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Wildlife Hazard Management in Aviation Safety Policy at Indonesian Airports: A Qualitative Gap Analysis

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Abstract

Wildlife strikes remain a persistent safety risk for airport operators because birds and terrestrial animals can damage aircraft, disrupt schedules, and threaten passengers and crews. In Indonesia, the issue is particularly important because airports operate in diverse ecological settings, including coastal zones, forest edges, wetlands, agricultural areas, settlements, and rapidly urbanizing airport vicinities. This study evaluates the implementation of Wildlife Hazard Management (WHM) at Indonesian airports by synthesizing published airport evidence and comparing reported practices with ICAO standards and Indonesian aerodrome regulations. A qualitative documentary review and structured gap analysis were conducted using ICAO Annex 14, ICAO Doc 9137 Part 3, ICAO Safety Management System principles, Indonesian CASR Part 139-related regulations, and empirical studies from several Indonesian airports. The analysis was organized around eight WHM components: wildlife assessment, habitat and attractant control, patrol and surveillance, reporting and risk assessment, equipment and technology, personnel competence, emergency preparedness, and off-airport stakeholder coordination. The findings show that Indonesian airports have generally adopted core WHM practices, including patrols, reporting, grass cutting, perimeter control, and deterrent equipment. However, implementation remains uneven. Key gaps include limited species-specific and seasonal risk assessment, incomplete evidence on reporting quality, insufficient recurrent training and simulation, suboptimal placement and maintenance of deterrent equipment, and weak documentation of off-airport coordination within the 13 km wildlife-risk area. The study contributes a comparative policy-implementation framework for strengthening WHM as part of airport Safety Management Systems in Indonesia.

Keywords: Aviation Safety; Gap Analysis; Indonesian Airports; Policy Implementation

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INTRODUCTION

Air transportation is essential for passenger mobility, cargo distribution, tourism, trade, and regional connectivity. As flight activity increases, airport operators are required to maintain high levels of safety while managing risks generated by infrastructure growth, environmental change, and operational complexity. In Indonesia, this challenge is amplified by a large and geographically dispersed airport network. The Ministry of Transportation designated 36 public airports as international airports through KM 37 of 2025, while PT Angkasa Pura Indonesia reported operating 37 airports and serving more than one million aircraft movements in 2024 (Directorate General of Civil Aviation, 2025; Ministry of Transportation, 2025). This scale of operations makes consistent airport safety governance increasingly important.

One operational risk that requires continuous attention is the presence of wildlife on or near aerodromes. Wildlife strikes, particularly bird strikes but also collisions with mammals and other terrestrial animals, can damage aircraft, delay flights, increase maintenance costs, and create safety consequences during take-off, landing, and low-altitude flight phases. Recent international studies emphasize that wildlife strike risk is not only a biological problem but also a safety-management problem because it depends on local habitat characteristics, reporting quality, airport procedures, personnel competence, and the ability of airport operators to evaluate risk systematically (Altringer et al., 2024; Ball et al., 2021; Ha, 2025).

ICAO guidance requires aerodrome operators to develop a Wildlife Hazard Management Programme (WHMP) based on wildlife hazard assessment, continuous monitoring, habitat management, deterrence, reporting, personnel training, and coordination with relevant stakeholders in the aerodrome vicinity (ICAO, 2020, 2025a). In Indonesia, these expectations are reflected in the regulatory framework governing aerodromes, including SKEP/42/III/2010 on Wildlife Hazard Management on or in the vicinity of an aerodrome, PM 83 of 2017 on CASR Part 139, and KP 21 of 2023 on technical and operational standards for land aerodromes (Directorate General of Civil Aviation, 2010, 2023; Ministry of Transportation, 2017).

Previous Indonesian studies have examined wildlife hazard practices at individual airports such as Tjilik Riwut, Aji Pangeran Tumenggung Pranoto, Taufik Kiemas, Hang Nadim, Adi Soemarmo, Juanda, Jenderal Ahmad Yani, and I Gusti Ngurah Rai. These studies provide valuable operational descriptions, including the use of patrols, grass cutting, perimeter fences, audiosonic deterrents, coordination among airport units, and reporting procedures (Aswiratin et al., 2024; Indra Martadinata et al., 2022; Nurhawani et al., 2024; Oktaviani et al., 2019; Sutarwati & Simanjuntak, 2023; Wicaksono et al., 2022). However, the literature remains fragmented. Most studies focus on single-airport descriptions and do not systematically compare implementation patterns across airports or map them against ICAO standards, Safety Management System (SMS) principles, and policy implementation requirements.

This gap limits the scientific and practical contribution of the existing literature. Without comparative synthesis, it is difficult to identify which WHM components are consistently implemented, which are only partially implemented, and which require policy attention at the national level. Moreover, the available literature often describes activities without clearly explaining how gap analysis is conducted or how observed practices relate to the larger safety-risk management cycle. Therefore, a more transparent and analytically structured review is needed to transform case descriptions into evidence-based policy recommendations.

The novelty of this study lies in its comparative policy-implementation perspective. Rather than evaluating one airport, this study synthesizes evidence from multiple Indonesian airports and maps it to ICAO WHM requirements, Indonesian aerodrome regulations, and SMS principles. The objectives are: (1) to identify the regulatory and conceptual requirements for effective Wildlife Hazard Management at airports; (2) to synthesize implementation evidence from Indonesian airport studies; (3) to conduct a structured gap analysis between reported practices and international/national requirements; and (4) to propose policy and operational recommendations for strengthening WHM in Indonesian airport safety management.

LITERATURE REVIEW

Aviation Safety, Wildlife Strikes, and Airport Risk

Aviation safety management requires continuous identification, assessment, mitigation, and monitoring of operational hazards. Wildlife strikes are a recurrent aerodrome hazard because aircraft and wildlife share critical airside environments, especially during take-off, approach, landing, and ground movement. The severity of a strike is influenced by species, body mass, flock

size, aircraft speed, flight phase, and whether the strike affects engines, windshields, landing gear, or other critical components (Ball et al., 2021; Metz et al., 2020). Consequently, wildlife hazard management must combine ecological knowledge with operational risk control.

Recent studies show that wildlife strike risk is difficult to measure because strike reports may reflect both real changes in risk and changes in reporting behavior. Altringer et al. (2024) found that wildlife hazard management can improve both reporting quality and realized risk reduction, demonstrating that program evaluation must distinguish between better reporting and lower underlying risk. This insight is important for Indonesian airports because documented increases in wildlife occurrences should not automatically be interpreted as worsening safety; they may also indicate improved reporting discipline.

ICAO and Indonesian Regulatory Foundation for WHM

ICAO Doc 9137 Part 3 explains that an effective WHMP should be specific to each aerodrome and supported by accurate data, wildlife hazard assessment, habitat management, reporting and recording, dispersal and deterrence procedures, and personnel training (ICAO, 2020). ICAO Asia-Pacific guidance further emphasizes that wildlife hazard management should be based on local ecological conditions and should include continuous assessment, a formal WHM plan, periodic audits, and coordination between aerodrome operators and responsible authorities (ICAO, 2025a).

In Indonesia, SKEP/42/III/2010 operationalizes WHM under the aerodrome safety framework by requiring airport operators to identify bird and wildlife hazards, monitor the aerodrome and surrounding area, reduce attractants such as tall grass and open drainage, and record wildlife activity. PM 83 of 2017 and KP 21 of 2023 place these obligations within broader CASR Part 139 aerodrome safety standards (Directorate General of Civil Aviation, 2010, 2023; Ministry of Transportation, 2017). These regulations provide a formal basis for WHM, but implementation quality depends on resources, competence, coordination, and local adaptation.

Safety Management System and Policy Implementation Perspective

WHM should not be treated as a stand-alone operational routine. Under an SMS perspective, wildlife hazards must be integrated into hazard identification, risk assessment, mitigation planning, safety assurance, and safety promotion. This means that airport wildlife reports, patrol findings, species data, equipment condition, training records, and emergency simulations should be used as safety data for monitoring safety performance and improving procedures (ICAO, 2020; ICAO, 2025b).

A policy implementation perspective is also necessary because WHM involves multiple actors. Airport operators, Apron Movement Control (AMC), Airport Rescue and Fire Fighting units, Aviation Security, Safety and Risk Management units, Air Traffic Control, airlines, local governments, waste-management agencies, communities, and environmental stakeholders all influence wildlife risk. Implementation therefore requires clear rules, adequate resources, inter-unit coordination, technical competence, communication channels, and enforcement of land-use controls in the aerodrome vicinity.

Indonesian Airport Evidence and the Need for Comparative Synthesis

Indonesian case studies show that WHM practices have been implemented in different forms. For example, studies report patrols and wildlife control systems at Tjilik Riwut Airport, community support for wildlife control at Taufik Kiemas Airport, wildlife species identification at Hang Nadim Airport, AMC involvement at Adi Soemarmo Airport, audiosonic placement issues at Juanda International Airport, and ATC situational-awareness challenges at I Gusti Ngurah Rai International Airport (Indra Martadinata et al., 2022; Nurhawani et al., 2024; Sutarwati & Simanjuntak, 2023; Wicaksono et al., 2022).

The main weakness of this literature is not its relevance but its limited synthesis. Individual studies often describe what is present at a particular airport, but they do not consistently ask

whether reported practices satisfy the complete WHMP cycle required by ICAO. A comparative gap analysis is therefore needed to determine whether Indonesian WHM implementation has moved from formal compliance toward risk-based, data-driven, locally adaptive, and SMS-integrated practice.

Table 1. Regulatory and conceptual framework for Wildlife Hazard Management analysis

Framework source	Main WHM requirement	Function in this study
ICAO Annex 14 and PANS-Aerodromes	Aerodrome design and operations; wildlife hazard prevention in and around aerodromes	Provides the international basis for aerodrome operators to identify and manage wildlife hazards.
ICAO Doc 9137 Part 3	Wildlife Hazard Management Programme, assessment, habitat management, reporting, deterrence, and training	Defines the technical components used as comparison indicators in this study.
ICAO Annex 19 / SMS principles	Hazard identification, risk assessment, mitigation, assurance, and safety promotion	Frames WHM as part of the airport safety-risk management cycle rather than only a field patrol activity.
SKEP/42/III/2010 / AC 139-03	Wildlife Hazard Management on or in the vicinity of an aerodrome	Requires identification, monitoring, control of attractants, activity recording, and attention to the 13 km vicinity.
PM 83 of 2017 and KP 21 of 2023	CASR Part 139 aerodrome standards and technical/operational requirements	Provides the national aerodrome regulatory structure for implementing WHM in Indonesian airports.

METHOD

This study used a qualitative documentary review with structured narrative synthesis and gap analysis. The design was selected because the objective was not to measure wildlife strike frequency directly but to evaluate how reported WHM practices at Indonesian airports correspond to international and national regulatory expectations. The unit of analysis was the WHM policy-implementation evidence reported in regulations, ICAO guidance, official documents, and Indonesian airport studies.

The study setting comprised Indonesian airports discussed in available WHM-related publications and official documents. The reviewed evidence covered airports with different ecological and operational characteristics, including coastal, urban, agricultural, forest-edge, and mixed land-use surroundings. This diversity is relevant because ICAO guidance requires each airport to adapt its WHMP to local wildlife species, habitat characteristics, seasonal patterns, and operational risk profile.

The data sources consisted of two document groups. The first group included regulatory and guidance documents: ICAO Annex 14, ICAO Doc 9137 Part 3, ICAO SMS principles, ICAO Asia-Pacific WHM guidance, SKEP/42/III/2010, PM 83 of 2017, and KP 21 of 2023. The second group included empirical and descriptive studies on WHM implementation at Indonesian airports, including studies on Tjilik Riwut, Aji Pangeran Tumenggung Pranoto, Taufik Kiemas, Hang Nadim, Adi Soemarmo, Juanda, Jenderal Ahmad Yani, and I Gusti Ngurah Rai airports, as well as the 2025 ICAO Asia-Pacific information paper on wildlife hazards at PT Angkasa Pura Indonesia airports.

Documents were selected using purposive criteria. Inclusion criteria were: (1) direct relevance to wildlife hazards, bird strikes, or WHM in airport operations; (2) relevance to Indonesian airports or international standards applicable to Indonesian aerodromes; (3) availability of sufficient methodological or operational description; and (4) publication or regulatory relevance from 2019 onward, except for foundational regulations and standards that remain applicable. Exclusion criteria were documents that discussed wildlife conservation without an aviation safety component, non-airport transportation hazards, or opinion-based sources without identifiable evidence.

Data were extracted into a matrix containing: airport or document name, ecological setting where reported, wildlife species or hazard type, responsible units, WHM practices, equipment and

technology, reporting mechanisms, training or simulation, coordination arrangements, and stated weaknesses. Regulatory requirements were translated into eight analytical indicators: (1) wildlife hazard assessment; (2) habitat and attractant control; (3) patrol and surveillance; (4) reporting and risk assessment; (5) equipment and technology; (6) personnel competence and training; (7) emergency preparedness; and (8) off-airport stakeholder coordination.

Gap analysis was conducted in four steps. First, the ICAO and Indonesian regulatory documents were reviewed to define expected WHM practices. Second, evidence from each airport study was coded against the eight indicators. Third, each indicator was classified as implemented, partially implemented, not reported, or gap identified. Fourth, cross-airport patterns were synthesized to identify recurring strengths and weaknesses. The purpose of the coding was not to rank airports, because the available studies used different methods and levels of detail, but to identify policy-relevant implementation patterns.

To improve trustworthiness, the analysis retained a transparent audit trail linking each gap judgement to a regulatory expectation and a source-based observation. Claims were limited to evidence available in the reviewed documents. Where the documents did not report a specific WHM component, the finding was interpreted as a documentation gap rather than definitive proof that the practice was absent. This conservative approach protects the scientific integrity of the study and avoids overgeneralization.

Table 2. Document selection criteria

Criterion	Inclusion	Exclusion
Document type	Regulations, ICAO guidance, official information papers, and empirical airport studies	General aviation news without evidence; non-airport wildlife studies
Time frame	2019-2026 for empirical literature; earlier documents retained only if still regulatory/foundational	Outdated sources replaced where more recent and relevant sources were available
Geographic relevance	Indonesian airports and international standards applicable to Indonesian aerodromes	Studies unrelated to Indonesia or not transferable to aerodrome WHM
Substantive focus	Wildlife hazards, bird strikes, wildlife strike reporting, WHM policy, airport safety management	Wildlife conservation or environmental management without aviation safety linkage
Evidence sufficiency	Documents containing identifiable practices, gaps, procedures, or regulatory requirements	Opinion-only sources lacking operational or methodological detail

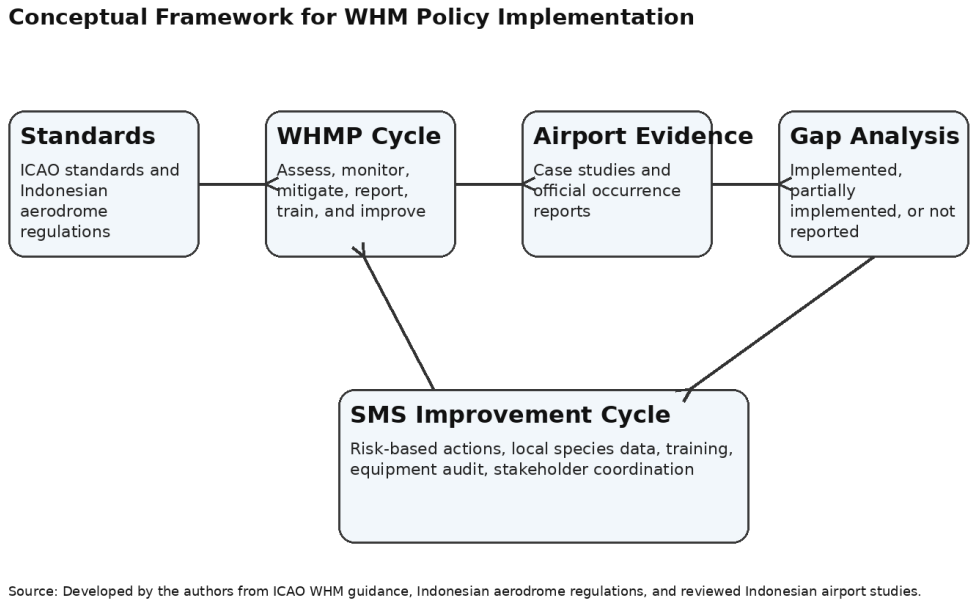

Figure 1. *Conceptual framework for evaluating WHM policy implementation in Indonesian airports*

RESULTS

The reviewed documents indicate that Wildlife Hazard Management is recognized by Indonesian airport operators as an operational safety issue rather than an incidental environmental problem. Across the studies, common practices include airside patrols, grass cutting, drainage or habitat control, perimeter monitoring, reporting of wildlife presence, coordination between AMC and other airport units, and the use of deterrent equipment such as vehicle patrols, sirens, audiosonic devices, CCTV, and other repellent tools. These practices show general alignment with the minimum requirements of SKEP/42/III/2010 and ICAO guidance.

However, the implementation evidence is uneven across WHM components. Patrol and basic deterrence are more consistently reported than risk assessment, reporting quality assurance, recurrent training, emergency simulation, species-specific mitigation, and off-airport land-use coordination. This pattern suggests that many airports have implemented operational control activities but have not yet fully institutionalized WHM as a data-driven SMS process.

The comparative synthesis is presented in Table 3. The table does not rank airports; instead, it identifies recurring implementation themes and gaps reported across airport case studies and official documents.

Table 3. Comparative synthesis of WHM implementation evidence at Indonesian airports

Airport / evidence source	Reported WHM implementation	Analytical gap identified	Main source
Tjilik Riwut Airport, Palangka Raya	Prevention, dispersal, and control of birds/wildlife in the runway area; multi-unit collaboration involving ATC, safety, infrastructure, PKP-PK, and security units	Need for continuous coordination and more systematic risk documentation to convert field activities into SMS evidence	Wicaksono et al. (2022)
Aji Pangeran Tumenggung Pranoto Airport, Samarinda	Airport located near forested areas; wildlife presence includes dogs and other animals entering through fence gaps; WHM activities reported	Absence or limited availability of dedicated wildlife-handling personnel; need stronger perimeter and species-specific mitigation	Aswiratin et al. (2024)
Taufik Kiemas Airport, West Coast	Community perception supports airport efforts to control wildlife hazards	External stakeholder support exists, but off-airport coordination needs formalization in land-use and attractant-control mechanisms	Indra Martadinata et al. (2022)
Hang Nadim International Airport, Batam	Identification of multiple wildlife species; classification based on animal behavior and movement/flight speed	Species information is useful, but should be linked to quantitative risk prioritization and mitigation planning	Sutarwati & Simanjuntak (2023)
Adi Soemarmo Airport, Surakarta	AMC involvement in wildlife hazard handling; snakes and wildlife in bush/grass areas reported	Habitat control and bush/grass management need to be connected to recurrent surveillance and risk-zone mapping	Mafaza & Haryati (2022); Oka et al. (2024)
Juanda International Airport, Surabaya	Audiosonic bird-deterrent equipment and airside monitoring practices reported	Placement and maintenance of deterrent equipment require reassessment based on updated wildlife gathering points and runway-risk zones	Aldi (2024)
Jenderal Ahmad Yani International Airport, Semarang	WHM implementation and prevention activities reported; safety socialization involving airport units	Need for clear Indonesian-language SOPs and recurrent training so new officers can use equipment consistently	Oktaviani et al. (2019)
I Gusti Ngurah Rai International Airport, Bali	Wildlife hazard handling involves ATC situational awareness and reporting of wildlife presence	ATC workload and staffing constraints may limit wildlife detection; reporting should be supported by clear unit responsibilities and shared surveillance data	Nurhawani et al. (2024)
PT Angkasa Pura Indonesia airports	Official reports identify bird strikes as a significant safety issue during 2022-2024 and note five airports with highest potential bird-strike risk; mitigation includes acoustic deterrents, laser devices, bird traps, working groups, and training	National data create an opportunity for big-data-based WHM, but airports still need standardized indicators, species-level records, and performance measurement	Directorate General of Civil Aviation (2025); ICAO (2025b)

The gap matrix in Table 4 shows that implementation gaps are concentrated in the transition from operational activity to risk-based safety management. In other words, many practices exist, but the documentation does not consistently demonstrate how those practices are evaluated, adapted to local species, linked to safety indicators, or improved over time.

Table 4. Gap analysis matrix based on ICAO and Indonesian WHM requirements

WHM component	Expected standard	Evidence of implementation	Gap	Recommended improvement
Wildlife hazard assessment	Aerodrome-specific assessment based on accurate wildlife data and local ecology	Species lists and local observations are reported in several airports	Risk assessment is often descriptive; limited evidence of standardized scoring by species, season, location, and severity	Develop a national WHM risk matrix with local species weighting and periodic review.
Habitat and attractant control	Grass cutting, drainage management, waste control, removal of food/water/shelter attractants	Grass cutting, bush clearing, drainage control, and fence monitoring are commonly reported	Evidence on off-airport attractants, landfill/wetland/agricultural coordination, and long-term habitat planning remains limited	Integrate airport WHMP with land-use governance within the 13 km vicinity.

Patrol and surveillance	Routine surveillance of the movement area and wildlife activity recording	Patrols by AMC/security/safety units are frequently reported	Surveillance schedules, detection coverage, and data quality are rarely compared across airports	Standardize patrol logs and include time, species, location, weather, runway direction, and mitigation response.
Reporting and risk analysis	Incident reporting, recording, risk classification, and feedback into SMS	Wildlife presence and strike reporting are acknowledged	Incomplete evidence on report completeness, confirmed/unconfirmed classification, damage reporting, and trend analysis	Create a centralized, auditable national wildlife-strike reporting database linked to SPIs and safety targets.
Equipment and technology	Appropriate deterrent equipment selected and placed based on risk zones	Audiosonic, laser, vehicle patrols, CCTV, and other tools are reported	Equipment placement and maintenance may not always match changing wildlife gathering points	Conduct periodic equipment effectiveness audits and relocate equipment based on current wildlife maps.
Personnel competence and training	Trained personnel able to assess, deter, report, and respond to wildlife hazards	Some training and socialization activities are reported	Recurrent training, simulation frequency, and certification standards are not consistently documented	Implement recurrent WHM training for AMC, safety, PKP-PK, aviation security, ATC, and relevant contractors.
Emergency preparedness	Procedures and simulations for wildlife strike scenarios and post-strike response	Emergency scenarios and simulations are mentioned in some airport contexts	Limited evidence that wildlife-strike scenarios are routinely integrated into emergency exercises	Include wildlife-strike scenarios in airport emergency plans and evaluate response time, coordination, and reporting.
Stakeholder coordination	Coordination with ATS, airlines, local government, waste management, communities, and environmental agencies	Internal airport coordination is often reported; community support appears in some studies	Formal off-airport coordination mechanisms are weakly documented	Establish or strengthen airport wildlife safety committees and interagency data-sharing mechanisms.

DISCUSSION

The findings indicate that Indonesian airports have moved beyond the absence of WHM policy; the stronger issue is uneven implementation maturity. Basic operational activities such as patrols, grass cutting, deterrent use, and reporting are widely reported. These practices demonstrate formal alignment with national regulation. However, ICAO guidance expects WHM to be aerodrome-specific, data-driven, and continuously improved. Therefore, formal compliance should be distinguished from effective risk-based implementation.

A first critical finding is the need for local adaptation. Indonesian airports operate in varied ecological contexts, including coastal wetlands, forest edges, agricultural land, open grass areas, and urban settlements. This makes uniform WHM procedures insufficient. The ICAO Asia-Pacific discussion of “one airport, one programme; one bird, one strategy” is relevant because each airport requires mitigation measures based on its local species, habitat, seasonal movement, and operational exposure. Evidence from Hang Nadim, Aji Pangeran Tumenggung Pranoto, Adi Soemarmo, and Juanda shows that wildlife species and gathering points vary across airports; therefore, equipment placement, patrol timing, and habitat control must also vary.

A second finding concerns reporting and risk measurement. Several studies mention wildlife presence or strike reporting, but few explain whether reports are complete, whether confirmed and unconfirmed strikes are separated, whether damage is recorded, or whether wildlife observations are linked to risk scoring. This is important because improved reporting may initially increase the number of documented occurrences even when underlying risk is being reduced. Altringer et al. (2024) emphasize that wildlife strike metrics depend on reporting quality, meaning airports need reliable data before they can evaluate programme effectiveness.

A third finding relates to human factors and SMS integration. WHM requires coordination between AMC, safety management, PKP-PK, aviation security, ATC, airlines, and airport infrastructure units. The Ngurah Rai evidence suggests that ATC situational awareness and workload can affect wildlife hazard handling. This finding supports the argument that WHM should not place unrealistic detection responsibility on one unit. Instead, it should be supported by shared surveillance data, clear responsibility allocation, and SMS-based communication channels.

A fourth finding is that habitat and infrastructure management remain central. Tall grass, open drainage, insects, water accumulation, damaged fences, and nearby attractants can create habitats or entry routes for wildlife. The studies on Aji Pangeran Tumenggung Pranoto, Adi Soemarmo, and other airports show that wildlife hazards are strongly connected to airport physical conditions. This finding is consistent with ICAO guidance that WHM must manipulate habitat and animal behavior, not merely disperse animals after they appear in the movement area.

The study contributes theoretically by connecting WHM with SMS and policy implementation perspectives. It shows that wildlife hazard control is not only a technical field activity but also a governance process involving standards, resources, competence, coordination, monitoring, and feedback. This perspective helps explain why airports with similar regulatory obligations can show different implementation gaps.

The practical implications are direct. Airport operators should develop airport-specific WHMPs based on current species inventories, risk maps, and seasonal patterns. The Directorate General of Civil Aviation and airport operators should also strengthen national reporting standards, develop common WHM performance indicators, conduct recurrent training, audit equipment placement, and institutionalize wildlife safety committees involving local governments and community stakeholders. For large airports, technology such as radar, CCTV analytics, acoustic deterrents, and digital reporting can support WHM, but technology should be evaluated through risk reduction and reporting-quality indicators, not merely procurement.

This study has limitations. First, the analysis relies on published documents and available airport studies, so it cannot verify undocumented practices at each airport. Second, the reviewed studies differ in method, scope, and level of operational detail, making statistical comparison inappropriate. Third, some references are national journal studies rather than indexed international papers because Indonesian airport WHM evidence is still emerging. Future research should use mixed methods, including field observation, interviews with WHM personnel, standardized wildlife counts, strike-report analysis, and before-after evaluation of mitigation interventions. Quantitative studies should also examine the relationship between aircraft movements, wildlife abundance, habitat variables, reporting quality, and damaging strike rates.

CONCLUSION

This study evaluated Wildlife Hazard Management implementation at Indonesian airports through a qualitative documentary review and structured gap analysis. The findings show that WHM is already recognized in Indonesian airport safety practice and is supported by national regulations aligned with ICAO guidance. Across the reviewed airports, core activities such as patrols, reporting, habitat control, perimeter monitoring, and deterrent equipment have generally been implemented.

Nevertheless, the study also identifies important gaps. WHM implementation remains uneven in species-specific risk assessment, seasonal data collection, reporting quality assurance, recurrent personnel training, emergency simulation, equipment placement, and off-airport stakeholder coordination. These gaps indicate that WHM should be strengthened as an SMS-integrated and data-driven programme rather than treated only as a routine airside patrol activity.

The main contribution of this study is a comparative framework that connects Indonesian airport evidence with ICAO standards, national regulation, SMS principles, and policy implementation requirements. Practically, the study recommends airport-specific WHMPs, standardized reporting indicators, recurrent cross-unit training, periodic equipment audits, national data integration, and stronger coordination with local governments and communities in the aerodrome vicinity. Future empirical research should test these recommendations through

field-based risk assessment, quantitative wildlife-strike analysis, and evaluation of mitigation effectiveness at airports with different ecological profiles.

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