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Abstract

The breeding period of birds is a critical and sensitive period. Understanding how human use of urban greenspaces affects nest survival can improve our understanding of conserving breeding bird populations in cities and support science-based management of urban greenspaces that benefit both people and nature. We conducted a nest survival field study between April and August of 2023 in multiple greenspaces in Montreal, Quebec, Canada, the country's second-largest city. We asked whether human presence (distance to trails and amount of human activity) influences the nest survival of four common open-cup nesting bird species. We also asked if variables traditionally associated with nest survival, vegetation concealment and seasonality, would influence nest survival. Our analyses surprisingly revealed no significant influence of human activity, vegetation concealment, and seasonality on nest survival for our target species. We found for nests that did fail, nests established during the earlier part of the nesting period failed faster. Within the limitations of our study system, our findings suggest that human presence is not negatively impacting the nesting success for our target bird species using urban greenspaces. Our study provides integrated science advice to land managers so they can support opportunities for people to connect with nature without causing trade-offs with biodiversity conservation.

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Statement of Ethics Compliance

All details of animal monitoring were approved by Concordia University's Animal Care Facility and by The Canadian Wildlife Service (Permit no. SC-98).

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1 **Introduction**

2 Natural areas in cities are increasingly recognized for their value in providing support for wildlife and services for
3 people. Birds often take refuge in city parks and forests, hereafter referred to as “urban greenspaces”, which are
4 defined as delineated patches of land containing natural components (trees, shrubs, grasses, gardens) (De Haas et al.
5 2021). For example, in Montreal, researchers found a higher abundance and diversity of shrub-nesting birds in parks
6 compared to residential areas (Rousseau et al. 2015), implying that these are important spaces for avian conservation
7 (Buron et al. 2022). Parks also have more opportunities for coordinated efforts to improve habitat quality and
8 diversity for birds. In contrast, residential spaces like backyards and gardens are more difficult to manage at a large
9 scale, as individual property owners have varied preferences for vegetation and may choose ornamental, non-native
10 plants that do not support biodiversity (Threlfall et al. 2017). Urban greenspaces provide wildlife, including birds,
11 with shelter, areas to raise young, and food, which is particularly important in cities where green cover is low
12 (Vasquez & Wood 2022).

13 In urban settings, birds are widespread and known to be biodiversity indicators (Fraixedas et al. 2020). They often
14 stop in urban greenspaces along their migration routes to rest and replenish fat stores (Rodewald & Matthews 2005;
15 Seewagen et al. 2010), while others are drawn in by artificial light pollution (McLaren et al. 2018). Urban
16 greenspaces can be attractive to open cup shrub-nesting bird species specifically, as cities often have many of their
17 preferred shrubby edge habitats (Kurucz et al. 2021). These species have lower rates of nest survival in comparison
18 to species that use other nesting strategies (Ospina et al. 2018). Their nests are often and easily accessed by
19 mesopredators, which are common in cities in the absence of sensitive apex predator species (Morosinotto et al.
20 2012). Cities present many general dangers to birds, including building and window collisions, and novel predators
21 (Van Doren et al. 2021; López-Flores et al. 2009). Furthermore, the fragmented nature of urban habitats poses
22 challenges to birds as it can limit their movement and increases vulnerability to predation and competition (Marzluff
23 2001). These challenges underscore the need for long-term avian monitoring in urban spaces and the need to
24 implement conservation solutions, which could include improving the management of urban greenspaces to support
25 birds.

26 Responsibility for protecting and managing urban greenspaces is shared between federal or provincial initiatives and
27 local municipal governance. In Canada, for example, federal initiatives such as the National Urban Parks initiative,

the Growing Canada's Community Canopies initiative, and the Nature Smart Climate Solution Fund provide funding and/or guidance to promote the conservation, restoration, and management of urban nature. (Parks Canada 2023; Natural Resources Canada 2024; Environment and Climate Change Canada 2024). The establishment, protection, and management of urban greenspaces is particularly important for biodiversity in southern Canada, as this region is heavily developed, but also contains the majority of the country's species at risk. Furthermore, southern Canada has experienced low conservation responses relative to the threats facing biodiversity in these regions (Kraus & Hebb 2020).

In addition to protecting biodiversity, urban greenspaces facilitate human-nature interactions, with urban birds representing some of the most accessible wildlife to people. Interactions with nature have been shown to reduce the frequency of violence, mortality and heart rate, while improving attention span and the frequency of physical activity (Kondo et al. 2018). Additionally, human-bird interactions specifically help to reduce symptoms of anxiety, paranoia, and depression (Stobbe et al. 2022). A recent study found a positive relationship between urban bird diversity and self-reported good mental health, indicating that cities with greater biodiversity may enhance overall mental wellbeing (Buxton et al. 2024). Birds provide people with important cultural services, such as promoting feelings of relaxation and a strong connection to nature through activities such as birdwatching or bird feeding (Cox & Gaston 2016). These positive interactions provide incentive to protect and maintain our urban greenspaces.

While people receive mainly positive effects from birds, studies have reported that human presence in urban greenspaces can impact the diversity and abundance of bird species (Bötsch et al. 2018; Jokimäki 1999; Kangas et al. 2010; Lepczyk et al. 2008; Van der Zande et al. 1984). Some studies have suggested that urbanization and human presence are negatively correlated with bird species richness (Peña et al. 2022; Bötsch et al. 2018). A recent publication showed that most bird species cannot tolerate a high level of human pressure, with only 22 % of over 6000 global species of birds being more tolerant (Marjakangas et al. 2024). Yet, there is a lack of consensus on how more direct measurements of bird population well-being, might be impacted by human disturbance (Chamberlain et al. 2009; Vincze et al. 2017). A strong example of a direct measurement is reproductive success, as the breeding period represents a critical and vulnerable period in a bird's life and allows for the survival of a species (Forslund & Pärt 1995).

Research in more natural areas has suggested that human presence and recreation have negative consequences on avian reproductive success, but evidence and consensus of this in urban greenspaces is lacking. Human disturbance had a significantly negative effect on nest success in seabirds in a nature park in Scotland (Beale & Monaghan 2004). Another study on blue tits (*Cyanistes caeruleus*) in experimentally placed nest boxes in a forest 60 kilometres outside of Madrid found that nestlings hatched on holidays, linked to an increase in recreation and human gatherings, were associated with impaired development (Remacha et al. 2016). Nests closer to roadways and human development are also more likely to be abandoned by the cavity-nesting American kestrel (*Falco sparverius*) (Strasser & Heath 2013). Waterfowl are reported to spend less time at their nests due to human disturbance, thereby increasing the chance of nest predation (Stien & Ims 2015). Predation is globally known to be the primary source of nest mortality (Ricklefs 1969). Mesopredator populations, including common nest predators such as crows and raccoons, often explode in urban environments, as these spaces favour conditions that increase mesopredator survival and reproduction (Prugh et al. 2009; Kövér et al. 2015, Prange & Gehrt 2004).

Conversely, a study in a suburban area of Colorado found that experimentally placed nests closer to trails incurred less predation, likely because human presence and recreation decreased known predators of shrub and low-nesting bird species (Miller & Hobbs 2000; Miller & Hobbs 2002). This is known as the “human shield” hypothesis, which proposes that in regions with higher human activity, human presence acts as a buffer against the impacts of predation on prey species, effectively shielding these animals from their predators and increasing survival (Berger 2007, Gámez & Harris 2021; Pérez-González et al. 2024). Another study on Northern cardinals (*Cardinalis cardinalis*) in Ohio publicly owned parks (including some in highly urbanized areas) found that human recreation did not have an apparent effect on nest survival, and that height was the mediator of human disturbance and likelihood of flushing (when birds leave their nest in response to disturbance) (Smith-Castro & Rodewald 2010b). They believed that nests where birds flushed their nests at further distances from humans, compared to those where birds flushed when humans were closer, would experience more predation because their nests are unoccupied for longer (Smith-Castro & Rodewald 2010b). Evidence that human disturbance both does and does not impact reproductive success highlights the need for clarity on the subject, especially as cities expand and the number of people using urban greenspaces increases.

The overall aim of our work is to assess whether human presence in urban greenspaces influences the nest survival of common species of open-cup shrub nesting birds on the island of Montreal. We also sought to understand how aspects of the vegetation in the nest patch and seasonality might influence nest survival, as these are often included in traditional nest survival studies and are known to be important predictors of nest survival (Davis 2005; Ringelman 2019). For nests that failed, we also investigated whether these variables were significant predictors of the total number of active days that a nest experiences—defined as the number of days from nest inception (first day of building) to nest failure. We did this by conducting a nest survival study across three sites, measuring vegetation variables at the nest patch, quantifying human activity using anonymous cellphone data (Filazzola et al. 2022), and distances of nests to trails, and conducting Cox proportional hazards modelling.

We predict that nesting survival would rise with greater distances from trails and higher rates of human activity, given birds' vulnerability to disturbances posed by trail users, such as loud noises and dogs (Steven et al. 2011), which could increase flushing and signal predators to the location of the nest (Martin et al., 2000) or cause parental abandonment (Beale & Monaghan 2004; Boyd, n.d.; Strasser & Heath 2013). Additionally, we predict that nests higher from the ground, that have more vegetative concealment and shrubby vegetation would increase nest survival and the number of active days a nest experiences. We anticipated this as ground predators common in urban forests may face more difficulty finding and accessing nests (Martin 1993; Seibold et al. 2013; Ringelman & Skaggs 2019) and that nests would be more shaded from the sun, which is crucial for regulating temperatures for healthy nestling development (Corregidor-Castro & Jones 2021). We expected that nests would experience higher rates of success and more active days with the progression of time through the season, as there is more dense foliage later in the season to conceal and shade nests and a lower likelihood of cold weather events.

Methods

Study Sites

The Island of Montreal is in the St. Lawrence Lowlands of Southern Quebec and contains Canada's second largest city. The Island of Montreal covers an area of 498.29 km² with an average human density population of 4022.3 people / km² (Government of Canada 2022). The area hosts various habitats such as woodlands, wetlands, brown-lands and shoreline habitats amongst a developed, urban landscape, allowing for approximately 145 bird species to nest each year (Québec Breeding Bird Atlas – n.d.). We conducted our study in three urban greenspaces on the

primarily residential and industrial west side of the Island of Montreal: Bois-de-Liesse Nature Park, Technoparc, and Stoneycroft Wildlife Area—selected to span a gradient of human activity (Appendix A). While the parks differ in total size, their vegetation composition is relatively similar and all contain similar dense shrubs, which attract our target bird species.

Bois-de-Liesse is a high visitation park managed by the city of Montreal that is used by cyclists, runners, and dog-walkers, as well as for recreational activities such as picnics and children’s day camps. Technoparc is a large greenspace that includes both newly acquired city land (yet to be managed for recreation) and privately owned areas. The area is informally managed by a non-profit organization and is primarily used by birders and nature photographers. Stoneycroft Wildlife Area is a private research area with no public access that is owned by McGill University and hosts a small field station that is active 6 months each year. Our nest searching efforts in all three greenspaces were focused along both small footpaths and larger, more heavily trafficked trails.

Study Species

We studied four target species that commonly nest in all our study sites: American robins (*Turdus migratorius*), gray catbirds (*Dumetella carolinensis*), Northern cardinals (*Cardinalis cardinalis*), and yellow warblers (*Setophaga petechia*). These species are generalist open cup nesters and thus have likely comparable survival and predation rates (Billerman et al. 2022; Leston & Rodewald 2006). Despite their status of “least concern”, they are still vulnerable to threats posed by human influence and a changing climate (Lindenmayer et al. 2011). Focusing on managing for common species could thus serve as a strategy to indirectly support and protect at-risk species, particularly those with similar nesting and reproductive behaviours. These common species are also more likely to be known and recognized by the general public, which helps facilitate people’s interactions with nature.

Nest Monitoring

We initiated nest searching at dawn, the period of peak avian vocalization and activity (Southworth 1969) and ended at 14:00 between April 26th and August 4th, 2023. Searching was conducted at one site per day rotating through each of the three sites. We did not search for nests on days with heavy rainfall or other inclement weather, such as thunderstorms or days with extreme heat warnings, when birds are known to be less active (Rosamond et al. 2020). Nest searching methods included both territory mapping (Smith et al. 2009) as well as opportunistic observations of target species. Behavioural cues used in finding nests included observing individuals carrying nesting material,

vocalizing, or feeding young (Martin & Geupel 1993). During territorial mapping we marked the location of adult birds on a physical map each time we were in that area and approximated the extent of individual territory (Jablonski et al. 2010). We also noted the location of male birds vocalizing, as this often indicates that they were at the edge of a territory (Stoddard et al. 1991).

Once found, we recorded nest geographic coordinates using a Garmin GPS (Extrexx 22X). We also collected data on weather conditions, the time the nest was found, the species to which the nest belonged, the nest substrate or tree species, and the presence of potential nest predators that could be seen or heard within a 10m radius of the nest (Purcell & Verner 1999; DeGregorio et al. 2016)

We monitored nests every three to five days, following previously established nest monitoring methods (Bailey et al. 2019). Unlike searching, we conducted nest monitoring in a variety of weather, including light rain. In some cases, nests could not be monitored by direct observation at eye level, and we used binoculars and/or an elevated endoscopic camera. We noted the presence of an adult incubating eggs or brooding nestlings, and the nest was presumed to be active. At each nest monitored, we collected the following data: time, date, weather, information on the status of adult birds (if present), eggs (if present), young (if present), condition of the nest (whether it was unfinished, fully constructed, flattened with fecal matter, or removed), whether predators could be observed or heard in a 10m radius of the nest, and any other noteworthy information (Bailey et al., 2019). In some cases, we observed instances of active predation on nests, and we took note of this. If a nest had been removed from where it had once been located, we noted the condition and location of the disturbed nest.

Vegetation Surveys

We surveyed vegetation at three spatial scales: the nest tree or shrub (henceforth “nest tree”), a 1 m radius nest patch, and a 5 m radius nest patch. We conducted these surveys typically within five days (but 10 surveys were conducted within 5-12 days) of the nest failure or success date to capture vegetation characteristics of the nest patch as accurately as possible. For each nest tree, we recorded the diameter at breast height (DBH), species, height, nest height, vegetative complexity (see Appendix B), and canopy cover above the nest using digital image analysis (see Appendix B). To estimate nest concealment, we used checkerboards (three by three alternately black-and-white squares) of three sizes to accommodate differently sized nests, adapted from Nudds’ method of estimating vegetative cover of deer (Nudds 1977, see Appendix B). For the 1 m radius vegetation survey we identified all woody stems in

a 1 m radius around the nest tree to species level and tallied the number of stems based on size classes (< 1 cm, 1-3 cm, 3-6 cm, and 6-9 cm DBH). In the 5m radius vegetation survey we identified each tree greater than 5cm to species and measured their DBH. Lastly, we measured the distance of each nest to the nearest trail.

Human Activity Indices

To investigate the human impact of nest survival, we obtained human activity indices of our three sites by using ©MapBox Movement data (www.mapbox.com/movement-data). These data were recorded from 2020 to 2022, and while they did not correspond to our study year, we assumed that the average activity in this timeframe would reflect the human activity present at our sites in 2023. The activity indices were obtained from anonymized cellphone location data within 10 m x 10 m plots per two-hour window (following Filazzola et al. 2022). We subsequently overlaid these human activity indices with our nest GPS points through spatial analysis using R version 4.3.2 (R Core Team 2023), using the stars, sf, stringr, and dplyr packages (Pebesma & Bivand 2023; Pebesma 2018, Wickham 2023; Wickham et al. 2023) to extract mean activity indices within a 20 m radius of each nest location.

Nest Survival Analysis

We used program RMark (Laake 2013) to estimate daily survival rates (DSR) of each of our target species and used the DSR to the power of the average nesting period for each species to calculate species-specific modelled nest success (Jehle et al. 2004). For American robins, the average nesting period is 35 days, for gray catbirds it is 32, for Northern cardinals it is 30, and for yellow warblers it is 31 (Billerman et al., 2022). To visualize survival over time for each of our target species, we plotted Kaplan-Meier curves using ggsurvfit, ggplot2, and magrittr packages (Sjöberg et al, 2024; Wickham 2016; Bache & Wickham 2022) in R 4.3.2 (R Core Team 2023). These curves display the probability of the nest surviving each day through the nesting period.

To assess the effects of distance to trail, human activity, vegetation variables, and seasonality on nest survival, we used Cox proportional hazard modelling (Cox 1972). This modelling approach is used when testing the effects of various covariates on the duration until nest failure while accounting for censoring, and time-varying factors (Nur et al. 2004; Roper 2003; Heisey et al. 2007; Liebezeit et al. 2009). Nest successes were our censored events, and were assigned values of “0”, whereas nest failures were assigned as “1”.

Preceding our model building, we checked our variables of interest for collinearity. We established a cutoff for collinearity of 0.7, consistent with studies in ecology. We calculated Pearson correlation coefficients and then

visualized the correlations using the `corrplot()` function in R Studio and checked for any significant correlation (Wei & Simko 2021; R Core Team 2023). We also ensured that our models met the assumptions associated with Cox proportional hazards modelling. The fundamental assumption for Cox proportional hazards modelling is that the hazard of the event of interest occurring is constant over time. We assessed this assumption using the `cox.zph()` function from the R survival package, visually assessing plots of the residuals (Therneau 2024).

We built five models (Table 1) based on our hypotheses, aiming to identify variables (Table 2) that may impact nest survival of our target species. We included site and species as random effects variables in all models to account for the fact that our studied sampling locations were nested within sites and that the species may respond differently. Our chosen explanatory variables were regressed against the number of days the nests survived. This generated hazard ratios for nest failures over time. Hazard ratios indicate the probability that an event of interest will occur, in our case, these events were nest failures.

Table 1. Our built models with their explanatory variables used in Cox proportional hazards modelling of avian nest survival in Montreal urban forests. The response variable for all models was the time to nest failure. Random effects of site and species are included.

Model Name	Hypothesis	Explanatories
Human Impact	The proximity of nests to trails and the average human activity around nests strongly influences nest survival.	Distance to Trail + Human Activity Indices + (1 Species) + (1 Site)
Vegetation	The vegetative cover, the height, and the density of stems surrounding nests strongly influences nest survival	Vegetation Concealment + Nest Height + # Small Stems/Ha + (1 Species) + (1 Site)
Seasonality	Seasonality, quantified by the day of year when nest building was first initiated, strongly influences nest survival	Initiation Date + (1 Species) + (1 Site)
Global		Distance to Trail (m) + Human Activity Indices + Vegetation Concealment + Nest Height + # Small Stems/Ha + Initiation Date + (1 Species) + (1 Site)
Null		(1 Species) + (1 Site)

We fit models using the `coxme()` function from the Coxme (Therneau 2012) and survival (Therneau 2024) packages in RStudio 4.3.2 (R Core Team 2023). We used Akaike's information criterion (AIC), the widely used maximum-likelihood estimator, to assess the most parsimonious and predictive model (Table 4) (Lebreton et al. 1992).

Number of Active Days Analyses

For nests that failed, we used a multivariate linear regression model to assess the impacts of human presence variables (distance to trail, human activity index, and site), seasonality (day of year) and concealment variables (coverage, canopy cover, vertical complexity, density of surrounding vegetation). Analysis was done with packages lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2017), and visualization was done with ggplot2 (Wickham 2016). Our resulting mixed model is the following:

$$\text{Active days} \sim \text{concealment} + \text{canopy cover} + \text{vertical complexity} + \text{1m vegetation density} + \text{distance to trail} + \text{human activity} + \text{day of year failed} + (1|\text{site}) + (1|\text{species})$$

Results

Nest survival of target species

We found and monitored 93 nests of our target species across three urban sites until failure or success. A nest was considered successful if at least one nestling successfully fledged. Four nests were removed from the analysis as they were determined to be outside site boundaries. An additional two nests were removed as we could not access them for proper monitoring, so their fates were unknown. This resulted in a final sample size of 87 nests (Appendix C & D). For all four target species and across all three sites, we found an overall apparent nest success rate of 24.1%. American robins had the highest modelled nest survival estimate, followed by yellow warblers, gray catbirds, and Northern cardinals had the lowest modelled nest survival estimate (Table 3).

Table 2. Summary statistics for variables measured and used in this study of bird nest survival (American robins, gray catbirds, Northern cardinals, and yellow warblers) in Montreal, Canada.

Variable	Range	Median	Mean (+/- SD)
Distance to Trail (m)	0.10 – 110.00	5.20	15.63 (+/- 22.46)
Vegetative Concealment	0.00 – 6.00	2.19	2.22 (+/- 1.30)
Human Activity	4.16×10^{-4} – 0.05	4.53×10^{-3}	0.01 (+/- 0.01)
Initiation Date (DOY)	1.00 – 58.00	34.50	32.17 (+/- 14.67)
Canopy Cover	0.06 – 45.53	1.84	6.22 (+/- 11.53)
Vegetation Density (1m from nest)	$0.00 – 3.18 \times 10^5$	1.59×10^4	2.66×10^4 (+/- 4.81×10^4)
Vertical Complexity	1.00 – 3.00	2.00	2.09 (+/- 0.71)

Table 3. Daily survival rates estimated, standard errors (SE) and the percentage of successful nests for American robins (n = 32), gray catbirds (n = 11), Northern cardinals (n = 23), and yellow warblers (n = 23) using the RMARK program.

Species	DSR	SE	Modelled Nest Success
American robins	0.94	0.01	11.5%
Gray catbirds	0.89	0.04	2.4%
Northern cardinals	0.82	0.05	0.03%
Yellow warblers	0.90	0.03	3.8%

Kaplan-Meier survival estimate curves show the probability something will survive through time. We observed steep decreases in nest survival probabilities during the first half of the nesting period, and more graduate declines in the second half of the period (Figure 1). These patterns were consistent across all four target species.

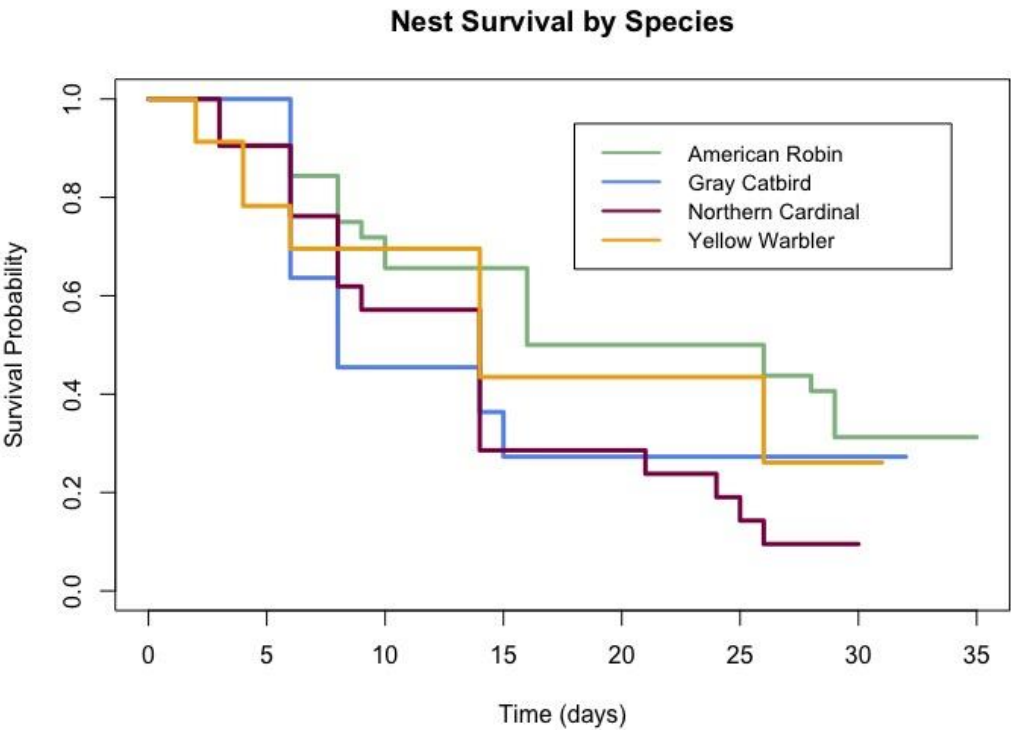


Figure 1. Kaplan-Meier survival curve displaying the survival probability of our four target species: American robins, gray catbirds, Northern cardinals, and yellow warblers across three urban forested sites in Montreal over time.

We built our Cox proportional hazard models and then ranked their fit based on AIC, providing us with measurements of how well our hypothesized models fit our nest survival data. None of our models differed enough to classify any one of them as more or less parsimonious than others (Appendix E & F).

Table 4. Results from candidate models predicting nest survival of American robins, gray catbirds, Northern cardinals, and yellow warblers in three urban forests of Montreal. Each model is named based on its predictors. The number of parameters (k), the corrected delta AIC (AICc), and the fitted Log-Likelihood are reported for each model.

Model	Variables	k	$\Delta AICc$	loglik
Seasonality	Nest Initiation date	3	0	-225.86
Null	N/A	2	0.2	-226.75
Human Influence	Distance of nest from trail + Mean human activity index	4	3.6	-226.65
Vegetation	Number of small stems/hectare + nest height + vegetation concealment	5	5.3	-226.38
Global	Number of small stems/hectare + nest height + vegetation concealment + distance of nest from trail + mean human activity indices + calendar date	8	9	-225.37

Determinates of number of active days in failed nests

Human presence (distance to trail) and concealment (concealment, canopy cover, vertical complexity, and vegetative density) did not have significant effects on the number of active days. These effects were similar across site (random effect variance 0.00). Seasonality (day of year) was the only explanatory variable to significantly predict the number of active days (β : -0.09, 95% CI: 0.24 – 0.76) prior to a nest failing, with nests that were active earlier in the season failing faster (i.e., less active days before failure).

Discussion

We asked whether the presence of humans, nest patch vegetation, and seasonality in urban greenspaces with varying degrees of human activity on the Island of Montreal predicted the nest survival of four common species of open-cup nesting passerines. For nests that failed, we explored whether these same variables predicted the number of active days nests had before failure. Surprisingly, we found that none of the chosen predictors, including human activity and distance to trails, significantly explained variations in nest success, despite varying values of the predictors across nests and sites. Through linear mixed modelling, seasonality was the best predictor of a nest's number of active days before failure, with nests active earlier in the season failing faster. These urban greenspaces were thus found to accommodate human use without compromising bird success.

Studies looking at modelled nest survival of various bird species in urban landscapes have found varying results. One study in Costa Rica found that survival in the clay-coloured thrush (*Turdus grayi*) was reduced in urban environments due to the presence of brightly coloured artificial materials in their nests that attracted predators to their nests (Corrales-Moya et al. 2023). Another study of shrub nesting birds in Hungary found that modelled nest survival was higher in urban areas compared to rural areas, but it was looking at artificially built nests (Kurucz et al. 2021). Another in the northeastern US investigated modelled nest survival through a lens of predation and included three of four of the target species we used: gray catbirds, northern cardinals, and American robins. They found modelled nest survival of American robins and gray catbirds to be higher in urban areas compared to rural areas, but they did not specifically incorporate human activity in their modelling, instead looking at a gradient of urbanization (Ryder et al. 2010).

Our four target species had low rates of modelled nest survival compared to previous studies of these species in both urban and wild greenspaces. Studies in residential and urban areas found that American robin nests had modelled nest survival rates between 1 and 42 %, depending on the presence of predators (Yen et al., 1996, Malpass et al. 2016). In more forested, natural sites, American robins have been found to have modelled nest success of 43 % (Duguay et al. 2001). Gray catbirds are modelled to have nest survival around 40 – 50 % in both urban areas and more forested habitats (Peak et al. 2004; Piergallini & Yahner 2001; Ryder et al. 2010). Modelled nest survival for yellow warblers in natural forest settings is reported to be around 30 – 50 % (Humple & Burnett 2010; Briske 1995), but can be as low as 10 % in urban or suburban areas (Strusis-Timmer 2009). Cardinals have been found to have

lower rates of modelled nest survival in both natural forests (15 %) and urban forests (15-25 %) (Filliater et al. 1994; Smith-Castro & Rodewald 2010a; Billerman et al. 2022). Our survival rates were much lower than most of these modelled survival rates (Table 3), which could be showing these sites are not high-quality habitat for these species in general.

Contrary to our prediction that nests exposed to higher human activity would experience higher rates of abandonment or predation, we did not find a significant effect of human presence on predicted nest survival. There are a couple of alternative explanations that may explain this finding. Firstly, wildlife in urban spaces may become more tolerant of human presence as time progresses. For example, recent research has found that birds in urban spaces have been less fearful of humans following the COVID-19 pandemic (Diamant et al. 2023). Our target species are also known to be common in urban spaces, meaning that they likely have higher tolerances to human presence and activity. Secondly, a hypothesis known as the “human shield hypothesis” has been proposed in which we may observe an increase in wildlife population abundances due to a decrease in predators (Geffroy et al. 2015; Møller 2012; Valcarcel and Fernández-Juricic 2009). Recent literature has suggested that human presence is positively related to an increase in bird songs and vocalizations, and authors posited that the human shield hypothesis could be the driver (Pérez-González et al. 2024). Perhaps a reduction in predation and habituation to city life could explain the lack of sensitivity to human disturbance we found.

In contrast to previous studies that suggest nest patch vegetation is influential in nest survival, it was not a significant predictor of nest survival in our study area. Perhaps there are vegetative drivers at play that we did not measure. For example, the amount of suitable nest habitat area within a greenspace, or the amount of green land cover surrounding each of our sites. Nest survival in ground-nesting species has been shown to increase with an increase in suitable nest habitat for multiple species (Webb et al. 2012; Simonsen & Fontaine 2016), with the amount of greenspace in the matrix around sites also increasing rates of nest success (Simonsen & Fontaine 2016).

While seasonality was not a significant predictor of nest survival, our seasonality model performed marginally better than the others, indicating that seasonality may influence nest survival in our study area. We found that our target species nesting in urban greenspaces are more likely to experience nest failure earlier in the season and most nests are likely to fail before the fifteenth day of the nesting period, regardless of site (Figure 1). We can also observe that for our four target species, nest failure rates were steepest in the first two weeks of the nesting period, which

correspond to nest building, egg laying and early incubation periods (Figure 1). These periods are when nests are most vulnerable. Birds are more likely to abandon nests before their nestlings hatch – at which point they have invested a lot of energy into their nesting attempt and are less likely to abandon (Verboven & Tinbergen 2002). Furthermore, the incubation period is when nest predation events are known to be most common (Roper & Goldstein 1997; Farnsworth & Simons 1999).

Birds attempting to nest early in the season encounter several challenges that could explain our results. Key hazards to their survival earlier in the nesting season are lower temperatures, decreased food availability, and shorter days (Dunn 2004; Germain et al. 2015; Nager 2006). Producing and incubating eggs is an extremely costly task for the parents, and maintaining an optimal temperature for both their survival and proper embryo development is more difficult in the colder temperatures of the early nesting season (D’Alba et al. 2009; Kim & Monaghan 2006; Nager 2006). Additionally, birds learn from past nesting attempts and can even acquire knowledge on how to best build nests from more experienced adults (Guillette et al. 2016). And lastly, earlier in the nesting season the vegetation is just starting to leaf out, so nests will have less concealment from predators and are easier to find (Ringelman & Skaggs 2019). These factors likely contributed to the lower number of active days experienced by early-season failures and to seasonality being the best predictor of overall nest survival.

A few limitations may have influenced our results. While the study sites varied widely in their access, management, and levels of human activities, they were all larger, more ‘natural’ greenspaces. Future research could include areas with even greater human activity, as human influence might become more influential in such areas. There may be a threshold of tolerance or a point at which higher rates of human activity become harmful to nest survival. We also (for logistical reasons) targeted four species that were known to commonly nest in these areas, and as such may be species predisposed to be adaptive to human presence. Other rarer species may indeed be more sensitive to disturbance than the target species of this study, as it was recently shown that 78 % of bird species do not tolerate high human-dominant environments (Marjakangas et al. 2024).

Within the context of the study’s caveats, generally our findings suggest that human activity and the presence of trails used for human recreation are not negatively impacting the nesting success for our target bird species using urban greenspaces. This may tentatively suggest that urban greenspaces can provide recreational activity and connection to nature for people without additional negative effects for common nesting birds. Land managers, such

as municipal governments, have a great need for such integrated science advice that meets their desire to understand multiple goals of managing urban greenspaces. Future research that continues to improve our understanding of synergies and trade-offs between connecting people with natural spaces and human-wildlife interactions is useful in guiding both place-based management and general best practices and policies.

References

- Bache, S., Wickham, H. (2022). *magrittr: A Forward-Pipe Operator for R*. <https://magrittr.tidyverse.org>, <https://github.com/tidyverse/magrittr>
- Bailey, R. L. T., Phillips, T., Faulkner-Grant, H., Lowe, J., Martin, J. M., Bonney, R. (2019). NestWatch Nest Monitoring Manual. Ithaca, NY: Cornell Lab of Ornithology
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*. 67(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Beale, C. M., Monaghan, P. (2004). Human disturbance: people as predation-free predators? *Journal of Applied Ecology*. 41(2): 335-343. <https://doi.org/10.1111/j.0021-8901.2004.00900.x>
- Beckschäfer, P. (2015). Hemispherical_2.0 – Batch processing hemispherical and canopy photographs with ImageJ – User Manual. Chair of Forest Inventory and Remote Sensing, GeorgAugust-Universität Göttingen, Germany. www.uni-goettingen.de/en/75936.html
- Berger, J. (2007). Fear, human shields and the redistribution of prey and predators in protected areas. *Biology Letters*. 3(6): 620-623. <https://doi.org/10.1098/rsbl.2007.0415>
- Billerman, S. M., Keeney, B. K., Schulenberg, T. S. (Editors) (2022). Birds of the World. Cornell Laboratory of Ornithology, Ithaca, NY, USA. <https://doi.org/birdsoftheworld.org/bow/home>
- Bötsch, Y., Tablado, Z., Scherl, D., Kéry, M., Graf, R. F., Jenni, L. (2018) Effect of Recreational Trails on Forest Birds: Human Presence Matters. *Frontiers in Ecology and Evolution*, 6: e175. <https://doi.org/10.3389/fevo.2018.00175>
- Boyd, R. (n.d.). Fact or Fiction?: Birds (and Other Critters) Abandon Their Young at the Slightest Human Touch. Scientific American. Retrieved April 2, 2024, from <https://www.scientificamerican.com/article/fact-or-fiction-birds-abandon-young-at-human-touch/>
- Briske, J. V. (1995). Nesting Biology of the Yellow Warbler at the Northern Limit of its Range. *Journal of Field Ornithology*. 66(4): 531-543
- Buron, R., Hostetler, M. E., Andreu, M. (2022). Urban forest fragments vs residential neighborhoods: Urban habitat preference of migratory birds. *Landscape and Urban Planning*. 227: e104538. <https://doi.org/10.1016/j.landurbplan.2022.104538>
- Buxton, R. T., Hudgins, E. J., Lavigne, E., Villeneuve, P. J., Prince, S. A., Pearson, A. L., Halsall, T., Robichaud, C., Bennett, J. R. (2024). Mental health is positively associated with biodiversity in Canadian cities. *Nature Communications: Earth & Environment*. 5: 310. <https://doi.org/10.1038/s43247-024-01482-9>
- Chamberlain, D. E., Cannon, A. R., Toms, M. P., Leech, D. I., Hatchwell, B. J., Gaston, K. J. (2009). Avian productivity in urban landscapes: a review and meta-analysis. *Ibis*. 151: 1-18

- Corrales-Moya, J., Barrantes, G., Chacón-Madrigal, E., Sandoval, L. (2023). A potential consequence for urban birds' fitness: Exposed anthropogenic nest materials reduce nest survival in the clay-colored thrush. *Environmental Pollution*. 326: 121456. <https://doi.org/10.1016/j.envpol.2023.121456>
- Corregidor-Castro, A., Jones, O. R. (2021). The effect of nest temperature on growth and survival in juvenile Great Tits *Parus major*. *Ecology & Evolution*. 11(12): 7346-7353. <https://doi.org/10.1002/ece3.7565>
- Cox, D. R. (1972). Regression Models and Life-Tables. *Journal of the Royal Statistical Society: Series B*. 34(2): 187-202. <https://doi.org/10.1111/j.2517-6161.1972.tb00899.x>
- Cox, D. T. C., Gaston, K. J. (2016). Urban Bird Feeding: Connecting People with Nature. *PLOS ONE*. 11(7): e0158717. <https://doi.org/10.1371/journal.pone.0158717>
- D'Alba L, Monaghan P, Nager RG. (2009). Thermal benefits of nest shelter for incubating female eiders. *Journal of Thermal Biology*. 34(2): 93-99
- Davis, S. K. (2005). Nest-Site Selection Patterns and the Influence of Vegetation on Nest Survival of Mixed-Grass Prairie Passerine. *Ornithological Applications*. 107(3): 605-616. <https://doi.org/10.1093/condor/107.3.605>
- DeGregorio, B. A., Chiavacci, S. J., Benson, T. J., Sperry, J. H. (2016). Nest Predators of North American Birds: Continental Patterns and Implications. *BioScience*. 66(8): 655-665. <https://doi.org/10.1093/biosci/biw071>
- De Haas, W., Hassink, J., Stuiver, M. (2021). The Role of Urban Green Space in Promoting Inclusion: Experiences From the Netherlands. *Frontiers in Environmental Science*. 9: e618198. <https://doi.org/10.3389/fenvs.2021.618198>
- Diamant, E. S., MacGregor-Fors, I., Blumstein, D. T., Yeh, P. J. (2023). Urban birds become less fearful following COVID-19 reopenings. *Proceedings of the Royal Society B Biological Sciences*. 290(2023): e20231338. <https://doi.org/10.1098/rspb.2023.1338>
- Dueser, R. D., Shuggart Jr., H. H. (1979). Niche Pattern in a Forest-Floor Small-Mammal Fauna. *Ecology*. 60(1): 108-118. <https://doi.org/10.2307/1936473>
- Duguay, J. P., Wood, P. B., Nichols, J. V. (2001). Songbird Abundance and Avian Nest Survival Rates in Forests Fragmented by Different Silvicultural Treatments. *Conservation Biology*. 15(5): 1405-1415
- Dunn, P. (2004). Breeding Dates and Reproductive Performance. *Advances in Ecological Research*. 35: 69-87. [https://doi.org/10.1016/S0065-2504\(04\)35004-X](https://doi.org/10.1016/S0065-2504(04)35004-X)
- Environment and Climate Change Canada. (2024). Nature Smart Climate Solutions Fund. Environment and Climate Change Canada. <https://www.canada.ca/en/environment-climate-change/services/environmental-funding/programs/nature-smart-climate-solutions-fund.html>
- Farnsworth, G. L., Simons, T. R. (1999). Factors affecting nesting success of wood thrushes in Great Smoky Mountains National Park. *The Auk*. 116: 1075-1082
- Filazzola, A., Xie, G., Barrett, K., Dunn, A., Johnson, M. T. J., MacIvor, J. S. (2022). Using smartphone-GPS data to quantify human activity in green spaces. *PLoS Computational Biology*. 18(12): e1010725. <https://doi.org/10.1371/journal.pcbi.1010725>
- Filliater, T. S., Breitwisch, R., Nealen, P. M. (1994). Predation on Northern Cardinal Nests: Does Choice of Nest Site Matter? *The Condor*. 96: 761-768
- Forslund, P., Part, T. (1995). Age and reproduction in birds - hypotheses and tests. *Trends in Ecology and Evolution*. 10(9): 374-378. [https://doi.org/10.1016/s0169-5347\(00\)89141-7](https://doi.org/10.1016/s0169-5347(00)89141-7)

- Fraixedas, S., Linden, A., Piha, M., Cabeza, M., Gregory, R., Lehtikainen, A. (2020). A state-of-the-art review on birds as indicators of biodiversity: Advances, challenges, and future directions. *Ecological Indicators*, 118: e106728. <https://doi.org/10.1016/j.ecolind.2020.106728>
- Gamez, S., Harris, N. C. (2021). Living in the concrete jungle: carnivore spatial ecology in urban parks. *Ecological Applications*. 31(6): e02393. <https://doi.org/10.1002/eap.2393>
- Geffroy, B., Samia, D. S. M., Bessa, E., Blumstein, D. T. (2015). How Nature-Based Tourism Might Increase Prey Vulnerability to Predators. *Trends in Ecology and Evolution*. 12: 755-765. <https://doi.org/10.1016/j.tree.2015.09.010>
- Germain, R. R., Schuster, R. Delmore, K. E., Arcese, P. (2015). Habitat preference facilitates successful early breeding in an open-cup nesting songbird. *Functional Ecology*. 29(12): 1522-1532. <https://doi.org/10.1111/1365-2435.12461>
- Government of Canada, S. C. (2022). The Daily—Canada’s large urban centres continue to grow and spread. <https://www150.statcan.gc.ca/n1/daily-quotidien/220209/dq220209b-eng.html>
- Guillette, L. M., Scott, A. C. Y., Healy, S. D. Social learning in nest-building birds: a role for familiarity. *Proceedings of the Royal Society B: Biological Sciences*. 283: 20152685. <https://doi.org/10.1098/rspb.2015.2685>
- Heisey, D. M., Shaffer, T. L., White, G. C. (2007). The ABCs of Nest Survival: Theory and Application from a Biostatistical Perspective. *Studies in Avian Biology*. 34: 13-33
- Humple, D. L., Burnett, R. D. (2010). Nesting Ecology of Yellow Warblers (*Dendroica petechia*) in Montane Chaparral Habitat in the Northern Sierra Nevada. *Western North American Naturalist* 70(3): 355-363
- Jablonski, K. E., McNulty, S., Schlesinger, M. D. (2010). A Digital Spot-mapping Method for Avian Field Studies. *The Wilson Journal of Ornithology*. 122(4): 772-776. <https://doi.org/10.2307/40962348>
- Jehle, G., Yackel Adams, A. A., Savidge, J. A., Skagan, S. K. (2004). Nest Survival Estimation: A Review of Alternatives to the Mayfield Estimator. *The Condor*. 106(3): 472-484
- Jokimäki, J. (1999). Occurrence of breeding bird species in urban parks: Effects of park structure and broad-scale variables. *Urban Ecosystems*. 3: 21-34
- Kangas, K., Luoto, M., Ihanola, A., Tomppo, E., Siikamäki, P. (2010). Recreation-induced changes in boreal bird communities in protected areas. *Ecological Applications*. 20(6): 1775-1786. <https://doi.org/10.1890/09-0399.1>
- Kim, S.-Y., Monaghan, P. (2006). Effects of early incubation constancy on embryonic development: an experimental study in the Herring Gull *Larus argentatus*. *Journal of Thermal Biology*. 31(5). <https://doi.org/10.1016/j.jtherbio.2006.02.002>
- Kondo, M. C., Fluehr, J. M., McKeon, T., Branas, C. (2018). Urban Green Space and Its Impact on Human Health. *Int. J. Environ. Res. Public Health*, 15(3): e445. doi: <https://doi.org/10.3390/ijerph15030445>
- Kövé, L., Gyüre, P., Balogh, P., Huettmann, F., Lengyel, S., and Juhász, L. (2015). Recent colonization and nest site selection of the Hooded Crow (*Corvus corone cornix* L.) in an urban environment. *Landscape and Urban Planning*. 133: 78–86. <https://doi.org/10.1016/j.landurbplan.2014.09.008>
- Kraus, D., Hebb, A. (2020). Southern Canada’s crisis ecoregions: identifying the most significant and

- threatened places for biodiversity conservation. *Biodiversity and Conservation*, 29: 3573-3590. <https://doi.org/10.1007/s10531-020-02038-x>
- Kuznetsova, A., Brockhoff, P. B., Christensen, R. H. B. (2017). “lmerTest Package: Tests in Linear Mixed Effects Models.” *Journal of Statistical Software*. 82(13): 1–26. <https://10.18637/jss.v082.i13>
- Kurucz, K., Puger, J. J., Batáry, P. (2021). Urbanization shapes bird communities and nest survival, but not their food quantity. *Global Ecology and Conservation*. 26: e01475. <https://doi.org/10.1016/j.gecco.2021.e01475>
- Laake, J. (2013). “RMark: An R Interface for Analysis of Capture-Recapture Data with MARK.” AFSC Processed Rep. 2013-01, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Seattle, WA. <https://apps-afsc.fisheries.noaa.gov/Publications/ProcRpt/PR2013-01.pdf>
- Lebreton, J-D., Burnham, K. P., Clobert, J., Anderson, D. R. (1992). Modelling Survival and Testing Biological Hypotheses Using Marked Animals: A Unified Approach with Case Studies. *Ecological Monographs*. 62(1): 67-118
- Lepczyk, C. A., Flather, C. H., Radeloff, V., Pidgeon, A., Hammer, R. B., Liu, J. (2008). Human Impacts on Regional Avian Diversity and Abundance. *Conservation Biology*, 22(2): 405-416. <https://doi.org/10.1111/j.1523-1739.2008.00881.x>
- Leston, L., Rodewald, A. D. (2006). Are urban forests ecological traps for understory bird? An examination using Northern Cardinals. *Biological Conservation*, 131(4): 566-574. <https://doi.org/10.1016/j.biocon.2006.03.003>
- Liebezeit, J. R., Kendall, S. J., Brown, S., Johnson, C. B., Martin, P., McDonald, T. L., Payer, D. C., Rea, C. L., Streever, B., Wildman, A. M., Zack, S. (2009). Influence of human development and predators on nest survival of tundra birds, Arctic Coastal Plain, Alaska. *Ecological Applications*. 19(6): 1628-1644. <https://doi.org/10.1890/08-1661.1>
- Lindenmayer, D. B., Wood, J. T., McBurney, L., MacGregor, C., Youngentob, K., Banks, S. C. (2011). How to make a common species rare: A case against conservation complacency. *Biological Conservation*, 144(5): 1663-1672
- López-Flores, V., MacGregor-Fors, I., Schondube, J. E. (2009). Artificial nest predation along a Neotropical urban gradient. *Landscape and Urban Planning*. 92(2): 90-95. <https://doi.org/10.1016/j.landurbplan.2009.03.001>
- Malpass, J. S., Rodewald, A. D., Matthews, S. N. (2017). Species-dependent effects of bird feeders on nest predators and nest survival of urban American Robins and Northern Cardinals. *The Condor*. 119: 1-17. <https://doi.org/10.1650/CONDOR-16-72.1>
- Marjakangas, E-L., Johnston, A., Santangeli, A., Lehtikoinen, A. (2024). Bird species' tolerance to human pressures and associations with population change. *Global Ecology and Biogeography*. 33(5): e13816. <https://doi.org/10.1111/geb.13816>
- Martin, T. E. (1993). Nest Predation and Nest Sites. *Bioscience*, 43(8): 523-532
- Martin, T. E., Geupel, G. R. (1993). Nest-Monitoring Plots: Methods for Locating Nests and Monitoring Success. *Journal of Field Ornithology*. 64(4): 507-519
- Martin, T. E., Scott, J., Menge, C. (2000). Nest predation increases with parental activity: separating nest site and parental activity effects. *Proceedings of the Royal Society B*. 267: 2287-2293. <https://doi.org/10.1098/rspb.2000.1281>

- Marzluff, J. M. (2001). Worldwide urbanization and its effects on birds. In *Avian Ecology and Conservation in an Urbanizing World*. (pp. 19-47). Springer, Boston, MA
- McLaren, J. D., Buler, J. J., Schreckengost, T., Smolinsky, J. A., Boone, M., van Loon, E. E., Dawson, D. K., & Walters, E. L. (2018). Artificial light at night confounds broad-scale habitat use by migrating birds. *Ecology Letters*. 21(3), 356–364
- Miller, J. R., Hobbs, N. T. (2000). Recreational trails, human activity, and nest predation in lowland riparian areas. *Landscape and Urban Planning*. 50: 227-236
- Miller, J. R., Hobbs, R. J. (2002). Conservation Where People Live and Work. *Conservation Biology*. 16(2): 330-337. <https://doi.org/10.1046/j.1523-1739.2002.00420.x>
- Møller, A. P. (2012). Urban areas as refuges from predators and flight distance of prey. *Behavioural Ecology*. 23(5): 1030-1035. <https://doi.org/10.1093/beheco/ars067>
- Morosinotto, C., Thomson, R. L., Hänninen, M., Korpimäki, E. (2012). Higher nest predation risk in association with a top predator: mesopredator attraction? *Oecologia*. 170(2): 507-515. <https://doi.org/10.1007/s00442-012-2320-1>
- Natural Resources Canada, Canadian Forestry Service. (2008). *Canada's National Forest Inventory ground sampling guidelines: specifications for ongoing measurement*. Pacific Forestry Centre, Victoria, British Columbia.
- Nager R. G. (2006). The challenges of making eggs. *Ardea*. 94, 323-346
- Nudds, T. D. (1977). Quantifying the Vegetative Structure of Wildlife Cover. *Wildlife Society Bulletin*. 5(3): 113-117
- Nur, N., Holmes, A. L., Geupel, G. R. (2004). Use of Survival Time Analysis to Analyze Nesting Success in Birds: An Example Using Loggerhead Shrikes. *The Condor*. 106(3): 457-471
- Ospina, E. A., Merrill, L., Benson, T. J. (2018). Incubation temperature impacts nestling growth and survival in an open-cup nesting passerine. *Ecology and Evolution*. 8(6): 3270-3279. <https://doi.org/10.1002/ece3.3911>
- Parks Canada. (2023). Toward a national urban parks policy – Discussion paper. Parks Canada. <https://parks.canada.ca/pun-nup/politique-policy/discussion>
- Peak, R. G., Thompson III, F. R., Shaffer, T. L. (2004). Factors Affecting Songbird Nest Survival in Riparian Forests in a Midwestern Agricultural Landscape. *The Auk*. 121(3): 726-737
- Pebesma E, Bivand R (2023). *Spatial Data Science: With applications in R*. Chapman and Hall/CRC, London. <https://doi.org/10.1201/9780429459016>, <https://r-spatial.org/book/>
- Pebesma E (2018). “Simple Features for R: Standardized Support for Spatial Vector Data.” *The R Journal*. 10(1): 439–446. doi:10.32614/RJ-2018-009, <https://doi.org/10.32614/RJ-2018-009>
- Peña, R., Schleuning, M., Miñarro, M., García, D. (2022). Variable relationships between trait diversity and avian ecological functions in agroecosystems. *Functional Ecology*. 27(1): 87-98. <https://doi.org/10.1111/1365-2435.14102>
- Pérez-González, J., Rey-Gozalo, G., Hidalgo-de-Trucios, S. J. (2024). Human presence is positively related to the number of bird calls and songs: Assessment in a national park. *European Journal of Wildlife Research*. 70: e20. <https://doi.org/10.1007/s10344-024-01772-9>
- Piergallini, N. H., Yahner, R. H. (2001). Nest Site Selection and Nesting Success by Gray Catbirds in Irrigated Forests. *Journal of the Pennsylvania Academy of Science*. 75(1): 3-7

- Prange, S., and Gehrt, S. D. (2004). Changes in mesopredator-community structure in response to urbanization. *Canadian Journal of Zoology*. 82: 1804–1817. <https://doi.org/10.1139/z04-179>
- Prugh, L. R., Stoner, C. J., Epps, C. W., Bean, W. T., Ripple, W. J., Laliberte, A. S., Brashares, J. S. (2009). The Rise of the Mesopredator. *BioScience*. 59(9): 779-791. <https://doi.org/10.1525/bio.2009.59.9.9>
- Purcell, K. L., Verner, J. (1999). Nest Predators of Open and Cavity Nesting Birds in Oak Woodlands. *Wilson Bulletin*. 111(2): 251-256
- Québec Breeding Bird Atlas -. (n.d.). Retrieved March 30, 2024, from <https://www.atlas-oiseaux.qc.ca/donneesqc/datasummaries.jsp?extent=Rg&summttype=SpList&year=allyrs&atlasver=3&byextent1=Prov&byextent2=Sq®ion2=1&squarePC=®ion1=9&square=®ion3=0&species1=MOVE&lang=en>
- R Core Team. (2023). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna, Austria. URL: <https://www.R-project.org/>
- Remacha, C., Delgado, J. A., Bulaic, M., Pérez-Tris, J. (2016). Human Disturbance during Early Life Impairs Nestling Growth in Birds Inhabiting a Nature Recreation Area. *PLOS ONE*. 11(11): e0166748. <https://doi.org/10.1371/journal.pone.0166748>
- Ricklefs, R., E. (1969). An analysis of nesting mortality in birds. *Smithsonian Contribution to Zoology*. 9: 1-48
- Ringelman, K. M., Skaggs, C. G. (2019). Vegetation phenology and nest survival: Diagnosing heterogeneous effects through time. *Ecology and Evolution*. 9(4): 2121-2130. <https://doi.org/10.1002/ece3.4906>
- Rodewald, P. G., Matthews, S. N. (2005). Landbird use of Riparian and Upland Forest Stopover Habitats in an Urban Landscape. *Ornithological Applications*. 107(2): 259-268. <https://doi.org/10.1093/condor/107.2.259>
- Roper, J. T., Goldstein, R. R. (1997). A test of the Skutch hypothesis: does activity at nests increase nest predation risks? *Journal of Avian Biology* 28: 111–116
- Rosamond, K., Goded, S., Soultan, A., Kaplan, R., Glass, A., Kim, D. H., Arcilla, N. (2020). Not Singing in the Rain: Linking Migratory Songbird Declines With Increasing Precipitation and Brood Parasitism Vulnerability. *Frontiers in Ecology and Evolution*. 8: 1-19. <https://doi.org/10.3389/fevo.2020.536769>
- Rousseau, J. S., Savard, J-P. L., Titman, R. (2015). Shrub-nesting birds in urban habitats: their abundance and association with vegetation. *Urban Ecosystems*. 18: 871-884. <https://doi.org/10.1007/s11252-014-0434-4>
- Ryder, T. B., Reitsma, R., Evans, B., Marra, P. P. (2010). Quantifying avian nest survival along an urbanization gradient using citizen- and scientist-generated data. *Ecological Applications*. 20(2): 419-426. <https://doi.org/10.1890/09-0040.1>
- Schneider, C., Rasband, W. & Eliceiri, K. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*. 9: 671-675
- Seewagen, C. L., Slayton, E. J., Guglielmo, C. G. (2010). Passerine migrant stopover duration and spatial behaviour at an urban stopover site. *Acta Oecologica*. 36(5): 484-492. <https://doi.org/10.1016/j.actao.2010.06.005>
- Seibold, S., Hempel, A., Piehl, S., Bässler, C., Brandl, R., Rösner, S., Müller, J. (2013). Forest vegetation structure has more influence on predation risk of artificial ground nests than human activities. *Basic and Applied Ecology*. 14(8): 687-693. <https://doi.org/10.1016/j.baec.2013.09.003>
- Simonsen, V. L., Fontaine, J. J. (2016). Landscape Context Influences Nest Survival in a Midwest Grassland. *The*

- Journal of Wildlife Management*. 80(5): 877-883. <https://doi.org/10.1002/jwmg.1068>
- Sjöberg, D., Baillie, M., Fruechtenicht, C., Haesendonckx, S., Treis, T. (2024). *ggsurvfit: Flexible Time-to-Event Figures*. R package version 1.1.0, <https://www.danielsjoberg.com/ggsurvfit/>
- Smith, P. A., Bart, J., Lanctot, R. B., McCaffrey, B. J., Brown, S. (2009). Probability of Detection of Nests and Implications for Survey Design. *The Condor*. 111(3): 414-423. <https://doi.org/10.1525/cond.2009.090002>
- Smith-Castro, J. R., Rodewald, A. D. (2010a). Behavioral responses of nesting birds to human disturbance along recreational trails. *Journal of Field Ecology*. 81(2): 130-138. <https://doi.org/10.1557-9263.2010.00270.X>
- Smith-Castro, J. R., Rodewald, A. D. (2010b). Effects of Recreational Trails on Northern Cardinals (*Cardinalis cardinalis*) in Forested Urban Parks. *Natural Areas Journal*. 30(3): 328-337. <https://doi.org/10.3375/043.030.0308>
- Southworth, M. (1969). The sonic environment of cities. *Environment and Behavior*. 1(1), 49–70. <https://doi.org/10.1177/001391656900100104>
- Steven, R., Pickering, C., Castley, J. C. (2011). A review of the impacts of nature based recreation on birds. *Journal of Environmental Management*. 92(10): 2287-2294. <https://doi.org/10.1016/j.jenvman.2011.05.005>
- Stien, J., Ims, R. A. (2015). Management decisions and knowledge gaps: learning by doing in a case of a declining population of slavian grebe *Podiceps auratus*. *Wildlife Biology*. 21(1): 44-50. <https://doi.org/10.2981/wlb.00026>
- Stobbe, E., Sundermann, J., Ascone, L., Kühn, S. (2022). Birdsongs alleviate anxiety and paranoia in healthy participants. *Scientific Reports*. 12(1): e16414. <https://doi.org/10.1038/s41598-022-20841-0>
- Stoddard, P. K., Beecher, M. D., Horning, C. L. (1991). Recognition of individual neighbors by song in the song sparrow, a species with song repertoires. *Behavioural Ecology and Sociobiology*. 29: 211-215
- Strasser, E. H., Heath, J. A. (2013). Reproductive failure of a human-tolerant species, the American kestrel, is associated with stress and human disturbance. *Journal of Applied Ecology*. 50(4): 912-919. <https://doi.org/10.1111/1365-2664.12103>
- Strusis-Timmer, M. (2009). Habitat associations and nest survival of yellow warblers in California. *Master's Thesis*. 3682. <https://doi.org/10.31979/etd.sb3f-z3a6>
https://scholarworks.sjsu.edu/etd_theses/3682
- Therneau, T. (2024). *A Package for Survival Analysis in R*. R package version 3.7-0, <https://CRAN.R-project.org/package=survival>
- Therneau, T. (2012). *coxme: mixed effects Cox models*. R package version 2.2-3. Vienna, Austria: R Foundation for Statistical Computing
- Threlfall, C. G., Mata, L., Mackie, J. A., Hahs, A. K., Stork, N. E., Williams, N. S. G., Livesley, S. J. (2017). Increasing biodiversity in urban green spaces through simple vegetation interventions. *Journal of Applied Ecology*. 54(6): 1874-1883. <https://doi.org/10.1111/1365-2664.12876>
- Valcarcel, A., Fernández-Juricic, E (2009). Antipredator strategies of house finches: Are urban habitats safe spots from predators even when humans are around? *Behavioural Ecology and Sociobiology*. 63(5): 673-685. <https://doi.org/10.1007/s00265-008-0701-6>
- van der Zande, A. N., Berkhuisen, J. C., van Latesteijn, H. C., ter Keurs, W. J., Poppelaars, A. J.

- (1984). Impact of outdoor recreation on the density of a number of breeding bird species in woods adjacent to urban residential areas. *Biological Conservation*. 30(1): 1-39
- Van Doren, B. M., Willard, D. E., Hennen, M., Horton, K. G., Stuber, E. F., Sheldon, D., Sivakumar, A. H., Wang, J., Farnsworth, A., Winger, B. M. (2021). Drivers of fatal bird collisions in an urban center. *PNAS*. 118(24): e2101666118. <https://doi.org/10.1073/pnas.2101666118>
- Vasquez, A. V., Wood, E. M. (2022). Urban parks are a refuge for birds in park-poor areas. *Frontiers in Ecology & Evolution*. 10: e95872. <https://doi.org/10.3389/fevo.2022.958572>
- Verboven, N., Tinbergen, J. M. (2002). Nest desertion: a trade-off between current and future reproduction. *Animal Behaviour*. 63(5): 951-958
- Vincze, E., Seress, G., Lagisz, M., Nakagawa, S., Dingermanse, N. J., Sprau, P. (2017). Does Urbanization Affect Predation of Bird Nests? A Meta-Analysis. *Frontiers in Ecology and Evolution*. 5: e29. <https://doi.org/10.3389/fevo.2017.00029>
- Webb, S. L., Olson, C. V., Dzialak, M. R., Harju, S., Winstead, J. B., Lockman, D. (2012). Landscape features and weather influence nest survival of a ground-nesting bird of conservation concern, the greater sage-grouse, in human- altered environments. *Ecological Processes*. 1: 1-15. <https://doi.org/10.1186/2192-1709-1-4>
- Wei T, Simko V (2021). R package 'corrplot': Visualization of a Correlation Matrix. (Version 0.92), <https://github.com/taiyun/corrplot>
- Wickham, H., François, R., Henry, L., Müller, K., Vaughan, D. (2023). *dplyr: A Grammar of Data Manipulation*. R package version 1.1.4, <https://github.com/tidyverse/dplyr>, <https://dplyr.tidyverse.org>
- Wickham, H. (2023). *stringr: Simple, Consistent Wrappers for Common String Operations*. R package version 1.5.1, <https://github.com/tidyverse/stringr>, <https://stringr.tidyverse.org>
- Wickham H (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. ISBN 978-3-319-24277-4, <https://ggplot2.tidyverse.org>
- Xiong, Y., West, C. P., Brown, C. P., Green, P. E. (2019). Digital Image Analysis of Old World Bluestem Cover to Estimate Canopy Development. *Agronomy Journal*. 111(3): 1247-1253. <https://doi.org/10.2134/agronj2018.08.0502>
- Yen, C-F., Klaas, E. E., Kam, Y-C. (1996). Variation in Nesting Success of the American Robin, *Turdus migratorius*. *Zoological Studies*. 35(3): 220-226

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