Trends and Roost Size Dynamics of Chimney Swifts in London, Ontario: Results from the 2003-2023 Monitoring Program

A report to Nature London

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PREFACE & ACKNOWLEDGEMENTS

In 2023–2024, author Mackenzie Amlin, under the supervision of professor Yolanda Morbey, completed an Honour's Thesis on the patterns of chimney use by Chimney Swifts in London, Ontario. Mackenzie continued the project during a Western University Undergraduate Summer Research Internship in the summer of 2024. This report to Nature London is a compilation of analyses that were completed. We note that the results have not been peer-reviewed. Heartfelt thanks go to Winnie Wake, who provided the long-term monitoring data on Chimney Swifts. Financial assistance to MA was provided by Western University and the Nature London Eco-Grants program.

ABSTRACT

The Chimney Swift (*Chaetura pelagica*) is a nationally and provincially threatened avian species. Habitat loss, insect-related factors, and weather are considered to be the primary threats to Chimney Swifts, although weather impacts are largely unexplored. Drawing on extensive citizen science data collected from 2003–2023 in London, Ontario, we examined trends in roost size across years and the effect of temperature on roost size variation and post-breeding migration date. We also identified nesting chimneys versus key roosting chimneys. Survey effort was inconsistent among years and chimneys, and roost size was also highly variable among and within years. Despite some limitations due to uneven sampling effort, we found evidence of declining numbers of Chimney Swifts among monitored chimneys during pre-breeding and post-breeding migration. Data also suggest an advancing post-breeding migration date from 2005–2013. Neither the variability in roost sizes nor the pre-breeding migration date could be directly

attributed to weather. This study demonstrates the significant value of Chimney Swift monitoring and calls for further research, monitoring, and evaluation into the factors shaping population trends, roost size dynamics, and phenology of Chimney Swifts.

INTRODUCTION

Aerial insectivores are one of the most imperilled groups of birds, experiencing a 59% population decline across Canada since the 1970s (Nebel et al., 2020). Population declines have been observed globally and encompass various species such as swallows, swifts, and nightjars. Within this guild, long-distance migrant species in the northeastern range of North America seem to be declining at the highest rate (Nebel et al., 2010). Among these, the Chimney Swift (*Chaetura pelagica*) warrants particular concern, as its Canadian population has declined by 87.9% since 1970 (Smith et al., 2023). Chimney Swifts, designated as threatened both nationally and provincially, are Neotropical migrants that breed in North America during the summer months before migrating to the South American Amazon basin for the winter (COSEWIC, 2018). These aerial insectivores have unique claws adapted for clinging to vertical surfaces. Initially, hollow trees served as the primary habitat of Chimney Swifts in both the breeding and wintering seasons (Steeves et al., 2020), however, as urbanization destroyed suitable forest habitat in North America, they began inhabiting chimneys instead.

Chimney Swifts are known for their distinctive mating behaviours, characterized by lifelong, monogamous pair-bonds and occasional cooperative breeding where non-parental Chimney Swifts assist with parental tasks such as brooding and food provision (Dexter, 1969). Moreover, they exhibit remarkable nest-site fidelity, often returning to the same chimney year after year for breeding purposes (Steeves et al., 2020). Chimney Swifts typically nest solitarily, with each breeding pair occupying a specific chimney. Non-breeding Chimney Swifts engage in communal roosting, with some roosts accommodating over 1000 birds. This social behaviour is commonly observed in flocking birds and is thought to confer benefits such as reduced energy costs of thermoregulation, increased foraging efficiency through information exchange, and decreased predation risk (Beauchamp, 1999).

The rapid decline of Chimney Swifts prompts research into the factors affecting their breeding success and survival. Researchers have indicated habitat loss, weather and climate change, and insect-related factors as primary population threats (COSEWIC, 2018). Concerning habitat loss, the widespread adoption of modern heating technologies has rendered chimneys unnecessary. Consequently, the construction of suitable chimneys has declined, and existing ones are often capped or demolished (Rioux et al., 2010). As of 2016, out of 166 chimneys known to have held Chimney Swifts in London, Ontario, 29% are no longer available to Chimney Swifts (Wake, 2016). The number of nesting sites is not yet a limiting factor in Ontario, however, as research indicates that only 24% of suitable chimneys are being occupied by Chimney Swifts (Fitzgerald et al., 2014). Evidence suggests that roosting chimneys, having greater area requirements, may be rarer than suitable nesting chimneys (Rioux et al., 2010).

If habitat availability is not constrained, it follows that habitat quality may be the underlying issue. Masonry chimneys (as opposed to metal chimneys) are the only suitable chimney type for Chimney Swifts, as they provide texture for the swifts to grip onto (Kyle & Kyle, 2004). Almost all of these chimneys in London, however, are over 60 years old (Wake, 2016). As such, many of them are deteriorating, warranting repairs, alterations, and destruction for safety reasons. Beyond the chimney material, Chimney Swifts show preferences for characteristics such as chimney height, temperature, and internal area (Fitzgerald et al., 2014;

Laughlin et al., 2022). It becomes important then, to prioritize understanding habitat selection in both nesting and roosting Chimney Swifts in order to better provide and preserve habitat, especially for roosts that support large numbers of swifts, deemed “key roosting sites” (Farquhar, 2017).

The common diet of aerial insectivores is hypothesized to be significantly related to their widespread decline (Spiller & Dettmers, 2019). Pertaining to Chimney Swifts, insect-related factors are believed to have the highest impact on population stability (COSEWIC, 2018). Insect declines have been linked to the widespread use of potent insecticides since the 1950s (Nebel et al., 2010; Nocera et al., 2012). Chimney Swifts may be particularly susceptible to declines in insect abundance, due to their near-constant state of flight and subsequent energy requirements (Steeves et al., 2020). Chimney Swifts consume many aquatic insects due to their high energy content (Steeves et al., 2020), however, these insects are more susceptible to pesticides than their terrestrial counterparts, posing a heightened risk to Chimney Swifts' food sources (Siegfried, 1993). In addition to insect abundance, insect quality may also impact Chimney Swift populations. Nocera et al. (2012) showed that Chimney Swifts began consuming more true bugs than beetles following the rise of harmful pesticide use, likely due to selective declines in prey of choice. Though true bug populations are less susceptible to pesticides, they are of lower nutritional value and thus may be insufficient to sustain Chimney Swifts. Declines in insect abundance and quality not only affect the survival of adult Chimney Swifts but also impact the nutrition of offspring, reducing breeding success and the overall fitness of the species (COSEWIC, 2018).

Weather and climate change are known to affect birds’ distributional ranges, behaviours, and migratory patterns (Parmesan & Yohe, 2003). Insectivorous birds are highly sensitive to changes in temperature as insect availability is temperature-dependent (Spiller & Dettmers, 2019). Research shows that optimal insect abundance occurs between 18.5°C and 25°C (Glick, 1939; Winkler et al., 2013). This relationship is evidenced in Chimney Swifts by increased time elapsed between feedings of offspring in hot weather, indicating lower foraging success (Zammuto & Franks, 1981). Thus, Chimney Swifts employ strategies to reduce energy expenditure during periods of low food availability. Zammuto & Franks (1981) found that roost size increases in cold and rainy weather as Chimney Swifts "huddle" or aggregate as a thermoregulatory strategy. This effect is so pronounced that some roost flock sizes doubled. Additionally, Chimney Swifts are known to exhibit torpor, a brief state of inactivity similar to hibernation, when temperatures drop below 5°C (Ramsey, 1970). Research also indicates the implementation of huddling behaviour in warmer temperatures, presumably to reduce evaporative water loss (Farquhar et al., 2018). Weather may also have more direct impacts on Chimney Swifts as extreme temperatures and harsh storms have been found to kill broods (Dexter, 1969; Kyle & Kyle, 1997).

Weather variables such as temperature have a significant impact on the phenology of various species (Spiller & Dettmers, 2019). For example, the emergence of insects is associated with the onset of spring, both of which have advanced over the years as a result of climate change (Robertson et al., 2024; Shipley et al., 2022). When there is a mismatch between the emergence of insects (described as a "pulse" because of their heightened abundance) and the arrival of breeding migratory birds, it can have drastic effects on the nutrition of the birds and their offspring, potentially affecting breeding success. While more reliable cues like photoperiods are thought to prepare birds for migration, some birds are able to use variables such as temperature and wind to refine departure times (Burnside et al., 2021). Research shows that many birds have advanced their spring migration over the years, with those birds exhibiting stable or enhanced reproductive success relative to birds that did not adjust migratory departure (Imlay et al., 2018). Regarding fall migration, it may be beneficial for migratory species to delay departure if warmer temperatures prolong favourable foraging conditions on the breeding grounds (Brisson-Curadeau et al., 2020). This advantage may be particularly significant for species like Chimney Swifts, where conditions on the wintering grounds improve later in the season, as the Amazon's dry season ends as late as November and is shifting to later dates each year (Fu et al., 2013). From 2009 to 2018, Chimney Swifts delayed fall migration by 4.2 days per year based on analyses of North American eBird data (Prytula et al., 2023).

Although the Chimney Swift's dependence on human-built structures increases its vulnerability to anthropogenic threats, it also positions it as a model species for study as its presence in urban environments enhances accessibility and detection. Thus, many studies on swifts utilize citizen science data from various sources such as eBird, the North American Breeding Bird Survey (BBS), and volunteer-run monitoring programs (Sullivan et al., 2009; Smith et al., 2023). By analyzing count data gathered by volunteers in London, Ontario, this study aimed to achieve several objectives: describe and evaluate trends in the data, examine the impact of temperature on roost size and post-breeding phenology, and pinpoint key roosting sites.

METHODS

Data Acquisition, Tidying, and Selection

We used data from Nature London’s Swift Monitoring Program. This program began unofficially in 2003 when volunteer monitors intermittently observed and counted Chimney Swifts at a few chimneys in the fall. By 2007, the program became more organized, involving weekly evening swift counts (covering the time of sunset) at several chimneys in both the spring and fall. In 2010, Nature London encountered a setback when support from Bird Studies Canada was redirected to the Ontario SwiftWatch initiative, leading to a temporary halt in monitoring activities with no official program in place from 2010 to 2016. During this period, efforts were made to conduct simultaneous surveys on designated national swift count nights (late May to early June) set by the Canadian Wildlife Service, along with sporadic monitoring out of interest and more consistent visits to roost sites during the post-breeding period. In 2017, Nature London established its official monitoring program, which still operates today, though there were interruptions in spring monitoring due to COVID-19 restrictions in 2020 and 2021. Following a standardized swift monitoring protocol, monitors record the number of swifts occupying each chimney once per week from the beginning of May until the end of September, or until the last swift departs for post-breeding migration. Surveys begin 30 minutes prior to sunset and last one hour, and during this time monitors count the number of swifts entering and exiting the chimney. The count of swifts exiting the chimney is then deducted from the count of swifts entering the chimney, yielding the net number of swifts inhabiting the chimney. In addition to the data on swifts, observers record the chimney identity, survey times and dates, and additional notes. Some weather information was recorded by survey participants, but this information was sometimes incomplete and so was not used. Most chimneys were located in the city of London.

Survey data from 2003 to 2023 were anonymized, merged, and tidied such that all dates and geographical coordinates were in a consistent format. Unique chimneys were assigned unique codes. High-quality data were selected for detailed analyses. The years 2003 and 2004 were excluded due to a late onset or sparseness of monitoring. Among the remaining years, the onset of monitoring ranged from 19 April to 30 June (median = 5 May). Chimneys were included if they were surveyed with some regularity. Although over 350 chimneys were visited over the 20 years, many were demolished or capped (Appendix Table A1 indicates the addresses of seven with high maximum counts), and as monitoring efforts expanded, data were gathered relatively consistently from a small subset. For analyses, we focused on the 18 chimneys that were surveyed at least 10 times during the 2018 to 2023 period within the city of London (Appendix Table A2). For each chimney in each year (2005–2023), we calculated the monitoring period as the number of weeks between the first and last survey date. Survey effort was calculated as the average number of surveys per week, with the expectation that most chimneys would be monitored once per week. R was used for data tidying and all subsequent analyses (v.4.3.1, R Core Team, 2023).

The Parsing of Seasonal Periods

Survey dates were segmented into pre-breeding migration, breeding, and post-breeding migration periods by evaluating how the chimney counts varied across the season (Figure 1). To do so, we first calculated the mean count among chimneys that were surveyed (up to 18) on each survey date, and then calculated the mean of these values among all years to get the pooled mean. For delimiting the pre-breeding migration season, we initially considered the range of dates for the National Swift Count nights (day of year 140 to 159), roughly corresponding to May 20 to June 7. During this period, counts are expected to peak as birds arrive to breed or pass through on pre-breeding migration. Based on Figure 1, the onset of pre-breeding migration was advanced to day of year 130 to accommodate its earlier timing in London, Ontario. The breeding period was defined as day of year 160-195. This follows the COSEWIC's (2018) use of 15 July (day of year 196) as the onset of the post-breeding period and is consistent with the seasonal pattern. However, we defined the post-breeding migration period as day of year 230-265 (17 August to 22 September), which coincides with the peak of juvenile recruitment and/or post-breeding migratory passage.

Trends

Trends in roost sizes were analyzed for the pre-breeding and post-breeding periods. Given that swifts are not necessarily faithful to their roost chimney on a night-to-night basis, many roosts should be surveyed simultaneously in order to avoid double counting and obtain an accurate abundance index. To find common sets of chimneys that were surveyed simultaneously, we explored the patterns of missing data among dates. Based on this assessment of data quality, we identified a common set of four chimneys (1, 2, 3, and 4) that was simultaneously surveyed at least once during the pre-breeding period in each of nine years from 2013–2023 (after dropping one complete survey from 2008). In years outside of this range, one or more of these chimneys was missing data. A linear mixed model was used with $\log_{10}$-transformed sum of the counts –

across the set of four chimneys – as the response variable and year as an independent variable. We also included random intercepts for year to account for uneven sampling by year. For these analyses, we used the function lmer in the package lmer (Bates et al., 2015) and lmerTest (Kuznetsova et al., 2017). Alternatively, if the assumptions of the models were grossly violated, we used quantile regression on the median swift counts using the function rq in the package quantreg (Koenker 2024). We also considered a less restrictive set of survey dates when at least four large capacity chimneys were surveyed. A large capacity chimney was defined as one with a maximum count exceeding 100 (Appendix Table A2). In these cases, we used the $\log_{10}$-transformed mean of the counts. We note that a common set of 11 chimneys (1,…,11) was surveyed at least three times during the pre-breeding period in each of 2018, 2019, 2022, and 2023, but this time series was not sufficient to evaluate trends.

Identification of Nesting Chimneys

To identify nesting chimneys, we first defined criteria for nesting chimneys. With a breeding pair and the potential presence of 1-3 helpers, we expected there to be a maximum of five swifts consistently observed at a nesting chimney. Exploratory analyses indicated occasional larger values often less than nine, prompting an adjustment in nesting criteria to ensure potential nesting chimneys were not overlooked. Subsequently, nesting criteria were redefined to include a consistent count of eight or fewer swifts during the breeding period (~day of year 160–196), accounting for the potential presence of helpers or fledged young. This criterion's validity was assessed by colour-coding swift counts based on the nesting criteria for the years 2021 to 2023 and assessing differences in patterns between potential roosting and nesting chimneys. The criterion was then used to identify the nesting status of each of the regularly monitored chimneys (1–18) in each year it was monitored, considering only years with a minimum of two observations during the breeding period. We then summarized the number of years each chimney was monitored, the number of years that chimney was a nesting chimney, the median number of swifts observed during nesting periods, and the proportion of years it was a nesting chimney. The package ggmap (Kahle & Wickham, 2013) was used to generate a map showing the locations of the 18 chimneys.

Weather Effects on Roost Size and Post-breeding Migration Phenology

To test the effects of weather on roost size, we selected the period between the end of breeding and the onset of the post-breeding period (day of year 197–229) for the years 2018–2023. This seasonal period was selected because counts were generally stable. We also selected the chimneys ($n = 14$) that had a maximum roost size exceeding 100. This was to ensure sufficient contrast in the counts. Finally, counts were transformed to proportions by dividing by the maximum roost size; this allowed for partial accounting of variability among chimneys in their capacity to host swifts. Using general linear models, we modelled relative count as a function of temperature, temperature^2, year, and chimney ID. Including temperature and temperature^2 allowed us to test for a non-linear, quadratic relationship. A similar model was used with precipitation (rainy versus dry) instead of temperature and temperature^2. To acquire weather data, the suntools package (Bivand, 2023) was used to obtain the approximate time of sunset for each day. The temperature (°C) at sunset was extracted using the NCEP_interp function from the RNCEP package (Kemp et al., 2011), which accesses weather data from the National Centers for

Environmental Predictions. Similarly, we acquired precipitation rate (kg/m^2/s) over a 6 h period starting from a reference time of 4 hours before sunset. We then categorized the precipitation variable into a binary format where precipitation rates greater than zero indicate rain and precipitation rates equal to zero reflect dry conditions. Evaluation of the residuals confirmed that model assumptions were reasonable. More complex models were evaluated but did not reveal any substantive differences or additional insight compared to the basic models we present.

To evaluate trends and the effect of temperature on post-breeding departure from London, we identified the last day of year when swifts were present in chimney surveys. Two sets of dates were chosen. The first set was the last day a swift was observed in any chimney. The second set was similar but required that the final day be followed by a zero count within two weeks to confirm absence. Mean daily temperature for the 6 h period beginning at noon was acquired using NCEP_interp. Average daily temperature for 1–10 September was used, as this was the period preceding the earliest departure among years. Quantile regression was used to determine the 50th percentile (median) of the last day swifts were present with year or average September temperature. More complex analyses also were considered, but none provided any additional insight.

RESULTS

The final, tidied data set contained data for 5191 chimney surveys (unique chimney-date combinations), 1741 unique survey dates, and 344 unique chimneys. There was substantial variation in the number of chimneys monitored within and among years. The number of chimneys visited in a given year ranged from 2–161, and the duration of monitoring of a chimney ranged from 1–20 years. Out of the 344 unique chimneys, 170 (49%) hosted at least one swift in one survey. Out of these 170 chimneys, 43 (25%) were capped or demolished during the monitoring period.

Weekly Survey Effort and Trends in Swift Counts

Among the set of 18 commonly surveyed chimneys, weekly survey effort varied considerably, with the frequency of surveys per week for a given chimney ranging from 0.1 to 5.3 (Figure 2). Weekly surveys were very common. Values below one indicate under-sampling, resulting in gaps in the data as long as two months, while values above one indicate over-sampling, meaning monitors visited the same chimney several times in one week. Roost size varied considerably, with the maximum number of swifts per chimney ranging from 1 to 1604 (Appendix Table A2).

During the pre-breeding period (10 May to 7 June), we identified a common set of four chimneys that were simultaneously surveyed on 36 nights from 2013 to 2023. Over this ten-year period, the $\log_{10}$-transformed sum of the counts showed a significant decline (linear mixed model: $\beta = -0.069$, SE = 0.022, $t_{7.2} = -3.09$, $p = 0.017$; Figure 3A). After back-transforming, the predicted sum of the counts dropped from 534 to 188 from 2013 to 2023. The less restrictive survey data allowed for the inclusion of more survey dates and some from 2008-2009, but assumptions of linearity were clearly violated. While the trend from 2013–2023 remained the same based on visual inspection, counts during 2008 were relatively low (Figure 3B).

In the post-breeding period, the common set of four chimneys was simultaneously surveyed on 36 nights from 2005 to 2023. Gaps in the time series and an excess of very high or very low counts on some survey dates violated the assumptions of a linear mixed model. Despite this issue with the data, neither the visualization nor the quantile regression supported an overall trend in the median $\log_{10}$-transformed sum ($t = -0.212$, $p = 0.833$; Figure 4A). However, when using the less restrictive data set, the median $\log_{10}$-transformed mean of the counts declined with year ($\beta = -0.037$, SE = 0.007, $t = -5.20$, $p < 0.001$; Figure 4B).

Chimney Types and Locations

Nesting chimneys exhibited relatively consistent counts of eight or fewer swifts before day of year 200 (late July; Figure 5). After this point, the counts of the nesting chimneys sometimes surpassed eight, suggesting a transition from nesting to roosting chimney status, or alternatively, the count sometimes decreased to zero, indicating abandonment of nesting chimneys for roosting chimneys once young swifts have fledged. Twelve chimneys were identified as nesting chimneys in at least one year during 2021–2023. In contrast to those chimneys designated as nesting chimneys, six roosting chimneys consistently maintained counts exceeding eight swifts, gradually decreasing as the end of September (and post-breeding migration) approached, and eventually reaching zero (Figure 6). Nesting and roosting chimneys were spatially mixed (Figure 7) and chimney status could change among years. Out of the 18 common chimneys, 16 showed evidence of nesting in at least one year, and 10 of the 18 showed evidence of nesting in more than 50% of the monitored years (Table 1). Many of the chimneys were used for nesting in more than 80% of the years.

Weather Effects

Neither daily temperature nor temperature^2 had discernible effects on $\log_{10}$-transformed counts during the interval between breeding and post-breeding after accounting for variability due to year and chimney ID (Table 2). Similarly, there was no effect of daily precipitation on the $\log_{10}$-transformed counts (Table 2).

The final day when swifts were present ranged from day of year 255 to 290 and advanced from 2003-2023 (quantile regression: $\beta = -0.75$, $SE = 0.27$, $t_{19} = -2.80$, $p = 0.012$; Figure 8A). While there was a hint that the final day of presence advanced when September temperatures were warmer, variability in the data resulted in the trend being non-significant (quantile regression: $\beta = -1.51$, $SE = 1.22$, $t_{19} = -1.23$, $p = 0.232$; Figure 8B). This set of results did not change when using the refined set of final dates.

DISCUSSION

Seasonal patterns of chimney occupancy by Chimney Swifts in London, Ontario, indicate an initial surge in late May as swifts make their way into and beyond London during pre-breeding migration. The swift count then declines sharply in the following weeks until it is at its lowest in late June as migration has concluded and the core nesting period begins. A sharp increase in swift counts is observed in early August, which can attributed to an influx of swifts during post-breeding migration from surrounding areas and the inclusion of newly fledged young. The beginning of August thus demarcates the end of the breeding season in London. The destination of the pre-breeding migrants and the source of the post-breeding migrants cannot be known with any certainty, but it is likely north of London, as the breeding range for Chimney Swifts extends further north into Ontario and Québec (Steeves et al., 2020).

Counts made during the pre-breeding migration period from late May to early June provided evidence of declining numbers of swifts over the 2013–2023 period. Summed across a set of four commonly-surveyed chimneys, counts declined from over 500 in 2013 to fewer than 300 in 2023. This trend appears to be robust given that a similar trend was observed when including any set of at least four high-capacity chimneys. However, lower counts in 2008 and 2009 suggest that 2013 may have been a localized peak. In comparison, long-term data (1970–2021) from the BBS indicates an average annual decrease of 5.69% in Ontario swift populations (Smith et al., 2023). A more narrow analysis from 2011 to 2021 showed a lesser decrease of 1.21% in Ontario and a slight increase (0.1%) in the national population. Because the BBS is carried out in rural areas, the percent decrease estimates may be inflated as swifts primarily live in urban areas in their North American range (COSEWIC, 2018). The differences in trends at different spatiotemporal scales (e.g., local, regional, and national) suggest that demographic processes are also scale-dependent. At the local scale of London, Ontario, continued monitoring at high-capacity chimneys will help improve understanding of year-to-year dynamics in Chimney Swift abundance.

Counts made during the post-breeding period were quite variable, and while there is much uncertainty, there was some evidence for a decline from 2005 to 2023. Several non-mutually exclusive hypotheses may account for a declining trend. First, there may be a true decline in the number of Chimney Swifts migrating into London during the post-breeding period due to changing migratory routes or breeding distributions (Spiller & Dettmers, 2019). Second, migrant Chimney Swifts may be using alternate roost sites in London that are monitored less frequently or not at all. Third, migrant Chimney Swifts may stage in London for fewer days before continuing their migration. Finally, juvenile recruitment may be declining in London and elsewhere. If lower recruitment of juveniles is happening, this may be driven by insect-related factors. For example, studies indicate poor insect quality in southwestern Ontario rivers, attributed to harmful chemicals from plastics (Ciborowski & Corkum, 1988). Additionally, insect abundance decreases with rising road traffic, particularly in densely populated cities like London (Martin et al., 2018). Thus, London's environment may exacerbate insect-related stress for swifts and lower reproductive success. In addition to continued monitoring to better understand year-to-year dynamics, effort should be put towards addressing some of these key uncertainties about the ecological mechanisms driving swift numbers.

Our analyses indicate a significant advancement in the timing of post-breeding migration, yet this did not appear to be driven by a warming climate. Two main hypotheses may account for this trend. First, pre-breeding, breeding, and post-breeding timing may be closely linked with all three phases advancing due to warmer spring and the earlier availability of insects. Supporting research suggests that fall migratory departure can be closely related to the cessation of the breeding period in some species (Mitchell et al., 2012). Alternatively, long-distance migrants, which typically migrate early, may be encountering deteriorating late summer foraging conditions, thus forcing earlier migration (Jenni & Kéry, 2003). Interestingly, analysis of eBird abundance data indicates that Chimney Swifts delayed their post-breeding migration from 2009 – 2018 (Prytula et al. 2023). The difference in observed trend between our study and that of Prytula et al. (2023) warrants careful scrutiny.

While the present data were insufficient to examine phenological patterns in the spring, evidence from the literature supports advances in spring migration for long-distance migrants.

Research in the U.S. indicated that the arrival of migratory birds wintering in South America was four days earlier on average in the late 1900s compared to the early 1900s (Butler, 2003). The same study indicated Chimney Swifts advanced their arrival to Worcester County in Massachusetts by five days from 1932–1993. Similarly, according to eBird data, the first Chimney Swift seen in Canada was six days earlier in 2022 than in 2019 (Sullivan et al., 2009). Earlier and more consistent onset of monitoring at key chimneys (e.g., 1, 2, 3, and 4) could help more effectively document trends in spring phenology.

Weather did not influence variability in roost size, potentially indicating more complex factors at play. While recent research suggests that Chimney Swifts tend to huddle closer together at warmer temperatures (Farquhar et al., 2018), no attempts have been made to correlate warmer temperatures directly with roost size. It is therefore plausible that a certain threshold of Chimney Swifts is adequate to derive benefits (in this case, reductions in water loss) from huddling behaviour, beyond which increasing roost size does not yield additional benefits. The study performed by Zammuto & Franks (1981) indicated increased roost size in extended periods of cold and rainy weather, though the thresholds delineating “extended periods” and “cold and rainy weather” are unclear. In this way, it is possible that weather conditions in our study did not meet the necessary thresholds in order to impact roost size. For instance, existing literature indicates that the temperature inside a roost is significantly warmer than the ambient temperature, often differing by as much as 15°C (Farquhar, 2017). Moreover, the lowest ambient temperature recorded in my study was 7°C, which is 2°C warmer than the conditions known to induce torpor in swifts (Ramsey, 1970). Given that the internal temperature of chimneys was likely even warmer, it is possible that swifts did not need to employ energy-saving thermoregulatory mechanisms but instead benefited from the insulation provided by the chimney structure itself. This aligns with recent findings suggesting that Chimney Swifts exhibit greater tolerance to cold temperatures compared with hot ones, as evidenced by their preference for cooler nesting sites and their aggregation in warmer temperatures only (le Roux et al., 2019; Farquhar et al., 2018).

Social factors also likely play a significant role in the roosting dynamics of Chimney Swifts. As highly social birds, swifts may communicate information about habitat quality including surrounding foraging opportunities. For example, one study found that Chimney Swifts spent more time close to an artificial habitat when provided with auditory conspecific cues (Finity & Nocera, 2012). Furthermore, a recent study indicated that variation in roost size is primarily attributed to habitat characteristics such as chimney height and lack of canopy cover, allowing for easier entry (Laughlin et al., 2022). Thus, there may be an interaction between sociality and habitat quality that is primarily responsible for variations in roost size. This is supported by the finding that Chimney Swifts form social networks between multiple roosts (le Roux & Nocera, 2021). The movement of these social networks, then, likely drives variations in roost size at an individual roost.

Interestingly, it is estimated that 60% of Chimney Swifts on breeding grounds do not breed in a given year (le Roux & Nocera, 2021) – a phenomenon uncommon among migratory birds. This may suggest limited breeding resources and highlight the importance of preserving both roost and nest site quantity and quality. Our analyses revealed a pattern of high re-use of chimneys for nesting. We also found chimneys can be used for nesting and roosting. le Roux and Nocera (2021) demonstrated that the majority of Chimney Swifts use more than one roosting site throughout the season and that the removal of just one key roosting site disrupted interconnected social networks. Laughlin et al. (2022) had similar findings, indicating that the use of roost sites is sequential in a season. As such, it is important to maintain a network of key roosting sites. We were able to identify chimneys 1, 2, 3, and 4 as key roosting sites. The demolition or capping of such chimneys could lead to the displacement of over 1000 breeding and non-breeding swifts.

Given that many individuals comprising the maximum roost size at a chimney are from other cities gathering in London before departing in autumn, the impact of habitat destruction on regional Chimney Swift populations could also be considerable. Consequently, it is important to preserve these key roosting sites, perhaps by implementing regular maintenance to prevent their destruction for safety reasons. Beyond habitat preservation, these key roosting sites may possess high-quality habitat characteristics that discerning Chimney Swifts consider during habitat selection. Consequently, examining the features of key roosting sites may inform the development of artificial habitats, a conservation strategy that has seen limited success in Canada thus far (Finity & Nocera, 2012). Ultimately, until habitat selection in Chimney Swifts is better understood, it is important to preserve as many habitats as possible.

It is important to acknowledge the strengths and limitations of this study. While citizen science data offers invaluable access to a large dataset, it comes with challenges such as limited control over sampling effort. Not all chimneys are monitored consistently in every year, nor are all chimneys equal in their capacity to host Chimney Swifts. This means that one unit of effort (a chimney-date combination) is not the same among chimneys. This is why it is important to conduct simultaneous surveys over a large number of chimneys in a study region. Moreover, it is possible that some high-capacity roosts were undetected and therefore not monitored. Despite these limitations, the data allowed us to evaluate trends during the pre-breeding and post-breeding periods, describe seasonal occupancy patterns, identify the nesting status of chimneys, and test hypotheses regarding weather impacts on roost sizes and post-breeding migration timing. The outcomes of this study encourage further exploration of citizen science data, emphasizing its value in studying ecological questions.

CONCLUSIONS

The findings of this study shed light on the nuanced dynamics of swift populations within the London area. Among the monitored roosts, swift numbers appear to be declining in the pre-breeding period (2013–2023) and post-breeding period (2005–2023). While there are key uncertainties regarding these trends, this is a concern worthy of continued study. Refinements to monitoring may help to produce higher-quality data for the evaluation of trends and roost dynamics. Chimney occupancy varied extensively, yet we still do not understand the drivers. Tracking individuals through radiotelemetry or other methodologies will provide data to evaluate the ecological mechanisms underlying chimney use in London, Ontario.

The continuation of monitoring programs is important in collecting data that may address key uncertainties. Furthermore, monitoring programs raise awareness for swift conservation in the general public, garnering support for conservation initiatives and fostering a collective commitment to preserving swift populations and their habitats for future generations. Chimney Swifts were listed under the Species at Risk Act in 2007, and thus are protected by law (COSEWIC, 2007). The destruction of swift habitat is prohibited when the habitat is in use, and the alteration or destruction of habitat during the winter season requires a permit. In London, some high-capacity chimneys have been capped or demolished. Given the mobile nature of Chimney Swifts, it is difficult to attribute population-level impacts to these losses. However, protecting chimneys in perpetuity will likely mitigate the impact of other stressors.

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TABLES

Table 1. Summary of commonly surveyed chimneys in London, Ontario, showing the number of years monitored during the breeding period (N), the number of years nesting (N_{nest}), the median number of Chimney Swifts if nesting (Count), and the proportion of years nesting (p).

Chimney ID	N	N_{nest}	Count	p
1	13	1	4.0	0.08
2	15	0	—	0
3	11	4	2.5	0.36
4	10	4	4.0	0.40
5	9	3	2.0	0.33
6	7	7	2.0	1.00
7	6	6	2.0	1.00
8	6	6	2.0	1.00
9	7	6	2.0	0.86
10	7	5	3.0	0.71
11	7	3	4.0	0.43
12	6	0	—	0
13	7	3	3.0	0.43
14	3	3	2.5	1.00
15	3	3	2.0	1.00
16	4	4	2.0	1.00
17	2	2	2.0	1.00
18	2	2	2.0	1.00

Table 2. Analysis of variance table for the linear model of the $\log_{10}$-transformed count of Chimney Swifts with temperature (or binary coded precipitation), chimney ID, and year.

Model	F	df	p
With temperature			
temperature	0.748	1	0.388
temperature^2	0.538	1	0.464
chimney ID	21.925	13	<0.001
year	9.793	1	0.002
With precipitation			
precipitation	1.235	1	0.267
chimney ID	4.042	13	<0.001
year	1.268	1	0.261

FIGURES

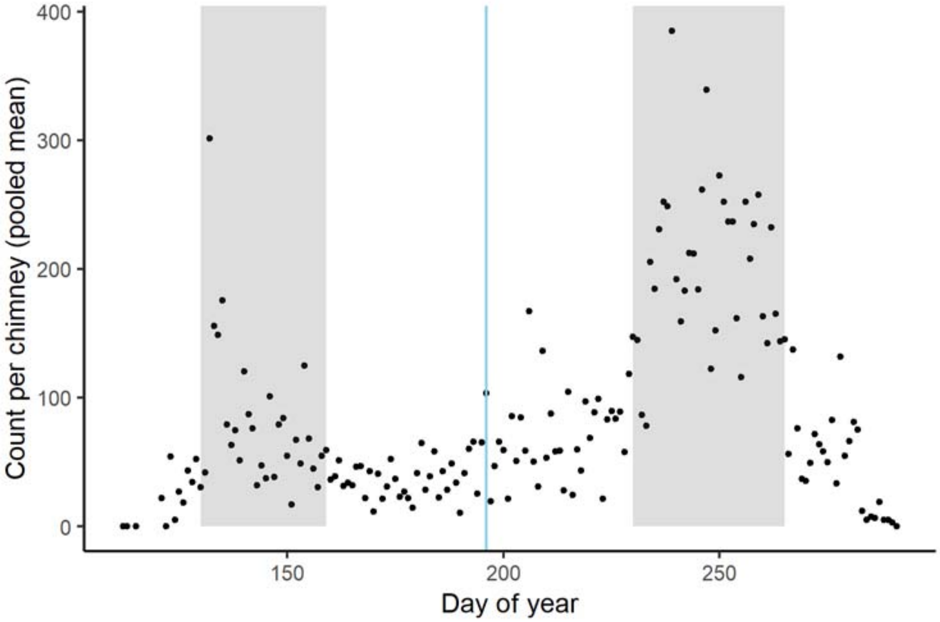

Figure 1. The average seasonal pattern of Chimney Swift counts in London, Ontario. Shown are the daily means averaged among the years 2005–2023. Shading shows the pre-breeding and post-breeding periods as defined for this report. The vertical blue line indicates the end of breeding.

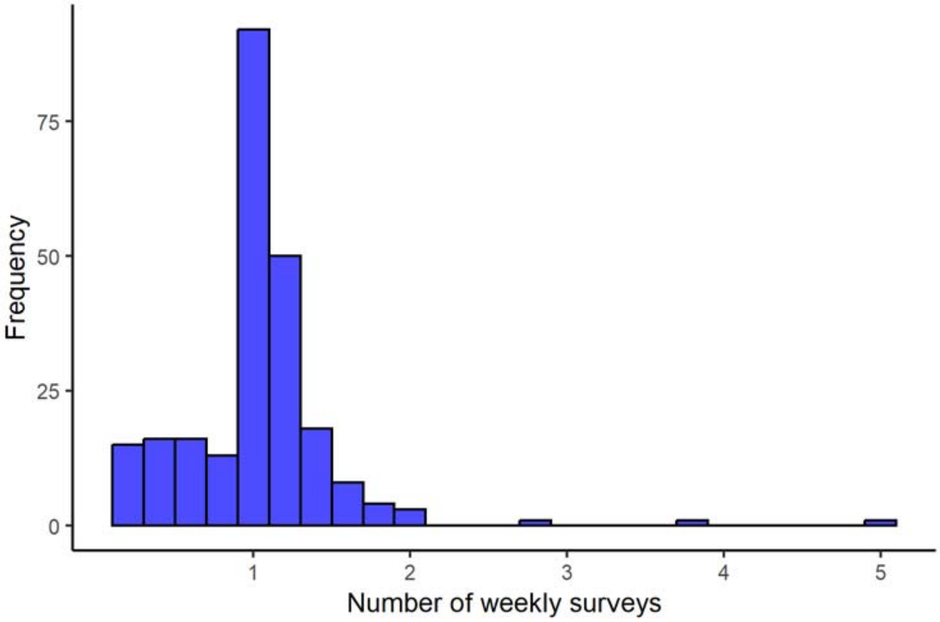

Figure 2. Histogram of the average number of surveys per week per chimney per year in London, Ontario.

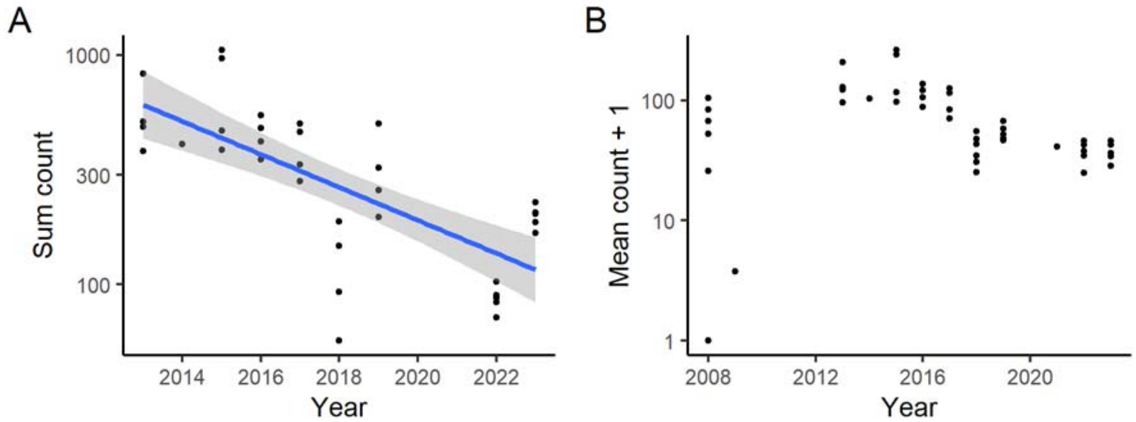

Figure 3. Trends in Chimney Swift counts during the pre-breeding period (10 May to 7 June) in London, Ontario. Panel A shows the sum of counts for a common set of four chimneys that were surveyed simultaneously. Also shown is the trend line (with standard error) from a linear regression. Panel B shows the mean counts for any set of at least four high-capacity chimneys that were surveyed simultaneously. In both panels, the y-axis is log10-transformed.

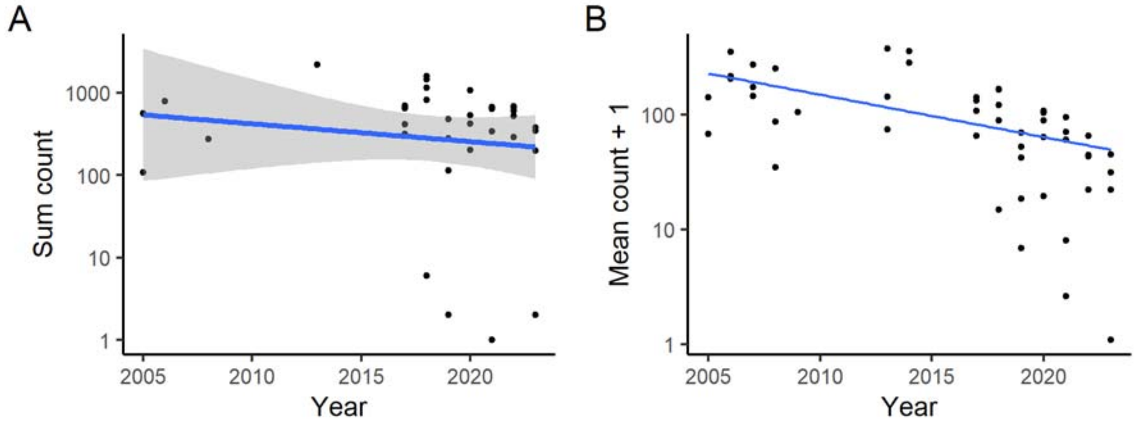

Figure 4. Trends in Chimney Swift counts during the post-breeding period (17 August to 22 September) in London, Ontario. Panel A shows the sum of counts for a common set of four chimneys that were surveyed simultaneously. Also shown is the trend line (with standard error) from a linear regression. Panel B shows the mean counts for any set of at least four high-capacity chimneys that were surveyed simultaneously. The line shows the estimated median. In both panels, the y-axis is log10-transformed.

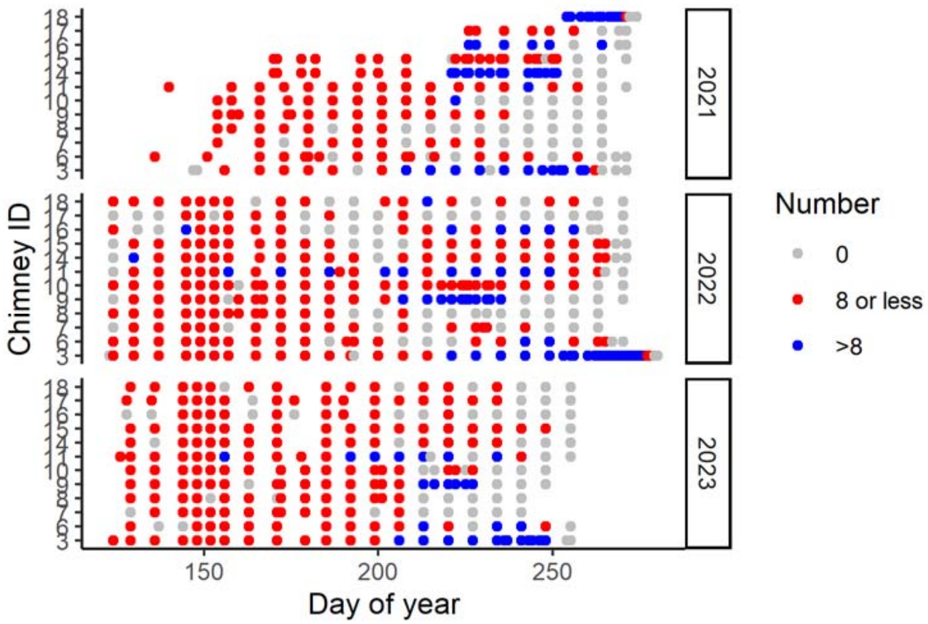

Figure 5. Dot charts depicting the number of Chimney Swifts versus day of year in chimneys used for nesting in at least one of 2021, 2022, and 2023 in London, Ontario. For each chimney, the majority of surveys have fewer than eight birds before day of year 200. Nesting chimneys sometimes become roosting chimneys after day of year 200.

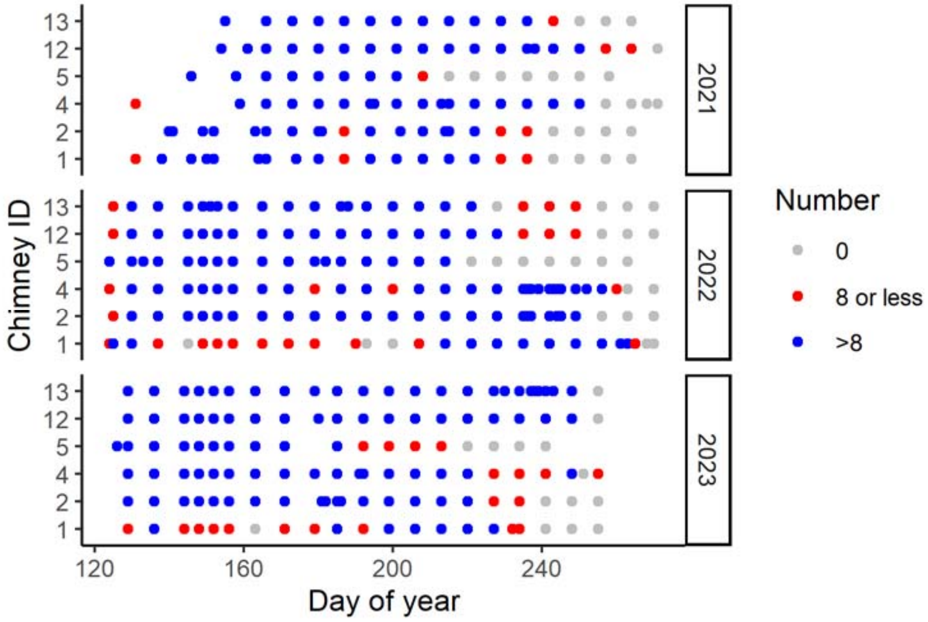

Figure 6. Dot charts depicting the number of Chimney Swifts versus day of year in chimneys used primarily for roosting in 2021, 2022, and 2023 in London, Ontario. For each chimney, the majority of surveys have more than eight birds during the breeding period (day of year 160–196).

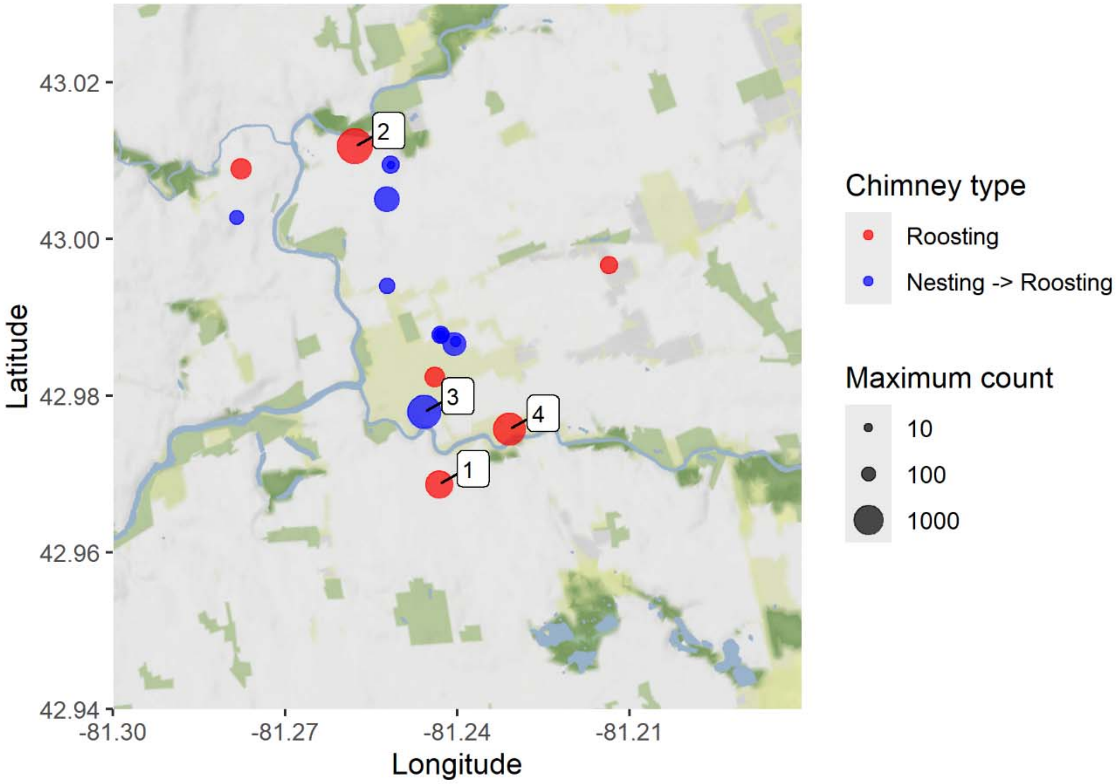

Figure 7. Map showing the approximate locations of the 18 commonly surveyed chimneys (14 unique addresses) in London, Ontario. Symbols indicate the dominant chimney type (roosting only or nesting to roosting) during 2021–2023 and the maximum count on any given survey date from 2005–2023. Numerical labels indicate chimney IDs with maximum Chimney Swift counts exceeding 800. Symbols for chimneys 16 and 17 overlap.

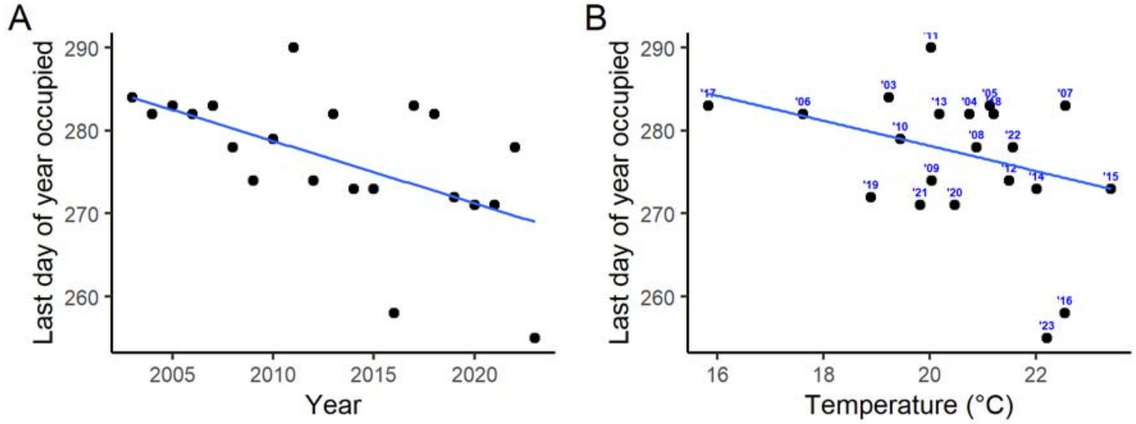

Figure 8. The last day of year that a Chimney Swift was observed occupying a chimney in London, Ontario, versus year (A) and mean temperature in early September (B). The lines show the predicted 50% percentiles of the data. The relationship was statistically significant only in (A).

APPENDIX

Table A1. Location, numerical identifier (ID), number of years surveyed from 2003 to 2015 (N), maximum count (Max), and fate of chimneys that were demolished or capped. Only chimneys with Max > 100 are shown.

ID	Location	N	Max	Fate
29	215 Wharncliffe Rd. S, Jeanne Sauve French Immersion Public School	1	150	Capped 2005
30	130 Wharncliffe Rd. S, Victoria Public School	7	621	Capped 2007
31	1250 Dundas St., Thames Valley District School Board	3	144	Capped 2006
32	1205 Riverside Dr., Residential Building	5	103	Demolished 2009
33	130 Dundas St., Kingmill's Department Store	11	251	Demolished 2016
34	150 Simcoe St., Labatt Brewery	2	300	Demolished 2005
35	1108 Dundas St., EMCO Ltd. Homeowners	9	345	Demolished 2013

Table A2. Location and numerical identifiers (ID) of chimneys that were surveyed at least 10 times from 2018 to 2023. Also shown are the number of years the chimney was surveyed (N) from 2005-2023 and the maximum count (Max).

ID	Location	N	Max
1	371 Tecumseh Ave. E, London South Collegiate Institute	20	835
2	266 Epworth Ave., Kings University College, Misogner Wemple Hall	19	1604
3	183 Simcoe St., Labatt Brewery Garage	19	1397
4	22 Maitland St., Smith L&H Fruit Co Ltd	20	1260
5	300 Wellington St., Phoenix Interactive Design Inc.	19	330
6	940 Waterloo St., Old North Public School	19	650
7	350 Queens Ave, First-St. Andrew’s United Church (SE chimney)	8	5
8	350 Queens Ave., First-St. Andrew’s United Church (NE chimney)	9	12
9	350 Queens Ave., First-St. Andrew’s United Church (N chimney)	15	217
10	350 Queens Ave., First-St. Andrew’s United Church (S chimney)	13	100
11	1201 Western Rd., Elborn College	14	103
12	471 Nightingale Ave., Hunts Flour Mill	16	221
13	1349 Western Rd., Huron University College, O’Neil/Ridley Hall	12	364
14	370 Huron St., Kingsway Academy (N chimney)	3	223
15	370 Huron St., Kingsway Academy (S chimney)	3	6
16	388 Dundas St., London Homeless Coalition	14	500
17	423 Colborne St., SE chimney	9	24
18	700 Richmond St., ICORR Properties Management	9	150