University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
December 2021

Factors Influencing Fatal Bird-Window Collisions on the University of North Carolina Asheville Campus

Paulina M. Jones
Environmental Science
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina 28804 USA

Faculty Advisor: Dr. Andrew Laughlin

Abstract

This study sought to determine the scope of fatal bird-window collisions on the University of North Carolina Asheville campus and the factors that influenced them. The specific factors investigated were migration density during the Fall and Spring migratory season, species demographics, context variables (surrounding vegetation structure), and building variables (window aspect). Sixty-six avian carcass surveys were conducted around eight campus buildings during the 2020-2021 academic year. These surveys were distributed across three, five-week periods during Fall 2020, Winter 2021, and Spring 2021. In total, 146 carcasses were observed across the three survey periods. Observations made during the Fall comprised over half of the total observations made, including ad hoc observations not made during the surveys. Juvenile, migratory passerines fatally collided with windows more than adult migratory and resident species. Night-time migration density was not significantly related to observed avian mortality during the Fall or Spring. Window aspects and surrounding vegetation structure had the greatest influence on collision frequency at campus buildings. This study will inform the process of implementing collision-mitigation measures at the building windows that produced the most mortalities. The data can also be used to aid in testing the efficacy of novel collision-mitigation technology in the future.

1. Introduction

Populations of migratory songbirds are declining at an alarming rate. Nearly 30% of birds in North America have been lost since 1970 due to human activity[1]. This decline is attributed to climate change[2], habitat loss and fragmentation[3], feral and domesticated cat predations[4], and fatal window collisions[5]. Most birds (98%-99%) that collide with windows incur fatal injuries[6]. These injuries can occur when the distance between the initial take-off and the window is only 1 m7. One in eight birds that collide with windows die immediately upon impact[7]. It has been estimated that up to 988 million birds fatally collide with windows in the United States every year[5], which makes this the second leading cause of songbird mortality in the United States.

The causes of bird-window collisions are varied and the factors that influence each collision are not well-understood. It is theorized that lack of prolonged exposure to glass surfaces in urban environments has not put enough evolutionary pressure on migratory songbirds to develop the capability to differentiate between reflection and reality[8]. Unlike humans, wild birds have a very difficult time perceiving glass. Their frontal vision is unrefined, as they rely primarily on bilateral vision[8]. When on the wing, birds will tilt their head so that their eyes are parallel to the ground, rendering them blind to objects immediately in front of them[8]. This explains why most collisions with windows are head-on and result in devastating head trauma.

Transparency and reflectivity of windows seem to influence the likelihood of a bird-window collision[9,10]. Most birds cannot differentiate between reflections of objects and the actual object (e.g., a reflection of a shrub in a window will register as an actual shrub to a bird)[7,8]. Windows that are situated to reflect surrounding vegetation or show vegetation on the other side of the building are most likely to cause collisions[5,9,10]. Context variables (e.g., surrounding vegetation, proximity to suitable habitat) have a larger effect on collision likelihood than building variables (e.g., building height, building to window ratios)[9]. While most collisions occur at glass surfaces on buildings between one and 11 stories tall[5,9], this is related to the proximity of windows to surrounding vegetation[9].

The purpose of this study was to identify the scope of fatal bird-window collisions on the University of North Carolina Asheville campus. Other universities have conducted similar studies[9,10,11,12] to identify campus buildings most lethal to birds with the goal of implementing mitigation strategies. Given Asheville's location along the convergence of the Mississippi Flyway and the Atlantic Flyway, this study sought to determine what species and age of passerine are most likely to fatally collide with campus building windows. The frequency of resident versus migratory bird collisions was also investigated. On peak migration nights, over 50,000 migratory passerines per kilometer pass over the City of Asheville every hour[13]. The relationship between estimated migratory passerine density and collision frequency was also investigated. Further, the influence of context and building variables on collision frequency were investigated. The end goal of this project was to encourage UNC Asheville to address problem windows by implementing collision-mitigating window treatment.

2. Methodology

The study was conducted at eight buildings located on the University of North Carolina Asheville campus in the Southern Appalachian Mountains of Western North Carolina. The University of North Carolina Asheville campus is located along the convergence of the Mississippi Flyway and the Atlantic Flyway. The campus is situated at roughly 670 m above sea level, within an expanding urban environment, and is surrounded by patches of mixed deciduous hardwood forested areas. There are two somewhat large protected urban forested parks adjacent to the southeast of the campus. Because the purpose of this project was to determine fatal bird-window collision frequency at suspected problem buildings on campus, the eight buildings surveyed were not randomly selected. Rather, the buildings were selected based on the presence of architectural features identified as hazardous for birds in other similar studies[11,12], as well as previous history of incidental window collisions. The buildings selected were the following: Rhoades-Robinson Hall, Zeis Hall, Ramsey's Library, Highsmith Student Union, Sherrill Center-Student Recreation Center, Founder's Hall, Mill's Hall, and Ponder Hall (figure 1). A total of 1,952 m was surveyed around the eight campus buildings. The buildings surveyed comprise roughly 23% of all campus buildings.

Three 5-week surveys were conducted across three seasons from September 2020 to April 2021. The first survey period was conducted from September 28th, 2020, to October 30th, 2020 (Fall migration); the second from January 19th, 2021, to February 19th, 2021 (Winter period); and the third from March 29th, 2021 to April 30th, 2021 (Spring migration). Surveys were conducted Monday through Friday during the survey periods. The first survey day of each week (Monday) was categorized as a pre-survey clean up. The carcasses counted and collected during the pre-survey clean ups controlled for collisions that may have occurred outside of the standardized survey period during the weekend. Additionally, the carcasses counted and collected during the pre-survey clean up were not used for statistical analyses, only for qualitative analyses. The way surveys were conducted were modeled after similar carcass survey studies[11.12].

The surveys which took place Tuesday through Friday were standardized and the data collected was used for statistical analyses. The protocol used for both the pre-clean up and standardized surveys was the same. Building perimeters were surveyed within a 2m distance from the side of the building. Surveys were conducted between 10:00AM to 4:00PM. Certain buildings were not surveyed around their entire perimeter due to lack of accessibility or lack of windows present (Sherrill Center-Student Recreation Center, Highsmith Student Union, Founders Hall). The surveyor walked at a speed of 1 kilometer/hour around the perimeter of each building. When a carcass was detected within the survey area, the following data was collected: building location, surrounding foliage height, aspect of building where found, carcass condition, and the time at which it was found, and whether the carcass was collected. Each observation was assigned a unique identification number and this number corresponded to the carcass ID number if the carcass was collected. If determinable, the species, age, and migratory status of each carcass was also recorded either in the field or in the lab after each survey. All collected carcasses were stored in a laboratory freezer. Carcasses or evidence of carcasses (e.g., a feather pile) that were not collected were removed from the survey area after data was collected.

For each standardized survey day, the Birdcast Score[13,14] of the previous night was also recorded. Birdcast scores utilize AI and weather radar to measure predicted migratory bird density between sunset and sunrise in units of thousands of birds per kilometer per hour[13,14]. The Birdcast tool measures migration density on a gradient scale[13,14].

This scale was broken into three categories (1: Low [0.01-0.5], 2: Medium [0.5-10], 3: High [10-50+]) and the average density present over Asheville from sunset to sunrise prior to each survey was recorded as the Birdcast Score on the data sheet.

During the survey period, incidental collisions were recorded ad hoc utilizing an electronically accessible Google Form. Incidental collisions were considered those that occurred either outside of the survey area (e.g., UNC Asheville campus buildings that were not included in the pre-survey clean up and standardized surveys) or outside of the survey time frame that resulted in the death of a bird. This form was made available to Campus Facilities and Groundskeeping staff, as well as students and faculty for the duration of each survey period.

Fifteen pre-survey clean up surveys were conducted across the three survey periods (5 per survey period). Three standardized surveys were omitted from each standardized survey period, resulting in a total of 51 standardized surveys being completed (17 per survey period). These omissions were due to the occurrence of a campus emergency that resulted in the closing of the campus for two days, followed by one Friday where surveys were not able to be conducted by the researcher during the Fall 2020 survey period. Each omitted day occurred during a scheduled standardized survey. To keep standardized survey days even across the three survey periods, three standardized survey days were skipped during the Winter and Spring survey periods. Those that were omitted during the Winter and Spring followed the same pattern as those missed during the Fall survey: a Thursday and Friday were missed consecutively, followed by a single Friday. This allowed for the pre-survey clean up days to remain consistent across all three survey periods. During each survey period, a total of 22 surveys were conducted, resulting in 66 survey days across the three survey periods. Each survey required an average of 90 minutes to complete. Surveyors spent an average of 99 hours surveying across the three survey periods (33 hours per survey period).

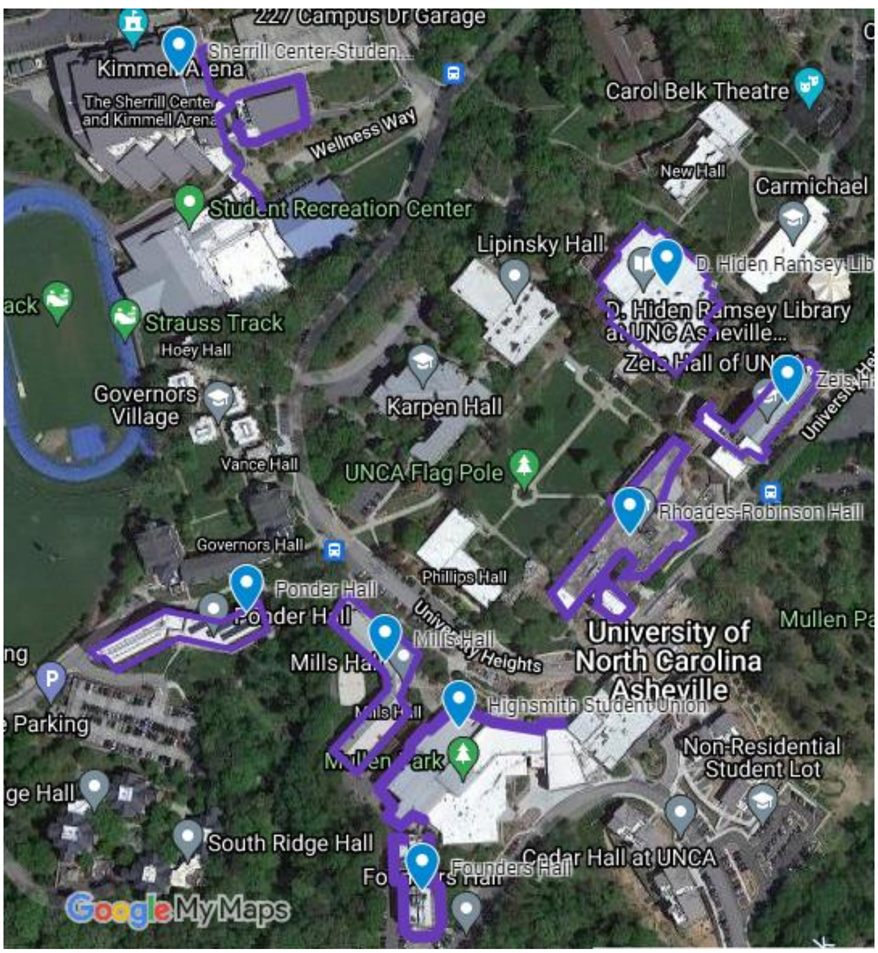

Figure 1 A map of UNC Asheville campus with carcass survey route highlighted in purple. Carcass survey route highlighted in purple.

3. Results

3.1 Species Demographics and Richness

Across the three survey periods, evidence of 146 total fatal collisions were observed: 116 during the Fall (79.45%), 21 during the Winter (14.38%), and 9 during the Spring (6.16%) (figure 2). Of the total observations made across the three survey periods, 104 (71.2%) were identifiable to species while 42 (28.3%) were unable to be identified to species with certainty. In total, 33 different identifiable species of birds fatally collided with windows across the three survey periods (Table 1). Migratory bird species comprised 89.4% of those identified. Swainson's thrush (*Catharus ustulatus*) was the most common species found, accounting for 19.9% of all identifiable carcasses. Sex differences in species were not investigated because many species collected are not sexually dimorphic.

During the Fall 2020 survey period, 70.8% of all carcasses collected could be identified to species. Of these, 89% could be aged using distinct feather features[15]. It was found that of those identifiable to species and intact enough for aging, 30.5% were aged as adults ("AHY" for after hatch-year), and 69.5% were aged as juvenile ("HY" for hatch year). Differences in age of birds were only investigated during the Fall 2020 survey period.

Table 1. Species identified from fatal window-collisions across the three survey periods. Data were collected at the University of North Carolina Asheville during the 2020-2021 academic year.

Species	**Common Name**	**Number Observed**	**Migratory Status**
Catharus ustulatus	Swainson's Thrush	29	M
Turdus migratorius	American Robin	12	M
Leiothlypis peregrina	Tennessee Warbler	8	M
Setophaga tigrina	Cape May Warbler	5	M
Catharus minimus	Gray Cheeked Thrush	5	M
Catharus guttatus	Hermit Thrush	4	R
Setophaga caerulescens	Black Throated Blue Warbler	3	M
Archilochus colubris	Ruby Throated Hummingbird	3	M
Vireo solitarius	Blue Headed Vireo	2	M
Baeolophus bicolor	Tufted Titmouse	2	R
Setophaga americana	Northern Parula	2	M
Vireo olivaceus	Red Eyed Vireo	2	M
Zenaida macroura	Mourning Dove	2	R
Piranga olivacea	Scarlet Tanager	2	M
Seiurus aurocapilla	Ovenbird	2	M
Geothlypis trichas	Common Yellow Throat	2	M
Pheucticus ludovicianus	Rose Breasted Grosbeak	2	M
Picoides pubescens	Downy Woodpecker	2	R
Passerina cyanea	Indigo Bunting	1	M
Coccyzus americanus	Yellow-billed Cuckoo	1	M
Setophaga castanea	Bay Breasted Warbler	1	M
Toxostoma rufum	Brown Thrasher	1	M
Setophaga magnolia	Magnolia Warbler	1	M

Cyanocitta cristata	Blue Jay	1	R
Hylocichla mustelina	Wood Thrush	1	M
Cardinalis cardinalis	Northern Cardinal	1	R
Setophaga fusca	Blackburnian Warbler	1	M
Mimus polyglottos	Northern Mockingbird	1	M
Sphyrapicus varius	Yellow Bellied Sapsucker	1	M
Sialia sialis	Eastern Bluebird	1	M
Setophaga palmarum	Palm Warbler	1	M
Melospiza melodia	Song Sparrow	1	R
Zonotrichia albicollis	White Throated Sparrow	1	M
	Unknown	42	
Total	146	**% Migratory**	89.4*

***Percentage of migratory species of total observations identifiable to species (n=104)**

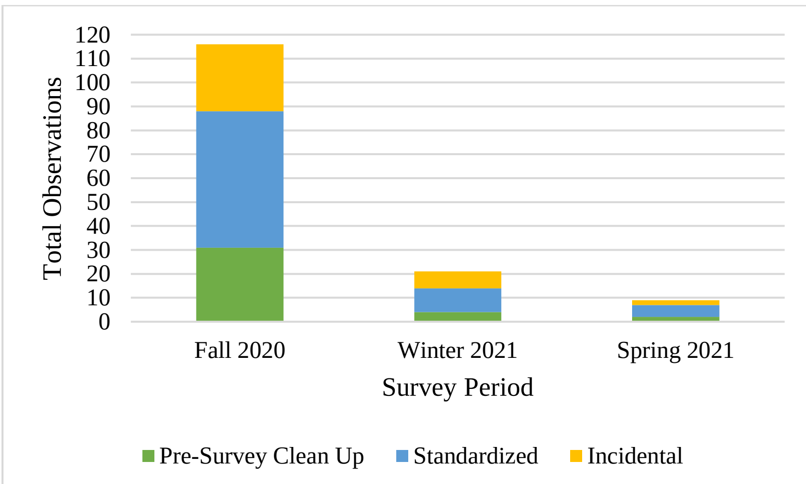

Figure 2. Distribution of fatal window-collisions across the three survey periods

Figure 2 Distribution of fatal window-collisions made over the Fall 2020, Winter 2021, and Spring 2021 survey periods. Observations made during the pre-survey clean ups, standardized surveys, and incidental observation responses comprise the total observations in each column. Data were collected at the University of North Carolina Asheville campus from Fall 2020 to Spring 2021.

3.2 Birdcast

Birdcast scores[13,14] were recorded during the Fall 2020 and Spring 2021 survey periods. The scores were not collected during the Winter 2021 survey due to this survey not being conducted during a major migratory season for neotropical migratory birds and thus the tool was not available for use. Birdcast scores were separated into three categories: 1-low (0.01-0.5 thousands/km/hr), 2- medium (0.5-10 thousands/km/hour), and 3- high (10-50 thousands/km/hr). There was a slightly positive correlation between Birdcast scores and total observation during the Fall and Spring surveys, however these relationships were not significant. An ANOVA determined that there is no significant difference in means between the three categories (p=0.69; figure 3)[16].

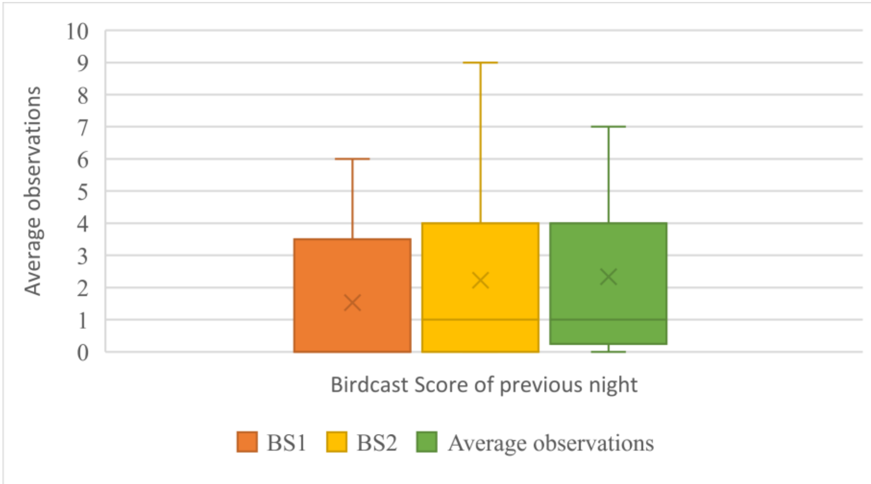

Figure 3. A comparison of mean collision observations relative to Birdcast scores[13,14] preceding the standardized surveys during the Fall 2020 and Spring 2021 survey period.

Figure 3 A comparison of mean collision observations relative to Birdcast scores[13,14] preceding the standardized surveys during the Fall 2020 and Spring 2021 survey period. BS1, BS2, and BS3 correspond to the low (0.01-0.5 thousands/km/hr), medium (0.5-10 thousands/km/hour), and high (10-50 thousands/km/hr) categories, respectively. The means and variances for each category were: BS1, $\bar{x}$=1.53, s^2=4.26; BS2, $\bar{x}$=2.22, s^2=8.94; BS3, $\bar{x}$=2.33, s^2=8.66. The differences between the means of each category were not significant (p=0.69). Data were collected at the University of North Carolina Asheville campus during the 2020-2021 academic year.

3.3 Foliage and Aspect

Surround vegetation structure was recorded at each observation site and placed in one of four categories: 1=low, no plants above grass height; 2=light, <1m tall; 3=medium, 1-3m tall; and 4=high, >3m tall. Most carcasses were found at locations in category 3 (52.7%). Category 1 comprised 38% of the total survey area, category 2 comprised 9%, category 3 comprised 40%, and category 4 comprised 12%. Most carcasses were found at locations in category 3 (52.7%), despite the fact that category 3 covered only 40% of the study area. Low and High vegetation structure was present at a similar percentage of locations where carcasses were found (low=18.9%, high=20.3%). Light vegetation structure was present at where the fewest carcasses were found (8.1%; Table 2). Window collisions during the Fall, Winter, and Spring standardized survey periods were not evenly distributed across the four foliage categories, and collisions occurred in category 3 at a higher than expected rate (Chi-square Goodness of Fit, n=82; χ^2_3=8.327; p=0.018, α=0.05; figure 4)[16].

Table 2. Surrounding foliage structure of windows where fatal window-collisions across the three survey periods.

Foliage Height	% Survey Area	Number of Observations		
		Fall 2020	**Winter 2021**	**Spring 2021**
F1	38	17	0	6
F2	9	19	3	0
F3	40	40	5	2
F4	12	11	12	1
*Unknown		29	1	0
Total		116	21	9

***Unknown values due to lack of information via incidental observation reporting.**

The "Foliage Height" categories correspond to the following heights: F1=low, no plants above grass height; F2=light, <1m tall; F3=medium, 1-3m tall; and F4=high, >3m tall. The "% Survey Area" column refers to the distribution of specific foliage height about the entire survey area. Data were collected at the University of North Carolina Asheville campus during the 2020-2021 academic year.

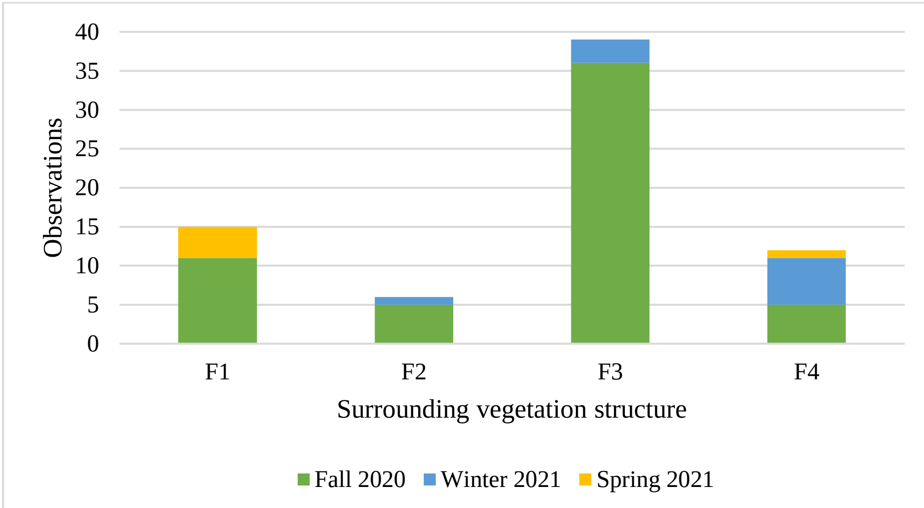

Figure 4. Distribution of foliage heights surrounding fatal window-collisions during the Fall 2020, Winter 2021, and Spring 2021 standardized survey periods.

Figure 4 Distribution of foliage heights surrounding fatal window-collisions during the Fall 2020, Winter 2021, and Spring 2021 standardized survey periods. The categories of the x-axis correspond to the following heights: F1=low, no plants above grass height; F2=light, <1m tall; F3=medium, 1-3m tall; and F4=high, >3m tall. Data were collected at the University of North Carolina Asheville during the 2020-2021 academic year.

The aspect of windows under which carcasses were found was recorded for all pre-survey clean up and standardized observations. There was not an even distribution of window aspects across the survey area (Table 3). The distribution of observations made during the standardized survey periods during the Fall, Winter, and Spring was not evenly distributed across available aspects (Chi-Square Goodness of Fit: n=68; χ^2_7=78.477; p<0.0001; α=0.05; figure 5)[16]. Eastern and Western facing windows produced the most observations (21% and 22%, respectively), despite comprising a total of only 12% of survey building aspects (8% and 4% respectively). Northern and Southern facing windows produced the fewest observations (1% and 3%, respectively) and comprised 8% of the total aspects surveyed. The majority of observations (76%) occurred at windows at azimuths between 90º and 270º.

Table 3**.** Window aspects corresponding to fatal window-collisions across the three survey periods.

Aspect	**% Survey Area**	**Number of Observations**		
		Fall 2020	**Winter 2021**	**Spring 2021**
N	4	2	1	0
NE	16	11	3	0
E	8	23	7	1
SE	24	27	3	4
S	4	5	1	0
SW	16	13	0	0
W	4	19	1	0
NW	24	15	4	4
*Unknown		1	1	0
Total		116	21	9

*** Unknown values due to lack of information via incidental observation reporting.**

The “% Survey Area” column refers to the distribution of aspects about the entire survey area. Data were collected at the University of North Carolina Asheville campus during the 2020-2021 academic year.

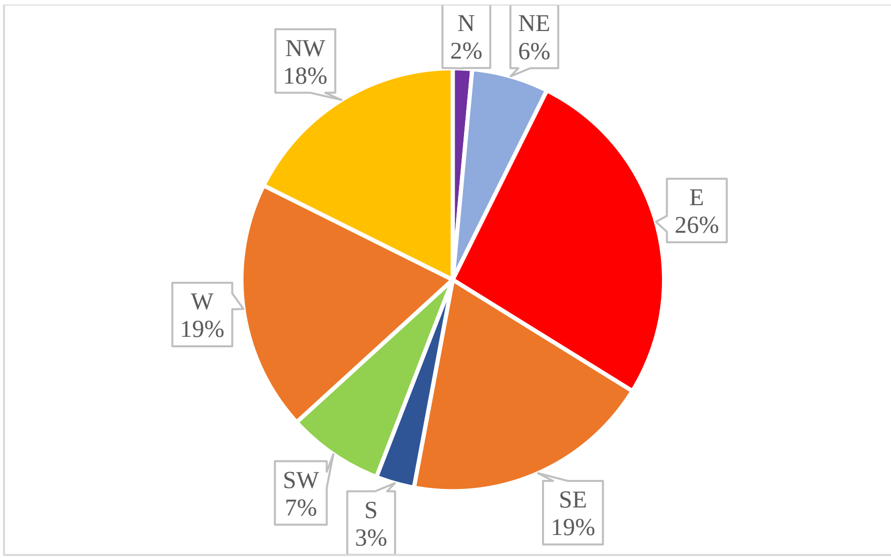

Figure 5. Distribution of fatal window-collisions during the standardized Fall 2020, Winter 2021, and Spring 2021 survey periods at different aspects across the survey area.

Figure 5 Distribution of fatal window-collisions during the standardized Fall 2020, Winter 2021, and Spring 2021 survey periods at different aspects across the survey area. Data were collected at the University of North Carolina Asheville during the 2020-2021 academic year.

The relationship between surrounding foliage structure and window aspect was investigated. Surrounding vegetation structure and window aspect were not independent variables (Permuted Chi-square test of independence: replication=2000; n=68; χ^2=59.205; p=0.0004; α=0.05)[16]. Standardized residuals from the permuted Chi-square test of independence were compared to the corresponding critical value (z=-3.163), derived from the standardized Bonferroni-adjusted p-value (α=0.00156), to conclude that surrounding foliage structure between 1-3 m (category 3) produced significantly more observation at windows facing East (residual z=3.843; p=0.00389; α=0.05) and West (residual z=3.562; p=0.011; α=0.05). Foliage structure greater than 3 m (category 4) produced significant more observations than expected at Southwest facing windows (residual z=3.206; p=0.043; α=0.05). Northwest facing windows with surrounding foliage structure of 1-3 m had significantly less collisions than expected (residual z=-3.270, p=0.034; α=0.05; figure 6)[16].

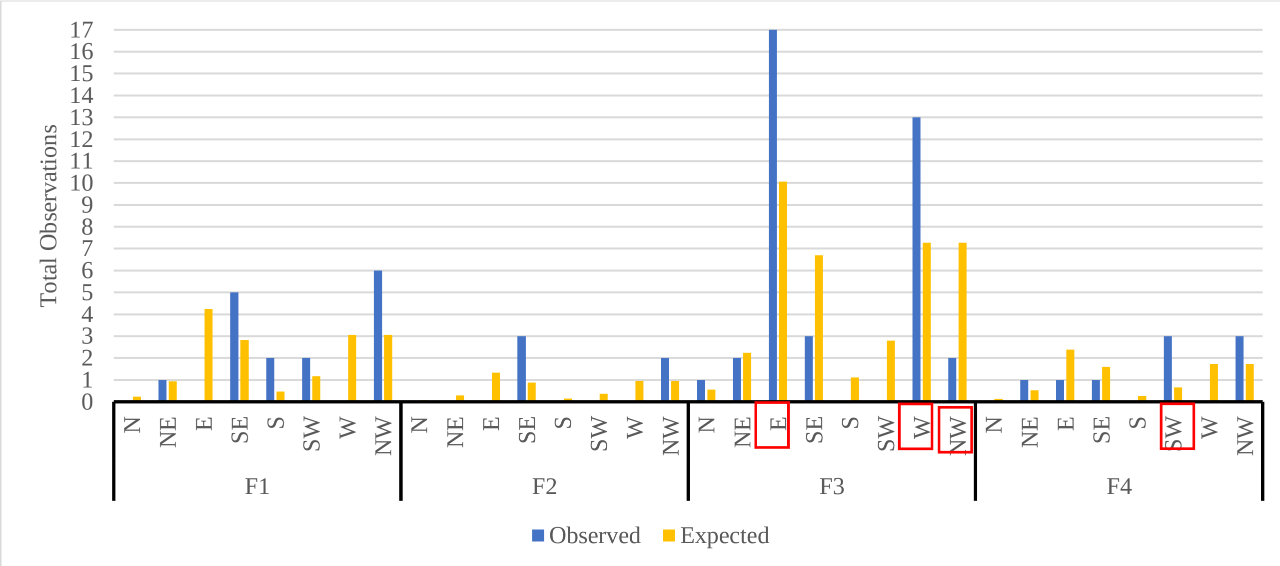

Figure 6. Observed versus expected observation values across the survey area from the Fall 2020, Winter 2021, and Spring 2021 standardized survey periods

Figure 6 Observed versus expect observation values across the survey area from the Fall 2020, Winter 2021, and Spring 2021 standardized survey periods. The "Foliage Height" categories correspond to the following heights: F1=low, no plants above grass height; F2=light, <1m tall; F3=medium, 1-3m tall; and F4=high, >3m tall. Expected values were determined by multiplying the total number of window-collisions by the relative proportion of each window aspect in a given foliage category. Significant discrepancies (outlined in red) occurred in the F3 category at the E, W, and NW aspects, and in the F4 category at SW aspects. Data were collected at the University of North Carolina Asheville during the 2020-2021 academic year.

3.4 Buildings

Across the three survey periods, the most observations were made at Founders Hall (26%, n=38) and the fewest observations were made at Mill's Hall (3%, n=4). During the Fall 2020 survey period, most carcasses were found at Founder's Hall (n=37). During the Winter 2021 survey period, most carcasses were found at Zeis Hall (n=7). During the Spring 2021 survey period, most carcasses were found at Rhoades-Robinson Hall (n=6). Mill's Hall accounted for the fewest fatal window-collisions within the survey area across all three survey periods (Table 4; figure 7). Almost all (96%) of fata window-collisions were made at building within the survey area, with only 4% being from incidental collisions recorded at building outside of the survey area.

Table 4. Total number of fatal window-collisions at surveyed buildings across the three survey periods.

Building	**Fall 2020**	**Winter 2021**	**Spring 2021**
Founders	37	1	0
Rhodes-Robinson	18	3	6
Zeis	16	7	0
Sherrill Center-Student Recreation Center	17	4	1
Ponder	10	4	0
Ramsey Library	5	1	0
Highsmith Student Union	4	0	2
Mills	4	0	0

Other	5	1	0
Total	116	21	9

Data from pre-survey clean up, standardized, and incidental surveys included in the table. Data were collected at the University of North Carolina Asheville campus during the 2020-2021 academic year.

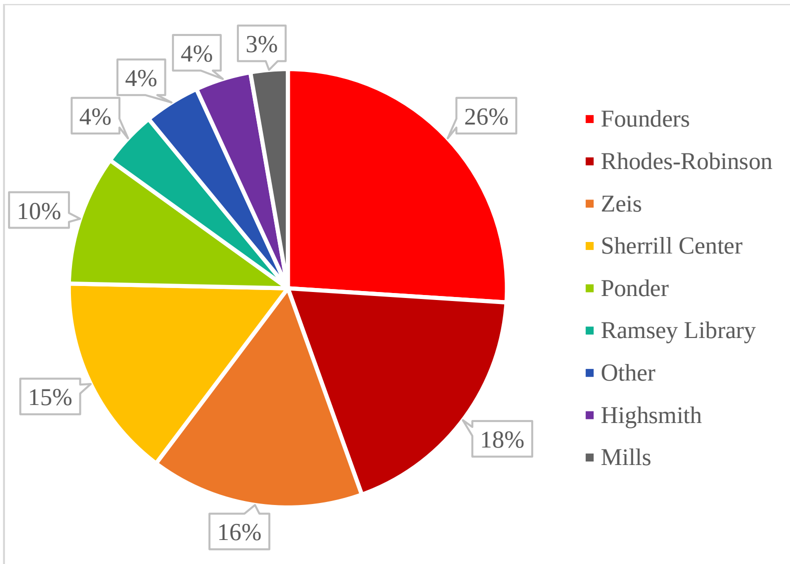

Figure 7**.** Percentage of fatal window-collisions at each surveyed building during the Fall 2020, Winter 2021, and Spring 2021 survey periods combined.

Figure 7 Percentage of fatal window-collisions at each surveyed building during the Fall 2020, Winter 2021, and Spring 2021 survey periods combined. Data from pre-survey clean up, standardized, and incidental surveys included in the figure. Data were collected at the University of North Carolina Asheville during the 2020-2021 academic year.

5. Discussion

Migratory avian species fatally collided with windows on the UNC Asheville campus significantly more than resident avian species. Passerines belonging to the Turdidae (thrushes) and Parulidae (wood warblers) families accounted for most species recovered during the carcass surveys. This finding is in alignment with findings from similar studies[5,11,12], reinforcing the theory that migratory Turdidae and Parulidae species are particularly vulnerable to window collisions in the human-built environment[5,11]. During the Winter 2021 survey period, 33% of observations were American Robins (*Turdus migratorius*) that were part of a large flock feeding on American Holly berries. These collisions occurred over a period of two days, suggesting that large feeding frenzies occurring in close proximity to buildings may increase the likelihood of multiple avian mortalities within a short period of time (i.e., a mass collision event).

During the Fall 2020 survey, significantly more juvenile birds fatally collided with windows than adult birds. One theory that explains this finding suggests that more juvenile birds collide with windows than adults, during the Fall, because juveniles comprise a greater portion of the population demographics during the Fall[7]. Other theories suggest that juveniles collide with windows more frequently because of their lack of experience navigating urban environments[8]. In order to fully understand why juvenile birds collided more frequently than adults during this study, further research is needed in a controlled setting to observe the differences between adult and juvenile avian interactions with window surfaces.

It was surprising to find that estimated nighttime migratory bird densities[13,14] was not significantly related to fatal window collisions. This finding dispelled the prediction that estimated nighttime migratory bird densities would be positively associated with window collision-related avian mortality. Collision and estimated migratory bird density data collected over a broader spatial and temporal scale may reveal a stronger relationship between these variables than what was observed within the scope of this study.

Some studies suggest that context variables (e.g., surrounding foliage structure) have the greatest influence on the likelihood of bird-window collisions[9]. However, it seems like there is an interaction between surrounding foliage structure and window aspect. In the present study, it appears that window aspect is important when certain foliage structure is present, and that foliage structure is more important when windows are oriented toward a specific aspect. Most buildings in the survey area were oriented Northeast-Southwest, and few buildings had windows facing directly North, South, East, and West. A multi-year observational survey that includes more buildings with more North, East, South, and West window aspects is necessary to determine whether the building variable (aspect) or the context variable (surrounding foliage structure) has the greater influence on the likelihood of a collision occurring.

Given that one in eight birds that collide with windows dies immediately upon impact[7] and having observed 146 individual carcasses across the three survey periods, it can safely be estimated that over 1000 birds collided with windows at UNC Asheville during the study. Because surveys were conducted over one year, the findings as they relate to buildings, may not fully represent the threat of these buildings to birds.

Founders Hall accounted for the most carcass observations during the Fall 2020 survey period. However, observations at this building decreased significantly for the Winter 2021 and Spring 2021 surveys. This may suggest that the use of collision mitigation window treatment should be prioritized during the Fall season at this building. Rhodes Robinson hall was consistently hazardous across the three survey periods. Permanent collision-mitigating window treatments should be installed at Rhodes Robinson Hall. Zeis Hall, Ponder Hall, and the Sherrill Center (specifically, the main entrance to the Kimmel Arena) should also be treated with permanent collision-mitigating window treatments due to the locations' consistent observations during the Fall and Winter survey periods. The Ramsey Library had very few observations during the Fall and Winter surveys, and none during the Spring. Temporary collision-mitigating window treatment may be appropriate at this building during the Fall migratory season. Highsmith Student Union posed a threat only during the Fall and Spring surveys, which suggests that temporary window treatments may be appropriate to prevent collisions during the Fall and Spring migration periods. Mills Hall was the least lethal across all three survey periods, suggesting that collision-mitigating window treatment may not be necessary at this building. All surveyed buildings produced significantly more observations during the Fall 2020 survey period than in the Winter or Spring. This finding is consistent with other studies' findings[5] that collisions occur more frequently during the Fall migratory season than during other times of the year.

6. Conclusion

This study provided necessary data to understand the scope of fatal bird-window collisions on the UNC Asheville campus and the factors that may contribute to collision frequency. Based on the findings of this research, avian mortality may be significantly reduced by installing collision mitigating treatments at Founders Hall and at the main entrance to the Kimmel Arena. A multi-year, comparative study would provide greater insight into the relationship between window aspect and surrounding foliage structure as it relates to window collision frequency. This data will allow novice collision-mitigating treatment technology to be tested at campus buildings in the future and will serve to illustrate the scope of fatal bird-window collisions in the Asheville area to motivate the adoption of bird-safe building ordinances for the city.

7. Acknowledgements

The author wishes to express her appreciate to Dr. Andrew Laughlin for his guidance throughout this research process, Sarah Branagan for her assistance with carcass surveys, the Steiner Foundation for the research scholarship, the students, faculty, and staff at UNC Asheville for contribution to project via incidental survey responses and notifying researchers of strikes, and the University of North Carolina Asheville for allowing me to conduct these surveys on campus property.

8. References

1. Rosenberg KV, Dokter AM, Blancher PJ, Sauer JR, Smith AC, Smith PA, Stanton JC, Panjabi A, Helft L, Parr M, Marra PP. (2019). Decline of the North American avifauna. Sci (American Association for the Advancement of Science). 366(6461): 120-124. https://doi.org/10.1126/science.aaw1313
2. Ricklefs RE. 2006. The Unified Neutral Theory of Biodiversity: Do the Numbers Add Up? Ecol. 87(6):1424-1431.
3. Donovan TM, and Curtis HF. 2002 Relationships among North American Songbird Trends, Habitat Fragmentation, and Landscape Occupancy. Ecol Appl, 12(2):364-374.
4. Loss SR, Will T, Marra PP. 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nat Comm 4:1396.
5. Loss SR, Will T, Loss SS, Marra PP. 2014. Bird-building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116(1):8-23.
6. Veltri, CJ, Klem D. 2005. Comparison of fatal bird injuries from collisions with towers and windows. J. Field. Ornithol. 76(2):127-133.
7. Trudell H. 2021, March 16. Window Pain: Helping Birds Survive a Human World [Lecture recording]. Facebook live stream.
8. Martin GR. 2011. Understanding bird collisions with man-made objects: A sensory ecology approach. Ibis (Lond. 1859). 153(2):239-254.
9. Klem D, Farmer CJ, Delacretaz N, Gelb Y, Saenger PG. 2009. Architectural and Landscape Risk Factors Associated with Bird-Glass Collisions in an Urban Environment. Wilson J. Ornithol. 121(1): 126–134.
10. Brown BB, Kusakabe E, Antonopoulos A, Siddoway S, Thompson L. 2019. Winter bird-window collisions: Mitigation success, risk factors, and implementation challenges. PeerJ. doi: http://dx.doi.org/10.7717/peerj.7620
11. Ocampo-Peñuela et al. 2016. Patterns of bird-window collisions inform mitigation on a university campus. PeerJ. 4:e1652; DOI 10.7717/peerj.1652
12. Somerlot KE. 2003. Survey of songbird mortality due to window collisions on the Murray State University campus. Jo. Service Learning in Cons. Biol. 1:1-9.
13. Dokter, A. M. 2020. BirdCast, live migration map; September 28, 2020-October 30, 2020. Cornell Lab of Ornithology. birdcast.info/live-migration-maps.
14. Dokter, A. M. 20201. BirdCast, live migration map; January 19, 2021-February 19, 2021; March 29, 2021-April 30, 2021. Cornell Lab of Ornithology. birdcast.info/live-migration-maps.
15. Pyle P. 1997. Identification Guide to North American Birds: a Compendium of Information on Identifying, Ageing, and Sexing "near-Passerines" and Passerines in the Hand. Bolinas, Calif.:Slate Creek Press, 1997.
16. R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/