Window related avian mortality at a migration corridor

A THESIS
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
OF THE UNIVERSITY OF MINNESOTA
BY

Annie McLean Bracey

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

Adviser, Dr. Gerald Niemi

May 2011

Acknowledgements

I would like to thank my advisor, Dr. Gerald Niemi for the opportunity to conduct this research as well as for all of his invaluable assistance and advice. I would also like to thank my committee members, Dr. Matthew Etterson and Dr. Richard Green for their exceptional guidance. I thank my family, Benjamin Marsen, and my friends for support. I send a special thanks to all of the Park Point residents who allowed us to conduct this study at their homes, without which this project would not have been possible. I thank the University of Minnesota Duluth, particularly the Biology Department and the Integrated Biosciences Graduate Program for providing me with teaching assistantships.

Overview

Various man-made structures act as barriers to the movement of migrating birds. In the United States alone hundreds of millions of birds are estimated to die annually from window collisions. This risk increases when urban environments exist along important migratory corridors. Although all birds are susceptible to collisions with windows, nocturnally migrating songbirds make up the largest portion of observed window fatalities. Minnesota Point located on the western tip of Lake Superior is a valuable study location for quantifying collision fatalities because birds rely on this location to rest and forage during migration and because it is a highly developed landscape. To estimate mortality rates, a total of 42 residential homes were searched periodically during five migratory periods between 2006 and 2009 for avian window kills. To increase the accuracy of this estimate, an experiment was incorporated into the study to account for fatalities undetected by searchers due to removal by scavengers. A total of 40 identifiable species and 108 individual birds were recorded as window collision fatalities and of these, 90% were short and long distance migrants. During the spring and fall of 2009, bird density estimates were calculated to compare the abundance of species flying through the area to the abundance of observed species fatalities. The density of migrants utilizing the area was greater than that of resident species and was reflected by the higher mortality rates observed for migrants. The probability of a carcass being scavenged within 6 d averaged 79%. Variation in scavenging rate was best explained by the location of the house and the size of the carcass used. With adjustments made for scavenging, an annual estimate of avian window fatalities for houses on Minnesota Point during peak migration is 1333 ± 73 birds per year. Avian window collisions contribute significantly to annual mortality rates and are potentially avoidable. Deriving accurate estimates of mortality is vital to predicting long term population effects, especially for species susceptible to window collisions.

Table of Contents

List of Tables

List of Figures

Introduction

Research indicates that birds have nearly a 70 percent chance of flying through at least one major metropolitan area during migration (Brown and Capunto, 2007). It is estimated that anywhere from 100 million to one billion birds die in the United States annually from collisions with windows and buildings (Klem, 1989). After habitat loss, window collisions cause more bird fatalities than any other human related source (Klem, 1989, 1990a, 2006; Erickson et al., 2001). Accelerated human population growth is expected to result in increased habitat fragmentation and the expansion of urban environments. Mortality rates are also expected to increase in locations where migratory bird densities become concentrated, such as in cities located along the Great Lakes (Dunn and Nol, 1980). Experimental and observational studies have shown that birds are unable to visually recognize clear or reflective glass as a barrier (Klem, 1989), and that approximately half of all window collisions result in death due to intracranial hemorrhaging (Klem, 1990b, Veltri and Klem, 2005). The intensity of strike rates varies spatially and therefore requires independent study to determine which variables contribute to observed site specific mortality rates (Klem, 1989). Because window collisions are nondiscriminatory, they could negatively impact avian populations (Ogden, 1996).

Migration is a perilous but necessary behavior that allows birds to exploit seasonal food supplies and favorable weather conditions. Birds are exceptionally vulnerable during this phase of their life cycle and finding adequate food, water, and shelter in unfamiliar and continually changing landscapes can be energetically taxing, particularly for juveniles (Heglund and Skagen, 2005). The probability of an individual surviving in part depends on its ability to be physiologically prepared. Physiological strategies vary among species and are often a reflection of flight distance and terrain (Ogden, 1996). Some birds migrate in short bursts, stopping frequently to forage while others fly great distances on energy stored from a single foraging event (Alerstam, 1994; Ogden, 1996). From an evolutionary perspective, the benefits associated with migration have outweighed the risks for numerous species. Many migrate to the northern regions of the United States and Canada to reproduce, often utilizing well established flight paths or flyways (USGS, 2007). Although migration is by no means restricted to these flyways, the density of migrants tends to become concentrated in these locations, which are determined largely by topographic and ecological features (USGS, 2007).

The longest flyway in the western hemisphere is the Mississippi Flyway, which is located along the Mississippi Valley and past the Great Lakes (USGS, 2007). During migration large numbers of birds depend on quality stopover locations along this route to rest and forage. Many songbirds which are diurnally active outside of their migratory period will migrate at night to utilize daylight for locating food (Weir, 1976; Alerstam 1994). In the evening, conditions are generally more favorable, with wind turbulence decreasing along with air temperature. This allows nocturnal migrants to reduce their energy expenditure and may offer protection from potential predators (USGS 2007). Many of these important flyways and stopover locations are becoming developed, leading to decreased foraging habitat and increased vulnerability to encounters with man-made structures. During the day, windows reflect the surrounding sky and vegetation, and in the evening, the illumination of buildings can disorient migrants (Klem, 1989). To better understand how bird populations are being affected by development, it is necessary to study the impacts associated with human influenced fatalities and mitigate the effects of urbanization on avian populations.

Factors influencing collision frequency

There are many factors that influence collision related mortalities. Bird density and behavior are two important factors to consider (Klem, 1989, 2006). The greater the density in a given area, the more likely window collisions will occur. Research suggests that although many species have been found to collide with windows, some seem to be found at greater frequencies than others (Drewitt and Langston, 2008), and while collisions occur year round, mortality rates have been observed to increase during the migratory season (Klem, 1989).

Certain flight characteristics and behavioral patterns may also increase a bird's susceptibility to collision (Drewitt and Langston, 2008). Although flight distance and height vary among species, songbirds in general are known to fly at low altitudes (Able, 1970). Flight distance and height also vary with environmental factors, such as topography and weather, as well as with the time of day (Jenni and Schaub, 2003). Aggressive behaviors also intensify during spring migration as a consequence of increased hormone levels, which can cause disorientation and distraction, increasing the probability of a window collision (Klem, 1989).

Taking into account how environmental factors correspond to strike rates may be useful in predicting when and where collision intensity is likely to be highest. The spatial arrangement of vegetation near windows is one factor that may influence the likelihood of a collision (Klem et al., 2004, 2009). Trees and shrubs located in the vicinity of residential homes may attract birds and increase their exposure to windows (Erikson et al., 2005). Since birds are not able to detect clear or reflective glass as physical barriers, this illusion will be intensified when vegetation is placed in close proximity to windows.

Meteorological conditions can affect the ability of a bird to navigate. Window collisions have commonly been reported in locations prone to fog and low lying clouds (Brown et al., 2007). It is also more difficult for migrants to navigate on dark, windy, and rainy nights, which sometimes force birds to fly at lower altitudes, increasing the probability of contact with man-made structures (Alerstam, 1990, Brown et al., 2007). The artificial lighting of structures also interferes with a bird's ability to see landscapes clearly. Night migrants that encounter intense artificially lit locations become disoriented and susceptible to collision with these structures (Herbert, 1970).

Factors influencing detectability

When quantifying the rate of window collisions based solely on the presence or absence of a bird carcass, several important factors must be considered such as 1) birds that hit windows but fly away and die elsewhere, 2) the number of birds that are removed by scavengers, and 3) the number of fatalities that remain undetected by searchers. Each of these factors reduces the accuracy with which window kill estimates are made.

Mortality rates will always be underestimated because the birds that fly off and die elsewhere are virtually impossible to detect. However, the number of birds undetected by searchers and those removed by scavengers can be estimated experimentally. Studies suggest that avian carcasses located below windows are regularly removed by scavengers (Klem et al., 2004) reinforcing the need to account for carcass removal.

Study objectives

Minnesota Point is located at the western tip of Lake Superior. It is an important stopover location for migratory birds and is a highly developed landscape. The objectives of this study were to 1) quantify mortality rates at residential homes and adjust those estimates based on experimentally determined scavenging rates, 2) categorize each species collected based on their migratory status, to determine whether migratory behavior influences vulnerability, 3) examine whether the structural characteristics of houses or specific weather conditions were associated with the risk of collision, and 4) estimate migration intensity to determine whether observed fatalities correspond to the abundance of migrants. To insure that the study location was adequately sampled, searches were conducted during multiple migratory periods.

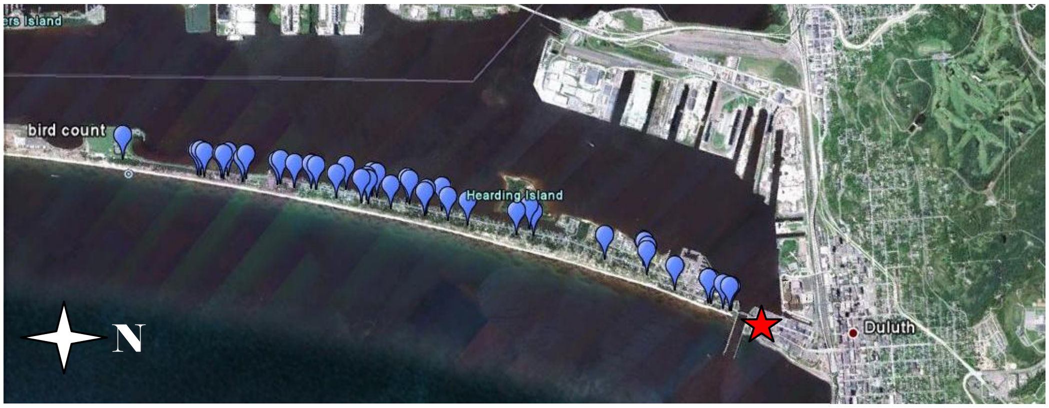
Methods

Study Area-Minnesota Point

Minnesota Point and associated Wisconsin Point is a freshwater sandbar stretching along Duluth, Minnesota and Superior, Wisconsin. Minnesota Point is approximately 11.3 km long, averages 152 m in width, and has a population of approximately 1,500 people. This location experiences a significant increase in bird density during migratory periods because birds tend to avoid crossing large bodies of water such as Lake Superior, and concentrate along the shoreline (Diehl et al., 2003). Because of its location at the western tip of Lake Superior, density increases during both spring and fall migration.

Quantifying Collision Fatalities

In the spring of 2006, Minnesota Point residents were sent letters asking for participation in a window collision study. In addition, residents were contacted by phone and personally at their homes. Over the course of five migratory periods between 2006 and 2009, a total of 42 residential homes agreed to participate in the study (Figure 1), each of which was considered an independent sampling unit.



* The star represents the location of the areal lift bridge.

Figure 1. Location of study sites on Minnesota Point, Duluth, MN USA. Each of the blue balloons represents one of the 42 participating homes. The furthest balloon from the areal lift bridge (labeled bird count), represents the location of the point count survey in 2009.

The 42 houses represent individuals that would allow early morning searches at their residence. The number of houses participating in the study each season were: 21, 26, and 35 for 2006, 2007, and 2009 respectively. A distance of approximately 5 km spans the range of homes included in the study and encompasses a sample of the residential homes on Minnesota Point.

The best time to search for window collision fatalities is just after sunrise when many species are highly active. This also reduces the probability that visual scavengers have displaced or removed any carcasses (Klem, 1989). The perimeter of each house was walked in the early morning hours by researchers to collect bird carcasses found near windows. Local residents also agreed to collect and report bird carcasses found around their windows. Searches were typically completed within a 1.5 to 2 hr period and it was assumed that all bird carcasses found near windows were the result of a window collision. Any birds found, were placed in coolers and taken to the University of Minnesota-Duluth where they were identified and stored.

Each house and window was assigned a unique identification number to estimate the location of each bird strike. Detailed sketches were also drawn to record the approximate size and location of each window. However, no direct window measurements were taken at any of the houses due to homeowner concerns. The number of bird feeders at each house was also recorded. If a bird was found beneath a window it was collected and the following information recorded: date, house and window identification number, time collected, time last checked, migratory status, weather conditions, and any additional comments that were applicable. Birds were separated into three major classes; 1) long distance migrants (LD), 2) short distance migrants (SD), and 3) year-round resident species (R). Birds were recorded as residents if they potentially live in the area year round. Species that may breed in the area but leave during the winter were recorded as migrants (SD or LD). Because many passerines are known to migrate at night, weather conditions for both the night before and the day of a recorded fatality were compared with recorded deaths. The weather data was accessed from the Duluth Sky Harbor airport station located on Minnesota Point, Duluth, MN (SDCW, 2010).

During the spring and fall migration of 2009, point counts were conducted on Minnesota Point to estimate the number of birds passing through the area. The number and species of birds counted were compared with the number of dead birds discovered during this time period. Counts were conducted daily either one hour before or directly following window kill searches. The counts were conducted from a fixed location for a one hr period (Figure 1). Observational distance was unlimited, and all individuals seen or heard were identified to the species level to the extent possible. The date, time, and weather conditions were also recorded daily.

Scavenging Experiment

A total of 140 bird carcasses were used to estimate scavenging rates at the 35 residential homes participating in the 2009 window collision study. To determine scavenging rates and detection probability by residents, a total of four bird carcasses were placed beneath windows at each of the 35 homes. All birds were placed in close proximity to windows, where the searches were concentrated. One toe was clipped on each bird to identify it as the specimen placed there for the experiment and all carcasses were intact and concurrently unthawed to reduce possible scavenging bias associated with the initial integrity of the birds used.

For the scavenging model used here, the following information was collected for each of the 140 avian carcasses: 1) the date and time that each carcass was placed, 2) the date and time interval within which the carcass was last known to exist, 3) the direction and position in which each carcass was placed, and 4) the size of each carcass. The direction of carcass placement refers to the compass direction in which the window faced relative to the carcass. The position refers to the orientation of each carcass, with two being placed out in the open and two in a less obvious location, such as under shrubbery. The size of the carcass was categorized as being either small or large based on visual estimates. Any bird the size of a warbler or smaller was assigned the number one and anything larger than a warbler such as a thrush was assigned the number two. The size of the birds used ranged from a Ruby-throated hummingbird (Archilochus colubris) to a Ring-billed gull (Larus delawarensis). The species used and the location with which each bird was placed was decided by randomly assigning a bird to a house and then randomly choosing a window identification number at that home. The placement of the carcass, whether or not it was exposed or hidden, was also randomized. Each of the above factors, along with the location of each house with respect to the areal lift bridge (proximity to increased human activity) was recorded.

Two six day scavenging experiments were conducted during the fall of 2009. The first experiment began on 14 September at 06:30 and ended on 20 September at 07:55. The second experiment began on 29 September at 06:30 and ended on 5 October at

08:03. On the initial day of each experiment, two carcasses were placed at each of the 35 homes and subsequently checked at approximately five hr intervals twice during the first day. On each of the following days, searches were performed once in the early morning simultaneously with the window kill study. At the end of the six day period, any carcasses that were not taken by scavengers or home owners were removed. The date and time of each occurrence, the time interval between searches, the number of birds found by residents or scavengers, the location of the bird, and the number of birds remaining at the end of each experiment were systematically recorded.

The 140 carcasses were monitored daily, unless they were scavenged or removed by homeowners prior to the end of the six day experimental interval, thus totaling 604 exposure days. The daily scavenging rates for the two, six-day experimental periods were pooled and used as an estimate for local scavenging events. Here an event was defined as a success when the experimentally placed carcass was not removed by a scavenger or home owner. Conversely, an event was defined as a failure when a carcass was removed by a scavenger or homeowner. The survival of a carcass was referred to as the probability that it would not be removed within a 24 hr period. The failure-time was classified to within an interval spanned by two visits.

Data Analyses

Quantifying Window Kills

Data were analyzed using the statistical software R (R Project, 1997) and the program MCestimate (Etterson, unpubl.). The ratio of migratory birds killed to that of resident birds was compared to determine whether or not proportions were similar. Poisson regression analysis was used to describe the relationship between mortality rates, weather variables and house characteristics. A Poisson regression model was used to express the natural logarithm of the event of window collisions as a linear function of their distribution along Minnesota Point. For the comparison of the magnitude of the spring and fall migration counts in 2009, a log likelihood ratio was calculated to determine whether or not the abundance of birds utilizing different migratory strategies would be reflected in the observed species fatalities.

Quantifying Scavenging Rates

The program MCestimate (Etterson, unpubl.), which was designed to examine the causes of avian nest-failure, was used here to estimate scavenging rates. Because of the fundamental similarities between these two types of data, this method of analysis was used to approximate scavenging rates. MCestimate, programmed in MATLAB (Mathworks 2009), builds upon Mayfield's (1961, 1975) methods for estimating the probability of avian nest failure. The program allows covariates to be evaluated separately for multiple fates, to determine the influence that each variable may have on cause-specific failure rates, using the Markov chain algorithms, of Etterson et al. (2007a, 2007b).The three possible fates for carcasses in the scavenging experiment were: 1) removal by a scavenger, 2) removal by a homeowner, or 3) body remains in the location that it was placed.

The scavenging model produced, estimated both the daily and the overall probability of a scavenging event occurring. The daily scavenging rate was determined by using the time interval (*l* = 6 d) to estimate the daily survival rate for both of the experiments. These were combined to make one scavenging estimate for all of the 35 residential homes. Akaike's Information Criterion (AIC) (1973) was used to select scavenging models based on these covariates. Each model was ranked relative to the lowest ΔAIC value produced. The model with the lowest value was then chosen as the best explanatory model, relative to the models provided, for the observed variation in scavenging rates. To determine whether observed differences in scavenging rates between homes were significant, the test statistic

$$Z = \frac{\hat{m}_1 - \hat{m}_2}{\sqrt{s^2{}_{\hat{m}_1} + s^2_{\hat{m}_2}}} \qquad (1)$$

was used, where $s^2_{\hat{m}_1}$ and $s^2_{\hat{m}_2}$ were calculated from Bart and Robson (1982) using

$$s_{\hat{m}} = \left[\sum_l^L \frac{n_l\, l^2 \hat{m}^{l-2}}{1-\hat{m}^l}\right]^{-.5} \qquad (2)$$

where $n_l = n_{ls} + n_{lf}$, n_{ls} = number of intervals of length *l* in which carcass removal did not occur, n_{lf} = number of intervals of length *l* in which carcass removal did occur, *l* = interval length in days, *L* = maximum interval length.

Estimating Mortality Rates

Once scavenging rates were estimated, Shoenfeld's (2004) equation which was modeled after Erickson et al.'s (1998) equation for estimating avian mortality based on a Poisson search model was calculated. The model assumes that birds were killed by windows at random times and that the subsequent removal of a bird by a scavenger or homeowner was also random. This model also assumes that all birds that were killed by windows were found and removed by a researcher, homeowner, or scavenger. The probability that each bird killed and lying on the ground in front of a window was found at the time of a search was assumed to be independent and to occur at some rate. For a steady state time interval of duration T_T, we used the following formula from Shoenfeld (2004) to estimate the expected number of birds killed during the five season study.

$$N_k = N_F \frac{pT_{R+}T_S}{pT_R} \qquad (3)$$

where, N_K = the expected number of birds killed, N_F = the expected number of birds found by searchers, p = detection probability, T_R = mean lag time of removal by a scavenger, and T_S = the mean time between searches in days. To estimate the annual migratory mortality rate (m) for all of the homes on the Point, we used the Erickson et al.'s (1998) formula,

$$m = \frac{N{*}T_S{*}N_F}{k{*}T_R{*}p} \qquad (4)$$

where, N = the total number of houses on Minnesota Point, T_S = the interval between searches in days, N_F = the total number of carcasses detected for the period of study, k = the number of houses sampled, T_R = the mean carcass removal time in days, and p = the observer efficiency rate.

Results

Window Kills

There were 46 window kills recorded for the three spring seasons and 62 recorded for the two fall seasons (Table 1). A total of 4268 individual observations were made during the study (number of houses x number of daily searches), with an average of 102 observations per house. A total of 40 identifiable species and 108 individual birds were recorded as window collision fatalities over the course of five migratory seasons (Appendix A).

Table 1. Avian window collision fatalities and the mean number of days searched, recorded by year and season on Minnesota Point, Duluth, MN USA[1]. (NS) is listed when searches were not conducted.

	Spring April-June			Fall August-October			Annual Total
Year	fatalities	mean days searched	SD	fatalities	mean days searched	SD	fatalities
2006	20	12	3.98	38	21	1.39	58
2007	12	27	0	NS	NS	NS	12
2009	14	33	1.43	24	49	0	38
Mean	*15*	*24*		*31*	*35*		*22*
Total	46	78		62	72		108

[1] The number of houses participating each season were; 21, 26, 26, 35, and 35 for each respective year.

Of the 42 participating residential homes, 10 were located on the bayside and 32 on the lakeside. Thirty-two of the 42 homes experienced window collision mortality, representing approximately 76% of the homes surveyed. There were no recorded fatalities at ten of the houses, five of which were located on the bayside and five on the lakeside (Appendix B). Of the 108 window fatalities recorded, 89 were migrant species, 10 were resident species (Figure 2), and nine were unidentifiable. Of the migrants killed, 44 % were long distance migrants, 34 % were short distance migrants, and 11% were classified as possible short or long distant migrants (Appendix A).

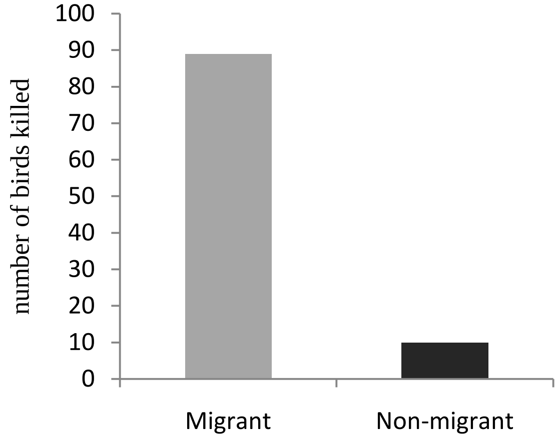


Figure 2. Migratory and resident birds found as collision fatalities during periodic searches of 42 residential homes. Values represent the total number of birds collected during five migratory periods between 2006 and 2009.

The six species that experienced the highest relative mortality rates included; the Ruby-throated Hummingbird (Archilochus colubris)(n= 5), Swainson's Thrush (Catharus ustulatus)(n= 14), Hermit Thrush (Catharus guttatus)(n= 5), Ovenbird (Seiurus aurocapillus)(n= 6), Common Yellowthroat (Geothlypis trichas)(n= 4), and the White-throated Sparrow (Zonotrichia albicollis)(n= 8). These six species represented 43 % of the observed window kills, with Swainson's Thrush accounting for 32% of the long distant migrants killed and 16% of the total.

Window-fatalities increased with distance from the areal lift bridge (n = 42, p = 0.01) (Figure 3). Based on collision fatalities with recorded window locations (n =101), the direction in which each window was facing relative to the observed fatality indicated that for each home, on average, fatalities occurred more frequently on windows facing east, towards Lake Superior (Figure 4), with 3 df, and an $\alpha = 0.05$, the calculated $X^2 = 31.23 > 9.815$.

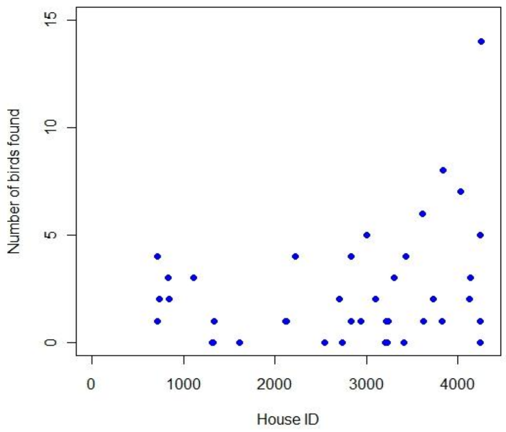


Figure 3. The distribution of window collision fatalities at 42 residential homes. The sample size is n = 42, p = 0.01. Each point represents the number of bird carcasses found per house.

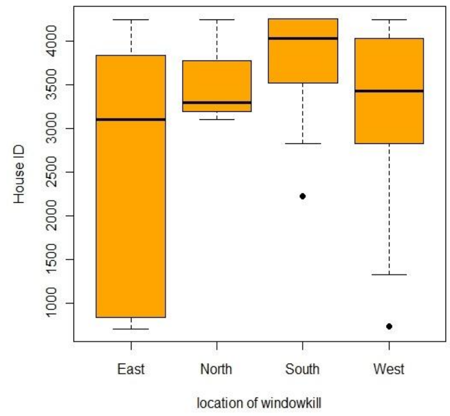


Figure 4. The direction in which window collision fatalities occurred along Minnesota Point. The distribution of window collisions is based on the location (House ID) of each strike relative to the cardinal direction in which each window was facing.

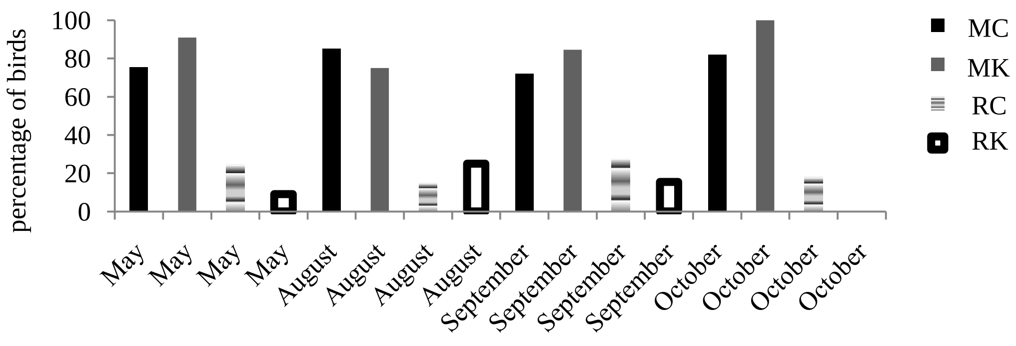
East facing windows represented approximately 41 % of the observed mortalities (Table 2). The fewest observed fatalities occurred on windows facing north towards the areal lift bridge, which represented approximately 3% of the observed fatalities (Table 2). There was not a difference between the total number of windows facing any direction and the number of recorded fatalities.

Table 2. The number of recorded fatalities , Chi squared values, and the mean number of windows relative to the direction in which each window was facing (n = 108).

Window direction	# of fatalities	X^2	mean # of windows	SD
North	3	19.61	4	2
East	41	9.82	6	3
South	32	1.8	6	4
West	25	0	6	2

General linear regression analysis revealed that the approximate distance of each house to the shoreline (m) and the size of each house (gross sq m) did not appear to influence the occurrence of window collisions. Nor was there a detectible association between wind speed, wind direction, temperature, or precipitation and collision frequency. The only weather variable that had a significant negative association with collision frequency was sky cover. The percentage of sky cover both the night before an observed collision fatality and the day of the fatality suggested that the number of birds killed increased with decreasing sky cover (n =108, r = 0.56 and 0.53 respectively, *p* =0.003).

A log likelihood ratio comparing the relative frequency of birds counted to those that were killed in 2009, revealed a non-significant difference between the frequency scores. This signified that the mortality rates observed for each migratory class during these two seasons were proportional to the recorded species counts (Appendices C1 & C2, and Figure 5).



*MC = % migrant birds counted, MK = % migrant birds killed, RC = % resident birds counted, RK =% resident birds killed.

Figure 5. The percentage of birds counted during point counts relative to those killed by windows during the spring and fall migration of 2009. Values represent percentages.

Scavenging Experiment

The projected average scavenging rate for all 35 homes during the six day period was approximately $\hat{p} = 0.79$ (Table 3, Appendices E1-E3). By day three, 55% of the experimentally placed bird carcasses had been scavenged. Differences in scavenging rates between the two houses separated by the largest distance in the study (HID 712 and HID 4256), were also examined. The estimated rates for HID 712 ($\hat{p}_1$) and 4256 ($\hat{p}_2$) for both six day time intervals were $\hat{p}_1$ = 0.65 and $\hat{p}_2$ = 0.89 respectively, a difference of Δ = 0.24. A z value was calculated to determine whether these observed differences in scavenging rates were significant. The calculated z value = - 4.982 with a *p* value = 0.00 < 0.05, indicated that the observed differences between the two scavenging rates were significant.

Table 3. The probability of a bird being scavenged (pr(scavenged)) between one and six days is listed for all 35 houses, for HID *712*[1], and for HID *4256*[2]. The values represent the maximum likelihood estimate (MLE) for each day and location. SE = one standard error.

	pr(scavenged) *mean for all 35 houses*		pr(scavenged) *HID 712*		pr(scavenged) *HID 4256*	
days	MLE	SE	MLE	SE	MLE	SE
1	0.24	0.03	0.16	0.04	0.32	0.05
2	0.41	0.04	0.30	0.06	0.53	0.06
3	0.55	0.05	0.41	0.07	0.68	0.07
4	0.65	0.05	0.50	0.08	0.78	0.06
5	0.73	0.05	0.58	0.09	0.84	0.05
6	0.79	0.05	0.65	0.09	0.89	0.04

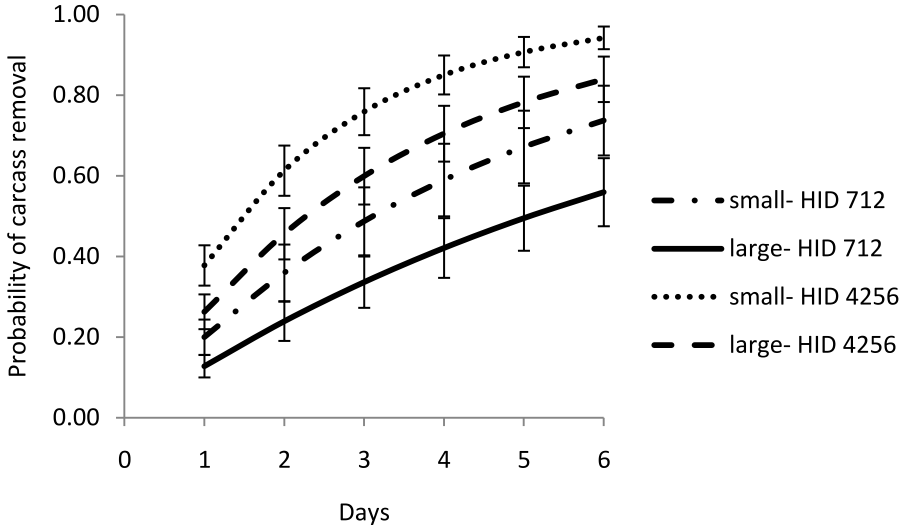
[1] The house closest to the areal lift bridge (city center) [2] The house farthest from the areal lift bridge

To evaluate the contribution of each variable examined, different combinations of covariates were used to build a set of candidate models. There were 13 models produced, one of which was the intercept only model. The remaining 12 models examined the effects of carcass size, house location (HID), window direction, carcass position, date, and experiment (1 or 2) on scavenging rates (Table 4).

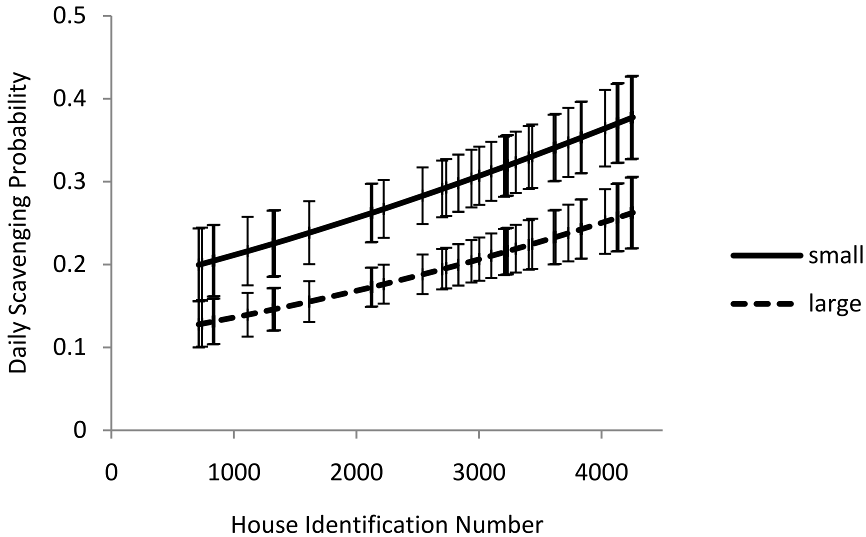
Table 4. AIC statistics for 13 models of scavenger removal rates (failure), based on a single failure class. Each model is listed with its corresponding AIC, ΔAIC, and weight. Models are ranked from lowest to highest ΔAIC values.

Model	AIC	Δ AIC	Weight
1. T{Size+House.ID}	483.42	0.00	0.86
2. T{Size+Direction}	486.51	3.09	0.04
3. T{Direction+House.ID}	486.56	3.14	0.04
4. T{House.ID}	486.87	3.45	0.03
5. T{Position+House.ID}	487.27	3.85	0.02
6. T{Size}	487.90	4.48	0.01
7. T{Size+Position}	489.72	6.30	0.00
8. T{Direction+Position}	490.13	6.71	0.00
9. T{Direction}	491.14	7.72	0.00
10. T{Position}	493.05	9.63	0.00
11. T{.}	493.06	9.64	0.00
12. T{Date}	493.99	10.57	0.00
13. T{Experiment}	494.98	11.56	0.00

The main effects of each covariate were modeled (Models 4, 6, and 9-13) as well as four additive models (Models 1-3, 5, 7, and 8). Using Akaike's Information Criterion (AIC) (1973), the model which best explained the variation in scavenging rates on Minnesota Point was the model that included both the distance of the house from the areal lift bridge and the size of the bird being scavenged, ΔAIC = 0 (Table 4). The scavenging rates increased with distance from the areal lift bridge, with smaller birds being removed at a quicker rate than that of large birds (Figures 6a & 6b). The differences in scavenging rates between HID 712 and HID 4256 by day six were 28% for large birds and 20% for small birds.



6a.



6b.

Figure 6. The probability of a scavenging event occurring within six days based on the size of the carcass and the location of the house. 6a. Probability of carcass removal by a scavenger or homeowner during the six day experimental period. Values represent probabilities for the house closest to the areal lift bridge (city center (HID 712)) and the house farthest from the areal lift bridge (city center (HID 4256)). Error bars represent one standard error. Figure 6b. Daily scavenging probability for all 35 houses on Minnesota Point (House Identification Number). Values are based on large and small carcass sizes. Error bars represent one standard error.

Only two of the 140 carcasses were removed and reported by homeowners during the course of the experiment. Based on these results, the detection probability of a home owner was $\hat{p}$ = 0.014. Because of this low detection probability by homeowners, modeling this same data set and using two classes of failure: 1) removal by scavengers, and 2) removal by homeowners, only produced slightly different estimates for scavenger removal rates with $\hat{p}$ = 0.78 by day six.

Birds placed in an open environment were scavenged at a quicker rate than those that were hidden (Table 5), with an estimated difference of 9% by day six. There was also a difference in scavenging rates based on the orientation of the windows. The predicted rate of scavenging on north facing windows was approximately 21% lower than any other direction by day six (Table 5).

Table 5. The average scavenging rate for all 35 houses based on carcass position (hidden or open) and window direction (N,E,S,W). The values represent the maximum likelihood estimate (MLE) for days 1, 3, and 6. SE = one standard error.

	Day 1		*Day 3*		*Day 6*	
	MLE	SE	MLE	SE	MLE	SE
open	0.26	0.03	0.60	0.05	0.84	0.04
hidden	0.21	0.03	0.50	0.05	0.75	0.05
North	0.16	0.03	0.40	0.06	0.64	0.08
East	0.25	0.04	0.57	0.07	0.82	0.06
South	0.28	0.04	0.63	0.07	0.86	0.05
West	0.28	0.05	0.63	0.08	0.87	0.06

Mortality Rates

Based on the scavenging rates calculated, we were able to estimate the migratory mortality rate for the 42 homes included in the study as well as for those expected to occur on all residential houses in the study area. Using Shoenfeld's equation (2004), with N_F = 108, $\hat{p}_h$ = 0.014 for homeowners and $\hat{p}_r$ = 1 for researchers (assuming researchers are finding all birds that would have died), T_R = 1.32, and T_S = 1.34, a point estimate of mortality during the study period is N_K = 218 ± 30 based on the researchers detection probability. Because the time period between searches was only known for researchers, the mortality estimates provided incorporate only the researcher's detection probability.

To estimate the mortality rate for all of the houses on the Point, we used Erickson et al.'s (1998) formula, where N = 580 residential homes on Minnesota Point, T_S = 1.34, N_F = 108, k = 42, T_R = 1.32, and $\hat{p}_r$ = 1 for researchers. When calculating the predicted number of birds killed for the 580 homes on Minnesota Point during the study period, and using the researcher detection probability, the estimate was 1514 ± 78.

Since the average number of days searched for each study season was 34 d. Using the point estimate of N_K = 1514, the estimated number of birds killed (N_K) per 34 d was equal to approximately 303. Spring and fall migration in Duluth occurs between mid March to early June and mid August to late October, roughly 150 d. This predicts that a mean of 1333 ± 73 birds will be killed each year during peak migration at residential homes on Minnesota Point.

Discussion

Window Kills

Of the 42 residential homes included in this study, 76% reported at least one collision fatality. There were more fatalities recorded during fall migration than during spring, which may be attributed to an increased density of birds flying due to newly hatched young. Other studies have found that the majority of the window collision fatalities reported are nocturnally migrating passerines (Drewitt and Langston, 2008), and species that are most active on or near the ground, such as thrushes, wood warblers, and finches (Klem, 1990a, 1991). Of the mortalities reported in this study, 42 % were ground, ground and foliage, and ground and bark gleaning foragers (Appendix D). The majority of the recorded fatalities were migratory species not commonly found at feeders and approximately 50% of the window kills occurred at houses without bird feeders (Appendix F). Without monitoring the activity of feeders, it is not possible to know the extent to which their presence influenced mortality rates, nor whether or not they were being actively used. Of the six species that experienced the highest relative mortality rates, all except for the Ruby-throated Hummingbird were migratory species that spend a lot of time on or near the ground. In a recent study conducted on two college campuses in northwestern and southwestern Illinois, Hager et al. (2008) found the species to incur the highest rates of mortality to be nearly identical to those found in this study.

Although the number of window fatalities recorded in this study increased with distance from the aerial lift bridge, where human densities are greater, the overall variance between homes appeared to be small. The farthest house in the study from the areal lift bridge (HID 4256) with 14 recorded fatalities likely influenced the slope (Figure 3). The size of houses and the number of windows were not correlated with strike intensity, which is consistent with other window collision studies (Klem 1989, Klem et al., 2009). Klem (1989, 2008) found that birds are most likely to strike large windows located on the ground level. He also found that for residential homes, most collisions occur during the day, independent of the degree of cloud cover or the orientation of the windows. In our study, sky cover was the only weather variable that was negatively associated with collision frequency. It is unclear whether this may have enhanced the reflective qualities of the glass windows, leading to increased mortality rates. The north facing windows had the lowest number of recorded fatalities (n=3), whereas all other directions had over 20 recorded fatalities (Table 2). On average, the distance separating the houses included in this study, was smallest on the north side. This suggests that birds may be less likely to encounter windows facing north or that they may not be able to fly at speeds high enough to produce fatal collisions.

The number of windows was not an important contributing factor in the probability of a strike occurring. It is possible that the location of the windows that incurred the most frequent strike rates appeared as clear 'flyways' or had higher reflective qualities than those with few or no recorded fatalities. Several studies have reported increased strike rates at windows reflecting vegetation (Gelb and Delacretaz, 2006, Klem et al. 2009). The house farthest from the areal lift bridge was located on the northern side of a 0.5 mi stretch of woods. Nearly every window collision reported at this house occurred on a southern facing window which reflected the surrounding wood lot.

Avian Density

There were more migratory birds found as window kills which corresponded to the greater percentage of migrants observed during point counts. Hager et al., (2008), studied window collisions on several buildings year round and documented zero collision mortalities in winter, even when there was not a detectible difference in the abundance of birds counted between seasons. This suggests that migratory behavior may be a more influential predictor of collision frequency than abundance alone.

To better understand the local species abundance, forest bird monitoring data collected over 16 years in the Superior National Forest was compared with species mortalities observed during the entire study period. This forest located north of Duluth was chosen because of its proximity to Minnesota Point and because of the long term data available for comparison (Niemi et al., 2010). The compiled species data from 1991 through 2009 showed that of the 20 most common forest birds, four of the six most common species found in our study were included on the list. It is expected that species found in high abundance should also be found more often as collision fatalities. However, many of the remaining 16 species were found less frequently or not at all in our study. Swainson’s Thrush, recorded as a frequent window collision fatality, also shows a decreasing trend over time in the Superior National Forest (Niemi et al., 2010). Although not all birds that are commonly found as window collisions show declining trends, those that do should be considered more carefully. It is believed that fatalities associated with avian window collisions may be more influential in declining population numbers than previously expected (Ogden 1996), which makes documenting and, more importantly, taking measures to mitigate the effects of collisions a vital step in avian conservation.

The Influence of Scavenging on Mortality Estimates

Nearly all deaths associated with window collisions remain unaccounted for and therefore it is assumed that the number of recorded window kills represents a conservative number of actual fatalities. It is estimated that one out of every two birds that hits a window will die immediately and of those that do, many will be removed by predators and scavengers (Klem, 1990a, Klem et al., 2004). Vertebrate scavenging efficiency has been estimated to average 75% (DeVault et al., 2003) and this value is consistent with the results from our scavenging experiment. It was assumed that the scavenging rates would be uniform across all houses surveyed. However, variation in the scavenging rates of avian carcasses was found to be a function of both the size of the carcass and the location of the house. The density of scavengers may increase as one moves away from the city center, where the distance between houses becomes greater and more habitat with cover is available. However, minus one cat that was observed removing a carcass during the experiment, the species identity of scavengers was unknown (e.g., domestic cats, dogs, crows, gulls). Smaller birds were removed more quickly than large birds (Figure 6a), which may reflect the average size of the scavenger involved in carcass removal. North facing windows showed a lower removal rate relative to the other window directions, which like the observed collision fatalities could reflect the reduced visibility and accessibility of the carcasses facing that direction. It has been suggested that predators and scavengers are attracted to areas with abundant prey and may return to locations, such as windows, where they have had previous success (Klem, 1981).

Compiled results from 22 scavenging experiments, averaging six days and involving avian carcasses, estimate an average removal rate of 70% (DeVault et al., 2003). However, the range of efficiency varied between 13-100% for scavenging on small birds (DeVault et al., 2003). This suggests that scavenging rates, like mortality rates, vary spatially and reinforces the importance of including a scavenging experiment when estimating site-specific mortality rates. A small percentage of the birds removed during the scavenging experiment (1.4%) were recovered by home owners. This low recovery rate coupled with the high scavenging rates observed, suggest that a significant number of window kills likely go undetected. Our results suggest that detection probability greatly impacts estimates and should be taken into consideration during scavenging studies.

Factors Influencing Mortality Rates

The current range of annual estimates of mortality of birds from window kills is broad and will require continual study to more accurately assess the significance of this issue. Even with conservative estimates, window collisions are considered to be a major cause of avian mortality, warranting serious attention. Even with the limited number of collision fatalities that have been recorded, there are sometimes hundreds of birds estimated to die at a single structure in a single evening (Erickson et al., 2001). Although collision frequency is not always that severe, it is likely that some species of migratory birds are being negatively impacted (Ogden, 1996). The impact that individual species incur will in part depend on their population size, which for many remains unknown (Erickson, 2005).

The ability of a bird to detect a man-made structure as a barrier and avoid collision will depend on its ability to detect approaching objects and on the volume of space around which it can gather information (Blackwell et al., 2009). Photoreception, which is determined by the density of retinal ganglion cells, coupled with environmental factors (such as local weather conditions) will influence the perceived intensity of a light source on or around an object (Blackwell et al., 2009).   Each of these factors varies among species and can influence their ability to assess risk and respond to it in a sufficient amount of time to avoid a collision (Blackwell et al., 2009). Understanding the degree of variability within the avian visual system may help determine species vulnerability and help mitigate risk factors along routes that are particularly hazardous.

It is believed that without the aid of starlight, night migrants are unable to distinguish the detail of the surrounding landscape (Ogden, 1996). It has been suggested that the inadequacy of their night vision was not problematic prior to the expansive development of urban structures, making it an unnecessary adaptation in the past when flight paths were clear (Ogden, 1996). Species that rank among some of the highest reported collision fatalities have been categorized as 'tunnel fliers' (Snyder, 1946).This type of flight behavior has been described as swift movements through restricted passages and heavy cover, where individuals are guided by a light source (Snyder, 1946). This type of flight behavior is characteristic of many of the forest dwelling avian species.

Klem (2009) suggests that although multiple factors can influence the probability of a bird encountering a window and that collision intensity will vary among locations, the avian visual system may be fundamentally incapable of perceiving glass as a barrier. Unlike other longer lived avian species, it is believed that many of the small passerine birds commonly found as window kills are currently able to respond to population fluctuations and to compensate for window collision fatalities (Drewitt and Langston 2008). The significance of encountering man-made barriers will be greatest for rare and vulnerable species (Drewitt and Langston 2008); however, with current declines in even the most common species, reducing the risks associated with window collisions is desirable. Avian window collisions, likely contribute significantly to annual mortality rates and therefore deriving accurate estimates of mortality is vital to predicting long term population effects. Reducing the probability of a collision occurring and encouraging research in the design and implementation of structures that reduce these occurrences is essential.

Literature Cited

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267-281 *in* B.N. Petran and F. Csaki, editors. International symposium on information theory. Second edition. Akademiai Kiado, Budapest, Hungary.

Alerstam, T. 1990. Bird Migration. Cambridge University Press. Cambridge, UK.

Bart, J., and D.S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. *Ecology* 63(4): 1078-1090.

Blackwell, B.F., Fernàndez-Juricic E., Seamans T.W., and T. Dolan. 2009. Avian visual system configuration and behavioral response to object approach. *Animal Behavior* 77: 673-684.

Brown, H. and Capunto S. 2007. Bird-safe building guidelines. New York City Audubon Society, Inc., New York. 59 p.

DeVault, T.L., Rhodes O.E. Jr., and Shivik J.A. 2003. Scavenging by vertebrates: behavioral, ecological, and evolutionary perspectives on an important energy transfer pathway in terrestrial ecosystems. *OIKOS* 102: 225-234.

Diehl, R.H., Larkin R.P., and Black J.E. Radar observations of bird migration over the Great Lakes. *The Auk 120(2): 278-290.*

Drewitt, A.L. and Langston R.H.W. 2008. Collision effects of wind-power generators and other obstacles on birds. *Ann. N.Y. Acad. Sci.* 1134:233-266.

Dunn, E.H. and Nol, E. 1980. Age-related migratory behavior of warblers. *Journal of Field Ornithology* 51(3): 254-269.

Dunn, E.H. 1993. Bird mortality from striking residential windows in winter. *Journal of Field Ornithology* 64(3): 302-309.

Erickson W.P., Strickland M.D., Johnson G.D., and Kern J.W. 1998. Examples of statistical methods to assess risks of impacts to birds from wind plants. Proceedings of the Avian-Wind Power Planning Meeting III. National Wind Coordinating Committee Meeting, May 1998, San Diego, CA, Washing, DC.

Erickson W.P., Johnson G.D., Strickland M.D., Young Jr. D.P., Sernka K.J., and R.E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. This is a resource document of the National Wind Coordinating Committee (NWCC), Washington D.C., USA.

Erickson W.P., Johnson G.D., and Young Jr. D.P. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191 pp.1029-1041.

Etterson M.A, Nagy L.R, Rodden-Robinson T. 2007a. Partitioning risk among different causes of nest failure. *Auk* 124:432-443.

Etterson M.A, Olsen B.J, Greenberg R. 2007b. The analysis of covariates in multi-fate Markov chain nest failure models. *Studies in Avian Biology* 34:55–64.
Etterson, M.A.2010. Mcestimate. Smithsonian Migratory Bird Center. Free Statistical Software.

Gelb, Y. and N. Delacretaz. 2006. Avian window strike mortality at an urban office building. *The Kingbird 56:* 190-198.

Hager, S.B., Trudell H., McKay K.J., Crandall S.M. and Mayer L. 2008. Bird density and mortality at windows. *Wilson Journal of Ornithology* 120(3): 550-564.

Heglund, P.J. and Skagen S.K. 2005. Ecology and physiology of en route Nearctic Neotropical migratory birds: a call for collaboration. *Condor* 107: 193-196.

Herbert, A.D. 1970. Spatial disorientation in birds. *Wilson Bulletin* 82(4): 400-419.

Jenni, L. and Schaub, M. 2003. Behavior and physiological reactions to environmental variation in bird migration: a review. In: Berthold, P., Gwinner, E. and Sonnenschein, E. (eds). Avian migration. Springer-Verlag, Berlin Heidelberg, pg. 155-171.

Klem, D. Jr. 1981. Avian predators hunting birds near windows. *Proceedings of the Pennsylvania Academy of Science* 55: 90-92.

Klem, D. Jr. 1989. Bird-window collisions. *Wilson Bulletin* 101(4): 606-620.

Klem, D. Jr. 1990a. Collisions between birds and windows: mortality and prevention. *Journal of Field Ornithology* 61(1): 120-128.

Klem, D. Jr. 1990b. Bird injuries, cause of death, and recuperation from collisions with windows. *Journal of Field Ornithology* 61(1): 115-119.

Klem, D. Jr. 1991. Glass and bird kills: an overview and suggested planning and design methods of preventing a fatal hazard. Pp. 99-104 in L.W. Adams and D.L. Leedy (Eds.),Wildlife Conservation in Metropolitan Environments. Natl. Inst. Urban Wildl. Symp. Ser.2, Columbia, MD.

Klem, D. Jr., Keck D.C., Marty K.L., Miller Ball A.J., Niciu E.E., and C.T. Platt. 2004. Effects of angling, feeder placement, and scavengers on avian mortality at plate glass. *Wilson Bulletin* 116(1): 69-73.

Klem D. Jr. 2006. Glass: a deadly conservation issue for birds. *Bird Observer 34(2): 73-81.*

Klem D. Jr. 2008. Avian mortality at windows: the second largest human source of bird mortality on earth. Proceedings Fourth International Partners in Flight Conference 2008, McAllen, Texas, USA. USDA, Forest Service Technical Report: In press.

Klem, D. Jr., Farmer C.J., Delacretaz N., Gelb Y., and P.G. Saenger. 2009. Architectural and landscape risk factors associated with bird-glass collisions in an urban environment. *Wilson Journal of Ornithology* 12(1): 126-134.

Mathworks. 2009. MATLAB: The language of technical computing. The Mathworks, Inc. Natick, MA.

Mayfield H.F. 1961. Nesting success calculated from exposure. *Wilson Bulletin* 73:255-261.

Mayfield H.F. 1975. Suggestions for calculating nesting success. *Wilson Bulletin* 87:456-466.

Niemi G., Howe R., Danz N., and Etterson M. 2010. A 15 and 20 year summary of breeding bird trends in National Forests of Northern Minnesota and Wisconsin. This is an NRRI Technical Report: NRRI/TR-2010/19. The data contained in this report is being prepared for a peer-reviewed publication and, therefore, its contents should be limited to internal use within the USDA Forest Service.

Ogden, L.J. 1996. Collision course: the hazards of lighted structures and windows to migrating birds. World Wildlife Fund Canada and the Fatal Light Awareness Program. 46 pages.

R Project, 1997: R version 2.11.1. Free statistical software.

SDCW. South Dakota Climate and Weather, cited 2010: Duluth (Sky Harbor) airport station (ASOS/AWOS) archived hourly weather data. [Available online at http://www.climate.sdstate.edu/airport/surface/archive]

Shoenfeld, P. 2004. Suggestions regarding avian mortality extrapolation. Prepared for the Mountaineer Wind Energy Center Technical Review Committee. Curry & Kerlinger, LLC-2-14-04 2003 Mountaineer WEC Annual Rpt. – Avian and Bat Fatalities.

Snyder, L. L. 1946. “Tunnel fliers” and window fatalities. *Condor* 48(6):278.

USGS.United States Geological Survey. 2007. Routes of migration. <http://www.npwrc.usgs.gov/resource/birds/migratio/routes.htm>. Accessed April 2009.

Veltri C.J. and Klem D. Jr. 2005. Comparison of fatal bird injuries from collisions with towers and windows. *Journal of Field Ornithology* 76(2): 127-133.

Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Department of Fisheries and the Environment. Canadian Wildlife Service, Ontario Region.

Appendix A. The number of fatal window collisions recorded on Minnesota Point, Duluth, MN during five migratory periods between 2006 and 2009. The migratory status, number of fatalities recorded, % composition, and foraging guild were recorded for each species found. NA = unknown for species that could not be identified.

Species Common name/ Scientific name	Status[a]	Fatalities[b]	% Comp.[c]	Foraging guild[d]
Ring-billed Gull (Larus delawarensis)	SD*	2	1.85	6
Mourning Dove (Zenaida macroura)	SD*	1	0.93	1
Ruby-throated Hummingbird (Archilochus colubris)	LD*	5	4.63	5
Belted Kingfisher (Ceryle alcyon)	SD	1	0.93	6
Yellow-bellied Sapsucker (Sphyrapicus varius)	SD/LD	2	1.85	3
Downy Woodpecker (Picoides pubescens)	R*	1	0.93	3
Northern Flicker (Colaptes auratus)	SD*	1	0.93	1
Traill's Flycatcher (Empidonax traillii)	LD	1	0.93	2
Blue Jay (Cyanocitta cristata)	R	1	0.93	1
Barn Swallow (Hirundo rustica)	LD*	1	0.93	4
Black-capped Chickadee (Poecile atricapillus)	R	2	1.85	2
Brown Creeper (Certhia americana)	SD	4	3.7	3
Sedge Wren (Cistothorus platensis)	SD	1	0.93	1
Veery (Catharus fuscescens)	LD	1	0.93	1
Swainson's Thrush (Catharus ustulatus)	LD	14	12.96	2
Hermit Thrush (Catharus guttatus)	LD/SD	5	4.63	1
American Robin (Turdus migratorius)	R	1	0.93	1
Gray Catbird (Dumetella carolinensis)	SD*	1	0.93	1
Cedar Waxwing (Bombycilla cedrorum)	SD*	3	2.78	2
Tennessee Warbler (Vermivora peregrina)	LD	2	1.85	2
Yellow Warbler (Dendroica petechia)	LD*	2	1.85	2
Chestnut-sided Warbler (Dendroica pensylvanica)	LD	1	0.93	2
Cape May Warbler *(Dendroica tigrina)*	LD	4	3.7	2
Yellow-rumped Warbler (Dendroica coronata)	SD	2	1.85	2
Black-and-white Warbler (Mniotilta varia)	LD	2	1.85	3
American Redstart (Setophaga ruticilla)	LD	2	1.85	2
Ovenbird (Seiurus aurocapillus)	LD	6	5.56	1
Northern Waterthrush (Seiurus noveboracensis)	LD	1	0.93	1
Common Yellowthroat (Geothlypis trichas)	SD/LD*	4	3.7	2
Song Sparrow (Melospiza melodia)	SD*	2	1.85	1
Swamp Sparrow (Melospiza georgiana)	SD*	2	1.85	1
White-throated Sparrow (Zonotrichia albicollis)	SD	8	7.41	1
Dark-eyed Junco (Junco hyemalis)	SD	2	1.85	1
Scarlet Tanager (Piranga olivacea)	LD	1	0.93	2
Rose-breasted Grosbeak (Pheuticus ludovivianus)	LD	1	0.93	2
Red-winged Blackbird (Agelaius phoeniceus)	SD*	1	0.93	1
Brewers Blackbird (Euphagus cyanocephalus)	SD	1	0.93	1
Common Grackle (Quiscalus quiscula)	SD*	2	1.85	1
House Finch (Carpodacus mexicanus)	R	2	1.85	1
House Sparrow (Passer domesticus)	R	3	2.78	1
Unidentified	NA	4	3.7	NA
Unidentified Woodpecker	NA	3	2.78	NA
Wing Only	NA	2	1.85	NA
Total		***108***	**100**	

Appendix A (Continued)

[a] status (LD= long distance migrant, SD= short distance migrant, R= resident)
[b] number of fatalities
[c] percent species composition
[d] foraging guild
1 = ground, ground and foliage gleaner, ground and bark gleaner 2 = foliage gleaner, foliage and bark gleaner
3 = bark gleaner 4 = aerial forage 5 = hover and glean 6 = high dives and fish, high dives and surface dips
* migrant potentially nesting in the area

Appendix B. Location and house identification number (HID) of each house participating in the window collision study between 2006 and 2009. The number of birds killed, duration of participation, and house characteristics are listed for each of the 42 residential houses. *Loc* = location of houses (LS = Lake Superior, Bay = bayside of the point), N = number of dead birds found. *Windows (total #, N,E,S,W).*

Loc	*HID*	*N*	*days in study*	*seasons in study*	*windows*					*gross area square m*	*distance to L. Sup (m)*	*Bay (m)*
					total #	*N*	*S*	*E*	*W*			
LS	*712*	1	140	5	20	6	7	3	4	268	56	92
LS	*714*	5	140	5	32	3	9	12	8	651	51	101
LS	*740*	2	145	5	38	5	11	13	10	580	45	100
LS	*828*	3	62	3	30	4	5	13	8	816	51	146
LS	*840*	3	144	5	32	4	10	10	7	393	50	146
LS	*1112*	3	136	5	17	5	1	5	6	356	43	171
LS	*1316*	0	82	2	30	3	7	13	7	468	97	218
LS	*1320*	0	82	2	18	4	4	5	5	222	129	177
Bay	*1329*	0	82	2	14	2	2	5	5	304	170	135
Bay	*1335*	1	82	2	24	4	7	4	9	212	169	152
LS	*1615*	0	82	2	22	4	7	5	6	308	123	271
LS	*2118*	1	82	2	13	3	2	4	4	217	153	69
Bay	*2129*	1	77	2	21	5	5	5	6	421	202	22
LS	*2223*	4	123	4	27	8	4	7	8	515	118	101
LS	*2540*	0	60	3	19	5	5	3	6	307	98	110
LS	*2700*	2	82	2	20	3	7	5	5	415	94	114
Bay	*2733*	0	50	3	23	2	8	6	7	315	169	31
LS	*2832*	1	82	2	24	7	6	7	4	327	115	70
LS	*2833*	4	142	5	26	8	8	4	6	331	80	113
Bay	*2939*	1	82	2	8	1	1	2	4	304	169	27
Bay	*3003*	5	82	2	16	1	2	2	11	801	173	23
LS	*3101*	2	140	5	20	4	6	4	6	214	78	107
Bay	*3205*	0	82	2	13	1	3	3	6	510	166	14
Bay	*3221*	1	48	2	14	3	4	3	4	301	167	11
LS	*3230*	0	82	2	22	5	8	6	3	439	73	99
LS	*3236*	1	130	4	18	4	6	3	5	324	116	73
LS	*3301*	3	82	2	16	2	3	7	4	366	87	77
Bay	*3407*	0	144	5	7	0	1	1	5	507	170	15

Appendix B (continued)

Loc	*HID*	*N*	*days in study*	*seasons in study*	*total #*	*windows N*	*S*	*E*	*W*	*gross area square m*	*distance to L. Sup (m)*	*Bay (m)*
LS	*3435*	5	136	5	30	4	4	10	12	345	81	100
LS	*3610*	7	145	5	22	4	6	6	6	424	122	55
LS	*3626*	1	130	4	30	9	8	7	6	283	120	46
LS	*3730*	2	145	5	12	3	3	2	4	205	95	76
LS	*3831*	1	75	2	19	5	2	4	8	268	107	66
LS	*3839*	9	130	4	19	3	7	3	6	277	96	95
LS	*4030*	10	147	5	33	6	8	11	8	458	70	93
LS	*4124*	2	62	3	48	12	10	17	9	516	95	139
LS	*4136*	3	144	5	42	6	7	17	12	409	68	162
LS	*4139*	3	82	2	25	6	8	7	4	305	67	173
LS	*4240*	1	144	5	16	2	2	7	5	410	55	105
LS	*4242*	0	57	3	X	X	X	X	X	263	103	58
LS	*4246*	6	63	3	25	7	6	7	5	277	68	84
LS	*4256*	14	149	5	11	2	4	3	2	399	62	80

Appendix C1. Avian density estimates from point counts conducted in the spring and fall of 2009. Values represent the total number of each species counted.

Common Names	Scientific Names	Spring	Fall
Great Blue Heron	*Ardea herodias*	0	1
Bald Eagle	*Haliaeetus leucocephalus*	1	2
American Kestrel	*Falco sparverius*	0	1
Merlin	*Falco columbarius*	0	2
Killdeer	*Charadrius vociferus*	1	1
Spotted Sandpiper	*Actitis macularius*	0	5
Common Tern	*Sterna hirundo*	9	12
Mourning Dove	*Zenaida macroura*	1	3
Common Nighthawk	*Chordeiles minor*	0	4
Ruby-throated Hummingbird	*Archilochus colubris*	1	3
Yellow-bellied Sapsucker	*Sphyrapicus varius*	0	4
Downy Woodpecker	*Picoides pubescens*	1	4
Hairy Woodpecker	*Picoides villosus*	1	6
Northern Flicker	*Colaptes auratus*	0	28
Least Flycatcher	*Empidonax minimus*	3	0
Eastern Phoebe	*Sayornis phoebe*	2	1
Eastern Kingbird	*Tyrannus tyrannus*	5	26
Red-eyed Vireo	*Vireo olivaceus*	0	2
Blue Jay	*Cyanocitta cristata*	53	36
Tree Swallow	*Tachycineta bicolor*	2	0
Black-capped Chickadee	*Poecile atricapillus*	26	157
Red-breasted Nuthatch	*Sitta canadensis*	8	81
Brown Creeper	*Certhia americana*	0	14
Winter Wren	*Troglodytes hiemalis*	0	1
Golden-crowned Kinglet	*Regulus satrapa*	2	3
Ruby-crowned Kinglet	*Regulus calendula*	6	3

Appendix C1 (Continued)

Common Names	Scientific Names	Spring	Fall
Eastern Bluebird	*Sialia sialis*	0	1
Swainson's Thrush	*Catharus ustulatus*	0	6
Hermit Thrush	*Catharus guttatus*	0	5
American Robin	*Turdus migratorius*	9	25
Gray Catbird	*Dumetella carolinensis*	3	9
Brown Thrasher	*Toxostoma rufum*	1	4
European Starling	*Sturnus vulgaris*	0	3
Cedar Waxwing	*Bombycilla cedrorum*	0	576
Golden-winged Warbler	*Vermivora chrysoptera*	0	1
Tennessee Warbler	*Vermivora peregrina*	0	1
Nashville Warbler	*Oreothlypis ruficapilla*	8	75
Northern Parula	*Parula americana*	0	5
Yellow Warbler	*Dendroica petechia*	6	12
Chestnut-sided Warbler	*Dendroica pensylvanica*	8	7
Magnolia Warbler	*Dendroica magnolia*	3	10
Cape May Warbler	*Dendroica tigrina*	6	5
Yellow-rumped Warbler	*Dendroica coronata*	12	287
Black-throated Green Warbler	*Dendroica virens*	2	3
Blackburnian Warbler	*Dendroica fusca*	2	2
Black-and-white Warbler	*Mniotilta varia*	10	11
American Redstart	*Setophaga ruticilla*	12	72
Ovenbird	*Seiurus aurocapillus*	1	8
Northern Waterthrush	*Seiurus noveboracensis*	0	1
Common Yellowthroat	*Geothlypis trichas*	1	1
Canada Warbler	*Wilsonia canadensis*	0	3
Eastern Towhee	*Pipilo erythrophthalmus*	0	1
Chipping Sparrow	*Spizella passerina*	32	
Song Sparrow	*Melospiza melodia*	19	10
Swamp Sparrow	*Melospiza georgiana*	0	3
White-throated Sparrow	*Zonotrichia albicollis*	1	185
White-crowned Sparrow	*Zonotrichia leucophrys*	1	1
Dark-eyed Junco	*Junco hyemalis*	0	74
Northern Cardinal	*Cardinalis cardinalis*	0	1
Rose-breasted Grosbeak	*Pheuticus ludovivianus*	1	0
Red-winged Blackbird	*Agelaius phoeniceus*	25	0
Common Grackle	*Quiscalus quiscula*	65	3
Brown-headed Cowbird	*Molothrus ater*	6	0
Baltimore Oriole	*Icterus galbula*	1	0
Purple Finch	*Carpodacus purpureus*	0	5
Pine Siskin	*Spinus pinus*	2	0
American Goldfinch	*Spinus tristis*	6	51
Unknown duck		1	0
Unknown flycatcher		1	4
Unknown large bird		0	1
Unknown bird (passerine)		180	132
Unknown sparrow		8	28
Unknown swallow		28	0
Unknown Thrush		0	4
Unknown vireo		1	0
Unknown warbler		25	175
Unknown woodpecker		0	7

Appendix C2. Dates that point counts were conducted in 2009. Values represent the total count per day surveyed. The X's represent days in which point counts were not conducted due to weather conditions.

Date	# birds counted	Date	# birds counted	Date	# birds counted	Date	# birds counted
5/12/2009	74	10/9/2009	45	9/17/2009	X	8/29/2009	71
5/14/2009	32	10/7/2009	72	9/16/2009	22	8/28/2009	52
5/15/2009	31	10/6/2009	29	9/15/2009	62	8/27/2009	56
5/16/2009	33	10/5/2009	129	9/14/2009	39	8/26/2009	50
5/17/2009	45	10/4/2009	59	9/13/2009	X	8/25/2009	73
5/18/2009	60	10/3/2009	70	9/12/2009	49	8/24/2009	55
5/19/2009	14	10/2/2009	X	9/11/2009	117	8/23/2009	70
5/20/2009	63	9/30/2009	29	9/10/2009	X	8/22/2009	X
5/21/2009	22	9/29/2009	96	9/9/2009	54	8/21/2009	112
5/22/2009	60	9/27/2009	17	9/8/2009	X	8/20/2009	458
5/24/2009	74	9/25/2009	25	9/7/2009	43	8/19/2009	64
5/26/2009	28	9/23/2009	94	9/6/2009	34	8/18/2009	94
5/27/2009	35	9/22/2009	59	9/5/2009	56	8/17/2009	96
5/28/2009	46	9/21/2009	25	9/4/2009	93	8/16/2009	43
5/29/2009	22	9/20/2009	44	9/3/2009	145	8/15/2009	187
5/31/2009	44	9/19/2009	X	9/2/2009	78		
6/2/2009	25	9/18/2009	31	8/31/2009	47		

Appendix D. Foraging guild, number of fatalities, and percent composition of avian window collisions found on Minnesota Point, Duluth, MN during 2006-2009 surveys.

Foraging guild[a]	Fatalities	% Comp.
1	42	42.4
2	39	39.4
3	9	9.1
4	1	1
5	5	5.1
6	3	3
Total	99	100

[a]foraging guild

1 = ground, ground and foliage gleaner, ground and bark gleaner

2 = foliage gleaner, foliage and bark gleaner 3 = bark gleaner

4 = aerial forage 5 = hover and glean

6 = high dives and fish, high dives and surface dips

Appendix E1. Scavenging data collected during two, six day experiments in 2009. For each experiment, species identification, carcass size, and the direction and position in which each carcass was placed was recorded by house identification number (HID). T= indicated that birds were scavenged or removed by homeowners during the experiment, F= birds were not scavenged nor removed by homeowners. V1= the date carcasses were first placed, v2 and v3= dates that birds were scavenged, removed by homeowners, or removed at the end of the six day period. Exp. = experiment 1 or 2.

Exp.	HID	species	bird size	direction	position	taken	v1	v2	v3
1	4256	PISI	1	S	open	T	14-Sep	15-Sep	
1	4256	WTSP	1	N	hidden	T	14-Sep	15-Sep	
1	4240	YWAR	1	W	open	T	14-Sep	15-Sep	
1	4240	CEDW	2	N	hidden	T	14-Sep	19-Sep	20-Sep
1	4139	SWTH	2	E	open	T	14-Sep	16-Sep	17-Sep
1	4139	WTSP	1	S	hidden	T	14-Sep	15-Sep	
1	4136	SWTH	2	E	open	T	14-Sep	18-Sep	19-Sep
1	4136	DEJU	2	N	hidden	T	14-Sep	17-Sep	18-Sep
1	4030	OVEN	2	W	hidden	T	14-Sep	19-Sep	20-Sep
1	4030	RBGR	2	E	open	T	14-Sep	15-Sep	
1	3839	RTHU	1	E	open	F	14-Sep	20-Sep	
1	3839	SWTH	2	S	hidden	T	14-Sep	15-Sep	16-Sep
1	3831	CSWA	1	W	hidden	T	14-Sep	15-Sep	16-Sep
1	3831	MOWA	1	S	open	F	14-Sep	20-Sep	
1	3730	HOFI	1	E	hidden	T	14-Sep	15-Sep	
1	3730	COYE	1	N	open	T	14-Sep	15-Sep	
1	3626	CEDW	2	N	open	T	14-Sep	15-Sep	
1	3626	AMRO	2	S	hidden	T	14-Sep	19-Sep	20-Sep
1	3610	CEDW	2	S	hidden	T	14-Sep	17-Sep	18-Sep
1	3610	AMRE	1	N	open	F	14-Sep	20-Sep	
1	3435	WTSP	1	E	open	T	14-Sep	15-Sep	
1	3435	SEWR	1	N	hidden	T	14-Sep	17-Sep	18-Sep
1	3407	SOSP	1	S	hidden	T	14-Sep	15-Sep	
1	3407	TEWA	1	W	open	T	14-Sep	15-Sep	16-Sep
1	3301	RTHU	1	E	open	T	14-Sep	16-Sep	17-Sep
1	3301	SWSP	1	W	hidden	F	14-Sep	20-Sep	
1	3236	HOFI	1	N	open	T	14-Sep	16-Sep	17-Sep
1	3236	SOSP	1	N	hidden	T	14-Sep	15-Sep	
1	3230	CEDW	2	E	open	T	14-Sep	15-Sep	
1	3230	MODO	2	S	hidden	T	14-Sep	15-Sep	16-Sep
1	3205	OVEN	2	N	open	T	14-Sep	19-Sep	20-Sep

Appendix E1 (Continued)									
Exp.	HID	Species	bird size	direction	position	taken	v1	v2	v3
1	3205	VEER	2	S	hidden	F	14-Sep	20-Sep	
1	3101	DEJU	2	N	open	T	14-Sep	15-Sep	16-Sep
1	3101	YBSA	2	S	hidden	T	14-Sep	19-Sep	20-Sep
1	3003	YRWA	1	N	hidden	T	14-Sep	15-Sep	
1	3003	BAWW	1	W	open	T	14-Sep	15-Sep	16-Sep
1	2939	OVEN	2	N	hidden	F	14-Sep	20-Sep	
1	2939	CSWA	1	S	open	F	14-Sep	20-Sep	
1	2833	BRCR	1	E	open	T	14-Sep	15-Sep	16-Sep
1	2833	TEWA	1	N	hidden	T	14-Sep	15-Sep	
1	2832	EAPH	1	N	hidden	F	14-Sep	20-Sep	
1	2832	HETH	2	S	open	T	14-Sep	15-Sep	
1	2700	OVEN	2	E	hidden	T	14-Sep	15-Sep	
1	2700	OVEN	2	S	open	T	14-Sep	15-Sep	
1	2223	CSWA	1	W	open	T	14-Sep	15-Sep	16-Sep
1	2223	YRWA	1	E	hidden	T	14-Sep	15-Sep	
1	2129	WTSP	1	N	hidden	T	14-Sep	17-Sep	18-Sep
1	2129	OVEN	2	E	open	F	14-Sep	20-Sep	
1	2118	TRFL	2	N	open	T	14-Sep	17-Sep	18-Sep
1	2118	HETH	2	S	hidden	T	14-Sep	15-Sep	
1	1615	SWTH	2	E	open	T	14-Sep	15-Sep	
1	1615	REVI	1	W	hidden	T	14-Sep	15-Sep	16-Sep
1	1335	RBGR	2	E	hidden	F	14-Sep	20-Sep	
1	1335	SOSP	1	W	open	T	14-Sep	15-Sep	16-Sep
1	1329	SWTH	2	N	open	F	14-Sep	20-Sep	
1	1329	SWTH	2	S	hidden	F	14-Sep	20-Sep	
1	1320	CMWA	1	S	open	T	14-Sep	15-Sep	
1	1320	SWTH	2	E	hidden	T	14-Sep	17-Sep	18-Sep
1	1316	SWTH	2	E	open	T	14-Sep	15-Sep	
1	1316	HETH	2	N	hidden	F	14-Sep	20-Sep	
1	1112	DEJU	2	W	hidden	T	14-Sep	15-Sep	16-Sep
1	1112	RTHU	1	N	open	F	14-Sep	20-Sep	
1	840	GCKI	1	N	open	F	14-Sep	20-Sep	
1	840	COYE	1	S	hidden	T	14-Sep	19-Sep	20-Sep
1	740	WTSP	1	E	open	T	14-Sep	15-Sep	16-Sep
1	740	RBGR	2	S	hidden	T	14-Sep	17-Sep	18-Sep
1	714	BAWW	1	S	hidden	T	14-Sep	15-Sep	
1	714	TEWA	1	N	open	F	14-Sep	20-Sep	

Appendix E1 (Continued)

Exp.	HID	Species	bird size	direction	position	taken	v1	v2	v3
1	712	SWTH	2	N	hidden	T	14-Sep	19-Sep	20-Sep
1	712	VIRA	2	S	open	T	14-Sep	15-Sep	
2	4256	BRCR	1	S	open	T	29-Sep	30-Sep	
2	4256	EUST	2	E	hidden	T	29-Sep	1-Oct	2-Oct
2	4240	SWSP	1	E	open	T	29-Sep	3-Oct	4-Oct
2	4240	EUST	2	S	hidden	T	29-Sep	30-Sep	1-Oct
2	4139	EUST	2	N	hidden	T	29-Sep	1-Oct	2-Oct
2	4139	BRCR	1	E	open	T	29-Sep	4-Oct	5-Oct
2	4136	TEWA	1	W	open	T	29-Sep	1-Oct	2-Oct
2	4136	EUST	2	E	hidden	F	29-Sep	5-Oct	
2	4030	HOSP	1	S	hidden	T	29-Sep	30-Sep	
2	4030	EUST	2	E	open	T	29-Sep	30-Sep	
2	3839	EUST	2	N	hidden	T	29-Sep	30-Sep	
2	3839	MAWA	1	S	open	T	29-Sep	30-Sep	
2	3831	EUST	2	E	hidden	T	29-Sep	30-Sep	
2	3831	HOSP	1	S	open	T	29-Sep	30-Sep	
2	3730	SWSP	1	E	hidden	T	29-Sep	30-Sep	
2	3730	EUST	2	S	open	T	29-Sep	2-Oct	3-Oct
2	3626	EUST	2	S	hidden	F	29-Sep	5-Oct	
2	3626	WTSP	1	W	open	T	29-Sep	30-Sep	
2	3610	WTSP	1	W	hidden	T	29-Sep	4-Oct	5-Oct
2	3610	EUST	2	N	open	F	29-Sep	5-Oct	
2	3435	YWAR	1	W	hidden	T	29-Sep	30-Sep	
2	3435	EUST	2	N	open	T	29-Sep	1-Oct	2-Oct
2	3407	CMWA	1	W	open	T	29-Sep	30-Sep	
2	3407	EUST	2	S	hidden	T	29-Sep	2-Oct	3-Oct
2	3301	WTSP	1	E	open	T	29-Sep	2-Oct	3-Oct
2	3301	EUST	2	W	hidden	T	29-Sep	30-Sep	
2	3236	EUST	2	N	hidden	T	29-Sep	30-Sep	
2	3236	OVEN	2	E	open	T	29-Sep	30-Sep	
2	3230	BCCH	1	N	open	F	29-Sep	5-Oct	
2	3230	EUST	2	S	hidden	F	29-Sep	5-Oct	
2	3205	HOSP	1	S	hidden	T	29-Sep	30-Sep	1-Oct
2	3205	TEWA	1	W	open	T	29-Sep	1-Oct	2-Oct
2	3101	CMWA	1	E	open	T	29-Sep	30-Sep	1-Oct
2	3101	EUST	2	S	hidden	T	29-Sep	3-Oct	4-Oct
2	3003	EUST	2	E	hidden	F	29-Sep	5-Oct	

Appendix E1 (Continued)

Exp.	HID	Species	bird size	direction	position	taken	v1	v2	v3
2	3003	BCCH	1	W	open	T	29-Sep	30-Sep	1-Oct
2	2939	SWSP	1	E	open	F	29-Sep	5-Oct	
2	2939	HOSP	1	W	hidden	T	29-Sep	30-Sep	
2	2833	COYE	1	S	open	T	29-Sep	30-Sep	
2	2833	EUST	2	N	hidden	T	29-Sep	30-Sep	
2	2832	CMWA	1	E	open	T	29-Sep	30-Sep	
2	2832	EUST	2	W	hidden	F	29-Sep	5-Oct	
2	2700	EUST	2	N	hidden	T	29-Sep	3-Oct	4-Oct
2	2700	WTSP	1	E	open	T	29-Sep	1-Oct	2-Oct
2	2223	DOWO	2	E	open	T	29-Sep	30-Sep	
2	2223	EUST	2	N	hidden	T	29-Sep	30-Sep	1-Oct
2	2129	HOSP	1	S	hidden	T	29-Sep	30-Sep	
2	2129	COYE	1	W	open	T	29-Sep	30-Sep	
2	2118	EUST	2	N	open	F	29-Sep	5-Oct	
2	2118	SWTH	2	W	hidden	T	29-Sep	30-Sep	
2	1615	CEDW	2	N	open	T	29-Sep	1-Oct	2-Oct
2	1615	EUST	2	E	hidden	T	29-Sep	3-Oct	4-Oct
2	1335	EUST	2	N	hidden	F	29-Sep	5-Oct	
2	1335	SCTA	2	E	open	F	29-Sep	5-Oct	
2	1329	EUST	2	S	hidden	F	29-Sep	5-Oct	
2	1329	SWTH	2	W	open	F	29-Sep	5-Oct	
2	1320	EUST	2	E	hidden	F	29-Sep	5-Oct	
2	1320	NOWA	1	W	open	F	29-Sep	5-Oct	
2	1316	EUST	2	N	hidden	F	29-Sep	5-Oct	
2	1316	BAWW	1	E	open	T	29-Sep	1-Oct	2-Oct
2	1112	BRBL	2	W	hidden	T	29-Sep	30-Sep	1-Oct
2	1112	EUST	2	E	open	T	29-Sep	30-Sep	
2	840	ROPI	1	S	open	T	29-Sep	30-Sep	
2	840	EUST	2	N	hidden	F	29-Sep	5-Oct	
2	740	EUST	2	S	open	T	29-Sep	30-Sep	
2	740	BRBL	2	W	hidden	F	29-Sep	5-Oct	
2	714	RBNU	1	E	hidden	T	29-Sep	1-Oct	2-Oct
2	714	EUST	2	E	open	T	29-Sep	1-Oct	2-Oct
2	712	SWTH	2	E	hidden	F	29-Sep	5-Oct	
2	712	EUST	2	S	open	T	29-Sep	30-Sep	

Appendix E2. Estimated scavenging rates for small bird carcasses (size 1) for days 1-6 for each of the 42 houses in the study (HID). The z-value for confidence intervals is 1.96.

	DAY 1				*DAY 2*		*DAY 3*		*DAY 4*		*DAY 5*		*DAY 6*	
HID	MLE	SE	L_CL	U_CL	MLE	SE	MLE	SE	MLE	SE	MLE	SE	MLE	SE
712	0.2	0.04	0.13	0.3	0.36	0.07	0.49	0.08	0.59	0.09	0.67	0.09	0.74	0.09
714	0.2	0.04	0.13	0.3	0.36	0.07	0.49	0.08	0.59	0.09	0.67	0.09	0.74	0.09
740	0.2	0.04	0.13	0.3	0.36	0.07	0.49	0.08	0.59	0.09	0.67	0.09	0.74	0.09
828	0.2	0.04	0.13	0.3	0.37	0.07	0.5	0.08	0.6	0.09	0.68	0.09	0.75	0.08
840	0.2	0.04	0.13	0.3	0.37	0.07	0.5	0.08	0.6	0.09	0.68	0.09	0.75	0.08
1112	0.22	0.04	0.15	0.31	0.39	0.06	0.52	0.08	0.62	0.08	0.7	0.08	0.77	0.07
1316	0.22	0.04	0.16	0.31	0.4	0.06	0.53	0.07	0.64	0.07	0.72	0.07	0.78	0.07
1320	0.22	0.04	0.16	0.31	0.4	0.06	0.53	0.07	0.64	0.07	0.72	0.07	0.78	0.07
1329	0.23	0.04	0.16	0.31	0.4	0.06	0.54	0.07	0.64	0.07	0.72	0.07	0.78	0.07
1335	0.23	0.04	0.16	0.31	0.4	0.06	0.54	0.07	0.64	0.07	0.72	0.07	0.78	0.07
1615	0.24	0.04	0.17	0.32	0.42	0.06	0.56	0.07	0.66	0.07	0.74	0.06	0.8	0.06
2118	0.26	0.04	0.2	0.34	0.45	0.05	0.6	0.06	0.7	0.06	0.78	0.05	0.84	0.05
2129	0.26	0.04	0.2	0.34	0.46	0.05	0.6	0.06	0.7	0.06	0.78	0.05	0.84	0.05
2223	0.27	0.03	0.2	0.34	0.46	0.05	0.61	0.06	0.71	0.06	0.79	0.05	0.84	0.04
2540	0.28	0.03	0.22	0.35	0.49	0.05	0.63	0.05	0.74	0.05	0.81	0.05	0.86	0.04
2700	0.29	0.03	0.23	0.36	0.5	0.05	0.64	0.05	0.75	0.05	0.82	0.04	0.87	0.04
2733	0.29	0.03	0.23	0.36	0.5	0.05	0.65	0.05	0.75	0.05	0.82	0.04	0.87	0.04
2832	0.3	0.03	0.23	0.37	0.51	0.05	0.65	0.05	0.76	0.05	0.83	0.04	0.88	0.04
2833	0.3	0.03	0.23	0.37	0.51	0.05	0.65	0.05	0.76	0.05	0.83	0.04	0.88	0.04
2939	0.3	0.03	0.24	0.38	0.51	0.05	0.66	0.05	0.76	0.05	0.84	0.04	0.89	0.03
3003	0.31	0.04	0.24	0.38	0.52	0.05	0.67	0.05	0.77	0.05	0.84	0.04	0.89	0.03
3101	0.31	0.04	0.25	0.39	0.53	0.05	0.67	0.05	0.78	0.05	0.85	0.04	0.89	0.03
3205	0.32	0.04	0.25	0.39	0.53	0.05	0.68	0.05	0.78	0.05	0.85	0.04	0.9	0.03
3221	0.32	0.04	0.25	0.39	0.54	0.05	0.68	0.05	0.78	0.05	0.85	0.04	0.9	0.03
3230	0.32	0.04	0.25	0.39	0.54	0.05	0.68	0.05	0.79	0.05	0.85	0.04	0.9	0.03
3236	0.32	0.04	0.25	0.39	0.54	0.05	0.68	0.05	0.79	0.05	0.85	0.04	0.9	0.03
3301	0.32	0.04	0.26	0.4	0.54	0.05	0.69	0.05	0.79	0.05	0.86	0.04	0.9	0.03
3407	0.33	0.04	0.26	0.41	0.55	0.05	0.7	0.05	0.8	0.05	0.86	0.04	0.91	0.03
3435	0.33	0.04	0.26	0.41	0.55	0.05	0.7	0.05	0.8	0.05	0.87	0.04	0.91	0.03
3610	0.34	0.04	0.27	0.42	0.56	0.05	0.71	0.05	0.81	0.05	0.87	0.04	0.92	0.03
3626	0.34	0.04	0.27	0.42	0.57	0.05	0.71	0.05	0.81	0.05	0.88	0.04	0.92	0.03
3730	0.35	0.04	0.27	0.43	0.57	0.05	0.72	0.05	0.82	0.05	0.88	0.04	0.92	0.03
3831	0.35	0.04	0.27	0.44	0.58	0.06	0.73	0.05	0.82	0.05	0.89	0.04	0.93	0.03
3839	0.35	0.04	0.27	0.44	0.58	0.06	0.73	0.05	0.83	0.05	0.89	0.04	0.93	0.03
4030	0.36	0.05	0.28	0.46	0.6	0.06	0.74	0.06	0.84	0.05	0.9	0.04	0.93	0.03
4124	0.37	0.05	0.28	0.47	0.6	0.06	0.75	0.06	0.84	0.05	0.9	0.04	0.94	0.03
4136	0.37	0.05	0.28	0.47	0.6	0.06	0.75	0.06	0.84	0.05	0.9	0.04	0.94	0.03

Appendix E2 (continued)

HID	DAY 1 MLE	SE	L_CL	U_CL	DAY 2 MLE	SE	DAY 3 MLE	SE	DAY 4 MLE	SE	DAY 5 MLE	SE	DAY 6 MLE	SE
4139	0.37	0.05	0.28	0.47	0.6	0.06	0.75	0.06	0.84	0.05	0.9	0.04	0.94	0.03
4240	0.38	0.05	0.29	0.48	0.61	0.06	0.76	0.06	0.85	0.05	0.91	0.04	0.94	0.03
4242	0.38	0.05	0.29	0.48	0.61	0.06	0.76	0.06	0.85	0.05	0.91	0.04	0.94	0.03
4246	0.38	0.05	0.29	0.48	0.61	0.06	0.76	0.06	0.85	0.05	0.91	0.04	0.94	0.03
4256	0.38	0.05	0.29	0.48	0.61	0.06	0.76	0.06	0.85	0.05	0.91	0.04	0.94	0.03

Appendix E3. Estimated scavenging rates for large bird carcasses (size 2) for days 1-6 for each of the 42 houses in the study (HID). The z-value for confidence intervals is 1.96.

HID	DAY 1 MLE	SE	L_CL	U_CL	DAY 2 MLE	SE	DAY 3 MLE	SE	DAY 4 MLE	SE	DAY 5 MLE	SE	DAY 6 MLE	SE
712	0.13	0.03	0.08	0.19	0.24	0.05	0.34	0.06	0.42	0.07	0.49	0.08	0.56	0.08
714	0.13	0.03	0.08	0.19	0.24	0.05	0.34	0.06	0.42	0.07	0.49	0.08	0.56	0.08
740	0.13	0.03	0.08	0.19	0.24	0.05	0.34	0.06	0.42	0.07	0.5	0.08	0.56	0.08
828	0.13	0.03	0.09	0.19	0.24	0.05	0.34	0.06	0.43	0.07	0.5	0.08	0.57	0.08
840	0.13	0.03	0.09	0.19	0.25	0.05	0.34	0.06	0.43	0.07	0.5	0.08	0.57	0.08
1112	0.14	0.03	0.1	0.2	0.26	0.05	0.36	0.06	0.45	0.07	0.53	0.07	0.59	0.07
1316	0.15	0.03	0.1	0.2	0.27	0.04	0.38	0.06	0.47	0.06	0.54	0.07	0.61	0.07
1320	0.15	0.03	0.1	0.2	0.27	0.04	0.38	0.06	0.47	0.06	0.54	0.07	0.61	0.07
1329	0.15	0.03	0.1	0.2	0.27	0.04	0.38	0.06	0.47	0.06	0.55	0.07	0.61	0.07
1335	0.15	0.03	0.1	0.2	0.27	0.04	0.38	0.06	0.47	0.06	0.55	0.07	0.61	0.07
1615	0.16	0.02	0.11	0.21	0.29	0.04	0.4	0.05	0.49	0.06	0.57	0.06	0.64	0.06
2118	0.17	0.02	0.13	0.22	0.31	0.04	0.43	0.05	0.53	0.05	0.61	0.06	0.68	0.05
2129	0.17	0.02	0.13	0.22	0.32	0.04	0.43	0.05	0.53	0.05	0.61	0.06	0.68	0.05
2223	0.18	0.02	0.13	0.23	0.32	0.04	0.44	0.05	0.54	0.05	0.62	0.05	0.69	0.05
2540	0.19	0.02	0.15	0.24	0.34	0.04	0.46	0.05	0.57	0.05	0.65	0.05	0.71	0.05
2700	0.19	0.02	0.15	0.25	0.35	0.04	0.48	0.05	0.58	0.05	0.66	0.05	0.73	0.05
2733	0.2	0.02	0.15	0.25	0.35	0.04	0.48	0.05	0.58	0.05	0.66	0.05	0.73	0.05
2832	0.2	0.03	0.15	0.25	0.36	0.04	0.49	0.05	0.59	0.05	0.67	0.05	0.74	0.05
2833	0.2	0.03	0.15	0.25	0.36	0.04	0.49	0.05	0.59	0.05	0.67	0.05	0.74	0.05
2939	0.2	0.03	0.16	0.26	0.37	0.04	0.49	0.05	0.6	0.05	0.68	0.05	0.74	0.05
3003	0.21	0.03	0.16	0.26	0.37	0.04	0.5	0.05	0.6	0.05	0.68	0.05	0.75	0.05
3101	0.21	0.03	0.16	0.27	0.38	0.04	0.51	0.05	0.61	0.05	0.69	0.05	0.76	0.05
3205	0.21	0.03	0.17	0.27	0.38	0.04	0.52	0.05	0.62	0.05	0.7	0.05	0.77	0.05
3221	0.22	0.03	0.17	0.28	0.38	0.04	0.52	0.05	0.62	0.05	0.7	0.05	0.77	0.05
3230	0.22	0.03	0.17	0.28	0.38	0.04	0.52	0.05	0.62	0.05	0.7	0.05	0.77	0.05

Appendix E3 (continued)

	DAY 1				*DAY 2*		*DAY 3*		*DAY 4*		*DAY 5*		*DAY 6*	
HID	MLE	SE	L_CL	U_CL	MLE	SE	MLE	SE	MLE	SE	MLE	SE	MLE	SE
3236	0.22	0.03	0.17	0.28	0.39	0.04	0.52	0.05	0.62	0.05	0.7	0.05	0.77	0.05
3301	0.22	0.03	0.17	0.28	0.39	0.04	0.52	0.05	0.63	0.05	0.71	0.05	0.77	0.05
3407	0.22	0.03	0.17	0.29	0.4	0.05	0.53	0.05	0.64	0.06	0.72	0.05	0.78	0.05
3435	0.22	0.03	0.17	0.29	0.4	0.05	0.53	0.05	0.64	0.06	0.72	0.05	0.78	0.05
3610	0.23	0.03	0.17	0.3	0.41	0.05	0.55	0.06	0.65	0.06	0.73	0.06	0.8	0.05
3626	0.23	0.03	0.18	0.3	0.41	0.05	0.55	0.06	0.65	0.06	0.73	0.06	0.8	0.05
3730	0.24	0.03	0.18	0.31	0.42	0.05	0.56	0.06	0.66	0.06	0.74	0.06	0.8	0.05
3831	0.24	0.04	0.18	0.32	0.43	0.05	0.57	0.06	0.67	0.06	0.75	0.06	0.81	0.05
3839	0.24	0.04	0.18	0.32	0.43	0.05	0.57	0.06	0.67	0.06	0.75	0.06	0.81	0.05
4030	0.25	0.04	0.18	0.34	0.44	0.06	0.58	0.07	0.69	0.07	0.77	0.06	0.82	0.05
4124	0.26	0.04	0.18	0.34	0.45	0.06	0.59	0.07	0.69	0.07	0.77	0.06	0.83	0.06
4136	0.26	0.04	0.18	0.34	0.45	0.06	0.59	0.07	0.69	0.07	0.77	0.06	0.83	0.06
4139	0.26	0.04	0.19	0.34	0.45	0.06	0.59	0.07	0.69	0.07	0.77	0.06	0.83	0.06
4240	0.26	0.04	0.19	0.35	0.45	0.06	0.6	0.07	0.7	0.07	0.78	0.06	0.84	0.06
4242	0.26	0.04	0.19	0.35	0.46	0.06	0.6	0.07	0.7	0.07	0.78	0.06	0.84	0.06
4246	0.26	0.04	0.19	0.35	0.46	0.06	0.6	0.07	0.7	0.07	0.78	0.06	0.84	0.06
4256	0.26	0.04	0.19	0.36	0.46	0.06	0.6	0.07	0.7	0.07	0.78	0.06	0.84	0.06

Appendix F. The number of bird feeders and window kills found at each house. HID = house identification number. NA = # of feeders unknown.

HID	# feeders	# birds killed	HID	# feeders	# birds killed	HID	# feeders	# birds killed
712	0	1	*2700*	1	2	*3626*	0	1
714	1	5	*2733*	NA	0	*3730*	4	2
740	0	2	*2832*	6	1	*3831*	0	1
828	NA	3	*2833*	2	4	*3839*	1	9
840	0	3	*2939*	0	1	*4030*	0	10
1112	0	3	*3003*	2	5	*4124*	NA	2
1316	2	0	*3101*	0	2	*4136*	1	3
1320	4	0	*3205*	2	0	*4139*	2	3
1329	0	0	*3221*	NA	1	*4240*	1	1
1335	0	1	*3230*	0	0	*4242*	0	0
1615	1	0	*3236*	7	1	*4246*	0	6
2118	0	1	*3301*	0	3	*4256*	0	14
2129	2	1	*3407*	2	0			
2223	4	4	*3435*	0	5			
2540	NA	0	*3610*	3	7			