

Bird Hazard Management At Zambian Airports: A Critical Analysis Of Current Practices And Future Directions

Kabaso Emmanuel Musonda, Kamalata Chipotu Joe, Emmanuel Zingapeta,
Elaston Njovu

School Of Engineering, Northrise University, Ndola, Zambia
School Of Engineering, Copperbelt University, Kitwe, Zambia

Abstract

Bird strikes pose a significant threat to aviation safety in Zambia. This study employed a multi-method approach to investigate challenges faced by Zambian airports and explore solutions for mitigating bird hazard risks. The research reviewed existing literature on bird strike prevention, conducted interviews with airport personnel and wildlife management authorities, analyzed data on past bird strike incidents, and conducted physical observations of bird activity and habitat features around airports. The findings revealed a lack of dedicated wildlife management programs and staff knowledge at Zambian airports, creating vulnerabilities to bird activity. Factors attracting birds included improper waste disposal, insects near short-cut grass areas, proximity to national parks, and compromised perimeter security. The study identified positive correlations between strong government policies, improved waste management practices, and effective bird hazard management (BHM) strategies. While further investigation is needed regarding the effectiveness of technological deterrents, this research suggests their potential as complementary tools alongside established methods. Overall, the study emphasizes the need for a multi-faceted BHM strategy in Zambia, focusing on improved wildlife management plans, enhanced waste management practices, and better communication among stakeholders for a safer aviation environment.

Keywords: Bird hazard management, Bird Strike Prevention, Aviation safety, Zambian Airports, Wildlife management, ICAO Standards

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I. Introduction

Bird strikes, collisions between aircraft and birds at or near airports, pose a growing threat to aviation safety as air traffic steadily increases. A recent study by Hu et al. (2020) underscores this concern, highlighting the need for proactive strategies to manage bird strike risks at airports. Statistics from available studies paint a worrying picture. Data from the Civil Aviation Administration of China (CAAC) shows a dramatic rise in bird strike accidents, jumping from 326 in 2007 to a staggering 4618 in 2016 (as cited in Robin Radar Systems, 2022). This trend is not limited to China as the Federal Aviation Agency (FAA) in the United States reported a similar surge, with bird strikes reaching a record high of 13,668 in 2014 compared to 1,851 in 1990 (Robin Radar Systems, 2022). The Federal Aviation Administration (FAA) dashboard shows a significant increase in wildlife strikes on aircraft in the United States and globally. Reported wildlife strikes have risen from approximately 1,800 in 1990 to 18,000 in 2018. Between 1990 and 2023, there were a total of 291,600 wildlife strikes involving civil aircraft. In 2023 alone, 19,400 strikes occurred at 713 airports across the United States. Additionally, U.S. air carriers reported 5,100 strikes at foreign airports last year representing 92 airports in 55 countries. (Redbird Flight, 2024). Since pilots' report wildlife strikes voluntarily, the information listed only represents what the FAA has received from airlines, airports, general aviation pilots, and other sources. In other words, the number of strikes that occur each year may exceed those reported.

The Federal Aviation Administration (FAA) attributes the rising number of reported wildlife strikes to several factors, including expanding wildlife populations, increased air traffic, the development of faster and quieter aircraft, and enhanced reporting efforts within the aviation community. Birds account for 97% of wildlife strike incidents, with larger species posing greater risks. Waterfowl, gulls, and raptors are particularly problematic in the United States. These species are frequently identified by pilots as the primary culprits in wildlife strikes.

Wildlife strikes on U.S. civil aircraft result in substantial damage and downtime, costing an estimated \$718 million and 567,000 hours annually. From 1988 to 2020, these strikes have led to 293 fatalities and the destruction of 271 aircraft (Redbird Flight, 2024).

These increasing incidents have severe consequences, leading to aircraft grounding, delays, travel disruptions, and significant safety risks and economic losses. Zambia, as a signatory to the convention on civil Aviation, Chicago 1944, has adopted all the provisions specified in Annex 14 to the convention and several circulars are available on the civil Aviation Authority of Zambia. (Civil Aviation Authority of Zambia, 2024). Unfortunately, little published research data could be found on the increase of bird strikes in Zambia

However, as Zambia's aviation industry experiences continuous growth, effectively managing bird strike risks becomes even more critical. Airport Bird Hazard Management (ABHM) practices provide a crucial line of defense. The International Civil Aviation Organization (ICAO) plays a leading role in establishing global standards for ABHM. Recognizing the escalating threat of bird strikes, ICAO has actively promoted risk assessment and mitigation measures since the 1990s (ICAO, 2021). These recommendations were later elevated to mandatory ICAO Standards in 2003, underscoring their vital role in safeguarding aviation safety. More recently, ICAO has emphasized a risk-based approach to wildlife hazard management, including bird strikes, at airports (International Civil Aviation Organisation, 2021). This approach highlights the importance of tailoring strategies to the specific risks at each airport.

As Zambia's aviation industry flourishes, mitigating bird strike risks becomes paramount. Here's where Airport Bird Hazard Management (ABHM) strategies take center stage. The cornerstone of an effective ABHM strategy lies in a comprehensive Wildlife Risk Assessment (WRA). Recent guidance from the Federal Aviation Administration (FAA) emphasizes the importance of WRAs (Federal Aviation Administration, n.d.). These assessments identify bird species present at and around airports, including their population size, behavior patterns, and habitat use. This information is crucial for pinpointing high-risk species and their seasonal variations, allowing for targeted management efforts. The Zambia Wildlife Authority (ZAWA) is mandated under the Zambia Wildlife Act No. 12 of 1998 to manage and conserve Zambia's wildlife, which covers 31 percent of the country's land mass. ZAWA endeavors to integrate the wildlife policy with economic, environmental and social policies to ensure effective contribution to sustainable national development. (Zambia Wildlife Authority, n.d.). Therefore, comprehensive collaboration between ZAWA and aviation industry in Zambia is crucial to ABHM. Ministry of tourism (MoT)The Department of National Parks and Wildlife was established in 2015 to protect and conserve Zambia's wildlife and improve the quality of the life among communities in the wildlife estates. The Department also aims to sustain biodiversity in national parks and game management areas. (Department of National Parks and Wildlife [DNPW], n.d.) Habitat management forms another crucial element of ABHM. The goal here is to make airport environments less attractive to birds. This might involve actions like improving drainage to eliminate standing water sources, controlling vegetation through mowing or selective removal of plants that attract birds, and implementing proper waste management practices to reduce food and nesting opportunities. Recent publications by Transport Canada (2022) highlight the effectiveness of these practices in deterring birds.

Active bird dispersal techniques remain a vital line of defense. These techniques utilize tools like pyrotechnics, bioacoustics (distress calls or predator sounds), and trained personnel to deter birds from airfields (Transport Canada, 2022). By implementing a comprehensive ABHM strategy with recent best practices in mind, airports in Zambia can significantly reduce the risk of bird strikes, ensuring the safety of passengers, crew and aircraft at large.

Data collection and monitoring of bird activity patterns are crucial for informing risk assessments and tailoring Airport Bird Hazard Management (ABHM) strategies over time (Federal Aviation Administration [FAA], n.d.). These data allow airport authorities to track changes in bird populations, behavior, and potential threats (FAA, n.d.). Effective ABHM relies on well-trained airport personnel equipped with the knowledge and skills to identify birds, implement dispersal techniques, collect data, and respond to bird strike incidents (FAA, n.d.). Bird control methods vary depending on several factors, including location, bird species, behavior, season, and climate (Díaz et al., 2021) There is no single universally effective method, and successful bird control programs are typically tailored to the specific conditions at each airport (Transport Canada, 2021). Bird control methods can be broadly categorized into three main perspectives: habitat modification, resource protection, and population management (Díaz et al., 2021; Porter et al., 2021)

Habitat modification involves altering the landscape to make it less attractive. Recent studies by Demerdzhiev et al. (2022) suggest that maintaining low vegetation height around runways is crucial for minimizing avian strike risk. Additionally, removing invasive plant species that provide food and cover for birds is another effective strategy (Transport Canada, 2021).

Resource protection focuses on making resources like food and water within the airport inaccessible or unattractive to birds. Techniques like covering landfills, managing standing water, and implementing effective waste management practices can significantly reduce bird activity (Sambo et al., 2020; Wang & Hubbard, 2022)

Population management, a more targeted approach, encompasses methods like capturing and relocating nuisance birds, hazing with predator models or distress calls, and in extreme cases, culling specific bird populations in collaboration with wildlife authorities (Klug et al., 2022). However, population management

methods should be used cautiously and only after exploring all other options due to ethical and ecological considerations. This is where ZAWA becomes crucial as it is the only organ in Zambia that is mandated to control wildlife in Zambia.

All these methods, including habitat modification, resource protection, and population management, are typically implemented within the airport boundaries and its immediate vicinity. This prioritizes mitigating bird strike risks at lower altitudes during takeoff and landing, where they pose the greatest threat to aircraft safety (Díaz et al., 2021; Porter et al., 2021)

A recent and promising development in bird strike risk reduction involves predicting bird presence on a larger scale, beyond airport boundaries and at higher altitudes (Metz et al., 2020). This approach utilizes complex computer models that combine various technologies and data sources, such as radar, satellite imagery, bird distribution information, and factors influencing migration patterns. While not directly controlling bird populations, this predictive approach holds significant potential for preventing bird strikes and is an active area of research (Transport Canada, 2021; Metz et al., 2021).

While research exists on Airport Bird Hazard Management (ABHM) practices in specific regions and airports (Froneman, 2000; Phillips et al., 2018; Qiao & Zhang, 2019), information regarding the current state of ABHM in Zambia is limited. This study aims to address this gap by critically analyzing existing practices at the four main airports; Lusaka City Airport, managed by the Zambia Air Force (ZAF) for VIP and military use, Kenneth Kaunda International Airport (KKIA), Peter Zuze Air Force Base formerly known as Simon Mwansa Kapwepwe Airport (Ndola), and Harry Mwansa Nkumbula International Airport (Livingstone). By evaluating current strategies against established International Civil Aviation Organization (ICAO) standards and best practices, this research will identify areas for improvement and propose recommendations for enhancing bird hazard management at Zambian airports.

II. Methods

This study employed a mixed-methods research design to comprehensively investigate bird hazard management (ABHM) practices at Zambian airports. As outlined by Dawadi et al. (2021) and Creswell & Creswell (2018), mixed-methods research combines quantitative and qualitative data collection methods. This approach was particularly valuable for this study, as it allowed for a nuanced understanding of ABHM practices, capturing both quantitative data on current practices and qualitative insights from airport personnel (Sifuna, 2021).

A questionnaire was administered to assess awareness levels among airport personnel. The study included 42 respondents out of the targeted 60 potentially relevant personnel from Zambia National Airport Cooperation Limited, with 17 (40.50%) having worked for less than a year, 9 (21.40%) for 2-5 years, 12 (28.60%) for 6-10 years, 1 (2.40%) for 11-15 years, and 2 (4.8%) for 21 years or more. Most respondents (17, 40.50%) had less than a year of experience. Among the 42 respondents, 18 (42.90%) held lower management positions, 17 (40.50%) were in middle management, and 7 (16.7%) were in top management. Lower management positions were most common, with 18 respondents (42.90%).

Regarding the highest education level, 8 (19.00%) of the 42 respondents had college certificates, 19 (45.20%) had college diplomas, 13 (31.00%) had university degrees, and 2 (4.80%) had postgraduate degrees. The most common highest education level was a college diploma, with 19 respondents (45.20%).

Additionally, qualitative data collection methods, such as secondary data analysis (International Civil Aviation Organization, 2020), semi-structured interviews (DeJonckheere & Vaughn, 2019), and direct observations (Zamora-Marín et al., 2021), were used to gain a deeper understanding of current practices and challenges. The study utilized a descriptive and explanatory research design, targeting employees from Zambia Airports Cooperation and the Zambia Air Force. A systematic random sampling method was employed to select participants, focusing on employees in safety departments and management positions. A closed-ended questionnaire was developed based on previous literature, with questions presented on a five-point Likert scale. Respondents were assured of confidentiality and encouraged to provide objective responses. Secondary data was obtained from published sources, including books, journals, newspapers, and academic websites.

To assess the need for a more rigorous bird hazard management system, a correlation analysis was conducted on the quantitative data collected through questionnaires using SPSS Version 20 (IBM Corp., 2011). A Pearson correlation matrix was employed to examine relationships between various factors, such as levels of ABHM awareness and reported bird strike incidents (Miot, 2018). Descriptive statistics, including percentages, figures, and tables, were generated to analyze and interpret the data.

III. Results

This study investigated the bird hazard management practices employed at Kenneth Kaunda International Airport (Lusaka), Lusaka City Airport (Lusaka), Peter Zuze Air Force Base (Ndola), and Harry

Mwansa Nkumbula International Airport in Zambia. The findings reveal several critical shortcomings in the airport's approach to bird control, potentially increasing the risk of bird strike incidents.

Findings at Kenneth Kaunda International Airport (KKIA):

The study documented the presence of several mammal species, including common duikers, side-striped jackals, and bushbucks. Their distribution is illustrated in the wildlife habitat map (Figure 1).



Figure 1: Mapping of birds and mammals' wildlife habitat at the Kenneth Kaunda International Airport (KKIA)

Kenneth Kaunda International Airport (KKIA) faces significant threats from birds and wildlife, posing a safety risk to aircraft operations. Research suggests specific bird species can be particularly hazardous to aircraft. black-headed heron (*typhon melanocephalus*) and african fish eagle (*haliaetus vocifer*) are known to cause bird strikes globally (Phillips et al., 2018) (Their presence at KKIA requires targeted mitigation strategies).

KKIA's vulnerability extends beyond birds. The presence of larger animals like common duikers (*sylvicapra grimmia*) and side-striped jackals (*canis adustus*) necessitates a broader wildlife hazard management (WHM) approach (Pagany, 2020). These mammals can cause significant damage to aircraft upon collision. Open vegetation and insect activity within the airport perimeter create attractive habitats for wildlife. A lack of proper fencing, as identified in this study, further exacerbates the issue (Transport Canada, 2021). Addressing these environmental factors through habitat modification is crucial for reducing wildlife presence.

Insufficient information and training on wildlife management among airport personnel is a recurring challenge globally (Metz et al., 2021). For this reason, equipping staff with the knowledge and skills to identify wildlife hazards and implement appropriate deterrents is critical. The unclear division of responsibility between Zambia Airports Corporation Limited (ZACL) and the Department of National Parks and Wildlife (ZAWA) regarding wildlife culling within the airport creates a management gap. Collaborative efforts and clearly defined roles are essential for effective WHM (Sifuna, 2021).

Agricultural practices in the vicinity of the airport can attract birds seeking food and water. Investigating collaborative strategies with local farmers to implement bird-detererring practices in surrounding areas could be beneficial (Iglay et al., 2017). The presence of streams and dambos (seasonal wetlands) within the airport's vicinity provides additional habitat for wildlife. A comprehensive WHM plan should consider these areas and incorporate strategies to deter wildlife from utilizing them. (Phillips et al., 2018)

A diverse insect population, including bees, wasps, grasshoppers, and termites, thrives at KKIA, creating a smorgasbord for many bird species These insects act as a magnet, drawing birds into the airport grounds (Phillips et al., 2018)

The vandalized perimeter fence at KKIA creates easy access for wildlife and unauthorized individuals, significantly increasing the risk of bird strikes (Transport Canada, 2021). This compromised barrier necessitates immediate repair and maintenance to enhance airport safety and security.

The natural vegetation surrounding KKIA presents a double-edged sword. While aesthetically pleasing, the Miombo woodland (Figure 2) and open grasslands (Figure 3) provide ideal nesting and foraging habitat for birds (Metz et al., 2021). This natural environment attracts birds, potentially increasing the risk of encounters with aircraft.

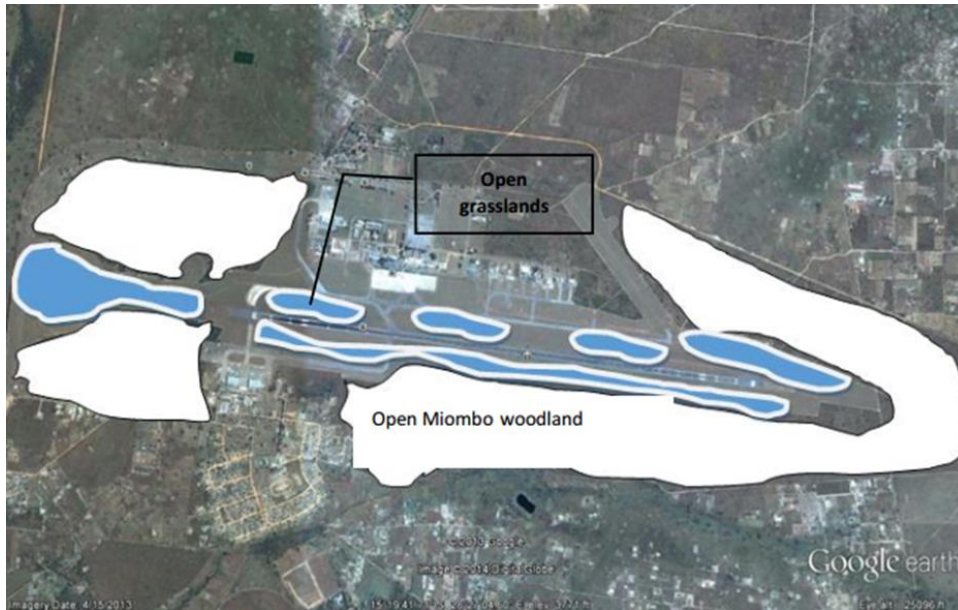


Figure 2: Vegetation distribution on the KKIA



(a)

(b)

Figure 3: (a) Miombo woodland; (b) Open grassland on the airport

Agricultural activities like maize and wheat cultivation right next to the airport boundaries create another unintended attractant for wildlife. These crops provide a readily available food source, drawing animals closer to the airport (Iglay et al., 2017). Similarly, fish and poultry farms in the vicinity can also contribute to wildlife presence near KKIA.

Improper waste disposal by residents and farmers near the airport creates a haven for birds like pied crows. These birds are scavengers and are attracted to the easy pickings offered by discarded waste. Community education programs on proper waste management practices are crucial to reducing this attractant (Gupta et al., 2023).

The presence of streams and dams on the south side of the airport provides breeding grounds for birds and amphibians. This can potentially increase bird activity near the airport, posing a safety threat (Transport Canada, 2021).

While the presence of wildlife attractants is concerning, the study also identified challenges associated with effective WHM at KKIA. The study revealed a lack of knowledge and training on wildlife management among some airport personnel. Effective WHM requires a skilled workforce to implement appropriate deterrents and reporting protocols (Metz et al., 2021). The desire for stricter wildlife control at KKIA can clash with the Department of National Parks and Wildlife (ZAWA)'s wildlife protection mandates. Finding a balance between aviation safety and wildlife conservation may necessitate improved collaboration and potentially revised wildlife management laws specifically for airports (Sifuna, 2021). ZAWA's slow response times due to distance and resource limitations highlight the need for better collaboration between airport authorities and ZAWA (Pagany, 2020). A more coordinated approach with clearly defined roles and responsibilities can improve overall WHM effectiveness.

By addressing these wildlife attractants and management challenges, KKIA can develop a more comprehensive WHM program. This program should include Staff training programs on wildlife identification, deterrents, and reporting protocols. Collaboration with surrounding communities to promote wildlife-deterrent land-use practices. Repair and maintenance of the airport perimeter fence to restrict unauthorized access. Exploration of habitat modification strategies to reduce insect populations and discourage nesting. Planned relocation of settlers and farming activities around the airport's perimeter fence can significantly contribute to airport safety and security, and reduce bird activity. Partnership with the Lusaka City Council to implement community education programs on proper waste disposal practices. Working with ZAWA to develop a more collaborative WHM plan with clearly defined roles and responsibilities. Investigating the feasibility of revising wildlife management laws at airports to ensure both aviation safety and wildlife conservation. By taking a multi-faceted approach, KKIA can create a safer environment for both aircraft and wildlife.

Findings at Lusaka City Airport

Lusaka City Airport, managed by the Zambia Air Force (ZAF) for VIP and military use, presents a unique challenge for bird hazard management (BHM) due to limited information available to the public. While security restrictions make it difficult to obtain comprehensive data, the study was able to identify several key attractants for birds and concerning knowledge gaps among airport personnel.

The study aligns with recent research by Sebastian and Louis (2021) highlighting the importance of proper waste management in BHM. Inadequate waste disposal practices in surrounding residential areas, airport restaurants, and detachment kitchens with leftover food readily available create a significant attractant for birds. This echoes Sebastian and Louis findings that poor waste management practices present a major risk factor for bird strikes at airports. Another attractant identified in the study is the presence of trees around the airport. As highlighted by Phillips et al. (2018) in his research on bird strike risks and habitat modification, these trees offer birds shelter and potential nesting sites, making the airport grounds more attractive.

The study revealed a significant gap in BHM practices at Lusaka City Airport. Unlike the International Civil Aviation Organization's (ICAO) recommendations for a dedicated bird control team (ICAO, 2020), the airport currently lacks such a program. The fire department's occasional runway inspections, while helpful, fall short of a comprehensive BHM strategy. This lack of a dedicated team suggests a potential reactive approach to bird hazards, rather than a proactive one.

Furthermore, the study identified varying levels of bird strike experience and awareness among airport personnel. Some personnel acknowledged experiencing bird strikes, while others seemed unaware of the potential dangers. This inconsistency suggests a potential underestimation of the threat posed by bird strikes. Research by Metz et al. (2021) emphasizes the importance of education and training programs to improve awareness and preparedness for bird strike incidents.

To effectively mitigate bird strike risks, Lusaka City Airport requires a robust BHM program. This program should establish a dedicated and well-trained team responsible for monitoring, controlling, and mitigating bird hazards within the airport's premises. Following Phillips et al. (2018) recommendations, strategies like removing or managing overgrown vegetation, open water sources, and waste materials can reduce bird attractants. Additionally, implementing training programs can address knowledge gaps and improve overall preparedness for bird strike incidents. By addressing these critical areas, Lusaka City Airport can develop a more robust BHM program, enhancing aviation safety and minimizing bird strike risks for both aircraft and wildlife.

Findings at Peter Zuze Air Force Base (Ndola)

Peter Zuze Air Force Base, similar to other Zambian airports like Kenneth Kaunda International Airport (KKIA) and Harry Mwanga Nkumbula International Airport, faces significant threats from various bird and animal species (Phillips et al., 2018). Factors like insects, surrounding vegetation, and potential waste disposal sites near the airport can attract wildlife, increasing the risk of bird strikes and animal incursions (Metz et al., 2021). A study by Iglay et al. (2017) highlights how agricultural activities near airports can also attract birds seeking food and water. Investigating these potential attractants and implementing mitigation strategies are crucial. A damaged fence, whether due to wildlife activity or vandalism, creates easy access points for animals, further amplifying safety concerns (Transport Canada, 2021). Repairing and maintaining the perimeter fence is essential to restrict unauthorized wildlife access. A lack of specific knowledge and training on wildlife management among airport personnel appears to be a recurring issue across Zambian airports Metz et al (2021). Equipping staff with the knowledge and skills to identify wildlife hazards and implement appropriate deterrents is critical for effective wildlife hazard management (WHM). By addressing these challenges, Peter Zuze Air Force Base can enhance aviation safety and minimize wildlife-aircraft collisions. Implementing a multi-faceted WHM program that integrates habitat modification, deterrents, improved waste management practices, and staff training is essential.

Findings at Harry Mwanga Nkumbula International Airport:

Harry Mwanga Nkumbula International Airport, situated just 5km from Livingstone, Zambia's tourist capital, and a mere 15km from the majestic Victoria Falls (Figure 4), faces unique wildlife hazard challenges. This study highlights the key threats and draws upon recent research to inform potential mitigation strategies.

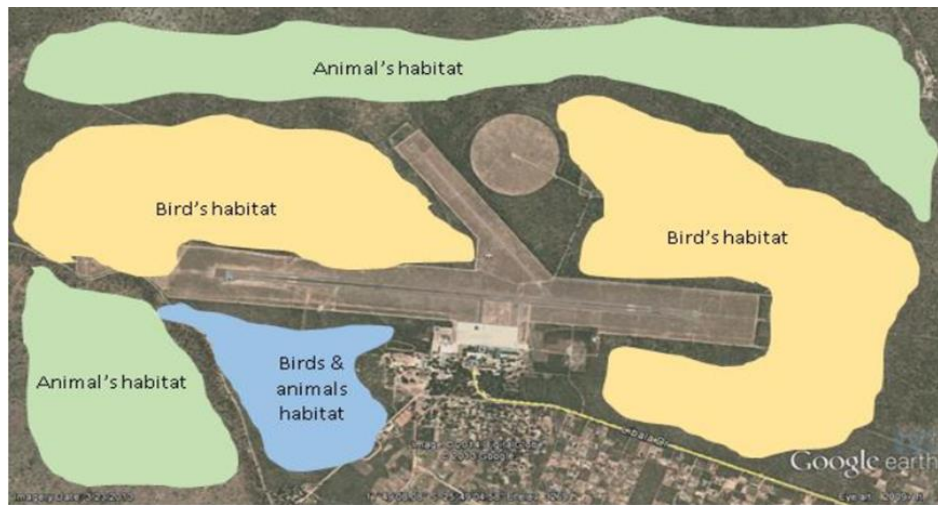


Figure 4: Mapping of Birds and mammals habitat (Harry Mwanga Nkumbula International Airport)

The airport's proximity to protected areas and abundant wildlife necessitates a more nuanced approach to wildlife hazard management (WHM) compared to airports in less ecologically sensitive locations. Notably, a study by Pagany (2020) emphasizes the importance of understanding wildlife movement patterns when developing WHM plans at airports near wildlife corridors.

The study identified birds like black-headed herons (*typhon melanocephalus*), fish eagles (*haliaetus vocifer*), and swallows as potential threats, echoing concerns raised by Phillips et al.(2018) regarding the hazards posed by these particular species .

Animals like duikers, jackals, and even elephants and buffaloes, according to records, have been observed near the airport. Elephants, in particular, pose a significant threat due to their size and potential for runway incursions. During the rainy season, the abundance of insects in short-cut grass areas attracts insectivorous birds like black-headed herons, swallows, and larks, as documented in the study. This aligns with research by Iglay et al. (2017) highlighting the role of habitat management in reducing insect populations that attract birds.

The diverse vegetation surrounding the airport provides food and shelter for various animals and insects, further increasing wildlife activity. The presence of nearby dumping sites, as highlighted in the study, managed by the Zambia Air Force and Livingstone City Council, creates a readily available food source for wildlife like crows, eagles, hawks, and baboons, potentially attracting them onto the airport grounds.

The natural ecosystem of nearby National Parks contributes to bird presence at the airport. Some species might migrate through or reside near the airport due to its landscape features, underscoring the importance of collaboration with wildlife authorities for effective WHM strategies. The deteriorated state of the airport fence, due to a combination of elephant activity and vandalism creates easy access points for wildlife and trespassers. Repairing and maintaining the fence is crucial to enhance airport security, as emphasized by Transport Canada (2021).

Similar to other Zambian airports, Harry Mwanga Nkumbula Airport lacks a dedicated wildlife management program. Inspections currently focus on foreign objects rather than bird hazards. Equipping staff with wildlife identification skills and implementing bird hazard deterrents are essential steps, as highlighted by Metz et al. (2021) in their review of bird strike avoidance measures.

By addressing these unique challenges, Harry Mwanga Nkumbula International Airport can develop a comprehensive WHM program. This program should include, collaboration with wildlife authorities to understand animal movement patterns and implement mitigation strategies. Habitat modification strategies to reduce insect populations and discourage nesting, focusing on areas with short-cut grass. Improved waste management practices in collaboration with the Livingstone City Council to eliminate attractants for wildlife. Repair and maintenance of the perimeter fence to restrict unauthorized access. Staff training programs on wildlife identification, deterrents, and reporting protocols. By taking a proactive approach and implementing these evidence-based recommendations, Harry Mwanga Nkumbula International Airport can create a safer environment for both aircraft and wildlife.

Data Presentation

The data collected from airport personnel who completed the questionnaire is presented in the following tables.

Table 1: Experience or Encounters with birds around the airports

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	13	31.0	31.0	31.0
	no	4	9.5	9.5	40.5
	Not aware	25	59.5	59.5	100.0
	Total	42	100.0	100.0	

As shown in Table 1, 13 (31.00%) of the 42 respondents reported that their airports experience bird strikes, while 4 (9.50%) indicated no encounters, However, a significant portion (25, 59.50%) were unaware of whether their airports had experienced bird strikes. This discrepancy suggests a lack of awareness among airport personnel regarding bird hazard management systems.

Table 2: Satisfaction with quality of airport bird hazard management methods at the airport

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very unsatisfied	2	4.8	4.8	4.8
	Unsatisfied	16	38.1	38.1	42.9
	Satisfied	9	21.4	21.4	64.3
	Very Satisfied	15	35.7	35.7	100.0
	Total	42	100.0	100.0	

According to Table 2, most of respondents expressed satisfaction with the quality of airport bird hazard management methods. Only 2 (4.80%) were very unsatisfied, while 16 (38.10%) were unsatisfied. Cumulatively, this means that 18 out of 42 respondents (42.9%) were dissatisfied or very dissatisfied.

Regarding the quality of methods employed in bird management, 4 (9.50%) of respondents rated them as poor, 19 (45.20%) as average, 5 (11.90%) as good, and 14 (33.30%) as excellent. This indicates that while a significant portion of respondents were satisfied with the methods, the majority (45.2%) rated them as average, suggesting room for improvement in bird hazard management practices.

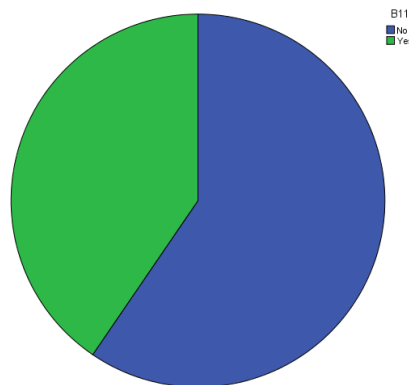


Figure 5: Existence Of An Active Airport Bird Hazard Management System

According to Figure 5, a significant portion of respondents were unaware of the existence of an active airport bird hazard management system. Only 17 (40.50%) indicated that such a system was in place, while 25 (59.50%) were unaware.

Regarding perceived factors affecting bird control at airports, a majority of respondents agreed that garbage accumulation is a significant issue. None strongly disagreed, 5 (11.90%) disagreed, 4 (9.50%) were unsure, 19 (45.20%) agreed, and 14 (33.30%) strongly agreed.

To further understand the lack of ABHM systems, 5 (11.90%) strongly disagreed with the existence of a garbage management unit, 9 (21.40%) disagreed, 1 (2.40%) were unsure, 14 (33.30%) agreed, and 13 (31.00%) strongly agreed. This suggests that a lack of proper garbage management contributes to the problem.

Additionally, 8 (19.00%) strongly disagreed that restaurants lack a waste management system, 4 (9.50%) disagreed, 11 (26.20%) were unsure, 11 (26.20%) agreed, and 8 (19.00%) strongly agreed. This indicates that restaurants also play a role in attracting birds to airports through improper waste management.

Furthermore, 6 (14.30%) strongly disagreed with the presence of many pools and water bodies at the airport, 3 (7.10%) disagreed, 3 (7.10%) were unsure, 18 (42.90%) agreed, and 12 (28.60%) strongly agreed. This confirms that water bodies act as attractants for bird species at airports.

Finally, 4 (9.50%) strongly disagreed with the lack of proper equipment for bird control, 3 (7.10%) disagreed, 3 (7.10%) were unsure, 12 (28.60%) agreed, and 20 (47.6%) strongly agreed. This suggests that a significant portion of respondents believe that airports lack adequate equipment for effective bird control.

These findings align with Sebastian and Louis (2021), who emphasize the importance of hazard awareness, well-organized waste management, modern equipment, and training for effective airport bird hazard management.

Regarding the availability of information on airport bird hazard management, a significant majority of respondents (54.80%) strongly agreed that such information is not readily available to staff at Zambia Airports Cooperation Limited. Only 2 (4.80%) strongly disagreed, 3 (7.10%) disagreed, 9 (21.40%) were unsure, and 5 (11.90%) agreed. This indicates a significant lack of accessible information on bird hazard management among airport personnel.

Table 3: Possible reasons of difficulties in information flow between the department of Wildlife & National Parks and personnel

	Frequency	Percent	Valid Percent
Lack of information dissemination	18	42.9	42.9
Lack of Training	18	42.9	42.9
Lack of understanding of procedures	24	57.14	57.14
Insufficient supervision	20	47.62	47.62
Lack of adherence to safety principles	28	66.67	66.67
Total count	42		

Respondents were asked to identify possible reasons for difficulties in information flow between the department of Wildlife & National Parks and personnel. According to Table 3, lack of understanding of procedures was the most frequently cited reason, with 24 respondents (57.14%) identifying it as a significant obstacle. Lack of information and lack of training were also frequently mentioned, with 18 respondents (42.90%) citing each as a contributing factor. Insufficient supervision and lack of adherence to safety principles were also identified as potential barriers to effective information flow, with frequencies of 20 (47.62%) and 28 (66.67%) respectively.

Regarding training, 10 (23.80%) of respondents disagreed with the adequacy of training in bird hazard management, 7 (16.70%) were unsure, 12 (28.6%) agreed, and 13 (31.00%) strongly agreed. This suggests that a significant portion of respondents believe that training in bird hazard management is insufficient.

Furthermore, 2 of the 42 respondents strongly disagreed with the existence of supervision by management involved in bird hazard management, 11 (26.20%) disagreed, 13 (31.00%) were unsure, 10 (23.80%) agreed, and 6 (14.30%) strongly agreed. This indicates that supervision by management is not consistently present in bird hazard management activities at the airports.

Table 4: Existence of routine checks at the airports on bird hazards

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	3	7.1	7.1
	Disagree	8	19.0	26.2
	Not sure	6	14.3	40.5
	Agree	17	40.5	81.0
	Strongly agree	8	19.0	100.0
Total	42	100.0	100.0	

Regarding the adherence to safety protocols during routine checks in Table 4, 3 (7.10%) of respondents strongly disagreed with their existence, 8 (19.00%) disagreed, 6 (14.30%) were unsure, 17 (40.50%) agreed, and 8 (19.00%) strongly agreed. This indicates that while a majority of respondents agreed that routine checks are conducted, there is still a significant portion who are unsure or disagree, suggesting potential gaps in safety protocol adherence.

Table 5: Compliance in dealing with bird hazard management in the set standard and recommended practices by ICAO.

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Disagree	13	31.0	31.0
	Not sure	10	23.8	54.8
	Agree	11	26.2	81.0
	Strongly agree	8	19.0	100.0
	Total	42	100.0	100.0

According to Table 5, a significant portion of respondents (26.20%) believe that there is compliance with ICAO standards and recommended practices for bird hazard management. However, 13 (31.00%) disagreed, 10 (23.80%) were unsure, and 8 (19.00%) strongly disagreed, indicating that compliance is not universally adhered to.

Regarding the implementation of bird dispersal exercises or workshops for internal staff capacity building, a majority of respondents (50.00%) were unsure, suggesting a lack of clarity or knowledge about such initiatives. Only 6 (14.30%) strongly disagreed, 6 (14.30%) disagreed, 6 (14.30%) agreed, and 3 (7.10%) strongly agreed.

Regarding training in bird control, 3 (7.10%) strongly disagreed with the lack of adequate training, 6 (14.30%) disagreed, 15 (35.70%) were unsure, 10 (23.80%) agreed, and 8 (19.00%) strongly agreed. This suggests that a significant portion of respondents (35.70%) are unsure about the adequacy of training programs, highlighting a potential area for improvement in bird hazard management.

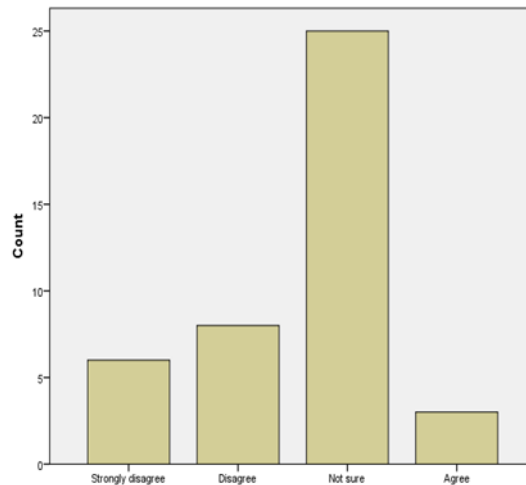


Figure 6: Shows whether or not the airport uses new technologies to manage birds at the airport.
Source: Field data

Regarding the use of new technologies for bird management at the airport in Figure 6, a majority of respondents (59.50%) were unsure. Only 6 (14.30%) strongly disagreed, 8 (19.00%) disagreed, and 3 (7.10%) agreed. This suggests a lack of awareness or understanding regarding the use of new technologies in bird hazard management at the airport.

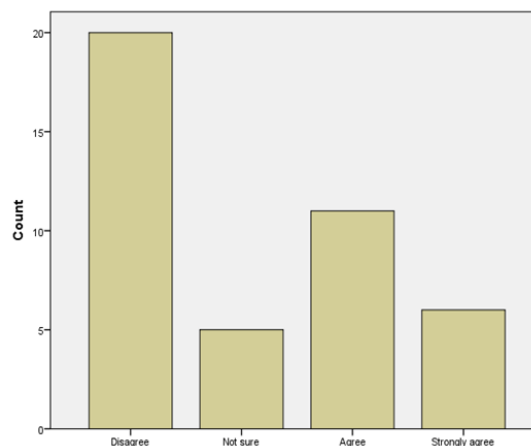


Figure 7: Government Support towards Airport Bird Hazard Management

Figure 7 indicates that a significant majority of respondents (47.60%) disagreed with the government's support for airport bird hazard management programs. Only 5 (11.90%) were unsure, 11 (26.20%) agreed, and 6 (14.30%) strongly agreed. This indicates a lack of government commitment to this issue, aligning with Sifuna (2021), who emphasized the importance of top management commitment for successful organizational initiatives. It was further established that the Ministry of Transport and Communication in Zambia does not provide financial or technological support to airports for bird management and control.

Correlation Analysis

Table 6: Ministry of Transport & Logistics commitment and effort Vs Airport Bird Hazard Management

Correlation matrix (Pearson):		
Variables	Airport Bird hazard management	Ministry's commitment and effort
Airport Bird hazard management	1	0.2537
Ministry's commitment and effort	0.2537	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 6 illustrates that there is a positive weak relationship between the Government Ministry's commitment and effort, and Airport Bird hazard management.

Table 7: Government policies Vs Airport Bird Hazard Management

Correlation matrix (Pearson):		
Variables	Airport Bird hazard management	Government policies
Airport Bird hazard management	1	0.8943
Government policies	0.8943	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 7 illustrates that there is a positive very strong relationship between government policies and Airport Bird hazard management.

Table 8: Waste Management Vs Airport Bird Hazard Management.

Correlation matrix (Pearson):		
Variables	Airport Bird hazard management	Waste management
Airport Bird hazard management	1	0.2085
Waste management	0.2085	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 8 illustrates that there is a positive weak relationship between Waste management materials and Airport Bird Hazard Management.

Table 9: Information flow Vs Airport Bird Hazard Management

Correlation matrix (Pearson):		
Variables	Airport Bird hazard management	Information flow
Airport Bird hazard management	1	0.7422
Information flow	0.7422	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 9 illustrates that there is a positive strong relationship between information flow and Airport Bird hazard management.

Table 10: Technology Vs Airport Bird Hazard Management

Correlation matrix (Pearson):		
Variables	Airport Bird hazard management	Technology
Airport Bird hazard management	1	0.1521
Technology	0.1521	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 10 Illustrates that there is a positive weak relationship between technology and Airport Bird hazard management.

IV. Discussions

Questionnaire revelation

A quantitative data collection method, a questionnaire, was employed to gather information from 42 airport personnel. The questionnaire revealed concerning information about bird hazard management (ABHM) at the airports. A substantial portion (40.5%) of respondents acknowledged bird strikes occurring at the airports. However, a worryingly high number (59.5%) were unaware of the frequency of these incidents. This finding aligns with research by Metz et al. (2021) who identified a potential gap between awareness of bird strikes and the actual number of incidents reported at airports. This highlights a potential lack of awareness or clear remedial structures and reporting procedures for bird strikes at the studied airports.

Furthermore, a significant majority (59.5%) of respondents were unaware of an active bird hazard management system in place at the airports. This aligns with concerns raised by Phillips et al.(2018) regarding

the importance of clear communication and staff training on existing ABHM practices. A lack of awareness about established protocols could hinder overall preparedness to address bird strike threats.

Additionally, a large percentage (66.7%) of respondents felt personnel disregarded safety protocols, suggesting a need for stricter enforcement and improved safety culture. Communication and training emerged as critical areas for improvement. Over half (54.8%) of respondents felt a lack of information was a major issue, and a similar number (42.9%) identified the absence of proper training as a hindrance to effective bird hazard awareness. These findings echo similar concerns raised by Sifuna (2021) regarding the importance of fostering a strong safety culture through effective communication and training programs for airport personnel.

The quality of current bird hazard management (ABHM) practices at the airports also appears uncertain. While some respondents rated the methods used as average (45.2%), a significant portion remained unsure about their effectiveness. This aligns with concerns raised by Phillips et al. (2018) regarding the importance of evaluating existing ABHM practices to ensure their efficacy.

Furthermore, a lack of knowledge regarding the use of new technologies for bird control was evident, with over half (59.5%) unsure of their implementation. This finding highlights a potential gap in communication and training on modern ABHM approaches, as identified by Metz et al. (2021) Integrating new technologies, such as bird radar systems or bio-acoustic deterrents, could significantly improve bird strike prevention efforts (Transport Canada, 2021).

The report also highlights a potential gap in government support for ABHM programs. Nearly half (47.6%) of respondents disagreed that the government actively supports these programs. This finding aligns with research by Sifuna (2021) who emphasises the critical role of government agencies in providing resources and collaborating with airport authorities to establish effective ABHM strategies.

According to Qiao & Zhang (2019), there is no single universally applicable method for airport bird management. Therefore, airport environmental and safety departments must identify the most suitable approaches based on their country's circumstances and capabilities. Sifuna (2021) suggests several areas where assistance can be provided: financial assistance in the form of soft loans, prompt payment of invoices, procurement of modern equipment, and management support. Wildlife management organisations and environmental friendly institutions can contribute by funding workshops and capacity-building seminars to enhance knowledge and skills in bird hazard control. By providing training and sharing valuable information, these organisations can support the development of standards and quality practices in airport bird hazard management.

In conclusion, the questionnaire paints a picture of a bird hazard management system in need of a significant overhaul. Improved communication, training on existing and emerging ABHM methods, and a focus on implementing modern technologies are crucial. Additionally, stronger government support, adherence to clear safety protocols, and collaborative effort between airport authorities and government agencies are essential to creating a more comprehensive and well-coordinated bird hazard management program at Zambian airports.

Correlation analysis

This section analyzes the factors influencing bird hazard management (BHM) at Zambian airports using a Pearson correlation matrix. The results provide valuable insights, supported by recent studies, for strengthening BHM practices. The study revealed a very strong positive correlation between government policies and airport BHM practices. This aligns with research by Sifuna (2021) emphasizing the importance of clear and well-enforced wildlife management policies. Effective policies can encourage airports to prioritize BHM and allocate necessary resources.

A weak positive correlation emerged between waste management practices and bird strike risk, suggesting that proper waste disposal can deter birds. This echoes the findings of Sebastian and Louis (2021) who highlights the critical role of waste management in reducing bird attractants at airports. Implementing improved waste management systems, including proper disposal of food waste from restaurants and detachment kitchens, regular garbage collection, and potentially using deterrents like bird netting, can significantly reduce bird activity near airports. The study suggests a potential positive correlation between transparency and BHM, hinting at the benefits of improved communication. While not explicitly measured, "information flow" could be another important factor. Metz et al. (2021) emphasize the importance of effective communication and data sharing among airport personnel, wildlife authorities, and government agencies for successful BHM implementation.

The study identified a weak positive correlation between technology use and bird strikes at Zambian airports. While this finding does not definitively disprove the effectiveness of technological deterrents in bird hazard management (BHM), it highlights the need for further research. A closer look at the current state of knowledge and the potential of technology in BHM strategies have yielded mixed results regarding the effectiveness of specific technological deterrents. Phillips et al. (2018) evaluated a bird radar system at a large airport and found a reduction in bird strikes, but questions remain about long-term effectiveness and generalisability across airports with different bird populations and environments. Similarly, a review by Transport Canada (2021) highlighted the limitations of some technological deterrents, such as bio-acoustic devices, due to

habituation by birds. Relying solely on technology can create a false sense of security and potentially lead to neglecting other crucial BHM practices like habitat modification and waste management (Metz et al., 2021). A comprehensive BHM strategy should consider technology as a complementary tool, not a replacement for other established methods. Emerging technologies like bio-acoustic devices with species-specific sounds or laser deterrent systems might hold promise for targeted deterrents. However, further research is needed to evaluate their long-term effectiveness and cost-efficiency for large-scale implementation at airports (Silaeva and Pedenko, 2023). While the current evidence base for technological deterrents in BHM is inconclusive, there are promising avenues for further investigation. Research comparing the effectiveness of different technologies across various airport environments is crucial to identifying the most promising solutions. Studies evaluating the combined impact of technology with habitat modification and waste management practices can provide valuable insights for developing holistic BHM strategies. Investing in data collection and analysis of bird strike incidents in conjunction with specific technologies can provide more definitive evidence regarding their effectiveness. By conducting further research and focusing on targeted approaches that complement existing BHM practices, technology has the potential to become a valuable tool in mitigating bird strike risks at airports.

Effective BHM goes beyond habitat modification. Waste management practices throughout the airport require significant attention. This includes, implementing proper disposal systems for food waste generated by restaurants and detachment kitchens. Ensuring regular garbage collection to eliminate readily available food sources for birds. Utilising deterrents like bird netting or spikes on structures that provide shelter or nesting grounds. By addressing these critical aspects and implementing the recommendations outlined above, Zambian Airports can significantly improve its BHM practices, leading to a safer operational environment for both aircraft and wildlife.

V. Conclusion

This study has revealed several key challenges faced by Zambian airports, highlighting the need for a multi-faceted approach to bird hazard management (BHM). One major concern identified in the study is the lack of dedicated wildlife management programs and staff knowledge at Zambian airports. Airport personnel often lack the training and resources necessary to effectively identify and deter wildlife hazards. This knowledge gap can lead to a reactive approach to bird strikes, rather than a proactive one focused on prevention.

Furthermore, the study identified a variety of factors attracting birds and wildlife to Zambian airports. Improper waste disposal practices, particularly near restaurants and detachment kitchens, create a readily available food source for birds. Additionally, the presence of insects in short-cut grass areas and the proximity of national parks to airports contribute to increased wildlife activity on and around airport grounds. Compromised perimeter security due to elephant activity and vandalism further exacerbates the problem by creating easy access points for animals.

However, the study also offers promising solutions. The research revealed positive correlations between government policies, waste management practices, and effective BHM strategies. Strong and well-enforced government policies that prioritise BHM and allocate necessary resources are crucial for establishing effective airport wildlife management programs. Improved waste management practices, such as proper food waste disposal, regular garbage collection, and potentially using deterrents like bird netting, can significantly reduce bird activity near airports. Enhancing communication and information flow among airport personnel, wildlife authorities, and government agencies is also essential for a coordinated approach to BHM.

While the effectiveness of technological deterrents like bird radars or bio-acoustic devices requires further investigation, a comprehensive BHM strategy should consider them as a complementary tool alongside established method. By addressing the critical areas identified in this study, Zambian airports can significantly improve their BHM programs. Implementing robust wildlife management plans, improving waste management practices, and fostering better communication will not only enhance aviation safety but also minimize wildlife casualties. This will lead to a safer operational environment for both aircraft and wildlife, ensuring a more sustainable future for Zambian aviation.

Further research is recommended to investigate the effectiveness of specific technological deterrents and compare the success of different BHM strategies across various Zambian airport environments. Additionally, exploring the economic feasibility and long-term effectiveness of implementing these strategies is crucial for long-term success. By continuing research efforts and taking action based on the findings of this study, Zambian aviation authorities can create a more robust BHM framework, ensuring safer skies for Zambia and other countries flying in and out of Zambia.

VI. Recommendations

Based on the findings, the following recommendations are crucial for mitigating bird hazards at Zambian airports and can be adapted for broader application in an international context:

1. To effectively manage bird hazards, airports should adopt internationally recognized best practices outlined by organizations like ICAO and the FAA. These strategies should be tailored to local conditions and wildlife populations. Engaging with local communities is essential to understand their concerns and ensure their support for wildlife management initiatives.
2. To effectively manage bird hazards, airports should employ a diverse range of control techniques, including habitat modification, predator control, and repellents. Additionally, exploring advanced technologies like bird detection systems and laser bird dispersal devices can enhance bird control efforts.
3. Data-driven decision-making is crucial for effective bird hazard management. Implementing comprehensive monitoring programs and conducting regular risk assessments can help airports identify and prioritise areas of concern. By analyzing collected data, airports can make informed decisions and optimize their bird control strategies.
4. To effectively manage bird hazards, airports should establish dedicated bird control teams composed of qualified personnel. These teams should receive ongoing training and professional development to stay updated on best practices and emerging technologies. International collaboration can facilitate knowledge sharing and the exchange of innovative approaches to bird control.
5. Developing comprehensive emergency response plans is essential for mitigating the impacts of wildlife strikes. Ensuring effective coordination among airport staff, wildlife control agencies, and other relevant stakeholders is crucial during emergencies.
6. Public awareness campaigns can help educate the community about the importance of bird hazard management and the measures being taken to address the issue. Encouraging community involvement in wildlife conservation efforts can foster a sense of ownership and support for bird control initiatives.
7. Airports must comply with relevant national and international regulations regarding wildlife management and airport safety. Advocating for the development of clear and effective policies can help to create a supportive environment for bird hazard management efforts.
8. To strengthen bird hazard management efforts, airports should actively participate in international forums and networks to exchange information and best practices. Collaborating with researchers and institutions from other countries can foster knowledge sharing and promote advancements in understanding and addressing bird hazards.

By implementing these recommendations, airports worldwide can enhance their efforts to mitigate bird hazards and ensure safer operations. It is essential to tailor these strategies to local conditions and engage with relevant stakeholders to achieve sustainable and effective results.

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