BUILDING DESIGN AND BIRD FATALITIES: A SYNTHESIS OF BIRD-WINDOW COLLISION STUDIES ON NORTH AMERICAN UNIVERSITY CAMPUSES

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by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Abstract

Bird-window collisions (BWC) have become an interest in the scientific community. However, there is still speculation regarding some of the drivers of these collisions. Kent State University in Kent, Ohio, USA was surveyed for deceased birds from BWC in 2023. Throughout the study, we monitored 8 buildings over 43 days. A total of 16 deceased birds, of eight species, were found. Our preliminary data suggests some buildings surveyed may have a greater potential for BWC. To contextualize our local findings, we compiled similar BWC data from 12 additional North American universities. We calculated the average number of birds found per day per building, allowing a comparison of the rate of collisions recorded on the Kent State campus to other universities. We found that the Kent State University campus appears to have fewer bird-window collisions than other universities. Similarly to another study of this type, we observed that because few incidents were observed throughout our study, we were not able to statistically examine environmental drivers of trends. However, several barriers to data synthesis were noted because not all studies observed the same reporting standards. We recommend thoughtful standardization of observation efforts across campuses as we continue to monitor campus buildings to gain a better understanding of how our university is affecting the nearby wildlife. Increasing our knowledge will allow us to make educated decisions about mitigation on our campus to provide a more eco-friendly campus and benefit the bird populations that we come into contact with.

Introduction

As the human population continues to increase, so do the impacts humans have on the environment. Intensified anthropogenic influence coupled with a changing climate is likely affecting all levels of biodiversity (Brown et al., 2020, Malhi et al., 2020, Evans et al., 2011). As land development for human use expands, the field of urban ecology has grown: scientists seek to understand how natural elements like biodiversity respond to and use human-made structures in their life histories and biologies (Lepczyk et al., 2017, Norton et al., 2016). Furthermore, in recent years, the scientific community has focused on habitats inside and outside cities to understand how our ecosystems may be shaped in a future of rising global temperatures and increased human influence (Shivanna, 2022). Urban and suburban ecosystems are interesting from an ecological perspective because, in addition to their rapid rates of change, they may offer new resources, habitats, and hazards to the species that utilize them (McKinney, 2006).

Over 50% of the world's population resides within urban spaces (UN Department of Economic and Social Affairs, 2018). This percentage is expected to increase to 68% by 2050. Ecological studies are necessary to further analyze how these growing populations affect nearby wildlife communities. Increasing resident involvement through citizen science within these areas has become an increasingly common way to understand biodiversity loss and how urban areas impact this effect (Lepczyk et al., 2009). Involving residents in these areas, not only improves the amount of data collected but also heightens community concern for the local environment (Smith et al., 2024). Citizen science data collection has become an important way for community members to gain knowledge and increase interaction within their local environments (Cooper et al., 2007). Despite lacking a professional science background, volunteer data has been determined to be well-founded and useful for many studies as they can generate large amounts of data (Brown and Williams, 2019). Citizen science involvement can be found in federal-based studies such as the Christmas Bird Count (CBC) and studies founded by universities like Cornell, which has 600 citizen science projects at their university alone (Dickinson et al., 2010).

Birds, in particular, are an interesting taxon to monitor. With many charismatic species present in many urban and suburban systems, the community contains both migratory and non-migratory bird species (Buron et al., 2022). Non-migratory species are characterized as species that are resident within a certain region throughout the breeding and non-breeding season, while migratory species have separate wintering grounds in which birds spend the non-breeding season and they migrate to a new area during the breeding season (Ohio Bird Conservation Initiative). These migratory birds may move relatively short distances or thousands of miles to Central and South America (Hunter, 1993). In Ohio, spring migration dates typically go from March 15- June 1 and fall migration goes from August 15- October 31 (Ohio Bird Conservation Initiative). Examining trends between both of these groups allows greater insight into factors impacting bird populations in urban environments because the different migration strategies present unique environmental vulnerabilities (Stratford and Robinson, 2005, Van Doren et al., 2021). As migratory birds travel between areas, they interact with a larger variety of different buildings such as skyscrapers or low-residential structures, which more frequently pose a novel risk to them as they travel through new regions (Loss et al., 2014). Evans Ogden (1996) suggested that migratory birds may become exhausted after becoming disorientated by artificial light emitted from buildings.

Role of Anthropogenic Changes in Bird Declines

Many authors have noted declines in bird population species across the United States and the rest of the world (Fischer and Islam, 2020, Loss et al., 2014, Betts et al., 2022). Although explanations for these losses vary, it is estimated between 21- 26% of bird habitat will be lost by 2050, and that loss will increase to as much as 35% by the next century (Jetz et al., 2007). Habitat loss, particularly the destruction of large areas of contiguous habitat for urbanization, could mean the extinction of many species of birds globally (Czech et al., 2000). Habitat loss is expected to continue to clear land for development or resources and compound ongoing bird declines (Betts et al., 2022). Zmihorski et al. (2022) found that new buildings pose a greater risk for BWC than old buildings and trees planted near houses can increase this risk as well.

Beyond habitat loss, birds are vulnerable to many other human-driven impacts. For instance, the greatest direct cause of mortality in birds is domestic cats (*Felis catus*). One study estimates 2.4 billion birds are killed by cats each year in the United States alone (Loss et al., 2015). Loss et al. (2015) further discuss how bird-window collisions

(BWC) have become heavily studied in recent years as the second most influential human-caused driver of bird decline. Insidiously, these two factors can interact with each other. BWC is the phenomenon when birds collide into windows or other reflective surfaces because they are unable to perceive the transparent or reflective surface on a structure (Klem Jr, 1989, Loss et al., 2014). When birds collide with windows they may either be killed directly or injured in such a way that makes them more susceptible to predators. Rebolo-Ifrán et al. (2021) found that predation on stunned birds by pets is estimated to kill 6 million birds in Argentina. Understanding how these two causes of mortality interact with one another to exacerbate the number of birds killed per year will be important to creating proactive measures to protect birds in the future.

Factors that Drive Window Collisions

Current estimates state around 1 billion birds are killed each year around the world from collisions with windows (Loss et al., 2014). Migratory birds are particularly at risk for death or injury due to collisions with buildings, due to their unfamiliarity with transient environments. Reflective windows pose a hazard to birds because glass reflects an image of the surroundings to the bird as it is flying. In rural areas, birds may fly into windows due to the reflection of the sky or open areas around the building (Klem Jr, 2006). Taller buildings in cities have increased reflective window surface area and high levels of light pollution, which can increase BWC (Lao et al., 2020). Transparent windows create a different type of hazard as birds cannot perceive the glass panel and collide with the surface (Klem Jr, 1989).

Figure 1. Images of deceased birds collected from the Kent State Campus, Portage County, Ohio, U.S.A

Several other factors such as time of day, weather, season, and presence of vegetation near windows may contribute to BWC. Klem et al (2009) reported four times as many collisions in the early to late morning than at any other time of day due to higher flight activity associated with early morning. A study of BWC in downtown Manhattan, New York found the greatest number of collisions occurring between 0900 and 0930 hrs (Gelb and Delacretaz, 2009). Further, one study found that 90% of all BWC occurred during the migratory season (Borden et al. 2010); these migrant species were nine times more likely to have fatal collisions than the resident species. Collisions during the migratory season were found mostly likely to occur on clear days without harsh wind conditions (Scott et al., 2023).

The presence of vegetation may affect the likelihood of BWC. Gelb and Delacretaz (2009) found that vegetation presence had a statistically significant effect on BWC. A study on the Cleveland State University campus found similar results that large windows, the presence of trees, and the reflection of trees on the windows significantly increase BWC (Borden et al., 2010). These studies included a variety of plants occurring in the vicinity of monitored buildings such as trees, shrubs, and manicured beds. All of these features attract birds to the proximity of the windows and increase the likelihood of a collision (Brown et al. 2021).

Public Awareness of Bird-Window Collisions

Many cities have initiated monitoring plans and awareness campaigns to quantify and mitigate bird collisions. Large cities in Ohio such as Cleveland, Cincinnati, and Akron have been following a program called "Lights Out Ohio" which spreads awareness of light pollution and its role in bird collisions (Ohio Bird Conservation Initiative). This program recruits volunteers who monitor downtown buildings for bird mortalities. Similar programs can be found in metropolitan areas outside of the United States, such as the Fatal Light Awareness Program (FLAP) based in Toronto, Canada (Cusa et al., 2015). These programs are active in migratory periods to raise awareness of artificial light at night and how it may lead to the BWC of nocturnally migrating birds (Lao et al., 2020).

While patterns of BWCs in cities are well documented, the effects of similar collisions in suburban environments such as university campuses are less described; although many campuses have, at one point or another, examined BWCs, studies tend to be shorter-term or use varied methodology.

To address the knowledge gap of BWCs in suburban environments, we monitored BWCs around buildings at Kent State University (KSU) in Kent, Ohio. At just under 1,000 acres, KSU is a large campus, with a high proportion of green spaces and is a flyover area of migratory birds, which makes it an important campus to monitor for such collisions (Kent State University). The buildings on campus have varied architectural styles, designs, and layouts, providing a natural experiment to examine building attributes and their role in BWCs. In total, 8 buildings were selected to be included in the BWC survey to gain insights into trends surrounding bird fatalities on the Kent campus. Data from the Kent survey will be compared to other North American university campuses to understand trends of bird fatalities in these spaces. We hypothesize that: 1) buildings with greater proportions of glass will exhibit greater numbers of bird-window collisions, 2) areas that are near thick vegetation around the buildings will have higher numbers of collisions recorded, 3) the greatest number of bird fatalities will occur during spring and fall migrations, and 4) Kent State University campus will have a similar BWC rate as other North American campuses

Methods

Window Surveys

This study was conducted at Kent State University in Kent, Ohio, Portage County, U.S.A. (Figure 2). Eight buildings were included in the study across the Kent Campus. These buildings included the Kent State University (KSU) Library, Cunningham Hall, Integrated Science Building/Williams Hall, Design Innovation (DI) Hub, Taylor Hall, Cartwright Hall, Merrill Hall, and John Elliot Center for Architecture and Environmental Design. The Integrated Science Building/ Williams Hall is one connected building and will hereafter be referred to as “ISB”. The John Elliot Center for Architecture and Environmental Design will hereafter be referred to as “Architecture Building.” Each building was selected based on its differences in height, window area, window tint, and architectural style (Figure 3).

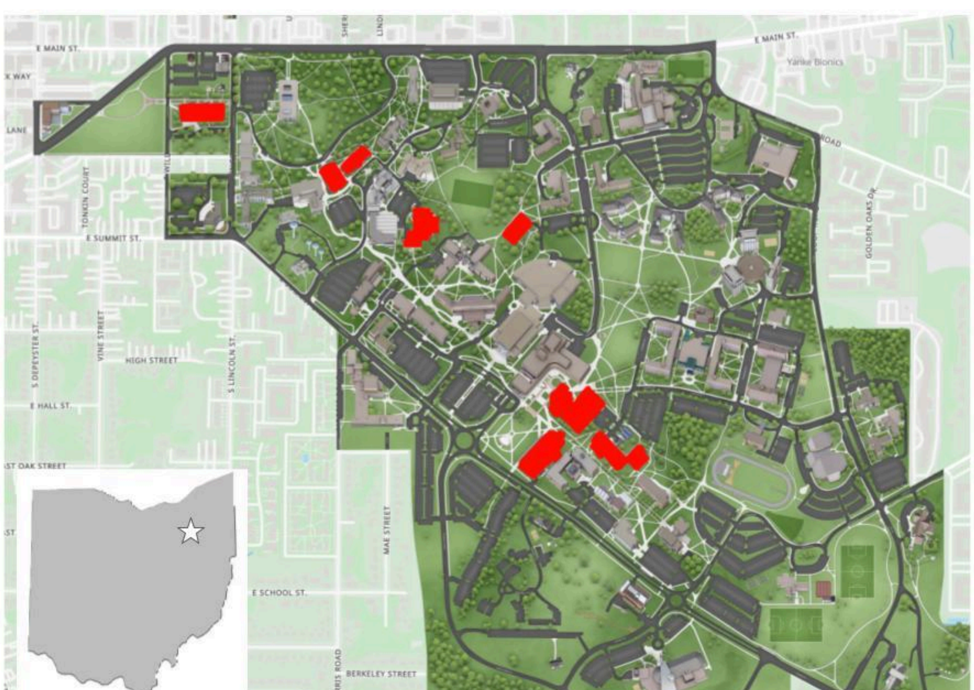

Figure 2. Map of Kent State University (KSU) campus buildings in Kent, Ohio. Buildings colored in red were surveyed in the study. Approximate location of KSU is indicated with a star on the map of Ohio in the bottom left corner.

Figure 3. Pictures of four buildings surveyed on the Kent campus. (Left side, top to bottom: Merrill Hall, Taylor Hall, ISB; Right side: KSU Library)

We surveyed buildings approximately twice a week from April 3, 2023, to November 21, 2023. The first three buildings surveyed were Cunningham Hall, ISB, and KSU Library. As the availability of surveyors increased, more buildings were added. The DI Hub was added on May 20, 2023, followed by Cartwright Hall and the Architecture Building on June 6, 2023, and Merrill Hall and Taylor Hall on June 8, 2023. In total, we surveyed 43 days throughout the data collection period. Surveyors walked the premises of the building and noted any deceased birds within 6 feet of the building and any dust, dirt, or blood marks on the windows that may indicate a collision. In areas of dense vegetation, surveyors attempted to check around and near the ground to the best of their ability. Additionally, information on location, temperature, cloud cover, and wind was recorded. To minimize bias, the daily observation order of buildings and the physical path traveled around each building was reversed on each successive day of observation.

We recorded photos of possible collisions and deceased birds. Images of possible collisions and deceased birds were uploaded to separate folders to organize the data according to the building it was collected. Photos were named with the unique code corresponding to the deceased bird or collision evidence. This code was recorded and allowed us to trace the reported fatality or possible window collision to the photographs taken. Specimens, where available, are currently held in the Bahlai lab biodiversity collection.

The presence and density of vegetation were included in building summaries. Vegetation density was estimated using the vegetation code protocol outlined in Thaker (2021). Each of the buildings surveyed was paired with a number to correlate with the amount of nearby vegetation. Similar codes were created for sun level and cloud cover to simplify data for comparison (Table 1).

Table 1: Bird-Window Collision observation variables coding chart

	0	**1**	**2**
Weather	Sunny	Partly Cloudy	Cloudy
Wind	Still	Breeze	Windy
BWC Evidence	No bird	Possible Collision	Carcass Found
Vegetation	Little to no fully grown trees nearby	Areas with some trees and bush cover	Many trees with branches within 2-5 m from windows, those with vine coverage along the walls, and those with extensive brush nearby

Bird Identification

Images of deceased bird carcasses were uploaded to iNaturalist. The bird species were not considered confirmed until they reached “research grade” observations. This level is obtained when a majority of contributors agree on the proposed species of the bird in the image. Photos that were unidentified or only included bones and/ or feathers were categorized as “unidentified.”

Window Area

Blueprints for each of the buildings surveyed were obtained from the Office of the University Architect at Kent State University. These documents were uploaded to ImageJ, which measured the relative area of the buildings. The percentage of windows on each side of the building was calculated using this information. All sides were totaled and averaged to provide an average percent area of window cover for each building.

External University Bird-Window Collision Studies

To compare results collected on the Kent campus to other bird-window collision studies, the keywords: “bird-window collision” and “campus” were entered into the Google Scholar search engine. The top 1000 results were downloaded and analyzed. Inclusion criteria included: more than one building surveyed, exclusive data collection by window surveys, location of survey on college or university campus, and campus locations within North America. The study was exclusive to North American studies to eliminate bias on different migration patterns of the Southern Hemisphere. Studies were not included if they did not specify between fatal collisions, possible collisions, and witnessed survived collisions. The search was truncated when limited relevant sources were being uncovered: when five successive studies in a row did not pertain to university or college campus bird-window collisions and did not meet the other inclusion criteria discussed.

For each study, we gathered information regarding the survey location and duration, number of survey days, number of species found, number of fatal collisions, whether mitigation was implemented in the study period, and whether mitigation decreased the number of collisions. Universities that added BWC mitigation strategies during a portion of their study were split up into pre- and post-mitigation periods to assist with data analysis. This allowed the data collected before and after the mitigation was implemented to be analyzed. However, some data from one study (Thaker 2021) was excluded due to unclear dates as to when mitigation was implemented. As a result, approximate dates before mitigation were used; any bird collisions recorded after this date in the study were not included. Ohio State University had two independent BWC surveys conducted by different teams, so we included both surveys in the analysis.

To calculate the number of birds per survey day per building, we used the following equation used in another campus BWC study (McLain 2019).

$$\left(\frac{\#\ of\ birds\ found}{\#\ survey\ days}\right)/(\#\ of\ buildings\ surveyed)\ =\ \#\ birds\ per\ day\ per\ building$$

We utilized the equations presented in McLain (2019) on our data, which enabled us to graph the shifts in bird collisions at these locations. When graphing the number of birds found per survey day by the number of buildings, we did not include post-mitigation collision information in surveys that implemented mitigation strategies for only a portion of their study to eliminate bias from the change in procedure. The ppre- andpost-mitigation collision data were analyzed separately.

Table. 2 Species of birds killed in window collisions identified at Kent State University during a 43-day sampling period in 2023

Bird Species (Common Name)	Scientific Genus and Species	Migratory Status	Number Found
Cedar Waxwing	*Bombycilla cedrorum*	Nomadic	4
Brown Thrasher	*Toxostoma rufum*	Migratory	2
House Sparrow	*Passer domesticus*	Resident	2
American Robin	*Turdus migratorius*	Resident	1
White Breasted Nuthatch	*Sitta carolinensis*	Resident	1
Grey Catbird	*Dumetella carolinensis*	Migratory	1
American Goldfinch	*Spinus tristis*	Resident	1
Dark-eyed Junco	*Junco hyemalis*	Migratory	1
Unidentified	NA	--	3
Total			16

Results

We documented 16 fatal bird collisions on campus between April 3, 2023, and November 21, 2023 (Figure 4). The ISB and Cunningham Hall each had four collisions recorded. The Library, DI Hub, and Merrill Hall had two collisions each. Taylor Hall and the Architecture Building had one collision each. Cartwright Hall was the only building included in the study without a recorded

collision. Collision-only data, where evidence of collision without a deceased bird was recorded, was not included in the subsequent analysis due to inconsistent data recordings for this measurement and a lack of comparable data from other university BWC studies.

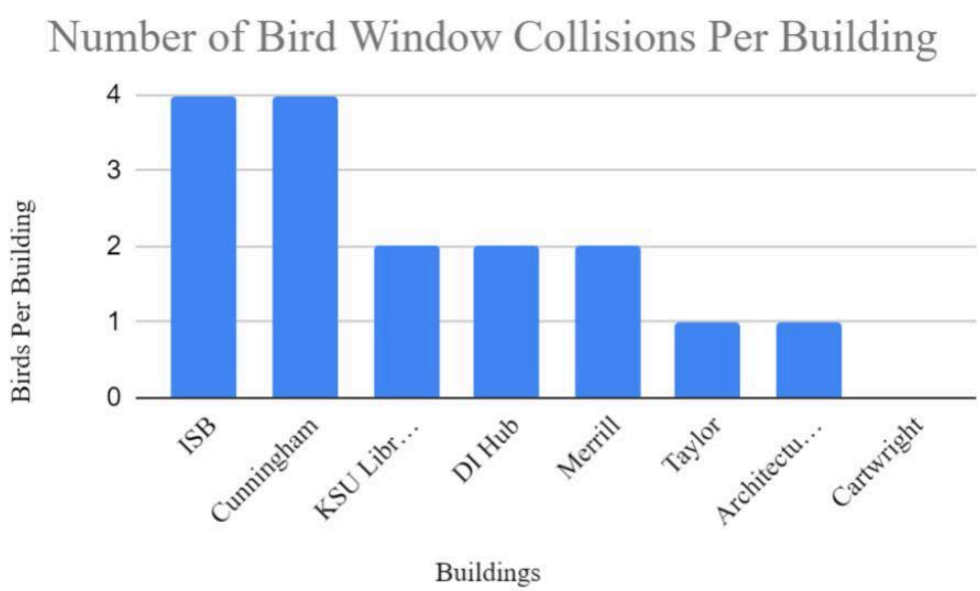

Figure 4. Total number of bird fatalities due to window collisions observed across 8 buildings over a 43-day observation period in 2023.

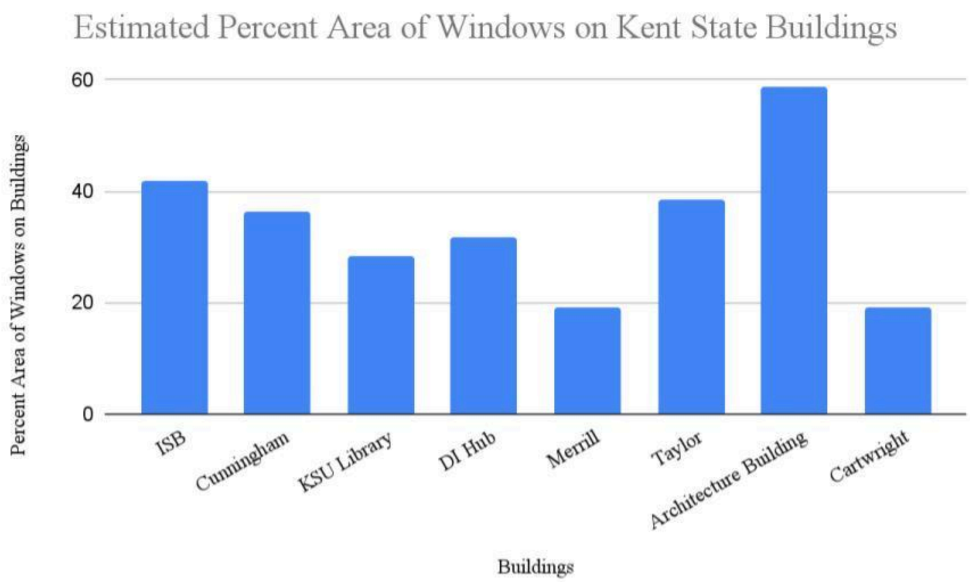

Figure 5. The percent of window area on each side of the buildings surveyed was calculated. The percentages collected were averaged to create an estimate of the buildings with the most area of windows at Kent State University.

We identified 8 different species within the 16 deceased birds found on campus (Table 2). Of the birds recorded, Cedar Waxwings had the greatest number of window fatalities with four individuals found. Three of the birds found were partially or mostly scavenged and could not be identified. Brown Thrasher and House Sparrows each were recorded with two collisions.

The Architecture Building has approximately 58% glass which is the greatest percentage of area for all the buildings surveyed (Figure 5). Cartwright Hall had the smallest percentage of glass with only 19% of the building having windows. ISB was found to have the second-greatest percentage of glass and had the greatest number of BWC. Cunningham Hall, which tied for the greatest amount of BWC, had the fourth greatest percent area of glass. We were unable to find a significant relationship between the percent area of glass and BWC.

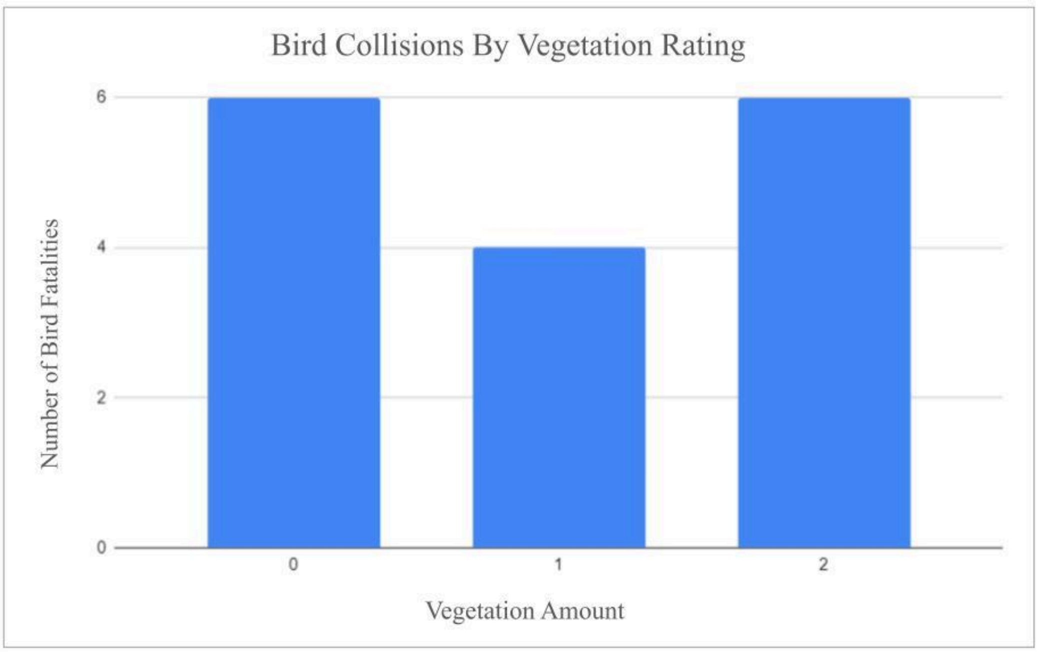

Figure 6. Total number of bird collisions for 3 different amounts of vegetation around buildings surveyed on the Kent State University campus. No presence of mature trees and little to no areas of bush cover was represented by 0; 1 indicated presence of some trees and bush cover; 2 represented extensive tree and bush cover.

Vegetation rating did not seem to influence BWC risk. Six collisions occurred on buildings with a rating of 0 and 2 (Figure 6). These ratings were representative of little to no areas of bush cover (0) and areas of extensive vegetation (2). As a result, we were not able to discern a difference in risk between varying vegetation ratings. We are unable to make firm conclusions regarding this data, which is likely due to the small sample size collected at KSU. While looking at migration periods, we found nine out of the 16 collisions occurred during spring and fall migration. This made up approximately 56% of our recorded collisions.

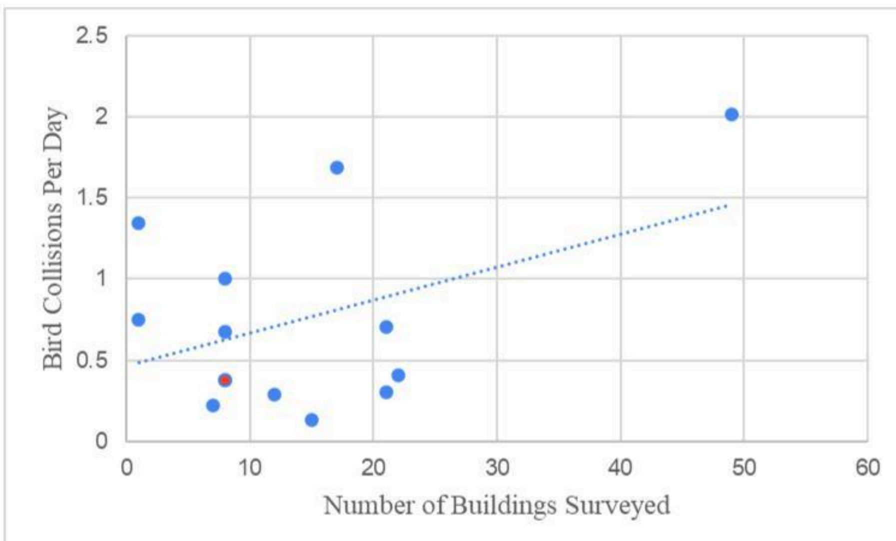

Figure 7. Number of bird collisions per day per building was calculated for 13 different University bird window collision surveys. The red marker indicates Kent State University. The 14th study was excluded from this analysis reduce outlier bias on the collision rate trendline.

Campus Comparison Studies

A total of 14 studies from 13 different universities were used for comparative analysis. These universities included between 1-49 buildings in their campus surveys (Table 3). Kent State University had the fewest total birds found with 16 and Louisiana State University had the largest total of 363 birds. The duration of these studies ranged from 38 to 1180 days. Using the McLain (2019) equation, we found that the Kent State campus is below the typical rates of BWC for the other campus studies, which suggests that KSU has a lower average rate of collisions (Figure 7). Duke University and Utah State University implemented mitigation measures partially through their survey period. These universities were able to record shifts in bird fatalities on the retrofitted windows. We detected a decline in collisions at Duke University and Utah State University following mitigation measures.

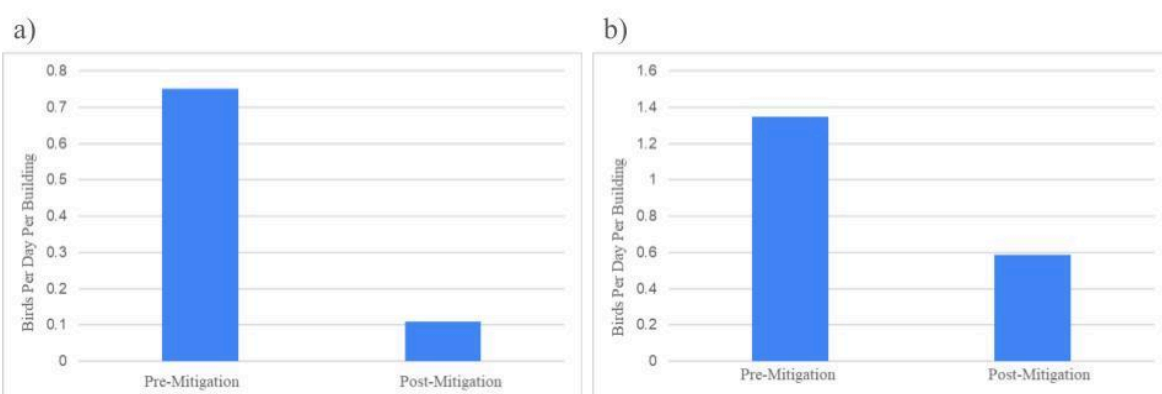

Figure 8. Number of birds per day per building included in the survey before and after mitigation measures at ***a)*** University of Utah ***b)*** Duke University

Table 3. Location and data summaries from all campus bird-window collision surveys used in this study, including Kent State University. Universities marked with an asterisk (*) indicate studies that implemented mitigation strategies during the study. (^) indicates study which was excluded from analysis due to outlier bias.

Location	Number of Buildings	Total Deceased Birds Found	Duration of Study (Days)
Radford University, Virginia, USA	15	52	393
University of Utah, Utah, USA*	1-8	37	45
Ball State, Indiana, USA	12	158	552
Queen's University, Ontario, Canada	8	58	171
Georgia Southern University-Streetsboro Campus, Georgia, USA	21	73	103
Lousiana State Univeristy, Lousiana, USA	21	363	1180
Duke University, North Carolina, USA*	1	122	126
National School of Higher Studies of the National Autonomous University of Mexico, Leon, Mexico	7	69	309
Virginia Tech Corporate Research Center, Virginia, USA	22	240	586
University of British Columbia, Vancouver, Canada	8	152	225
University of New Mexico Central Campus, New Mexico, USA	17	76	45
Ohio State University, Ohio, USA ^	20	339	38
Ohio State University, Ohio,USA	49	161	80
Kent State University, Ohio, USA	8	16	43

Discussion

Our results illustrate patterns of BWC collisions on the KSU campus, and although data was too sparse to conduct statistical tests, we found patterns in BWC that allow comparison to similar studies on other college campuses and can inform mitigation strategies. We were able to compare bird collision rates of other North American university campus surveys to the rate we calculated for the KSU campus to understand how BWC risk varied between them. We visualized the data collected on the KSU campus regarding the percentage of window area, surrounding vegetation, and migration period. After analyzing our results, we suggest expanding survey efforts on campus and implementing mitigation at KSU.

We did not find a relationship between percent glass and BWCs on the KSU campus. The Architecture Building had the greatest area of glass, however, there was only a single collision recorded on this building. In contrast, ISB had the second-greatest area of glass on the building and had 4 bird collisions recorded. This suggests it is not the glass area alone that defines the likelihood of a BWC. Similarly, vegetation did not appear to have a significant role in BWC on campus, although those data were sparse. We were unable to perform robust statistical tests because of low sample sizes: the same number of bird collisions were recorded across all vegetation ratings. However, we were able to find and further explore trends within the collected data without statistically significant analyses.

Spring and fall migration periods experienced a greater amount of bird-window collisions than other times within the survey period. Our results corroborate the findings of previous studies that found higher rates of BWC during spring and fall migration, however, more data is needed to verify this pattern. Increasing our survey length, survey frequency, and number of buildings included in the study may allow future surveys on campus to unveil more precise trends. For instance, Borden et al. (2010) noted a significant correlation between BWCs and migration period, and the survey included data collection for 23 buildings three days a week for 12 months.

Species found in the Kent State survey have overlapped with other BWC surveys. Large volumes of Cedar Waxwing fatalities have been recorded in other window surveys (Loss et al., 2014; Klem et al., 2009). Brown et al. (2020) reported that 23 out of the 39 bird-collision fatalities that they recorded were Cedar Waxwings. Fitzgerald et al. (1990) found that Cedar Waxwing may become disoriented from ethanol toxicosis after eating fermented berries. This may contribute to an increased risk of BWC in Cedar Waxwings. Cusa et al. (2015) found that building proximity to green areas or even high levels of surrounding urbanization appears to affect certain groups of birds differently. Species-specific trends may be an important factor to analyze in the future.

Compared to other university studies, Kent State Campus appeared to have a lower-than-average number of bird collisions per day per building, although not atypically so. When the outlier was excluded, there were six studies near or above the trendline of collision rates. This outlier was removed due to the dramatically higher rates of observations in this study compared to similar studies, leading to a strong bias in the calculated trendline. The outlier was from one of two surveys on the Ohio State University campus (Ficker and Tonra, 2020). Using the calculated values, this study had approximately nine birds per day per building surveyed; whereas, all other included studies were between zero and two. With the outlier present only two other university studies were above the trendline, with the outlier removed there is a more even distribution of study results above and below the trendline. Seven studies, including Kent State, were below this line. However, we were unable to determine, from the literature alone, what environmental or structural factors contributed to differences in rates between study sites. Further examination of this rate in more university studies will be necessary to determine the robustness and transferability of these findings. Understanding the average rate of BWC on college campuses can elucidate if the BWC rate on a particular campus is higher than average and inform mitigation efforts. Using campus surveys to gain knowledge to build benchmarks will be vital to determining if mitigation should be implemented and if certain locations pose a greater risk for bird collisions than others. These “benchmarks” should be considered on an individual basis with respect to the goal of each study. For example, a study could begin finding patterns of BWC within a certain area. Using this information, a benchmark could be created to compare rates of collisions before and after the installation of mitigation. Without benchmarks, it is impossible to determine if preventative measures are benefitting the area. For instance, the University of Utah survey analyzed before and after they installed Feather Friendly® film on a side of the building that was being surveyed. They determined that the film reduced collision rates by 71% (Brown et al., 2020). However, Brown et al. (2020) expanded to include 7 more buildings in their survey route, which included buildings that had existing fritted patterns in the glass, so analysis regarding the effectiveness of these windows was impossible. Future research on the Kent State campus should include surveys that implement mitigation measures to explore how different deterrents could prevent future BWCs.

Kent State University has already implemented a bird dot pattern to break up the reflective image of vegetation or open areas to prevent bird-window collisions on one of the buildings we surveyed. The silk-screened glass used in the windows of the DI Hub was present before the start of the campus survey. Throughout the survey period, we only found one fatal collision on this building; however nearby Cartwright Hall, which does not have this preventive pattern, also did not have a recorded collision. However, the absence of window collisions on Cartwright Hall could be due to the smaller window area compared to the DI hub. While we are unable to statistically determine if the preventative pattern is reducing bird collisions on windows on the Kent State campus, other campus surveys that implemented mitigation during their study reported a reduction in BWC (Brown et al. 2021; Winton et al., 2018). Future studies should aim to robustly test for the effectiveness of mitigation strategies such as Feather Friendly® window film. Using the data collected in 2023 as a baseline, future studies may be able to implement mitigation strategies on buildings such as the ISB and Cunningham Hall, which experienced the greatest number of collisions during the study, and see if there is a reduction in the number of BWC.

Figure 9. Top Image: Back-side of Cunningham Hall– an example of dense vegetation surrounding areas of windows and near the ground. Bottom Image: Side of DI Hub– example of little to no vegetation. Additionally, the DI Hub was the only building surveyed that had a fritted pattern in the windows to prevent collisions on the Kent State University campus.

Although we identified instances of BWC on the KSU campus, we expect we had low detection probability, thus inducing underreporting of the actual number of collisions on the Kent campus. Several confounding factors can skew the detection of BWC-induced injuries or mortality. For example, scavenging injured or dead birds by cats or other carnivorous animals can remove evidence of BWC (Klem et al. 2012). Further, dense foliage surrounding the area can prevent the detection of injured or dead birds. While greater amounts of vegetation outside of windows can lead to increased collision probability (Gelb & Delacretaz 2009; Borden et. al., 2010), thick foliage can make it difficult to survey the entirety of the chosen buildings exhaustively (O'Connell 2001). Additionally, the relatively short period of this study and the few available surveyors undoubtedly limit our scope of inference. However, the issues present in this study are not unique; a similar study struggled to collect an adequate amount of data to make meaningful statistical conclusions (Winton et al. 2018). Continuing these surveys with an increased number of surveyors and survey days would likely enhance the results presented here and increase the ability to conduct robust statistics on the data to elucidate trends in BWC in a suburban setting more clearly. Future monitoring would be able to use the data collected in 2023 to compare year totals and species trends across years and seasons to inform decisions and potentially implement mitigation on additional buildings around campus. Additionally, it will be important to monitor scavenger activity around the surveyed buildings to understand the role of animals in scavenging carcasses before they can be recorded (Klem et al. 2004). This is particularly relevant for the Kent State campus which is frequented by many small mammals, such as squirrels, raccoons, and feral cats, that may scavenge on bird carcasses.

While gathering external university surveys, we encountered frequent difficulties aggregating enough data. Unfortunately, there appeared to be an absence of clear data collection protocols in many studies. Many studies did not include specific start/end dates, the number of days surveyed, number of birds collected, and several studies did not differentiate between a survived and fatal collision. Compiling the data in Table 3 required several estimations regarding survey lengths. Beyond this, outlining clear dates, specific numbers, and clear parameters for how the survey is handling collisions vs. fatal collisions is necessary for analysis in the future to be successful.

Conclusion

This study is vital to determine possible mitigation efforts to offset the environmental impacts that occur on the Kent campus to protect the numerous bird species in the area. BWC monitoring should be expanded to continue building a larger pool of data to show possible collision trends that are occurring on the Kent campus. It will be important for future studies to find significantly impactful buildings on campus and use that information to inform possible mitigation efforts. As the university continues to expand, we should consider the ways our development may be negatively impacting the natural world around us and make better decisions to ensure a safe future for us and the environment.

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Appendix

Title	Author	Location
Investigating campus features that influence bird-window collisions at Radford University, Virginia.	KE Powers, LA Burroughs, BM Mullen, HC Reed…	Radford University
Winter bird-window collisions: mitigation success, risk factors, and implementation challenges	BB Brown, E Kusakabe, A Antonopoulos, S Siddoway…	University of Utah
Identifying Bird-Window Collisions On a University Campus During Spring and Fall Migration	Silas E. Fischer and Kamal Islam	Ball State University
Assessing and addressing bird-window collisions on the Queen's University main campus	M Thaker	Queen's University
Bird Window Strikes on a College Campus: Mortality Estimates and Possible Mitigation	Antarius D. McLain	Georgia Southern University-Streetsboro Campus
Collisions on Campus: Species-specific susceptibility of resident and migrant birds to window strikes at Louisiana State University	JA Mouton	Louisiana State University
Geo-referencing bird-window collisions for targeted mitigation	RS Winton, N Ocampo-Peñuela, N Cagle	Duke University
The invisible enemy: Understanding bird-window strikes through citizen science in a focal city	P Uribe-Morfín, MA Gómez-Martínez…	National School of Higher Studies of the National Autonomous University of Mexico
Year-round monitoring reveals prevalence of fatal bird-window collisions at the Virginia Tech Corporate Research Center	RM Schneider, CM Barton, KW Zirkle, CF Greene…	Virginia Tech Corporate Research Center
Year-round monitoring at a Pacific coastal campus reveals similar winter and spring collision mortality and high vulnerability of the Varied Thrush	KL De Groot, AN Porter, AR Norris, AC Huang…	University of British Columbia
A Survey Of Bird-Building Collisions And Building Characteristics At The University Of New Mexico	DB SIMMONS	University of New Mexico-Central Campus
Lights Out Buckeyes–Landscape and Architectural Influences on Avian Window Collisions	T Ficker	Ohio State University
Lights Out Buckeyes-Factors Influencing Avian Window Collisions	K Glanville	Ohio State University