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Bird Community Composition and Bird-Strike Risk Management at Lombok International Airport, Indonesia

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Abstract: Lombok International Airport (LOP) was built on former rice fields and plantations, which are habitats for various bird species, making it vulnerable to the threat of bird strikes. This study aimed to determine the composition of birds and determine the appropriate bird strike management strategy for LOP. The sample of observation areas and respondents was selected using purposive sampling. The abundance and frequency of each bird species were observed using the point count technique at 30 points in the airport operational area, and the data were then processed to determine the composition of bird species and their potential to cause bird strikes. Data on the implementation of bird strike management were collected through interviews with 21 respondents and processed using a SWOT analysis to determine the appropriate bird strike management strategy for LOP. The results showed that 29 bird species were found in the LOP, which, based on bird-strike risk, comprised 1 severe, 6 major, 8 moderate, 7 minor, and 7 negligible species. The SO strategy was suitable for bird strike management at the LOP, namely utilizing the airport's strengths and seizing opportunities in aspects that include strengthening the wildlife hazard management system, proactive habitat modification, detection technology and early warning systems, as well as multi-stakeholder education and outreach.

Keywords: Bird Species Composition; Bird Strike; LOP; SO Strategy.

Introduction

The global aviation industry in Indonesia continues to grow, with the number of aircraft operating in the country increasing. Aviation safety is a key priority in ICAO standards. In the airport environment, this system is implemented by establishing a specialised safety unit led by a safety manager, focused on hazard identification across all aspects of airport management [1][2][3].

Wildlife hazard management is a component of airport operational procedures, which aims to reduce the airport's attractiveness to birds and other wildlife. The presence of wildlife around airports can threaten flight safety, thus requiring airport operators to maintain the environment to avoid attracting birds and other animals to the airport's operational area [4][5]. Certain wild animals, especially those that have flying activities, such as birds, can pose a risk of bird strikes and disrupt flight operations, as happened in the incident of the cancellation of a Batik Air flight at Lombok International Airport (LOP) because a bird entered the plane's engine [6][7].

LOP is a strategic facility that plays an important role in supporting Indonesia's air transportation system, particularly international flights. This airport was built on former rice fields and plantations, which are habitats for various bird species. Therefore, it is vulnerable to bird strikes. The current threat of bird strikes certainly depends on the composition of bird species, which are influenced by the current environmental conditions, such as the presence of rice fields, plantations and other forms of vegetation, open land and standing water, in addition to being influenced by the effectiveness of the wild animal hazard management system, which is implemented by the airport. Regarding wildlife-related risks, the aviation industry must meet standards to ensure flights can take place safely and in an orderly, efficient manner [8][9].

Based on the background of the problem above, this research was conducted to determine the composition of bird species and their potential to cause bird-strike incidents at LOP. The study also aimed to find the right bird strike management strategy for LOP.

Research Methods

Research location

The research was conducted in the operational area of Lombok International Airport (LOP). The airport was situated on a 538.8-hectare lowland area, with a 3,300-meter-long and 45-meter-wide runway. The area around the airport consists of residential areas, rice fields and plantations. The distance from this airport to the nearest beach was 18 km. LOP was located in the administrative area of Pujut District, Central Lombok Regency, West Nusa Tenggara Province, Indonesia (Figure 1).

Work procedure

The research was carried out in three main stages, namely preliminary survey or preparatory (Socialization, sample determination and determination of data collection techniques), data collection and data analysis (Figure 2).

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Figure 1. Location of Lombok International Airport (LOP) in Central Lombok, Indonesia

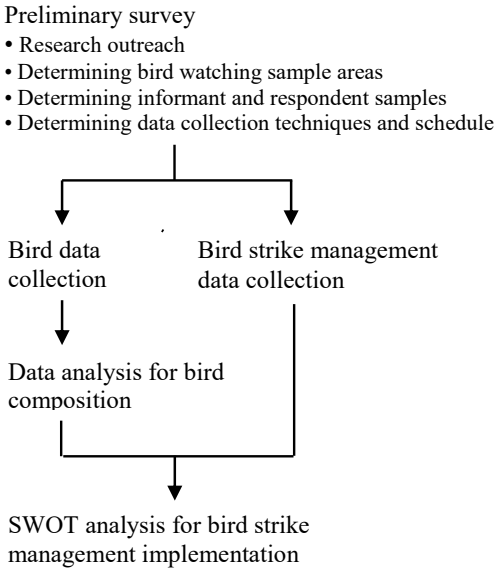


Figure 2. Workflow chart of bird strike research at Lombok International Airport

A preliminary survey was conducted to socialize the research plan, determine the sample of bird watching areas and sample of informants, and determine data collection techniques, including preparation of instruments for interviews and recording cameras. The observation area was determined using purposive sampling, selecting 30 points in locations where bird-aircraft interactions are likely to occur, such as runways, aprons, open areas, and puddles. The selection of informants was also carried out purposively to parties directly involved in bird strike risk management, namely WHMT (Wildlife Hazard Management Team), ATC (Air Traffic Control), security officers, ground handling staff, and the surrounding community, with a total of 21 respondents.

Bird data were collected using a point-count technique adapted from [2][10]. The study area, consisting of 30 observation points, comprises airport ponds, open areas, and vegetation (Figure 3). Centralized observation of predetermined strategic points, each within a radius of 30 m, was conducted to count the number of individuals and the frequency of presence of each species found in a certain time period, namely morning, afternoon and evening for 5 days. The use of binoculars and cameras was very important for identifying bird species from a distance without disturbing them.



Figure 3. Some examples of bird observation points in the form of airport ponds, open areas and vegetation.

Data collection on the implementation of bird management was carried out through a combination of techniques adapted from [6][11], namely direct observation, structured interviews with selected informants, respondents from the community around the airport and reviews of internal documents such as the Wildlife Hazard Management Plan, Safety Management System and Environmental Management System.

Data analysis

Data analysis was directed at determining the composition of bird species and their potential to cause bird strike incidents, and determining effective bird strike management strategies for LOP. Data on the number of individuals and the frequency of each bird species' presence were processed to produce its dominance value, which indicates its potential to pose a bird-strike risk, using criteria adapted from [12][13][14].

Data on the implementation of bird hazard management, after being tested for validity and reliability, were processed alongside bird data using methods that sorted them into strengths, weaknesses, opportunities, and threats (SWOT analysis). Additionally, the Internal Factors Analysis Summary (IFAS) evaluates internal factors (strengths and weaknesses), while the External Factors Analysis Summary (EFAS) assesses external factors (opportunities and threats). The combination of these three analytical tools provides a comprehensive overview as a basis for formulating an effective and sustainable bird strike management strategy. Using the IFAS and EFAS matrices, internal and external factors were systematically assessed with scores and weights according to criteria adapted from [15][16][17][18]. The values obtained were used to determine the strategic position within the SWOT quadrant, serving as a basis for formulating an effective and sustainable bird-strike management strategy in the LOP.

Results and Discussion

Bird species composition and their potential to pose a bird strike risk in the LOP

In the operational area of LOP, there were a total of 2962 birds, which were observed in 447 encounters over five days at 30 observation points. These birds were identified as belonging to 29 species across 21 families. A list of bird

species and local names observed in the LOP operational area, along with their dominance values, is shown in Table 1.

The dominance value for each bird species, calculated from its density and frequency of occurrence, was used to assess its hazard level for bird-strike incidents. The bird strike hazard level was classified into 5 categories, namely negligible, minor, moderate, major, and severe. Of the 29 bird species observed at LOP, there were 7 negligible species, 7 minor species, 8 moderate species, 6 major species, and 1 severe species.

Species were classified into five bird-strike risk categories: severe, major, moderate, minor, and negligible-based on dominance values calculated from species abundance and frequency of occurrence. These indicators were used as proxies for birds' potential exposure to aircraft operations in the LOP area. Because detailed information on body mass, flight height, movement patterns, and historical strike records was not available, the resulting categories represent a relative ranking of species' potential exposure rather than a comprehensive quantitative risk assessment. Future studies should integrate these additional variables to refine the risk classification and support more targeted management actions.

Table 1. List of observed bird species and their bird strike risk-categories in the LOP.

Bird species	Local name	Frequency of occurrence	Number of individuals	Dominance value	Bird strike risk category
Ploceus philippinus	Manyar tempua	29	1026	0.4113	Severe
Ploceus manyar	Manyar jambul	24	380	0.1820	Major
Lonchura leocogastriodes	Bondol peking	28	296	0.1626	Major
Collocalia linchi	Wallet linci	23	183	0.1132	Major
Lonchura pallida	Bondol kepala-pucat	24	169	0.1107	Major
Cisticola juncidis	Cici padi	24	86	0.0827	Major
Passer montanus	Burunggereja erasia	16	109	0.0726	Major
Orthotomus sepium	Cinenen jawa	23	62	0.0724	Moderate
Lalage sueurii	Kapasan sayap putih	19	69	0.0658	Moderate
Ardeola speciosa	Belekok sawah	22	44	0.0641	Moderate
Anthus novaeseelandiae	Apung tanah	20	50	0.0616	Moderate
Pycnonotus aurigaster	Cucak Kutilang	18	57	0.0595	Moderate
Haliastur indus	Elang bondol	19	44	0.0574	Moderate
Merops philippinus	Kirikkirik laut	19	39	0.0557	Moderate
Cacomantis sepulcralis	Wiwik uncuing	15	41	0.0474	Moderate
Elanus caeruleus	Elang tikus	14	34	0.0428	Minor
Ixobrychus cinnamomeus	Bambangan merah	14	28	0.0408	Minor
Streptopelia chinensis	Tekukur biasa	13	32	0.0399	Minor
Geopelia striata	Perkutut jawa	12	27	0.0360	Minor
Pycnonotus goiavier	Merbah cerukcuk	11	26	0.0334	Minor
Dicaeum maugie	Cabai lombok	8	31	0.0284	Minor
Cinnyris jugularis	Burung madu sriganti	8	23	0.0257	Minor
Lonchura molucca	Bondol jawa	7	27	0.0248	Negligible
Amandava amandava	Pipit benggala	7	16	0.0211	Negligible
Taeniopygia guttata	Pipit zebra	7	16	0.0211	Negligible
Turnix suscitator	Gemak loreng	7	13	0.0200	Negligible
Lichmera indistincta	Isapmadu Australia	6	12	0.0175	Negligible
Alcedo coerulescens	Rajaudang biru	6	11	0.0171	Negligible
Acridotheres javanicus	Kerak kerbau	4	11	0.0127	Negligible
Total		447	2962		

The manyar tempua bird (*P. philippinus*) was classified as a severe-risk species based on its dominance value in the LOP due to its very high density (1026 individuals in 30 points with a radius of 30 m), in addition to having a high frequency of occurrence (with a frequency of occurrence of 29 over five days). Despite their small size, collisions with large flocks of birds can cause multiple strikes that can potentially damage the aircraft's structure, including engines, windshields, wings, and sensors, especially during the vulnerable takeoff and landing phases. The kinetic energy of a collision increases sharply with aircraft speed, so even if the birds are small in mass, the impact can still be serious when there are many and densely packed [19][20][21]. The high dominance of *Ploceus philippinus* at LOP is associated with the surrounding agricultural landscape, particularly rice fields, plantations,

open grasslands, and small water bodies, which provide food and nesting resources for this gregarious passerine. Its large flocks move between feeding and roosting areas and frequently use open habitats within and near the airport operational area, especially in the morning and evening. Therefore, habitat management that reduces food availability, roosting and nesting sites, and standing water near operational areas is recommended as a priority measure to reduce this species' exposure to aircraft operations.

Six other species (*P. manyar*, *L. leocogastriodes*, *C. linchi*, *L. pallida*, *C. juincidis* and *P. montanus*) were major (dangerous) species, with densities of 86 to 380 individuals in the study area and a frequency of 16 to 28 encounters over 5 days. Despite their small size, these birds always flock together in large groups and frequently appear. The larger the group size (the number of individuals in the group), the greater the frequency of their flights. These birds are active during the day, especially in the morning and evening, foraging in open areas such as grasslands, agricultural land, and bushes, which are often near runways [22][23].

The presence of birds that live in colonies and nest in dense groups requires serious attention in the context of aviation safety. The potential for bird-aircraft collisions increases when these groups move simultaneously between nesting sites and food sources in the vicinity of airport operational areas. Although not an endangered species, it depends on artificial habitats not designed for conservation, indicating a hidden ecological vulnerability [24][25]. The five-day survey, conducted in the morning, afternoon, and evening, provides a baseline description of bird community composition in the LOP operational area. Because the observation period was relatively short, the risk categories should be interpreted as reflecting conditions during the study period rather than year-round patterns. Repeated surveys across different seasons are recommended to better represent temporal variation in bird occurrence. The relatively high occurrence of granivorous and insectivorous passerines, including *Ploceus philippinus*, *Ploceus manyar*, *Lonchura* spp., and *Passer montanus*, is consistent with the availability of agricultural and semi-open habitats around LOP. Aquatic and semi-aquatic species, such as *Ardeola speciosa* and *Ixobrychus cinnamomeus*, were also recorded in areas associated with ponds and standing water. These findings indicate that habitat features around the airport may influence bird occurrence and should therefore be considered in wildlife hazard management planning.

Bird-strike risk management in the LOP

A SWOT analysis was conducted to identify factors influencing the formulation of bird collision management strategies at the LOP. Through this analysis, the airport's strategic position in relation to internal conditions (strengths and weaknesses) and external conditions (opportunities and threats) influencing the effectiveness of bird collision control can be identified [26][27].

The SWOT factors were identified through field observations, interviews, questionnaires, reviews of airport documents, and literature studies. A total of 21 respondents were purposively selected based on their involvement in airport operations and wildlife hazard management. Internal factors were classified into strengths and weaknesses, whereas external factors were classified into opportunities and threats. The questionnaire was assessed using the Product–Moment correlation at a 5% significance level and Cronbach's alpha reliability testing. Each factor was assigned a weight ranging from 0.00 to 1.00, with the total weight within each factor group standardized to 1.00. A rating of 1–4 was then assigned to represent the actual condition and management response associated with each factor. The weighted score (WS) was calculated as the product of the weight (W) and the rating (R). The internal coordinate was obtained by subtracting the total weakness score from the total strength score, while the external coordinate was calculated by subtracting the total threat score from the total opportunity score. The complete IFAS and EFAS matrices, including the identified factors, weights, ratings, and weighted scores, are provided as supplementary tables to improve the transparency and reproducibility of the analysis.

Table 2. Internal Factors Analysis Summary (IFAS)

Internal factors	W	R	WS
Strengths			
Airport personnel have a good understanding of bird-strike risks to flight safety and airport operations.	0.20	3	0.60
Habitat management is implemented around the airport as a preventive measure.	0.20	3	0.60
Airport personnel understand that large birds have a higher potential to cause bird strikes.	0.20	3	0.60
Bird-strike management policies help reduce aircraft damage and operational disruptions.	0.20	4	0.80
Habitat management and bird-dispersal activities are implemented to reduce the risk of bird strikes.	0.20	3	0.60
Total strengths	1.00		3.20
Weaknesses			
Bird-strike management equipment is limited and not yet fully adequate.	0.25	2	0.50
The bird-dispersal technology currently in use is insufficiently effective.	0.25	2	0.50
Bird-strike incidents may cause flight cancellations or delays and generate operational losses.	0.25	1	0.25
Bird-strike incidents affect operational efficiency by increasing time and resource use.	0.25	1	0.25
Total weaknesses	1.00		1.50
Internal coordinate (X)			3.20 − 1.50 = 1.70

Table 2. External Factors Analysis Summary (IFAS)

External factors	W	R	WS
Opportunities			
Educational and awareness programs on bird-strike risks and prevention are available for the surrounding community.	0.30	3	0.90
The surrounding community understands the importance of bird-strike management and is open to cooperation.	0.30	3	0.90
Local communities are actively involved in training and environmental management activities related to bird-strike prevention.	0.40	4	1.60
Total opportunities	1.00		3.40
Threats			
A high bird population is present around the airport.	0.20	3	0.60
Vegetation around the airport attracts birds to the operational area.	0.30	3	0.90
Water puddles around the airport support bird movement and migration.	0.20	3	0.60
Agricultural activities in the surrounding community may attract birds to the airport area.	0.30	3	0.90
Total threats	1.00		3.00
External coordinate (Y)			3.40 − 3.00 = 0.40

If the S and W scores (IFAS) and the O and T scores (EFAS) are plotted in a SWOT matrix, the ideal strategic position for the system under study can be determined [28][29]. The SWOT matrix for implementing bird strike management at LOP is shown in Figure 4.

For IFAS, the strengths score (S = 3.2) is significantly higher than the weaknesses score (W = 1.5), resulting in a positive overall score for IFAL (1.7; right quadrant). This indicates that the airport has sufficient internal resources to handle bird strikes. The total score for the EFAS is also positive, at 0.4 (upper quadrant), with the opportunity score (O = 3.4) higher than the threat score (T = 3.0). This indicates a supportive external environment. The position for the combination of S>W and O>T is quadrant I, an SO strategy (Strengths-Opportunities) or known as an aggressive strategy, which uses strengths to maximize opportunities [30][31]. This is the most ideal position to formulate a bird strike strategy at the LOP.

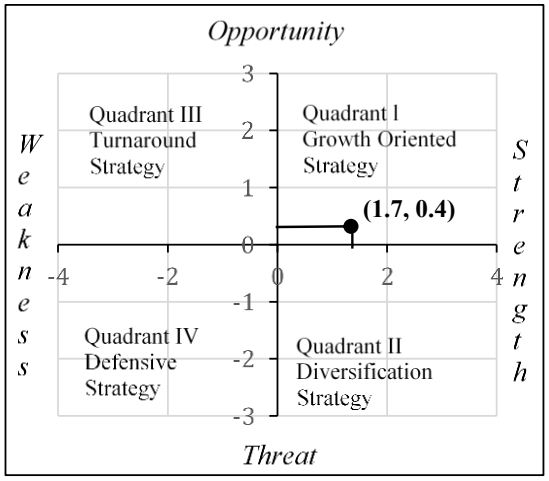


Figure 4. SWOT Quadrant Matrix for Bird Strike Management at LOP

The formulation of specific SO strategies for bird strike management at LOP was carried out using adapted techniques [11][32]. The SO-specific strategy formulation for LOP was conducted systematically using metadata, taking into account the absolute values of the IFAS and EFAS scores, as well as the individual strengths (S), weaknesses (W), opportunities (O), and threats (T) scores. Aspects targeted by the specific SO strategy for LOP include strengthening the wildlife hazard management system, proactive habitat modification, detection technology and early warning systems, and multi-stakeholder education and outreach. These ecological insights directly inform the "Proactive habitat modification" component of the SO strategy. Reducing the attractiveness of the airport and its immediate surroundings to high-risk species requires targeted actions aligned with the ecology of the dominant hazardous species. For granivorous and insectivorous passerines that dominate the LOP operational area, this includes modifying vegetation structure to reduce food and nesting resources, managing grass height and density, and limiting shrub and tree species that provide roosting and nesting sites near the runway. For aquatic and semi-aquatic species, managing ponds and standing water to reduce foraging opportunities is critical. Coordination with local authorities and communities to minimize illegal dumping, fish waste, and agricultural practices that increase food availability near the airport further supports these measures. By tailoring habitat management to the specific ecological requirements of the dominant hazardous species, the proposed actions are more likely to reduce their local abundance and, consequently, the overall bird-strike risk at LOP. A summary of the results of formulating specific SO strategies for bird strike management at LOP is shown in Table 4.

Table 4. Summary of specific bird strike management strategies based on the SO quadrant for LOP

	Use strength	Seize the opportunity	Out put
Strengthening the wildlife hazard management system.	LOP had Airside Safety personnel and ICAO standard equipment	Collaboration with the NTB Natural Resources Conservation Center and the University of Mataram for research on bird movement and seasonal occurrence patterns around the LOP.	SOP for wildlife control based on local data, not a generic SOP.

Proactive habitat modification.	LOP has the authority to manage 10-13 km^2 of land around the airport according to ICAO Doc 9137.	CSR program and support from the Central Lombok Regional Government for the conversion of illegal landfills and rice fields around the airport into areas that are not attractive to birds.	Reducing the main attractant of bird strikes in LOP.
Detection technology and early warning systems.	LOP's status as an international airport facilitated access to budget and technology.	Adoption of radar bird detection technology and collaboration with AirNav Indonesia for real-time bird NOTAM to pilots.	Pilots can get bird risk info before landing/takeoff
Multi-stakeholder education and outreach.	LOP had an Airport Collaborative Decision Making [ACDM]	Involve local communities, farmers and fishermen to control the disposal of garbage and fish waste that attracts birds.	Reducing bird food sources outside the airport area.

Conclusion

In LOP, there were 29 bird species, which, based on the risk of bird strikes, comprised 1 severe, 6 major, 8 moderate, 7 minor, and 7 negligible species. The SO strategy was suitable for bird strike management at the LOP, namely utilizing the airport's strengths and seizing opportunities in aspects that include strengthening the wildlife hazard management system, proactive habitat modification, detection technology and early warning systems, and multi-stakeholder education and outreach.

Author's Contribution

Wahyuni: conceptualization, investigation; Suripto: methodology, writing-review and editing; L.M.A. Dujana: investigation, writing-review and editing

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