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# Invisible to visible: A field study investigating dirty windows and bird-friendly artwork as mitigation strategies against bird-window collisions

Prepared by: Kelsey Leung

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# Invisible to visible: A field study investigating dirty windows and bird-friendly artwork as mitigation strategies against bird-window collisions

Kelsey Leung

Department of Applied Animal Biology

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Dr. Kristen Walker

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**ABSTRACT**

Estimates suggest that 16 to 43 million bird deaths occur annually due to collisions with buildings in Canada. Buildings on the University of British Columbia Vancouver campus may contribute up to 10,000 bird deaths each year. The reflective and transparent properties of glass, combined with birds having poor spatial acuity in the direction of motion, make it challenging for birds to perceive glass as a solid barrier, resulting in bird-window collisions. This study investigates the effect of two mitigation strategies employed by the UBC Botanical Garden: reducing window washing frequency, which allows dirt to accumulate on windows and the installation of bird-friendly artwork. A comparison of collision frequency over an 8-week monitoring period in late winter and early spring of 2021 and 2022 is used to investigate the effectiveness of these strategies. A 97% decrease in collision evidence was reported from 2021 to 2022, suggesting that dirty windows and bird-friendly artwork are effective at reducing bird-window collisions. We recommend that both strategies should be implemented at other buildings on the UBC campus and suggested to businesses and homeowners to reduce the negative impact windows have on bird populations. Further studies should be conducted on the effect of dirty windows, as limited research directly investigates this strategy. Additionally, a comparison between the effectiveness of dirty windows, bird-friendly artwork, and other mitigation strategies (such as decals or ultraviolet film application) should be conducted to determine which offers the highest level of protection against bird-window collisions. Future research should also investigate social aspects of bird-window collisions, including public perception and awareness, in order to improve mitigation strategies and better understand barriers to their implementation.

## INTRODUCTION

Canadian buildings are responsible for an estimated 16 to 43 million bird deaths annually (Basilio et al. 2020), and structures on the University of British Columbia (UBC) Vancouver campus are no exception. One study estimates 360 deaths resulting from bird-window collisions over 225 days of monitoring at only 8 buildings on campus (De Groot et al. 2021). Considering that there are over 200 buildings of similar size on campus, it is possible that up to 10, 000 birds die as a result of collisions with UBC buildings each year (UBC Science 2022).

From this alone, it is evident that human-wildlife conflict is a prevalent issue on the UBC campus. Human-wildlife conflict arises when the needs, behaviours, or goals of people conflict with those of wildlife, or vice versa, resulting in a negative outcome for one or both parties (Madden 2010). Bird-window collisions exemplify unintentional human-wildlife conflict, as the human goals of urban development conflict with the natural behaviours of wild birds, resulting in unfavourable outcomes for birds when they mistakenly strike the glass. Bird-window collisions occur when birds cannot differentiate between the glass pane and a clear flight path (Machtans et al. 2013). This results when the transparent properties of glass cause birds to believe they are able to fly through it, or the reflective properties of glass cause birds to perceive the reflection as an extension of their habitat (De Groot et al. 2021). Moreover, the visual anatomy of birds projects their field of view laterally, meaning they do not have a high spatial resolution in the direction of motion, thus increasing their susceptibility to colliding with objects during flight (Martin 2011).

Several characteristics of the UBC Botanical Garden may contribute to an increased risk of collisions. Located on the pacific coast, the UBC campus is directly in the path of the Pacific Flyway used by migratory species (Wilson 2010). Evidence suggests that migratory birds have an increased risk of collision during the migration period, when they fly through urban areas which they are unfamiliar with (Cusa et al. 2015; Loss et al. 2019). Additionally, geographical factors such as proximity to forested areas or large bodies of water can increase local bird abundance, resulting in a higher likelihood of collisions when urban centres are located close to these areas (Hager et al. 2017). The UBC Botanical Garden is not only less than half a kilometer away from the Pacific Ocean but is also surrounded by the Pacific Spirit Regional Park forest. Numerous studies have also shown that the presence of vegetation near windows is correlated with increased collision risk (Loss et al. 2019; Machtans et al. 2013). This is due to the reflection of vegetation in the glass falsely appearing as habitat (Riding et al. 2019). Given that the Botanical Garden is densely populated with vegetation, most glass panes within the garden are adjacent to or in close proximity of vegetation, resulting in increased collision risk.

The mission statement of the Botanical Garden is "to assemble, curate, and maintain a documented living collection of temperate plants for the purposes of education, research, conservation, community outreach, and public display" (UBC Botanical Garden 2020). While the many diverse plants in the garden create a variety of different microhabitats and help to support avian biodiversity and conservation, the buildings on site are working against the conservation of bird populations by posing a significant threat to birds in flight. In recent years, the Botanical Garden has acknowledged this issue and has been actively working on reducing the number of collisions that occur through two main strategies that aim to enhance the visibility of windows to birds. Firstly, bird-friendly artwork designed by Derek Tan was applied to the windows at the Pavilion. Bird-friendly artwork has been suggested as a mitigation strategy (De Groot et al. 2021), although limited peer-reviewed literature reports on its effectiveness in practice. The second strategy adopted by the Botanical Garden is allowing glass in the reception area to get dirty.  Recent anecdotal evidence suggests that reducing window cleaning frequency and allowing dirt to accumulate on the glass may help to minimize collision risk (Żmihorski et al. 2022), but to our knowledge, no published research to date directly examine the effect of dirty windows using field studies.

This project aims to investigate the effectiveness of bird-friendly artwork and dirty windows as a mitigation strategy to reduce bird-window collisions using field data collected in the UBC Botanical Garden.  We hypothesize that both of these strategies will aid in the reduction of bird-window collision frequency by increasing the visibility of windows.

## MATERIALS AND METHODS

### Study Area

The study was conducted in two areas within the UBC Botanical Garden: the Botanical Garden Reception and the Botanical Garden Pavilion.  The study area has a total of 19 facades within the two areas being monitored, with facades 1 to 15 located in the reception area and facades 16 to 19 at the Pavilion (see Figure 1).  Facades 1 to 12 and facade 15 consist of glass panes lining the boardwalk, whereas facades 12 to 14 and facades 16 to 19 are located along buildings with glass windows or doors.  Please see the appendix for images of each facade.

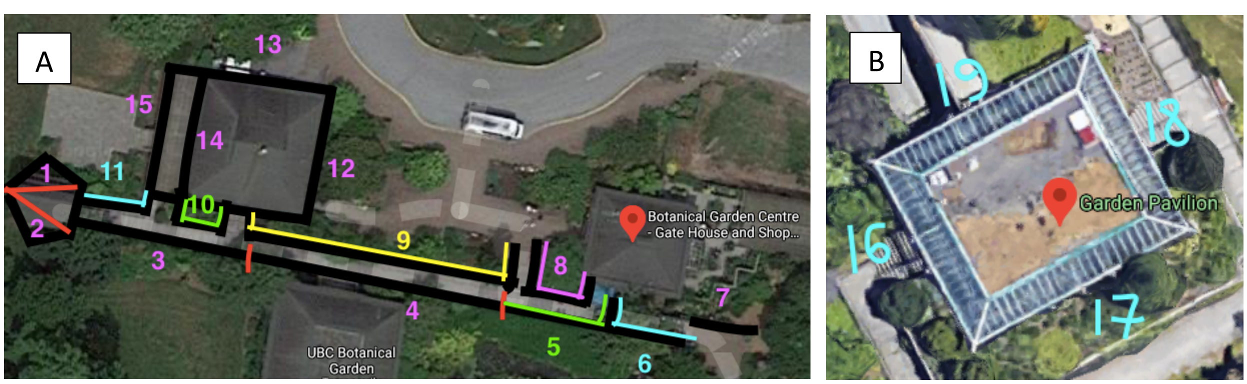


**FIGURE 1.** Map of facade locations at the Botanical Garden reception area (A) and the Botanical Garden Pavilion (B).

**Collision Monitoring Protocol**

Our collision monitoring protocol follows a standardized approach to conducting bird collision surveys adapted from Hager and Cosentino (2014) by our community partner, Krista De Groot of Environment and Climate Change Canada. Evidence of bird-window collisions that we were searching for includes bird carcasses, feather piles, and feather smears. For this study, a feather pile is defined as at least 10 feathers within a 1m diameter circle, and a feather smear is defined as any feather(s) directly attached to a glass pane.

Before beginning our weekly monitoring schedule, two members of our group conducted a clean-up day on January 27th to remove any evidence of bird-window collisions that occurred prior to the monitoring period. All facades within the study area were searched for any evidence of bird collisions (carcasses or feathers), which were removed to ensure that evidence found during monitoring indicates a bird strike that occurred during the study period. Collision monitoring began on January 28th and continued for approximately 8 weeks, with the last survey conducted on March 29th. Surveys of the study site were conducted in pairs, with each pair monitoring two days per week for a total of 4 surveys each week. In total, 35 days of monitoring were conducted. Each day of monitoring was conducted in the morning and completed by 10:00am to minimize confounding variables, such as scavenger activity.

At the beginning of each survey, the date, time, building, and weather conditions were recorded. Weather conditions were assessed using the Weather Bureau Sky Condition Codes from the breeding bird survey protocols (Government of Canada 2017) as listed in Table 1. Both surveyors would start at the same point and conduct the survey simultaneously in opposite directions around the study site. This was done to increase the likelihood of finding any evidence that was present, as evidence may be more or less visible depending on which direction it is approached from.  The area along each facade was thoroughly searched up to 2m away from the facade, including under vegetation and other objects.  At facades 1 to 6 and facades 8 to 11 along the boardwalk, the ground below within 2m of the glass panes lining the boardwalk was inaccessible.  For these facades, we searched the boardwalk itself, examined both sides of the glass for the presence of feather smears, and looked over the edge of the boardwalk to the ground below to check for carcasses or feather piles.  If any evidence was found, the facade number and specific location along the facade were noted, however, surveyors did not discuss or remove any evidence that was observed until both group members had completed the survey of the area.  Once complete, the survey end time was noted and both surveyors returned to any evidence to record additional details.

**TABLE 1.** Weather Bureau sky condition codes (adapted from the Government of Canada breeding bird survey protocols, 2017)

| Sky Condition Code | Description |
|---|---|
| 0 | Clear or a few clouds |
| 1 | Partly cloudy (scattered) or variable sky |
| 2 | Cloudy (broken) or overcast |
| 4 | Fog |
| 5 | Drizzle |
| 6 | Rain |
| 7 | Snow |
| 8 | Showers |

Once at the location of the collision evidence, specific data was collected according to the type of evidence, then all evidence was removed to avoid double counting during the following surveys.   For carcasses, we noted the condition as intact, scavenged, or decomposing, as well as a description of the carcass and the species if we were able to identify it.  Additionally, three photographs were taken: a ventral view, a dorsal view, and a lateral view.   For feather piles, we noted a description of the feathers and recorded the exact number of feathers if there were fewer than 15, or an estimate of either more than 20, more than 50, or more than 100 if there were more than 15 feathers. We collected carcasses and feather piles using gloves and placed them in individual Ziploc bags. Collected evidence was labelled with a unique ID in the following format: YYYY-MM-DD BGX SPECIES, which includes the date (YYYY-MM-DD format), building and facade ID (BGX, where X is the facade number), and the species if known. Bags containing collision evidence were given to Krista De Groot for further examination and species identification. Feather smears were not collected, but the feather was removed from the glass to avoid double counting. For feather smears found above a carcass or feather pile, we indicated the presence of a feather smear in our notes but did not enter it as a unique collision. Feather smears that were not above carcasses or feather piles were considered a unique collision with an unknown outcome, as it is impossible to tell from a feather smear if the bird survived the collision or not.

All data was uploaded to a shared spreadsheet within 24 hours, with one surveyor inputting the data and the second checking for errors. A line in the spreadsheet was added for each facade, regardless of whether or not any evidence was found. Each line includes the date, season, building name, building code (BG), facade number, survey start and end time, and if any evidence was found. For facades where evidence was observed, all additional details mentioned above were also recorded in the line. All photos were uploaded to a shared folder and labelled with the same unique ID assigned to the Ziploc bag.

**Carcass Persistence Trials**

Carcass persistence trials were also conducted to investigate the presence and activity of scavengers. Two carcasses were obtained from Krista De Groot, who prepared the carcasses by clipping the hallux to ensure the carcass is not mistaken as collision evidence. Facades were chosen using a random number generator; however, as we did not separate facades by area, we unfortunately placed both carcasses in the reception area and had no carcass placed at the Pavilion. Carcasses were placed at random within 2m of the chosen facade, ensuring no scavengers were present to observe placement. The carcasses were placed at 1:45pm, at which time we recorded the date, time, facade, and unique ID (same format as above: YYYY-MM-DD BGX SPECIES). A photograph was taken of each carcass and uploaded to the shared folder, labelled with the unique ID given to the carcass. The type of substrate and visibility ranking was also noted according to the codes in Table 2.

**TABLE 2a.** Substrate codes for carcass persistence trials.

| Code | Description |
|---|---|
| c/s | Concrete/asphalt |
| g | Grass |
| w | Wood chips |
| l | Simple substrate (concrete, asphalt, grass, or wood chips) with substantial leaf litter |
| r | River rock |
| s | Top of shrubs/ground cover |
| u | Under shrubs/ground cover |

**TABLE 2b.** Visibility ranking for carcass persistence trials

| Ranking | Description |
|---|---|
| 1 | Very visible |
| 2 | Somewhat visible |
| 3 | Blends in |
| 4 | Hard to see |
| 5 | Very difficult to see |

On the day the carcasses were placed, we returned to check on the status at 4:30pm. Carcass checks were also performed each morning for the following four days or until there was no evidence of the carcass remaining. For each carcass check, the time, initials of the observer performing the carcass check, and the carcass code (see Table 3) was recorded and inputted into our shared spreadsheet.

**TABLE 3.** Carcass condition codes for carcass persistence trials

| Code | Description |
|---|---|
| i | Carcass intact |
| g | Gone without a trace |
| s | Scavenged but still parts present |
| f | Feather pile remaining |
| d | Decomposing (presence of maggots, etc.) |

**Data Analysis**

All data manipulation was performed in excel. We examined the data that we collected, as well as data collected at the Botanical Garden in 2021 by previous APBI/CONS 495 students. The same protocol was followed for both years of data collection, over roughly the same time period. The total number of collisions at each building was compared from 2021 to 2022 to determine the percent change in collisions at the reception area and the Pavilion. Additionally, collisions were grouped by facade to identify areas of increased risk.

## RESULTS

**Collision Monitoring**

The number of collisions decreased drastically in 2022 compared to 2021, as shown in Figure 2. In 2021, 84 incidences of collisions were reported in the reception area, whereas evidence was only found 3 times in this area in 2022. At the Pavilion, the number of times collision evidence was found decreased from 11 in 2021 to 0 in 2022. In total, collisions decreased from 95 to 3, a 97% decrease from 2021 to 2022.

As seen in Figure 3, some facades report higher collision rates than others. Notably, facades 6 and 9 in the reception area were responsible for 11 collisions each. At the Pavilion, facade 17 reported the highest incidence of collisions, with evidence being found 7 times.

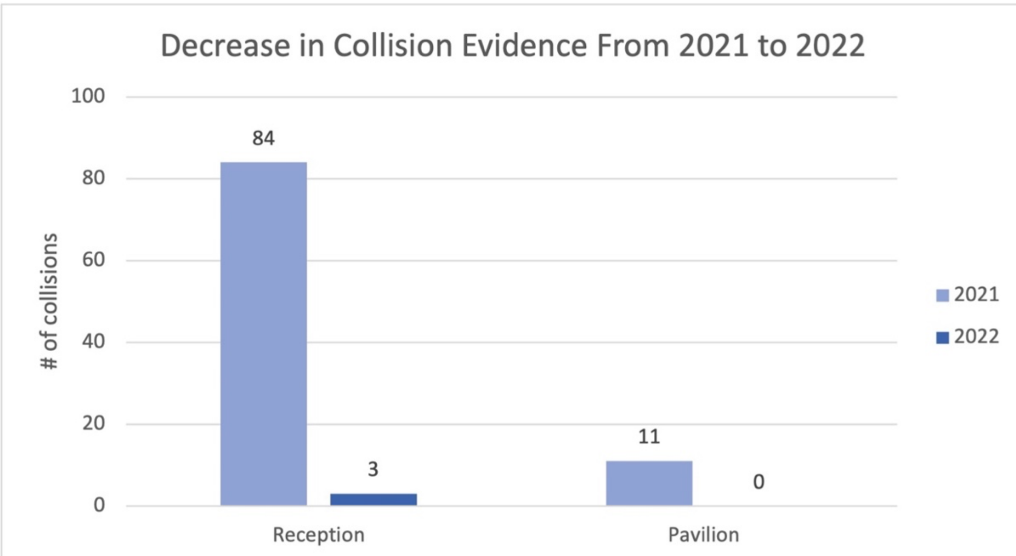


**FIGURE 2.** The number of collisions has decreased at both locations in the Botanical Garden from 2021 to 2022. The number of times collision evidence was found at the reception area decreased from 84 to 3, whereas the Pavilion decreased from 11 to 0.

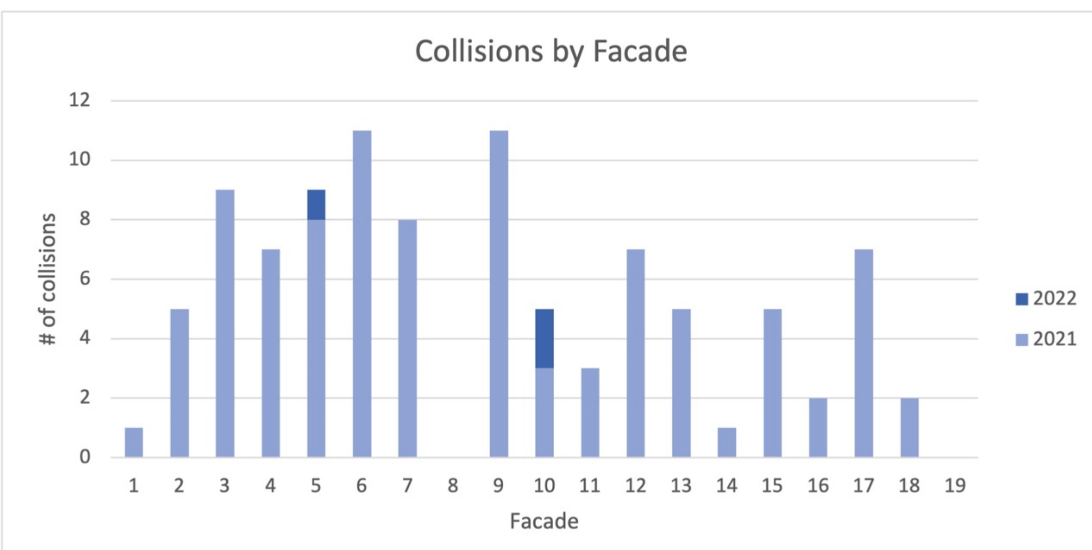


**FIGURE 3.** Total collisions in 2021 and 2022 grouped by facade. Collision hotspots include facades 6 and 9, which recorded 11 collisions each, followed by facades 3 and 5, which recorded 9 collisions each.

**Carcass Persistence**

Carcass persistence trial results are summarized in Table 3. At facade 10, the carcass was scavenged one day after placement, at which point the status did not change until the fourth day after placement when only a feather pile remained. In contrast, the carcass at facade 4 experienced no scavenging activity throughout the duration of the trial.

**TABLE 3a.** Carcass persistence results for the chickadee carcass placed at facade 10. Carcass was partially scavenged 1 day after placement. Carcass remained partially scavenged until 4 days after placement, when only a feather pile remained.

| Species | Facade | Substrate | Visibility | Placement date/time | Carcass check date/time | Carcass check status |
|---|---|---|---|---|---|---|
| Chickadee | 10 | s | 2 | 2022-03-17 1:45pm | 2022-03-17, 4:30pm | Intact |
| | | | | | 2022-03-18, 8:30am | Scavenged |
| | | | | | 2022-03-19, 10:00am | Scavenged |
| | | | | | 2022-03-20, 10:00am | Scavenged |
| | | | | | 2022-03-21, 9:00am | Feather pile remaining |

**TABLE 3b.** Carcass persistence results for the red-breasted nuthatch carcass placed at facade 4. Carcass remained intact for the duration of the trial.

| Species | Facade | Substrate | Visibility | Placement date/time | Carcass check date/time | Carcass check status |
|---|---|---|---|---|---|---|
| Red-breasted nuthatch | 4 | s | 4 | 2022-03-17 1:45pm | 2022-03-17, 4:30pm | Intact |
| | | | | | 2022-03-18, 8:30am | Intact |
| | | | | | 2022-03-19, 10:00am | Intact |
| | | | | | 2022-03-20, 10:00am | Intact |
| | | | | | 2022-03-21, 9:00am | Intact |

## DISCUSSION

### Significance of Results

Results from the reception area suggest that dirty windows may be an effective mitigation strategy to reduce bird-window collisions. The dirt and algal growth on the window surface that has accumulated since window cleaning was halted makes the glass less transparent and reduces the mirroring effect of glass by adding texture to the otherwise smooth and reflective surface (see Figure 4a). Even facades previously identified as collision hotspots exhibited very low collision rates in 2022. To date, very limited information on the effect of dirty windows exists, although a recent citizen-science based paper found a correlation between cleaning regimes and bird-window collisions (Żmihorski et al. 2022). Similarly, a study investigating collisions between birds and glass bus shelters reported fewer collisions at bus shelters that were dirty than those that had recently been cleaned (Zyśk-Gorczyńska et al. 2020). Not cleaning windows represents a novel approach to reducing bird-window collisions that is extremely easy and cost-effective, making it a highly accessible mitigation strategy.

Bird collisions at the Pavilion have also significantly decreased following the installation of the bird-friendly artwork in Spring 2021 (see Figure 4b), as we did not detect any evidence of collisions during the 2022 monitoring period. Bird-friendly artwork is commonly suggested to retrofit existing buildings that experience bird-window collisions, as it helps increase the visibility of windows (De Groot et al. 2021). Artwork should have high contrast to further enhance the visibility to birds (Martin 2011). Additionally, studies have found that any decals and artwork must be strategically spaced to prevent birds from believing they can fly through gaps (Brown et al. 2020). As seen in Figure 4b, the artwork at the Pavilion is dense and high contrast, which helps the window stand out.

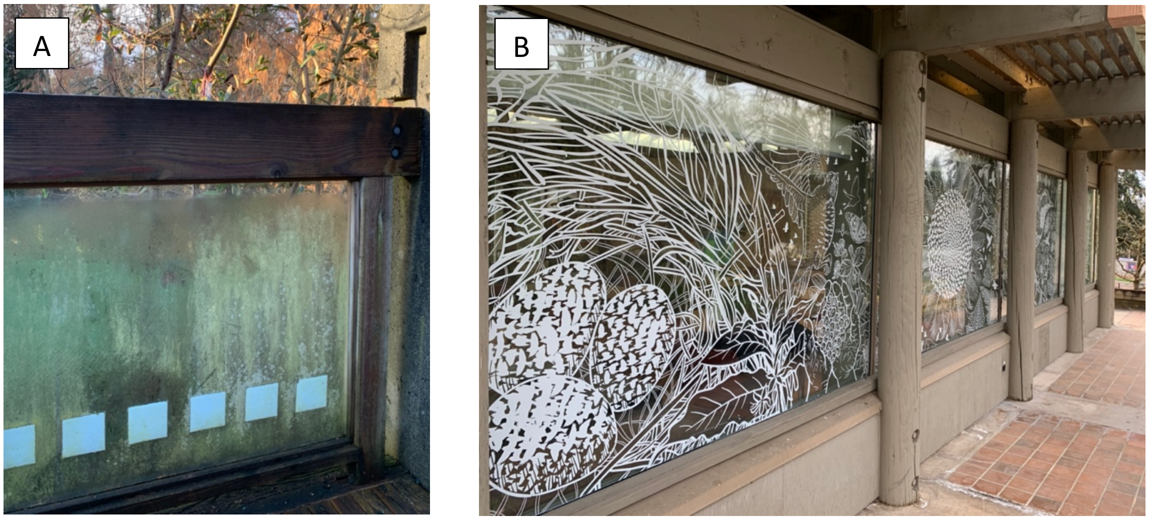


**FIGURE 4.** Two strategies at the Botanical Garden have helped to reduce bird-window collisions: dirty windows in the reception area (A) and bird-friendly artwork at the Pavilion (B).

While we do not have sufficient data to create a trend for scavenger activity and carcass persistence, the results of carcass persistence trials confirm the presence of scavengers at the Botanical Garden. It is important to keep scavengers in mind while interpreting results, as it is possible that additional carcasses were present in the study area but were removed before being detected. Scavengers vary with location, but in the Botanical Garden, possible scavengers include rodents, raccoons, other bird species, or human removal by the garden staff (Hager et al. 2012; Kummer et al. 2016; Loss et al. 2019).

**Management Implications**

The results of this study help to inform management techniques that can reduce the frequency of bird-window collisions, as both strategies demonstrate promising results. Based on our results, we recommend that dirty windows and bird-friendly artwork are suggested to building managers and owners as collision mitigation strategies. Bird-friendly artwork may be preferred in areas that are concerned with aesthetics, as it is more visually pleasing than dirty windows (McGregor et al. 2020). In addition, artwork can engage the public and offers social benefits, such as promoting local artists and adding cultural value to public spaces through the addition of art (McGregor et al. 2020). On the other hand, dirty windows require no work or money to implement, making them a highly accessible option to anyone who wishes to reduce their negative impact on local bird populations. We recommend that these strategies be implemented at other buildings on the UBC campus that experience high collision rates.

Beyond the two strategies in this study, other mitigation strategies that can be applied to existing buildings include adhesive markers (De Groot et al. 2022) or ultraviolet films (Swaddle et al. 2020). Adhesive markers and ultraviolet films both function by increasing the visibility of windows to birds, however, traditional markers are also visible to humans. In contrast, ultraviolet films are visible to birds as their vision extends into the ultraviolet spectrum, but invisible to humans as we are unable to visually detect ultraviolet wavelengths (Martin 2011).

**Study Limitations**

A major limitation of this study is the lack of comparison photos showing the difference between the level of dirt on the windows in 2021 and 2022. As 2021 data was collected by a different group of students, the change in the opacity of the windows is unclear, although we assume that windows would become increasingly visible over time as more dirt accumulates.

Imperfect searcher efficiency is a limitation of any collision monitoring study, as surveyors may not detect all evidence of collisions, resulting in an underestimate of collision frequency (Brown et al. 2020). It is important to note that the inaccessibility of the ground below the boardwalk may have also contributed to lower searcher efficiency, as we were not able to search this area as thoroughly. Additionally, there were 8 days throughout our monitoring period where only one surveyor was able to monitor, which could contribute to imperfect searcher efficiency as there would be a greater chance of evidence being missed. Due to time and scheduling constraints, we were unable to conduct searcher efficiency trials for this study to better understand this limitation. However, searcher efficiency would have been a limitation of data collection in 2021 as well, therefore, the observed decrease in collisions across the two years of data collection is likely still valid.

Scavenger activity is a confounding variable that may also lead to underestimates of collision frequency, as scavengers may remove a carcass before detection by surveyors (Hager et al. 2012). Despite conducting a carcass persistence trial to investigate the effect of scavengers, scavenger activity remains largely unknown for our study. As there was no carcass persistence trial conducted at the Pavilion, scavenger activity in this area is unknown. The trials conducted at the reception area have varying results, with one carcass being partially scavenged after one day and the other being untouched for the duration of the trial. Unfortunately, there is insufficient data to understand any patterns or trends of scavenger activity.

**Future Areas of Research**

More studies are required to better understand the effect of dirty windows on collision rates. Future research on this topic should include a control group to allow for comparison. This could be done by comparing clean and dirty windows simultaneously in the same area, or by using the same windows over multiple monitoring periods with different cleaning regimes. Such studies would help directly investigate the magnitude of the effect of window cleaning.

A comparison between the effectiveness of different mitigation strategies would also be useful to determine which strategies are superior at preventing collisions. Although several mitigation strategies, including dirty windows, bird-friendly artwork, adhesive markers, and ultraviolet patterns have demonstrated effectiveness in reducing collisions (De Groot et al. 2022; De Groot et al. 2021; Swaddle et al. 2020), their relative effectiveness has not been investigated.

Future studies should also consider social aspects of bird-window collisions, especially considering that this is a human-caused issue. For instance, understanding the public perception of bird-window collisions could help to inform appropriate mitigation strategies. Moreover, studies have found that the vast majority of collisions in Canada occur at private residences (Machtans et al. 2013), so informing the public is essential to help prevent collisions on a larger scale. Additionally, education about bird-window collisions and the effects of dirty windows could help increase the social acceptability of allowing dirt to accumulate and reduce negative connotations associated with an unkempt look.

## CONCLUSION

Buildings on the UBC campus contribute significantly to the millions of avian deaths that occur annually in Canada due to window strikes. Birds typically hit windows as a result of the transparent or reflective properties of glass; therefore, mitigation strategies should target these properties. Dirt accumulation on windows reduces transparency and reflectivity, although very few studies look at the effect that this has on bird-window collisions. Similarly, artwork helps to increase window visibility, although limited research exists on its impact in practice. Results from the Botanical Garden suggest that both dirty windows and bird-friendly artwork are practical solutions that are effective in the field. Although limitations exist, including imperfect searcher efficiency, lack of comparison photos, and poorly understood scavenger activity, preliminary results show promise. Future studies should aim to address these limitations, as well as investigate the relative effectiveness of different strategies and examine social aspects of bird-window collisions. We recommend that both strategies should be suggested to building managers and owners to reduce human-wildlife conflict between birds and windows.

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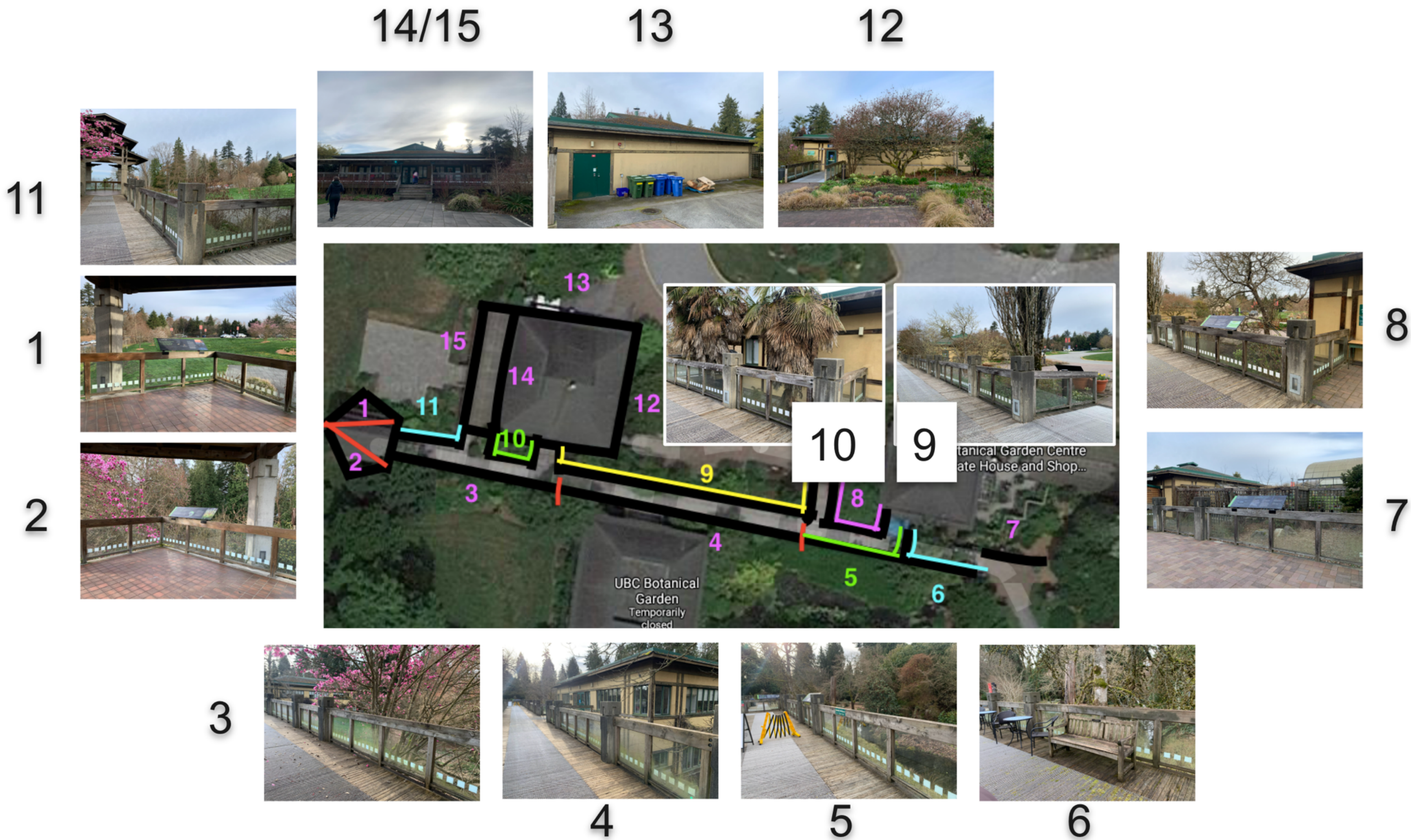
**APPENDIX** – Facade Images



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