**Title:** Strolling through a century: replicating historical bird surveys to explore 100 years of change in an urban bird community

**Short title:** Century of birding

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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, IL – 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 between the Walter’s study to their 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 significantly change, community composition did. Of the 121 species frequencies analyzed, 32 increased [e.g., red-winged blackbird (*Agelaius phoeniceus*)] and 22 decreased [e.g., red-headed woodpecker (*Melanerpes erythrocephalus*)]. Our observations mostly reflect the last century’s statewide population trends, though differences from these trends likely indicate varied species-specific responses to urbanization. Overall, this survey highlights the slow and subtle ways in which bird species may respond to urbanization.

# Introduction

1. Humans have altered biodiversity a whole bunch due to landscape change (cities!) . However, a lot of these explorations have been comparisons of what was there historically to what currently inhabits a city. Examples. While cities have been around for millenia, relatively little is known how community composition may change within a over time.
2. It could be that the community composition is subject to processes at larger spatial scales. If that is the case then regional changes in species composition should reflect what is observed within a city. It could be that as a city continues to urbanize the selective pressures continue to hone down which species may succeed. Most urban species are generalists, and so over time we may expect those who have a larger diet breadth, perhaps are larger, or use more foraging stratagies would become more common. As the city itself continues to change, the selective pressures may continue to be exacerbated!
3. We explored this using historical data in Chicago for birds. We blah blah blah blah…

Since the start of the 20th century the proportion of people living in cities has increased from 10% to over 50% (Citation). To facilitate humankinds’s shift towards urban life the amount and intensity of urban land cover has greatly increased (Citation). Over this same time frame the largely negative influence urbanization has on biodiversity has become undeniable. Cities are, after all, often located in biodiversity hotspots and the associated habitat loss that comes along with urbanization is a primary driver of WHAT I’M TRYING TO SAY IS THAT SPECIES GO LOCALLY EXTINCT. Yet,

A forest turned suburb in the last 100 years likely tells a different story than a major metropolitan city over the same time frame.

As forests became suburbs and suburbs became cities, the influence that urbanization has on biodiversity is undeniable. understanding how biodiversity responds to an ever-urbanizing world has become a major research topic (Citation).

Not only are cities generally located in biodiversity hotspots (citation), the probability a species is listed as endangered by the IUCN is higher for species with a greater perfe

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Historical bird surveys are relatively common and can be replicated to explore temporal changes in bird diversity and community composition over time (Igl and Johnson 2005, Fidino and Magle 2017). Tingley et al. (2013), for example, resurveyed locations that Joseph Grinnell surveyed between 1911 and 1929 in the Sierra Nevada mountains of California, USA and found that bird species richness decreased over a century. Further, urbanization at lower elevations caused substantial community turnover as birds better suited for human-modified habitats replaced those that were not (Tingley et al. 2013). Similarly, by replicating a century old survey throughout Illinois, USA, Ward et al. (2018) demonstrated that many bird species increased their statewide occupancy by adapting to urban habitats. Overall, the insights gained from such studies would be near impossible without historical data for comparison. Historical surveys can serve as a key reference point for current ecological inquiries, especially because long-term studies disproportionately add to our understanding of how species respond to environmental change (Hughes et al. 2017).

We replicated a historical survey to investigate a century of change in the urban bird community at Lincoln Park, the largest park in Chicago, IL, USA. The original surveyors, Herbert and Alice Walter, surveyed Lincoln Park from March to May between 1898 and 1903 and wrote a field guide for city bird watchers (Walter and Walter 1904). Along with species descriptions, the Walter’s book summarized their field notes for future comparison. The Walter’s survey was then continued by William Dreuth – a stock clerk and amateur naturalist – between 1927 and 1932 (Clark and Nice 1950). Decades later, a colleague found a copy of The Walter’s book in a Chicago antique store, and subsequent investigations into the Walter’s survey led us to William Dreuth’s original field notes 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) how this bird community changed over a century and 2) if the temporal trends observed in Lincoln Park mimic those observed throughout Illinois. The extreme levels of urbanization Chicago experienced in the last century make this survey unique. Since the Walter’s 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 (Randall et al. 1999, Sovacool 2009). Replicating these historical surveys highlights frequency changes of the resident and migrant birds that comprise Chicago’s avian community across 100 years of urbanization in a large metropolitan city.

# Methods

## Study Area

Lincoln Park is mostly linear and located along the western shore of lake Michigan, roughly 4.5 km north of downtown Chicago (Figure 1). The park has increased in size since the original bird survey from about 125 ha in 1898 to 481 ha currently (Figure 1). The land added has been north of Lincoln Park’s original boundary (Clark and Nice 1950; Figure 1). Primarily built for recreation, Lincoln Park has ponds, sports fields, nature areas, and expanses of turf grass 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 migratory season to roughly 15 °C by May (NOAA 2019). In March, sunrise begins near 7:30 AM and, by May, advances to about 5:00 AM. Regarding precipitation, snow is common in March. Sometimes it snows in April (NOAA 2019).

## Replicating the historical bird surveys

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

At a minimum, historical surveys included the number of days per year 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 in their birding guide – a time they deemed the height of migration – we assumed 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 the available information but followed a standard methodology to increase repeatability. We delineated a 2.45 km line-transect from the northern-most point to the southern-most point of the original park boundaries (Figure 1). In the last century, many walking paths have not changed. Therefore, we used walking paths whenever possible. To count birds, one trained observer (Author’s initials) walked the transect at about 2 km hour-1 and started roughly one hour 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 (Figure 1). We conducted counts each weekday of March and April and then daily in May. This protocol more so replicates the Walter’s survey. We did this because their book was the basis for our survey. Lincoln Park birders made us aware of Dreuth’s survey after our surveys began.

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. The Walters also excluded gannets and grebes, cranes and rails, ducks and geese, loons, terns and gulls, and pelicans, from their counts. Dreuth documented all species but the house sparrow. While we recorded all species encountered on our counts, we were only able to compare with what the historical surveyors recorded.

## Statistical analysis

Because abundances were not available from the first survey, we used the proportion of days species were observed per year as an index of relative frequency. This metric is comparable within but not between species (Royle and Nichols 2003). We calculated alpha diversity during each survey period as the number of species observed. We compared proportional similarity in bird communities as 1 – Jaccard dissimilarity using the proportion of days a species was observed each survey period (Legendre and Legendre 2012).

We used binomial generalized linear models (GLM) to determine if a species frequency changed between survey periods. 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 survey period (1898 – 1903, 1922 – 1927, and 2012 – 2015) as categorical variables in each species model. We then used analysis of deviance to determine statistical differences between survey periods (α ≤ 0.05, Dalgaard 2005). If a difference was observed, we calculated pairwise contrasts between survey periods with the Tukey multiple comparison test, which adjusts P-values to correct for multiple testing (Dalgaard 2005). Based on pairwise differences between three survey periods, a species could follow one of 13 possible temporal trends. For example, a species could have similar frequency in the first two survey periods followed by a higher frequency in the last survey period or could monotonically decrease in frequency from the first to the third survey. Following Shultz et al. (2012) we placed these 13 patterns into five groups. Thus, a species occurrence frequency through time could 1) not change, 2) monotonically increase, 3) monotonically decrease, 4) be highest on the second survey period (mid-best) or 5) be lowest on the second survey period (mid-worst).

Some data had to be censored from our GLM analysis. For example, a species’s data was censored if they were only observed in one of the three survey periods, but were included if they were observed in at least two of the three survey periods. Likewise, waterbirds, shorebirds, and house sparrows were excluded from this analysis due to their omission from the first survey period. Analyses were done in R version 3.5.3 (R core team 2019) with the vegan package (Oksanen et al., 2019) to calculate proportional similarity and the emmeans package for Tukey multiple comparison tests (Lenth 2019).

# Results

## Bird richness and similarity

In total, 145 species in 34 families were observed across all survey periods. *Parulid* warblers represented the greatest portion of the species pool (n = 33 species), followed by New World sparrows in *Passerelidae* (n = 19 species), and blackbirds in *Icteridae* (n = 10 species). Overall, fewer species were observed between 1898 – 1903 (n = 114 species), while an equal number of species were observed between 1927 – 1932 (n = 127) and 2012 – 2015 (n = 127, Figure 2). Community composition as estimated by 1 – 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). Only the American robin (*Turdus migratorius*) and common grackle (*Quiscalus quiscula*) remained in the 10 most common species across survey periods (Table 1).

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| **Table 1.** The proportion of days the 10 most common species were observed during each survey period in Lincoln Park, Chicago, IL, USA between March to May. Species are listed from most to least frequent. The proportion of days a species was observed per survey period follows their name. | | |
| 1898 – 1903 | 1927 – 1932 | 2012 – 2015 |
| American Robin – 0.84 | Common Grackle – 0.90 | Red-winged Blackbird – 0.91 |
| Common Grackle – 0.80 | American Robin – 0.71 | European Starling – 0.91 |
| Blue Jay – 0.72 | Northern Flicker – 0.72 | American Crow – 0.89 |
| Brown-headed Cowbird – 0.56 | Red-winged Blackbird – 0.62 | American Robin – 0.80 |
| Dark-eyed Junco – 0.50 | Purple Martin – 0.55 | Common Grackle – 0.79 |
| Eastern Towhee – 0.47 | Dark-eyed Junco – 0.51 | Northern Cardinal – 0.76 |
| Song Sparrow – 0.42 | White-throated Sparrow – 0.50 | Song Sparrow – 0.72 |
| Northern Flicker – 0.40 | Brown Thrasher – 0.49 | Black-capped Chickadee – 0.72 |
| Ruby-crowned Kinglet – 0.38 | Eastern Towhee – 0.45 | Rock Pigeon – 0.68 |
| White-throated Sparrow – 0.37 | Yellow-rumped Warbler – 0.43 | Downy Woodpecker – 0.64 |

## Species trends over time

Of the 145 species detected, 121 could be analyzed with a binomial GLM. We failed to detect a change in the occurrence frequency of 35 species (Figure 2). Of these, 19 species were common across all survey periods – being detected on more than 5% of days per survey period – while 16 were consistently rare, being detected on less than 5% of days per survey period (Figure 2). The American robin, a representative example of a common species who has not changed in occurrence frequency, were observed on 84% (80.72–87.74%) of days across survey periods. Of the rare species in this category, golden-winged warbler (*Vermivora chrysoptera*) were observed on less than 1% of days. Nine species were least frequent during the 1927 – 1933 survey (i.e., mid-worst). Notable species in this category are the American crow (*Corvus brachyrhynchos*) and black-capped chickadee (*Poecile atricapillus*), who greatly increased in frequency between 2012 – 2015 relative to other periods (Figure 2). From the oldest to most recent survey American crow were observed on 14.76% (11.78–18.33%), 8.38% (5.89–11.80%), and 89.36% (84.73-92.71%) of days. Chickadees followed a similar pattern and were observed on 3.96% (2.51–6.20%), 0.57% (0.14 – 2.28%), and 71.91% (65.83–77.29%) of days across surveys.

Twenty-three species were most prevalent during the second survey (i.e., mid-best; Figure 2). Common grackle, for example, were observed on 90.46% (86.88–93.14%) of days between 1927–1933 but only observed on 79.52% (75.55–82.98%) of days during the first and third survey period. Over the last century, a total of 22 species became less common (Figure 3). Blue jay precipitously declined over time from the oldest to most recent survey and were observed on 71.37% (67.03–75.33%), 40.46 (35.41–45.72%), and 15.74% (11.63–20.98%) of days. Eastern bluebird (*Sialia sialis*) followed a similar pattern and were observed on 33.04% (28.86–37.50%), 11.56% (8.59–15.38%), and 2.55% (1.15–5.57%) of days from the oldest to most recent survey. Conversely, yellow-bellied sapsucker (*Sphyrapicus varius*) started their decline after the second survey and were observed on 31.06% (26.97–35.47%) of days during the first two surveys but only on 17.45% (13.11–22.84%) of days between 2012–2015.

Thirty-two species became more frequent over time (Figure 2). Some species monotonically increased. For example, the proportion of days red-winged blackbirds were observed increased from 5.27% (3.57 – 7.76%) in 1898-1903 to 62.14 % (53.91 – 67.10%) in 1927-1932 and then up to 91.49% (87.18 – 94.44%) in 2012-2015. From the oldest to most recent survey northern cardinal (*Cardinalis cardinalis*) were observed on 0.22% (0.03 – 1.54%), 4.62% (2.85 – 7.41), and 76.17% (70.31 – 81.19%) of days. Other species increased in frequency between 1927-1932 and 2012-2015 (Figure 2). American goldfinch (*Spinus tristis*), for example, were historically observed on 20.93% (17.43–24.91%) of days in 1898-1903 and 1927-1932. By 2012-2015, however, the proportion of days observed more than doubled to 47.66% (41.34–54.49%). Similar to the American goldfinch, downy woodpecker (*Picoides pubescens*) were observed on 13.22% (10.40 – 16.65%) of days during the first two surveys, but their frequency more than quadrupled to 63.83 % (57.50 – 69.72%) of days between 2012-2015.

# 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 jay were historically common year-round but are now only seen during the migratory season (Walter and Walter 1904). These changes, however, are probably not related to Lincoln Park itself – even after 100 years many walking paths, ponds, and plantings remain relatively unchanged. Moreover, Lincoln Park is one of many stopover sites for migrant birds, and therefore community turnover could arise from habitat alteration at larger spatial scales. If this is the case, our results should reflect statewide bird population trends. They largely do (Walk et al. 2010, Ward et al. 2018), though there are some key differences.

The Northern Illinois landscape, where Chicago resides, has become more forested and urban between 1898 and 2015, which benefited some birds (Walk et al. 2010). Northern cardinal and red-bellied woodpecker were rare in Northern Illinois but expanded their range northward due to increased forest cover (Walk et al. 2010). Both species are now common in Lincoln Park (Figure 2). The black-capped chickadee – a common cavity nester of Illinois’ deciduous or mixed forests – was historically rare in Lincoln Park but became the 7th most frequent species (Table 1). While we attribute most of the chickadee’s success to Illinois’ increased forest cover, 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 (Figure 2). Thus, many differences in the Lincoln Park migratory community reflect statewide population trends over the last century, especially for Illinois breeding birds.

The red-winged blackbird was one species whose frequency change in Lincoln Park did not reflect statewide population trends. In Lincoln Park, the blackbird had one of the greatest frequency increases over time. In Illinois, however, red-winged blackbird populations remained plentiful and stable for at least a century (Walk et al. 2010). But it is not blackbird abundance that has changed over time so much as where they are seen. Historically, red-winged blackbirds were marsh specialists and rarely observed in urban green spaces such as Lincoln Park (Ridgway 1889, Walter and Walter 1904). Now – owing to the loss of 90% of Illinois marsh and wetland habitat in the last century – the species nests along roadsides and in agricultural fields, upland habitats, and urban green space (Walk et al. 2010). Red-winged blackbirds began nesting in Lincoln Park, for example, during the second survey period (1927 – 1933) and continue to do so today (Clark and Nice 1950). Thus, the blackbird’s adaptive capacity helped it transition from rare during the first survey period to the most common species between 2012–2015 (Table 1). Other marsh specialists such as the yellow-headed blackbird (*Xanthocephalus xanthocephalus*), unfortunately, do not share the red-winged blackbird’s adaptive ability and have become less abundant with the loss of Illinois’ wetlands and marshes (Ward et al. 2010).

About 20% of the species analyzed decreased in frequency over time. The blue jay decreased in frequency despite stable or increasing populations in Illinois (Walk et al. 2010). As a common suburban bird, 100 years of urbanization around Lincoln Park may have pushed the blue jay to Chicago’s less urban periphery (Walk et al. 2010). Red-headed woodpeckers (*Melanerpes erythrocephalus*) also decreased which reflects statewide population trends (Walk et al. 2010). Other decreases may result from methodological differences between surveys. Common nighthawks (*Chordeiles minor*), for example, were seen on the first two survey periods but not on our own. At dusk, nighthawks are common in Lincoln Park, but we never observed the species on morning counts. Thus, it could be that historical surveyors counted birds at different times of day than we did. Despite possible methodological differences across surveys these results share many similarities to statewide trends, which likely indicates these data could be used for future comparisons.

While Illinois has historical statewide bird surveys (Walk et al. 2010), Chicago was only added to the bird census in the 2000s. In fact, few cities have historical ecological records, possibly because they have long been regarded as inadequate habitat for wildlife (Fidino and Magle 2017). This is unfortunate as large urban green space not only offer significant resources for migratory birds (Brawn and Stotz 2001); many species persist in cities. In the face of dramatic urbanization, 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 (Table 1). Replicating historical surveys – like these – can provide a glimpse into community changes over time, which is critical on our rapidly changing. We hope that our efforts in standardizing and compiling these data across surveys will be useful for others in the future and may encourage a future naturalist to replicate the survey again – but perhaps in less than 75 years.

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Figure legends

Figure 1. A map of Lincoln Park in Chicago, IL. We conducted our bird surveys between 2012-2015 within the park’s original boundaries.

Figure 2. Trends observed in the number of days species were observed during the migratory season throughout Lincoln Park through time as supported by the GLM analysis. Trends are represented as ball-and-stick graphics which fall into 5 major categories: no change in frequency, frequency highest or lowest between 1927 – 1932, or monotonic increases or decreases across the three time periods birds were surveyed. Dots in the ball-and-stick graphics represent the three time periods bird counts were conducted while their relative vertical placement describe how frequency has or has not changed between periods, where higher relative placement indicates higher frequency for a given time period. Birds in which no change was detected are further classified into ‘abundant’ (a) or ‘rare’ (r), the latter being species who were detected on less than 5% of days each year.