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Data-Driven Analysis of Engine-Related Wildlife Strikes in Multi-Engine Jet Aircraft (2009–2023)

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Wildlife strikes remain a persistent hazard to aviation safety, with engine ingestions representing a particularly serious threat to aircraft performance and operational integrity. This study analyzes 13,467 wildlife strikes involving aircraft engines reported in the FAA National Wildlife Strike Database (2009-2023) to identify patterns and operational factors influencing the frequency and severity of engine strikes in multi-engine civil jet aircraft. Building upon Dolbeer's (2017) findings, preliminary results indicate a modest left-side predominance, with 4,112 strikes (52.9%) recorded on left-side engines and 3,659 strikes (47.1%) on right-side engines. A total of 2,266 strikes (16.8%) resulted in engine damage, most frequently during the takeoff, climb, and approach phases of flight. Nearly 47% of all engine strikes occurred below 1,000 feet AGL, underscoring the near-ground nature of these events. Although small-bodied species accounted for most engine strikes (N = 8,757; 64.1%), large-bodied species, representing only 7.1% of events, produced the highest proportion of damaging engine strikes (61.6%). These results demonstrate a clear relationship between animal size, impact energy, and engine vulnerability. Collectively, the findings confirm that engine strikes remain predominantly a low-altitude, airport-environment hazard, reinforcing the need for species-specific mitigation strategies, enhanced habitat management, and data-driven Safety Management System initiatives to improve wildlife-hazard risk assessment and operational resilience across the aviation industry.

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Introduction

Wildlife strikes remain a persistent hazard to aviation safety worldwide. In the United States alone, more than 313,000 wildlife strikes to civil aircraft were reported between 1990 and 2024, resulting in at least 126 aircraft destroyed and 82 fatalities (Dolbeer et al., 2025). Despite major advances in airport-based mitigation and habitat management (Cleary & Dolbeer, 2005), the frequency of reported strikes continues to rise, largely due to increasing aircraft movements, expanding populations of large bird species protected under the Migratory Bird Treaty Act, and improved awareness and reporting practices. While many strikes occur near airports, events beyond the airfield perimeter, particularly those involving turbofan-powered, multi-engine aircraft remain an operational safety and economic concern. Engine ingestions account for a significant proportion of damaging strikes and can result in power loss, precautionary landings, or catastrophic failure (FAA, 2025a). The Federal Aviation Administration's (FAA) National Wildlife Strike Database (NWSD) provides an extensive dataset to analyze these occurrences and guide hazard-mitigation strategies across flight phases and aircraft types (FAA, 2025b).

Dolbeer (2017) analyzed NWSD records from 1990 to 2015 for commercial transport and business jets equipped with two underwing-or fuselage-mounted turbine engines to determine whether bird strikes occurred more frequently on one side of the aircraft. The study found a statistically significant bias toward strikes on the left (red-lighted) side, suggesting that avian visual sensitivity to longer wavelengths may reduce birds' ability to detect and avoid aircraft from that direction. Building upon this foundation, the current investigation revisits the phenomenon using an expanded dataset (2009-2023) to evaluate whether the left-side bias identified by Dolbeer (2017) persists in modern fleets. Specifically, the study compares the frequency of bird strikes between left and right engines, as well as the proportion of damaging strikes affecting each side. In addition, descriptive analyses are conducted to examine operational variables associated with these events, including phase of flight, time of day, and altitude of strikes.

Understanding the distribution and characteristics of engine-specific wildlife strikes is vital for improving hazard identification, risk assessment, and mitigation within the aviation system. Studies of this nature play a critical role in advancing aviation safety by transforming operational data into actionable insights that guide technology development, regulatory policy, and Safety Management System (SMS) initiatives (Ayres et al., 2009). The findings contribute to ongoing efforts to enhance wildlife-hazard management through evidence-based safety strategies and data-driven decision-making.

Methods

Data for this study were obtained from the FAA NWSD, which documents voluntarily and mandatorily reported wildlife strikes involving civil aircraft in the United States (FAA, 2005b). The dataset for this ongoing study includes strike reports submitted by pilots, maintenance personnel, airport operators, and other aviation stakeholders from 2009 through 2023. To ensure consistency and comparability, only turbine-powered, multi-engine civil jet aircraft were included in the analysis. The dataset was first filtered to include strikes involving aircraft equipped with two, three, or four jet engines. Records missing information about engine number and time of day were excluded to maintain analytical accuracy.

Engine position was standardized to allow comparison of left- and right-side strikes across different aircraft configurations. For two-engine aircraft, left-engine strikes corresponded to *engine #1*, and right-engine strikes to *engine #2*. For three-engine aircraft, left-side strikes included those involving *engine #1* and *engines #1 and #2*, while right-side strikes included those involving *engine #3* and *engines #2 and #3*. For four-engine aircraft, left-side strikes included *engine #1*, *engine #2*, and *engines #1 and #2* combined, while right-side strikes included *engine #3*, *engine #4*, and *engines #3 and #4* combined. This categorization provided a consistent framework for comparing strike frequency and severity between the left and right sides of multi-engine civil aircraft.

Descriptive analyses were then conducted to examine the total number of strikes and the proportion of damaging strikes reported for each side. Additional variables extracted from the NWSD included phase of flight (e.g., takeoff, approach, and landing), time of day (day, night, dawn, dusk), and altitude of strike occurrence. These variables were organized to identify patterns and operational conditions most frequently associated with engine strikes. A more robust statistical analysis will be conducted to further investigate potential differences between left- and right-engine strikes; however, this paper presents preliminary descriptive findings to highlight emerging trends and guide subsequent inferential work.

Preliminary Findings and Discussions

The wildlife hazard problem must first be understood before it can be effectively mitigated. As Cleary and Dolbeer (2005) noted, "a vital first step toward understanding and solving the multidimensional wildlife hazard problem is the collection and analysis of data from actual wildlife strike events" (p. 5). In this context, the present analysis examines wildlife strikes involving multi-engine civil jet aircraft to identify patterns, trends, and operational factors specifically associated with engine strikes. This study focuses exclusively on engine-related wildlife strikes, excluding all events involving other aircraft components such as wings, fuselage, landing gear, and or windshield. Between 2009 and 2023, a total of 13,467 wildlife strikes involving aircraft engines were reported in the FAA NWSD, of which 2,266 (16.8%) resulted in damage to one or more engines. The majority of reported engine strikes involved two-engine civil jet aircraft (n = 13,059), although three- and four-engine configurations (n = 408) were also represented.

When combining all aircraft configurations, left-side engines accounted for 4,112 strikes (52.9%) of all recorded engine events, while right-side engines accounted for 3,659 strikes (47.1%), indicating a modest but consistent left-side predominance consistent with Dolbeer's (2017) findings. In terms of damaging events, 803 strikes were reported to left-side engines and 775 to right-side engines, a distribution similar to that observed for total strikes. These results suggest that while left engines experience a slightly higher overall exposure to bird strikes, the proportion of damaging events relative to total strikes is comparable between sides. Analysis by time of day showed that engine strikes were most frequent between 6:01 a.m. and 6:00 p.m., accounting for 6,342 events (47.1%) of all reported cases. The largest number occurred during the morning period (6:01 a.m. to noon; n = 3,686; 27.4%), followed by the afternoon period (12:01 p.m. to 6:00 p.m.; (n = 2,656; 19.7%). The highest proportion of damaging events (20.7%) was observed during the afternoon hours, when both bird activity and air traffic density tend to peak. Strikes occurring during nighttime hours (6:01 p.m. 6:00 a.m.) represented 3,762 events (27.9%), of which 665 (17.7%) resulted in damage. These findings suggest that while the majority of engine strikes occur during daylight, the risk of damage remains appreciable across all time periods, likely reflecting variations in both avian behavior and operational lighting environments.

Phase-of-flight data revealed that total engine strikes were most frequent during the approach (n = 3,970; 29.5%), climb (n = 1,493; 11.1%), and takeoff (n = 1,332; 9.9%) phases, reflecting increased bird activity and aircraft proximity to ground-level habitats. In contrast, damaging engine strikes were proportionally more common during the climb (N = 631; 42.3%), takeoff (n = 413; 31.0%), and cruise (n = 16; 26.7%) phases, when higher airspeeds and engine thrust could increase the severity of impact (Eschenfelder; 2005; Mendonca et al., 2024). Altitude data confirmed that the vast majority of engine strikes occurred below 1,000 feet AGL, within the airport environment or its immediate vicinity. A total of 6,379 strikes (47.4%) were recorded below this altitude band, including 5,787 strikes (43.0%) between 0–500 feet and 592 strikes (4.4%) between 501-1,000 feet. Of these, 1,233 (19.3%) resulted in damage to one or more engines, underscoring that most hazardous wildlife interactions occur during takeoff, landing, or low-altitude maneuvering. These findings reaffirm that engine strikes are overwhelmingly a near-ground hazard, emphasizing the continued importance of airport-area wildlife management, habitat modification, and low-altitude operational awareness as suggested by Dolbeer et al. (2025).

Analysis by size of animal revealed a strong association between species body mass and the severity of engine strike outcomes (Dolbeer, 2020). Of the 13,647 engine strikes analyzed, the majority involved small-bodied species (n = 8,757; 64.1%), but these accounted for a comparatively low proportion of damaging engine strikes (n = 659; 7.5%). Medium-sized species (n = 2,538; 18.6%) were responsible for 829 damaging engine strikes (32.7%), while large-bodied species (n = 975; 7.1%) produced the highest proportion of damaging engine strikes (n = 601; 61.6%). This pattern demonstrates a direct positive relationship between animal size and the severity of engine impact, aligning with prior findings that larger birds and mammals transfer greater kinetic energy to turbine components upon collision (DeVault et al., 2011). These results underscore the critical importance of species- and size-specific risk management strategies in reducing the probability of damaging engine strikes within the airport environment.

Conclusions

This study provides a focused examination of engine-specific wildlife strikes involving multi-engine civil jet aircraft between 2009 and 2023, expanding upon earlier research by Dolbeer (2017). The descriptive findings reveal that the vast majority of strikes occur below 1,000 feet AGL, predominantly during takeoff, climb, and approach, and that left-side engines experience slightly greater exposure than right-side engines. Although most events involve small-bodied species, the likelihood of damage increases substantially with animal size. Collectively, these findings reinforce that engine strikes are primarily a low-altitude, airport-environment hazard that warrants continued emphasis on habitat management, avian-activity monitoring, and risk-based mitigation strategies. The significance of this study lies in its ability to inform evidence-based safety practices and support the development of predictive models for engine-strike risk assessment, contributing to more effective SMS integration and enhanced operational resilience across the aviation industry.

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