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Bird-window Collisions at UMK Jeli Campus and the Impact of Building Design and Environmental Context

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ABSTRACT

Bird-window collisions pose a significant conservation concern, contributing to avian mortality in urban and semi-urban environments. This study examines the influence of building characteristics and environmental factors on bird collisions at Universiti Malaysia Kelantan Jeli Campus, Malaysia. Surveys conducted from February to March 2023 recorded six bird carcasses across two buildings, with the UMK Jeli Library Office experiencing the highest number of collisions. The prevalence of collisions at this site is attributed to its large transparent windows, while additional factors such as vegetation density and artificial lighting may have also contributed. Statistical analyses revealed a significant relationship between window size and collision frequency ($p < 0.05$), while building height negatively correlated with collision rates. Additionally, non-migratory species were more affected than migratory species, likely due to their continuous presence near buildings. Future research should assess mitigation strategies and environmental variables such as window reflectivity and artificial to develop bird-friendly architectural solutions.

Keywords: Avian conservation, bird-window collisions, building design, mitigation strategies, transparent windows, university campus

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INTRODUCTION

Bird-window collisions are a major conservation concern, contributing to substantial avian mortality across urban and semi-urban landscapes (Fischer & Islam, 2020). Estimates suggest that up to one billion birds die annually from window

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collisions in North America alone (Van Doren et al., 2021), with similar threats increasingly reported worldwide. These fatalities highlight the urgent need for mitigation strategies, particularly in regions undergoing rapid urban expansion.

While bird-window collisions are well-documented in temperate regions, data from tropical areas, especially Southeast Asia, remain scarce (Patankar et al., 2021). In Malaysia, scientific documentation of bird-window collisions is limited. However, local anecdotal and preliminary reports indicate this issue is becoming more prominent with increasing urban development. For example, a growing number of bird collisions have been reported in urbanized areas of Kuala Lumpur and Selangor, according to preliminary observations by the Malaysian Nature Society (personal communication, 2021). In Kelantan, while formal statistics are lacking, informal records maintained by Universiti Malaysia Kelantan (UMK) campus staff reported over 40 bird collision incidents between 2021 and 2023 (UMK staff, personal communication, 2023).

The lack of comprehensive data in Malaysia highlights the need to address this gap through targeted research. Given the rise in glass-dominated architectural designs, especially in institutional buildings like universities (Loss et al., 2023), and the presence of natural landscapes that attract avian species, campuses are ideal environments to study collision patterns.

This study investigates bird-window collisions at the UMK Jeli Campus, which features modern reflective glass architecture surrounded by secondary forest. Reports from campus personnel and students from 2021 to 2023 indicate frequent bird strikes on several buildings, suggesting this is a localised but persistent issue.

Additionally, the role of environmental context, such as nearby vegetation, remains under debate. Some studies propose that green areas increase collision risk by attracting birds near reflective surfaces (Brown et al., 2021), while others emphasise the impact of specific architectural features (Emerson, 2021). This research examines both vegetation proximity and building design to determine their influence on bird collisions in a tropical setting.

By analysing spatial patterns and environmental factors, this study contributes to a better understanding of bird-window collisions in Malaysia and tropical ecosystems more broadly. The findings aim to support evidence-based conservation strategies at UMK Jeli and inform bird-friendly building practices across the region.

MATERIALS AND METHODS

Study Area and Site Justification

This study was conducted at Universiti Malaysia Kelantan (UMK) Jeli Campus, located in Kelantan, Malaysia. The campus is surrounded by secondary forest, landscape vegetation, and fragmented greenery patches, featuring native and introduced tree species such as

Dipterocarpus spp., *Shorea spp.,* and *Hevea brasiliensis*. These vegetated areas serve as suitable foraging, roosting, or stopover sites for both resident and migratory birds. The campus's proximity to these vegetated areas suggests potential interactions between the built environment and bird movement.

UMK Jeli is situated in Kelantan, Malaysia – a state that falls within the broader region influenced by the East Asian-Australasian Flyway (EAAF), a major migratory route for numerous bird species (BirdLife International, 2022; EAAFP, 2023). While UMK Jeli Campus itself is not officially designated as a migratory hotspot, anecdotal observations and preliminary campus records have noted the presence of migratory birds during peak seasons from March-May and September-October (Department of Wildlife and National Parks, personal communication, 2023). These ecological conditions, along with the campus's proximity to forested areas, support its relevance as a study site for investigating bird-window collisions in a tropical context.

Building Selection

Six buildings Figure 1 were selected based on three criteria: (i) structural characteristics (especially glass façade area), (ii) proximity to vegetation, and (iii) anecdotal reports of

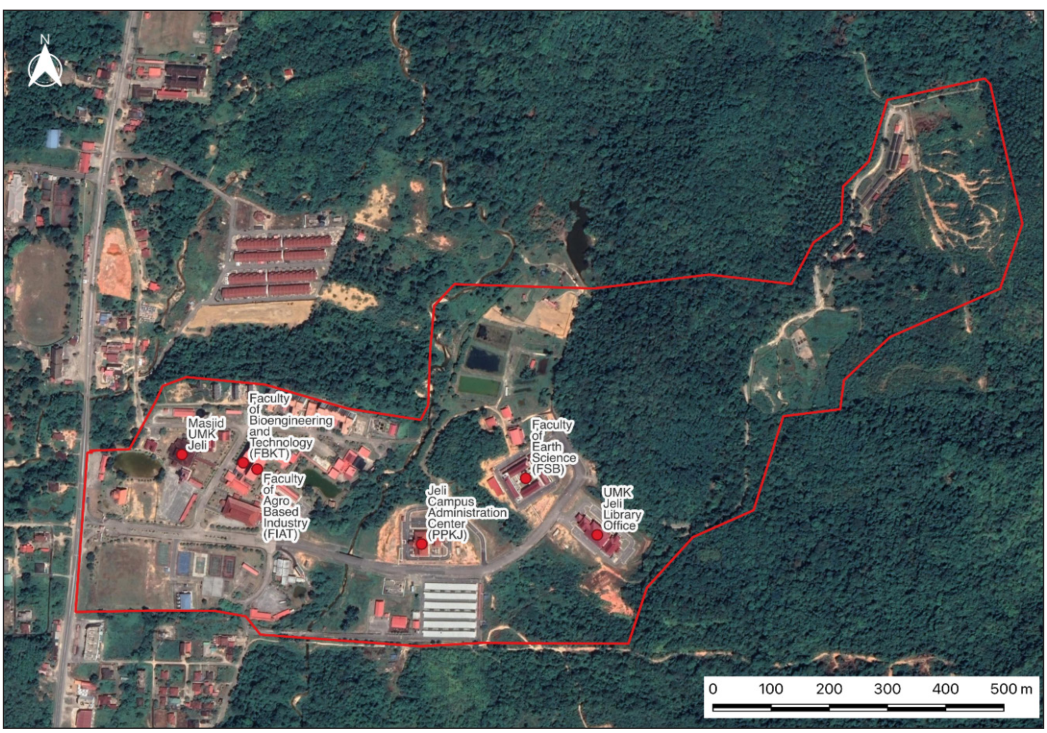

Figure 1. Map of UMK Jeli Campus showing the six surveyed buildings

bird collisions from staff and students. These buildings represent varying levels of glass coverage and architectural designs Figure 2:

- High-glass coverage: UMK Jeli Library Office
- Moderate-glass coverage: Masjid UMK Jeli
- Low-glass coverage: Faculty of Agro-Based Industry (FIAT), Faculty of Bioengineering and Technology (FBKT), Faculty of Earth Science (FSB), and Jeli Campus Administration Centre (PPKJ)

The selection aims to compare collision frequency across different environmental and architectural contexts while controlling for site-specific variability. Other buildings

Figure 2. Six surveyed buildings

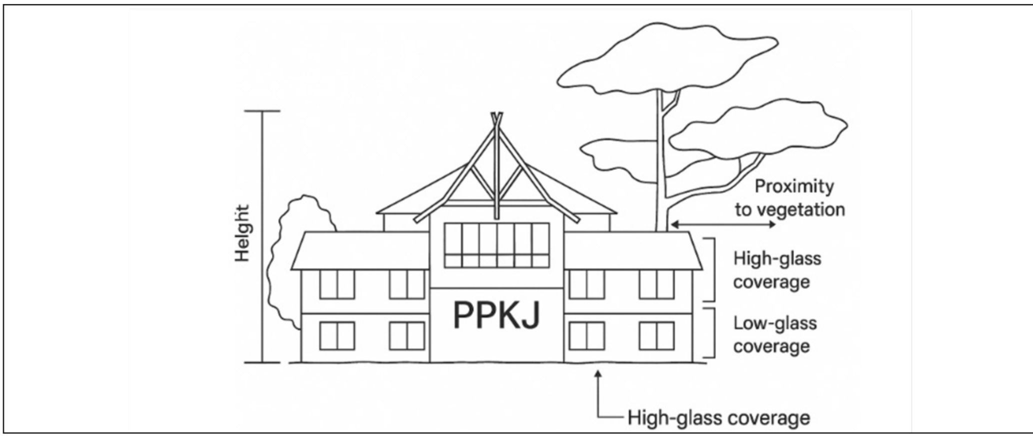

Figure 3. Building elevation sketch showing window coverage and surrounding vegetation

were excluded due to either restricted access, ongoing renovation, or lack of significant glass facades. A building elevation sketch Figure 3 illustrates structural features, window surface area, and vegetation proximity. This aids in visualising the collision risk context.

Survey and Data Collection

Bird-window collision monitoring was conducted from February to March 2023, covering the early onset of the northward spring migration. Although the period did not coincide with peak migration (typically March-May), this timeframe was selected to assess early collision trends and logistical constraints. Future studies will incorporate longer durations to cover full migratory windows.

Surveys were conducted daily from 0800 to 1800 hours. Early morning observations prioritised overnight collisions. Observers walked the perimeter of each building and recorded any evidence of bird-window collisions.

Each carcass was photographed, map in relation to the window, and identified using field guides. Ambiguous identifications were reviewed with ornithologists. One case (16.7%) was classified as "unidentified species" due to advanced decomposition. Scavenger bias was minimised through consistent daily surveys, while weather conditions, ambient light, and visibility were recorded to account for variation in detection probability.

All survey procedures followed ethical guidelines approved by the UMK Research Ethics Committee and the American Ornithological Society's standards for bird research. No live birds were handled. All carcasses were documented through photography and species identification, then disposed of according to UMK waste protocols to prevent recounting.

Building and Environmental Measurements

Windowpane Area

Windows were categorised based on total surface area:

- Small: <500 m^2
- Large: ≥500 m^2

The 500 m^2 threshold aligns with previous bird collision risk assessments (Kaplan, 2024; Szurlej-Kielanska et al., 2021).

Building Height

Height was measured using a Bosch GLM 50 C laser rangefinder and validated against official blueprints, including rooftop slopes and parapets (Lucy & Petty, 2021).

Vegetation Proximity

Vegetation proximity was assessed using GPS mapping (Garmin eTrex 32x) and Google Earth imagery. Buildings were classified as:

- Near vegetation: ≤50 m
- Distant: >50 m

The 50-metre threshold is supported by ecological data indicating increased collision risk near vegetated zones (Seress et al., 2025). A diagramme showing vegetation buffer zones, distances, and canopy characteristics is provided in Figure 4.

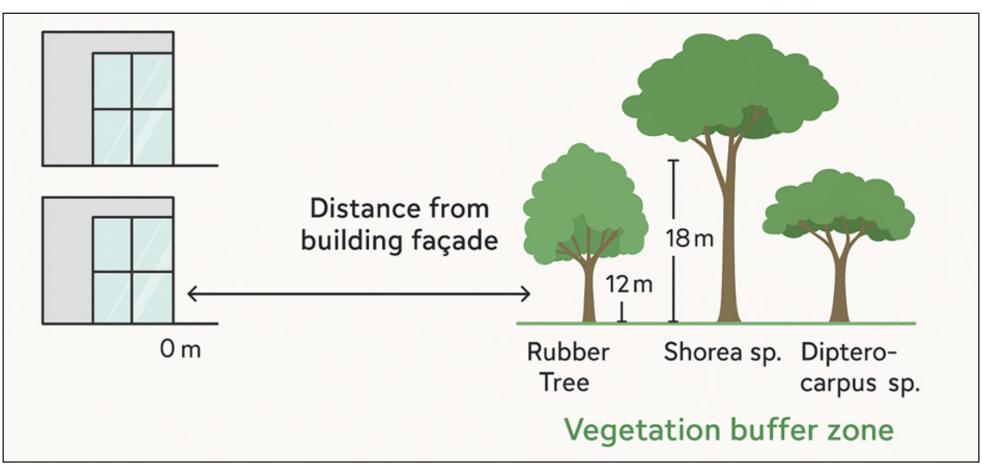

Figure 4. Vegetation buffer zones and distance from building facades with tree species and canopy height annotations

Statistical Analysis

Descriptive statistics were calculated to summarise collision frequencies. Inferential statistics included:

- Chi-square tests: relationship between window size and collisions.
- Correlation analysis: association between building height and collision rates
- Poisson regression: identified significant predictors for collision frequency

Normality was tested using the Kolmogorov-Smirnov and Shapiro-Wilk methods. All predictors passed multicollinearity checks (VIF < 5). Missing data (<5%) were managed via mean imputation. Seasonal analysis was limited due to the short survey period; this is acknowledged as a limitation.

RESULTS AND DISCUSSION

Statistical Limitations and Temporal Scope

While this study presents valuable insights into bird-window collisions at UMK Jeli Campus, we acknowledge that the limited sample size (n = 6) and short temporal scope February to March 2023 restrict the statistical power of the findings. Although inferential statistics showed significant correlations, these results should be interpreted cautiously. We now emphasise in the discussion that future research should include seasonal replication and longitudinal study designs to better assess variation in collision patterns, especially during peak migration periods.

Bird Collision Frequency and Building Characteristics

During the two-month survey period (February-March 2023), six bird-window collision incidents were documented across six selected buildings at UMK Jeli Campus (Figure 5). Daily observations were conducted from 0800 to 1800 hours to maintain consistent effort. It is noted that scavenger activity may have affected carcass detection rates (Walker et al., 2021).

The following species were identified:

- Emerald Dove (*Chalcophaps indica*) – non-migratory
- Yellow-vented Bulbul (*Pycnonotus goiavier*) – non-migratory
- Greater Racket-tailed Drongo (*Dicrurus paradiseus*) – non-migratory
- Barn Swallow (*Hirundo rustica*) – Migratory
- Spotted Dove (*Spilopelia chinensis*) – non-migratory
- Unidentified species – Recorded at Masjid UMK Jeli

Emerald Dove (*Chalcophaps indica*)

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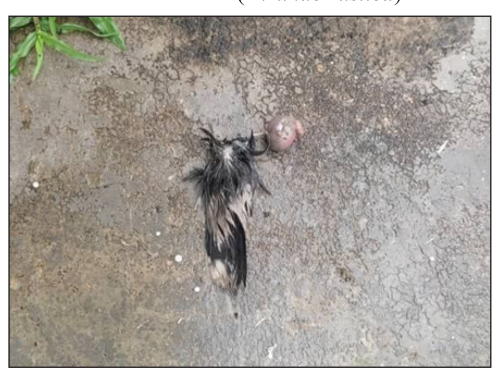
Barn Swallow (*Hirundo rustica*)

Spotted Dove (*Spilopelia chinensis*)



Unidentified species

Figure 5. Documented bird carcasses

Thus, four incidents involved non-migratory birds, and one incident involved a migratory species. This clarification addresses the migratory status concern raised.

Influence of Window Size on Collision Frequency

The UMK Jeli Library Office, which features the largest estimated glass surface area (~600 m^2), recorded the highest number of bird-window collisions (n = 4). A chi-square test confirmed a marginally significant association between window size and collision frequency ($\chi^2 = 5.63$, $p = 0.05$). Correlation analysis supported this relationship ($r = 0.52$, $p < 0.05$), and Cramer's V (0.46) indicated a moderate effect size. These findings are consistent with previous studies indicating that larger reflective surfaces increase collision risk by creating illusions of open sky or habitat (Emerson et al., 2022; Brown et al., 2021).

In addition to size, window orientation may also play a role. The library's east- and west-facing facades have the greatest glass exposure, which may enhance reflectivity due to direct sunlight during morning and afternoon hours. Comparative information on building height, glass area, vegetation proximity, and orientation is summarised in Table 1, allowing a contextualised interpretation of observed collision frequencies.

Table 1
Comparative summary of building characteristics and bird collision frequency

Building	Height (m)	Window Area (m^2)	Vegetation Proximity	Window Orientation Dominance	Recorded Collisions
UMK Jeli Library Office	~12	~600	Dense forest (≤50 m)	East & West	4
Masjid UMK Jeli	~15	~300	Sparse greenery (≤50 m)	East & West	1
FIAT	~14	~250	Fragmented greenery (≤50 m)	East	0
FBKT	~16	~200	Fragmented greenery (≤50 m)	Mixed	0
FSB	~18	~250	Fragmented greenery (≤50 m)	Mixed	0
PPKJ	~20	~270	Fragmented greenery (≤50 m)	Mixed	0

Note. Values are approximate and based on building sketches, satellite imagery, and on-site assessments. "Window orientation dominance" refers to the facades with the most glass exposure

Correlation between Building Height and Collision Rates

A negative correlation was observed between building height and collision frequency ($r = -0.47$, $p = 0.04$). This suggests that shorter buildings are more prone to bird strikes, likely due to birds flying at lower altitudes. This finding is supported by previous research indicating that low-rise structures present greater collision risk (De Groot et al., 2021).

Taller buildings may act as visual barriers, prompting birds to redirect their flight paths. Nonetheless, future studies should incorporate multivariate models and direct observations to confirm these interactions.

Environmental Context: Vegetation and Collision Risk

Figure 4 provides visual documentation of the dense vegetation adjacent to the UMK Library Office, supporting its classification as being near forested areas. Although PPKJ and FSB are also near vegetated areas, they experienced no bird collisions, indicating that proximity to vegetation alone does not account for collision risk.

Differences in vegetation structure may influence risk. The UMK Library Office is surrounded by tall trees and dense canopy, while FSB and PPKJ have fragmented and sparse greenery. This suggests that both architectural and environmental factors interact to influence bird-window collisions.

Species Residency Status and Collision Patterns

Non-migratory birds accounted for more collisions than migratory birds (4 vs. 1). This contradicts the common assumption that migratory birds are at greater risk due to unfamiliar environments. Resident species may face greater risk due to regular exposure to hazardous buildings within their territories (Doherty et al., 2022; Kubelka et al., 2022).

Future work should extend observation across migration periods and include species behaviour analysis to clarify susceptibility patterns.

Conservation and Mitigation Strategies

Protected species involved in collisions, such as the Greater Racket-tailed Drongo and Barn Swallow, underscore the urgency for mitigation efforts. These include:

- Installation of patterned or UV-reflective glass
- Use of window films
- Architectural redesigns to minimise reflective surfaces
- Reduction of artificial lighting during migration periods

Incorporating bird-friendly designs in campus planning, along with student awareness programs and collaboration with local wildlife agencies, could significantly reduce bird mortality.

Influence of the Surrounding Environment

Proximity to green areas alone did not fully explain the observed collision rates. While buildings such as FSB and PPKJ were located near vegetated zones, they recorded no bird strikes, whereas the UMK Jeli Library Office had the highest collision rate. This suggests that factors such as bird species composition, flight patterns, and seasonal migration behaviour may influence collision risk.

Differences in vegetation density and structure may have affected bird behaviour. The UMK Jeli Library Office is adjacent to dense, tall trees, which may attract birds navigating through tree gaps, increasing their risk of striking reflective windows. In contrast, the areas around FSB and PPKJ contain more open, fragmented vegetation, possibly reducing bird activity near windows.

This highlights the importance of architectural factors such as window size and building height in determining bird collision risk. The UMK Jeli Library Office has a significantly larger glass façade (~600 m^2) and is a low-rise structure, making it more hazardous to birds flying at lower altitudes. In contrast, FSB and PPKJ have smaller window surface areas (<300 m^2), potentially reducing their risk of bird strikes. Future studies should incorporate light intensity measurements and window reflectivity assessments to better understand their influence on collision rates.

CONCLUSION

This study highlights the significant role of architectural design in bird-window collisions at UMK Jeli Campus, with window size, material, and building height identified as key factors. Large glass-pane windows (>500 m^2) were associated with higher collision frequencies, while taller buildings (above three stories) experienced fewer incidents. Future studies should refine window size classifications to determine thresholds where collision risk escalates.

Proximity to green areas alone did not fully explain collision patterns, emphasising the greater influence of architectural features. Although vegetation type and density were not directly assessed, the variation in collision rates among with similar green surroundings suggests that factors such as glass reflectivity and building orientation may be more critical. Some buildings near dense vegetation recorded no incidents, underscoring the need for further investigation into how vegetation structure affects bird behaviour.

Given that some affected species, such as the Greater Racket-tailed Drongo *Dicrurus paradiseus* and Barn Swallow *Hirundo rustica*, are legally protected under Malaysia's Wildlife Conservation Act 2010, institutions like UMK should adopt conservation-focussed building policies. The Act emphasises biodiversity conservation, reinforcing the urgency of implementing bird-friendly architectural modifications.

Future research should evaluate the long-term effectiveness of mitigation measures and assess additional factors, such as artificial lighting and seasonal migration, in influencing collision rates. Experimental trials with bird-friendly window treatments, including UV-reflective glass and external film applications, could offer insights into the most effective strategies. Comparative studies across different seasons would help determine whether migration periods significantly alter collision risks at UMK Jeli Campus.

Addressing these concerns would position UMK Jeli Campus as a model for integrating biodiversity conservation into architectural planning, fostering a safer coexistence between human infrastructure and avian species. Successful bird-safe programmes in North America and Europe have demonstrated the effectiveness of mitigation strategies, and comparative case studies with institutions implementing bird-friendly designs could further strengthen conservation efforts in tropical environments like Malaysia.

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