016). Furthermore, long-term studies that were not detected with our search terms and were not cited in papers found with these terms will inherently be absent from this review. We believe that these caveats do not change the overall perspective of long-term urban bird research in this review and that the papers we did review represent the vast majority of long-term urban bird research.

9.3 Results and Discussion

9.3.1 A Systematic Perspective of Long-Term Urban Bird Research

As with the field of urban ecology in general, the publication rate of long-term studies on urban avifauna is increasing (Fig. 9.1). The first published long-term study of urban birds we found was Cramp and Teagle's (1952) report on the abundance and distribution of the birds within inner London from 1900 to 1950. The London studies are particularly noteworthy because they are still ongoing (e.g., Oliver 1997), making this one of the longest temporal datasets of birds, urban or otherwise. However, studies that include data prior to 1960 are the exception, as a vast majority of the published research ($n = 62$, 72.9 %) initiated data collection from 1960 onward, illustrating both the sparseness of historical data and the relatively recent interest in urban wildlife research (Magle et al. 2012).

Although the length of long-term urban bird studies ranged from 5 to 175 years, the distribution is skewed heavily toward the shorter end, with 71.8 % $\leq$30 years in

Fig. 9.2 The frequency of the temporal span of data in long-term urban bird studies in 5-year intervals. Most studies (>70 %) were less than 30 years in length

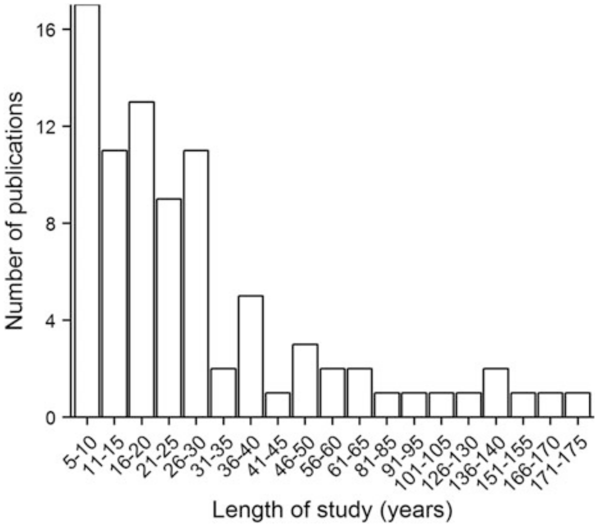
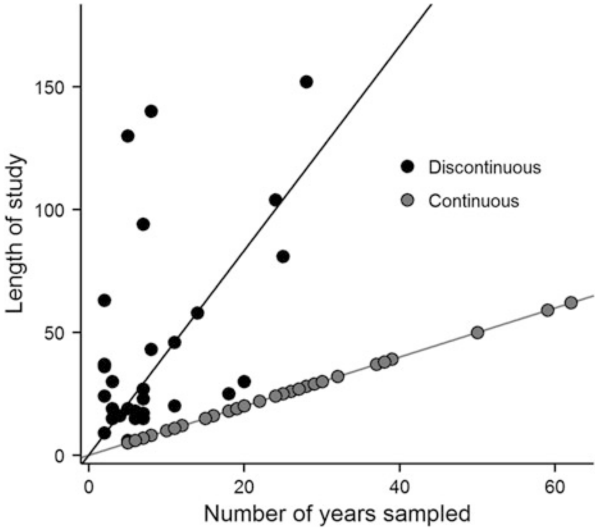


Fig. 9.3 Comparison of the number of years sampled in continuous and discontinuous studies to their overall length. The line for continuous studies is a simple 1:1 relationship, while the line for discontinuous studies is a linear regression with overall length as the response variable and number of years sampled as the explanatory variable ($r^2 = 0.61$, $P < 0.0001$)



length and 20 % ranging from 5 to 10 years (Fig. 9.2). In discontinuous studies (those that did not collect data yearly), very few were missing data for only 1–2 years (Fig. 9.3, e.g., Jokimäki and Huhta 2000), while most had large gaps between subsequent observations (e.g., Jokimäki and Suhonen 1993; Parker et al. 1996; Catterall et al. 2010). In some instances, studies had only 2 years of data separated by multiple years (e.g., Aldrich and Coffin 1980; Kentish et al. 1995; Wood and Recher 2004; Suhonen et al. 2009). However, discontinuous studies make up for a lack of continuity with increased study duration (Fig. 9.3), as 76.5 % of the studies

Table 9.1 Mean and median study durations (years) of community-level and population-level long-term urban bird studies

	Study type	
	Community	Population
Mean study duration	39.32	30.49
Median study duration	27	19
Number of studies	34	51

we reviewed $\geq$40 years in length ($n = 17$), and all of the studies with $\geq$100 years in length were discontinuous ($n = 7$). Indeed, the longest continuous study was Batten's (1978) 62-year article on the immediate causes of blackbird (*Turdus merula*) mortality throughout England, while the longest discontinuous study on the temporal dynamics of wildlife in New England spanned 175 years (Foster et al. 2002).

Community-level studies were slightly longer in length than population-level studies (Table 9.1), though the difference was not significant; t_{83} (0.56), $p = 0.29$. Most long-term community-level studies quantified effects of urbanization on species richness or species turnover through time ($n = 15$, 45.5 %), with a majority of studies ($n = 12$) solely focused on the breeding bird community.

Only five community-level studies collected data on birds during all seasons (Recher and Serventy 1991; Jones and Wieneke 2000; Namba et al. 2010; Shultz et al. 2012; Ormond et al. 2014). For population-level studies, a large proportion was conducted on single species ($n = 30$, 68.2 %). Of those, almost every species studied was of larger body size and weighed $\geq$80 g. For example, 12 studies were conducted on birds of prey (e.g., Kauffman et al. 2003; Stout et al. 2007; Rutz 2008), three on the common blackbird (Batten 1973, 1978; Kentish et al. 1995), and three on a variety of gull species (Milone and Grotta 1983; Annett and Pierotti 1999; Pierotti and Annett 2001). The most commonly studied small-bodied bird is the ubiquitous and cosmopolitan house sparrow (*Passer domesticus*, $n = 6$; Balmori and Hallberg 2007; Dott and Brown 2000; Robinson et al. 2005; Liker et al. 2008; Bell et al. 2010; Murgui and Macias 2010). As this once incredibly abundant species has declined significantly in some parts of its range in recent decades, interest in its ecology and demography has increased recently (for a review see De Laet and Summers-Smith 2007).

Geographically, studies were most commonly conducted in North America ($n = 37$, 43.53 %), Europe ($n = 37$, 43.53 %), and Australia or New Zealand ($n = 8$, 9.41 %). This is generally unsurprising as temperate zones and wealthier countries tend to be overrepresented in the literature (Martin et al. 2012). Only 3 of the 85 studies were outside of these three geographic regions, with one located in the Caribbean (Fonaroff 1974) and two in Japan (Nihei and Higuchi 2002; Namba et al. 2010). We did not find any long-term studies of urban birds that spanned multiple continents, though short-term studies of this nature do exist (Aronson et al. 2014). As the geographic region of a study site can influence the patterns and processes observed, geographical biases in data collection can limit the extent to which findings from commonly studied urban systems can be applied to less common systems (Martin et al. 2012). Though there is currently a dearth of data from Africa and Asia (but see Symes et al. 2016), these areas are prime locations to initiate long-term studies of urban avifauna. Over the next 35 years, both of these continents are expected to urbanize faster than other regions in the world (United Nations 2014), thereby providing opportunities for experimental, observational, and mensurative studies at a shifting urban-wilderness interface over time.

In summary, community-level studies disproportionately focus on breeding birds, while population-level studies tend toward large-bodied birds. Regardless of study type, studies in North America and Europe are much more common than other geographic locations. Most published research does not exceed 35 years in length. While this duration is likely adequate to determine how urbanization influences avian species with short generation times, it may not be enough time to study how long-lived species are impacted by urbanization. Moreover, studies that do exceed 35 years in length tend to have discontinuous datasets that integrate previous work. To highlight the important contributions that long-term studies have had on our understanding of how urbanization affects birds, we showcase a number of studies below. These particular examples have implications beyond their study systems and also provide a framework for future research directions.

9.3.2 Temporal Studies on Urban Bird Species Composition

The composition and richness of bird species are perhaps one of the most interesting parameters that evolve through time in urban environments. Short-term studies often report that species richness declines as urbanization increases (Tratalos et al. 2007), though levels may be highest at intermediate levels (Marzluff 2005; Catterall et al. 2010). Thus we may expect species richness to decrease as a single location becomes more urban over time. In our review, however, results were equivocal from studies that tracked species richness at urbanizing sites over time as studies alternately reported either no net loss in alpha diversity (Horn 1985; Jones and Wieneke 2000; Shultz et al. 2012), a slight increase in alpha diversity (Aldrich and Coffin 1980; Abs and Bergen 2008), or an overall decrease in alpha diversity (Batten 1972; Walcott 1974; Bezzel 1985; Biaduń et al. 2009; Catterall et al. 2010; Pidgeon et al. 2014; Strohbach et al. 2014). Given the wide range of responses we observed, we suggest that spatial differences observed along a gradient over short time frames do not adequately capture the many temporal forces that may subtly influence species richness, that different bird compositions may occur as urbanization increases through time, and that community composition may also be influenced by the rate at which urbanization increases. Thus, we consider here the complex ways time may influence urban bird communities.

Regardless of reported increases or decreases in species diversity, a high rate of turnover is a common trend in long-term studies with factors such as climate change (Travis 2003), the introduction of invasive species (Foster et al. 2002), maturation of local native or nonnative vegetation (Bloom and McCrary 1996; Jones and Wieneke 2000; Jerzak 2001; Gleditsch 2016), land-use legacies (DeGraff and Wentworth 1986; DeGraaf 1991), body size (Catterall et al. 2010), and habitat fragmentation influencing species persistence, colonization, and extinction rates in complex ways (Butcher et al. 1981; Tait et al. 2005; Walk et al. 2010). Thus, although species richness may not change at a site over time, the composition of species present does. However, while the notion that urbanization may not decrease species diversity through time is encouraging, such a conclusion does not consider the relative values of particular species, the functional diversity of the urban bird community, or the type of habitat that is urbanized.

For instance, species diversity increased with urbanization in Aldrich and Coffin's (1980) 37-year study of a forest turned suburban lot, but this growth was the result of increases in common suburban species [e.g., blue jays (*Cyanocitta cristata*), northern mockingbirds (*Mimus polyglottos*), and American robins (*Turdus migratorius*)] and was at the cost of species more characteristic to the deciduous forests of Eastern North America [e.g., wood thrush (*Hylocichla mustelina*), red-eyed vireo (*Vireo olivaceus*), and scarlet tanager (*Piranga olivacea*)]. Indeed, this trend was often reported in long-term community-level studies that tracked bird communities in urbanizing forested regions (e.g., Bezzel 1985; Horn 1985; Catterall et al. 2010; Biaduń and Żmihorski 2011; Parody et al. 2001; but see Shultz et al. 2012). Urbanizing grasslands and deserts, on the other hand, may instead increase the richness of at least some non-synanthropic species by providing increased access to important limiting factors such as water, food, and nest sites (DeGraff and Wentworth 1986; Marzluff et al. 2001b). As such, when studying the effect that urbanization has on bird communities through time, it is crucial to explore how the community changes and to think critically about how urbanization alters the structural complexity of the environment.

Time since urbanization may also influence the composition of species at a site. Pidgeon et al. (2014) suggest that urbanization influences urban communities in two distinct temporal phases. The initial phase of urbanization increases habitat heterogeneity and provides novel resources, thereby creating more niches for species to occupy and increasing alpha diversity. However, species richness later decreases as housing density and habitat fragmentation increase through time, which extirpate many native species. For example, more recently developed regions in the United States with lower housing densities tend to have a greater diversity of forest-dwelling bird species (Pidgeon et al. 2014). Conversely, older, more developed ecoregions with higher housing densities have fewer species (Bezzel 1985; Pidgeon et al. 2014).

The rate at which urbanization occurs may also influence species richness, with more rapidly urbanizing habitats having lower species diversity. However, most studies ($n = 55$) did not report metrics that could adequately quantify the rate of change in their urban environment. Of those that did, direct comparisons are complicated as there is little consensus on what metrics to report or at what scales. Nonetheless, articles that reported decreased alpha diversity over time appeared to experience greater levels of urbanization per unit time over the course of the study (see Batten 1972; Strohbach et al. 2014) than those that saw no decrease (see Aldrich and Coffin 1980; Jones and Wieneke 2000). As such, this paradigm of decline, with site-specific species richness dropping in response to rapid habitat loss via urbanization, may influence urban bird community composition.

Long-term studies provide compelling data on the dynamic nature of urban bird communities and indicate that temporal forces can have both positive and negative effects. While urbanization fragments natural habitats through time, which negatively influences many species, the maturation of landscaped vegetation or increased access to limiting factors (e.g., food and water) can positively influence others. The end result is often a high degree of turnover in species composition. At times, the species lost are those with more specialized habitat requirements (Aldrich and Coffin 1980; Jones and Wieneke 2000; Strohbach et al. 2014), but this is not always the case (see Shultz et al. 2012). As numerous forces may have time-lagged responses on the current urban bird community, much can be gained from including a temporal component into urban bird studies.

9.3.3 Temporal Studies on Urban Bird Demographic Parameters

Urbanization alters bird communities because species respond differently to human-dominated habitats, and therefore observed patterns in urban bird communities are a direct result of the mechanisms that influence populations of individual species. As such, community- and population-level studies can fit hand in glove, with well-designed population-level studies providing much needed mechanistic understanding to community-level patterns. At the population level, anthropogenic food sources have been cited as one of the most influential factors for urban birds, and long-term studies attribute it to higher breeding densities (Jerzak 2001), colonization rates (Raven and Coulson 1997; Rutz 2008), brood sizes (Gehlbach 1996; Solonen 2008), and survival rates (Gehlbach 1996). Given the large influence that anthropogenic food has on urban bird demography, it is of little surprise that supplemental feeding can have profound effects on urban avian assemblages (Fuller et al. 2007). However, anthropogenic food sources are not always beneficial to urban birds. Western gulls (*Larus occidentalis*) with diets rich in anthropogenic food sources hatch fewer young and breed for fewer years because such food sources may not provide adequate nutrition for nestlings or the formation of eggs during the breeding season (Annett and Pierotti 1999; Pierotti and Annett 2001). Furthermore, urban house sparrows are smaller and have worse body condition because urban nestlings may either receive a poorer diet or anthropogenic food sources allow birds in worse body condition to survive (Liker et al. 2008). While the presence of anthropogenic food sources is more dependent on spatial than temporal factors, long-term studies are able to link demographic parameters to population fluctuations, which is sorely needed in urban bird ecology.

In our review reproductive success was observed to be higher for many urban birds (Sodhi et al. 1992; Gehlbach 1996; Parker et al. 1996; Jerzak 2001; Kauffman et al. 2003; Stout et al. 2007; Solonen 2008). Factors associated to these increased rates indicate that urban areas may provide more stable food sources (Gehlbach 1996; Jerzak 2001; Solonen 2008), nesting conditions (Solonen 2008; Stout et al. 2007), decreased predation (Gehlbach 1996), and at times decreased human persecution (Rutz 2008). These factors may in turn increase clutch sizes, nestling weights, and/or nestling survival rates (Sodhi et al. 1992; Gehlbach 1996; Parker et al. 1996; Kauffman et al. 2003; Stout et al. 2007). However, six of these seven studies were conducted on birds of prey, which limit the generality of this statement, and other reviews have noted that reproductive rates are higher in rural populations of other urban bird species (Chamberlain et al. 2009). Two additional studies we reviewed reported a decrease in urban bird reproductive success (Tella et al. 1996; Pierotti and Annett 2001). Urban lesser kestrels (*Falco naumanni*) delivered prey to nestlings at a lower rate than their rural counterparts, which resulted in greater nestling mortality due to starvation despite the fact that urban nests were predated less (Tella et al. 1996). Western gulls also fledged fewer young at urban colonies due to disturbance caused by workmen and a lack of shelter from the elements for chicks that left the nest (Pierotti and Annett 2001).

While population-level studies were more common than community-level studies (Table 9.1), the vast majority ($n = 38$, 74.51 %) did not report metrics on urban bird demography and primarily tracked the abundance of one or multiple species through time. Many of these studies correlated population trends to environmental factors (e.g., Robinson et al. 2005; Mazgajski et al. 2008; Żmihorski et al. 2010) but were unable to determine the mechanisms that caused these population changes. Long-term studies also did not explore how demographic rates change through time in urban environments and more so used long-term datasets to quantify differences between urban and rural populations. As species composition changes temporally, there is no doubt variation in demographic rates and studies that explore this variation are needed. Given the diversity of species in urban environments and the apparent bias toward studying the demography of birds of prey, there is also a knowledge gap as to what spatial and temporal factors influence species in other guilds.

9.3.4 Long-Term Studies of Rapid and Cultural Urban Bird Evolution

Cities are complex systems, constantly changing, which revise the selective pressures of the landscape over time. In response to this, urban birds tend to have higher rates of behavioral plasticity, the better to mitigate the varied and dynamic costs associated with human-dominated landscapes (Shochat et al. 2010). However, behavioral plasticity alone cannot account for species persistence and adaptation, and the novel abiotic components of the urban landscape can facilitate rapid evolutionary and cultural change in urban bird populations (Able and Belthoff

1998; Yeh and Huang 2009; Brown and Brown 2013). Marzluff's (2012) recent review of urban evolutionary ecology illustrates how urban noise, novel food sources, temperature, and pollution can all exert selective pressure on urban birds, and we encourage those interested in this topic to refer to it for a more detailed overview. However, we would like to emphasize the importance of long-term studies in documenting evolutionary change in urban bird populations, as even the most rapid of changes take considerable time. Thus, we highlight a number of such studies absent from Marzluff's review.

Automobiles are one component of the urban environment that exerts selection on urban birds in both direct and indirect ways, which can in turn alter species morphology and influence cultural evolution (Luther and Baptista 2010; Luther and Derryberry 2012; Brown and Brown 2013). For example, the wingspan of cliff swallows (*Petrochelidon pyrrhonota*) that nest under overpasses along highways has significantly decreased over time, making them more maneuverable and possibly more able to dodge fast-moving cars (Brown and Brown 2013). As a result, the number of road-killed cliff swallows decreased over this 30-year study, while the swallows still hit by cars as the study progressed had significantly longer wingspans than the population at large. Additionally, automobiles can influence urban birds through the noise they generate, and birds have exhibited an increase in song frequency and volume in response (Slabbekoorn and Peet 2003; Halfwerk et al. 2011). However, studies of this nature have typically been conducted across spatial gradients that vary in urban noise, while few have explored this relationship as urban noise increases through time. By comparing 36-year-old recordings of the song frequency and dialects of white-crowned sparrows (*Zonotrichia leucophrys nuttalli*) in San Francisco to their own recordings in the same locations, Luther and Derryberry (2012) confirmed that the minimum frequency of male white-crowned sparrow songs increased. While short-term studies that compare song frequencies of urban and rural bird populations clearly indicate that urban birds sing at higher frequencies, long-term studies conducted on populations over time reveal another equally important facet to this process: behavioral adjustment to urban noise over time influences cultural evolution.

9.3.5 Historical Perspectives in Urban Bird Research

Over the last 20 years, many compelling arguments have been made about the importance of including historical perspectives into ecology, and the subfield of historical ecology has emerged as a result (Egan and Howell 2005; Jackson and Hobbs 2009). Although this field may be relatively new, over 75 years ago, Aldo Leopold (1992) argued that even during his time "...research programs pay too little attention to the history of wildlife... We do not yet appreciate how much historical evidence can be dug up, or how important it can be in the appraisal of contemporary ecology." To add this historical perspective, previous publications are often a useful starting place, and different approaches have been employed to add temporal breadth such as meta-analyses of results from the same geographic region (Bezzel 1985) or revisiting sites from previous studies and comparing results (Strohbach et al. 2014). However, a significant amount of data exists outside of published scientific literature, and a small number of the studies we reviewed incorporated data from nontraditional sources as well.

From newspaper articles and diaries to town records and museum collections, these nontraditional sources can greatly increase the temporal extent of a study and provide information on species abundance, presence, and distribution. The advantages of such historical datasets are great as they may provide baseline conditions before significant human impact and allow ecologists to explore subtle aspects of how humans influence birds over long time spans. Yet, these datasets can be difficult to analyze and interpret because they may be rife with geographic bias and contain reports from multiple observers using different methods, and data from different records likely vary in their grain and extent. Despite these constraints we argue that urban ecological research programs can greatly benefit by including historical perspectives from traditional and nontraditional sources alike.

Perhaps the most unique use of historical records, and by far the longest study we reviewed, is Foster and colleagues' (2002) 175-year study to determine how the physical, biological, and cultural changes within the New England landscape impacted wildlife assemblages. This particular study stands out in comparison to other publications due to the wide variety of sources the authors amalgamated to qualitatively analyze historical trends (e.g., explorers' accounts, museum collection, scientific studies, town records, harvest records, and newspapers). Furthermore, given the duration of this study, the authors were able to identify slow and subtle temporal processes that short-term studies could not.

Birds of prey, for example, have increased throughout New England due to improved cultural attitudes toward them and better water quality, a pattern also seen in other long-term studies that used more traditional methods (Walk et al. 2010; Shultz et al. 2012). Temporal shifts in habitat availability also had a profound influence on species abundance and turnover. While agricultural practices comprised a large proportion of the New England landscape during the mid-1800s, rates of farm abandonment at the time were high as farmers left the region for more fertile land west of the Appalachians (Askins 2002). This, in turn, created large amounts of suitable habitat for many grassland-dependent species, and populations skyrocketed as a result. At the same time, forest cover was at an all-time low, and many forest-dependent species were in decline. Conversely, the opposite pattern is observed today as the previously abandoned farmlands have slowly turned to forest, and grasslands have become less common. Subsequently, grassland-dependent species are now in decline, while a subset of forest-dependent species now thrive in the more abundant, though increasingly fragmented forests of New England (Butcher et al. 1981; Askins 2002; Foster et al. 2002).

Finally, historical records have shown that some species, certainly not all, have successfully adapted to the present landscape. A number of these were introduced, such as the European starling (*Sturnus vulgaris*) or house sparrow, but a few native species also responded favorably [e.g., northern mockingbird, northern cardinal

(*Cardinalis cardinalis*), and American crow (*Corvus brachyrhynchos*)]. This pattern has been observed throughout much of the world, with successful range expansions of invasive and native species alike (Sol et al. 2016). Common examples include the invasion of the common myna (*Acridotheres tristis*) to Australia (Jones and Wieneke 2000), Africa (Peacock et al. 2007), and Singapore (Yap et al. 2002) or the synurbanization of the blackbird throughout Europe (Batten 1978; Luniak and Mulsow 1988; Jerzak 2001). Indeed, historical records are an incredibly useful resource to explore different behaviors and range expansions in urban birds. Raven and Coulson (1997), for example, compiled data from other researchers, volunteers, and local governments to study the tremendous increase in the distribution and abundance of roof-nesting gulls in Britain and Ireland over an almost 30-year time period. While there currently are a small proportion of historical urban ecological studies, such work can greatly advance our knowledge of the long-term patterns and processes that change urban bird populations and communities.

9.3.6 Anthropogenic Change, Management Practices, and Urban Planning

From individual choices made by homeowners (Goddard et al. 2016) to management decisions made by city hall (Heyman et al. 2016; Meffert 2016), the cumulative effects of human decision-making influences bird community composition in complex ways (Alberti 2008; Belaire et al. 2014). Although variation in management practices inherently implies spatial differentiation in habitats, this process is also temporal. For example, the planting of trees in urban yards and parks has a time-lagged influence on birds (Bloom and McCrary 1996; Jones and Wieneke 2000; Jerzak 2001). As such, to better conserve, manage, and study biodiversity in urban areas, ecologists, land managers, policy makers, and conservationists should consider dynamic strategies that account for the rippling effects that current and past actions may have on urban bird communities (Hannah et al. 2002; Millar et al. 2007; Mcdonald et al. 2008).

One increasingly common aspect of city planning that benefits both humans and wildlife is the creation of urban green space (James et al. 2009; Fontana et al. 2011; Fuller et al. 2007; Murgui 2014; Szulczewska et al. 2014; Ferenc et al. 2014). Urban green space can open up the vertical dimension of cities by increasing tree and shrub cover, which over time can simultaneously raise urban bird diversity and people's experience of urban nature (Fontana et al. 2011; Fuller et al. 2007). Given the affinity that many urban bird species have for urban green space, it is unsurprising that city parks are often chosen as the sites for long-term studies. Studies in city parks often observe a general increase in the abundance of woodland-dependent species and a decrease in those that prefer more open habitats (Morneau et al. 1999; Murgui 2014). The shift in species composition in urban parks may be in part due to changes in vegetation structure as planted trees and shrubs increase in size, but other local and regional processes likely influence community structure as well. For example, shifts in urban bird populations may also coincide with population trends at larger spatial scales (Murgui 2014) or in response to increases in supplemental feeding (Morneau et al. 1999).

Long-term studies also indicate that urban green space may provide bird species a somewhat more natural environment, or buffer space, to habituate to urban life over time. Magpies (*Pica pica*), a well-studied and ubiquitous urban species throughout Europe (see Jerzak 2001 and references therein), were largely dependent on city parks for breeding prior to 1970 but have now colonized almost the entirety of inner London (Oliver 1997). In Finland, hooded crows (*Corvus corone cornix*) initially nested in city parks before World War I but now primarily nest in city centers, suburbs, and residential neighborhoods (Vuorisalo et al. 2003). Northern goshawks (*Accipiter gentilis*) in Germany were commonly observed in city parks years before breeding pairs would settle there (Rutz 2008). In this way, city parks and urban green space can function as a stepping stone between the urban wild and the urban core that birds may use to habituate to increasingly urban environments.

Though many of the papers we reviewed contain bountiful information useful for wildlife conservation and management in urban areas, only a small subset of these papers considered the effect of management practices by including it as a variable during statistical analysis or discussing how management practices may have impacted birds throughout the study (e.g., Recher and Serventy 1991; Namba et al. 2010; Heyman et al. 2016). Yet, there is a significant opportunity for applied urban research programs to better incorporate city planning and management into their work which could then benefit researchers, urban planners, and urban bird biodiversity. For instance, predicting how species richness of varying bird guilds changes in response to future levels or patterns of urbanization can have clear and potentially profound implications on proposed policies of urban development and prioritize locations for conservation (Hepinstall et al. 2008). Given that future population growth and urbanization are unavoidable, there is a need for urban bird research to help direct development and sustain biodiversity. This will require work at a variety of spatial and temporal scales, and therefore long-term studies are a necessary component of urban bird conservation.

9.4 Future Contribution from and Challenges with Long-Term Studies

The potential for long-term bird studies is virtually unlimited, but such datasets do provide challenges. One of the most significant issues with long-term datasets is variation in sampling effort and standard protocols (or lack thereof, for a review of bird censusing in urban areas see Van Heezik and Seddon 2016), especially when data collection is discontinuous (for a discussion of this see Strohbach et al. 2014). Because these data can be generated by multiple organizations, it is easy to introduce variation in the observational process through time, which can strongly bias results. Thus, it is important to ensure that historical data are comparable, and assumptions are made explicit as questions, statistical methods, and field techniques change. Here, we recommend a number of guidelines that can make future comparisons possible.

- Be as explicit as possible regarding the observational process. Common issues we observed include authors providing vague information regarding survey effort, number of observers, or the geographical boundaries of their study area. These issues make future comparisons impossible without making serious assumptions about the historical data.
- Include metadata. Datasets can become increasingly complex and large as time progresses. Having an effective "road map" to help interpret a dataset is necessary so others can make use of it in the future.
- Make published datasets accessible. All research is limited by access to data, and promoting an environment that rewards the sharing of high-quality datasets and comprehensive metadata will allow researchers to spend more time on analysis and reuse data meant for different applications.

Other challenges that arise include temporal autocorrelation and non-stationarity. Autocorrelation, or the propensity for single observations to share similarities with other observations, can be introduced temporally via cyclic patterns and trends, and many statistical approaches today can account for this. For example, generalized linear models can include temporal autoregression to address nonindependence in error terms and response variables (Chatfield 2013). Non-stationarity, or stochastic processes with probability distributions that change through time (e.g., climate change), can violate the assumptions in many statistical models if not explicitly addressed (Betancourt 2012). Wolkovich et al. (2014) speak at length on this matter, and we refer readers to their paper and references therein for techniques that address spatial and temporal non-stationarity.

Finally, very often temporal extent is traded for spatial extent in long-term studies. It is understandable that long time series are collected at a small number of sites, but this may preclude the possibility of hypothesis testing in some cases. Clearly, when designing a study with limited resources, it is difficult to simultaneously increase the spatial and temporal extent, and therefore any suggestion to do just that is of little use. Instead, we echo Strayer et al. (1986) and suggest that creating a flexible monitoring protocol allows researchers to study long-term processes while staying productive on the short term. This also forces researchers to maintain their long-term datasets, which should lead to better quality data and a more productive project. While the creation and management of long-term studies is difficult, and requires additional forethought, such datasets can yield many publications when used creatively and collaboratively.

Almost 15 years ago, Marzluff et al. (2001b) suggested that additional long-term bird research was needed, particularly studies that relate demographics to urban bird community composition. Though the number of long-term studies has increased since 2001, we did not identify any studies of this nature. Such studies could be highly beneficial as they would allow ecologists to explicitly test the mechanisms that influence urban bird populations and therefore urban bird communities. Through the union of community- and population-level studies, hypotheses on exactly how urban bird communities assemble, persist, and shift over time may be addressed, and we can determine whether assembly rules are city specific or interface specific or if there exists an "urban wildlife syndrome" that influences all urban environments.

To date, demographic studies have been biased toward large-bodied birds, particularly birds of prey. As smaller-bodied birds (e.g., sparrows, titmice and chickadees, finches, swallows and swifts, etc.) may exist at different densities, use different food sources or nesting structures, and interact with the environment differently, future work exploring population dynamics of smaller species may help illustrate the full suite of impacts that urbanization has on avian fauna. Studies that relate bird diversity and demography to other taxa are sorely needed as well, as the interaction between birds and other species in urban environments has been relatively unexplored. Arthropod abundance and diversity, for example, varies by fragment size, age, and edge proximity in urban environments (Bolger et al. 2000), but empirical studies are needed to quantify how this may affect the foraging ecology, demographics, and abundance of bird species along an urban gradient.

There are clear opportunities for long-term investigations in understudied locations around the world at varying levels of urbanization, especially in Africa and Asia where the urban-wild interface is rapidly changing. Not only would such studies be able to observe how the initial processes of urbanization influences bird populations and communities, they could also be used to determine if results from other geographic regions are applicable in different environments. In conclusion, we encourage ecologists to keep long-term ecological phenomena in mind when constructing short-term studies. As many of the central questions in ecology revolve around predicting the mechanisms responsible for ecosystem responses, long-term studies are critical in that they are the primary way to validate theoretical models to reality (Franklin 1989). The benefit of urban ecological research goes beyond validating theory though, as better understanding bird-habitat relationships is a critical step toward reconciling the impact that urban environments have on wildlife communities.

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Appendix: Long-Term Studies Reviewed

Author	Year published	Study type	Duration (yrs)
Able and Belthoff	1998	Population	37
Abs	2008	Community	43
Aldrich and Coffin	1980	Community	37
Annet and Pierotti	1999	Population	12
Askins and Philbrick	1987	Population	32
Baker	1980	Population	5
Balmori and Hallberg	2007	Population	5
Batten	1972	Community	140
Batten	1973	Population	8
Batten	1978	Population	62
Bell et al.	2010	Population	38
Bezzel	1985	Community	130
Biadun et al.	2009	Community	24
Biadun and Zmihorski	2011	Community	27
Bloom and McCrary	1996	Population	25
Boren et al.	1999	Community	24
Brown and Brown	2013	Population	30
Butcher et al.	1981	Population	23
Cannon et al.	2005	Population	8
Catterall et al.	2010	Community	15
Cramp and Agle	1952	Community	50
Cramp and Tomlins	1966	Community	15
Craves	2009	Community	15
Crosby and Blair	2001	Community	39
Decandio	2008	Population	138
DeGraff and Wentworth	1986	Community	5
DeGraff	1991	Community	5
Dott and Brown	2000	Population	18
Erskine	1992	Population	10
Faccio et al.	2013	Population	20
Fonaroff	1974	Community	8
Forman et al.	2002	Community	5
Foster et al.	2002	Population	175
Gehlbach	1996	Population	16
Hepinstall et al.	2012	Community	7
Herrando et al.	2012	Population	10
Horak and Lebreton	1998	Population	7
Horn	1985	Community	46
Jerzak	2001	Population	15
Jokimäki and Suhonen	1993	Community	20
Jokimäki and Suhonen	2000	Population	6

(continued)

Author	Year published	Study type	Duration (yrs)
Jones and Wieneke	2000	Community	16
Kauffman et al.	2003	Population	24
Kauffman et al.	2004	Population	24
Kentish et al.	1995	Population	24
Kosiński	2001	Population	5
Liker et al.	2008	Population	10
Luther and Baptista	2010	Population	30
Luther and Derryberry	2012	Population	36
Mazgajski et al.	2008	Population	16
Milone and Grotta	1983	Population	18
Morneau et al.	1999	Community	15
Murgui and Macias	2010	Population	11
Murgui	2014	Population	15
Namba et al.	2010	Community	15
Nentwich and Paulus	1999	Population	12
Nihei and Higuchi	2001	Population	20
Nowakowski	1996	Community	25
Oliver	1997	Community	28
Ormond et al.	2014	Community	32
Parker et al.	1996	Population	17
Parody et al.	2001	Community	50
Pidgeon et al.	2014	Community	30
Pierotti and Annett	2001	Population	22
Raven and Coulson	1997	Population	19
Recher and Serventy	1991	Community	58
Robinsin et al.	2005	Population	29
Roth and Johnson	1993	Population	16
Rutz	2008	Population	59
Shultz et al.	2012	Community	94
Sodhi et al.	1992	Population	19
Suhonen et al.	2009	Community	9
Solonen	2008	Population	30
Stout et al.	2007	Population	12
Strohbach et al.	2014	Community	152
Suhonen and Jokimäki	1988	Community	27
Tait et al.	2005	Population	166
Tella et al.	1996	Population	6
Tryjanowski et al.	2013	Community	27
Vuorisalo et al.	2003	Population	81
Walcott	1974	Community	104
Ward et al.	2010	Population	26
Wood and Recher	2004	Population	63
Yeh et al.	2004	Population	19
Zmihorski et al.	2010	Population	26

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