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The Influence of Building Surroundings and Glass Cover in Bird Collisions

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Simple Summary: Building surroundings can impact bird collisions with glass structures. This study examined the influence of factors including the presence of trees, the proximity of trees, the number of fruit trees, and the area of glass on bird collisions at a Brazilian university campus. Over one year, 24 bird deaths were recorded. The results showed that both the number of trees and the glass area significantly increased bird collisions, probably due to reflections of trees in the glass. To reduce bird collisions, limiting large glass surfaces or prioritizing mitigating the risk of bird collisions with building facades where vegetation is present by installing visual markers on the glass and reducing artificial light at night is recommended.

Abstract: The characteristics of building surroundings can influence the number of bird deaths caused by collisions with glass structures. Thus, this study investigated whether the number of trees, the distance to the nearest tree, the number of fruit trees, and the glass area influenced the number of bird collisions on a university campus in Brazil from March 2017 (breeding and non-breeding seasons) to January 2018 (breeding season). Twenty-four birds died due to collisions with the windows in the one-year sampling. Among the factors evaluated, the number of trees and the area of the glass predicted the number of deaths from collisions. The greater the number of trees and the glass area, the greater the number of bird collisions. This suggests that the more vegetation there is near windows, the more birds are attracted, and the less visible the glass barrier becomes, possibly due to the appearance of trees in reflections or scenes viewed through the glass, making it difficult for birds to distinguish the real landscape from the reflected environment. If large expanses of glass are placed on buildings near vegetation, including trees, more bird collisions will occur. Thus, to reduce bird collisions, building designs should reduce the amount of glass used on building exteriors near vegetation and ensure the glass is treated with visual markers.

Keywords: birds; building architecture; collision prevention; urban ecology; vegetation

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1. Introduction

Birds that inhabit the urban environment face many threats that may impair their survival in urbanized areas, such as collisions with glass on buildings [1]. Bird collisions with glass may also become a problem in rural areas if human structures that are built for leisure, such as mirror cabins/cottages, do not use a bird-friendly design, such as a pattern of visual markers on the glass [2]. Bird collisions with glass during the daytime usually occur due to two factors: (1) the glass may reflect the surrounding habitat, making the birds unable to distinguish the barrier between the real environment and the reflection, or (2) the windows may be transparent, which causes birds to see a free corridor, not change their flight course, and collide directly with the window [3,4]. Other environmental factors, such as the area of a glass window and the surrounding vegetation, can predict the risk of bird–window collisions [5,6], with increases in bird collisions being related to an increase in glass area [7,8] and vegetation (trees, shrubs, vines, and flowers) being close to glass windows because birds seek food and shelter in the vegetation [9]. In the present study, we focus specifically on the presence of trees around buildings, because in the study area, this type of vegetation is used in landscaping. Trees that bear fruit may attract more birds and increase their local abundance, as well as their risk of colliding with glass on nearby buildings [2]. Since buildings frequently do not have vegetation surrounding their entire perimeter, in studying bird collisions, facades with vegetation in the vicinity can be concentrated on [10,11].

Due to the magnitude of this problem, many alternatives have already been evaluated for avoiding or minimizing the number of bird collisions with glazing (glass panels or windows installed in buildings), like modifying the environment near the windows to avoid the attraction of birds [3,12,13]. Eliminating fruit-bearing vegetation less than 1 m from windows is a suggested measure to reduce the risk of collisions, in addition to applying visual markers on glass [2,13]. However, reducing vegetation around buildings may also compromise the quality of the habitat for birds in urban areas [14,15].

In Brazil, there are 1971 recorded bird species [16]. Few studies to date have recorded bird collisions with buildings in Brazil, and as a result, there is limited information about the effects of collisions on bird populations in the region [17–21]. Previous studies carried out in Brazil have not systematically evaluated the effects of local environmental variables and architectural characteristics on bird collisions. Thus, we investigated possible environmental factors (the number and distance of trees, the presence of fruiting trees, and glass area) that would influence the number of bird–window collisions. We predicted that the greater the number of trees and fruit trees, the closer the trees, and the greater the glass area, the greater the number of bird collisions.

2. Materials and Methods

2.1. The Study Area and Experimental Protocol

This study was carried out at the Federal University of Ouro Preto (UFOP) (20°23′ 42.49″ N, −43°30′43.20″ W) in the buildings of the Institute of Exact and Biological Sciences (ICEB) and the School of Nutrition (ENUT) (n = 8 buildings; Figure 1), located at the Morro do Cruzeiro Campus in the city of Ouro Preto, Minas Gerais, southeastern Brazil. The Institute of Exact and Biological Sciences buildings are low-rise (with one floor) or mid-rise (with two and three floors) structures. Connecting these buildings are corridors with transparent glass panes, without any kind of marks or reflective components other than the glass itself (Figure 2A). The School of Nutrition buildings are low-rise (one floor) structures. In these buildings, in addition to the glass windows, large transparent glass doors can be seen throughout the structure. Again, the doors have no reflective components other than the glass itself (Figure 2B). These buildings were selected because in these areas (corridors and doors) with many glass surfaces, bird mortality due to window strikes has been previously observed. In addition, the university buildings have gardens in their surroundings, with many fruit tree species, which offer an excellent availability of food for birds.

This study was conducted in eight sampling areas from March 2017 (during breeding and non-breeding seasons) to January 2018 (breeding season; Figure 1). The areas were visited daily for 10 min in each area, totaling 313 h of survey effort. Data sampling was always carried out by the same two researchers together, who always traveled the same walking route. Sampling was carried out in the morning (8:00–12:00 h a.m.) and in the afternoon (1:00–4:00 h p.m.). In each sampling area, the number of trees and fruiting trees [individual guava (*Psidium guajava*), Brazilian cherry (*Eugenia uniflora*), mulberry (*Morus* spp.), and loquat (*Eriobotrya japonica*) trees were present, but not all of the tree species were known]; the distance from the nearest tree to the windows; the area covered by the windows (hereafter referred to as surface area, calculated after measuring the length and height of the windows with a tape measure); and the diversity and total number of birds that collided with the glass windows were recorded (Table 1). Data about the characteristics of each study area (the nearest tree and number of fruiting trees) were collected up to a 50 m distance from the glass windows. All the trees were counted regardless of their size; a tree was defined as a plant with a high, woody, and robust main trunk (most of them were already large trees, but some smaller trees were also counted). All trees were counted to obtain the total number of trees in the area, and then a separate count for fruiting trees only was included. We measured the distance of the trees to a building/window using a tape measure from the trunk to the window in a straight line. Carcasses were included in the dataset only if they were found on the ground within 2 m of where the nearest building facade met the ground. Collisions where a carcass was removed/scavenged but other evidence was left behind (e.g., remaining feathers) would also be counted, but none of these cases occurred during the sampling period.

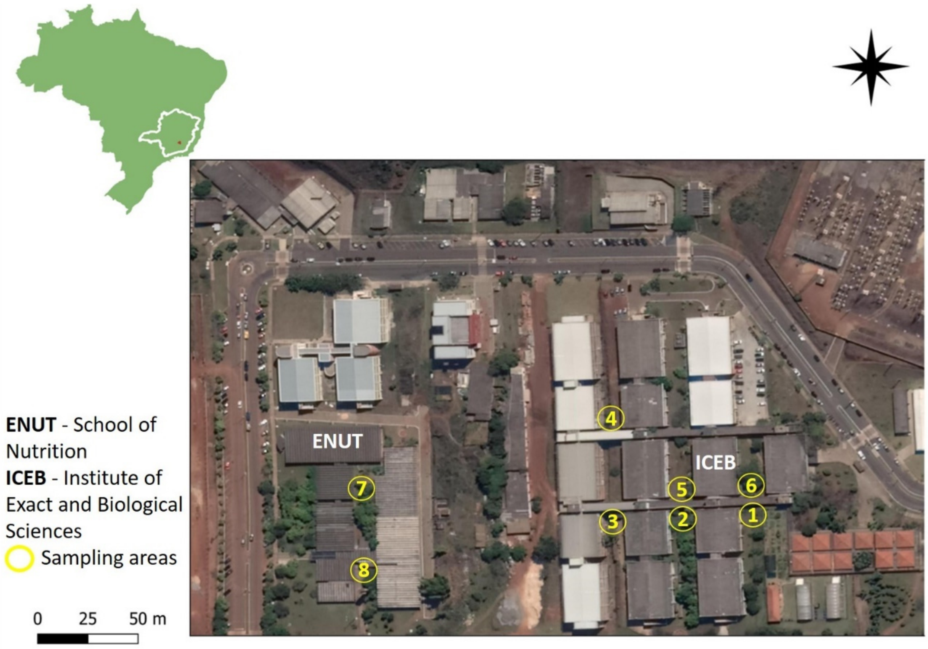

Figure 1. Sampling areas (yellow circles) of the Federal University of Ouro Preto (UFOP). Six areas were sampled at the Institute of Exact and Biological Sciences (ICEB) and two at the School of Nutrition (ENUT).

Table 1. Number of trees, distance from the nearest tree, and glass area found in each of the building sampled areas of the Institute of Exact and Biological Sciences (ICEB) and the School of Nutrition (ENUT) of the Federal University of Ouro Preto (UFOP).

Sampling Area	Number of Trees	Distance of the Windows to the Nearest Tree (m)	Glass Area (m^2)
1	12	8.55	64.53
2	15	1.35	36.75
3	3	8.85	43.29
4	4	0.22	46.49
5	8	2.58	36.75
6	6	0.80	46.22
7	21	10.83	10.37
8	5	42.74	4.752

Figure 2. (**A**) View of the corridors connecting the Institute of Exact and Biological Sciences (ICEB) buildings, highlighting the windows where bird collisions have been reported. (**B**) View of one of the School of Nutrition (ENUT) glass doors where bird collisions have been reported. Both areas are located at the Federal University of Ouro Preto (UFOP).

The dead birds found during this study were collected, taken to the Vertebrate Zoology Laboratory of the Federal University of Ouro Preto (LZV-UFOP), identified using Sigrist's field guide [22], taxidermized, and deposited into the LZV-UFOP's Zoology Collection.

2.2. Data Analysis

First, we evaluated the correlations among the model parameters. We found that the number of trees, the number of fruit trees, the distance of the nearest tree, and the surface area were not strongly correlated ($r < 0.7$) [23]. Then, we used generalized linear models (GLMs) to assess whether the number of bird deaths (response variable) was influenced by the number of trees, the surface area, the number of fruit trees, and the horizontal distance between the facade of glass and the nearest tree (explanatory variables). The generalized linear models were built using the package lme4 [24]. All statistical tests were run using the software R 4.4.1 [25] with a 95% ($\alpha = 0.05$) significance level and with a Gaussian distribution for the variables.

3. Results

In our monitoring of the buildings, we recorded twenty-four individual dead birds spanning 15 species that were killed by colliding with glass on the buildings at the UFOP Institutes. The species that were observed to collide most often were the Sayaca Tanager (*Thaupis sayaca*), the Swallow Tanager (*Tersina viridis*), and the Rufous-Bellied Thrush (*Turdus rufiventris*), with three individuals in each species (Table 2).

The number of trees in the area studied was positively associated with the number of birds killed by collision with the glass ($F_{1137} = 3.76$, $p < 0.001$, $n = 1138$; hereafter, the number subscripted in the results corresponds to the degrees of freedom used in the GLMs, while N represents the number of samples recorded during the data collection). The area covered by the windows ($F_{1137} = 3.16$, $p < 0.001$, $n = 1138$) was also positively associated with the number of bird collisions. Neither the nearest tree in each area ($F_{1137} = 1.63$, $p = 0.10$, $n = 1138$) nor the number of fruiting trees ($F_{1137} = -1.13$, $p = 0.26$, $n = 1138$) were associated with the number of bird collisions. We tested this model against the null hypothesis, and the model was significantly different ($F_{1137} = 7.11$, $p < 0.001$, $n = 1138$), with the number of trees and the surface area explaining 99% of the response (Pseudo $r^2 = 0.987$).

Table 2. Orders, families, and species of birds that collided in the sampling areas during the one-year sampling (2017–2018). The taxonomic classification of the birds follows the annotated checklist of the birds of Brazil by the Brazilian Ornithological Records Committee [16]. Information on the birds' diets was taken from scientific articles [26,27] and books [28,29].

Order	Family	Species	Diet	Number of Birds
Apodiformes	Trochilidae	Glittering-Throated Emerald *Chionomesa fimbriata* (Gmelin, 1788)	Nectarivorous	1
		Swallow-Tailed Hummingbird *Eupetomena macroura* (Gmelin, 1788)	Nectarivorous	2
Columbiformes	Columbidae	Ruddy Ground Dove *Columbina talpacoti* (Temminck, 1811)	Granivorous	1
Passeriformes	Icteridae	Shiny Cowbird *Molothrus bonariensis* (Gmelin, 1789)	Omnivorous	1
	Mimidae	Chalk-Browed Mockingbird *Mimus saturninus* (Lichtenstein, 1823)	Omnivorous	1
	Thraupidae	Sayaca Tanager *Thraupis sayaca* (Linnaeus, 1766)	Frugivorous–insectivorous	3
		Swallow Tanager *Tersina viridis* (Illiger, 1811)	Frugivorous–insectivorous	3
		Palm Tanager *Thraupis palmarum* (Wied, 1821)	Frugivorous–insectivorous	2
		Burnished-Buff Tanager *Stilpnia cayana* (Linnaeus, 1766)	Frugivorous–insectivorous	1
		Guilt-Edged Tanager *Tangara cyanoventris* (Vieillot, 1819)	Frugivorous	1
	Turdidae	Creamy-Bellied Thrush *Turdus amaurochalinus* Cabanis, 1850	Insectivorous–frugivorous	1
		Rufous-Bellied Thrush *Turdus rufiventris* Vieillot, 1818	Insectivorous–frugivorous	3
		Pale-Breasted Thrush *Turdus leucomelas* Vieillot, 1818	Insectivorous–frugivorous	1
	Tyrannidae	Yellow-Bellied Elaenia *Elaenia flavogaster* (Thunberg, 1822)	Frugivorous–insectivorous	1
Piciformes	Picidae	Green-Barred Woodpecker *Colaptes melanochloros* (Gmelin, 1788)	Frugivorous–insectivorous	2
Total				24

4. Discussion

We observed that the number of collisions increased according to the number of trees in the area studied such that the greater the number of trees, the greater the number of bird collisions in the windows. The trees probably attracted the birds near the buildings since they provide refuge and food for them. Our results are consistent with previous studies that also found a positive relationship between the presence of trees near glass on buildings and the incidence of bird collisions. For example, a study carried out in Cleveland (USA) found an increase in bird collisions was related to the number of trees less than 5 m away from the windows [30]. Thus, it is necessary for the designs of buildings and the landscaping around those buildings to consider that trees being planted close to windows may attract birds and lead to an increased risk of causing collisions. In the present study, the number of bird collisions was not related to the distance of the closest tree or the number of fruiting trees. The distance of the closest trees varied widely in the areas studied, from 80 cm to more than 8 m from the windows. The distance of the fruiting trees also varied. The overall distribution of the tree distances from the buildings may explain the lack of a significant effect of this variable on bird–window collision in the present study.

Collisions increase considerably when vegetation is close to glass windows [9]. Windows reflect what is around them [31,32], making it difficult for birds to distinguish between the environment and what is being reflected [31,33]. The architectural composition of the buildings, particularly the amount of their surface area covered by glass, predicted where the most bird collisions occurred, such that larger expanses of glass were more likely to suffer a greater number of collisions [7,8]. Thus, reducing the area covered with glass in buildings can decrease the number of bird collisions, reducing the impact of buildings on the bird community.

Reducing the area covered by glass is just one of the alternatives suggested for reducing bird collisions. Due to the magnitude of this problem, many alternatives have already been evaluated for avoiding or minimizing the number of bird collisions with glazing [34]. The suggestions are grouped into three major groups: (1) window screens; (2) barriers on windows; and (3) changes in the surroundings of the buildings [3].

In the group of window screens, the recommended actions involve applying materials onto the windows that allow birds to perceive the presence of a physical barrier and avoid it. Examples include installing curtains behind the glass and keeping them closed (suitable where glass appears transparent from the outside; this method is not effective where glass is reflective). Installing materials onto the outside surface of windows can help reduce their transparency and reflectivity. Stickers or decals may be applied onto windows to form a pattern, such as straight lines separated by 5 cm gaps vertically or horizontally, or points glued in parallel, forming an array. However, a single adhesive is insufficient; applications of any decals or stickers, such as silhouettes of predators, need to cover the entire glass surface without leaving gaps [12]. The same apples to applications of paint onto glass [13]. Finally, when windows are replaced during a renovation, it is possible to exchange the glass for alternatives with patterns embedded, such as sandblasted glass.

In the group of window barriers, the recommended actions focus on placing structures in front of the windows to prevent birds from colliding directly with the glass. Installing 2.5 × 20 cm nylon nets onto the outside of windows, 5 cm from the glass, and installing mosquito nets or similar meshes onto the outside of windows are examples of this type of solution [35].

In the group of changes in the surroundings, these actions are focused on modifying the environment near the windows to limit the attraction of birds. Eliminating fruit plants near the windows and placing bird feeders less than 1 m from the windows are suggested measures in this group [13]. Overall, the effectiveness of each of these methods for preventing bird collisions is affected by factors that are specific to each window, and therefore solutions should be considered on a case-by-case basis [3,35].

Of the 24 bird species recorded to fatally collide with the windows, most were frugivorous–insectivorous (Swallow Tanager, Palm Tanager, Sayaca Tanager, Rufous-Bellied Thrush, and Green-Barred Woodpecker), with one being nectarivorous (Swallow-Tailed Hummingbird). These birds were small to medium in size (15–28 cm in length) and included species that are solitary, as well as flocking and frequently observed in urban areas [28,29]. This result could suggest that the fruiting trees were attracting the birds to feed, but there was no relationship between the number of collisions and the number of fruiting trees in the study area. Some possible interpretations raised were that the birds sought shelter in the trees, looking for insects or nectar to feed on, or that they were simply abundant in the area, increasing their chances of being recorded to collide with the windows. The relationships between the composition of the vegetation, effects on the behavior of different bird species, and their vulnerability to collisions with glass are an important topic for future research.

In Brazil, few studies showing the number of bird deaths due to glazing collisions have been conducted. There are increasing reports of bird collisions with windows [4,19,21,36,37]. However, studies aiming to collect data on the number of bird–window collisions are still insufficiently considerate of collisions in Brazil [20], as well as in South America, where biodiversity is high and the human population is growing [32]. In Argentina, one study showed that birds colliding with windows is a common and widespread event [32]. Another example is a study carried out in the city of Brasília, which revealed that more than 100 individuals of 20 species of birds died annually due to collisions with mirrored facades [38]. In 2017, another study was published in the building of the Caraça museum in Serra do Caraça Natural Reserve (Minas Gerais state) that found 57 bird deaths due to glass collisions, including deaths of threatened, endemic, and migrant species [20].

This study provides a valuable addition to the literature on bird–window collisions, specifically by addressing a relatively understudied region of South America. It offers insights into the locations of the collisions, focusing on bird species and building characteristics that might differ from those observed in other regions. Given that many migratory bird species spend their winter in South America, it is crucial to understand how threats like window collisions impact these species across their migratory ranges. Moreover, this study stands out due to its careful control of the survey effort during the data collection, allowing the dataset to be integrated with results from other studies for broader comparative analyses. Additionally, these data gathered from a university campus in Brazil offer practical implications for conservation management by identifying specific buildings prone to causing bird collisions. These findings could guide targeted interventions, such as window treatments, to mitigate bird mortality based on empirical evidence. Finally, since the general public can play a role in contributing data on bird collisions by uploading photographs to citizen science platforms such as the Global Bird Collision Mapper [39] or iNaturalist [40], it is suggested that bird–window collisions be reported whenever they are observed. This approach has the potential to raise awareness of bird collisions in other regions of South America, thereby broadening the understanding of the issue across diverse geographical areas.

Although this study offers valuable insights into bird–window collisions, several limitations must be acknowledged when interpreting the results. The data were collected over a single year and from a very limited area, which restricts the broader applicability of the findings. The small sample size further reduces the strength of the conclusions. Additionally, the local bird species composition was not assessed, which could have influenced the collision rates due to species-specific behaviors or population densities. This study did not examine collisions in relation to factors like building surface area or floor space either, which might have revealed more about the structural and environmental drivers of collisions [41]. Another limiting factor is the fact that most of the plants evaluated are unidentified; as most of them are fruit-bearing plants, we expect that a greater number of frugivorous birds will end up colliding with the glass. However, many insectivorous species were observed colliding with the glass and this may be related to the species of trees at the site. It would therefore be important for future studies to properly identify the plant species located near the windows. Lastly, there is the possibility that not all fatalities were recorded due to the loss of bird carcasses by removing scavengers, lawn mowers (such as ants), or people, potentially leading to an undercount of the total number of collisions [42]. These limitations highlight the need for more comprehensive research to fully understand the factors influencing bird collisions with glass.

5. Conclusions

In conclusion, to decrease the number of or avoid bird deaths due to window collisions, the recommended strategies include reducing the size of the area on buildings covered with glass and prioritizing mitigation where trees are planted around building. Mitigation methods may include covering the exterior of glass surfaces with visual markers such as decals, insect screens, films, or curtains of cords without leaving gaps wider than 5 cm between markers [43]. This will help birds to perceive windows as barriers to be avoided.

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Informed Consent Statement: Not applicable.

Data Availability Statement: The original data presented in this study are openly available in the Mendeley Data Repository at doi 10.17632/spfyh38ndx.1.

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