**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

**Authors:** Mason Fidino1,\*, Kelvin Limbrick2, John Bender3, Travis Gallo4, and Seth B. Magle1

1. Urban Wildlife Institute, Lincoln Park Zoo, 2001 N Clark Street, Chicago, IL, 60614
2. KELVIN PUT WHAT YOU WANT HERE.
3. Lincoln Park Zoo, 2001 N Clark Street, Chicago, IL, 60612
4. Department of Environmental Science and Policy, George Mason University, 4400 University Dr. Fairfax, VA 22030

\* *Corresponding author*: [mfidino@lpzoo.org](mailto:mfidino@lpzoo.org)

**Manuscript type:** Natural History Miscellany

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

# Abstract

In 1898, Herbert and Alice Walter began a 5-year survey of birds in Lincoln Park – the largest park in Chicago, IL – and summarized their data in a field guide on urban birding titled ‘Wild Birds in City Parks’. Twenty-nine years later, William Dreuth conducted his own 5-year survey through Lincoln Park to compare the relative frequency of different bird species between the Walter’s survey and his own. We replicated The Walter and Dreuth historical surveys between 2012 and 2015 to investigate how bird diversity and community composition changed in urban Chicago over a century. We found that while species richness did not significantly change through time, community composition did. Of the 121 species analyzed, 32 increased in frequency [e.g., red-winged blackbird (*Agelaius phoeniceus*), European starling (*Sturnus vulgaris*), American crow (*Corus brachyrrhynchos*)] and 22 species decreased in frequency [e.g., red-headed woodpecker (*Melanerpes erythrocephalus*), eastern bluebird (*Sialia sialis*), and blue jay (*Cyanocitta cristata*)]. While the changes observed throughout Lincoln Park largely reflect statewide bird population trends over the last 100 years, differences likely reflect varied species-specific responses to a century of urbanization throughout Chicago. Overall, this survey highlights the slow and subtle ways in which bird species may respond to urbanization.

# Introduction

Historical bird surveys are relatively common and can be replicated to explore temporal changes in bird diversity and community composition over long time spans (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) showed that many bird species became more common statewide by adapting to urban habitats. Overall, the insights gained from such studies would be near impossible without historical data for comparison. Therefore, 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 of the urban bird community in Lincoln Park, the largest park in Chicago, IL, USA. The original surveyors, Herbert and Alice Walter, walked Lincoln Park from March to May between 1898 and 1903 and wrote a field guide for city bird watchers (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 – a stock clerk and amateur naturalist – between 1927 and 1932 (Clark and Nice, 1950). Years 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 findings inspired us to continue these Lincoln Park surveys between 2012 and 2015. Our goals were to determine 1) which species increased or decreased over this century and 2) if the temporal trends observed in Lincoln Park mimic those observed throughout Illinois. Unlike other historical surveys, this one is unique given the extreme levels of urbanization Chicago experienced in the last century. 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 horses have been replaced by automobiles (Randall et al. 1999, Sovacool 2009). Although Chicago has become more urban it remains a critical stopover site for migrant birds as it lies along a major migratory flyway (Brawn and Stotz 2001). Replicating these historical surveys allowed us to observe changes in the frequency of the resident and migrant birds that make up the 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 largest park in Chicago, Lincoln 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 while the southern end has remained at North Avenue since the park was created (Clark and Nice 1950; Figure 1). Primarily built 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 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. Like the rest of Chicago, the area surrounding Lincoln Park itself has dramatically urbanized in the last century.

Throughout Chicago, temperatures increase from near freezing at the start of the migratory season to roughly 15 °C by May (WEATHER CITATION). 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 and likely walked the entire park and counted species by sight and sound (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 (FIGURE?). Neither historical survey described 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 historical surveys included the number of days per year counts were conducted during the migratory season. Between 1898 – 1903, 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 usually counted birds each weekday in March and April but every day in May (Walter 1904). Conducting counts in this fashion would result in about 71 counts per year. Between 1927 – 1933, Dreuth conducted an average of 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. 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 (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 (MF or KL) walked the transect at a steady rate, 2 km hour-1, and started about one hour past local sunrise during clear weather. All bird species were identified by sight and sound within 50 m of the transect. A count’s start point was switched each day and started in the north or the south of the park (Figure 1). Counts were conducted each weekday of March and April and then every day in May. This protocol is closer to the Walter’s 1898 – 1903 survey, which occurred within the original park boundaries at similar frequency. Their book was the original basis for this study as we were only made aware of Dreuth’s second survey from Lincoln Park birders after we began conducting our surveys.

Finally, 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 ‘water and shore birds’ from their counts, which they classified as gannets and grebes, cranes and rails, waterfowl such as ducks and geese, loons, shorebirds such as terns and gulls, and pelicans. During the second survey, Dreuth documented all species but the house sparrow. While we recorded all species encountered in 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 abundance. 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. After fitting the GLM to a species’s data we used analysis of deviance to determine 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 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 or could monotonically decrease in frequency from the first to the third survey. Following Shultz (2012) we placed these 13 patterns into five groups. Thus, a species occurrence frequency through time 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).

Some data had to be censored from our GLM analysis. For example, a species data was censored if they were only observed in one of the three survey period 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

A total of 146 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 a near equal number of species were observed between 1927 – 1932 (n = 127) and 2012 – 2015 (n = 126). 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 (0.47). Community composition was also dissimilar between 1927 – 1932 and 2012 – 2015 (0.49). Only two species, the American robin (*Turdus migratorius*) and common grackle (*Quiscalus quiscula*), remained in the 10 most common species across survey periods (Table 1).

|  |  |  |
| --- | --- | --- |
| **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 frequency of occurrence for 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 frequency of occurrence, 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 the other survey 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 common 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%). The downy woodpecker (*Picoides pubescens*) followed a similar pattern to the goldfinch and were observed on 13.22% (10.40 – 16.65%) of days during the first two surveys but then 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 and present year-round but are now rare and only seen during the migratory season (Walter 1904). These changes, however, are probably not related to the 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 has benefited some birds (Walk et al. 2010). Northern cardinal and red-bellied woodpecker, for example, were rare in Northern Illinois but have 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 common species (Table 1). While we attribute most the chickadee’s success to Illinois’ increased forest cover, some of their increased presence may be because large older parks like Lincoln Park offer a high density of natural cavities that chickadees use to nest (LaMontagne et al. 2015; Bovyn et al. 2019). Additionally, we also noted a significant increase in the relative frequency of chickadee’s following 2013 due to the installation of 20 artificial cavities for a different study in the southern half of Lincoln Park, which likely increased the proportion of days we observed this species on our survey (Bender et al. 2016). Other urban tolerant species like the chimney swift (*Chaetura pelagica*), European starling (*Sturnus vulgaris*), American robin, and common grackle have become more common statewide (Ward et al. 2018). In Lincoln Park these species either increased in frequency or remained common through time (Figure 2). Thus, many of the 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 have not increased and have remained high 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 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 2). 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 since the first two historical surveys, which reflects statewide population trends (Walk et al. 2010). Other decreases may be 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.

Attitude changes towards some species over time may also help explain why their frequency has increased in Lincoln Park. Historically, hawks were persecuted and viewed as vermin. Now, most Illinois residents indicate they would prefer hawk populations to increase or stay the same, which implies a shift in positive attitudes towards such species (Walk et al. 2010). For example, Cooper’s hawks (*Accipiter cooperii*) were not observed by previous park surveyors, but the species has colonized much of Chicago in the last few decades (McCabe et al. 2018). On our own surveys, we detected the species numerous times per year and observed multiple nesting pairs. Though statewide habitat changes through time likely accounts for much of the observed differences, a decrease in persecution could also aid species that were historically disliked.

While Illinois is fortunate to have high quality 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 city parks like Lincoln Park not only offer significant resources for migratory birds (Brawn and Stotz 2001); many species nest throughout the park as well. Though Chicago has become dramatically more urban over the last century, 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, and we suspect the historical surveyors would be surprised to see species like the chickadee, cardinal, and crow ranked in the top 10 most common species of our survey (Table 1). Replicating historical surveys – like these – can provide a glimpse into community changes over long time spans, which is critical on a planet that is changing so rapidly.

The data that we generated, if combined with other sources, can likely be used to answer a variety of questions about bird population trends. For example, it would be interesting to relate changes in frequency to functional differences between species. Such an analysis would not only highlight the species that have been successful over time, but what aspects of their natural history facilitated their success. 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.

Acknowledgements

We would like to thank the Chicago Academy of Sciences for archiving William Dreuth’s original field notes, D. Roberts for giving us access to those field notes, and A. Sacerdote-Velat for finding the Walter’s book on birding in Lincoln Park in an antique store. These comparisons may not have been possible without them. We also acknowledge the work of the previous surveyors, A. Walter, H. Walter, and W. Dreuth. Finally, if there is someone who resumes this survey again in the future, we thank you for taking up the mantle and suggest you wear a hat. Not only does it shield your eyes from the sun, it also protects your head from the bountiful male blackbirds that now defend their nesting territory throughout Lincoln Park.

References

Bovyn, R. A., Lordon, M. C., Grecco, A. E., Leeper, A. C., & LaMontagne, J. M. (2019). Tree cavity availability in urban cemeteries and city parks. *Journal of Urban Ecology*, *5*(1), juy030.

Brawn, J. D., & Stotz, D. F. (2001). The importance of the Chicago region and the “Chicago Wilderness” initiative for avian conservation. In *Avian ecology and conservation in an urbanizing world* (pp. 509-522). Springer, Boston, MA.

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

Dalgaard, P. (2005). *Introductory Statistics with R*. Springer.

Hughes, B. B., Beas-Luna, R., Barner, A. K., Brewitt, K., Brumbaugh, D. R., Cerny-Chipman, E. B., ... & Figurski, J. D. (2017). Long-term studies contribute disproportionately to ecology and policy. *BioScience*, *67*(3), 271-281.

Igl, L. D., & Johnson, D. H. (2005). A retrospective perspective: evaluating population changes by repeating historic bird surveys. *USGS Northern Prairie Wildlife Research Center*, 49.

Lenth, Russel (2019). emmeans: Estimated Marginal Means, aka Least-Squares Means. R packageversion 1.3.5. <https://CRAN.R-project.org/package=emmeans>

LaMontagne, J. M., Kilgour, R. J., Anderson, E. C., & Magle, S. (2015). Tree cavity availability across forest, park, and residential habitats in a highly urban area. *Urban ecosystems*, *18*(1), 151-167.

Legendre, P., & Legendre, L. F. (2012). *Numerical ecology* (Vol. 24). Elsevier.

Likens, G. E. (1989). *Long-term studies in ecology*. New York etc.: Springer.

McCabe, J. D., Yin, H., Cruz, J., Radeloff, V., Pidgeon, A., Bonter, D. N., & Zuckerberg, B. (2018). Prey abundance and urbanization influence the establishment of avian predators in a metropolitan landscape. *Proceedings of the Royal Society B*, *285*(1890), 20182120.

National Oceanic and Atmospheric Administration [NOAA]. 2019. National weather service data <https://www.weather.gov/>. Accessed 25 June 2019.

Jari Oksanen, F. Guillaume Blanchet, Michael Friendly, Roeland Kindt, Pierre Legendre, Dan McGlinn, Peter R. Minchin, R. B. O'Hara, Gavin L. Simpson, Peter Solymos, M. Henry H. Stevens, Eduard Szoecs and Helene Wagner (2019). vegan: Community Ecology Package. R package version 2.5-4. <https://CRAN.R-project.org/package=vegan>

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

Royle, J. A., & Nichols, J. D. (2003). Estimating abundance from repeated presence-absence data or point counts. *Ecology*, 42, 203-206.

Socolar, J. B., Epanchin, P. N., Beissinger, S. R., & Tingley, M. W. (2017). Phenological shifts conserve thermal niches in North American birds and reshape expectations for climate-driven range shifts. *Proceedings of the National Academy of Sciences*, *114*(49), 12976-12981.

Sovacool, B. K. (2009). Early modes of transport in the United States: Lessons for modern energy policymakers. *Policy and society*, *27*(4), 411-427.

Strayer, D. L., Eviner, V. T., Jeschke, J. M., & Pace, M. L. (2006). Understanding the long-term effects of species invasions. *Trends in ecology & evolution*, *21*(11), 645-651.

Tingley, M.W., and S. R. Beissinger. 2013. [*Cryptic loss of montane avian richness and high community turnover over 100 years.*](http://www.esajournals.org/doi/pdf/10.1890/12-0928.1) *Ecology* 94:598–609

Vannette, R. L., & Fukami, T. (2014). Historical contingency in species interactions: towards niche‐based predictions. *Ecology Letters*, *17*(1), 115-124.

Verhulst, S., & Nilsson, J. Å. (2007). The timing of birds' breeding seasons: a review of experiments that manipulated timing of breeding. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1490), 399-410.

Walter, H. E., & Walter, A. H. (1904). *Wild Birds in City Parks: Hints on Identifying 145 Birds, Prepared Primarily for the Spring Migration in Lincoln Park, Chicago*. AW Mumford.

Ward, M. P., Semel, B., & Herkert, J. R. (2010). Identifying the ecological causes of long-term declines of wetland-dependent birds in an urbanizing landscape. *Biodiversity and conservation*, *19*(11), 3287-3300.

Ward, M. P., Stodola, K. W., Walk, J. W., Benson, T. J., Deppe, J. L., & Brawn, J. D. (2018). Changes in bird distributions in Illinois, USA, over the 20th century were driven by use of alternative rather than primary habitats. *The Condor: Ornithological Applications*, *120*(3), 622-631.

Wolkovich, E. M., Cook, B. I., McLauchlan, K. K., & Davies, T. J. (2014). Temporal ecology in the Anthropocene. *Ecology letters*, *17*(11), 1365-1379.