Natural History Note

Strolling through a Century: Replicating Historical Bird Surveys to Explore 100 Years of Change in an Urban Bird Community

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abstract: In 1898, Herbert and Alice Walter started a 5-year survey of birds in Lincoln Park—the largest park in Chicago, Illinois—and summarized their data in an urban birding field guide, *Wild Birds in City Parks*. Twenty-nine years later, William Dreuth compared the relative frequency of species in the Walters' study to that in his own 5-year Lincoln Park survey. Between 2012 and 2015, we replicated these surveys to investigate a century of bird diversity and community composition change in urban Chicago. While species richness did not change, community composition did. We found that (1) species with a greater diet breadth and (2) species that increased in statewide occupancy were more likely to increase in frequency over time. We conclude that factors at multiple scales brought temporal changes to Chicago's bird community. Overall, this survey highlights the slow and subtle ways in which species may respond to a century of urban intensification.

Keywords: long-term population trends, urban habitats, birds, green space, historical data.

Introduction

Since the start of the twentieth century, the proportion of people living in cities has increased from 10% to more than 50% (Seto et al. 2012). As a result, the amount and intensity of urban land cover have increased worldwide (Liu et al. 2018), and it has become undeniable that urbanization negatively influences biodiversity (McDonald et al. 2020). Cities are often located in biodiversity hot spots, and the associated habitat loss caused by urbanization is a major driver of species extirpations or extinctions (McDonald et al. 2008). Yet some nonhuman species persist, and at times thrive, in cities. As such, the selective pressures of urban environments provide an excellent opportunity to investigate ecological processes.

One underexplored process in urban environments is how species composition changes over time. Certainly, long-term comparisons of natural habitat converted to urban land cover demonstrate a decrease in species richness and substantial community turnover as the historically present species are lost and replaced by generalist urban-adapted species (Aldrich and Coffin 1980; Tingley and Beissinger 2013). Yet over 100 years a forest turned suburban lot likely tells a different story than an already urbanized city over the same time frame. As a city continues to urbanize over time, selective pressures likely increase, which can potentially result in a loss of species that cannot persist at higher levels of urban intensity (Pyšek et al. 2004; Aronson et al. 2016; Fidino et al. 2020). If this is the case, we would expect species richness to decrease. Additionally, temporal changes in urban species composition could reflect large-scale temporal shifts in the distribution and abundance of species in the regional pool (Murgui 2014; Ward et al. 2018). If this is the case, species turnover within a city should reflect overall regional trends. Yet while cities have existed for millennia, explorations into their ecology have increased only in recent decades (Magle et al. 2012). As a result, long-term urban ecological data sets are exceedingly rare, making it difficult to explore how long periods of urban intensification shape community composition in a city.

To explore how species composition changes over time in a city, we replicated a historical bird survey conducted at the turn of the twentieth century in Lincoln Park, the largest park in Chicago, Illinois. The original surveyors, Herbert and Alice Walter, surveyed Lincoln Park from

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March to May between 1898 and 1903 and wrote a field guide for city bird-watchers (Walter and Walter 1904). Along with accurate species descriptions, the Walters' book summarized their field notes for future comparison. Unbeknownst to the Walters, their survey was then continued by William Dreuth—a stock clerk, amateur naturalist, and expert birder—between 1927 and 1932 (Clark and Nice 1950). Decades later, one of our colleagues found a copy of the Walters' book in a Chicago antique store, and subsequent investigations into the Walters' survey led us to William Dreuth's original field notes stored in the back halls of the Chicago Academy of Sciences. These discoveries inspired us to continue these Lincoln Park surveys between 2012 and 2015. Our goals were to determine (1) whether this bird community had changed over a century, (2) whether generalist species became more common over time, and (3) whether the temporal trends observed in Lincoln Park mimicked those observed throughout the state of Illinois. The extreme levels of urban intensification that Chicago experienced in the past century make this survey unique. For example, since the Walters' bird counts in 1898, the height of the tallest building in downtown Chicago more than quadrupled, the average human population density doubled, and automobiles replaced horses as a primary mode of transportation (Randall et al. 1999; Sovacool 2009). Although this long-term study is of a single location, which limits our ability to assess general trends, replicating these historical surveys highlights frequency changes of the resident and migrant birds that make up Chicago's avian community and can help clarify the impacts that 100 years of urban intensification may have on species richness and composition.

Methods

Study Area

Lincoln Park is mostly linear and is located along the western shore of Lake Michigan, roughly 4.5 km north of downtown Chicago (fig. 1). Since the original bird survey, the park has increased in size from about 125 ha in 1898 to 481 ha currently (fig. 1), with most new land added to the north of Lincoln Park's original boundary (Clark and Nice 1950; fig. 1). Primarily built for recreation, Lincoln Park has ponds, sports fields, nature areas, and expanses of turfgrass peppered with mature trees and shrubs. These qualities have changed little since 1898. The Lincoln Park Zoo, which lies in the middle of the original park boundaries, was also present across all three survey periods.

Throughout Chicago, temperatures increase from near freezing at the start of the avian migratory season to roughly 15°C by May (NOAA 2019). In March, sunrise begins near 7:30 a.m. and, by May, advances to about 5:00 a.m. Average precipitation between March and May is 24.28 cm (NOAA 2019). Snow is common in March, but sometimes it snows in April (NOAA 2019).

Replicating the Historical Bird Surveys

There was little information on the routes that the Walters and Dreuth walked to count birds. Thus, we assumed that the Walters (1898–1903) did not follow a standard methodology, surveyed the entire park, and counted species by sight and sound because their birding guide included apt descriptions of birds and their songs (Walter and Walter 1904). Dreuth, who surveyed between 1927 and 1933, included the count's date and time as well as the end points of the path traveled in his field notes. Neither historical survey described the path traveled in the park, the distance from the path at which birds were identified, or the speed at which a surveyor walked.

At a minimum, the historical surveys included the number of days per year that the counts were conducted. The Walters averaged 75.66 (min $=$ 66, max $=$ 87) counts per year. Because the Walters included a figure of observed species richness per day between May 7 and 20—a time that they deemed the height of migration—in their birding guide, we assumed that they counted birds each weekday in March and April but every day in May (Walter and Walter 1904). Conducting counts this way results in about 71 counts per year. Dreuth averaged 57.66 (min $=$ 17, max $=$ 85) counts per year.

We replicated these surveys using this information but followed a standard methodology to increase repeatability. We delineated a 2.45-km line transect from the northernmost point to the southernmost point of the original park boundaries (fig. 1). In the past century, many walking paths have not changed. Therefore, we used walking paths whenever possible. To count birds, one trained observer (M. Fidino or K. Limbrick) walked the transect at about 2 km h^{-1} and started roughly 1 h past local sunrise during clear weather. Species were identified by sight and sound within 50 m of the transect. A count's start point was switched daily and started in the north or the south of the park (fig. 1). We conducted counts each weekday of March and April and then daily in May.

Some species were not included in the historical surveys. House sparrows (*Passer domesticus*) were—and still are—abundant in Lincoln Park, but the Walters and Dreuth did not count them. Additionally, even though the Walters provided a list of 31 water- and shorebirds encountered in Lincoln Park during their survey, they excluded gannets and grebes, cranes and rails, ducks and geese, loons, terns and gulls, and pelicans from their counts "due to a lack of sufficient data" (Walter and Walter 1904, p. 42). While we recorded all species encountered in our counts, we were able to compare only with what the historical surveyors recorded.

Figure 1: Map of Lincoln Park (Chicago, IL). We conducted our bird surveys between 2012 and 2015 within the park's original 1865–1910 boundaries.

Statistical Analysis

With the vegan package (ver. 2.5-6) in R (ver. 4.0.3; Oksanen et al. 2019; R Core Team 2020), we estimated α and β diversity for each survey period to quantify (1) whether species richness decreased over time and (2) how similar communities were among survey periods. For the α diversity analysis, we created a community matrix for the three survey periods (1898–1903, 1922–1927, and 2012–2015) with species along the columns and survey years along the rows. If a species was detected in a given survey year, the associated cell would equal 1 in that matrix; otherwise, it was 0. To account for potentially missed species in a survey period and correct for differences in sampling effort, we estimated α diversity from the communities' matrices with rarefaction in vegan, which provides a point estimate of species richness as well as standard errors of the point estimate (O'Hara 2005). To estimate β diversity, we compared proportional similarity in bird communities as 1 minus the Jaccard dissimilarity using the proportion of days a species was observed each year during a given survey period, where a value of 1 would indicate that communities are identical (Legendre and Legendre 2012). To quantify how much variability in community composition the survey period (i.e., 1898–1903, 1922–1927, and 2012–2015) explained, we applied a permutational multivariate ANOVA (PERMANOVA) to the same community matrices that we used to calculate β diversity, treating survey period as a categorical variable (Anderson 2017). Following this, we graphically represented the community each year in multivariate space using nonmetric multidimensional scaling, using the Bray-Curtis index to measure distances among the bird communities for each survey year.

To determine whether, over time, generalist species became more frequent or whether species trajectories reflected statewide trends, we used a binomial generalized linear mixed model (GLMM). Our response variable was the proportion of days a species was observed per year weighted by the number of counts conducted per year. We used this response variable because abundances were not available in the first survey period. We quantified each species' generalist ability by deriving their diet and foraging breadth from a global bird functional trait database (Wilman et al. 2014). For diet breadth we counted the number of different diet categories that each species was known to forage on, which included invertebrates, mammals and birds, reptiles, fish, vertebrates, carrion, fruit, nectar, seeds, or other plant material, such as seedlings, weeds, or lichen ($n = 10$, mean $= 1.6$, min $= 1$, max $= 6$). For foraging breadth, we used the same functional trait database and counted the number of different foraging strategies that a species was known to use, which could include foraging below water, on water, on the ground, in the understory, in the middle to high levels of trees, in the tree canopy, or in the air ($n = 7$, mean $= 2.4$, min $= 1$, max $= 5$). We subtracted 1 from the foraging and diet breadth of each species so that the model intercept represented a species with a foraging and diet breadth of 1. To determine whether changes in species' relative frequency followed statewide trends, we used statewide estimates of the absolute change in occupancy of breeding birds throughout Illinois between 1906 and 2008 (Ward et al. 2018). Statewide frequency data were scaled so that a 1-unit difference represented a 10% change in statewide occupancy. Only 55% of the birds in our analysis were represented in the Ward et al. (2018) data set. Birds not represented, such as nonbreeding birds migrating through our study area, were given a value of 0.

Our GLMM also included survey periods (1898–1903, 1922–1927, and 2012–2015) as categorical variables. We treated the first survey period as the reference category. Given the much longer 85-year span between our own sampling and the middle survey relative to the much shorter 19-year time span between the first and second survey periods, we included only interactions between the 2012–2015 period and the three continuous variables (i.e., diet breadth, foraging breadth, and change in statewide occupancy) to quantify whether the response to these variables changed in the last survey period relative to the other two periods. For the random effect structure of the model, we allowed all three survey periods to vary by species. This model was fitted in version 2.19.1 of Stan (Stan Development Team 2018) using the stan_glmer function in rstanarm (Goodrich et al. 2018). Following a 1,000-step burn-in, the posterior was sampled a total of 24,000 times across six chains. The intercept of the model was given a vague Cauchy$(0, 5)$ prior, while slope terms were given a Cauchy$(0, 2.5)$ prior (Gelman et al. 2008). Some data had to be censored from our GLMM analysis. For example, a species was removed if it was observed in only one of the three survey periods. Likewise, waterbirds, shorebirds, and house sparrows were excluded from this analysis because of their omission from the first survey period. Data for this analysis have been archived in the Dryad Digital Repository (https://doi.org/10.5061/dryad.w3r2280rb; Fidino et al. 2021).

Results

Bird Richness and Similarity

In total, 145 species in 34 families were observed across all survey periods. Birds known to breed in northeastern Illinois represented ~63%, 57%, and 60% of the community for each survey period, ordered from the oldest survey to the most recent. *Parulid* warblers represented the greatest portion of the species pool ($n = 33$ species), followed by New World sparrows in Passerellidae ($n = 19$ species) and blackbirds in Icteridae ($n = 10$ species). After we accounted for potentially missed species, fewer species were observed between 1898 and 1903 (mean $= 118.15$, SE $= 4.87$), while a similar number of species was observed between 1927 and 1932 (mean $= 135.31$, SE $= 6.89$) and between 2012 and 2015 (mean $= 131.22$, SE $= 5.15$). Community composition, as estimated by 1 minus the Jaccard dissimilarity, was most similar between 1898–1903 and 1927–1932 (0.59), which were closer together in time, and most dissimilar between 1898–1903 and 2012–2015 (0.45). Community composition was also dissimilar between 1927–1932 and 2012–2015 (0.48). With the PERMANOVA, the survey period explained 60.06% of the variation in this bird community ($P < .001$; fig. 2). The difference in the 10 most common species per survey period also helps illustrate the shift in community

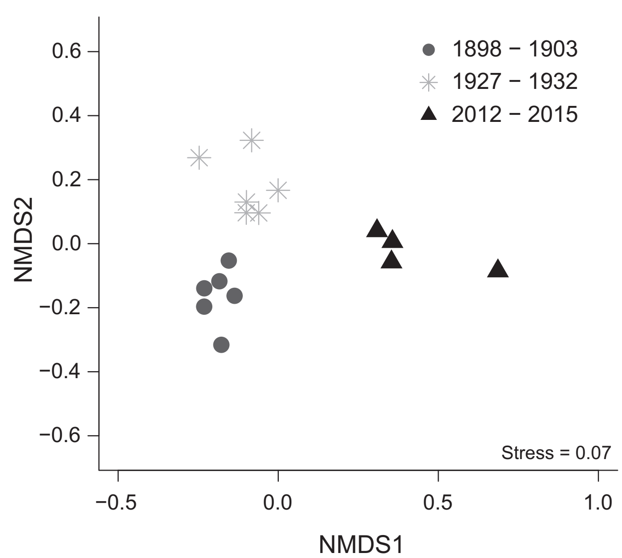

Figure 2: Ordination of the Lincoln Park (Chicago, IL) bird community across all survey years, showing the solution of nonmetric multidimensional scaling (NMDS). Distances among the bird communities each year were measured with the Bray-Curtis index.

composition (table 1). Only the American robin (*Turdus migratorius*) and common grackle (*Quiscalus quiscula*), for example, remained in the 10 most common species across survey periods (table 1).

Species Trends over Time

Of the 145 species observed, 121 could be analyzed with our GLMM. Assuming 70 survey days per year, species were, on average, observed 2.94 days per year between 1898 and 1903 (95% credible interval [CI] = 1.48 to 5.63 days), 4.32 days per year between 1927 and 1932 (95% CI = 2.21 to 8.09 days), and 2.45 days per year between 2012 and 2015 (95% CI = 1.16 to 5.13 days). Species-level variability for each survey period was high around this among-species average and was, respectively, 3.17 (95% CI = 2.41 to 4.20), 1.38 (95% CI = 1.03 to 1.89), and 2.74 (95% CI = 2.16 to 3.50), assuming normally distributed variation on the logit scale.

Table 1: Proportion of days the 10 most common species were observed during each survey period in Lincoln Park (Chicago, IL) between March and May

Period, bird	Proportion of days
1898–1903:	
American robin	.84
Common grackle	.80
Blue jay	.72
Brown-headed cowbird	.56
Dark-eyed junco	.50
Eastern towhee	.47
Song sparrow	.42
Northern flicker	.40
Ruby-crowned kinglet	.38
White-throated sparrow	.37
1927–1932:	
Common grackle	.90
American robin	.71
Northern flicker	.72
Red-winged blackbird	.62
Purple martin	.55
Dark-eyed junco	.51
White-throated sparrow	.50
Brown thrasher	.49
Eastern towhee	.45
Yellow-rumped warbler	.43
2012–2015:	
Red-winged blackbird	.91
European starling	.91
American crow	.89
American robin	.80
Common grackle	.79
Northern cardinal	.76
Song sparrow	.72
Black-capped chickadee	.72
Rock pigeon	.68
Downy woodpecker	.64

Note: Species are listed from most to least frequent. For the 2012–2015 data, all of these species were observed breeding in Lincoln Park during that time.

On their own, a species' diet breadth ($\beta = 0.18$, 95% CI = −0.07 to 0.45) or foraging breadth ($\beta = 0.11$, 95% CI = −0.24 to 0.46) was not associated with changes in a species' frequency. However, species with a greater diet breadth did, on average, increase in frequency over time, as evidenced by the positive interaction term between diet breadth and the third survey period in our GLMM ($\beta = 0.35$, 95% CI = 0.12 to 0.58). With other parameters held constant at zero, species that consumed one diet category were observed on an average of 3.50% of survey days (95% CI = 1.66% to 7.33%) between 2012 and 2015. Conversely, species that consumed three and five different categories were observed on an average of, respectively, 9.50% (95% CI = 5.17% to 16.83%) and 23.34% (95% CI = 9.97% to 44.58%) of survey days between 2012 and 2015. Unlike diet breadth, there was insufficient evidence of an association between foraging breadth and changes in species frequency through time ($\beta = -0.26$, 95% CI = −0.57 to 0.04).

Species that increased in statewide occupancy were, on average, more likely to increase in frequency over time in Lincoln Park, as evidenced by the positive interaction term between the change in statewide trends and the third survey period ($\beta = 0.40$, 95% CI = 0.21 to 0.57). There were some species, however, that increased statewide but became less common in Lincoln Park and vice versa (fig. 2). For example, American crows (*Corvus brachyrhynchos*) decreased in statewide occupancy over time, but their absolute frequency change in Lincoln Park between the historic surveys and our survey was 77.09% (95% CI = 72.11% to 81.32%; fig. 2). Conversely, brown-headed cowbirds (*Molothrus ater*) increased in statewide occupancy, but their absolute frequency change in Lincoln Park between the historic surveys and our survey was −28.30% (95% CI = −22.08% to −34.10%; fig. 2). Overall, of the 121 species analyzed in our GLMM, 58 of them exhibited changes in their observation frequency over time at the $\alpha = 0.95$ level (fig. 3).

Discussion

In one century, Lincoln Park's breeding and migratory bird community has profoundly changed. The rock pigeon (*Columba livia*) and American crow were rare 100 years ago but are now common (table 1). Blue jays were historically common year-round but are now seen only during the migratory season (Walter and Walter 1904). Our analysis of this century of data provided two key results that indicate what factors may be associated with temporal changes in this urban bird community. First, we found that species

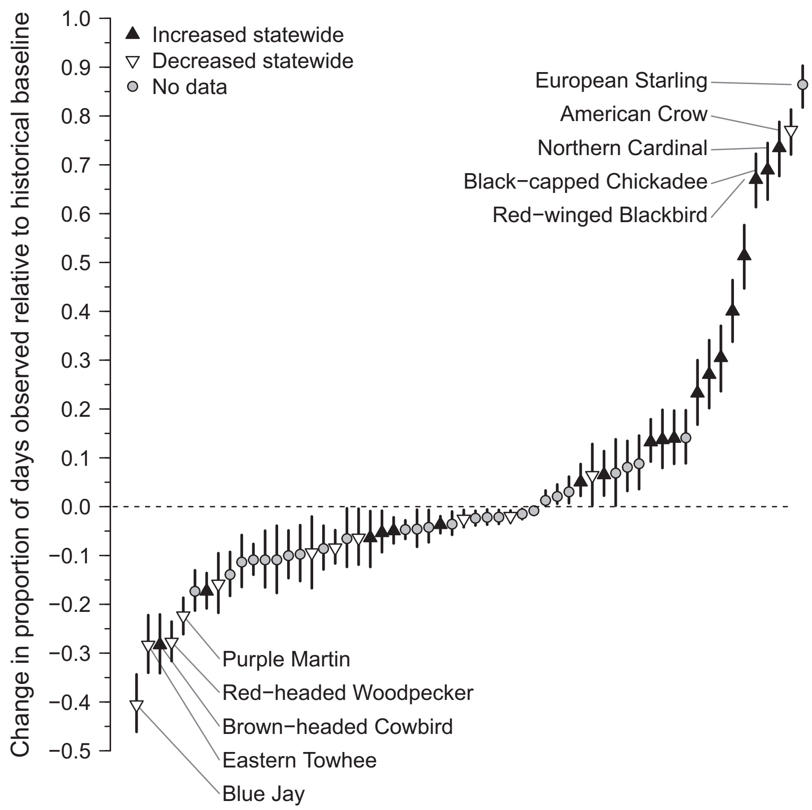

Figure 3: Of the 121 bird species analyzed, 58 had a change in the proportion of days observed in Lincoln Park (Chicago, IL) relative to their historical baseline at an $\alpha = 0.95$ level. Current estimates came from the 2012–2015 sampling period, while historical baselines were the average frequency estimates between the 1898–1903 and 1927–1932 sampling periods. Vertical lines indicate 95% credible intervals, whereas points indicate species-specific median estimates. For reference, we have added a horizontal dashed line at zero that indicates no change in frequency over time. Proportions are on a −1 to 1 scale.

with a more generalist diet were more likely to increase in frequency over time. Second, species that increased in statewide occupancy were also more likely to increase in Lincoln Park. When considered together, these results likely demonstrate that factors at both local and regional scales brought changes to Chicago's bird community.

As urbanization negatively influences local primary productivity (Imhoff et al. 2004) and generalist species are predicted to be favored in areas of low primary productivity (Evans et al. 2005), urban environments are often composed of generalist species (Callaghan et al. 2019, 2020). Our analysis agrees with this observed pattern, although we did observe that the strength of this relationship increased over time. We found that species with a greater diet breadth (i.e., more generalist) became more common in Lincoln Park over the past century, although we cannot causally attribute this result to increased levels of urban intensity. Such a result may indicate that the local selective pressures of the Chicago landscape have changed to favor species able to take advantage of the dynamic, heterogeneous resources a heavily urbanized city provides, and therefore maladapted, nongeneralist species are filtered out at the local scale (Aronson et al. 2016).

Because generalists increased in frequency, we had also expected species richness to decrease, which we did not observe. Instead, we observed substantial community turnover and large shifts in species frequencies yet comparable species richness through time. As other long-term comparisons of urban bird communities have also documented dramatic changes in community composition and species frequency over similar time frames, these patterns are perhaps general rules for urban environments (Major and Parsons 2010; Shultz et al. 2012; Strohbach et al. 2014; Fidino and Magle 2017). One apparent disagreement, however, is how α diversity may change through time, as other long-term studies have shown an increase, a decrease, or no net change in species richness (Fidino and Magle 2017 and references therein). What causes this disagreement may be partly due to the adaptive potential of species in the regional pool. If species are lost, others may take their place, and so the extent to which species can adapt to and colonize urban environments could result in variable differences in α diversity over time (Evans et al. 2009, 2010). In our study, this apparent stability in species richness may be due to the time of year birds were sampled combined with Lincoln Park's size and location along Lake Michigan, which make it an ideal stopover site for migrating birds. In Lincoln Park, migrant birds represented nearly one-third of the observed bird community during this study, and given the park's size and location, it is therefore likely to see a high diversity of birds during the migratory season. Nevertheless, while richness may not have changed over time, we do conclude that, as in other urban environments, the Lincoln Park bird community has become largely dominated by a small number of common urban-adapted species (table 1; McKinney 2006) but otherwise is peppered with an impressive array of species migrating through.

We also observed that, on average, species that increased in statewide occupancy increased in frequency in Lincoln Park. We attribute this to several regional changes throughout northern Illinois over the past century. For example, the landscape in northern Illinois, where Chicago resides, has become more forested and urban between 1898 and 2015, which benefited some birds (Walk et al. 2010). Northern cardinals and red-bellied woodpeckers were rare in northern Illinois but expanded their range northward for increased forest cover (Walk et al. 2010). Both species are now common in Lincoln Park. The black-capped chickadee—a common cavity nester of Illinois's deciduous or mixed forests—was historically rare in Lincoln Park but became the seventh most frequent species (table 1). While we attribute most of the chickadee's success to Illinois's increased forest cover, its increased presence may also be because large older parks like Lincoln Park offer a high density of natural cavities that chickadees nest in (LaMontagne et al. 2015; Bovyn et al. 2019). Other urban-tolerant species, like the chimney swift (*Chaetura pelagica*), European starling (*Sturnus vulgaris*), American robin, and common grackle, have become more ubiquitous statewide (Ward et al. 2018). In Lincoln Park, these species either increased in frequency or remained common through time (table 1; fig. 1). As such, many differences in the Lincoln Park migratory community reflect statewide population trends over the past century.

While Illinois is fortunate to have a long-term statewide bird survey (Walk et al. 2010), Chicago was added to this bird census only in the 2000s. In fact, few cities have historical ecological records, possibly because they have long been regarded as inadequate habitats for wildlife (Fidino and Magle 2017). This is unfortunate, not only because large urban green spaces offer significant resources for migratory birds (Brawn and Stotz 2001) but also because many species persist in cities. In the face of dramatic urban intensification, we did not see a decrease in species richness. In fact, species richness may have slightly increased over time. We did see, however, a dramatic change in community composition over a century, whereby the community generally became dominated by species that had increased statewide, had a greater diet breadth, or both. Replicating historical surveys—like these—can provide insights into long-term community changes that would be impossible for a single naturalist to carry out. We hope that our efforts in standardizing and compiling these data across surveys will be useful for others and may encourage a future naturalist to replicate the survey again—but perhaps in less than 75 years.

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Statement of Authorship

M.F. and S.B.M. conceptualized and developed the study. M.F., K.L., and J.B. collected data. M.F. analyzed the data. T.G. and M.F. made figure 1. M.F. made figures 2 and 3. S.B.M. acquired funding and supervised. M.F. wrote the original draft of the manuscript, and all coauthors substantially contributed to manuscript revisions.

Data and Code Availability

All data and code can be found at https://github.com/mfidino/historic_birds (https://doi.org/10.5281/zenodo.4916872; Fidino 2021).

Literature Cited

Aldrich, J. W., and R. W. Coffin. 1980. Breeding bird populations from forest to suburbia after thirty-seven years. American Birds 34:1–5.

Anderson, M. J. 2017. Permutational multivariate analysis of variance (PERMANOVA). Wiley StatsRef: Statistics Reference Online. https://doi.org/10.1002/9781118445112.stat07841.

Aronson, M. F. J., C. H. Nilon, C. A. Lepczyk, T. S. Parker, P. S. Warren, S. S. Cilliers, M. A. Goddard, et al. 2016. Hierarchical filters determine community assembly of urban species pools. Ecology 97:2952–2963.

Bovyn, R. A., M. C. Lordon, A. E. Grecco, A. C. Leeper, and J. M. LaMontagne. 2019. Tree cavity availability in urban cemeteries and city parks. Journal of Urban Ecology 5:juy030.

Brawn, J. D., and D. F. Stotz. 2001. The importance of the Chicago region and the "Chicago Wilderness" initiative for avian conservation. Pages 509–522 *in* J. M. Marzluff, R. Bowman, and R. Donnelly, eds. Avian ecology and conservation in an urbanizing world. Springer, Boston.

Callaghan, C. T., Y. Benedetti, J. H. Wilshire, and F. Morelli. 2020. Avian trait specialization is negatively associated with urban tolerance. Oikos 129:1541–1551.

Callaghan, C. T., R. E. Major, J. H. Wilshire, J. M. Martin, R. T. Kingsford, and W. K. Cornwell. 2019. Generalists are the most urban-tolerant of birds: a phylogenetically controlled analysis of ecological and life history traits using a novel continuous measure of bird responses to urbanization. Oikos 128:845–858.

Clark, C. T., and M. M. Nice. 1950. William Dreuth's study of bird migration in Lincoln Park, Chicago. Chicago Academy of Sciences, Chicago.

Evans, K. L., K. J. Gaston, A. C. Frantz, M. Simeoni, S. P. Sharp, A. McGowan, D. A. Dawson, et al. 2009. Independent colonization of multiple urban centres by a formerly forest specialist bird species. Proceedings of the Royal Society B 276:2403–2410.

Evans, K. L., J. J. Greenwood, and K. J. Gaston. 2005. Dissecting the species–energy relationship. Proceedings of the Royal Society B 272:2155–2163.

Evans, K. L., B. J. Hatchwell, M. Parnell, and K. J. Gaston. 2010. A conceptual framework for the colonisation of urban areas: the blackbird *Turdus merula* as a case study. Biological Reviews 85:643–667.

Fidino, M. 2021. Code from: Strolling through a century: replicating historical bird surveys to explore 100 years of change in an urban bird community. American Naturalist, Zenodo, https://doi.org/10.5281/zenodo.4916872.

Fidino, M., T. Gallo, E. W. Lehrer, M. H. Murray, C. A. M. Kay, H. A. Sander, B. MacDougall, et al. 2020. Landscape-scale differences among cities alter common species' responses to urbanization. Ecological Applications 31:e02253.

Fidino, M., K. Limbrick, J. Bender, T. Gallo, and S. B. Magle. 2021. Data from: Strolling through a century: replicating historical bird surveys to explore 100 years of change in an urban bird community. American Naturalist, Dryad Digital Repository, https://doi.org/10.5061/dryad.w3r2280rb.

Fidino, M., and S. B. Magle. 2017. Trends in long-term urban bird research. Pages 161–184 *in* E. Murgui and M. Hedblom, eds. Ecology and conservation of birds in urban environments. Springer, Cham.

Gelman, A., A. Jakulin, M. G. Pittau, and Y. S. Su. 2008. A weakly informative default prior distribution for logistic and other regression models. Annals of Applied Statistics 2:1360–1383.

Goodrich, B., J. Gabry, I. Ali, and S. Brilleman. 2018. rstanarm: Bayesian applied regression modeling via Stan. R package version 2.17.4. https://mc-stan.org/rstanarm.

Imhoff, M. L., L. Bounoua, R. DeFries, W. T. Lawrence, D. Stutzer, C. J. Tucker, and T. Ricketts. 2004. The consequences of urban land transformation on net primary productivity in the United States. Remote Sensing of Environment 89:434–443.

LaMontagne, J. M., R. J. Kilgour, E. C. Anderson, and S. B. Magle. 2015. Tree cavity availability across forest, park, and residential habitats in a highly urban area. Urban Ecosystems 18:151–167.

Legendre, P., and L. F. Legendre. 2012. Numerical ecology. Vol. 24. Elsevier, Amsterdam.

Liu, X., G. Hu, Y. Chen, X. Li, X. Xu, S. Li, P. Fengsong, and S. Wang. 2018. High-resolution multi-temporal mapping of global urban land using Landsat images based on the Google Earth Engine platform. Remote Sensing of Environment 209:227–239.

Major, R. E., and H. Parsons. 2010. What do museum specimens tell us about the impact of urbanisation? a comparison of the recent and historical bird communities of Sydney. Emu 110:92–103.

Magle, S. B., V. M. Hunt, M. Vernon, and K. R. Crooks. 2012. Urban wildlife research: past, present, and future. Biological Conservation 155:23–32.

McDonald, R. I., P. Kareiva, and R. Forman. 2008. The implications of urban growth for global protected areas and biodiversity conservation. Biological Conservation 141:1695–1703.

McDonald, R. I., A. V. Mansur, F. Ascensão, K. Crossman, T. Elmqvist, A. Gonzalez, B. Güneralp, et al. 2020. Research gaps in knowledge of the impact of urban growth on biodiversity. Nature Sustainability 3:16–24.

McKinney, M. L. 2006. Urbanization as a major cause of biotic homogenization. Biological Conservation 127:247–260.

Murgui, E. 2014. Population trends in breeding and wintering birds in urban parks: a 15-year study (1998–2013) in Valencia, Spain. Revista Catalana d'Ornitologia 30:30–40.

NOAA (National Oceanic and Atmospheric Administration). 2019. National Weather Service data. Accessed June 25, 2019. https://www.weather.gov/.

O'Hara, R. B. 2005. How many species can dance on the head of a pin? Journal of Animal Ecology 74:375–386.

Oksanen, J., F. G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P. R. Minchin, et al. 2019. vegan: community ecology package. R package version 2.5-6. https://CRAN.R-project.org/package=vegan.

Pyšek, P., Z. Chocholousková, A. Pyšek, V. Jarošík, M. Chytrý, and L. Tichý. 2004. Trends in species diversity and composition of urban vegetation over three decades. Journal of Vegetation Science 15:781–788.

Randall, F. A., F. H. Randall, and J. D. Randall. 1999. History of the development of building construction in Chicago. University of Illinois Press, Chicago.

R Core Team. 2020. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.

Seto, K. C., B. Guneralp, and L. R. Hutyra. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences of the USA 149:16083–16088.

Shultz, A. J., M. W. Tingley, and R. C. K. Bowie. 2012. A century of avian community turnover in an urban green space in Northern California. Condor 114:258–267.

Sovacool, B. K. 2009. Early modes of transport in the United States: lessons for modern energy policymakers. Policy and Society 27:411–427.

Stan Development Team. 2018. The Stan core library. Version 2.18.0. http://mc-stan.org.

Strohbach, M. W., A. Hrycyna, and P. S. Warren. 2014. 150 years of changes in bird life in Cambridge, Massachusetts from 1860 to 2012. Wilson Journal of Ornithology 126:192–206.

Tingley, M. W., and S. R. Beissinger. 2013. Cryptic loss of montane avian richness and high community turnover over 100 years. Ecology 94:598–609.

Walk, J. W., M. P. Ward, T. J. Benson, J. L. Deppe, S. A. Lischka, S. D. Bailey, and J. D. Brawn. 2010. Illinois birds: a century of change. Special publication no. 31. Illinois Natural History Survey, Champaign.
Walter, H. E., and A. H. Walter. 1904. Wild birds in city parks: hints on identifying 145 birds, prepared primarily for the spring migration in Lincoln Park, Chicago. A. W. Mumford, Chicago.
Ward, M. P., K. W. Stodola, J. W. Walk, T. J. Benson, J. L. Deppe, and J. D. Brawn. 2018. Changes in bird distributions in Illinois, USA, over the 20th century were driven by use of alternative rather than primary habitats. Condor 120:622–631.
Wilman, H., J. Belmaker, J. Simpson, C. de la Rosa, M. M. Rivadeneira, and W. Jetz. 2014. EltonTraits 1.0: species-level foraging attributes of the world's birds and mammals. Ecology 95:2027.

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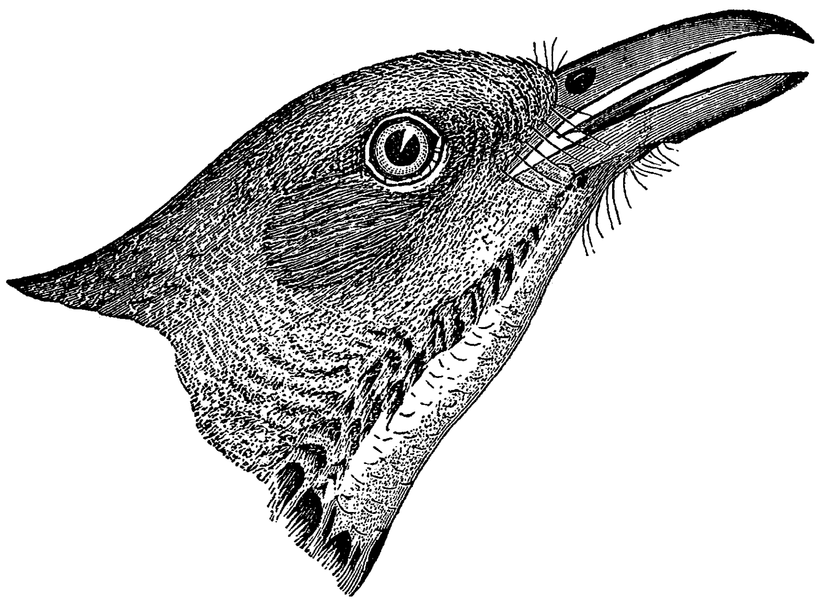

"Almost every one knows the Brown Thrush, or Thrasher (*Harporhynchus rufus*) of the Eastern United States—an abundant and familiar inhabitant of shrubbery, and a spirited songster, with some talent for mimicry." From "Some United States Birds, New to Science, and Other Things Ornithological" by Elliott Coues (*The American Naturalist*, 1873, 7:321–331).