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Impact of anthropogenic disturbance on nesting Chimney Swift (*Chaetura pelagica*) including best practices for conservation

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Abstract

The effect of anthropogenic disturbance on nesting Chimney Swift (*Chaetura pelagica*) is poorly described. We review five case studies of anthropogenic disturbance around Chimney Swift nest sites caused by building construction, demolition, and maintenance activities in St. Adolphe, Manitoba. Chimney Swift behaviour and nest site activity did not appear to be overtly influenced by building demolition and construction conducted on adjacent buildings or lots within 13–30 m of nest chimneys. In contrast, Chimney Swift behaviour and breeding success appeared to be negatively affected by loud interior renovations and rooftop work conducted in or on the same building as the nest chimneys. The presence of humans on the roof of the nest building prevented Chimney Swifts from entering the nest site and reduced the overall rate of feeding young. Based on these observations, we provide conservation best practices for building construction and maintenance projects conducted within or on the same building as nest chimneys to help ensure protection of Chimney Swifts and their nesting habitat during the breeding season.

Key words: Chimney Swift; disturbance; behaviour; Manitoba; habitat avoidance; breeding success; nest site; conservation

Introduction

Many animals perceive disturbances caused by the presence and activities of humans in a way similar to predation risk (Frid and Dill 2002). Anthropogenic disturbances, therefore, can cause physiological or behavioural responses in animals that often mimic responses to predators (Storch 2013; Van de Voorde *et al.* 2015). These responses can divert individuals from key activities, including feeding and caring for their young (Frid and Dill 2002). In birds, behavioural responses include avoidance of disturbed areas, temporary and permanent abandonment of nests, and reduced feeding; physiologically, stress hormones may also increase (Møller 2008; Strasser and Heath 2013; Moss *et al.* 2014; Samia *et al.* 2015). These disturbances are recognized for their insidious and cumulative impacts on wildlife and are often considered a primary conservation concern (Gill 2007; Price 2008). Consequently, many jurisdictions have legislation to protect vulnerable species from anthropogenic disturbance.

Chimney Swift (*Chaetura pelagica*), a bird that forages on aerial insects, is listed as a Threatened species under federal (*Species at Risk Act* [SARA]; S.C. 2002, c. 29; SARA Registry 2021) and provincial (*The Endangered Species and Ecosystems Act* [ESEA]; C.C.S.M. c. E111; 1990; Province of Manitoba 2016) legislation. It is also protected under the *Migratory Birds Convention Act* (MBCA; S.C. 1994, c. 22). The *Species at Risk Act* and its ensuing regulations include prohibitions against collecting, possessing, killing, harming, or harassing migratory birds (birds or eggs) listed as Extirpated, Endangered, or Threatened as well as against damaging or destroying their residences, i.e., nests, anywhere in Canada. Critical Habitat identified for listed migratory birds must be legally protected on federal lands and effectively protected on all other lands in Canada (SARA 2002). *The Endangered Species and Ecosystems Act* (ESEA 1990) makes it an offence to disturb or interfere with a member of an Endangered or Threatened species. Furthermore, ESEA (1990) provides the same level of protection to the habitat and the natural resources on which the species depends as it does to the individuals of such species.

Despite this legislated protection, three factors can reduce its effective application in Manitoba. First, Chimney Swifts are often unwittingly subject

to disturbances as building owners and managers are unaware of the presence of the species on their property. Most external building maintenance and construction projects in Canada, especially in the Prairie Provinces, occur during the spring, summer, and early fall, due to the prolonged periods of sub-zero temperatures in winter. This creates a risk of conflict between construction and maintenance of buildings and the protection of the species. Second, and most significantly, there is a lack of specificity in the Acts on what constitutes disturbance, which limits the ability of authorities to enforce protection for the species, most notably at their breeding sites. The proposed federal recovery strategy describes actions that prevent access to the chimney as examples of activities likely to result in destruction of those sites which meet the criteria for designation as Critical Habitat (ECCC 2022a). Third, there are no known published studies documenting the impacts of anthropogenic activity on Chimney Swifts. We address this last factor.

The Manitoba Chimney Swift Initiative (MCSI) is a collaborative partnership of environmental non-governmental organizations (NGOs), independent researchers, and biologists from provincial and federal governments that has provided a focus for monitoring, stewardship, outreach, and research of Chimney Swifts in Manitoba since 2007 (Stewart *et al.* 2017). The MCSI began an ongoing long-term study of five nest site chimneys in 2007 in St. Adolphe (49.672°N, 97.111°W), a town in the Red River Valley south of Winnipeg (Stewart and Stewart 2010, 2013). This is the longest known nest site study documenting annual phenology and breeding success in Canada. During four separate breeding seasons at these sites in St. Adolphe there were opportunities to observe the behaviour of breeding adult Chimney Swifts associated with potential anthropogenic disturbances. The disturbances were building construction, building demolition, interior renovation, and rooftop repairs. Here we report and evaluate the impacts of these activities on Chimney Swifts by comparing behaviour at the time of disturbance to expected behaviour at various stages of nesting (Stewart and Stewart 2010, 2013). We then suggest best practices for nest site management to support the application of protection measures currently afforded under primary legislation in Canada.

Methods

Five nest site chimneys on four historical buildings in St. Adolphe (Figure 1) were monitored for 15 Chimney Swift breeding seasons (2007–2021 inclusive; Stewart and Stewart 2010, 2013; B.E.S. unpubl. data). Single chimneys were located at a private residence (known as Main St.), the Paroisse St. Adolphe Church (Church), and Brodeur Bros./St. Adolphe Childcare Centre (known as Brodeur Bros.). The Brodeur Bros. building is no longer known under this name, but we have retained the name first applied (Stewart and Stewart 2010, 2013) to it to avoid confusion. Two chimneys were located at Club Amical (NE Club Amical, SE Club Amical). Breeding success was confirmed by behavioural observations of fledglings and physical evidence observed in the cleanout traps of the Brodeur Bros. and Main St. sites. Estimates of fledging at the Church and Club Amical were limited to behavioural observations due to inaccessible cleanouts.

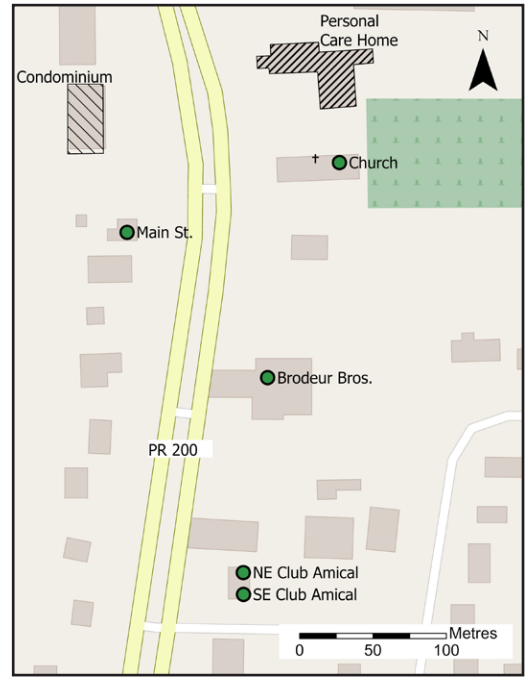

FIGURE 1. Plan of St. Adolphe, Manitoba, showing locations of all chimneys (circles), the site of the condominium construction and the site of the personal care home that was demolished in 2017. Map data copyrighted OpenStreetMap contributors and available from https://www.openstreetmap.org (https://wiki.openstreetmap.org/wiki/Researcher_Information).

Monitoring protocols remained constant across observation years. Monitoring involved watching a chimney top during the roosting hour (0.5 h before to 0.5 h after local sunset) or during the day (0.5 h before sunrise to 0.5 hour before sunset) and recording entries and exits of Chimney Swifts to the nearest second. Information about approaches and departures of Chimney Swifts (speed, direction, vocalizations, etc.) was also documented. Most observation sessions lasted 60–90 min, but ranged from 10 to 150 min. The

frequency and sequence of entry and exit events were used to identify the various stages of nesting (Stewart and Stewart 2010, 2013). We used the phenology derived from these studies to identify typical or expected behaviour (Table 1), deviations from which might be indicative of disturbance.

Monitoring effort varied among years, but a consistent effort was made to document dates for the onset of each stage of nesting. Incubation starts with the second last egg laid with clutch size varying from two to seven eggs (Steeves *et al.* 2020). It is difficult to establish the exact onset of incubation by behavioural observation, but it is possible to recognize incubation as it becomes established. Stewart and Stewart (2013) and B.E.S. (unpubl. data) have noted in St. Adolphe that as full-time incubation progresses, adult swifts increase attendance to ≥50% of the time and partner exchanges between incubating adults inside the chimney become shorter (from ≤10 min to 0.5–2 min) and less frequent (Table 1). Dates for hatching and the transition from feeding brooded to feeding non-brooded juveniles were established by observing increases in activity at the nest sites (Table 1). Daily monitoring was required to note these transitions.

Behaviourally, nest failure was indicated by waning of entry/exit rates over several days or an abrupt lack of attendance. These were confirmed by a lack of daytime entries or exits in three independent observation periods, each between 60–90 min duration, over at least two days.

As nesting progressed, observations of Chimney Swift behaviour were made during building construction, building demolition, interior building renovation, and while rooftop activity occurred. There were five instances of four types of possible disturbance: building construction near Main St., building demolition near the Church, major interior renovation in Brodeur Bros., and rooftop repair on Club Amical and Brodeur Bros. Controls used were: contiguous observations at the same site after the work had stopped, monitoring data from other local sites at the same stage of nesting on any given day, and published information (Table 1).

All observations were made by an experienced observer, B.E.S., who positioned herself to view the two chimneys at Club Amical simultaneously. Distances from the focal chimney to the construction and demolition sites were determined using Google Earth. For the construction of the condominium, the lot line marked the nearest site edge. For the demolition of the personal care home, churned earth marked the demolition area.

The observer was unaware of daily human activity until she arrived at the sites so data were obtained opportunistically, resulting in small sample sizes and "controls" that may not be ideal. Obtaining larger sample sizes, or a more robust experimental design, was not possible. Thus, there were too few data to warrant statistical tests.

We used data for entries because, unless there was excessive noise outside the chimney, Chimney Swifts may have been unaware of what was occurring in the vicinity when exiting the chimney (e.g., machinery or people nearby). On approach, the birds could make

Table 1. Typical or expected behaviour and activity for a pair of breeding Chimney Swift (*Chaetura pelagica*) at a nest site, based on 15 years of data from St. Adolphe, Manitoba, Canada (2007–2021; Stewart and Stewart 2010, 2013; B.E.S. unpubl. data). The roosting hour is defined as 0.5 h before to 0.5 h after sunset. All other observations are daytime records. Nest building continues through incubation until hatching. Note that attendance can vary in a given session due to weather and food availability.

Stage	Behaviour	Activity
Spring arrival	No daytime use of nest site	Two roosting entries; exits occur the following morning
Nest building (+ egg laying)	Daytime entries by a single Chimney Swift or pair together; egg laying cannot be estimated	1–2 entries and exits/h during the day; variable duration-in/turnaround times
Incubation (+ nest building until hatching)	Characterized by ≥50% attendance during observation session, ≤10 min duration in/ turnaround time, and/or 1 entry followed by exit within 0.5–2 min	One entry and one exit/h; one adult usually in chimney but short unattended periods
Feeding brooded young	Hatching = day 1 of feeding/brooding; young are brooded for 6–7 days	Two entries and two exits/h; short turnaround times for partner exchanges
Feeding non-brooded young	Periods with both parents absent; consecutive entries or exits indicate young are unattended	Four entries and four exits/h; longer duration-in intervals while parents feed young before exit
Fledging	Juveniles' first flights outside the nest site at 28–30 days of age	Highly variable daytime site use by young and adults; waning daytime use for ~7 days as juveniles' flight competency increases

a full assessment of activity in the area. Conversely, it is not possible to observe birds inside the chimney that abort an exit. There was, however, one exit of note. On 9 July when roofers were first observed on the Brodeur Bros. rooftop at 9:58:19, a bird exited at 9:58:42. Without knowing when the roofers arrived, we cannot say that the exiting bird had not entered when there were people on the roof.

Results

Building construction—Main St., 2012

Construction of a three-storey condominium on a previously vacant lot located ~30 m north of the Main St. nest site was at the framing stage when Chimney Swifts ($n = 4$) were first observed flying in town on 10 May. Equipment and activity were typical of a building site with truck traffic, power and pneumatic tools, generators, ladders, and platform lifts, which were used to position heavy materials on upper levels. Construction continued through the entire Chimney Swift nesting season.

Observations totalled 32 h 26 min spread across 30 days from 14 May to 20 August. Most observations (23 h 26 min) were made during the daytime. The first observed use of this chimney was on 16 May, when three birds roosted overnight. On 24 May, there were no entries during the day, but there was one on 31 May, indicating nest building. Thereafter, the breeding attempt proceeded as expected with hatching on 9 July. Young fledged on 5 August when both adults and juveniles were observed feeding above the new condominium building. On 8 August, a crane was lifting material to the roof of the new condominium building and there were no Chimney Swift entries in 1 h. On 9 August, while workers in an elevated bucket installed windows, there was one Chimney Swift entry. Day-use is highly variable at this stage of nesting (Table 1) and the observed use on 8 and 9 August was consistent with expected behaviour.

There were two observed changes in the behaviour of Chimney Swifts associated with the Main St. site. First, and throughout the summer, Chimney Swifts were observed hovering ~3 m over workers framing the south end of the condominium, which was the side closest to the nest chimney; it is uncertain the number of times this occurred because peripheral observations of the construction sites were made while watching the chimney rim. Head movements by the hovering birds were evident, suggesting the birds were observing the human activity at the construction site below. Second, Chimney Swifts typically exited to the north/northwest from the Main St. nest site. As building construction progressed, it appeared this trajectory shifted to the northwest/west; i.e., Chimney Swifts flew around the new condominium instead of over it.

Building demolition—Church, 2017

Chimney Swifts arrived at the Church site on 20 May and demolition of the adjacent 3.5-storey, 2787 m^2 personal care home took place on 23 May (Braun 2017; Ross 2017). Distance from the Church chimney to disturbed earth was 13 m. A hydraulic excavator (CAT 320D; Caterpillar Inc., Irving, Texas, USA) began and largely finished knocking the building down on 23 May. Activity by the excavator and backhoes loading dump trucks continued through 26 June as the site was cleared of debris. Plumes of dust and dirt were nearly constant during work hours.

Observations totalling 23 h 12 min were made between 9 May and 7 August, including five days (26 May–26 June, 4 h 30 min) while demolition and site restoration took place. The birds arrived in St. Adolphe between 9 and 14 May and were first observed using the Church chimney to roost on 20 May. On 26 May, Chimney Swifts were seen feeding over the clean-up area during work hours. There was no daytime use on 30 May, but there was at the next observation, on 2 June, when activity patterns were consistent with nest building (two entries in 38 min). On 26 June, Chimney Swifts collected twigs from a tree near the lot line where the final cleanup of the personal care home was being finished. There was no detectable change in the approach/departure trajectories of Chimney Swifts using this chimney.

It was later determined that the young hatched at the Church on 3–5 July, comparable to hatching dates at Main St. (3–5 July), SE Club Amical (3–5 July), and NE Club Amical (5–6 July; B.E.S. unpubl. data.). The remaining site in St. Adolphe, Brodeur Bros. was not occupied by Chimney Swifts in 2017. Two fledglings emerged from the Church on 31 July.

Major interior building renovations—Brodeur Bros., 2019

The Brodeur Bros. building was converted from its former use as a car dealership and recreational vehicle rental location to a daycare in 2019. The nest chimney remained open at this site, rising through the middle of the building. Nesting birds would likely have been aware of high decibel construction noises inside the building, e.g., pneumatic drill to break concrete and possibly other noisy equipment (power saws, pneumatic nailers, skid steer, etc.).

Chimney Swifts were first seen in St. Adolphe on 12 May. The noise of renovations was first detected by B.E.S. on 15 May and continued through the summer. Assessing this possible disturbance was complicated by two factors. First, B.E.S. was outside, ~90 m away, so noise levels at the chimney could not be

quantified. Second, the start of rooftop repairs began on 10 June so we deleted from this renovation analysis any observation hours that included rooftop activity.

Observations totalled 40 h 18 min over 27 days from 19 May to 4 July, the last day when inside noise was detected. In the 10 h 36 min when interior noises were heard by B.E.S., there were four entries (0.4/h) and in 29 h 42 min when there were no loud noises there were 54 entries (1.8/h). The entry rate with noise was less than expected, whereas the rate without noise was consistent with the rate typical for this particular stage of nesting (Table 1).

Rooftop activity—Club Amical, 2016

The effect of people walking and working on a flat roof was assessed at Club Amical by comparing entry rates when workers were present and when they were not (Table 2). Observations totalling 9 h were made on 11–17 and 19 July. Nesting was ongoing in both Club Amical chimneys when rooftop repairs began on 11 July. Roofing activities occurred daily through normal working hours on 11, 12, and 14 July; heavy rain fell on 13 July. Previous data indicated the breeding pair at NE Club Amical was tending non-brooded young for the duration of rooftop repairs, whereas the SE Club Amical Chimney Swifts were feeding brooded young. Both Club Amical chimneys were monitored simultaneously, so monitoring hours were equal. However, as the NE Club Amical breeding attempt failed earlier than the SE Club Amical breeding attempt (see below), the monitoring time of Chimney Swift response to potential disturbance was less.

The nest in NE Club Amical failed on 16 July. Entry rates with and without workers present were much lower than the expected 4/h when feeding non-brooded young (Table 1) and much lower than at a comparable site. In 2016, the breeding pair at the Church was at the same nesting stage and was observed on one day when NE Club Amical was monitored. There were three entries to the Church nesting chimney in 35 min (5/h).

At SE Club Amical, the entry rate when workers were present was slightly lower than when they were not, although both rates were above what would be expected when tending brooded young (2/h, Table 1). Additional data on entries and exits established that three adults were tending these brooded young, i.e., there was a "helper" (Dexter 1981). The nest at Brodeur Bros. was also at the feeding brooded young stage on 11 and 14 July 2016 (unpubl. data) and showed the expected two entries/hour when a helper is not present. A single exit was observed from SE Club Amical on 19 July 2016 after which the nest failed. There was no access to a cleanout trap for either of these chimneys so there is no further information about the nest failures.

Rooftop activity—Brodeur Bros., 2019

The effect of people walking and working on a flat roof was also assessed at Brodeur Bros. (Table 2). While the interior was being renovated in 2019 (see above), rain in June revealed leaks in the roof, near the chimney, that resulted in interior water damage and an emergency rooftop repair. Rooftop repairs were carried out on 10–12 and 27 June, and 8–9 and 15 July. Subsequent observations determined that hatching occurred on 10 July; 27 days of observations were made during nest building and incubation (Table 2) and seven days were during the feeding of brooded young stage. The data were partitioned to reflect this change in behaviour (Table 2). The parents stopped attending the nest after 16 July, which is the last day of data used.

During incubation, there were no entries when workers were on the roof, but the entry rate was as expected when workers were not on the roof (1.5/h; Tables 1 and 2). At this rate, one would expect 12 entries in the hours when workers were present.

Concurrent observations (3 h 26 min) on 10–12 June were made opportunistically at Main St. Subsequently, it was determined that hatching at Main St. and Brodeur Bros. were within 24 h of each other, so

Table 2. Number of daytime entries and hourly rates of entries of Chimney Swifts (*Chaetura pelagica*) at three nest sites in St. Adolphe, Manitoba, Canada in the presence of workers on the flat roofs and when there were no workers on the roof.

Site (stage of nesting)	Date	Workers on roof			No workers present		
		Obs. (h)	Entries (*n*)	Entries /h	Obs. (h)	Entries (*n*)	Entries /h
NE Club Amical (feeding non-brooded young)	11–15 July 2016	2.1	2	1.0	3.1	2	0.6
SE Club Amical (feeding brooded young)	11–17 July 2016	2.1	6	2.9	6.9	22	3.2
Brodeur Bros. (incubation/nest building)	10 June–9 July 2019	8.1	0	0.0	38.6	58	1.5
Brodeur Bros. (feeding brooded young)	10–16 July 2019	0.5	0	0.0	12.3	11	0.9

they were at the same stage of nesting (incubation) on those days. There were three observed entries at Main St. in 3 h 24 min or 0.9/h, which is in agreement with rates typical for this stage of nesting (Table 1) but higher than the entry rate seen at Brodeur Bros. (0/h).

There were fewer data when the parents were feeding brooded young at Brodeur Bros. (Table 2). There were no entries during the presence of workers. The one time (15 July) that workers left during an observation period was the last day of rooftop work, and the first Chimney Swift entry was seven minutes later. There was a single Chimney Swift entry in 2 h of observation on 16 July and none on 17–19 July. The nest had failed. Additional rooftop repairs were made on 25 and 31 July.

Behaviour observations indicated that hatching took place on 10 July (day 1); the predicted fledging dates were calculated as 6–8 August (day 28–30). Parental attendance waned below expected feeding rates (Stewart and Stewart 2010, 2013) on 15–16 July, then did not occur on 17–19 July (day 8–10). A nest failure was indicated. The eight half eggshells at the cleanout trap in September indicated that four eggs hatched. The 2019 nest remained on the wall of the chimney until it was dislodged by commercial cleaners in March 2020.

Rooftop activity and Chimney Swift approaches to nest site

Chimney Swifts sometimes approach their nest sites and depart without entering. At Brodeur Bros. in 2019, on days when observations were made both without and with workers on the roof, 5/19 approaches by the birds (26%, 11 h 42 min of observation) resulted in no entry when there were no workers on the roof. However, when workers were present, 9/9 (100%, 7 h 36 min of observation) approaches resulted in no entry.

At Club Amical in 2016, observations were made without and with workers present only on 12 July, so we used 13 and 15 July (workers absent) and 11 and 14 July (workers present) for comparison. In the absence of workers, 3/10 (30%, 3 h 6 min of observation) approaches did not result in entries. When workers were present, 11/18 (61%, 2 h 6 min of observation) approaches were followed by no entry.

Discussion

We found that Chimney Swift behaviour and nest site activity was not overtly influenced by building demolition and construction conducted on adjacent lots within 13–30 m of nest chimneys. In contrast, Chimney Swift behaviour and breeding success appeared to be negatively affected by loud interior renovations and rooftop work conducted in or on the same building as the nest chimneys. These findings are, to our knowledge, the first of their kind to be documented for this species. Given the protected status of Chimney Swifts in Canada, these findings can be used by regulatory authorities to provide guidelines on how to reduce disturbances from renovation and construction projects relating to buildings with nesting Chimney Swifts.

Chimney Swifts that nest in urban areas are routinely exposed to anthropogenic noise and road dust. Many MCSI sites are adjacent to busy thoroughfares and the St. Adolphe nest sites are all 20–45 m from a four-lane road. Construction of a three-storey condominium spanned the whole Chimney Swift nesting season. Slow, incremental changes to the height of the new building were accommodated by the Main St. breeding Chimney Swifts. The only impact was an apparent shift in exit trajectories. There was no discernible effect on nesting success. Demolition of the personal care home was brief and occurred before nest building began at the Church. Debris removal and site restoration spanned nest building, egg laying, and incubation. The breeding attempts at the Main St. and Church sites resulted in successful fledging. Overall, there was no apparent change in chimney use associated with either the condominium construction or demolition site restoration. We have no information on the possible deleterious effects of dust and noise during chick-feeding stages. Future demolition cases involving Chimney Swifts should be monitored diligently to document potential disturbances from dust, equipment movement, noise, etc., at this critical stage.

Renovations to the Brodeur Bros. building began before, then overlapped, rooftop activity. Before roof repairs started and while the Chimney Swifts were nest-building and incubating, the birds entered the chimney at lower rates during periods of loud noises, such as jackhammers breaking up the concrete floor, but entered at higher rates when it was quiet and no work was occurring. During those times, entry rates were at the higher end of the expected range and it is possible that the Chimney Swifts attempted to compensate for lost time in nest building and incubation. Several studies have shown that noise alone negatively impacts habitat use, feeding rates, nesting success, and nestling quality in birds and acute, unpredictable noise had greater impacts than chronic, more predictable noise (e.g., Merrall and Evans 2020; Mulholland *et al.* 2018; Rosa and Koper 2021). Similar effects may occur in Chimney Swifts based on our results. Breeding Chimney Swifts in Manitoba appear vulnerable to disturbance as a complete nesting cycle requires at least nine weeks and the reproductive season is short (< 14 weeks). No documented primary nesting attempt in St. Adolphe has succeeded

if initiated after 4–6 June and no secondary nesting attempt has ever been successful (Stewart and Stewart 2010, 2013; B.E.S. unpubl. data).

The duration of incubation in St. Adolphe appeared to be variable (16–21 days) as reported elsewhere (Steeves *et al.* 2020). Chimney Swifts can prolong incubation for several days during cool weather (Steeves *et al.* 2020) and, similar to other species of swifts (Apodidae spp.), the eggs might have a high tolerance to cool temperatures (O'Connor 1979; Malacarne *et al.* 1992). It is generally thought that unhatched Chimney Swift eggs are constantly attended as the parents take turns to leave the chimney to feed (Fischer 1958; Stewart and Stewart 2013). Sometimes we were unable to determine if an absence of entries by an adult during incubation meant the eggs were unattended or if one parent remained on the nest for an abnormally long time. The former might delay embryonic development and the latter might compromise the energetic reserves of the sitting (fasting) adult. Both parents share chick-rearing responsibilities (Kyle and Kyle 2005; Steeves *et al.* 2020). If one parent is on the nest and the other is excluded due to anthropogenic disturbance, the energetic costs to the parent on the nest may be acutely or chronically detrimental, potentially causing an energy shortage that might limit its subsequent capacity to feed its young (Moreno 1989). Therefore, it is reasonable to conclude that delays in the progression of nest building or incubation due to anthropogenic disturbance, particularly multiple cumulative delays over the course of a single nest cycle, may have negative impacts on reproductive success of nesting Chimney Swifts.

The presence of workers on the Brodeur Bros. roof stopped entries from 9 July onwards and the eggs hatched on 10 July. Roofers' presence was during a crucial period when the newly hatched young need to be fed. Unlike delayed nest building or incubation, lost feeding time cannot be compensated for by more frequent feedings later. Intense anthropogenic disturbances have also been shown to slow development in Blue Tit (*Cyanistes caeruleus*) chicks and cause them to fledge in poor body condition (Remacha *et al.* 2016). Poor fledgling physical condition, including low body mass and shorter wing length, is one factor that reduces survival rates of post-fledging birds, which in turn influences demographic rates, including annual survival and recruitment (Naef-Daenzer and Grüebler 2016).

We documented nest-site avoidance in the presence of rooftop workers and loud interior building noises surrounding the chimney base. Reduced activity in response to the threat of predation has been documented around nest sites in songbird species (e.g., Rohwer and Purcell 2019). Similarly, nest avoidance due to anthropogenic disturbance has been observed in European Pied Flycatcher (*Ficedula hypoleuca*) nesting near busy footpaths (Goodenough 2014). Chimney Swifts will fly over a nest chimney and disappear from sight before returning shortly afterwards, making a rapid entry into the chimney (Kyle and Kyle 2005; MCSI unpubl. data), possibly as they have satisfied themselves that no threat is present. We found that more approaches resulted in immediate departure without entry when workers were present on the rooftop. Indeed, during nest building, egg laying, and incubation at Brodeur Bros., no approaches resulted in entries when workers were on the rooftop. At both Club Amical nest sites, where chicks were being fed (assisted by a helper at the SE Club Amical site), there were more approach-departure events when workers were present than on contiguous days when there was no rooftop work being done. Chimney Swift behaviour that was negatively associated with anthropogenic rooftop activity included single or repeated instances of an approach followed by quick deflection or veering off, rapid altitudinal changes before immediate departure, circling of the site before departure, and hovering before departure.

Many birds respond to anthropogenic disturbances as if they were akin to a predation threat (Frid and Dill 2002). The behaviours we documented would suggest that human presence on the roof of a building, and the generation of loud noises surrounding the chimney base, elicit similar avoidance behaviours in Chimney Swifts to those observed in other bird species in response to perceived predation events (Frid and Dill 2002). Similarly, in London, Ontario, sandblasting and repointing of two chimneys was associated with two failed breeding attempts, while loud noises near the chimney from fireworks, a roaring crowd, and a drone flying near the nest chimney rim all resulted in apparent disruption of the birds' behaviour (W. Wake pers. comm. 13 November 2021).

At Brodeur Bros. in 2019, the young hatched on 10 July, roofers were present on 15 July, and the nest failed on 16 July. At Club Amical in 2016, there was roofing activity while the birds using both chimneys were feeding young on 11–12 and 14 July; heavy rain fell on 13 July. The NE nest failed on 16 July and the SE nest failed on 19 July. The low rate of feeding over several days at the NE chimney suggests that the nest attempt might already have been in the process of failing. At Brodeur Bros. it is possible that one or both parents entered the feeding-young stage energetically compromised due to enforced longer incubation periods brought on by anthropogenic disturbance. In turn, this may have contributed to nest failure.

Nest failures can be associated with a number of environmental stressors, but we consider the primary

cause of nest failure at Brodeur Bros. was the roofing activity. Extreme temperatures, especially low temperatures, and high precipitation have been associated with reduced body mass and low survival rate of juvenile swifts and swallows (Hirundinidae spp.; Cucco and Malacarne 1996; Winkler *et al.* 2013; Cox *et al.* 2019; Steeves *et al.* 2020). However, average daily maximum and minimum temperatures for July at Winnipeg Richardson International Airport, 28 km NW of St Adolphe, (2016: 25.1°C and 13.4°C; 2019: 26.7°C and 13.6°C; ECCC 2021) were not different than long term averages at Winnipeg (1981–2010: 25.9°C and 13.5°C; ECCC 2022b), suggesting that prolonged extreme temperatures were not a factor contributing to nest failure. Rainfall in July 2016 (82.7 mm) approximated the long-term average of 79.5 mm while July 2019 was drier (44.8 mm), which suggests that prolonged extreme rainfall was also not a factor contributing to nest failure. We are unaware of any alternative factors, in addition to rooftop activity, that might better explain the influences on swift behavior and reproductive success that we observed, although they may very well exist.

We have shown that rooftop activities and elevated noise levels correlate with diminished parental care in Chimney Swifts. With only one instance each of building construction and demolition, our study and its conclusions would have been stronger with increased sample sizes. Construction or demolition of a taller building, for example, might have greater impacts, or other unknown variation not captured by our sample might exist. Further quantitative studies of anthropogenic disturbances and Chimney Swift responses are required. Controlled experiments that purposely cause disturbance remain unacceptable. Monitoring Chimney Swift behaviour before, during, and after expected disturbances could be a permitting requirement when emergency repairs at a nest site are needed. Until more data become available, our results can be used to formulate best practices to mitigate potential negative effects of building construction and maintenance projects on this Threatened species and its habitat during the breeding season.

Recommended best practices

Our results suggest that rooftop activity and loud noises within the building containing the nest chimney (i.e., loud being audible from outside the building, 90 m away) cause reduced frequency of chimney entries by breeding adults. This reduction in attendance likely leads to avoidance of nesting habitat, reduced incubation activity, reduced rate of feeding young, and nest failure. These behavioural changes might be viewed as harassing individual birds or disturbing nests or eggs as prohibited by s. 5 and s. 6 of the Migratory Birds Regulations (2022) or as damaging the residence of Chimney Swifts as prohibited by s. 33 of SARA (2002). Our study supports regulators as they seek guidance on describing activities that demonstrably disturb Chimney Swifts and developing best practices for limiting the impacts of those activities.

It is best practice, therefore, to entirely avoid generating loud noises and any rooftop activities within or on the building containing the nest chimney during the usual season of Chimney Swift occupancy, and especially during known or suspected occupancy of any chimneys by nesting or roosting swifts. We note that having strong trusting relationships with property owners in St. Adolphe led to deferred work on three roofs in 2020 and 2021. Additionally, landowner letters and outreach from the Province of Manitoba led to other property owners avoiding disturbance by doing rooftop work when the birds were absent. Based on such successes, we highly recommend that these types of proactive efforts be made with landowners in instances where anthropogenic disturbance might negatively impact nesting Chimney Swifts.

In addition, we also recommend the following due diligence to help ensure protection and conservation of the swifts:

- monitor the nest site intensively to establish the pre-disturbance behaviour baseline, including typical approach and departure paths, nesting stage, activity sequences, and entry rates;
- monitor during potential disturbance events to identify avoidance behaviour that indicates displacement (e.g., increased frequency of approaches followed by quick deflection/veering off, rapid altitudinal adjustments and immediate departure, and circling or hovering prior to departure). Manage anthropogenic activities immediately to enable Chimney Swifts to access the nest site;
- establish a setback distance for storage and operation of equipment with movable arms as a precautionary approach to limit noise and movement of larger vehicles, which may interfere with flight lines (e.g., large hydraulic excavators, cement pumper trucks);
- limit the number and duration of events requiring people and equipment above the eaves and on the rooftop;
- avoid noisy interior construction and renovations close to the chimney, or in the same room as the chimney, during the breeding season; and
- avoid cleaning the interior of the chimney during the Chimney Swift breeding season.

When construction occurs at locations where Chimney Swifts are using the site for roosting only, monitoring needs to be particularly intensive.

Conventional wisdom is that the birds enter around sunset and depart around sunrise but entry and exit times are highly variable (Steeves *et al.* 2020; Pearce and Foot 2022). Only monitoring that allows estimating the numbers of birds inside the chimney at any given time can ensure there are no birds there to be disturbed. As well, all rooftop activities at nest and roost sites should cease during periods of increased environmental stress (e.g., storms, extreme temperatures, high winds, poor air quality due to smoke) to allow Chimney Swifts an opportunity to take shelter in the chimney.

Conclusion

Anthropogenic disturbances, notably loud interior noises and rooftop activities, elicit behavioural responses in Chimney Swifts that likely contribute to nest site failure through reduced attendance and feeding frequency. Human activities near nest sites should therefore be managed to limit negative impacts on the birds. This is best achieved through 1) community outreach with targetted landowners to raise awareness and promote cooperation and compliance, and 2) stringent use of the conservation best practices and guidance described above. Enforcement of species-at-risk and migratory bird legislation should only be used as a last resort, if absolutely necessary, when the above approaches fail or seem likely to fail to protect the swifts. Continued monitoring to identify new nest sites remains an ongoing priority as most property owners are unaware that their property is being used by Chimney Swifts. We also recommend further research into behavioural associations with various types of disturbance and the preparation of best practice documents for property owners to inform them how to limit nest site disturbances.

Author Contributions

Writing – Original Draft: T.F.P., B.E.S., and R.E.A.S.; Writing – Review & Editing: T.F.P., B.E.S., and R.E.A.S.; Conceptualization: T.F.P. and B.E.S.; Investigation: B.E.S.; Methodology: B.E.S. and R.E.A.S.; Formal Analysis: R.E.A.S.

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