



Research Article

Flight Safety Operations and Urban Birds Feeding Ecology in Douala International Airport, Littoral Region, Cameroon

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Abstract

The interplay between flight safety operations and urban birds' feeding ecology at Douala International Airport highlights the complexity of managing wildlife in urban aviation environments. Understanding these dynamics is crucial for developing effective interventions that enhance aviation safety while promoting biodiversity. Continued research and collaboration among stakeholders are essential to create a sustainable framework that benefits both the aviation sector and the rich avian diversity of the Littoral Region. The increasing frequency of air traffic at Douala International Airport has led to growing concerns about bird strikes and their implications for aviation safety. This study explores the intricate relationship between flight safety operations and the feeding ecology of urban birds in Douala International Airport. Through field surveys and behavioral observations, predominant bird species inhabiting the airport vicinity was recorded, and their feeding ecology was correlated with the proximity to flight paths at the runway. The results of this study recorded a high presence of village weaver (*Ploceus cucullatus*) 21.2%, black-crowned waxbill (*Estrilda nonnula*) 19.7% respectively, while pied crow (*Corvus albus*) 2.3% and black & white mannikin (*Lonchura bicolor*) 2.3% recorded the lowest presence. The study has also shown a significant association on flight routine operations $X^2=85.545$ $df=20$ $P=0.000$, day-period $X^2=67.172$ $df=20$ $P=0.000$, and climatic conditions $X^2=100.768$ $df=30$ $P=0.000$ respectively. More so, birds location during flight operations was significantly linked to birds strike risk assessment $X^2=28.531$ $df=2$ $P=0.000$, and the Social Activity of Birds $r=0.622$ $P=0.000$. Also, movement pattern of birds within the airport recorded a significance on climatic conditions $r=0.363$ $P=0.000$, and their habitat characteristics $r=0.768$ $P=0.000$. The relationship between birds' location during routine flight operations and the risk of bird strikes is a critical area of research that impacts aviation safety and wildlife conservation. As bird populations and behavior continue to evolve, understanding the nuances of their movements in relation to airport operations will be essential. This research underscores the importance of integrating ecological considerations within aviation safety protocols, advocating for sustainable practices that balance flight operational efficiency. The study equally highlights the importance of fostering a balanced coexistence between aviation operations and wildlife conservation. By prioritizing collaborative efforts and evidence-based strategies, Douala International Airport can serve as a model for sustainable aviation practices that both safeguard flight operations and protect the rich avian diversity of the Littoral Region.

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Keywords

Flight Safety, Urban Birds, International Airport, Activity of Birds, Balance Coexistence

1. Introduction

As one of the busiest airports in Cameroon, Douala International Airport plays a crucial role in facilitating air travel and trade in the region [5]. However, the increasing frequency of flight operations raises concerns over the interactions between aircraft and local wildlife, particularly urban birds. Understanding how these operations influence bird feeding ecology is essential to mitigate bird strike risks and promote biodiversity. Bird strikes pose significant risks to aviation safety, leading to potential damages, injuries, or loss of aircraft. According to the Federal Aviation Administration (FAA), bird strikes result in hundreds of millions of dollars in damages annually. Studies highlight that certain bird species, particularly larger ones, contribute disproportionately to these incidents [7]. At Douala International Airport, the prevalence of bird strikes calls for a detailed understanding of local bird populations. This involves not only identifying species frequenting the airport vicinity but also analyzing their behaviors in relation to flight patterns. According to [23], emphasizes the need for airport management to integrate ecological assessments into safety protocols to minimize wildlife-related risks.

Urbanization profoundly influences avian feeding behaviors. The adaptation of birds to urban environments often results in dietary shifts toward anthropogenic food sources. According to [19], many urban bird species exhibit flexibility in their diets, exploiting resources such as refuse and food waste. In the context of Douala International Airport, birds may rely on organic waste produced by airport operations and nearby urban areas. According to [3], urban birds, including pigeons and black-headed gulls, thrive due to the abundant food resources provided by human activities, raising concerns about their increased presence near flight paths. Aircraft operations create various disturbances that can affect bird behavior and habitats. Noise pollution from aircraft can disrupt avian communication and foraging patterns, leading to altered feeding strategies. According to [16], increased noise levels can cause birds to change their vocalizations and feeding times to avoid disturbances. At Douala International Airport, the interactions between bird species and flight operations suggest that noise could lead to temporal shifts in feeding, as birds may forage during quieter periods. This phenomenon necessitates further investigation to assess how noise might influence the feeding ecology of urban birds in the surrounding ecosystem [27].

The development and expansion of airport infrastructure invariably lead to habitat alteration, affecting the availability and distribution of food resources for birds. According to [20]

outlines how habitat fragmentation in urban areas can limit resource accessibility for avian species, impacting their feeding behaviors. A study focused on Douala Airport should evaluate shifts in habitat types due to urban development, assessing how these modifications influence food availability for local bird populations. Such assessments can provide valuable insights into the current ecological dynamics around the airport and highlight species that are particularly vulnerable to habitat changes. To mitigate risks associated with bird strikes while promoting avian conservation, effective management practices are essential. Integrated wildlife management strategies can enhance both safety and biodiversity. The implementation of non-lethal deterrence methods, habitat management, and waste management policies may help reduce the attractiveness of the airport environment to birds [9].

Furthermore, collaboration among airport authorities, ecologists, and conservationists is vital for developing sustainable practices that consider the ecological well-being of urban birds. Long-term monitoring programs can provide data to inform adaptive management approaches, ensuring a balance between aviation operations and wildlife conservation. As urban areas continue to expand, the interactions between flight operations and bird ecology will require ongoing research. Comprehensive assessments of bird species diversity and behavior in relation to flight operations [14]. Investigating the long-term effects of airport noise on avian communication and feeding. Understanding the socio-economic factors influencing bird populations near airports. In addition, implementing public engagement programs aimed at raising awareness about the ecological impacts of airport operations can foster community support for conservation efforts. The interplay between flight safety operations and urban birds' feeding ecology at Douala International Airport highlights the complexity of managing wildlife in urban aviation environments. Understanding these dynamics is crucial for developing effective interventions that enhance aviation safety while promoting biodiversity. Continued research and collaboration among stakeholders are essential to create a sustainable framework that benefits both the aviation sector and the rich avian diversity of the Littoral Region [24].

2. Materials and Method

2.1. Description of Study Area

Douala International Airport, located in the Littoral Region

of Cameroon, serves as the primary gateway for air travel in and out of the country [1, 10] (Figure 1). Understanding the geographical, climatic, and ecological characteristics of this area is essential for evaluating its impact on flight operations and local wildlife, particularly urban birds. This literature review provides a comprehensive overview of the study area, focusing on its geographical coordinates, climatic conditions, vegetation types, wildlife, and drainage systems. Douala International Airport is situated at approximately 4.0057° N latitude and 9.7085° E longitude, [17]. The airport lies near the coastline of the Atlantic Ocean [1], approximately 10 kilometers southwest of Douala, the economic capital of Cameroon

[10, 17]. This strategic location makes it a vital hub for both passenger and cargo traffic in Central Africa [1, 17]. The climate of Douala is classified as tropical, characterized by high humidity and significant rainfall throughout the year [1, 10]. Average temperatures range from 23°C to 31°C [1]. Douala experiences a bimodal rainfall pattern [1], with average annual rainfall around 3,000 mm, making it one of the wettest regions in Cameroon [1]. Humidity levels are consistently high, generally between 70% to 90% [1], contributing to the lush vegetation and diverse wildlife in the area [15].

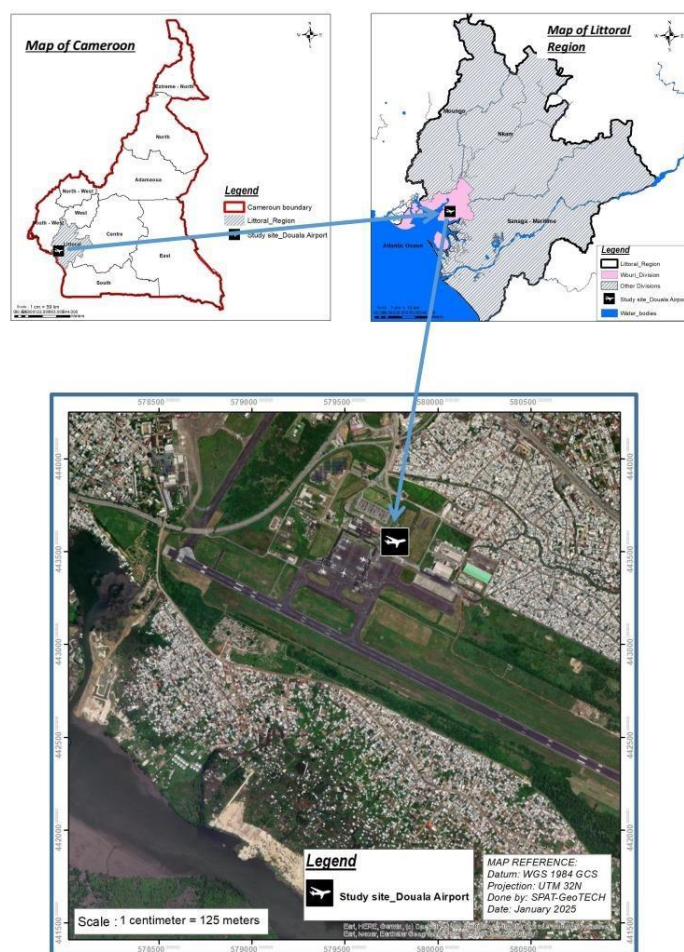


Figure 1. Map of Douala International Airport, Source: [15].

2.2. Method of Data Collection and Analysis

Research data collection was done for six months by the research team. Observations were done on fixed point transect around the airport to systematically observe and record bird species, numbers, and feeding behaviors. Observations were conducted during peak airport operational hours (early morning, afternoon, and evening). Observations were made four

times a month. Record weather conditions (temperature, wind speed, and precipitation) during observations to correlate with bird activity. Observations were equally done on habitat types and land use in the surrounding areas that may influence bird feeding patterns. More so, a structured interview was conducted with airport staff, wildlife control officers, and local residents to gather insights on bird behavior, feeding patterns, and observed impacts on aviation safety. This methodology provides a comprehensive framework for investigating how

birds' feeding ecology affects aviation safety, offering insights that can help improve safety measures at Douala International Airport. Chi-square and correlation statistical models were used to examine relationships between bird feeding behavior (time spent feeding) and flight safety incidents (number of bird strikes). The birds activity was also tested on the environmental factors, such as weather conditions.

3. Results

The results of this study recorded a high presence of village weaver (*Ploceus cucullatus*) 21.2%, black-crowned waxbill (*Estrilda nonnula*) 19.7% respectively, while pied crow (*Corvus albus*) 2.3% and black & white mannikin (*Lonchura bicolor*) 2.3% recorded the lowest presence (Figure 2). The marked presence of the village weaver and black-crowned waxbill, contrasted with the lower numbers of the pied crow and black and white mannikin, highlights the ecological diversity at Douala International Airport. Understanding these dynamics is crucial for developing effective wildlife management practices to ensure aviation safety. Bird populations

around airports significantly impact aviation safety due to the risks posed by bird strikes. This study focuses on the presence and ecological roles of specific bird species observed in Douala International Airport, notably the Village Weaver (*Ploceus cucullatus*), Black-crowned Waxbill (*Estrilda nonnula*), Pied Crow (*Corvus albus*), and Black and White Mannikin (*Lonchura bicolor*). The notable high presence of the Village Weaver (21.2%) and Black-crowned Waxbill (19.7%), contrasted with the lower incidence of the Pied Crow (2.3%) and Black and White Mannikin (2.3%), necessitates a detailed examination of their ecology and implications for airport operations. A social bird characterized by its bright yellow plumage and distinctive black face in males. Its intricate nest-building behavior is well-documented. Commonly found in grasslands, wetlands, and around human settlements, making it adept at inhabiting urban environments, including airport peripheries. Primarily granivorous, feeding on seeds, grains, and occasionally insects. The species thrives in areas with abundant food resources, particularly around agricultural lands and open fields.

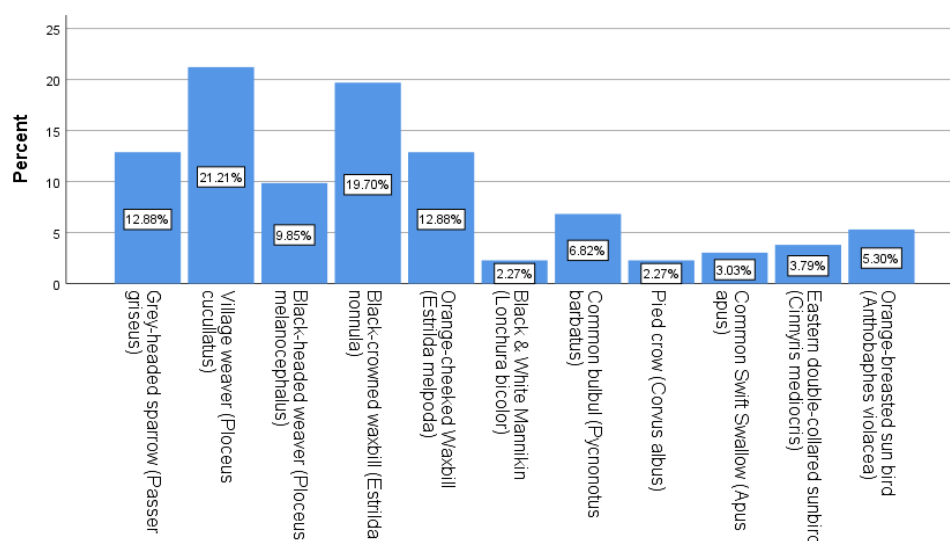


Figure 2. Predominant Birds Species.

The high presence of village weavers (21.2%) can lead to increased risks of bird strikes, especially in areas where they congregate for foraging and nesting. A small, brightly colored finch with a distinctive black crown and a red bill. Known for its sociable nature and energetic behavior. Prefers grasslands, scrublands, and areas with dense vegetation. It adapts well to urban environments where food availability is favorable. Feeds primarily on seeds and grains, often foraging in flocks. Its adaptability to different habitats contributes to its observed population size (19.7%). The presence of the black-crowned waxbill suggests a robust food supply, but they also pose a risk for bird strikes, particularly during communal activities. A

large, omnivorous bird with a black and white plumage known for its intelligence and adaptability. Commonly found in urban and semi-urban areas; prefers habitats close to human activity where food is more accessible. Highly opportunistic, feeding on a varied diet that includes carrion, refuse, grains, and insects, which allows for its survival in anthropogenic environments. pied crow's lower presence (2.3%) may be due to competition for food or nest sites with more abundant species like the village weaver. Although less frequently encountered, its large size and intelligent behavior can still pose a risk during aircraft operations. A small finch with distinctive black and white plumage, known for its sociable behavior and strong

flocking tendency. Prefers grasslands and areas with dense undergrowth; often found in small flocks. Feeds predominantly on seeds, particularly from grasses. Similar to the black-crowned waxbill, their presence suggests a suitable habitat with adequate food resources. The black and white mannikin,

with a presence of 2.3%, may face predation and competition pressures that limit its population compared to larger or more adaptable species. The varying presence of these species around Douala International Airport reflects their adaptability and ecological roles within the aviation landscape.

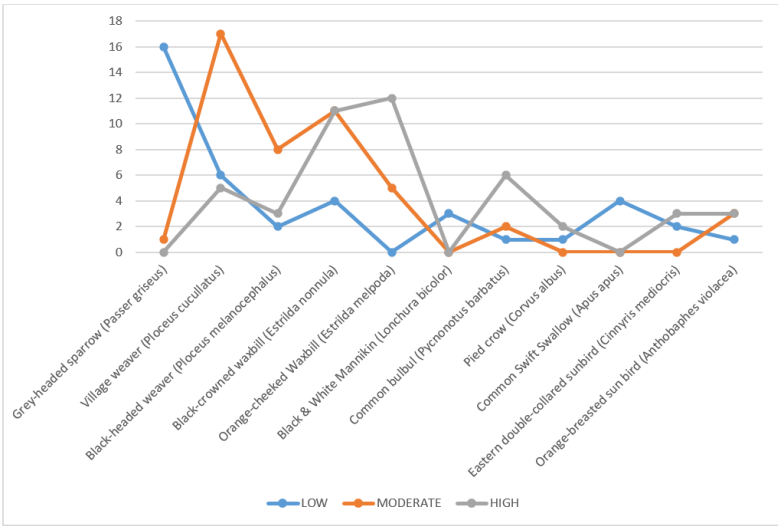


Figure 3. Predominant Bird Species and Flight Routine Operations.

The study has shown a significant association on flight routine operations $X^2=85.545$ $df=20$ $P=0.000$ (Figure 3), day-period $X^2=67.172$ $df=20$ $P=0.000$ (Figure 4), and climatic conditions $X^2=100.768$ $df=30$ $P=0.000$ (Figure 5) respectively. Bird strikes are a significant safety concern for aviation worldwide, particularly at airports located near bird habitats. Understanding how predominant species influence flight operations

bird, as well as how day periods and climatic conditions affect avian behavior, is crucial for developing effective wildlife management strategies. This review synthesizes existing literature on the interactions among bird species, their activity patterns throughout the day, and how climate influences these dynamics concerning airport operations.

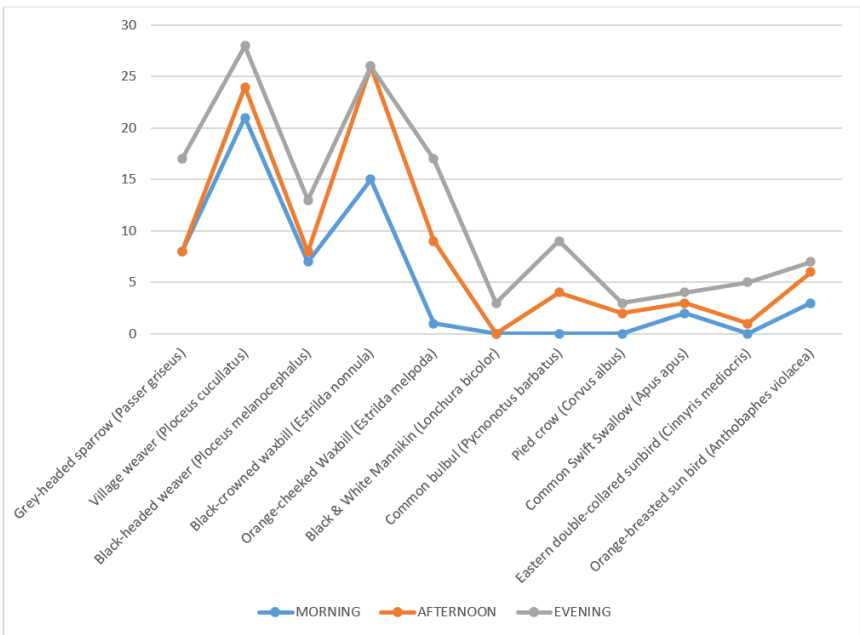


Figure 4. Predominant Bird Species and Day-period.

Frequently found at airports, these gulls are attracted to food sources generated by human activity, increasing their risk of interaction with aircraft. Urban pigeons thrive near airport environments, often gathering in flocks around food sources. Known for nesting in trees and shrubs, these birds can create hazards during high-traffic operations. These species may influence operations due to their behavioral patterns and tendencies to forage in runway areas. Many birds are attracted to food waste generated by airport operations. For instance, gulls often scavenge in refuse areas, increasing their presence near runways. Species such as weavers may establish nests near airport infrastructure, which can lead to increased local populations. Many bird species are most active during the early hours. For instance, gulls and weavers may forage extensively

for food at this time, making them more visible near runways. As temperatures rise, some species may reduce activity, seeking shade or water. However, scavenging birds such as pigeons may remain active due to human activity around food sources. Many species increase their activity again as they prepare to roost. This period may see increased bird movements near air traffic, thus raising strike risks. Higher bird activity during peak times may necessitate adjustments in flight operations. Airports may implement flight restrictions during specific periods of high avian activity to minimize risks. Airports may increase wildlife monitoring and management efforts during peak avian activity times to mitigate the risk of collisions.

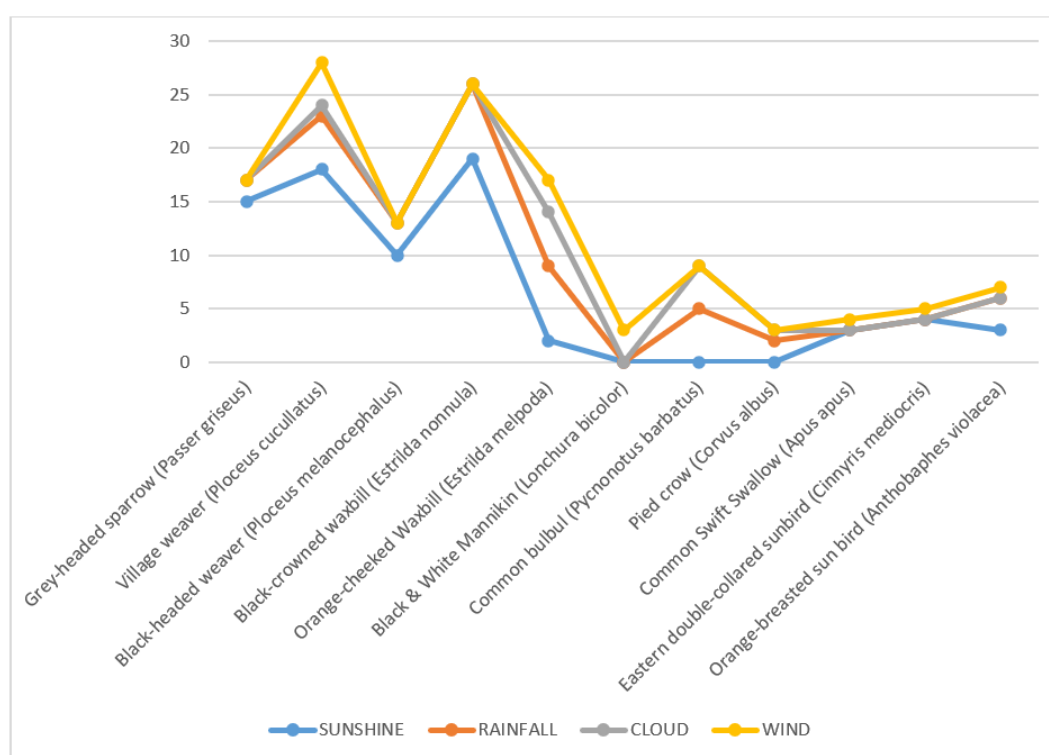


Figure 5. Predominant Bird Species and Climatic Conditions.

Climatic conditions can significantly affect bird behavior and, consequently, their interactions with airport operations. High temperatures can influence bird foraging behavior, with some species being more active in cooler parts of the day. Conversely, cooler temperatures may induce species to forage more actively as they prepare for nesting or survival needs. Rain can drive birds to seek out food sources exposed by floods or wet conditions. However, extreme weather, such as storms, may displace birds or limit their movements, complicating wildlife management. Wind patterns can affect flight

behavior. For example, strong winds may force birds closer to the ground, increasing the likelihood of collisions during take-off and landing. Effective wildlife management strategies that consider the interplay between bird species, day periods, and climatic conditions are vital for airports. Modifying landscaping to minimize bird nesting sites while providing adequate habitat for desired species can reduce risks. Implementing wildlife monitoring programs using radar or observers can help anticipate and mitigate bird.

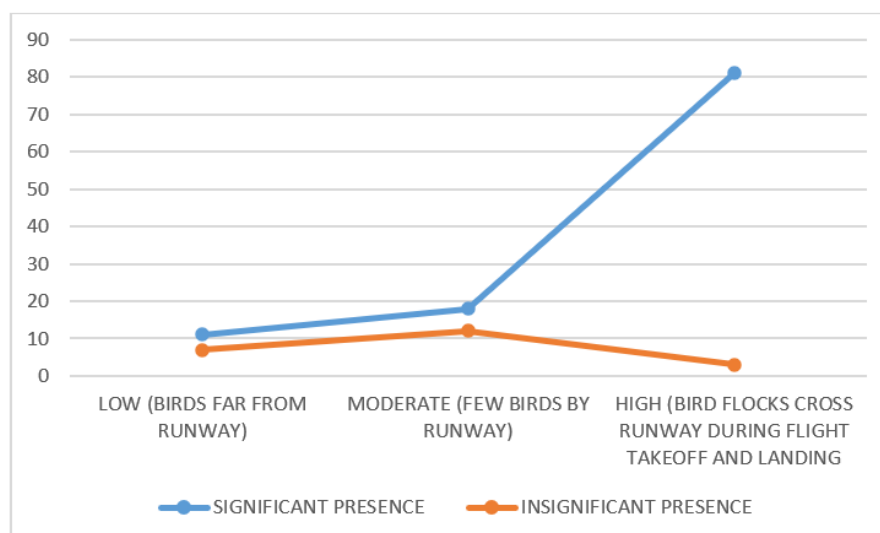


Figure 6. Birds Location during Routine Flight Operations and Birds Strike Risk Assessment.

More so, birds location during flight operations was significantly linked to birds strike risk assessment $X^2=28.531$ $df=2$ $P=0.000$ (Figure 6), and the social activity of birds $r=0.622$ $P=.000$ (Figure 7). Bird strikes pose significant hazards to aviation safety and can lead to severe accidents, resulting in injuries or fatalities. Understanding the influence of bird locations during routine flight operations, assessing the associated risks, and analyzing the social activities of birds is crucial for developing effective management strategies at airports. This review discusses the dynamics between bird behavior, their locations relative to airport activities, risk assessment methodologies, and the implications of social behaviors on aviation safety. Birds tend to congregate in habitats that provide food, water, and nesting opportunities. Areas adjacent to runways, such as wetlands and agricultural fields, often serve as key habitats for various species, increasing the likelihood of interactions with aircraft. Birds' flight behaviors, including foraging, preferring certain air spaces, and migrating, are influenced by physical geographical features. For example, avian species may follow river paths or landscape contours when approaching or leaving foraging sites, potentially aligning their trajectories with aircraft operations.

Bird strikes are a significant concern for aviation safety, resulting in property damage, injuries, and, in rare cases, fatalities. Understanding the influence of bird location during routine flight operations is crucial for assessing and mitigating the risk of bird strikes at airports. The review highlights key factors influencing bird movements, the implications for aviation safety, and strategies for effective management. Airports often lie in close proximity to various habitats that attract bird species, including wetlands, agricultural fields, and urban areas. Studies such as those by [18] emphasize that the presence of food source and suitable nesting sites influences bird concentrations around airport facilities, particularly near runways and approach paths. Different bird species exhibit unique behav-

iors that affect their location during flight operations. For instance, large birds, like Canada Geese (*Branta canadensis*) and gulls, are commonly found near water sources and grassy areas, which can coincide with flight operations. According to [8] these species often engage in flight patterns that increase their risk of collision with aircraft. Birds exhibit varying levels of activity throughout the day based on the time of year and weather conditions. Migratory species tend to follow specific routes influenced by environmental factors, resulting in heightened risks during migration seasons. Research by Hall et al. (2020) illustrates that migratory movements significantly peak during dawn and dusk, coinciding with increased airport operations, thereby elevating the potential for bird strikes. Predictive modeling has become an essential tool in assessing bird strike risks at airports. The [11] recommends using statistical analyses that incorporate bird counts, species identification, and spatial data to develop comprehensive risk assessments. Such models help quantify collision risks based on bird location and environmental factors.

Different bird species have distinct site preferences during critical times, impacting their interactions with aviation operations. Species like pigeons and gulls may be more prevalent near airports due to the availability of food sources, increasing the risk of strikes during takeoffs and landings. Migratory species may influence bird distributions seasonally, leading to peaks in flight operations coinciding with migration periods, thereby heightening strike risks during specific times of the year. Effective bird strike risk assessment requires a comprehensive understanding of various factors that contribute to bird presence and their potential to collide with aircraft. Historical data on bird strikes at specific airports help identify patterns and high-risk periods. Analysis of past strike incidents provides invaluable insights for future predictive models. Routine surveys to monitor bird populations around airports help assess current risks, including species identification, counts, and behavioral observations. This provides critical baseline data for understanding

strike risks under varying conditions. Assessing environmental factors such as land use changes, vegetative cover, and the

presence of water bodies can help identify potential attractants for birds.

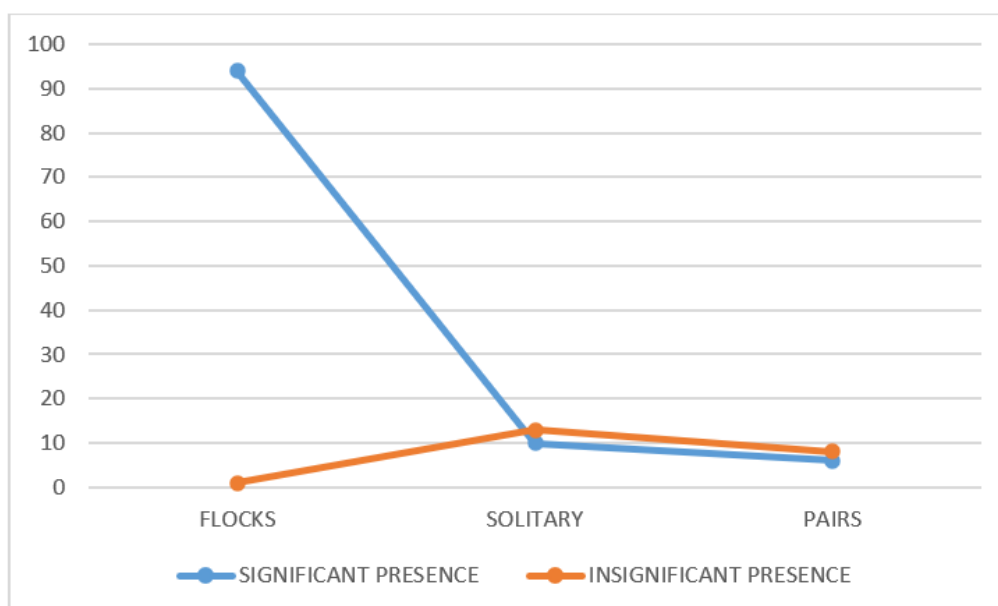


Figure 7. Birds Location during Routine Flight Operations and the Social Activity of Birds.

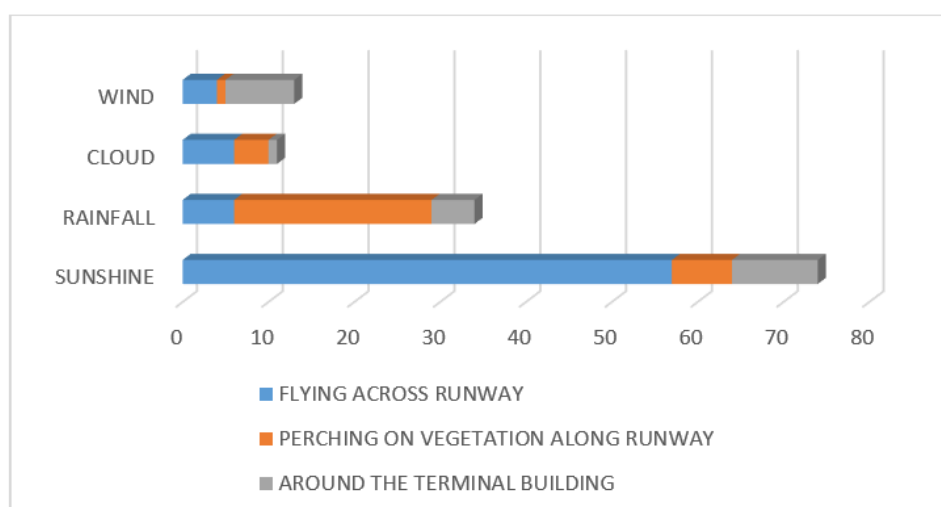


Figure 8. Movement Pattern of Birds within the Airport and Climatic Conditions.

Also, movement pattern of birds within the airport recorded a significance on climatic conditions $r=0.363$ $P=0.000$ (Figure 8), and their habitat characteristics $r=0.768$ $P=0.000$ (Figure 9). Understanding the movement patterns of birds within airport environments and how climatic conditions influence these patterns and habitat characteristics is essential for enhancing aviation safety. Bird movements can significantly affect the likelihood of bird strikes, while climatic variables can alter both bird behavior and habitat suitability. This review examines the interplay of bird movement patterns, climatic con-

ditions, and their habitat characteristics, focusing on implications for airport management and wildlife hazard mitigation. Birds frequently move between feeding sites and roosting locations. Species such as gulls and weavers are known to forage extensively near airports due to easily accessible food sources, including waste from airport operations.

Airports often serve as significant habitats for various bird species, and the interactions between climatic factors and avian behavior can affect both birds and aviation operations. This literature review examines the current research on how

climatic conditions influence bird movement patterns at airports, highlighting key findings, methodologies, and implications for airport management. Research shows that temperature significantly affects bird activity and movement patterns. Warmer temperatures can increase daytime activity and feeding behavior in species such as the European Starling (*Sturnus vulgaris*), as noted by Davis et al. (2019). Conversely, extreme heat can lead birds to avoid foraging during peak temperatures, potentially altering their movement to cooler times of the day. Rainfall and storm events influence bird activity by affecting food availability and habitat conditions. Heavy rainfall can lead to temporary flooding of habitats, forcing birds to migrate to more suitable areas. Studies by [7] Smith et al. (2021) have shown that increased precipitation often results in higher bird densities near airports, as birds seek refuge in flooded areas

despite the associated risks of bird strikes. Wind direction and speed can significantly affect bird flight paths and migratory patterns. Research conducted by [12] demonstrated that strong winds can redirect migration routes, often causing birds to congregate near airports, thus increasing the likelihood of bird-aircraft collisions. Wind also influences the flight behavior of species such as raptors, which utilize thermal updrafts for soaring. Seasonal climatic changes lead to shifts in bird populations and movement as migratory species seek breeding or wintering grounds. For example, studies by [13] have shown that the onset of spring and autumn significantly alters movement patterns, as birds respond to temperature and food availability. Airports located along migration routes see increased bird activity during these transitional periods.

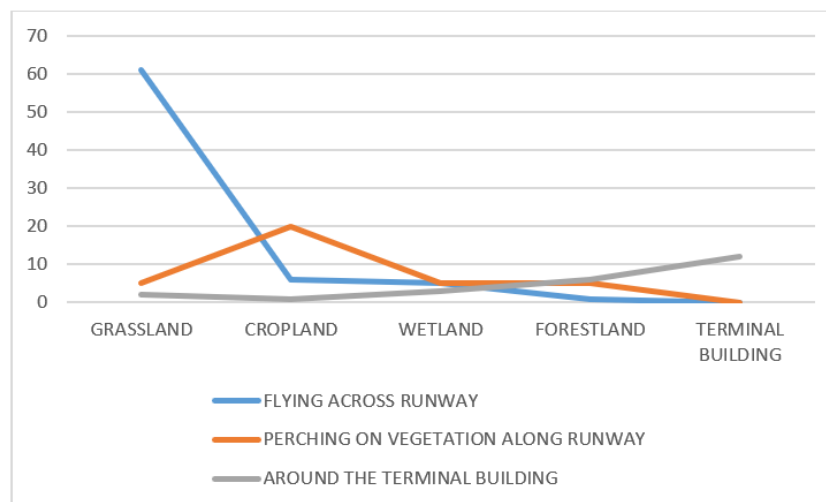


Figure 9. Movement Pattern of Birds within the Airport and Their Habitat Characteristics.

Some species, particularly during breeding seasons, exhibit territorial behaviors that can confine their movements to specific areas within or around the airport. For example, the Village Weaver (*Ploceus cucullatus*) may establish nests near trees and shrubs, influencing their movement patterns. Seasonal migrations can result in fluctuating bird populations at airports. During migratory periods, airports may experience increases in bird activity, necessitating heightened awareness of potential strike risks. Birds often engage in flocking behavior, which can complicate movement dynamics. Flocks typically change direction and altitude collectively, increasing the potential for group strikes during takeoff and landing phases. Birds may adjust their movement patterns in response to the presence of other species. For instance, scavenger species like the Black-headed Gull (*Chroicocephalus ridibundus*) might follow larger flocks to food sources, thereby altering their locations and routes within airport boundaries. Higher temperatures can alter foraging behaviors, with many species becoming more active during early mornings and late afternoons to avoid heat. Conversely, cooler temperatures may drive birds

to forage more actively throughout the day. Rainfall affects food availability and habitat characteristics, with some bird species adapting their movements to take advantage of increased foraging opportunities during wet conditions. For example, waders may be more active in flooded areas, impacting their location near runways. Strong winds can influence flight patterns and height, forcing birds closer to the ground. This behavior increases the risk of collisions with aircraft during takeoff and landing.

Regular monitoring of bird populations and their movements can inform risk assessments and help establish more detailed wildlife hazard management plans. Employing technologies such as radar and GPS tracking can provide insights into bird movements, allowing for better predictive management against possible strike incidents. Modifying existing habitats, such as reducing tall structures for nesting and enhancing open areas, can discourage birds from inhabiting high-risk zones near runways. Promoting community awareness about food refuse and waste disposal can reduce attractions to birds, aiding in management efforts. The movement patterns of birds in

airport environments, influenced by climatic conditions and habitat characteristics, play a crucial role in aviation safety. Understanding these dynamics enables airports to implement effective habitat management and wildlife monitoring strategies, ultimately reducing the risk of bird strikes. Continued research and adaptive management will be vital in addressing the changing ecological and climatic factors affecting avian behavior and airport operations.

4. Discussion

The study of predominant bird species at international airports in Sub-Saharan Africa is critical for understanding regional biodiversity and ensuring aviation safety [24]. The interplay between avian communities and airport ecosystems presents challenges and opportunities for conservation [27]. The presence of bird species at airports has garnered attention due to its implications for aviation safety and biodiversity conservation. International airports in Sub-Saharan Africa, characterized by unique ecosystems and a variety of habitats, host diverse avian communities. This literature review synthesizes current research on predominant bird species at these airports, highlights the ecological factors influencing avian presence, and discusses the significance of bird management at airport facilities. Sub-Saharan Africa is renowned for its rich biodiversity, which includes a wide array of bird species [14]. The region's climate, geography, and varied habitats—ranging from savannas to wetlands, contribute to the complexity of its avian communities. According to [4], Africa is home to over 2,300 bird species, with many endemic or vulnerable due to habitat loss and human activity. Several international airports in Sub-Saharan Africa, such as Johannesburg's OR Tambo International Airport (JNB), Nairobi's Jomo Kenyatta International Airport (NBO), and Accra's Kotoka International Airport (ACC), have been the focus of studies examining the interactions between birds and airport operations. The airport is frequented by several species including the Egyptian Goose (*Alopochen aegyptiaca*), African Sacred Ibis (*Threskiornis aethiopicus*), and various gull species. The surrounding grasslands and water bodies provide ample feeding and nesting opportunities. The proximity to urban areas also influences the diversity of avian species present.

Notable sightings include the Hadada Ibis (*Bostrychia hagedash*) and various raptor species. The airport's location near wetlands makes it a hotspot for migratory and resident birds. Bird strikes pose significant risks to aviation safety, prompting investigations into common bird species around airports. Research by [25] highlighted that certain species, particularly larger birds like Egyptian Geese, pose higher threats due to their size and flocking behavior. Strategies to mitigate risks include habitat management, monitoring avian movements, and implementing deterrent measures [5]. Effective bird management practices have been established at various airports to ensure safety while promoting biodiversity. Strategies such as habitat modification, wildlife control programs, and regular

monitoring have been adopted in response to the growing awareness of the ecological significance of airport surroundings. [6] emphasize the need for collaborative approaches to reconcile airport operations with bird conservation.

Changes in movement patterns due to climatic conditions can lead to increased collision risks. For instance, [29] highlight that when climatic factors induce changes in migration timing, bird concentrations can inadvertently rise near runways as they pursue alternate routes or habitats. Effective habitat management is vital to minimizing bird strike risks. Research by [6] suggests that modifying landscapes (e.g., altering vegetation or water bodies) could direct birds away from critical runway areas, particularly during peak migration times influenced by climatic changes. Implementing real-time monitoring systems that account for climatic forecasts can enhance safety measures at airports. For instance, [2] advocate for using predictive models to assess likely bird movements based on upcoming weather patterns, allowing airport authorities to adopt proactive measures.

Advances in monitoring technologies, including radar systems and infrared cameras, have improved the ability to track bird movements in and around airport airspace. Research by [28] emphasizes the effectiveness of these technologies in providing real-time data that can inform airport operations, enhancing safety by predicting potential strike risks based on bird activities. Weather conditions play a crucial role in bird behavior and movements in airport environments. For example, adverse weather can force birds into lower altitudes, which can overlap with aircraft operating altitudes. Studies by [22] indicate that storms and poor visibility can lead to sudden changes in bird location, requiring dynamic assessments of strike risks during inclement weather. A case study by [26] analyzed bird strike incidents at Toronto Pearson International Airport [9]. The findings demonstrated that strikes predominantly occurred near wetland areas and during migratory seasons, underscoring the need for targeted monitoring in these zones. According to [28], integration of real-time bird location data into operational protocols at Schiphol Airport. The results indicated that proactive monitoring and swift habitat management reduced the frequency of bird strikes significantly. Effective management of airport surroundings is crucial for reducing bird strike risks. Modifications to habitats, such as reducing food sources or creating barriers can deter birds from congregating near runways. [6] recommend that airports utilize habitat mapping to identify and manage high-risk areas effectively. The implementation of wildlife control programs, including the use of trained dogs or pyrotechnics, can effectively disperse birds from critical areas [9]. Education and outreach efforts to inform the public about minimizing food waste and pet activities near airports are also vital, as highlighted by [8]. Establishing protocols for responding to bird presence during operations can enhance safety. This may include temporarily halting takeoffs or landings when high concentrations of birds are detected, as suggested by [21].

5. Conclusion

The relationship between birds' location during routine flight operations and the risk of bird strikes is a critical area of research that impacts aviation safety and wildlife conservation. As bird populations and behavior continue to evolve, understanding the nuances of their movements in relation to airport operations will be essential. By employing advanced monitoring techniques, effective habitat management, and proactive response strategies, airports can significantly mitigate the risks associated with bird strikes, ensuring greater safety for both aviation and avian populations. The observed reliance on anthropogenic food sources highlights a dual challenge; while it may support certain bird species, it simultaneously raises concerns about increased bird strike incidents. The influence of waste management practices at the airport further complicates this relationship, attracting birds in ways that may conflict with safe flight operations. The study's insights into seasonal migration patterns also point to the need for ongoing monitoring, as changes in air traffic could have cascading effects on migratory routes and behaviors. This research has illuminated the critical nexus between flight safety operations and the feeding ecology of urban birds at Douala International Airport. Our findings indicate that the dynamics of flight operations significantly influence bird behavior, particularly in relation to feeding habits and habitat utilization. The adaptation of urban birds to the disturbances created by aircraft noise and traffic patterns underscores their resilience, yet it also reveals potential vulnerabilities that could impact both bird populations and aviation safety.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to this manuscript. None of the authors received funding or support from any organization that could influence the research. Additionally, authors have no personal relationships that could potentially bias the research or its outcomes. Also, authors have no competing interests or affiliations with organizations that might be perceived as influencing the manuscript. This statement is intended to ensure transparency and uphold the integrity of the research.

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