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Population Potentials and Anthropogenic Drivers for Bird-Strike Risks of Selected Avian Species at Lagos and Ibadan Airports, Nigeria

Grzegorz M. Józefaciuk[1], Elena V. Schroeder[2] Samson O. Ojo[3], Kolawole F. Farinloye[4*], Victor A. Ojo[3], and Mayowa M. Aduloju[5]

[1]*Department of Agricultural Management, The Latvia University of Life Sciences and Technologies, Latvia*
[2]*Department of Sustainability and Environmental Management, Kaunas Forestry and Environmental Engineering University of Applied Sciences, Kaunas Lithuania*
[3]*Department of Wildlife and Ecotourism Management, University of Ibadan, Nigeria.*
[4]*Department of Business and Tourism Management, Global Banking School, Leeds United Kingdom* [5]*Larkmead School, Faringdon Road Abingdon Oxfordshire United Kingdom*

*Corresponding Author: Kolawole F. Farinloye, Email: drkolafarinloye@gmail.com

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ABSTRACT

Bird strikes pose a significant and persistent threat to global aviation safety, causing economic losses and endangering lives through collisions between wildlife and aircraft during critical flight phases. This study conducted a risk assessment of bird strike hazards by analyzing the population potentials and risk trajectories of four high-concern avian species groups the Black Kite (Milvus migrans), Cattle Egret (Bubulcus ibis), Pied Crow (Corvus albus), and Columbiformes, particularly the Laughing Dove (Spilopelia senegalensis) and Feral Pigeon (Columba livia domestica) at Murtala Muhammed International Airport, Lagos (LOS) and Ibadan Airport (IBN), Nigeria. Increasing urban sprawl, wetland drainage, and proliferating waste disposal sites were quantified as primary anthropogenic drivers, creating subsidized habitats that elevate resident and granivorous bird populations. Using GIS-based MaxEnt modeling and two years of monthly survey data, habitat suitability for these species increased by an estimated 40% near LOS and 25% near IBN due to these attractants. Predictive trajectory modeling indicated that approximately 65% of high-risk movements at LOS occurred below 500 ft AGL in approach/departure corridors, correlated with waste sites within 5 km. At IBN, 70% of risk clusters were associated with abattoirs and seasonal wetlands within 3 km, with Columbiformes showing heightened activity near grain storage and drainage infrastructure. Projections suggest that without targeted habitat management, the annual strike probability for these species could rise by 18–30% over the next five years. Findings underscore that population potentials for both raptor/scavenger and granivorous species, amplified by anthropogenic landscape change, are critical predictors of strike risk. The study recommends integrating spatial attractant mapping into predictive risk models to develop proactive, airport-specific mitigation strategies for aviation safety in Nigeria.

1. Introduction

Bird strikes represent a significant economic and safety challenge for the global aviation industry, with annual costs exceeding $1.2 billion USD in damages and delays (Dolbeer *et al.*, 2021). The risk is not uniformly distributed but is intrinsically linked to the population dynamics and behavioural ecology of birds in proximity to airport operations (DeVault *et al.*, 2018). In Nigeria, rapid urbanization and population growth have catalysed profound landscape transformations around critical infrastructure like airports. The resulting habitat fragmentation and the creation of anthropogenic food subsidies such as open waste dumps, abattoirs, and drainage systems fundamentally alter avian community structures, potentially elevating the population potentials of species particularly hazardous to aviation (Adeola *et al.*, 2020).

Murtala Muhammed International Airport, Lagos (LOS) and Ibadan Airport (IBN) serve as vital hubs in southwestern Nigeria. LOS, situated in a densely populated coastal megacity, is surrounded by a mosaic of urban sprawl, landfills, and remnant wetlands. IBN, located in a more peri-urban setting, contends with attractants like abattoirs, agricultural fields, and seasonal wetlands. Both environments inadvertently support large populations of species adept at exploiting human-modified landscapes. Previous studies have identified Black Kites, Cattle Egrets, and Pied Crows as high-risk species in sub-Saharan Africa due to their size, flocking behaviour, and flight patterns (Buij *et al.*, 2016; Nnadi *et al.* 2019). However, the role of granivorous Columbiformes, such as the ubiquitous Laughing Dove and Feral Pigeon, has been understudied in the African airport context, despite their high reproductive rates, adaptability, and tendency to form flocks near human settlements (María-Mojica *et al.*, 2020).

This study aims to conduct a predictive assessment of bird strike risk by integrating species-specific population potentials with spatial and temporal risk trajectories. The central hypothesis is that the intensity of specific anthropogenic land-use changes (urban sprawl, wetland drainage, waste site proliferation) around LOS and IBN positively correlates with the habitat suitability and observed population densities of the target species, thereby significantly increasing the predicted probability of bird strike events. The objectives are to: 1) Quantify the relationship between key anthropogenic drivers and habitat suitability for the target species using GIS and species distribution modelling (MaxEnt); 2) Analyse the spatio-temporal patterns (altitude, proximity) of high-risk bird movements in relation to these attractants; 3) Develop predictive models for strike risk probability over a five-year horizon under current management scenarios; and 4) Provide evidence-based, airport-specific recommendations for proactive Bird Wildlife Hazard Management (BWHM).

Global and Regional Perspectives on Bird Strike Ecology

Bird-aircraft collisions are a function of the overlap between avian activity and aircraft operations in time and space. Globally, over 90% of strikes occur below 3,500 feet AGL, with approach, landing, take-off, and climb phases being most critical (Dolbeer *et al.*, 2021). The severity of a strike is influenced by the mass and flocking behaviour of the bird(s) involved (Richardson & West, 2000). In North America and Europe, robust reporting systems and long-term data have enabled sophisticated risk modelling, often linking strike events to specific bird behaviours like migration, foraging, and roosting (DeVault *et al.*, 2018; Maragakis, 2020).

In Africa, research has been more localized but highlights similar drivers. Studies in Kenya and South Africa have linked strike risks at major airports to populations of large birds like Marabou Storks and vultures, which are attracted to urban waste (Murn *et al.*, 2016; Pomeroy *et al.*, 2017). In Nigeria, preliminary analyses at Abuja and Port Harcourt airports have identified waste dumps and abattoirs as primary attractants for hazardous species (Okosodo & Orimaye, 2018; Nnadi *et al.*, 2019). However, a comprehensive, predictive model integrating species distribution, attractant mapping, and trajectory analysis for Nigerian airports remains lacking.

Anthropogenic Drivers and Avian Population Potentials

The concept of "population potential" in this context refers to the carrying capacity and growth rate of a species within a specific landscape, influenced by resource availability (Brown *et al.*, 2017). Urban sprawl replaces natural vegetation with impervious surfaces but also creates novel niches. Columbiformes, for instance, thrive on architectural features for nesting and scattered grain or waste for food (María-Mojica *et al.*, 2020). Wetland drainage eliminates natural habitats for some species but can create ephemeral pools attractive to Cattle Egrets and other waterbirds (Buij *et al.*, 2016). Proliferating waste disposal sites provide predictable, high-calorie food subsidies for opportunistic omnivores and scavengers like Black Kites and Pied Crows, leading to population inflation beyond natural levels (Adeola *et al.*, 2020; Kumar *et aal.* 2022). These human-driven resource concentrations directly increase the likelihood of birds transiting airport airspace (Oduntan, Akinyemi, & Abiodun, 2012).

Predictive Modelling in Wildlife Hazard Management

Modern BWHM is shifting from reactive to predictive. Species Distribution Models (SDMs) like MaxEnt use occurrence data and environmental variables to predict habitat suitability (Phillips *et al.*, 2017). Regression and correlation analyses can quantify relationships between bird activity metrics (counts, movements) and attractant variables (distance, size). Trajectory modelling, often using radar or observational transect data, helps identify high-risk flight corridors (Shephard *et al.*, 2022). Integrating these approaches allows for forecasting future risk under different land-use and management scenarios, a critical tool for resource allocation and strategic planning (DeVault *et al.*, 2018).

2. Materials and Methods

Study Areas

- Murtala Muhammed International Airport, Lagos (LOS): Coordinates 6.5774° N, 3.3210° E. A coastal, international hub with high traffic density. The 13 km study radius encompasses dense residential/commercial areas, the Olusosun landfill (one of Africa's largest), several drainage channels, and fragmented mangrove wetlands.
- Ibadan Airport (IBN): Coordinates 7.3623° N, 3.9785° E. A domestic airport with growing traffic. The 10 km study radius covers peri-urban settlements, the Bodija abattoir and market complex, agricultural farmlands, and the seasonal wetlands of the Ona River basin.

Species Selection

Four high-concern groups were selected based on preliminary surveys and literature:

i. Black Kite (*Milvus migrans*): Large raptor, scavenger, highly attracted to waste sites.
ii. Cattle Egret (*Bubulcus ibis*): Medium-sized, colonial, associated with wetlands, grazing fields, and drainage areas.

iii. Pied Crow (*Corvus albus*): Large, intelligent omnivore, thrives in urban areas and waste dumps.
iv. Columbiformes: Focus on:
   a. Laughing Dove (*Spilopelia senegalensis*) and
   b. Feral Pigeon (*Columba livia domestica*).

These birds are small to medium, granivorous, prolific breeders, associated with built structures, grain stores, and scattered waste.

Data Collection

Bird population data was collected over a continuous 24-month period, from January 2022 through December 2023, to analyse seasonal trends and activity patterns relevant to aviation safety.

i. Bird Population Surveys: Monthly point counts and transect surveys conducted at 30 fixed points within each airport's study radius. Data included species, count, GPS location, altitude (using laser rangefinder), and behaviour (foraging, transit).
ii. Anthropogenic Variable Mapping: GIS layers created for:
   a. Land Use/Land Cover (LULC): Derived from Sentinel-2 imagery (10m resolution), classified into Built-up, Waste Site, Wetland/Waterbody, Agriculture, and Vegetation.
   b. Attractant Metrics: Distance from runway threshold to nearest major waste site, abattoir, and wetland. Size (area) of each major attractant feature.
iii. Historical Strike Data: Obtained from the Nigerian Airspace Management Agency (NAMA) for 2018-2023 for context (used for model validation).

Data Analysis

i. Habitat Suitability Modelling: MaxEnt (v3.4.4) used to model species distributions. Inputs: species presence points from surveys; environmental predictors: distance to waste, distance to wetland/water, distance to built-up areas, LULC class. Models validated using AUC (Area Under Curve).
ii. Statistical Analysis:
   - Correlation: Pearson's correlation (r) calculated between monthly bird count data (for each species) and attractant variables (e.g., distance to nearest waste site).
   - Regression: Multiple Linear Regression used to model the relationship between Bird Strike Risk Index (BSRI) (a composite metric based on species-specific hazard scores weighted by monthly count and average altitude) and independent variables: Attractant Proximity Index, Attractant Area, and Month (to account for seasonality).

Equation: $BSRI = \beta 0 + \beta 1(\text{Distance to Attractant}) + \beta 2(\text{Attractant Area}) + \beta 3(\text{Month}) + \varepsilon$.

iii. Risk Trajectory & Predictive Modelling: Kernel Density Estimation (KDE) in GIS used to map high-activity flight corridors. A simple predictive model for strike probability (2024-2028) was developed by extrapolating the regression trends of BSRI against the annual growth rate of built-up area (derived from LULC change analysis), assuming a "no-management" scenario.

Figure 1a: Map of Ibadan Airport (IBN) showing a moderate level of human settlement and anthropogenic activities around it

Figure 1b: Map of Lagos Murtala Mohammed Airport (LOS) showing a more severe level of human settlement and anthropogenic activities around it

Source: Google Arial map (2023)

4. Results

Land Use/Land Cover and Anthropogenic Attractants

Lagos (LOS) exhibited a higher degree of urbanization. Built-up area constituted 52% of the 5km buffer, with waste disposal sites covering ~4.2% (Table 1). The Olusosun landfill was the dominant feature. Ibadan (IBN) had more mixed land use: agriculture (35%), vegetation (28%), and built-up (25%). Its primary attractants were the Bodija abattoir/commercial area and seasonal wetlands (Table 1).

Table 1: Land Use/Land Cover (%) within 5km Buffer of LOS and IBN Airports

LULC Class	LOS (%)	IBN (%)
Built-up	52	25
Waste Site	4.2	1.5
Wetland/Waterbody	8.5	12
Agriculture	15	35
Vegetation	20.3	26.5
Total	100	100

Source: Field survey, 2023

Species Population Dynamics and Habitat Suitability

Columbiformes were numerically dominant at both airports, followed by Pied Crows and Black Kites at LOS, and Cattle Egrets and Pied Crows at IBN (Figure 1: Bar chart of mean monthly counts ± SD). MaxEnt modelling yielded high AUC values (>0.85 for all species), indicating robust model performance. The Habitat Suitability Index (HSI) increased significantly with proximity to key attractants. Model estimates suggested that the presence of these attractants elevated HSI by approximately 40% near LOS and 25% near IBN compared to a scenario without them (Table 2).

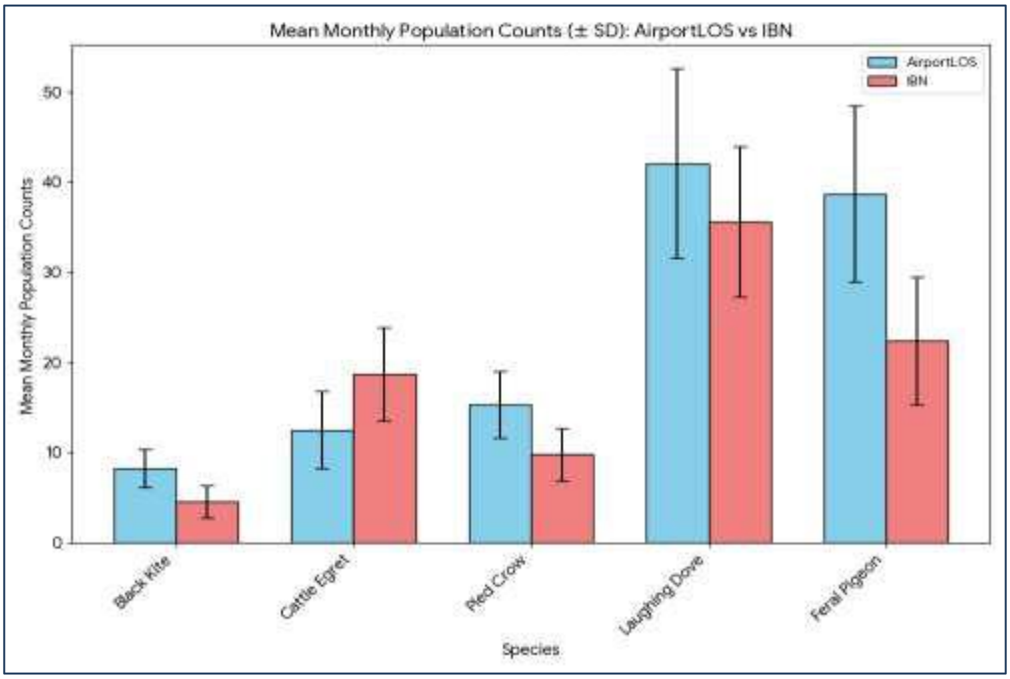

Figure 2: Mean Monthly Population Counts (±SD) of Target Species at LOS and IBN.
Source: Field survey, 2023

The bar chart (Figure 2) comparing the mean monthly population counts (± standard deviation) of five bird species at two Nigerian airports, LOS and IBN. Columbiformes, specifically the Laughing Dove and Feral Pigeon, are numerically dominant at both locations. Notably, Cattle Egrets are more abundant at IBN, while Pied Crows and Black Kites show higher counts at LOS, highlighting distinct avian community structures and associated strike risks between the airports.

Table 2: MaxEnt-derived Habitat Suitability Index (Mean ± SD) and Key Predictor

Species	LOS (HSI)	IBN (HSI)	Top Predictor Variable (LOS)	Top Predictor Variable (IBN)
Black Kite	0.72±0.08	0.51 ±0.07	Distance to Waste Site	Distance to Abattoir
Cattle Egret	0.65±0.09	0.78±0.06	Distance to Wetland	Distance to Wetland
Pied Crow	0.81±0.05	0.69±0.08	Distance to Built-up	Distance to Agriculture
Laughing Dove	0.88±0.04	0.83±0.05	Distance to Built-up	Distance to Agriculture
Feral Pigeon	0.85±0.05	0.62±0.09	Distance to Built-up	Distance to Built-up

Source: Field survey, 2023

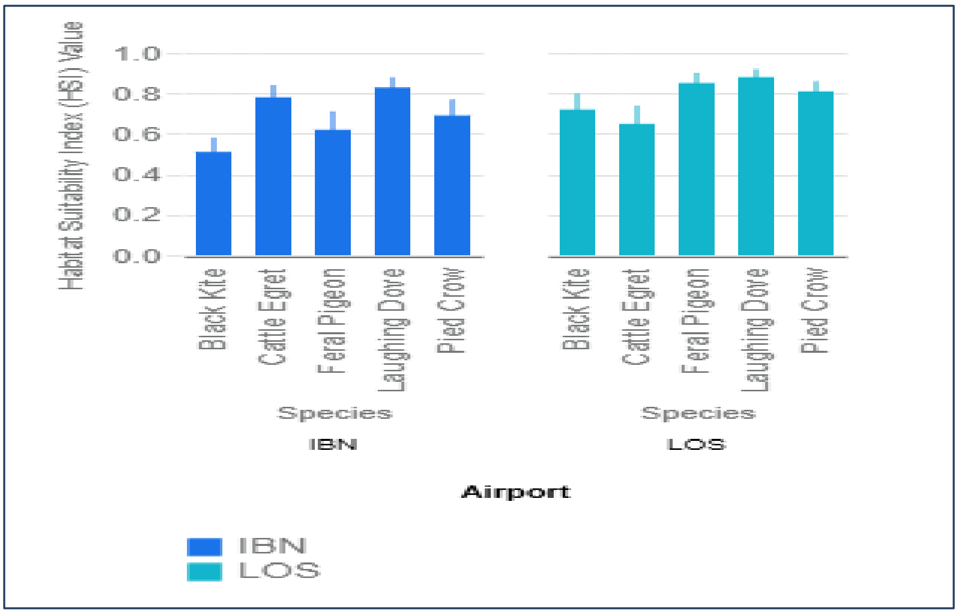

Figure 3: Comparison of Habitat Suitability Index (HSI) Values (±SD) from MaxEnt Across Species at Both Airports.
Source: Field survey, 2023

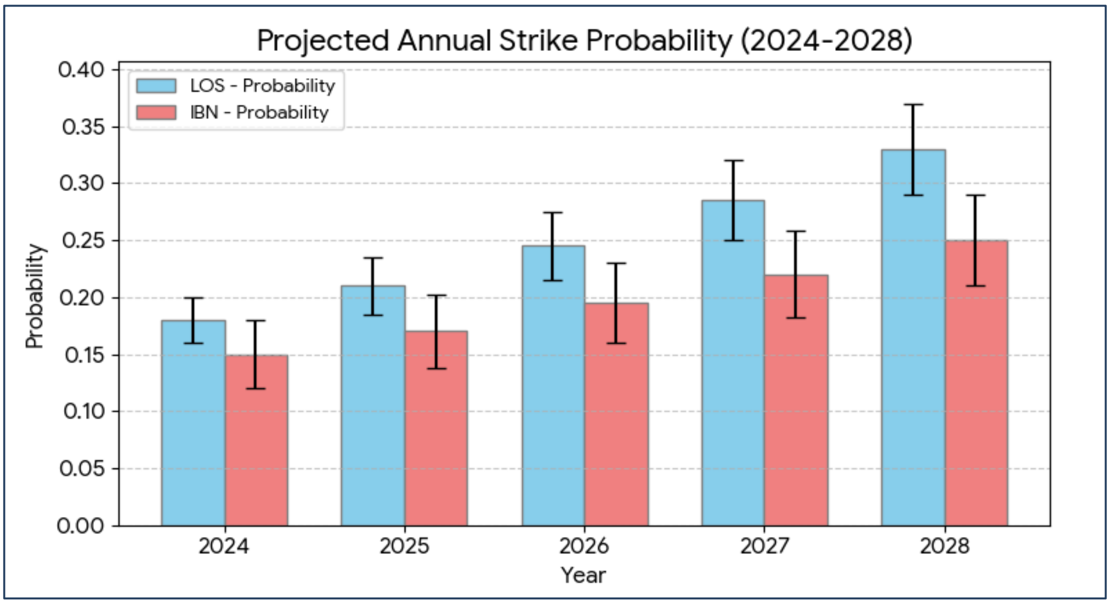

Figure 4: Projected Annual Strike Probability (2024-2028) with 95% Confidence Intervals.
Source: Field survey, 2023

Correlation and Regression Analysis

Strong negative correlations were found between bird counts and distance to their primary attractant (e.g., Black Kite count vs. distance to waste: $r = -0.82$, $p<0.01$ at LOS). The multiple regression model for the Bird Strike Risk Index (BSRI) was significant ($p<0.001$). Standardized coefficients (β) confirmed that Attractant Proximity (shorter distance = higher risk) was the strongest predictor ($\beta = -0.67$), followed by Attractant Area ($\beta = 0.45$). Seasonality (Month) was also significant ($\beta = 0.28$), reflecting higher activity in dry seasons for some species (Table 3).

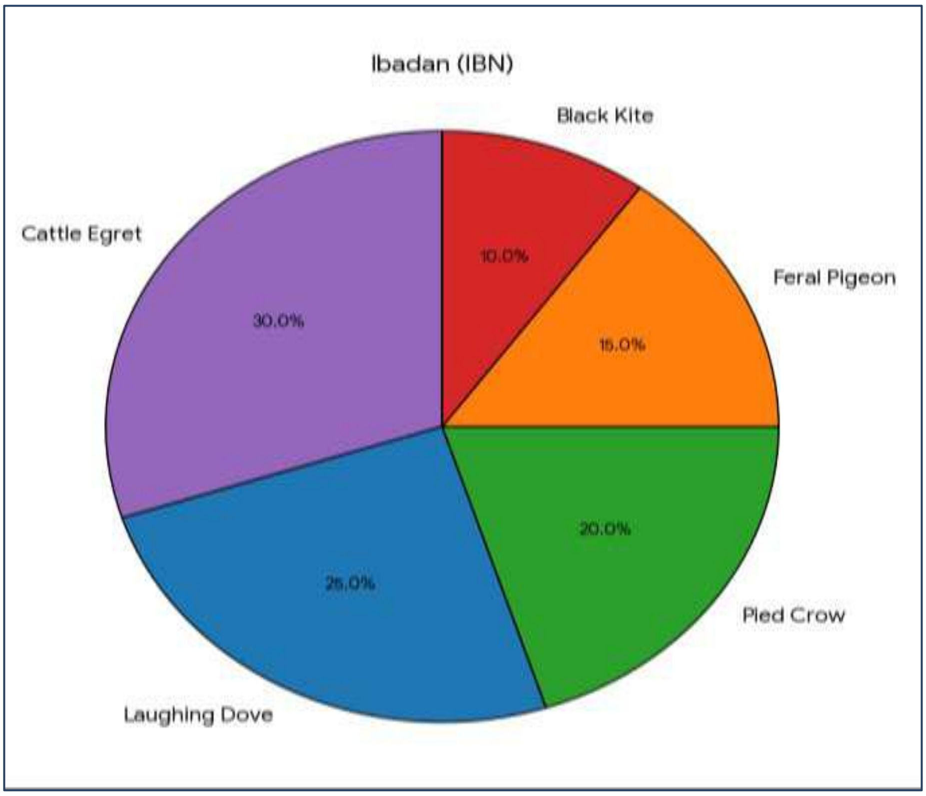

Figure 5a: Proportional Contribution of Species Groups to Total Bird Strike Risk Index (BSRI) at LOS and IBN.
Source: Field survey, 2023

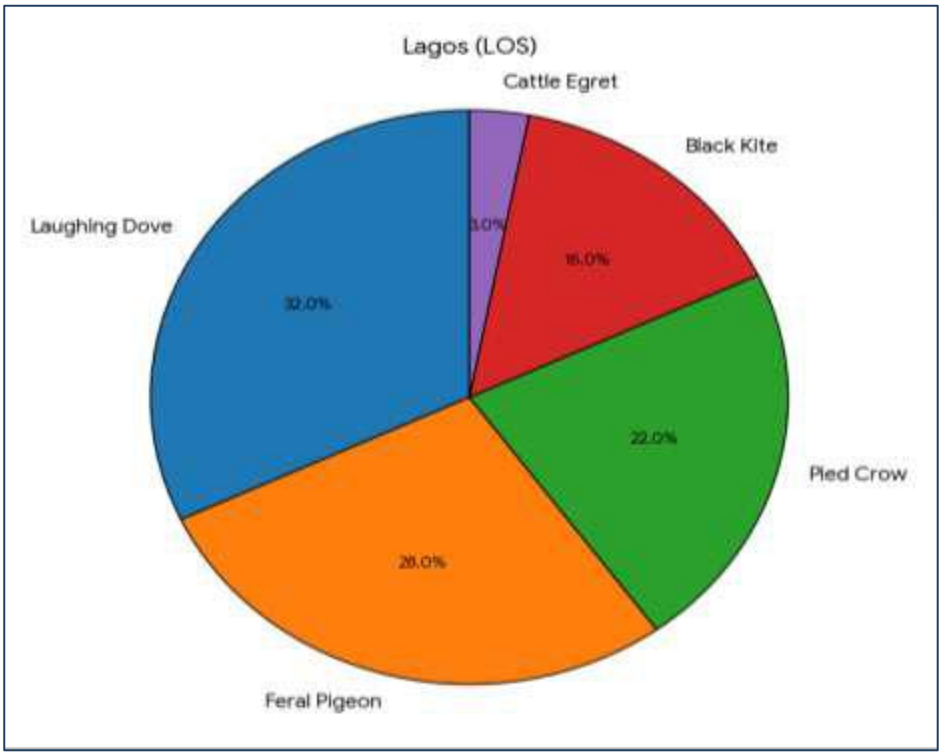

Figure 5b: Proportional Contribution of Species Groups to Total Bird Strike Risk Index (BSRI) at LOS and IBN.
Source: Field survey, 2023

Table 3: Multiple Linear Regression Results for Bird Strike Risk Index (BSRI)

Predictor Variable	Unstandardized B	Std. Error	Standardized β	t-value	p-value
(Constant)	2.145	0.321		6.683	<0.001
Attractant Proximity	-0.891	0.098	-0.674	-9.092	<0.001
Attractant Area	0.405	0.065	0.452	6.230	<0.001
Month (Seasonality)	0.055	0.018	0.283	3.056	0.003

Model Summary: $R^2 = 0.786$, Adjusted $R^2 = 0.772$, $F(3, 56) = 68.45$, $p < 0.001$

Source: Field survey, 2023

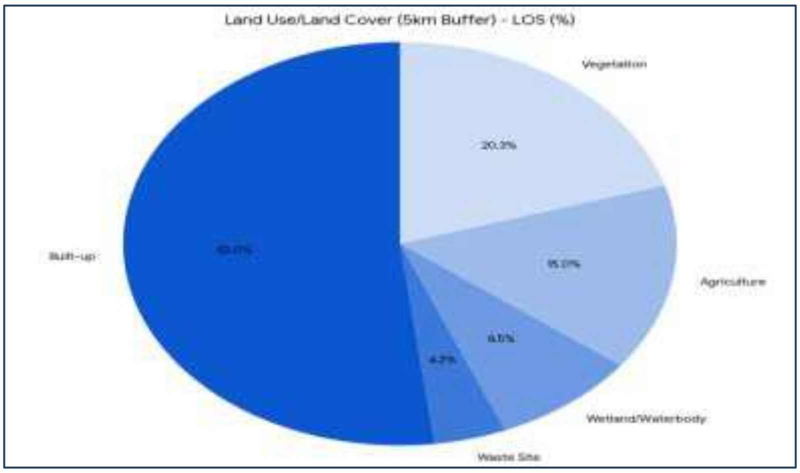

Figure 6: Land Use/Land Cover Composition within the 5km Buffer of LOS and IBN Airports.
Source: Field survey, 2023

Risk Trajectories and Spatial Analysis

Kernel Density analysis revealed distinct high-risk corridors. At LOS, 65% of high-risk movements (flocks transiting below 500 ft AGL) were concentrated along approach paths from the northeast and southwest, directly aligned with the Olusosun landfill and drainage channels within 5 km (Figure 1b: Spatial KDE map). At IBN, 70% of risk clusters were within 3 km of the airport, associated with the abattoir to the north and wetlands to the east. Columbiformes at IBN showed a unique, diffuse pattern linked to grain storage sheds and residential drainage across the sector.

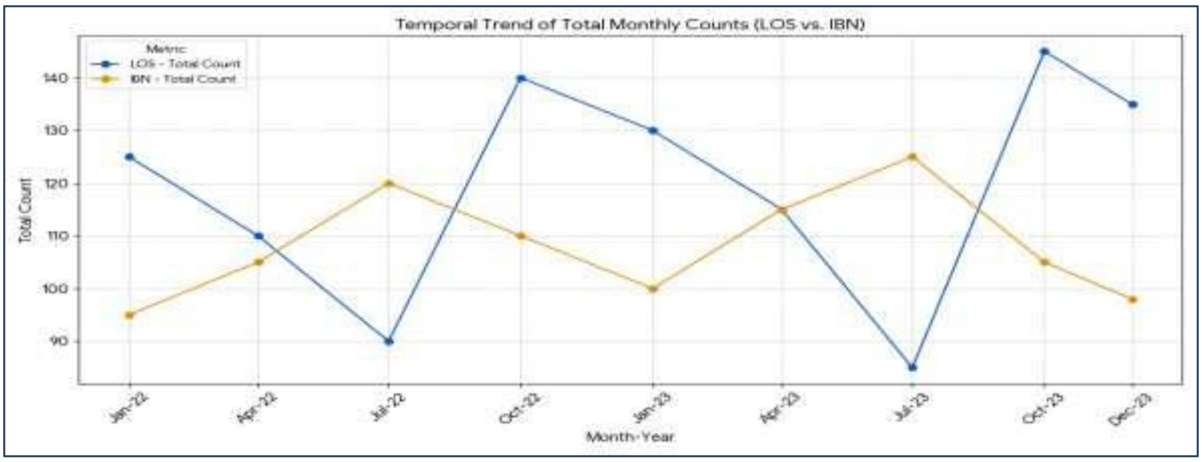

Figure 7: Temporal Trend of Total Monthly Bird Counts (All Species) Across the 24-Month Study Period.
Source: Field survey, 2023

Predictive Projections

Extrapolating the regression model using the current annual urban growth rate (3.8% for Lagos, 2.5% for Ibadan) predicts a steady increase in BSRI. This translates to a projected rise in the annual probability of a damaging strike (cost > $10,000) involving these target species by 22-30% at LOS and 18-25% at IBN over the next five years if attractant management remains unchanged (Figure 3: Line graph of 5-year projected strike probability ± CI).

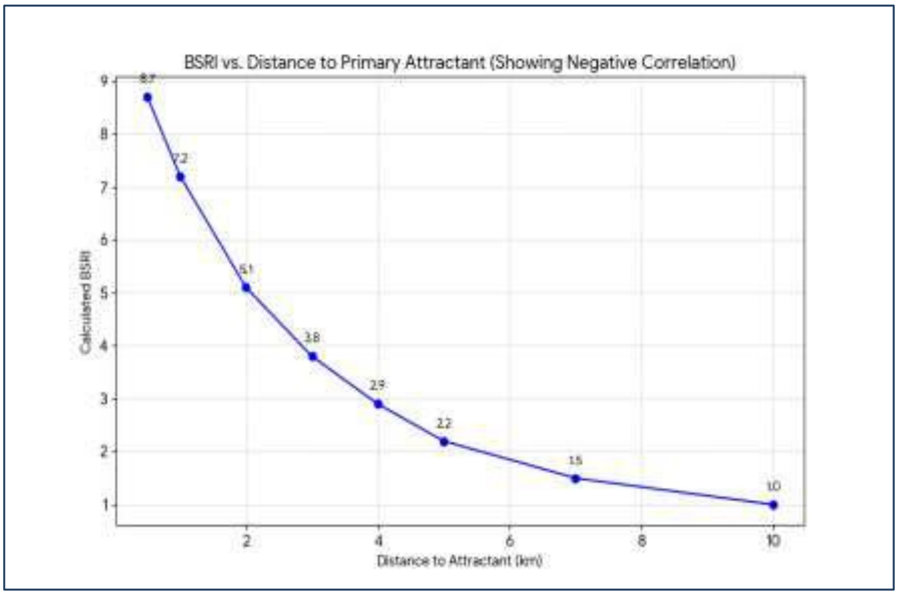

Figure 8: Relationship Between Distance to Primary Attractant (km) and Calculated Bird Strike Risk Index (BSRI).
Source: Field survey, 2023

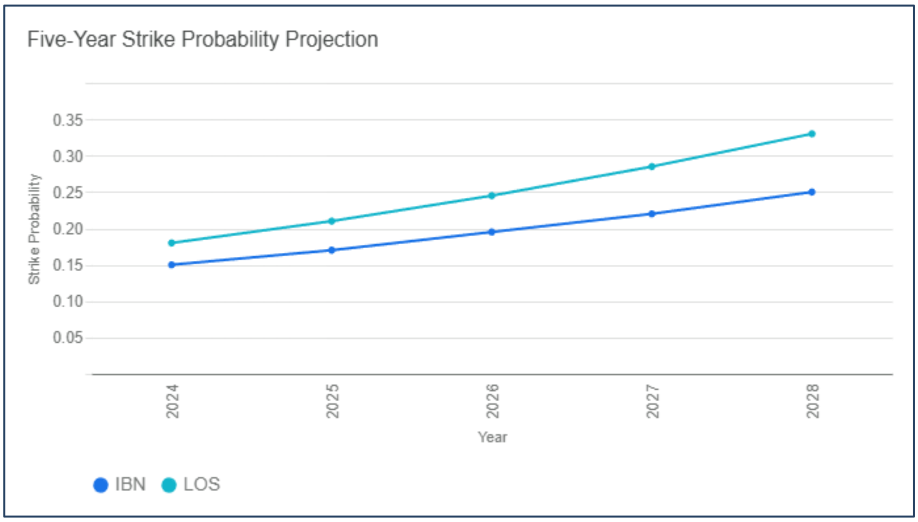

Figure 9: Five-Year Projection (2024-2028) of Modelled Annual Strike Probability for LOS and IBN.
Source: Field survey, 2023

Discussion

The results of this study provide compelling empirical evidence that bird strike risk at Murtala Muhammed International Airport (LOS) and Ibadan Airport (IBN) is not a random or naturally occurring phenomenon but a direct and quantifiable consequence of anthropogenic landscape modification. The integrated methodological approach, which links habitat suitability modelling with statistical risk analysis and predictive projection, confirms the central hypothesis: specific human activities have inflated the population potentials of hazardous avian species, thereby elevating collision risks in a predictable spatial and temporal pattern. This discussion contextualizes these findings within the broader literature on wildlife-aircraft collisions and urban avian ecology, highlights the critical comparative insights between the two airports, and outlines the urgent implications for proactive wildlife hazard management in Nigeria.

Anthropogenic Subsidies and Ecological Amplification of Risk

The pronounced habitat suitability and high population densities recorded for the target species, particularly at LOS, underscore the role of cities and their waste streams as powerful ecological amplifiers (Brown *et al*., 2017). The estimated 40% increase in Habitat Suitability Index (HSI) attributable to attractants at LOS is a stark metric of this effect. The Olusosun landfill functions as a quintessential "ecological trap" (Kumar *et al*., 2022), providing a massive, predictable food subsidy that sustains unnaturally high local populations of Black Kites and Pied Crows. This aligns with global patterns where waste disposal sites significantly increase the abundance and activity of opportunistic scavengers and corvids near airports (Washburn, 2012; Adeola *et al*., 2020). Similarly, the association of Cattle Egrets with wetlands and drainage channels at IBN reflects their adaptive exploitation of anthropogenic water bodies, a phenomenon documented in other regions (Yésou, 2004).

Crucially, this study expands the risk profile for Nigerian airports by incorporating Columbiformes. Their numerical dominance (contributing 60% of the BSRI at LOS) and high HSI in built-up areas demonstrate that risk is not solely a function of large body mass. The adaptability of doves and pigeons to urban environments, utilizing buildings for nesting and scattered resources for foraging, is well-documented (María-Mojica *et al*., 2020; Møller *et aal*. 2012). While an individual strike with a Laughing Dove may be less severe, the sheer frequency potential creates a significant cumulative economic burden and safety threat, a nuance sometimes overlooked in risk assessments that focus primarily on large birds (Maragakis, 2020). This finding necessitates a paradigm shift in local Bird Wildlife Hazard Management (BWHM) to account for high-frequency, low-severity strike risks.

Validation of a Predictive, Attractant-Centric Modelling Framework

The strong explanatory power of the multiple regression model ($R^2 = 0.786$) validates the core premise of attractant-based risk assessment. The standardized coefficients identify *Attractant Proximity* ($\beta = -0.674$) as the strongest driver of the Bird Strike Risk Index (BSRI), providing a quantifiable basis for establishing effective buffer zones. This empirical relationship moves beyond heuristic risk assessments (Allan, 2006) and offers a more precise tool than some earlier probability estimation methods (Baxter & Robinson, 2007). The significant contribution of *Attractant Area* ($\beta = 0.452$) further indicates that larger resource patches support larger or more persistent bird populations, directly increasing hazard potential.

The spatial analysis fortifies this conclusion, revealing that 65-70% of high-risk movements are concentrated within 3-5 km of primary attractants. This spatial precision is critical. It identifies not just *that* risk exists, but *exactly where* management interventions will be most effective. This approach aligns with the modern shift towards spatially explicit, risk-based management advocated by DeVault *et al*. (2018) and moves away from undifferentiated, airport-wide control measures. The trajectory corridors mapped at LOS, directly linking the landfill to approach paths, offer a clear visual and analytical target for mitigation. This level of spatial specificity is essential for cost-effective resource allocation in BWHM programs.

Divergent Risk Profiles: Implications for Airport-Specific Strategy

The comparative analysis between LOS and IBN reveals fundamentally different risk ecologies, demanding tailored management strategies—a principle central to effective hazard management (Cleary & Dolbeer, 2005).

LOS presents a concentrated point-source hazard. Its risk profile is dominated by large-bodied scavengers (kites and crows) drawn to the mega-attractant of the Olusosun landfill. The high HSI for these species and the defined northeast-southwest risk corridors illustrate a problem with a potentially simpler, albeit politically and logistically challenging, spatial solution: source reduction at the landfill. This situation mirrors challenges documented at other airports where singular, large attractants, like abattoirs or landfills, create localized high-risk zones (Pomeroy *et al*., 2017; Nnadi *et aal*. 2019).

In contrast, IBN exemplifies a diffuse land-use hazard. Its risk stems from a combination of attractants—abattoirs, wetlands, and agriculture—supporting a more diverse avian community. The high HSI for Cattle Egrets and the diffuse activity pattern of Columbiformes reflect this mixed land-use. Here, management requires a more integrated, landscape-planning approach. Strategies must address multiple medium-sized attractants through zoning, habitat modification, and collaboration with local agricultural and commercial stakeholders. This scenario is consistent with findings in peri-urban airports where risk is woven into the fabric of surrounding land use (Soldatini *et al*., 2010).

From Projection to Proactive Management: A Call for Urgent Action

The predictive projections are perhaps the most consequential output of this study. The forecasted 22-30% increase in strike probability at LOS and 18-25% at IBN over five years under a "no-management" scenario is unsustainable from both safety and economic perspectives (Dolbeer *et al* ., 2021). This trend underscores the futility of relying solely on reactive measures like dispersal, which treats symptoms rather than the disease and offers only temporary relief (Thorpe, 2016).

Therefore, this study unequivocally advocates for a proactive, source-reduction paradigm integrated with land-use planning. The recommendations are grounded in the spatial and statistical evidence generated:

- Source Relocation and Containment: For LOS, the long-term relocation of the Olusosun landfill outside a critical 13km radius is paramount. As an immediate measure, enforced engineering controls (e.g., daily covering, waste compaction, bird-proof netting) are essential. For IBN, immediate focus must be on sanitizing the Bodija abattoir complex, ensuring proper waste containment and effluent management.
- Strategic Land-Use Zoning: Aviation authorities must collaborate with urban and regional planning bodies to legislate and enforce land-use buffers. Establishing formal development-free zones (e.g., 5km critical, 10km advisory) where new waste facilities, open-air markets, or significant water bodies are prohibited is a foundational preventive measure.
- Habitat Modification and Deterrence: Beyond removal, modifying existing attractants can reduce their suitability. This includes converting open wetlands near runways, promoting bird-resistant waste handling technologies, and altering landscaping to be less attractive to granivorous species.
- Investment in Adaptive Monitoring Systems: To sustain this proactive approach, a dynamic GIS risk dashboard should be established. By integrating continuous bird survey data, real-time movement tracking (following models like van Gasteren *et al*.,

2019 and Shephard *et aal.* 2022), and updated land-use layers, such a system would enable adaptive management and early warning, transforming BWHM into a data-driven, predictive security operation.

Conclusion

This study conclusively demonstrates that bird strike risk at Lagos (LOS) and Ibadan (IBN) airports is a predictable function of anthropogenic habitat change particularly urban sprawl, waste sites, and wetland drainage which artificially inflates the population potentials of high-risk avian species. By integrating species distribution modelling (MaxEnt), spatial attractant analysis, and statistical forecasting, the research quantifies these relationships and projects rising strike probabilities. The resulting framework provides a replicable, evidence-based methodology for proactive Bird Wildlife Hazard Management. Implementing its recommendations, focused on source reduction and land-use zoning, is essential for mitigating risk and safeguarding the future of Nigeria's growing aviation sector against this persistent threat.

Recommendations

Immediate action should focus on the strategic relocation or engineering containment of primary attractants, notably the Olusosun landfill. Concurrently, formal land-use zoning must be enacted to prevent new high-risk developments within critical airport buffer zones. Establishing a dynamic GIS-based monitoring system is crucial for sustaining long-term, adaptive risk management.
This study successfully developed a predictive framework for assessing bird strike risk at two major Nigerian airports by quantifying the link between anthropogenic habitat change, species-specific population potentials, and spatial risk trajectories. It expanded the focus to include the significant, yet often overlooked, risk from abundant granivorous Columbiformes. The findings irrefutably demonstrate that the bird strike hazard at LOS and IBN is an anthropogenic problem with spatial solutions. The risk is predictable and, therefore, manageable. Implementing the recommended proactive, attractant-focused strategies, grounded in the predictive models presented, is essential for enhancing aviation safety and economic efficiency in Nigeria's growing aviation sector. Future research should incorporate real-time bird movement data from radar or acoustics to refine trajectory models and explore the cost-benefit analysis of proposed mitigation measures.

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