Trends in bird collisions at a teaching building (Buchanan) at UBC Vancouver

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Abstract

Bird collisions on buildings are a major driver of avian mortality in north America. As a result of large glass surfaces used in building construction, and the proliferation of urban green spaces that (a) attract birds for food and shelter and (b) reflect off the glass, birds are unable to distinguish glass facades and collide with them. The campus of the University of British Columbia has been the site for multiple studies investigating trends in collisions owing to its mosaic of large glass buildings and green spaces. For four years, students in partnership with biologists monitored collisions occurring at the Buchanan complex, a teaching facility. Monitoring thrice a week, students recorded any collisions after being trained. All results were processed in R for visualization. Since 2021, collision frequencies have consistently dropped (-79.5% by 2024, from 49 to 10 collisions), though so has searcher effort. Collision frequencies across the four years have been localized to specific blocks and facades. Two facades have been retrofitted with Feather Friendly markers in 2022 and 2023, with noticeable declines in collisions (no statistical test conducted). As part of the university's long-term vision to integrate natural systems and promote biodiversity on campus, addressing this issue is urgent. Buildings on campus are not required by the university's building code to be retrofitted, leaving the decision to individual building management. As a proven technique, bird-friendly retrofits like Feather Friendly Markers and glass artwork, both for which have been employed on UBC's campus, are strongly recommended, especially as results show that retrofits only need to target certain "problem" facades that consistently record collisions. It is also strongly recommended to incorporate citizen science such as student monitoring programs to help keep an up-to-date record of collision statistics across multiple campus buildings.

Contents

1. Introduction

By 2050, it is expected that 70% of the human population will live in urban areas (Seto & Shepherd, 2009). McDonald et al. (2019) delineate how this projected growth affects biodiversity and species assemblages directly and indirectly (Figure 1). Indirectly, urban growth increases consumption, trade, and pollution, which in turn also leads to natural habitat losses. Urban population growth inevitably leads to direct land use changes, with McDonald et al. (2019) projecting a 1.2 – 1.8 million km^2 increase in urban land area by 2030, from 350,000 km^2 in 1992. From 2000 – 2030, natural habitat loss directly from urban land use growth is expected to be 290,000 km^2.

Like with other land use changes such as agriculture (Billah et al., 2021), conversion of natural habitat into urban areas has also resulted in an increase in human-wildlife interactions and the potential for conflict (Soulsbury & White, 2015). In North America, common examples of urban human-wildlife conflicts is with black bears (*Ursus americanus*) (Lewis et al., 2015) and coyotes (*Canis latrans*) (Elliot et al., 2016). Nulkar (2017) distinguishes human-wildlife conflict into two categories – silent and violent. The former occurs inadvertently and is often unnoticeable (eg. urban declines in pollinator populations (Herrmann et al., 2023)). The latter is intentional, often with the goal of pest removal or public safety (eg. destruction of food-conditioned bears (CBC, 2023)).

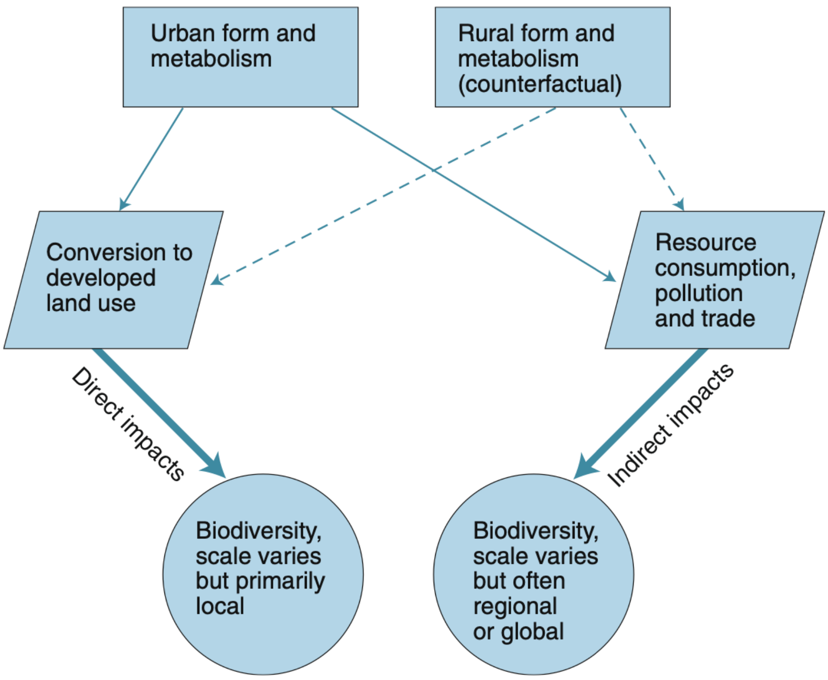

Figure 1. Urbanisation can have direct impacts through land use change, and indirect impacts through influencing other biodiversity pressures such as resource consumption and economic trade (McDonald et al., 2019).

Bird collisions on glass surfaces in urban areas is another example of a 'silent' human-wildlife conflict. In North America, building collisions are the second largest driver of avian mortality (after cats) (Loss et al., 2014). In Canada, it is estimated that approx. 25 million individual birds die due to collisions with buildings (Machtans et al., 2013).

Loss et al. (2019) concluded that bird collisions were correlated to magnitude of glass surface area and proximity of glass surface to vegetation, citing difficulties in perceiving glass surfaces as barriers. Furthermore, artificial light at night (ALAN) is another driver of bird collisions on buildings, as low nighttime visibility and reflections disorient birds (Adams et al., 2021; McLaren et al., 2018). Differences amongst species have also been observed. Migratory species like the varied thrush (*Ixoreus naevius*) (De Groot et al., 2021) have often been overrepresented in species composition of collision victims. Contrastingly, resident species and birds commonly associated with urban environments such as the black-capped chickadee (*Poecile atricapillus*) are under-represented in mortality statistics, being labelled by Arnold & Zink (2011) as a "super-avoider".

With barrier perception being cited as an issue, steps to attenuate collisions have often involved artificially improving visibility. For instance, adding stickers with opaque patterns is a commonly used tool – most notable being the symmetric dotted markers like those developed by FeatherFriendly. Other examples include the use of ultraviolet window markers (Håstad & Ödeen, 2014), and art (McGregor et al., 2020).

Figure 2. An example of FeatherFriendly® markers having been retrofitted on the facade of the Beaty Biodiversity Museum, located on the Vancouver campus of the University of British Columbia (University of British Columbia, 2019).

The campus of the University of British Columbia (UBC) in Vancouver has been the site of continued retrofits to make buildings more bird friendly (Figure 2). The university's long term plan, titled 'Campus Vision 2050', notes increasing on-campus biodiversity and species movements through campus green spaces as a future priority (UBC, 2023). Various campus buildings have been partially retrofitted over the last few years, including the Buchanan building block. Since 2021, successive members of the CONS 495/APBI 490D course have monitored the buildings in the Buchanan Block for evidence of collision, which has helped inform the Buchanan building management team.

This report builds on the work conducted by previous classes, with Buchanan being a building complex with data from four years – a rarity amongst UBC buildings. We used this data to understand the efficacy of consistent bird-friendly retrofits in attenuating window collision mortality. The 2024 season is the last data collection season for the Buchanan block. We hypothesize that, as the retrofit process continues, overall collision frequencies will have dropped in the Buchanan complex. We also expect to see a reduction in collisions associated specifically with the facades that have been retrofitted.

2. Materials and Methods

2.1 Study Site

The study takes place on the Vancouver campus of the University of British Columbia (UBC), located on the traditional, ancestral, and unceded territory of the Musqueam First Nation. This report focuses on the Buchanan complex, located on the north end of the campus at the corner of East Mall and Crescent Road. Constructed between 1958 and 1960 (George, 2019), the complex consists of five "blocks" (Figure 3) – A to E, and is notable for its courtyards that have a number of green spaces and large trees.

2.2 Methodology

In line with past years, the survey this year uses a modified version of that outlined by Hager & Cosentino (2014). As a three-member survey team, the decision was made to monitor three times a week, with each member surveying twice a week. All surveys were conducted in pairs. Prior to the survey beginning, the team conducted a cleaning (or if not possible, made a note) of all previous evidence of collisions, which allows for certainty that any evidence of collisions recorded occurred during the observation period. During the survey period, the week of February 19th was not monitored as it fell during spring break and no surveyors were available to monitor the building. A second 'clean-up' day was planned for right after spring break, and monitoring resumed until March 29th.

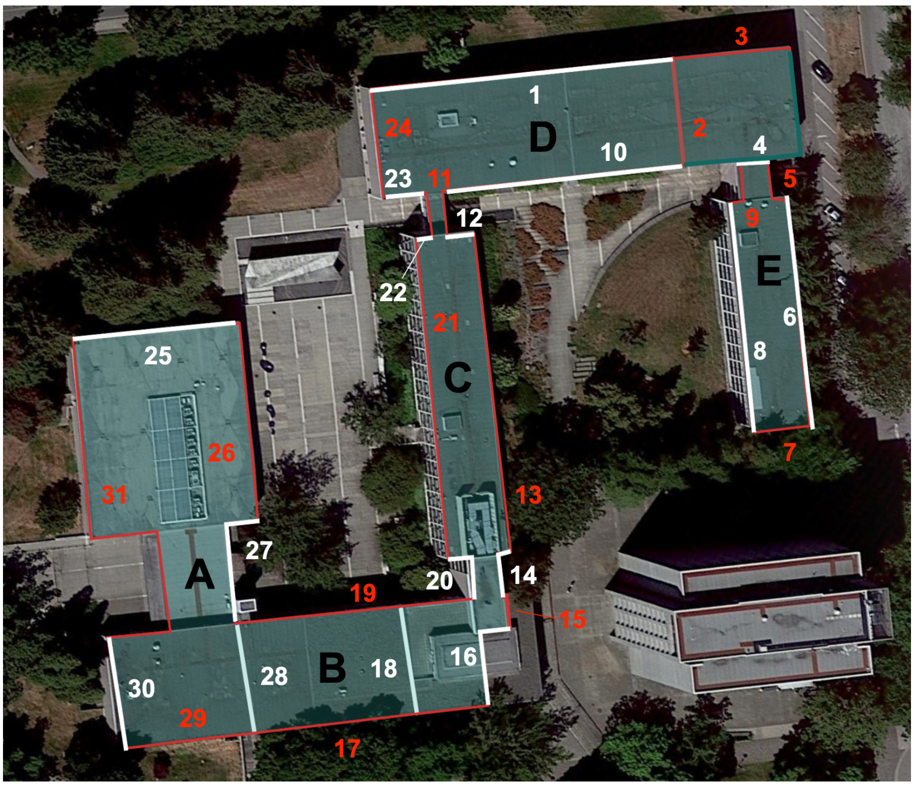

Figure 3. An aerial view of the Buchanan complex showing the five blocks, and each of the monitored glass facades, which have been numbered.

Beginning at Facade 31 (Figure 3), each surveyor would walk in opposite directions, silently observing for evidence of collision. Upon the end of the survey, both surveyors reconvened and, if there was evidence of a collision, would record it in Epicollect5. Evidence of collision include feather smears (where a single feather is stuck to a window), feather piles (where 10 or more individual feathers are located in a 1 meter radius circle), partial, or complete carcass. If no evidence was found, this would also be noted in Epicollect5, along with survey start time, surveyors present, and weather conditions. Evidence for collisions would only be recorded if observed within 2 meters of a facade. Binoculars were occasionally used to observe higher elevation facades. All surveyors were trained a week prior to the first week of data collection by a specialist representing our external partner, Environment and Climate Change Canada, at the Chan Centre for Performing Arts, located at 6265 Crescent Road on the UBC Vancouver campus.

If either a feather pile, partial, or complete carcass was observed, it was transported for storage and, if unable to be done so at site, identification. All surveyors were provided with masks, single-use gloves, cleaning disinfectant, high-visibility safety vests, and small zip-lock plastic bags. The three evidence types were safely bagged and stored in a freezer (MCML 208) in the MacMillan Building (2357 Main Mall). Feather smears were wiped clean using the provided surface disinfectant.

Over the years, different facades in Buchanan have been retrofitted with Feather Friendly® markers. Part way through the data collection period this year, facade 29 was retrofitted with the markers. This is reflected in the data, where all observations following the retrofit have the facade marked as having been retrofitted.

2.2.1 Carcass Persistence Trial

Using two carcasses, a carcass persistence trial was conducted to understand how long it took for a given carcass to be scavenged/removed. Carcasses used in this trial were distinguished by having a clipped hallux. One of the carcasses, a varied thrush (*Ixoreus naevius*), was randomly placed between facades 23 and 10, below a bridge connecting Buchanan C and D. The second carcass, a hummingbird, was randomly placed along facade 1, on a metal grate. In addition to the usual surveys, additional surveys were conducted to assess if the carcass had been removed. Additional scheduled check-ins to see if the carcass was still present were conducted at 12:00 hrs and 17:00 hrs on Tuesday (12^{th} March) and Wednesday (13^{th} March), and on 17:00 hrs on Thursday (14^{th} March). Time of removal was noted.

2.2.2 Searcher Efficiency Trial

A single carcass was randomly placed along the survey path on the week of 18th March to test the ability of observers to locate carcasses and to correct for any differences in searcher efficiency between observers. The carcass was placed along facade 17 (only known after the trial). If the carcass was spotted, it was to be distinguished as a searcher efficiency trial carcass through a clipped hallux, and then transported back to the freezer.

3. Results

Across all monitored buildings, Buchanan has the largest available data from past years, with collision data available from 2021. As seen in Figure 4, 2024 recorded the lowest number of collisions, with 10 collisions recorded. This represents an approx. 80 percent reduction in collision frequency compared to 2021, which recorded 49 collisions. Between all four years, the frequency of collisions has dropped consistently between 30 and 50 percent (Table 1). However, it should be noted that overall survey volumes have dropped in 2023 and 2024 (Figure 4). The average number of observations in 2023 and 2024 was 650, while the average for 2021 and 2022 was 982, representing an approx. 34 percent decline. All graphs were produced in R using the 'tidyverse' and 'ggplot2' packages. By block (Figure 5), Buchanan A recorded the highest number of collisions (4 – facades 25, 26, 31), accounting for 40% of all recorded collisions in 2024. The other four blocks (B (facade 19), C (facade 21), D (facade 10), E (facade 6)) recorded one to two collisions. Figure 6 adds collision data by block for the three previous years. In 2021 and 2022, Buchanan A also had the highest number of collisions. No carcasses were found during the data collection period.

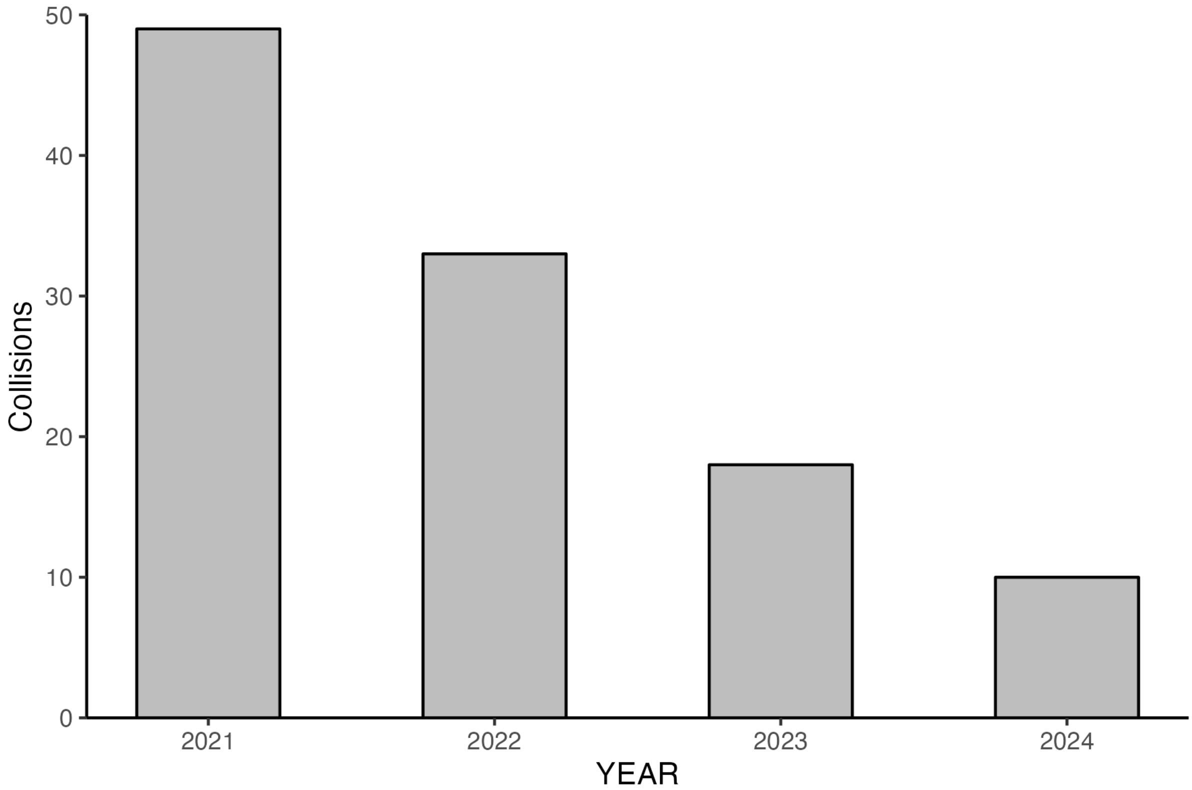

Figure 4. Trends in overall recorded collisions at the Buchanan complex from 2021 to 2024..

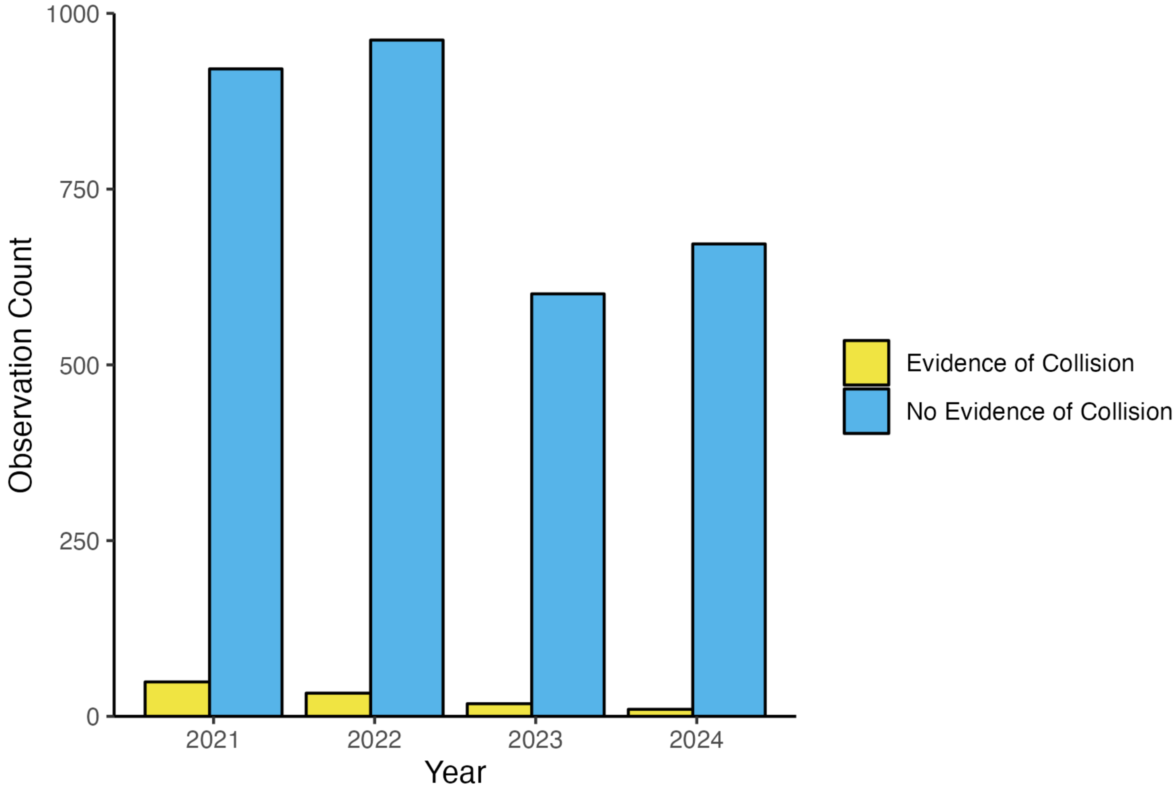

Figure 5. Changes in overall observation counts across surveyed years, split by whether the observation recorded a collision (represented in Figure 3) or no collision.

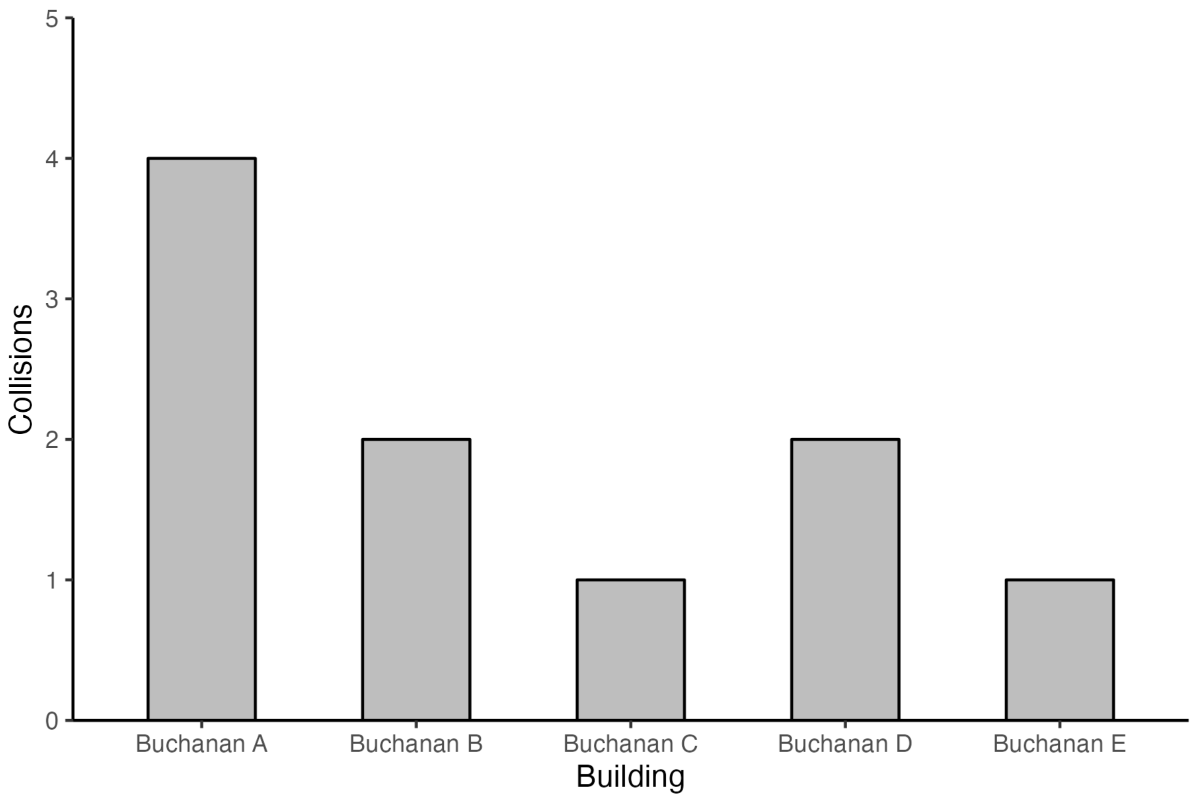

Figure 6. Collision frequency at Buchanan complex by block for the 2024 data collection period.

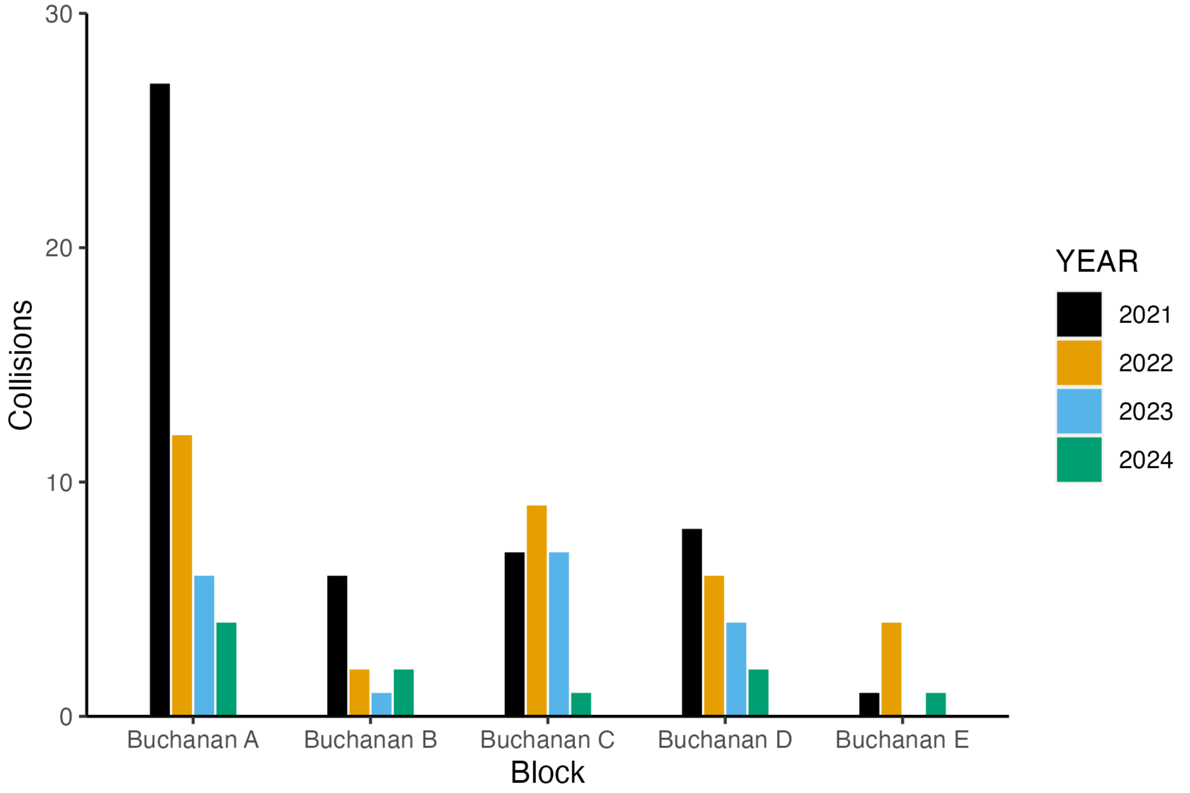

Figure 7. Collision frequency at Buchanan complex by block across all data collection years (including 2024).

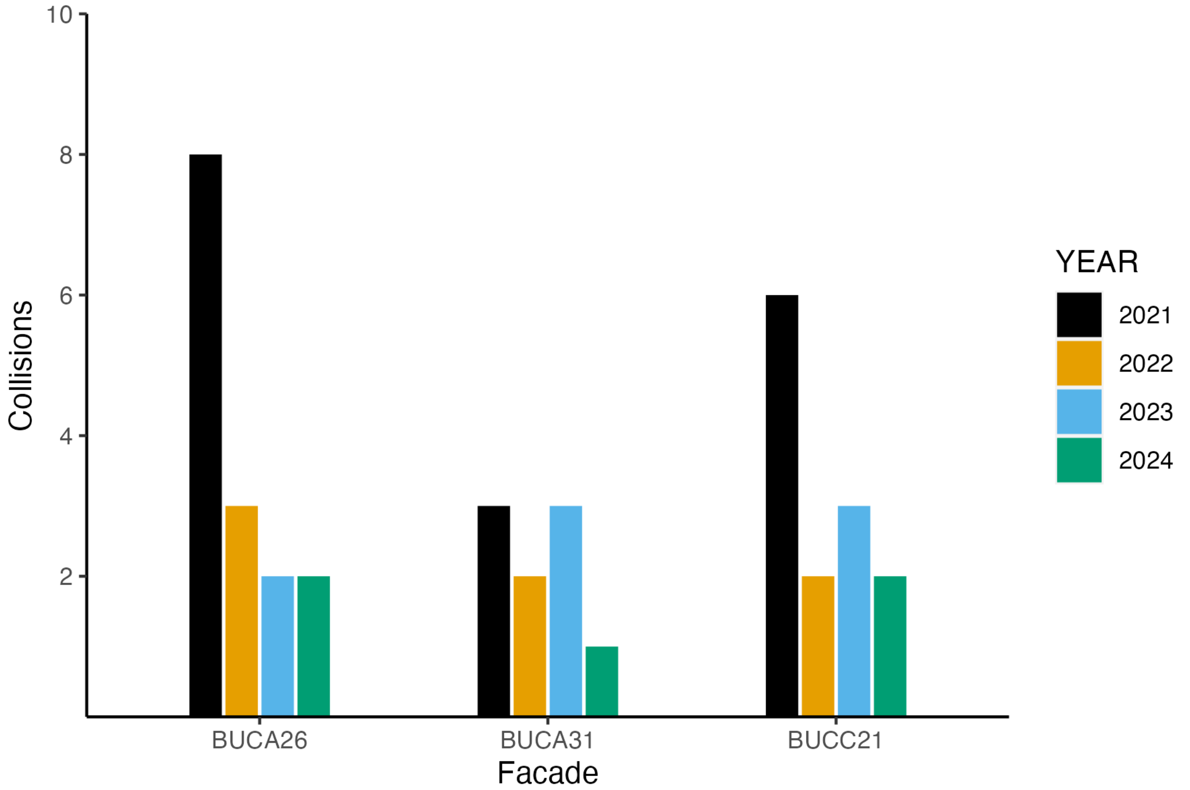

Figure 8. Collision frequencies for facades that recorded collisions for all data collection years (n = 3). Two of the facades are on Buchanan A, the block with the highest number of collisions recorded for three of the four data collection years.

Across all four years, a facade level analysis was also conducted to understand which facades recorded collisions consistently (Figure 7). From the assessment, facades 26, 31, and 21 were the three facades that recorded collisions across all four years (though they aren't necessarily the facades that had the highest number of collisions in a given year). None of these facades have been retrofitted with any bird-friendly films.

Table 1. Changes in collision frequencies at Buchanan complex from 2021 to 2024, with year-over-year percent changes in collisions as well as cumulative percent change between first and last year of data collection (2021 and 2024).

Year	Collision frequency	Percent change from previous year
2021	49	
2022	33	-32.7
2023*	18	-45.5
2024*	10	-44.4
	Cumulative change (2021 - 2024)	-79.6

* Years with three person monitoring team (compared to usual four person team)

Since 2021, the Buchanan building management team has steadily retrofitted three high-collision facades with Feather Friendly® markers. As of the end of the 2024 data collection period, three facades (25, 27, 29) have all been retrofitted. As facade 29 was retrofitted halfway through the 2024 data collection period, it is difficult to accurately understand the long-term impact of the retrofit on collisions. However, facades 25 and 27 had been retrofitted in 2022 and 2021 respectively (after each of their data collection periods had ended). Following retrofits, collision frequencies at both the facades dropped (Figure 8). By 2024, facade 27 had seen a 100% reduction in collisions compared to 2021. Similarly, facade 25 observed an 80% reduction in collision frequency between 2021 and 2024.

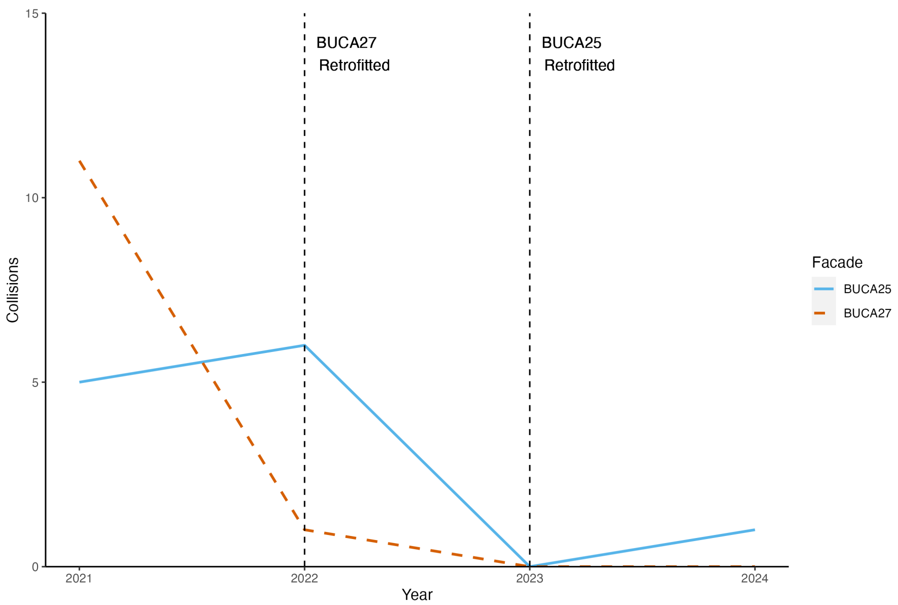

Figure 9. Changes in collision frequency in two retrofitted facades (25 and 27). Facade 27 was recorded as a retrofitted facade since the 2022 data collection period. Facade 25 was recorded as a retrofitted facade since the 2023 data collection period.

3.1 Searcher Efficiency and Carcass Persistence Trial Results

Within 48 hours of being placed, the varied thrush specimen was removed. However, it should be noted that the specimen had been moved from the pavement onto the soil of a hedge near its original location (at facade 10) a few hours after it had been placed. The hummingbird placed on the metal grate at facade 1 remained at that location till the end of the data collection period and was not removed.

Of the two observers scheduled on the day of the searcher efficiency trial, only one observer was able to correctly identify the placed carcass, which was placed at facade 17. Hence, searcher efficiency was observed to be 50% based on one trial.

4. Discussion

The main goal of this report is to longitudinally assess trends in bird collisions at this location, and if bird-friendly retrofits have had any noticeable impact on collisions frequencies (overall and at the facade level). While conducting a statistical test was outside the scope of the course in which this research was conducted, the results above suggest that bird-friendly retrofits have yielded declines in collisions.

Previous literature has attributed increases in bird collisions to a variety of factors. Loss et al. (2019), in a study investigating drivers of bird collisions in Minneapolis, USA, observed positive trends between frequency of bird collisions and (a) the total glass area and (b) proximity to vegetation. These results echo those from a decade earlier by Gelb & Delacretaz (2009) from Manhattan, USA. They link the trends in collisions to vegetation reflecting off the glass surface, hence leading to a higher number of collisions on the lower glass facades. In an analysis involving 40 different university campuses across north America, Hager et al. (2017) concluded that building size and glass area were key factors, and that rates of surrounding urbanization influenced the strength of these factors.

The Buchanan complex is surrounded by vegetation. As seen in Figure 9, many of the glass facades are highly reflective and many large trees are present within a few meters of the building. It is hence plausible then, as mentioned by previous reports on the Buchanan building (Hardy, 2022; Harter, 2022), vegetation continues to be a driving factor in collisions at Buchanan. In our study, collisions were localized to Buchanan A. No measured of total glass area, or glass area by block are available for the Buchanan complex. However, the localization reflects patterns seen by Loss et al. (2019), where most collisions are attributed to small number of "problem" buildings/facades.

Figure 10. An observer's view of facade 17 at the corner of facade 16 and 17. During days with good weather, trees can easily reflect strongly off the glass windows of offices in the building.

It was also observed that at least one office in the complex had a bird feeder attached outside their window. While studies on the effects of bird feeders as the primary variable are few, the few that do exist suggest a significant positive relationship between the presence of a bird feeder and likelihood of reporting a collisions (Kummer & Bayne, 2015). Food as a possible attractant is a possibility, given the presence of a local coffee shop within the Buchanan complex in Buchanan A (facade 26, a high collision facade, is the window for the café). However, previous studies on the effect of food on spatial use by species in the area like the varied thrush (*Ixoreus naevius*) found no significant relationship between food source and abundance in the winter (Koenig & Knops, 2022). However, such studies have mainly focused on natural food sources such as acorns, and not the anthropogenic food that may be available in higher abundance at the Buchanan complex.

Beyond abiotic characteristics such as vegetation and glass area, previous studies on the matter have also observed differences in the species composition of the collision victims. Specifically, many studies have cited the susceptibility of migratory species to collisions compared to resident species (Arnold & Zink, 2011; Colling et al., 2022; Loss et al., 2014). Loss et al. (2014) notes that increased travel distances through a variety of habitat types, particularly during night-time migration, all contribute to them representing a higher proportion of building collisions mortality (and peaks in collision frequencies in the spring and fall as they correspond with seasonal migrations).

However, as observed by De Groot et al. (2021), regional contextualization of this general trend is important in the Pacific northwest. Hiemstra et al. (2020) posited that, as a result of having milder winters, collision frequencies in the Pacific northwest might be higher than compared to studies that occur in eastern north America, where winters are more intense. Boyle & Martin (2015) highlighted the importance of the Fraser Valley as a migratory corridor for short-distance and altitudinal migrants. For instance, the varied thrush (*Ixoreus naevius*) is a locally migratory bird that breeds in Alaska and British Columbia and overwinters in the western United States (Koenig & Knops, 2022). In De Groot et al. (2021), the varied thrush was by far the most common species to be killed in a collision, comprising 13% of all collision carcasses. Furthermore, De Groot et al. (2021) noted a high collision mortality throughout the winter (equal to spring mortality), contrasting other non-local bird collision species composition assessments.

On the two facades that were retrofitted, both declined precipitously in the number of collisions recorded. However, facade 25 located on Buchanan A is located at an elevated surface with a ledge. Prior to data collection, many feather smears were visible on the facade, suggesting that collisions had nonetheless been occurring on the facade, though only one new smear was noted during the data collection period this year. The decline in collisions reflects literature on the impact of visibility improving mechanisms such as the

Feather Friendly® stickers. De Groot et al. (2022) observed a 95% reduction in collisions following a Feather Friendly® retrofit on a building in a wildlife management area in Delta, British Columbia. This is similarly the case in other studies in the United States (Brown, 2014; Riggs et al., 2023).

4.1 Experimental Limitations

Training observers is an important step in ensuring consistent searcher effort (Hager & Cosentino, 2014). Individuals were trained at the Chan Centre for Performing Arts (6265 Crescent Road) for two hours a week prior to surveys beginning. However, no training was provided at the Buchanan complex, which led to varied effort during the first week of survey as observer's familiarised themselves with the complex. Furthermore, routine construction temporarily hindered search efforts for some weeks at facade 6.

Owing to a difficult in scheduling, survey days were not consistent across the data collection period. During some weeks, observations would be conducted every day for three days, before not occurring for the next few days. Given the results from the carcass persistence trial that suggest that carcasses disappear within 48 hours, this may have led to an underestimation of carcasses as collisions on the last survey day of the week are likely removed by the time the next week begins. Another source of underestimation is the searcher efficiency trial, showing that only half of all carcasses are being observed. Since only one of the two observers identified the carcass, a potential 50% underestimation is possible, though more trials involving all observers in the team across multiple survey days will be needed to accurately correct for searcher biases.

4.2 Future Considerations for Management

Looking ahead, literature suggests that a few targeted retrofits can yield large changes in collision occurrences. Based on the last four years, it is strongly recommended that facades 21, 26, and 31 be considered for Feather Friendly® retrofits. These facades, as mentioned above, are the only surfaces to have had collisions every year of monitoring. This suggests that a confluence of factors influence the collision probability at these surfaces that, when combined, vary minimally enough year-to-year to cause collisions for four years. A public outreach and education campaign, particularly amongst teach staff and faculty that occupy the offices (which account for the largest amount of glass surface area), is also a valuable step forward. Loss et al. (2023) note the importance of citizen science campaigns in this regard, particularly given the limited institutional support provided for this human-wildlife issue. It can serve to improve the issue's visibility while also increasing the pool of knowledge available as individuals self-report collision occurrences.

Finally, the unique format of this experiment – relying on students in upper year conservation and wildlife classes, is a format that should be built upon. Such opportunities allow young practitioners to engage with external stakeholders and fieldwork while being a cost-effective solution to collect valuable data on an urgent conservation matter. However, expanding the scope of the experiment to cover the entirety of spring and fall migration (and if possible, summer) would improve the quality of the data significantly. It would allow for other comparisons such as across seasons on UBC's campus across multiple buildings (similar to De Groot et al. (2021)).

5. Conclusion

Bird collisions on buildings are a pressing issue on the campus of the University of British Columbia. Longitudinal studies have shown that collisions are occurring in high numbers (De Groot et al., 2021; Hardy, 2022; Harter, 2022) on existing buildings, which aren't mandated by the university's building recommendations UBC (2018) to be made bird-friendly. UBC's Campus Vision 2050 seeks to make the UBC Vancouver campus a pioneering human-wildlife co-existence space where human use and education aren't occurring at the expense of the wide variety of biodiversity in the area. Literature on the retrofitting of glass surfaces is clear – while not 100% effective, they are consistently significantly more effective than plain glass. Furthermore, retrofits, if targeted, can reduce collisions drastically for a small relative cost.

A pressing wildlife issue, a commitment from local policymakers, and an established and relatively cost-affordable solution that already is proven to work in the target location, should all be indicators to continue investments in making the Buchanan complex bird friendly.

6. Acknowledgements

As stated earlier, all work conducted in this paper occurred on the traditional and ancestral territories of the Musqueam First Nation, and that this land is unceded. All experimental work was conducted with the support of the CONS 495/APBI 490D teaching team and the course instructor for the 2023W2 session, Nadia Xenakis. Guidance was primarily provided by the community partner on the project, Simon Valdez Juarez, from Environment and Climate Change Canada.

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7. Supplementary R Material

7.1 Packages Used

```r
library('tidyverse')
library('ggplot2')
library('RColorBrewer')
library(stringr)
```

7.2 Figure 4 and Table 1

```r
Table_1 <- Master_Sheet %>%
  group_by(YEAR) %>%
  summarize(Collisions = sum(Evidence),
            No_Collisions = n() - sum(Evidence))
Figure_4 <- ggplot(Table_1, aes(x = YEAR, y = Collisions)) +
  geom_bar(stat = "identity", fill = "grey", color = "black",
  width = 0.5)+
  theme(panel.background = element_blank(),
        axis.line = element_line(color = "black"))+
  ylim(0,50)+
  scale_y_continuous(expand = c(0,0), limits = c(0, 50))
```

7.3 Figure 5

```r
Collision_Gather <- gather(Table_1, key = "variable",
                           value = "value", -YEAR)
Figure_5 <- ggplot(Collision_Gather, aes(x = YEAR, y = value,
fill = variable)) +
  geom_bar(stat = "identity",
  position = position_dodge(width = 0.8), color = "black") +
  scale_fill_manual(values = c("#F0E442","#56B4E9"), name = "",
            labels = c("Collisions" = "Evidence of Collision",
            "No_Collisions" = "No Evidence of Collision")) +
  labs(x = "Year", y = "Observation Count")+
  theme(panel.background = element_blank(),
  axis.line = element_line(color = "black"))+
  ylim(0,1000)+
  scale_y_continuous(expand = c(0,0), limits = c(0, 1000))
```

7.4 Figure 6

```
Buildings_2024 <- Master_Sheet %>%
  filter(YEAR==2024) %>%
  group_by(Building) %>%
  summarise(Collisions = sum(Evidence))
Figure_6 <- ggplot(Buildings_2024, aes(x = Building, y = Collisions)) +
  geom_bar(stat = "identity", fill = "grey", color = "black",
  width = 0.5)+
  theme(panel.background = element_blank(),
        axis.line = element_line(color = "black"))+
  scale_y_continuous(expand = c(0,0), limits = c(0, 5))+
  scale_x_discrete(labels = c("BUCA" = "Buchanan A",
                              "BUCB" = "Buchanan B",
                              "BUCC" = "Buchanan C",
                              "BUCD" = "Buchanan D",
                              "BUCE" = "Buchanan E"))
```

7.5 Figure 7

```
Buildings <- Master_Sheet %>%
  group_by(Building, YEAR) %>%
  summarise(Collisions = sum(Evidence))
cbbPalette <- c("#000000", "#E69F00", "#56B4E9",
"#009E73", "#F0E442", "#0072B2", "#D55E00", "#CC79A7")

Buildings <- Buildings[-9, ] #In case of double BUCB 2022 entry
Buildings$YEAR <- as.factor(Buildings$YEAR)

Figure_7 <- ggplot(Buildings, aes(x = Building,
y = Collisions, fill = YEAR)) +
  geom_bar(position = position_dodge2(width = 1.5,
  preserve = "single"), stat="identity", width = 0.5)+
  theme(panel.background = element_blank(),
        axis.line = element_line(color = "black"))+ ylim(0,30)+
  scale_y_continuous(expand = c(0,0), limits = c(0, 30))+
  scale_x_discrete(labels = c('Buchanan A', 'Buchanan B',
  'Buchanan C', 'Buchanan D', 'Buchanan E'))+
  labs(x = "Block")+
  scale_fill_manual(values=cbbPalette)
```

7.6 Figure 8

```r
Facade_FF <- Master_Sheet %>%
  group_by(YEAR, Facade) %>%
  summarize(Collisions = sum(Evidence)) %>%
  filter(Facade %in% c("BUCA25", "BUCA27"))
Figure_8 <- ggplot(Facade_FF, aes(x = YEAR, y = Collisions,
linetype = Facade, color = Facade, group = Facade)) +
  geom_line(linewidth = 0.9)+
  geom_vline(xintercept = 2022, linetype = "dashed",
  color = "black")+
  geom_text(aes(x = 2022, y = 13,
  label = str_wrap("BUCA27 Retrofitted", width = 5)),
             vjust = -0.5, hjust = -0.2, color = "black")+
  geom_vline(xintercept = 2023, linetype = "dashed",
  color = "black")+
  geom_text(aes(x = 2023, y = 13,
  label = str_wrap("BUCA25 Retrofitted", width = 5)),
             vjust = -0.5, hjust = -0.2, color = "black")+
  theme(panel.background = element_blank(),
        axis.line = element_line(color = "black"))+
  ylim(0, 15)+
  scale_y_continuous(expand = c(0,0), limits = c(0, 15))+
  labs(x = "Year")+
  scale_color_manual(values = c("#56B4E9", "#D55E00"))+
  scale_linetype_manual(values = c("solid", "dashed"))
```