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Review

A Review of Wildlife Strike Reporting in Aviation: Systems, Uses and Standards

Dan Parsons *, Steven Leib and Wayne L. Martin

School of Engineering and Technology, Central Queensland University, 13 G-14 University Drive, Bundaberg, QLD 4670, Australia; s.leib@cqu.edu.au (S.L.); w.martin@cqu.edu.au (W.L.M.)
* Correspondence: daniel.parsons@cqumail.com

Simple Summary

Collisions between aircraft and animals are among the most reported safety events in aviation. This literature review examines the question of whether wildlife strike reporting systems are meeting the needs of the industry in managing wildlife hazards in aviation. This paper concludes that while academics and industry have adopted systematic hazard management concepts and international guidance material has kept pace, international standards, the foundation for many national reporting systems, remain decades behind. To bring these standards into alignment, this paper proposes the use of robust methodologies to build consensus among the industry prior to the development of new requirements.

Abstract

Wildlife strikes in aviation are among the most reported safety incidents. As such, strikes have become the fundamental unit of understanding of the risk posed by wildlife. However, the management of wildlife risks to aviation has shifted to a hazard management philosophy. This literature review examines the argument that current wildlife strike reporting requirements are inadequate for modern wildlife hazard management techniques. This review utilised bibliometric analysis software to identify relevant academic research sourced from the Web of Science, as well as industry materials, to compile a final catalogue (n = 542). Further filtering revealed a limited set of relevant papers (n = 42) and even fewer papers that addressed the above question. Analysis of these papers and the wider catalogue noted limitations in current reporting requirements as they relate to hazard and risk management concepts. This analysis was supplemented with a review of international standards and relevant national requirements, concluding that while academics and industry have adopted systematic safety and hazard management techniques, and international guidance material has kept pace, international standards, the foundation for many national reporting systems, remain decades behind. This paper proposes the use of robust consensus-building methodologies, such as the Delphi technique, in the industry as a means of streamlining and supporting international standards development.

Keywords: airport; air traffic management; aviation; bird strike; incident reporting; risk; safety; safety reporting; wildlife management; wildlife strike

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1. Introduction

While aviation is considered "ultra-safe", with accidents and incidents relatively rare [1], collisions between aircraft and animals are one of the most commonly reported safety incidents [2]. Known today as wildlife strikes, the Australian Transport Safety

Bureau's (ATSB) national aviation occurrence database shows that, in the ten years to 2023 (inclusive), events involving wildlife accounted for 33% of safety reports in Australia [3]. As Dolbeer et al. [4] noted in their regular report on wildlife strikes in the United States, wildlife strikes "have become an increasing concern for aviation safety" (p. v).

The outcome of any single wildlife strike event will vary from negligible to catastrophic. Where a wildlife strike leads to some form of adverse outcome, the consequences may be limited to the impact area or trigger a "critical sequence of a rapidly occurring chain of events" [5] (p. 12) that leads to a serious accident. The preceding quote is from the 1960 accident report of Eastern Air Lines Flight 375, a Lockheed Electra L-188 that struck multiple birds on departure, resulting in an accident in which 62 passengers and crew were killed.

Research into the costs of wildlife strikes and associated events has recognised the economic impact on aviation. One of the most cited works on wildlife hazards in aviation is Allan [6], later followed up by Allan and Orosz [7], in which the annual worldwide costs of wildlife strikes in aviation were estimated at US $1.2 billion. Adjusted for inflation, this would equal more than US $2.2 billion in 2025. This figure, which includes direct and indirect components, will also likely underestimate the actual cost [7].

Wildlife strikes as a safety issue have been the focus of international standards [8] and national regulations [9–11] that require or otherwise influence aerodrome operators to implement wildlife hazard management programmes or similar systems. While such guidance promotes a general risk-based approach to wildlife hazard management, as this paper will note, the wildlife strike event is currently the fundamental unit of understanding across nearly all facets of wildlife hazard management. Wildlife strike events are used in various ways to describe the impact of wildlife on aviation as well as form regulatory triggers for study, review, and action. However, issues with international and national wildlife strike reporting systems have been noted in academic literature [12,13] and at industry conferences [14].

In particular, Eekeren's presentation [14] examined the definition of wildlife strike and called on the industry to consider the breadth of reportable wildlife-related events and their impact on legal liability, regulatory compliance and risk analysis. While other concerns include reporting rates and international consistency in report details (e.g., ecological factors), this research focused on the triggering event or circumstance as the reportable phenomenon.

In the following literature review, we evaluated the contention that current wildlife strike reporting requirements, particularly those defining which events must be reported, are no longer suited to modern, risk-based wildlife hazard management practices.

This question was examined through an analysis of a broad survey of academic and industry research articles filtered using bibliometric techniques to identify significant sections of relevant research activity. From here, we used the collected literature to review the nature of wildlife hazard management in terms of harm and risk in contrast to the role of international standards and national legislation. We then took a deeper dive into key areas where we believe the industry's focus on strikes, to the exclusion of other wildlife-related events, may be limiting the industry's hazard mitigation efforts. Our final discussion outlines the interplay between academic research, industry practice and the international standards development process, and how our future research may address the issues identified in the literature.

2. Methods

Using a relative board search query, we obtained a library of relevant research from the Web of Science database. The query searched for a combination of wildlife or bird strike

with aviation-related terms across all database fields. Throughout this paper, we use the term "wildlife" to denote the hazard at the centre of our research. However, for much of its history, the term "bird strike" has been more common, with over 95% of reported wildlife strikes in 2023 attributed to birds [4].

To help identify relationships between related, complementary and seemingly disparate sources, we used VOSviewer bibliometric analysis software (VOSviewer 1.6.20) to survey the academic landscape. This software allowed us to visualise and interpret patterns in the literature. These patterns are based on relationships between authors, keywords and citations [15] and when used in cross-disciplinary research, clusters related items and presents visual maps as a method for identifying relationships within a field of research.

Using VOSviewer, we segregated relevant from irrelevant clusters for further analysis. We supplemented this catalogue with industry material collated from a search of the proceedings of foremost industry conferences and fora. We then refined the catalogue to identify research addressing wildlife hazard management beyond the scope of wildlife strikes by filtering for papers with titles containing the terms hazard and management.

Finally, we analysed this catalogue in detail against the research question outlined above, utilising addition material from regulatory standards and supporting literature from the fields of risk and safety management.

3. Results

The initial search of the Web of Science database yielded 684 documents, representing a diverse range of disciplines, spanning the period 1991–2025.

Using VOSviewer, we produced a visualisation of the relationships between these documents using citations. The resulting visualisation, shown in Figure 1, showed three groups of documents. The first group, shown as a grey ring, indicated unconnected documents covering a variety of topics, including general biology and ecology [16,17], and unrelated aviation and aerospace topics [18,19].

The second group consisted of a super-cluster located in the lower-left quadrant. We identified this group as being related to aircraft-engineering topics. We reviewed the six largest clusters in this group (each n > 20) using VOSviewer's clustering algorithm [20]. These clusters covered topics like impact simulation and assessment on aircraft structures [21–23], involving jet engines [24–26], and involving laminate materials [27–29].

We focused on the last group, located in the upper-right quadrant of the diagram, which we would describe as the wildlife hazard management super-cluster. This super cluster also contained six clusters with more than 20 documents each. There appeared to be greater overlap between clusters, but some of the more significant papers explored risk management [30–32], wildlife biology and behaviours and their impact on wildlife strikes [33,34], wildlife strike statistical analysis [35], habitat management [36], intervention strategies [13,37] and wildlife strike outcomes [38–40]. This super-cluster consisted of 257 articles and other documents.

For industry materials, we searched the indexes of the International Bird Strike Committee (IBSC) Conference, the World Birdstrike Association (WBA) conferences, the North American Bird Strike Conference, and the Australian Aviation Wildlife Hazard Group (AAWHG) Forum. The resulting catalogue consisted of 542 documents.

Our filtering of wildlife hazard management papers yielded 67 documents (including one podcast). We excluded a further nine documents that related to the general topics of risk management, safety management systems, and land use management, as well as sixteen papers that also referenced wildlife strikes in the title, but were retained and one document on wildlife research that merely occurred on an airport.

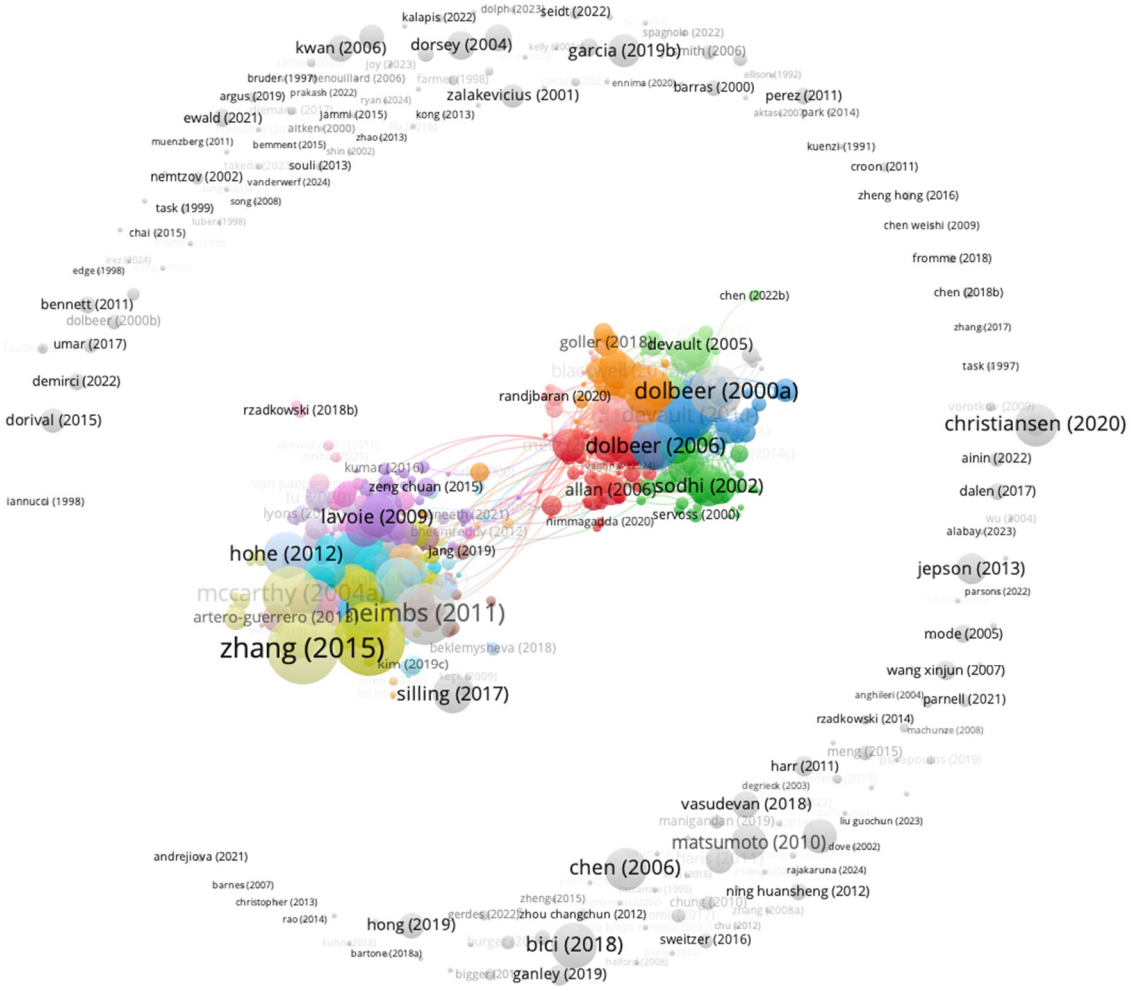


Figure 1. VOSviewer-produced Network Visualisation showing two main groups of connected and interconnected papers surrounded by a third group of unconnected papers.

Further analysis found that, when discussing the hazard posed by wildlife to aviation, all but one of the 41 remaining documents referred to wildlife strikes as the primary focus of the problem. These documents covered a range of research topics and purposes, including wildlife hazard management [41,42], wildlife risk assessment [32,43–45], habitat management [46–48], case studies [49–51], avian radar technologies [52–54], and regulatory guidance [55–58].

We sourced supporting international standards, guidance, and regulatory materials from the International Civil Aviation Organisation (ICAO) library and web resources, as well as aviation legislation and guidance materials from the US, European Union, and Australian governments.

4. Analysis

The management of wildlife strikes is a systemised business activity often undertaken by, but not necessarily exclusive to, an airport operator [59]. While wildlife hazard management may be considered broader than just the impact on aviation from wildlife strikes, the literature follows international standards and tends to equivocate and define these terms in a one-to-one relationship or to use them interchangeably. As exemplified by this quote from Davis et al. [44], who, in reviewing the wildlife hazard extant at a proposed airport site, state that "the final goal of the exercise is to reduce the risk of bird-strikes to aircraft" (p. 5).

The Airport Services Manual, ICAO's primary source of guidance on the subject, appears to define wildlife hazard in broader terms, "the presence of wildlife (i.e., birds and other animals, both wild and domestic) that could result in damage to aircraft" [60] (p. 1-1). Yet, it is subsequent discussion focuses on historical wildlife strike events before explicitly tying together the two concepts with the statement that the "objective of wildlife hazard management at aerodromes is to reduce the risk of a wildlife strike" [60] (p. 1–2).

The sole document identified in our catalogue that adopted the broader, hazard management approach to wildlife hazard was Mendonca [61]. In his analysis of safety management system principles, as they applied to wildlife hazard management, he consistently used the word "hazard", which, while defined with significant reference to wildlife strike scenarios, also included "incidents where the presence of birds on or around the airfield has any effect on a flight whether or not evidence of a strike can be found" [61] (p. 8). Here, Mendonca [61] combined the definitions for three categories of wildlife incidents established by the IBSC [62], which noted that such incidents are also "potentially dangerous" [62] (p. 14) and do not necessarily involve a wildlife strike.

Mendonca [61] supported the addition of non-strike events, citing Heinrich and Granniss' safety triangle, and the benefits of investigating near-miss events [63,64]. These considerations often conjure the image of an iceberg with the visible portion above the water representing the reports we receive, but the bulk of the "problem", near-miss events and hazard reports, sits below the surface and is hidden.

Other research has touched on the potential role of near-miss and other events. Swissair were capturing near-miss event reports as early as 1978 but were not using them in their statistical analysis [65]. Klope et al. [66] examined the role of near-miss wildlife event reports further and highlighted that, on any given airport, wildlife strikes are underreported and often decoupled from management actions. This makes them insensitive to changes in the environment that may precede wildlife strike events. The authors proposed the "augmentation" [66] (p. 213) of wildlife strike data to provide the necessary granularity for managing wildlife hazards.

Yet, as with any hazard, wildlife, as a "source of potential harm" [67] (p. 3), would be expected to realise that harm in more ways than just wildlife strikes. However, as discussed in further detail below, international standards and major national regulatory systems have constrained mandatory reporting requirements to aircraft-wildlife collisions [8,11,68–70]. The FAA, on the other hand, has established a voluntary reporting system that deems a strike to have occurred when wildlife on or near an aerodrome has had a "significant negative effect on a flight" [71] (p. 3). While this designation does not necessarily correspond to a general understanding of near-miss as it does not require proximity between the aircraft and the wildlife, and it places an additional threshold on outcomes, it was the only identified example of a national reporting system accommodating non-collision events.

We searched for an analysis of non-collision event reports in the latest FAA report, which analysed the data contained in the US National Wildlife Strike Database (NWSD), but we could not identify any statistical analysis of such events [4]. In an appendix, we found a single report, deemed a significant "strike", that described a non-strike event where a landing aircraft manoeuvred to avoid a deer and exited the runway onto the runway strip, colliding with a drainage culvert [72].

A search of the NWSD, where we filtered for reports where the number of birds/wildlife struck was left blank, found a total of 683 reports, many with the exact initial phrase of "not a strike" [72]. This figure represents only 0.2% of all reported strike events. This would suggest a clear indication of under-reporting, except for the provision that non-collision events must have a negative effect and reach a significance threshold.

Outside of the US, Smallie and Froneman [73] described the approach taken at South African airports as incorporating the non-collision negative effect on flight concept in their definition of bird strike, but subsequent discussion appears to omit these reports, as such reports are not even assigned a bird strike level.

With the above research confirming the existence of adverse impact on aircraft from non-collision events, we sought out and found the following examples of non-strike-related harm in the literature. House et al. [74] detailed their research on the impact of keyhole wasps on aircraft through blockages to pitot tubes. Their analysis described a 2013 incident involving an Airbus A330 that declared a Mayday due to airspeed discrepancies. An investigation found sand and mud deposited by wasps blocking a pitot tube. Bridgman [75] observed bird nesting activities during his career in the Royal Air Force. He discussed the difficulty in removing found nests and noted that some nests could impact flight safety. However, he reported that he could not find any records of accidents attributed to this hazard. Solman and Thurlow [76] detailed aerodrome damage by mammals, including flooding caused by beavers and noted that "failure at a critical phase of landing could cause a serious hazard" (p. 109). Finally, Marcus [77] reported on the impact on aviation from wildlife infiltrating aircraft, with the diversion of an AirAsia flight due to a stowaway snake in Malaysia. The airline cited safety as its top priority when deciding to divert. The report also referenced other snake-related incidents, including a smuggled cobra that bit the smuggler's hand in 2012 and a stowaway python in 2016.

Given the propensity of research to use wildlife hazards as a proxy for wildlife strikes, we utilised Scheer et al. [78] observations on risk communication, particularly with respect to the distinctions between hazard and risk. They outlined research examining how the use of each word impacted the management approach taken by different organisations and how they communicated, often depending on the circumstances. For example, regulatory bodies would use the terms interchangeably when speaking to the public, but distinctly when communicating with professionals. Scheer et al. [78] also noted that the term used to describe the management strategy also influences the approach's aims.

When hazard management is employed, the management strategy tends towards "rigorous limiting" [78] (p. 1272) of the hazard, without considering exposure to or the severity of harm. It is easier to understand and communicate these concepts compared to a risk-based approach. Risk management necessitates a more comprehensive analysis of the exposure and impact resulting from the hazard. Scheer et al. [78] posited that "the large majority of people do not fully understand the process and results of risk assessment" (p. 1272).

So, do these observations apply to the concept of wildlife hazard management? Our answer is no. A significant amount of wildlife hazard management research is devoted to risk assessment methodologies, including Allan [79], Dolbeer et al. [43], Zakrajsek and Bissonette [30], Shaw [80], Paton [81], Pfeiffer et al. [45], and DeVault et al. [82]. These risk assessment techniques provide structures for wildlife hazard managers to undertake a deeper analysis involving the severity of harm, exposure and probability. As such, wildlife hazard management is generally approached from a risk-based perspective.

Eekeren [14] specifically mentioned that differences in definitions can impact the risk assessment techniques used by wildlife hazard managers. At least two of the most prominent risk assessment methods utilise the percentage of damaging and/or negative effect on flight strikes as indicators for the potential risk severity for specific wildlife species. Allan's [31,79] model and the Dolbeer et al. [43] Relative Hazard Score (RHS) approach both consider the portions of total strikes resulting in an adverse outcome and, through different methods, calculate a severity/impact score to be used in further risk assessment.

If changes are made to the reporting system, the assessment results from these techniques may also change. Allan et al. [12] found this when they revisited the Allan [31] risk assessment matrix after the introduction of mandatory bird strike reporting in the United Kingdom. The data showed that increases in reporting rates of non-damaging strikes had caused an apparent increase in risk, which could cause airport-based wildlife hazard managers to invest resources into managing unnecessary species.

Allan et al. [12] also noted that reporting culture, differing reporting requirements, and varying application of existing requirements meant that risk analysis using similar techniques needs to be undertaken on a national basis using its own data. This would pose a challenge for smaller countries with limited data and those seeking to benchmark against other countries.

As a summary of issues resulting from not having a set of standard requirements for wildlife hazard event reporting, Eekeren [14] made a strong call to action on the need for common definitions of wildlife hazard events. He identified confusion regarding regulatory triggers following wildlife strikes, legal liability disputes, and miscalculation of wildlife risk as potential issues stemming from incomplete and inconsistent definitions. Discussions between conference participants highlighted frustrations with previous industry-based attempts to address this issue.

Unfortunately, these were not new issues. Dekker and Buurma [83] raised the importance of definitions and conventions in their discussion on mandatory reporting. Their concerns included whether non-avian strikes would be included and if there would be a minimal impact threshold for reporting. They suggest an expectation that agreement on these issues would be reached as a matter of course. Eekeren [14] indicated that little progress has been made, which suggests to the authors the need for targeted efforts at building consensus among the industry.

Another key concept to consider when taking a holistic hazard management approach is the interplay between risks and mitigation efforts, especially the question of what new risks might be introduced by the introduction of a new risk treatment [84]. These new treatments might introduce new hazards or alter the manifestation of existing ones. Within wildlife hazard management, a common mitigation technique involves the use of firearms for the harassment or removal of wildlife [57]. These firearms become a new source of harm, requiring additional hazard management and procedures [57].

While wildlife hazard mitigation is a multi-pronged endeavour, the prevailing airport-centric approach has been described as flawed by McKee et al. [42]. They advocate for separation of aircraft and wildlife, similar to the process by which ATC dynamically alters flight paths to separate air traffic from each other and other known hazards, such as weather [58], and recommend greater involvement of Air Traffic Control (ATC) in this strategy.

The feasibility of such a system was tested by Metz [85], who modelled various aspects of an air traffic control advisory system designed to prevent wildlife strikes (bird strikes, in particular). Through fast-time simulation, they showed that the introduction of an advisory system could prevent a significant percentage of wildlife strikes [86]. However, she [85] found that, where avoidance of strikes was greatly effective, "the number and duration of delays could get high for tight air traffic schedules on days with high bird abundances" (p. 116). While this type of system would, if introduced and successful, have a positive impact on wildlife strikes as they are reported in existing systems, the resulting negative impact on schedules and costs would not be captured.

Additionally, aerodrome operators may identify the reduction in wildlife strikes and curtail wildlife control measures as the advisory system carries the weight of the wildlife hazard management programme. Aircraft operators would likely register an increase

in costs after the changes take effect, and much like tracking wildlife strike events, this would be too late. This scenario further supports the need for consistent and standardised reporting of non-collision or wildlife avoidance events.

5. Discussion

As an international endeavour, the regulatory system surrounding aviation is substantial and complex. In the aftermath of World War II, the international community recognised that aviation was essential to global stability and a potential threat to security. They sought to cooperate in the development of standards and recommended practices that promote safety, order, equality, and sound economics [87]. Wildlife hazard management has been included in these standards, recommended practices, and guidance material for over five decades.

Despite the expectation that ongoing obligations on states should be published in annexes to the Convention on International Civil Aviation [87], as early as 1965, ICAO, via various State Letters, requested bird strikes involving aircraft be reported [88]. This expectation has since been incorporated into Annex 14—Aerodromes [8] along with several other wildlife strike hazard reduction specifications. Initially, as a recommendation and now as a standard, signatory states are required to establish a reporting system for wildlife strikes as a means of assessing the wildlife hazards on and around the aerodrome [60,89]. States must also collect and forward wildlife strike reports to ICAO for inclusion in the ICAO Bird Strike Information System (IBIS) and to take action to decrease the risk of collisions between wildlife and aircraft [60].

These provisions firmly place the emphasis on hazard management and reporting on wildlife strikes as actual collisions. The IBIS Manual [90], being of a similar era to these specifications, aligns closely with this approach, stating that "reports should be submitted only when a bird strike has actually taken place" (p. 4) and that "occurrences of birds flying near aircraft should not be reported" (p. 4).

But later guidance material developed by ICAO sought to broaden the scope of wildlife hazard event reporting. Doc 9981—Procedures for Air Navigation Services—Aerodromes [91] uses the phrase "wildlife strike-related events" when outlining accident and serious incident as well as IBIS reporting requirements. This document also establishes expectations for aerodrome operators to have procedures for recording, analysing and reporting wildlife incidents. It also expects WHMPs to contain procedures for collecting, reporting and recording wildlife strike and observation data and to warn aircraft operating on or nearby the aerodrome of wildlife hazards. However, it should be noted that the wildlife incident reporting criteria established in Appendix 2 to Chapter 6 [91] are focused on wildlife strike reporting only.

In the newer Doc 9137—Airport Services Manual—Part 3—Wildlife Hazard Management [60], the objective of wildlife hazard management is established as wildlife strike risk management, and then defines a strike in terms of collision. And yet, it then expands the scope of recordable events to include occurrences where the presence of wildlife could have a negative effect on a flight.

There may, however, be a difference between reportable and recordable events. This document describes recordable events as reported to the aerodrome operator; however, it is unclear whether they should also be reported to the National Aviation Authority (NAA) and/or the IBIS. It expects wildlife incidents, which may or may not include the events above, to be reported per the aerodrome operator's national incident reporting regulations. Relevant guidance to national aviation authorities merely repeats the requirements of Annex 14.

Given the numerous references to incidents above, it is necessary to consider Annex 13—Aircraft Accident and Incident Investigation [92], which defines incident in tandem with accident and serious incident as follows:

- An accident is an event involving the operation of an aircraft that results in the death or serious injury of a person, the aircraft sustains significant damage or the aircraft is missing. However, this definition excludes specific types of damage resulting from a bird strike.
- A serious incident is a situation that had a high probability of being an accident.
- An incident is any other type of occurrence that affects or could affect safety.

Finally, we explored the topic of safety reporting within the ICAO Safety Management System (SMS) framework as described in Annex 19—Safety Management [93]. This model establishes a much broader concept of safety reporting; however, the details of these specifications describe a system geared towards incident reporting, separate from mandatory reporting requirements to a national aviation authority. They also include the collection and analysis of a wide variety of safety data, which, for aerodrome operators, could include inspection records, risk assessment results and voluntary reports [94].

However, ICAO SARPs and guidance material do not directly impose a legal obligation within any specific state or operator. States, either through their national aviation authorities and/or independent safety bodies, establish national regulations on topics such as wildlife hazard management and event reporting. The following paragraphs will outline the approaches taken by the United States, the European Union, and Australia.

At a regulatory level, the United States has created the obligation to monitor wildlife strikes as a potential trigger for formal wildlife hazard management processes [9]. As noted above, the FAA maintains a voluntary national reporting system as described in advisory material [71]. The full definition of a wildlife strike covers two aspects.

Firstly, a wildlife strike should be reported if it involves a bird, a bat, a terrestrial mammal weighing more than one kilogram, or a reptile weighing more than one kilogram. Secondly, a strike is deemed to have occurred when either:

- Someone witnesses a collision between wildlife and an aircraft;
- There is evidence on an aircraft, including damage, of a collision with wildlife;
- The remains of wildlife are found either on or near a runway, on a taxiway or anywhere else near an aerodrome where there is no other explanation for the animal's death, or a collision is suspected;
- As discussed above, wildlife on or near an aerodrome has had a "significant negative effect on a flight" [71] (p. 3).

Within the European Union's aviation regulatory system, aerodrome operators are required to minimise wildlife collision risk, including having procedures to record and report wildlife strikes and to utilise this data in their wildlife risk assessments [11]. Aircraft operators and air traffic service providers must also report wildlife strikes [68]. There was no specific definition provided for wildlife strike, nor any commentary on the reporting of suspected wildlife strikes or other wildlife hazard-related events.

The European air navigation service provider Eurocontrol has defined a wildlife strike as a collision between an animal and an aircraft either in flight, taking off, or in the landing roll [69]. They also suggested that incidents where a collision is "narrowly avoided" should be reported [95].

In Australia, aerodrome operator regulations and standards have established the requirement for a wildlife hazard management system [96] and the monitoring of wildlife strikes on or near the aerodrome [10]. The requirement to report wildlife strikes that do not result in an air accident can be found in a different set of regulations [70], which establishes

that collisions with animals involving air transport operations or that occur on certified aerodromes as routine reportable matters.

Between the three regulatory regimes analysed as part of this literature review, we see a voluntary reporting system that includes some non-strike events, one mandatory reporting system with limited description of what is to be reported, while its associated air navigation service provider recommends reports of relevant non-strike events, and one mandatory reporting system that only requires collisions to be reported. This highlights variations in the specificity and scope of reporting requirements, particularly when evidence of a collision is limited or a collision was narrowly averted. This is not surprising given that international standards and guidance span multiple documents written over a thirty-year period.

Even beyond the weight and momentum behind wildlife strike reporting as a regulatory and academic standard, one of the most significant reasons as to why ICAO standards may become out of step with industry practices is that the process of amending them is complex and time-consuming. While the ICAO development and amendment process offers a range of methods for proposing changes and new material [97], all proposals must be approved by the Air Navigation Commission (ANC). The ANC reviews such proposals in consideration of its Work Programme and judiciously assigns Job Cards to the relevant Panel [98]. In the case of wildlife hazard management, the relevant panel, the Aerodrome Design and Operations Panel (ADOP), then seeks experts to contribute their time to implementing the proposal outlined in the Job Card.

However, the standards development process at ICAO is slow [99]. The International Federation of Air Traffic Controllers' Associations (IFATCA) [97] notes that this process may take up to five years. However, there are examples of Job Cards taking much longer. The review of Obstacle Limitation Surface (OLS) standards commenced in 2013 and was only finalised a decade later [100]. Even after this, the process may take another two years for the final amendment to become applicable [97].

The role of guidance material in this system is to support the application of standards and recommended practices [101]. Yet, where specific provisions of the Chicago Convention obligate contracting States to adopt the standards and recommended practices produced by ICAO, States may not incorporate guidance into their national legislation [102]. Nonetheless, guidance material can be considered easier to produce and amend under the expectation that this material, typically contained in technical manuals, is updated regularly [101]. Although Salih [101] also identifies areas where such material has become obsolete.

Only one of the ICAO documents discussed above, the IBIS Manual, was published or updated more than ten years ago. This document was recently reviewed with an update expected to be delivered by the end of 2023 [103]. But despite the modernisation of these supporting documents, do their inconsistencies and stagnant foundation, a standard rooted in a 50-year-old letter, best serve the industry today?

We believe that, although the literature is limited, it supports a call for revision of the underlying standards governing the reporting of wildlife strikes, specifically the types of events that should be reported to a national aviation authority. However, we also acknowledge the resource limitations that exist within the international standards development process and recommend that industry and academia take the lead in developing a consensus on this question ahead of lobbying for standards and regulatory change.

We have identified the Delphi method, developed by Dalkey and Helmer [104] for the RAND corporation, as a technique designed to produce "the most reliable consensus of opinion of a group of experts" (p. 1). Chalmers and Armour [105] go so far as to describe the technique as "unique" (p. 717) in achieving this aim. This method seeks to capitalise on the benefits of group performance without the social factors that may result in what is known as "process loss" [106] (p. 236). This loss is defined as a group performing worse

than the best individual within the group and is often attributed to factors like disparity in member status, confidence, and competence.

Targeted research, undertaken by the authors, utilising a panel of industry experts, who remain anonymous to each other, will seek to build a consensus on the types of events that should be reported. This consensus will form the basis for submissions to ICAO on the case for standards development.

6. Conclusions

Under the broadest definition of hazard, wildlife presents a complex and continued risk to aviation safety. While wildlife can interact with the aviation system in various ways, collisions between animals and aircraft are the primary concern for the industry. Previous research has established the nature and, in some cases, quantum of the wildlife strike problem. Yet, a holistic, systemic approach to hazard management calls on safety professionals to look beyond the ultimate manifestation of the hazard. Near-miss and other related events may provide as much actionable context and information to wildlife hazard managers as they do to other safety managers.

The literature review above demonstrates a dynamic and diverse sub-industry comprising professionals of various backgrounds and academics working to develop structures that support analysis and intervention. The history of this sub-industry shows its pragmatic approach to managing what has been measured, wildlife strikes. Advances in systemised safety and hazard management have made inroads into the field, with the adoption of wildlife hazard management practices becoming the norm.

However, the research and regulations still focus on the occurrence of wildlife strikes as the primary performance measure. The discussion above highlighted three areas where this focus may not lead to optimal outcomes. Near-miss events may not receive their due attention, and the avoidance of strikes may lead to unintended adverse effects on operations. These and other effects also impact broad risk assessment methodologies, which could mask underlying, latent conditions.

For the most part, ICAO's guidance material has been keeping pace with industry advancements. But the basis for wildlife strike reporting remains the standard established in the 1970s. Standards compliance is an obligation on contracting States, and the brief analysis above revealed variation between major regulatory systems involving guidance material provisions.

If these inconsistencies are to be resolved, the industry might have to establish a consensus before approaching ICAO to revise the standard. The resource limitations that drive ICAO to manage its Work Programme closely must be overcome with clear evidence that there is a need for change. Academia has a role to play in supporting efforts to build and show consensus on such issues through robust methods and engagement with the industry.

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Abbreviations

The following abbreviations are used in this manuscript:

AAWHG	Australian Aviation Wildlife Hazard Group
ADOP	Aerodrome Design and Operations Panel
ANC	Air Navigation Commission
ATC	Air Traffic Control
ATSB	Australian Transport Safety Bureau
FAA	Federal Aviation Administration
IBIS	ICAO Bird Strike Information System
IBSC	International Bird Strike Committee
ICAO	International Civil Aviation Organisation
IFATCA	International Federation of Air Traffic Controllers' Associations
NAA	National Aviation Authority
NWSD	National Wildlife Strike Database
OLS	Obstacle Limitation Surface
RHS	Relative Hazard Score
USDA-WS	US Department of Agriculture—Wildlife Services
WBA	World Birdstrike Association
WHMP	Wildlife Hazard Management Plan

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