# Introduction

Long-term ecological research is important albeit rarer and less funded than short-term but spatially expansive research (Likens, 1989, Hughes et al. 2017). This contrast between temporal and spatial ecology research may arise from a key difference between space and time: space can be manipulated over many scales while time cannot be fundamentally changed (Wolkovich et al. 2014). Certainly, the relative timing of events can be modified (Verhulst & Nilsson 2007, Vanette & Fukami 2014), but it is impossible to alter time absolutely. Thus, increasing temporal extent either requires the time to do so or, if available, historic data for comparison.

Fortunately, historic bird surveys are somewhat common and can be recreated to explore temporal changes in bird diversity and community composition over long times spans and often before significant human development has occurred (Igl and Johnson 2005, Fidino and Magle 2017). Tingley et al. (2013), for example, resurveyed locations along an elevation gradient in the Sierra Nevada mountains of California, USA that Joseph Grinnell originally surveyed between 1911 and 1929. Species richness decreased over this century throughout the Sierra Nevada mountains. Further, urbanization at low elevations resulted in high levels of community turnover as birds better suited for human-modified habitats replaced those that were not (Tingley et al. 2013). Similarly, by recreating a century old survey throughout Illinois, USA, Ward et al. (2018) showed that bird species who increased their use of urban habitats over time are now more common statewide. These studies, and many others, demonstrate how essential historical surveys are to evaluate changes in bird populations through time (Igl and Johnson 2005 and references therein).

We investigated a century of change in bird community composition and diversity during the migratory season in Lincoln Park, Chicago, IL, USA by recreating a historic survey. The original surveyors, Herbert and Alice Walter, walked the park between 1898 and 1903 and wrote a field guide for the city birder (Walter, 1904). Along with general species descriptions the Walter’s book summarized their field notes for future comparison. The Walter’s survey was then continued by William Dreuth who surveyed species in Lincoln Park during the migratory season between 1927 and 1932 (Clark and Nice, 1950). We continued this survey 80 years later between 2012 and 2015. Unlike other historical comparisons that primarily focus on breeding birds (Fidino and Magle 2017), this data set is unique as allows a glance into the migratory community over time at a major migratory stopover site along Lake Michigan.

# 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 largest park in Chicago, Lincoln Park has increased in size since the original bird survey from roughly 125 ha to 481 ha (Figure 1). The land added to Lincoln Park has been north of its original boundary, and the southern end has remained at North Avenue since the park was created (Clark and Nice, 1950). Primarily made for recreation, Lincoln Park has multiple ponds, sports fields, nature areas, and expanses of turf grass peppered with mature trees and shrubs. These qualities have mostly remained unchanged 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 (Table 1). In March, sunrise begins near 7:30 AM and advances to roughly 5:00 AM by May. Regarding weather, snow is common in March. Sometimes it snows in April.

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| Table 1. Average Temperature (°C) on the three months birds were surveyed in Lincoln Park, Chicago, IL, USA. Values in parentheses are average monthly minimum and maximum temperature during a survey period. | | | |
| Survey period | March | April | May |
| 1898 – 1903 | 1.88 (-1.67 – 4.72) | 8.11 (6.88 – 10.00) | 14.22 (12.28 – 15.44) |
| 1927 – 1933 | 2.90 (-1.05 – 6.28) | 8.92 (7.05 – 10.61) | 14.45 (13.11 – 16.22) |
| 2012 – 2015 | 3.50 (-0.17 – 11.94) | 9.39 (8.28 – 10.39) | 16.58 (15.78 – 18.67) |

## Recreating the historical bird surveys

There is little information about the paths historic surveyors walked to count birds. Because many historic bird surveys at the time of the first survey focused on specimen collection rather than observation (CITATION), we assume the Walter’s did not follow a standard methodology and simply walked the park between 1898 – 1903, documenting the species they encountered by sight and sound (Walter 1904). Dreuth, the surveyor between 1927 – 1933, included in his field notes the date, time, and end points of the path traveled for each count. Both historic surveys did not describe the specific path traveled in the park, the distance at which birds were identified from the travelled path, or the speed at which a surveyor walked.

At a minimum, both historic surveys included the number of days per year counts were conducted during the migratory season. Between 1898 – 1903, an average of 75.66 (min = 66, max = 87) counts happened per year. This number is roughly equal to counting birds each weekday in March and April and then every day in May. Because the Walter’s 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 arranged their counts this way (Walter 1904). Between 1927 – 1933, an average of 57.66 (min = 17, max = 85) counts were conducted per year.

Some species were not included in the historic surveys. Although house sparrows (*Passer domesticus*) were and still are abundant throughout Lincoln park, both the Walter’s and Dreuth did not count them. The Walter’s also excluded ‘water and shore birds’ from their counts, which they classified as gannets and grebes, cranes and rails, waterfowl such as ducks and geese, loons, and shorebirds such as terns and gulls, and pelicans. Save for the house sparrow, Dreuth documented all species present during the second survey.

We made our best attempt to recreate these surveys but followed a standard methodology to increase repeatability. To mimic a walk through Lincoln park, we delineated a 2.45 km line-transect from the northern-most point to the southern-most point of the original park boundaries. Because many of the walking paths in the park have not moved in a century, we chose to walk them whenever possible (Figure 1). To count birds, one trained observer (MF or KL) walked the transect at a steady rate, 2 km hour-1, and started roughly one hour past local sunrise during clear weather. All birds were identified by sight and sound within 50 m of the transect. A count’s start point was switched each day, either starting in the north or the south of the park. Counts were conducted each weekday during March and April and then every day in May. This protocol is closer to the Walter’s 1898 – 1903 survey, which only occurred within the original park boundaries and occurred in similar frequency. Their book was the original basis for this study and we only became aware of Dreuth’s second survey from birders in the park while we conducted our counts.

## Statistical analysis

Because abundances were not available from the first survey we used the proportional days species were observed each year as an abundance index, which is a metric that is comparable within but not between species (Royle and Nichols 2003). We calculated alpha diversity across the three surveys as the number of unique species observed each survey period. We compared proportional similarity in bird communities as 1 – Jaccard dissimilarity using the proportional days a species was observed during each survey period.

We used binomial generalized linear models (GLM) to determine if a species frequency changed between survey periods. Our response variable was the proportional 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 the independent variables in each species model. After fitting the GLM to a species’ data we conducted an analysis of deviance to determine if there were differences between survey periods (α ≤ 0.05). 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. Based on the pairwise differences between survey periods, a species could follow one of 13 possible trends over time. For example, a species could have similar frequency in the first two survey periods followed by a higher frequency in the last survey period. Following Shultz (2012) we group these 13 patterns into five groups. Through time, a species occurrence frequency could either 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). Species were only analyzed with a binomial GLM if they were observed across a minimum of two survey periods.

Water and shorebirds were excluded from all analyses due to their omission from the first survey period. House sparrows were excluded for the same reason. 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 (CITATION).

# Results

## Bird richness and similarity

Excluding water and shorebirds, 145 species in 34 families were observed across all survey periods. *Parulid* warblers represented the greatest portion of this pool at 33 species, followed by New World sparrows in *Passerelidae* (n = 19), and blackbirds in *Icteridae* (n = 10). Fewer species were observed between 1898 – 1903, while an equal number of species were observed in the last two survey periods (Figure 2). Community composition was most similar between the first two survey periods, which were closer together in time, and most dissimilar between the first and third survey periods (Figure 2). Only two species, the American robin (*Turdus migratorius*) and common grackle (*Quiscalus quiscula*), remained in the 10 most common species across survey periods (Table 2). Conversely, the red-winged blackbird (*Agelaius phoeniceus*) was historically rare but is now the most commonly observed species in Lincoln Park (Table 2). Blue jay (*Cyanocitta cristata*) were historically common in Lincoln Park but are now rarely seen.

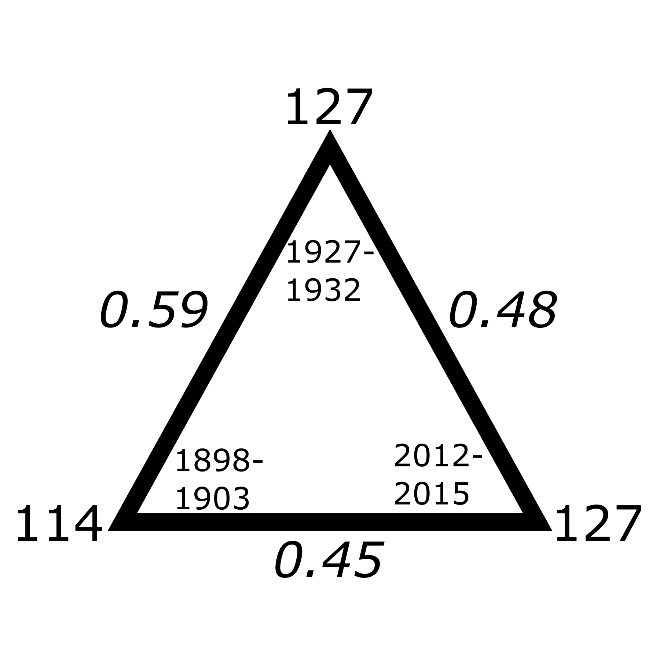


Figure 2. Alpha and beta diversity between survey periods in Lincoln Park, Chicago, IL, USA. Alpha diversity for a survey period is located on the edges of the triangle while proportional similarity (1 – Jaccard’s dissimilarity) between survey periods is along the edges.

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| **Table 2.** The proportional 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 proportional days a species was observed per survey period follows their name. | | |
| 1898 – 1903 | 1922 – 1927 | 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, 121 could be analyzed with a binomial GLM. We failed to detect a change in frequency for 35 species (Figure 3). Of these, 19 species were common across all survey periods, being detected on more than 5% of days per survey period, while 16 were rare (Figure 3). Of the common species, American robin were observed on 84% (80.72–87.74%) of days across survey periods. Of the rare species, golden-winged warbler (*Vermivora chrysoptera*) were observed on less than 1% of days. Nine species were least frequent between 1927 – 1933 (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 the other survey periods (Figure 3). 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 the same 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 common during the second survey (i.e., mid-best; Figure 3). While common across all survey periods, common grackle were observed on 90.46% (86.88–93.14%) of days between 1927–1933 and 79.52% (75.55–82.98%) of days during the first and third survey period. A total of 22 species became less common over the last century (Figure 3). Blue jay precipitously declined over time 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 per year across survey periods. 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 across the three surveys. Conversely, yellow-bellied sapsucker (*Sphyrapicus varius*) declined in recent years and was 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 3). This includes species the northern cardinal (*Cardinalis cardinalis*), red-winged blackbird, and European starling (*Sturnus vulgaris*). Swallows and new world sparrows were also commonly observed in this category (Figure 3). American goldfinch (*Spinus tristis*) have also become more common during the migratory season and were historically observed on 20.93% (17.43–24.91%) of days during the first two surveys but 47.66% (41.34–54.49%) of days between 2012–2015.

# Discussion

This pattern may be universal as many long-term studies report on the relationship between urbanization and temporal shifts in community composition (Fidino and Magle 2017 and references therein).

Lincoln Park’s migratory community has substantially changed over the last century. However, this community turnover is not likely related to Lincoln Park itself but instead to changes at larger spatial scales. We believe this for a few reasons. First, Lincoln Park is one of many stopover sites for migratory birds and these results could therefore arise from a habitat alteration along a species migratory route over time. Second, save for recent native plantings along Lincoln Park’s south pond, the landscape design within Lincoln Park’s original boundaries is relatively unchanged. As a result, community turnover over the last 100 years likely had little to do with the park itself. Third, our results share many similarities to Illinois bird population trends over the last 100 years (Walk et al. 2010, Ward et al. 2018). Thus, these data likely reflect how birds have responded to a changing Illinois landscape over the last century.

The landscape throughout Northern Illinois, where Chicago resides, has become considerably more forested and urban in the last 100 years which benefits some bird species (Walk et al. 2010). For example, northern cardinal and red-bellied woodpeckers were rarely observed in northern Illinois in the early 1900s but have expanded their range northward due to increased forest cover (Walk et al. 2010). In their initial surveys, the Walter’s only observed the cardinal once in 1900. Now, both species nest in Lincoln Park and were commonly seen during our surveys (Figure 3). Black-capped chickadee, another species that benefitted from increased forest cover, was the 7th most common species during our survey (Table 2). While we attribute most of the chickadee’s success to increased forest cover at least part of their increased presence may be due bird houses we had placed in the park to study the species during the time of our survey (Bender et al. 2016). Other urban tolerant species such as the chimney swift (*Chaetura pelagica*), mourning dove (*Zenaida macroura*), European starling, American robin, or common grackle have either increased in frequency throughout the Park or remain common (Figure 3), which is similar to what Walk et al. (2010) have observed throughout the rest of Illinois.

The red-winged blackbird had one of the greatest increases in frequency of all species throughout this 100-year survey. While this species has always been abundant throughout Illinois, they were not generally found in urban environments in the early 1900s (Walter 1904, Walk et al. 2010). Instead, the species was predominately found in the historically abundant wetlands and marshes throughout Illinois (Ridgway 1889). With the loss of over 90% of Illinois marsh and wetland habitat (CITATION), the red-winged blackbird adapted to a variety of new habitats over the last century and now nests throughout Lincoln Park around the numerous ponds. As a result, the blackbird was the most commonly observed species throughout our survey, though it was only observed a handful on times during the first survey period.

Some species have become less common in Lincoln Park as well. Historically present year-round in Lincoln Park (Walter 1904), the blue jay has decreased in frequency even though it has a stable population throughout Illinois (Walk et al. 2010). As a common suburban bird throughout Illinois, we suggest that urbanization surrounding the park has pushed this blue jay to the less urban periphery of Chicago over the last century (Walk et al. 2010). Red-headed woodpeckers (*Melanerpes erythrocephalus*) have also seen a marked decrease from when the first two surveys occurred, which reflects populations trends for this species throughout Northern Illinois (Walk et al. 2010). Other decreases may be the result of methodological differences between surveys. While we have observed common nighthawks (*Chordeiles minor*) at dusk throughout Lincoln Park when they are most active, we never detected them on our morning counts. As these species were historically observed in the park, it could be that the historic surveyors conducted counts at varying times.

A change in attitudes towards species such as crows and hawks may be why their frequency has increased throughout Lincoln Park. Historically, these species were seen as vermin and frequently persecuted. Now, most Illinois residents indicate they would like to hawk numbers, for example, to increase or stay the same (Walk et al. 2010). While the data was excluded from our own analysis, the previous park surveyors did not detect Cooper’s hawks (*Accipiter cooperii*) in Lincoln Park. In recent decades this species has become more urban adapted and is now one the most common hawk species throughout Chicago (McCable et al. 2018). On our survey we commonly detected Cooper’s hawks and observed multiple nesting pairs between 2012–2015. American crow, another historically persecuted species that was rarely seen in Lincoln Park, have greatly increased in frequency and were seen on 89% of days during our survey. Thus, the changes we observed not only reflect changes in the landscape over a century but may also be related to changes in attitudes towards birds as well.

CONCLUSION

If this survey is picked up again in 50 years, we suggest wearing a hat. Not only does it shield your eyes from the sun, it also protects your head from the bountiful male blackbirds that defend their nesting territory throughout Lincoln Park.

Hats were commonly worn during our survey, not to shield ones eyes from the sun, but more so to protect ones head from the many territorial male blackbirds defending their breeding habitat.

Historically, the species predominately nested in marshland habitat throughout Illinois when marshland was abundant (Ridgway 1889).

However, with a loss in marshland habitat this species began nesting in a variety of different habitat types, from agricultural fields to roadsides

northern cardinal and red-bellied woodpeckers expanded their breeding range northward

are two species who benefitted from increased forest cover and

were not present in Northern Illinois a century ago and therefore were

the landscape throughout Northern Illinois, where Chicago resides, has become considerably more forested and urban in the last 100 years. This landscape modification benefits some bird species but challenges others (CITATION). If the differences we observed are related to Illinois’ changing landscape, then our results would likely track Illinois birds who have become more common or rare in the last century.

For species that breed in Illinois who have become more common or rare in the last century

If the differences we observed are related to Illinois’ changing landscape, then our results likely reflect

species that breed in Illinois who have become more common or rare in the last 100 years would likely be reflected

Because many of the features within the original boundaries of Lincoln Park have remained the same over the last century, the turnover we observed is likely related to landscape changes at spatial scales much larger than Lincoln Park itself. We believe this is the case because many of the

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Some species have remained common, such as the common grackle and American Robin, while others have become less common And while these trends are only from a single location, the temporal shifts we observed have many similarities to those seen statewide over the last 100 years (Walk et al. 2011). For example, we observed increases in forest dwelling species such as red-bellied woodpeckers (*Melanerpes carolinus*) and northern cardinal. These two species were historically rare in northern Illinois, where Chicago resides, but have become more common in the last 50 years because the northern portion of Illinois has greatly increased the amount of forested land since the 1920’s (Walk et al. 2011

Temporal turnover of a bird community is a commonly observed pattern of long-term bird studies in urban areas (Fidino and Magle 2017 and references therein), and this result agrees with that research.

Illinois’ landscape has significantly

It is not surprising that compositional changes in the bird community occurred over a century. Furthermore, while these trends are only from a single park, the temporal changes we observed have many similarities to those seen statewide over the last 100 years (Walk et al. 2011).

Illinois’ landscape

In fact, this pattern may be universal in human-modified environments (Fidino and Magle 2017 and references therein).

and many long-term bird studies conducted in urban environments report ambiguous shifts in p However, the temporal differences observed throughout Lincoln Park closely track those seen statewide over the last 100 years (Walk et al. 2011)

In urban avian ecology, long-term studies of bird diversity demonstrate several patterns as green space urbanizes over time.

while the number of species observed in urban green space over time may increase (Abs and Bergen 2008), decrease (Catterall et al. 2010, Pidgeon et al. 2014, Strohbach et al. 2014), or not change at all (Jones and Wieneke 2000, Shultz et al. 2012), species composition does change (Aldrich and Coffin 1980, Jones and Wieneke 2000, Strohbach et al. 2014).

long-term studies are rare but increasing (Fidino and Magle 2017),. At the community level, long-term studies typically monitor breeding birds in urban green space over time as the surrounding environment urbanizes. Some temporal trends in bird diversity in urban green spacestudies are unclear. For example, as green space urbanizes over time alpha diversity can increase (Abs and Bergen 2008), decrease (Catterall et al. 2010, Pidgeon et al. 2014, Strohbach et al. 2014), or not change at all (Jones and Wieneke 2000, Shultz et al. 2012). Yet, while the total number of species may not change as urbanization increases, species composition does (Aldrich and Coffin 1980, Jones and Wieneke 2000, Strohbach et al. 2014). Reasons for temporal shifts in species composition include climate change (Travis 2003), maturation of landscaped vegetation (Jones and Wieneke 2000, Gleditsch 2016), the spread of invasive species (Foster et al. 2002), or habitat loss (Tait et al. 2005, Walk et al. 2010).

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