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Bird strikes during climb and approach: a need for innovative management strategies

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Abstract: Wildlife Hazard Management Plans at civil airports in the United States cannot directly address threats posed by birds moving through aircraft climb and approach paths unrelated to nearby bird-attractant habitats such as landfills. As an iconic example, an Airbus 320 departing LaGuardia Airport (New York, USA) on January 15, 2009, struck a flock of migratory Canada geese (*Branta canadensis*) 8 km out at 884 m above ground level (AGL) that resulted in a water landing now known as the "Miracle on the Hudson." We documented 1,841 and 458 strikes from 2009 to 2023 involving large (≥1.8 kg) and medium (1.1–1.7 kg) birds, respectively, and transport civil aircraft during climb or approach at ≥152 m AGL at Part 139-certificated airports, USA. This included 111 strikes involving multiple large birds that caused engine damage. The size of these birds exceeds certification standards for most aircraft components. The mitigation of strikes with large and medium birds during climb and approach will require a paradigm shift from managing birds to managing aircraft. Bird Detecting and Avoidance Radar (BDAR) focused on departure and arrival airspaces integrated with Air Traffic Control and the cockpit is a potential means of preventing these off-airport strikes. The process with BDAR would be akin to what was achieved with Terminal Doppler Weather Radar 30 years ago to provide real-time wind shear warnings. Enhanced aircraft lighting also may help birds detect and avoid aircraft. The alternative is the status quo—a continuation of these presently non-mitigated off-airport bird strikes, some of which may not have "miraculous" endings.

Key words: aircraft lighting, airport, airworthiness standards, bird strike, geese, radar, raptors, waterfowl

Wildlife Hazard Management Plans (WHMPs) at civil airports in the United States focus on wildlife attractants at the airport (Cleary and Dolbeer 2005) and generally cannot address threats posed by large or medium birds moving through aircraft climb and approach paths unrelated to bird-attractant habitats such as landfills within 8 km of airport runways (Dolbeer 2011, McKee et al. 2016, Metz et al. 2021). Airports often work with nearby landowners to minimize bird attractants (e.g., Beffre and Washburn 2020), but we are not aware of any U.S. airports that attempt to alter the movements of migrating, transiting, or soaring birds in aircraft climb and approach paths above 152 feet above ground level (AGL) unrelated to specific and manageable attractants.

As an iconic example of an off-airport strike that was beyond the ability of the airport to mitigate with traditional wildlife and habitat management techniques, an Airbus 320 departing LaGuardia Airport (New York, USA) on January 15, 2009, struck a flock of migratory Canada geese (*Branta canadensis*) 8 km out during climb at 884 m AGL. With both engines disabled, Captain Sullenberger made a water landing now known as the "Miracle on the Hudson" (Marra et al. 2009, National Transportation Safety Board 2010).

The reason these off-airport strikes with large birds are important is that the U.S. Federal Aviation Administration (FAA) has developed airworthiness standards for airframes and windshields of transport aircraft (>19 passenger seats) using a single 1.8-kg bird (large bird test) as the maximum mass that must be tested (apart from a 3.6-kg bird for the empennage). The bird mass required for turbine-engine testing varies by engine size but generally involves 1–3 birds with masses of 1.1 kg (medium bird test) and a single 1.8- or 3.6-kg bird (large bird test; Croft 2011, Code of Federal Regulations 2026). For the large bird test, the engine does not have to keep operating after the ingestion to pass these standards; rather, the engine must contain the damage, not catch fire, and be capable of shutdown. The standards do not address large or medium birds ingested simultaneously into both engines. MacKinnon et al. (2001) provide a more detailed discussion of airworthiness standards related to bird strikes.

Because a single 1.8-kg bird is the standard for testing most air frame components, and 1.1- and 1.8-kg birds are standards for most turbine-powered engines, wildlife hazard management programs to mitigate bird strikes need to give high priority to species weighing ≥1.1 kg. Previous studies have shown a strong correlation between mean body mass of a bird and the likelihood of a strike causing damage to aircraft (Dolbeer et al. 2024).

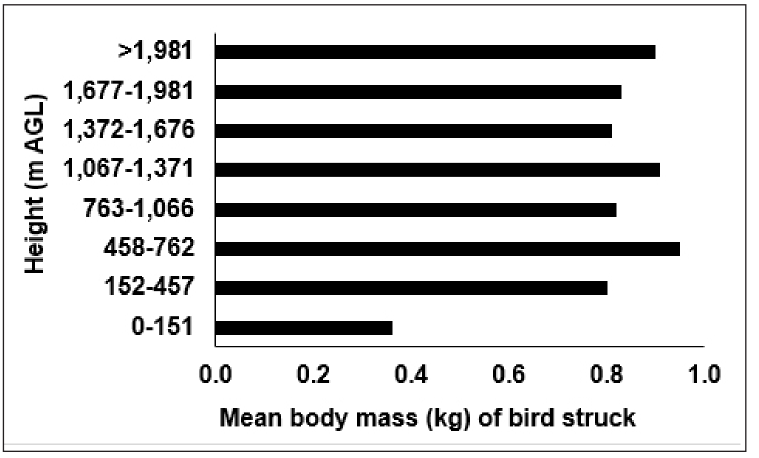

Figure 1. Mean body mass of birds (all species; *N* = 39,046 strike events) struck by transport civil aircraft (>2,250 kg maximum take-off weight) during approach, landing roll, take-off run, and climb at Part 139-certificated airports in relation to height above ground level (AGL), USA, 2009–2023. The mean body mass of birds struck at ≥152 m (0.86 kg, *N* = 7,398) was 2.4 times greater than the mean body mass of birds struck at <152 m (0.36 kg, *N* = 31,648).

Our first objective was to document the number and characteristics of strike events for the 15 years since the "Miracle on the Hudson" (2009–2023) involving large and medium birds and transport civil aircraft during departure and arrival at U.S. airports certificated for passenger service (Part 139-certificated airports; FAA 2025*a*). We wanted to determine the proportion of strike events occurring at <152 m AGL (strikes typically on airport and addressed by airport WHMPs) and at ≥152 m AGL (strikes during climb or approach typically not addressed by airport WHMPs; e.g., Marra et al. 2009). Because this initial comparison revealed a substantial number of events occurring at ≥152 m AGL, we then focused on these events involving multiple large and medium birds in which 1 or both engines were damaged. This is generally the most high-risk situation, as multiple aircraft components can be affected. With this foundation of data, we discuss the potential application of radar and aircraft lighting to address these presently non-mitigated off-airport strike events with large and medium birds. A factor that gives urgency to this subject is that most large and medium bird species in North America have shown substantial population increases in the past 30 years, and strikes involving these species have increased (Dolbeer 2020).

Methods

Bird strike data were obtained from the FAA National Wildlife Strike Database (Dolbeer et al. 2024, FAA 2025*b*). We examined reported bird strikes from 2009 to 2023 with transport civil aircraft (>2,250 kg maximum take-off weight) at Part 139-certificated airports in United States during approach, landing roll, take-off run, and climb. Using summary statistics, we compared strike characteristics (number of strikes, number and percent of strikes causing damage [at least 1 aircraft component had to be repaired or replaced; Dolbeer et al. 2024], number and percent of strikes involving multiple birds) for strikes with large and medium birds at <152 m AGL and at ≥152 m AGL. We then examined various characteristics, including reported economic losses, of those bird strikes involving large and medium birds during climb or approach at ≥152 m AGL. As noted above, these are strike events associated with an airport, but typically not mitigated by existing WHMPs, and the bird size often exceeds certification standards for aircraft parts and engines.

Table 1. Number of strikes, strikes with damage, and strikes involving multiple birds for large and medium birds and transport civil aircraft[a] during approach, landing roll, take-off run, and climb at Part 139-certificated airports[b] based on height above ground level (AGL; <152 m and ≥152 m)[c], USA, 2009–2023.

	Large birds (≥1.8 kg)		Medium birds (1.1–1.7 kg)		Large + medium birds (≥1.1 kg)	
Height (m AGL)	0–151	≥152	0–151	≥152	0–151	≥152
Total strikes	1,791	1,841	2,737	458	4,528	2,299
Damage strikes	501	842	485	198	986	1,040
% with damage	28.0	45.7	17.7	43.2	21.8	45.2
Multiple-bird strikes[d]	605	712	465	165	1,070	877
% involving multiple birds	33.8	38.7	17.0	36.0	23.6	38.1

[a]Fixed-wing aircraft rated at >2,250 kg maximum take-off weight.
[b]Airports certificated for passenger service (Federal Aviation Administration 2025*a*).
[c]Includes strikes where height not reported but distance from airport was ≥1.9 km.
[d]Flight crew observed ≥2 birds before impact, or it was determined from location of strikes on aircraft that ≥2 birds were struck.

These events at ≥152 m AGL will be referred to as "non-mitigated strikes."

Body masses for bird species were determined from Dunning (2008). For each species, we used the mean body mass for the gender with the greater mass, or if data were unavailable by gender, the mean body mass for unknown gender. For various analyses, we separated the species into 2 groups to correspond with the standards for bird ingestions into engines: large birds (≥1.8 kg) and medium birds (1.1–1.7 kg). Species identification for most strikes was made by the Smithsonian Feather Laboratory (Dove et al. 2008).

Results

Strikes at ≥152 m AGL compared to <152 m AGL

Overall, the mean body mass of birds (all species including those with body masses <1.1 kg) struck at ≥152 m AGL during climb and approach at Part 139-certificated airports (0.86 kg, N = 7,398) was 2.4 times greater than the mean body mass of birds struck at <152 m AGL during take-off run, initial climb, final approach, and landing roll (0.36 kg, N = 31,648; Figure 1). For all height bands at ≥152 m AGL, the mean mass of birds struck was consistently >2 times that of birds struck at <152 m AGL.

When we examined large birds, there were more strikes reported at ≥152 m AGL (1,841) than at <152 m AGL (1,791), and the probability of damage (% of strikes causing damage) for these non-mitigated strikes was 1.6 times higher than for strikes at <152 m AGL (Table 1). In contrast, the 458 strikes with medium birds at ≥152 m AGL were only one-sixth the number recorded at <152 m AGL (2,737); however, the strikes with medium birds at ≥152 m AGL were 2.4 times more likely to cause damage than strikes at <152 m AGL. Overall, strikes by large and medium birds combined at ≥152 m AGL were 2.1 times more likely to cause damage than were strikes by large and medium birds at <152 m AGL.

Strikes involving multiple large and medium birds followed the same pattern as damaging strikes (Table 1). There were more strikes involving multiple large birds at ≥152 m AGL (712) than at <152 m AGL (605), and the probability of damage for these strikes was 1.2 times higher than for strikes at <152 m AGL. In contrast, the 165 strikes with medium birds at ≥152 m AGL were one-third the number recorded at <152 m AGL (465); however, the multi-bird strikes at ≥152 m AGL were 2.1 times more likely to cause damage than strikes at <152 m AGL. Overall, strikes involving multiple large and medium birds combined at ≥152 m AGL were 1.6 times more likely to cause damage than were strikes by large and medium birds at <152 m AGL.

Multiple large-bird events with engine damage at ≥152 m AGL

There were 111 non-mitigated strike events involving multiple large birds in which at least 1 engine was damaged (Table 2; Appendix A).

Table 2. Summary of data from Appendices A and B regarding strikes involving multiple large birds (≥1.8 kg; 111 strikes) or medium birds (1.1–1.7 kg; 27 strikes) and transport civil aircraft during approach or climb at ≥152 m above ground level (AGL) at Part 139-certificated airports in which at least 1 bird was ingested, resulting in engine damage, 2009–2023, USA.

	Large birds (Appendix A)		Medium birds (Appendix B)	
Multiple-bird strike events at ≥152 m AGL with:	Number	% of total	Number	% of total
At least 1 engine damaged[a]	111	100	27	100
2 engines damaged	11	10	1	4
Engine(s) plus other aircraft parts(s) damaged	56	50	7	26
2–10 birds observed or struck	87	78	23	85
>10 birds observed or struck	24	22	4	15
Phase of flight (approach to airport)	44[b]	40	8	30
Phase of flight (climb out from airport)	66[b]	60	19	70
Negative effect on flight[c]	69[c]	62	17	63
Precautionary/emergency landing[d]	58	52	16	59
Engine shutdown	14	13	1	4
Other[e]	8	7	4	15

[a]In addition to the 138 strikes with engine damage at ≥152 m AGL, there were 346 multiple-bird strikes with no engine damage but 1–4 other aircraft parts damaged (303 for large birds, 43 for medium birds).
[b]Phase of flight (approach or climb) was not reported for one strike (at 610 m AGL).
[c]For large and medium birds, respectively, 58 (88%) and 16 (89%) of events with a negative effect on flight occurred during climb.
[d]Pilot completed take-off but returned to land at departure airport or an "other-than-destination" airport after strike. For large birds, 8 events with an engine shutdown and 3 events with "other" negative effect also had a precautionary/emergency landing. For medium birds, 1 event with an engine shutdown and 4 events with "other" negative effect also had a precautionary/emergency landing.
[e]Miscellaneous negative effects, such as reduced speed/impaired visibility because of shattered windshield, smoke in cabin, aborted landing (go-around).

In 11 events (10%), 2 engines were damaged. In 56 events (50%), 1–7 other aircraft components such as a pitot tube or radome were damaged in addition to the engine(s). Two to 10 birds were involved in 87 (78%) of the events, and >10 birds were involved in the remaining 24 events (22%). The phase of flight for these 111 events was climb (60%) and approach (40%). A negative effect-on-flight (e.g., precautionary/emergency landing) was reported in 69 (62%) of the events; 88% of these negative effect-on-flight events occurred when the phase of flight was climb.

Ten species of large birds were identified in these 111 events, with geese being by far the dominant species group (Table 3). Snow geese (*Anser caerulescens*; 30 strikes), Canada geese (25), greater white-fronted geese (*Anser albifrons*; 14), and unidentified geese (Anseriformes; 4) comprised 73 (66%) of the 111 strikes involving multiple birds and engine damage. Turkey vultures (*Cathartes aura*; 9), double-crested cormorants (*Nannopterum auritum*; 7), and sandhill cranes (*Antigone canadensis*; 5) comprised 19% of the strikes. Thirty-three (30%) of the strikes involved birds with a mean body mass >3.6 kg.

In addition to these 111 strikes with engine damage at ≥152 m AGL, there were 303 strikes with multiple large birds with no engine damage but 1–4 other aircraft parts damaged.

Multiple medium-bird events with engine damage at ≥152 m AGL

There were 27 non-mitigated strike events involving multiple medium birds in which at least 1 engine was damaged (Table 2; Appendix B). In 1 event (4%), 2 engines were damaged. In 7 events (25%), 1–4 other aircraft parts were damaged in addition to the engine(s). Two to 10 birds were involved in 23 (85%) of the events, and >10 birds were involved in the remaining 4 events (15%).

Phase of flight was climb and approach in 70% and 30% of the events, respectively. A negative effect-on-flight (e.g., precautionary/emergency landing) was reported in 17 (63%) of the events; 89% of these negative effect-on-flight events occurred when the phase of flight was climb.

Nine species of medium birds were identified in these 27 events, with ducks being the dominant species group (Table 4). Mallards (*Anas platyrhynchos*; 10 strikes), canvasbacks (*Aythya valisineria*; 2), common goldeneyes (*Bucephala clangula*; 1), and redheads (*Aythya americana*; 1)

Table 3. Ranking of species by number of strikes for the 111 strikes involving multiple large (≥1.8 kg) birds and transport civil aircraft during approach or climb at ≥152 m above ground level at Part 139-certificated airports in which at least 1 bird was ingested, resulting in engine damage, 2009–2023, USA (Appendix A).

Rank	Species	Scientific name	Mean body mass (kg)	# of strikes	% of total
1	Snow goose	*Anser caerulescens*	2.74	30	27
2	Canada goose	*Branta canadensis*	4.18	25	23
3	Greater white-fronted goose	*Anser albifrons*	3.00	14	13
4	Turkey vulture	*Cathartes aura*	2.30	9	8
5	Double-crested cormorant	*Nannopterum auritum*	2.01	7	6
6	Sandhill crane	*Antigone canadensis*	2.09	5	5
7	Black vulture	*Coragyps atratus*	4.80	3	3
8	American white pelican	*Pelecanus erythrorhynchos*	4.00	2	2
9	Brandt's cormorant	*Phalacrocorax penicillatus*	2.16	1	<1
9	Tundra swan	*Cygnus columbianus*	6.33	1	<1
	Unknown bird – large[a]	Aves	2.57	10	9
	Geese (unidentified species)	Anseriformes	7.20[b]	4	4
	Total		2.99[c]	111	100

[a]Species was not identified, but flight crew indicated birds were large (turkey vulture size or larger).
[b]Weighted mean body mass based on number of strikes for the 3 goose species listed in table.
[c]Weighted mean body mass based on number of strikes for each species listed in table.

Table 4. Ranking of species by number of strikes for the 27 strikes involving multiple medium (1.1–1.7 kg) birds and transport civil aircraft during approach or climb at ≥152 m above ground level at Part 139-certificated airports in which at least 1 bird was ingested, resulting in engine damage, 2009–2023, USA (Appendix B).

Rank	Species	Scientific name	Mean body mass (kg)	# of strikes	% of total
1	Mallard[a]	*Anas platyrhynchos*	1.25	10	37
2	Anhinga	*Anhinga anhinga*	1.24	6	22
3	Red-tailed hawk	*Buteo jamaicensis*	1.22	4	15
4	Canvasback	*Aythya valisineria*	1.25	2	7
5	Brant	*Branta bernicla*	1.37	1	4
5	Common goldeneye	*Bucephala clangula*	1.12	1	4
5	Osprey	*Pandion haliaetus*	1.57	1	4
5	Redhead	*Aythya americana*	1.12	1	4
5	Red-throated loon	*Gavia stellata*	1.49	1	4
	Total		1.21[b]	27	100

[a]Two mallard strikes were identified as mallard/American black duck (*Anas rubripes*) complex.
[b]Weighted mean body mass based on number of strikes for each species listed in table.

Table 5. Reported and projected repair costs (adjusted to 2023 U.S. dollars [$USD]), other costs, and aircraft downtime for strikes involving multiple large (111 strikes) and medium (27 strikes) birds and transport civil aircraft during approach or climb at ≥152 m above ground level (AGL) at Part 139-certificated airports in which at least 1 bird was ingested, resulting in engine damage, 2009–2023, USA (Appendices A and B)[a].

Multiple-bird strike events at ≥152 m AGL:	Large birds (≥1.8 kg)	Medium birds (1.1–1.7 kg)	Large + medium birds
With engine damage	111	27	138
With repair costs reported	26	7	33
Total repair costs reported	$47,864,369	$1,672,155	$49,536,524
Mean repair costs per report	$1,840,937	$238,879	$2,079,816
Projected repair costs for all 111 (large bird) and 27 (medium bird) events[b]	$204,344,007	$6,449,741	$210,793,748
With other costs reported[c]	11	5	16
Total other costs reported	$920,183	$467,096	$1,387,279
Mean other costs per report	$83,653	$93,419	$177,072
Projected other costs for all 111 (large bird) and 27 (medium bird) events[b]	$9,285,483	$2,522,318	$11,807,801
Total repair and other costs reported	$48,784,552	$2,139,251	$50,923,803
Projected repair and other costs for all 111 (large bird) and 27 (medium bird) events[b]	$213,629,490	$8,972,059	$222,601,549
With hours-out-of-service (downtime) reported	45	10	55
Total hours-out-of-service reported	7,547	548	8,095
Mean hours-out-of-service per report	167.7	54.8	
Projected hours-out-of-service for all 111 (large bird) and 27 (medium bird) events	18,615	1,480	20,095

[a]Repair cost for the "Miracle on the Hudson" event (hull loss estimated at $36 million USD in 2009) was excluded from analysis, as it would overinflate the projected repair costs for all 111 events.
[b]Assuming all 111 (large bird) and 27 (medium bird) reported strikes incurred similar amounts of repair costs, other costs, and downtime.
[c]Lost revenue from cancelled flights and other costs unrelated to direct repair costs.

comprised 14 (52%) of the 27 strikes involving multiple birds and engine damage. Anhinga (*Anhinga anhinga*; 6) and red-tailed hawks (*Buteo jamaicensis*; 4) comprised 37% of the strikes.

In addition to these 27 strikes with engine damage at ≥152 m AGL, there were 43 strikes with multiple medium birds with no engine damage but 1–4 other aircraft parts damaged.

Economic costs and downtime of multiple large- and medium-bird events with engine damage at ≥152 m AGL

In 26 of the large-bird events, repair costs of $47,864,369 USD (mean = $1,840,937 USD) were reported; in 11 events, other costs of $920,183 USD (mean = $83,653 USD) were reported (Table 5). Assuming all 111 strikes incurred these mean repair and other costs, the projected total costs of these strikes would be $204,344,007 USD. The aircraft downtime reported for 45 strikes was 7,547 hours, and the projected downtime for all 111 strikes was 18,615 hours.

In 7 of the medium-bird events, repair costs of $1,672,155 USD (mean = $238,879 USD) were reported; in 5 events, other costs of $467,096 USD (mean = $93,419 USD) were reported (Table 5). Assuming all 27 strikes incurred these mean repair and other costs, then the projected total costs of these strikes would be $8,972.059 USD. The aircraft downtime reported for 10 strikes was 548 hours, and the projected downtime for all 27 strikes was 1,480 hours.

The total reported costs and downtime for the combined large- and medium-bird events were $50,923,803 USD and 8,095 hours, and the projected costs and downtime were $222,601,549 USD and 20,095 hours.

Discussion

In the 15 years since the "Miracle on the Hudson," we are unaware of any measures that have been enacted at U.S. airports to prevent this type of bird strike (i.e., with large or medium birds moving through approach or climb airspace at ≥152 m AGL unrelated to manageable wildlife attractants within 8 km of runways). Our analyses show that these presently non-mitigated events, especially those involving multiple large birds that exceed certification standards for most aircraft components, continue to regularly occur with transport aircraft in the vicinity of Part 139-certificated airports. In fact, the number of reported strikes and damaging strikes with large birds at ≥152 m exceeds the number at <152 m. Notably, the mean body mass of birds struck at ≥152 m AGL is 2.4 times that of birds struck at <152 m AGL. This difference is due, at least in part, to wildlife management efforts at Part 139 airports that focus on keeping large and medium birds off the airport and immediate surroundings (Dolbeer 2011, Dolbeer et al. 2014, Rutledge et al. 2015, Dolbeer et al. 2024). Furthermore, the probability of damage with large and medium birds is greater for strikes at ≥152 m AGL compared to <152 m AGL, which is likely due to the greater speed of aircraft at these heights.

Aside from the safety concerns for passengers and flight crews, these strike events cost the aviation industry millions of dollars annually. Just considering the 138 strikes involving multiple large and medium birds at ≥152 m that caused engine damage from 2009 to 2023, the minimum reported cost was $50.9 million USD, and the projected cost was $222.6 million USD. We note that these estimates of economic loss are incomplete, but they demonstrate that losses are substantial (Altringer et al. 2021, 2022; Dolbeer et al. 2024).

The mitigation of these strikes with large and medium birds during climb and approach will require a paradigm shift. Bird strikes involve 2 components: the bird and the aircraft. Historically, the focus of bird strike prevention at civil airports in the United States has been the management of birds in the airport environment (Cleary and Dolbeer 2005). These traditional wildlife hazard management programs at airports are critical to minimize bird and other wildlife activity on the airport and in the immediate surroundings. However, these programs generally do not prevent off-airport strikes with large and medium birds (which exceed certification standards for most aircraft components) at heights ≥152 m AGL. Except for landfills, airports have no legal ability to control land-uses outside the airport property (Cleary and Dolbeer 2005) and even less ability to control birds that are migrating, transiting, or soaring at ≥152 m in aircraft climb and approach paths. Thus, we need technologies and procedures that flight crews and Air Traffic Control (ATC) can use to manage the aircraft and airspace during departure and arrival to avoid these birds (McKee et al. 2016, Koros and Hale 2019). Below, we discuss 2 potential approaches to achieving this goal. We hope this study also will generate additional ideas for approaches to mitigate these off-airport strikes.

Radar to mitigate off-airport strikes during climb and approach

Bird Detecting and Avoidance Radar integrated with ATC and the cockpit is a potential means of preventing these off-airport strikes with large and medium birds. We emphasize that the objective is not to detect and provide alerts for all birds in the airport environment; rather, BDAR would focus on large and medium birds potentially intersecting the flight paths of aircraft during climb out or on approach to airports. In fact, the feasibility of radar to provide such real-time alerts was demonstrated during the "Miracle on the Hudson" event. When the aircraft was at about 762 m AGL during climb, data from local Airport Surveillance Radar (ASR-9) indicated the aircraft's path intersected the path of a string of unidentified primary targets. Shortly thereafter, at about 884 m AGL, some of these primary targets (migrating Canada geese) were ingested in both engines (National Transportation Safety Board 2010).

Sowden and Eschenfelder (2009), Dolbeer (2011), and Dolbeer and Begier (2012) noted that BDAR had potential for mitigating strikes occurring outside the airport during approach and climb. Nohara et al. (2012, 3) stated:

> "If information for bird strike threats occurring off-airport were available [via BDAR]; and if this information was appropriately communicated to pilots, ATC, airlines, and airport operators, just as we provide other environmental hazard information such as windshear and volcanic eruptions, couldn't we improve aviation safety further? Shouldn't we?"

Recent studies by Hale (2018) in the United States, Bradbeer and Follett (2023) in Canada, and Metz et al. (2021) and Metz (2023) in Europe have indicated the feasibility of integrating BDAR into ATC systems to provide real-time alerts without overtasking air traffic controllers or flight crews. Nilsson et al. (2021) demonstrated that bird movements detected by weather radar (BirdCast 2025) could predict the probability of bird strikes at Part 139 airports; this technology is the foundation of the U.S. Air Force Avian Hazard Advisory System (2025).

An analogous situation occurred 30 years ago when Terminal Doppler Weather Radar (TDWR) was developed to provide real-time wind shear warnings for aircraft on approach or departure from airports. At least 511 people were killed in wind shear-related accidents in the United States from 1960 to 1994. It is impossible to control wind shear, just as it is impossible to control birds traversing climb and approach airspace outside the airport, but TDWR provided the means to manage aircraft to avoid wind shear. No wind shear accidents have occurred in the United States since 1994 (McCarthy et al. 2022).

Finally, we note that the FAA issued an Advisory Circular (AC) to provide guidance for airports to purchase and install bird-detecting radar (FAA 2010). This AC was directed to airport biologists and operations personnel and did not address providing real-time information to ATC and flight crews. The AC only mentioned that the FAA was assessing these integration issues.

Advanced aircraft lighting to mitigate off-airport strikes during climb and approach

Advance lighting systems with ultra-violet (UV) components, including pulsed-lights, may enhance aircraft detection and avoidance by birds during climb and approach. Reduced bird strike rates were reported for rotorcraft using pulsed-light systems (Fedy 2018, Mandernach 2018). Dwyer et al. (2019) showed a dramatic reduction in nighttime "strikes" by sandhill cranes with UV-illuminated powerlines. Research on bird-avoidance behavior and lighting by Bernhardt et al. (2010), Blackwell et al. (2012), Dolbeer and Barnes (2017), Foss et al. (2017), and Lunn et al. (2023) should be followed up with evaluations of advanced lighting systems on transport aircraft.

Management implications

The aviation community needs to broaden the view of bird strike risks from a ground-based wildlife management problem solely dealt with by airports to an airspace management problem that also encompasses ATC and flight crews. One approach, using wind shear alert systems as a model, is the integration of BDAR into existing airspace management protocols at Part 139-certificated airports. Critical to this integration, the reliability of BDAR to provide ATC and flight crews with real-time alerts to flocks of large and medium birds in climb and approach paths must be tested. Because most events documented in this study occurred during the climb phase of flight, mitigation of many of these strikes may be as simple as delaying departure for a short interval. A second promising approach is the development of advanced aircraft lighting systems, potentially with UV components and pulsed-lights, to enhance aircraft detection and avoidance by birds. There also may be other technologies that will help mitigate these off-airport strikes. The alternative is the status quo—a continuation of these presently non-mitigated "off-airport" strikes with large and medium birds, some of which may not have "miraculous" endings.

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Supplemental material

Supplemental material can be viewed at https://digitalcommons.usu.edu/hwi/vol19/iss1/13.

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