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Safety management systems: how useful will the FAA National Wildlife Strike Database be?

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Abstract: The National Wildlife Strike Database for Civil Aviation in the United States became operational in 1995 with the initiation of data entry of all strike reports beginning in 1990. The database contained 82,057 reported strikes from 1990 to 2007. About 9,800 of these strike reports noted damage to the aircraft, of which 2,700 indicated the damage was substantial. The database has proven to be a useful source of objective information on the extent and nature of wildlife strikes for personnel at individual airports and for researchers and regulatory agencies at the national level. With the impending requirement for airports in the United States to manage safety risks through a formal safety management system (SMS) approach, we propose that the database can be a key element for prioritizing wildlife risks and providing objective benchmarks of the effectiveness of wildlife hazard management plans (WHMP). We propose that airports use the number of damaging strikes ranked by causative species over the most recent 5-year interval in combination with species-specific wildlife count data prioritized by likelihood of damage. This would guide species-specific management actions to minimize future risk. We further propose that a benchmark or threshold rate of 0.96 damaging strikes per 100,000 aircraft movements per year be established. Any airport exceeding this damaging strike rate in a given year should reevaluate its WHMP, with a focus on those species posing the greatest risk. To enhance the utility of the database in an SMS, improvements are needed in the level and quality of reporting. In particular, all strikes and the wildlife species involved in them should be reported. During the past 13 years, the National Wildlife Strike Database has provided a scientific foundation for the various efforts underway to reduce the problem of wildlife strikes with aircraft. Improvements in reporting, as outlined above, will make the database even more useful as part of an SMS to enhance safety at airports nationwide.

Key words: aircraft, airport, aviation safety, bird strike, human–wildlife conflicts, safety management system, wildlife

Highly successful programs funded by the U. S. government during the past 40 years (e.g., pesticide regulation, expansion of the wildlife refuge systems, wetlands restoration), coupled with land-use changes, have resulted in dramatic increases in populations of many larger bird species in North America (Dolbeer 2000, Dolbeer and Eschenfelder 2003). For example, the nonmigratory population of Canada geese (*Branta canadensis,* 3.6 to 5.4 kg) almost quadrupled in the United States from 1.0 million birds in 1990 to 3.9 million birds in 2008 (Dolbeer and Seubert 2009). Many of these birds have adapted to urban environments and have found airports with large areas of grass and pavement to be attractive habitats for feeding and resting. Other wildlife, such as deer (*Odocoileus* spp.) and coyotes (*Canis latrans*), also are attracted to airport environments for similar reasons. In addition, modern turbofan-powered aircraft, with quieter engines, are less obvious to birds, compared to noisier piston-powered aircraft and older turbine-powered aircraft (Burger 1983, Kelly et al. 2001).

For these reasons, birds and other wildlife in the vicinity of airports are an increasing problem for the aviation industry. Dolbeer and Wright (2008) estimated that wildlife–aircraft strikes (98% involving birds) cost the civil aviation industry in the United States >$625 million per year. Allan (2002) estimated that bird strikes annually cost commercial air carriers >$1.2 billion worldwide. From 1988 to 2009, at least 219 people died and 212 aircraft were destroyed worldwide as a result of bird and other wildlife strikes with civil and military aircraft (Richardson and West 2000; Thorpe 2003, 2005; Dolbeer, unpublished data).

In 1990, the 190-member countries of the International Civil Aviation Organization (ICAO) adopted in Annex 14 to the convention on civil international aviation, 3 recommended

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practices regarding bird hazards to aviation: (1) assess the extent of the hazard posed by birds on and in the vicinity of airports certificated for passenger traffic, (2) take necessary action to decrease the number of birds, and (3) eliminate or prevent the establishment of any site in the vicinity of the airport that would be an attraction to birds and thereby present a danger to aviation. Because of the increasing threat to aviation caused by birds worldwide, member states voted to make these recommended practices into mandatory ICAO standards, effective November 2003 (ICAO 2004).

In the United States, approximately 570 airports are certificated for passenger traffic under Title 14, Part 139, of the U.S. Code of Federal Regulations (hereafter referred to as 14 CFR, Part 139) by the Federal Aviation Administration (FAA) for passenger traffic (CFR 2004). In concert with ICAO standards outlined above, any passenger-certificated airports that experience wildlife hazards (as defined under 14 CFR Part 139.337) is required to conduct a Wildlife Hazard Assessment (WHA). Almost all airports that conduct a WHA are then required to develop and implement a Wildlife Hazard Management Plan (WHMP). Wildlife Hazard Management Plans under 14 CFR Part 139.337 typically call for removal of habitat and food attractive to wildlife; use of techniques to exclude, disperse, or remove hazardous wildlife that pose a risk to aircraft; training airport personnel in wildlife management techniques; and establishment of an airport wildlife hazard working group. The FAA and U.S. Department of Agriculture have published a 348-page manual, titled Wildlife Hazard Management at Airports (Cleary and Dolbeer 2005), which provides detailed guidance and background material for airport personnel implementing WHMPs.

Thus, the current system for managing wildlife hazards at airports in the United States is regulatory-driven under 14 CFR Part 139. If an airport has conducted a wildlife hazard assessment and developed a WHMP that is acceptable to the FAA, the airport is in compliance. However, there are no formalized procedures defined to both (1) prioritize risk (hazard level or severity multiplied by the probability of occurrence) by wildlife species so that management efforts can be focused on the most critical species and (2) provide benchmarks to the effectiveness of the WHMP. Such procedures are needed in the development of airport Safety Management Systems (SMS), which will be required under recent amendments to Annex 14, Volume I, Aerodrome Design and Operations (ICAO 2004). The FAA has committed to implementing the use of SMSs at U.S. airports in a way that complements existing safety regulations in 14 CFR Part 139 (FAA 2007).

The National Wildlife Strike Database for Civil Aviation (hereafter called the National Wildlife Strike Database) in the United States became operational in 1995 with the initiation of data-entry of all strikes reported to the FAA beginning in 1990. With the impending requirement for airports in the United States to manage safety risks through a formal SMS approach, we propose that the database can be a key element for prioritizing wildlife risks and providing objective benchmarks of the effectiveness of WHMPs.

National Wildlife Strike Database, 1990–2007

The number of wildlife strikes involving civil aircraft reported annually to the FAA has grown from 1,759 in 1990 to 7,666 in 2007 (Dolbeer and Wright 2008, FAA 2008). The database contained 82,057 reported strikes from 1990 to 2007, of which 79,972 (97.5%) involved birds, 1,737 (2.1%) terrestrial mammals, 253 (0.3%) bats, and 95 (0.1%) reptiles. Damage to the aircraft was indicated in 9,814 (12%) of the reports; 2,700 reports indicated the damage was substantial (i.e., required major repair or replacement of critical parts as defined both by ICAO [1989] and Table 11 in Dolbeer and Wright [2008]). Of the 79,972 bird-strike reports, 34,304 (43%) provided information on the general category of bird (e.g., gull [*Larus* spp.] or hawk [Accipitridae]). Further, 20,974 (61%) of the 34,304 reports provided identification to species level (e.g., ring-billed gull [*L. delawarensis*] or red-tailed hawk [*Buteo jamaicensis*]). In all, 369 identified species of birds were struck by aircraft; 166 identified species were reported as causing damage.

The most frequently-struck terrestrial

mammals were Artiodactyls (primarily deer, 46%) and carnivores (primarily coyotes, 32%). Artiodactyls were responsible for 92% of the mammal–aircraft strikes that resulted in damage. In all, 36 identified species of terrestrial mammals and 8 identified species of bats were reported struck; 19 identified species of terrestrial mammals and 2 identified species of bats caused damage.

As the database has matured quantitatively and qualitatively over the past 13 years, it has provided an increasingly important foundation of objective information on the extent and nature of wildlife strikes for personnel at individual airports and for researchers and regulatory agencies at the national level (Dolbeer and Wright 2008). Our objective in this paper is to propose means by which the database now can be used as part of airport SMSs.

Proposed uses of database in SMS

Prioritizing risk by wildlife species

All wildlife species are not equally hazardous to aviation. In implementing WHMPs to reduce risk, airport operators and aviation regulatory agencies need guidance so that management actions can be directed toward the most hazardous species occurring at the airport. Dolbeer et al. (2000) provided a preliminary ranking of hazard level for 21 wildlife species or species groups based on 18,083 strike reports in the National Wildlife Strike Database, 1991–1998. The ranking was based primarily on the percentage of strikes causing damage to aircraft. As noted above, the database now contains 82,057 reports for 1990–2007, 4.5 times the number used in the initial rankings.

An analysis of the 82,057 reports revealed 89 wildlife species (78 birds and 11 terrestrial mammals) with 25 or more reported strikes per species. We ranked these species by percentage of strikes with reported damage to aircraft (i.e., the species with highest percentage of strikes causing damage was ranked 1, or most hazardous; Table 1). We adapted terminology provided by Allan et al. (2003) and FAA (2007) to classify the 89 species in 6 hazard (severity level) categories from extremely high (>40% of strikes causing damage) to very low (≤1% of strikes causing damage). The 78 bird species in the list were responsible for 93% of the 20,974 bird strikes in which the species was identified; the 11 terrestrial mammal species were responsible for 82% of the 1,725 terrestrial mammal strikes in which the species was identified. Thus, these 89 species represent the wildlife most commonly identified in strikes at airports in the United States.

We propose that airports can use this national list of 89 species, in conjunction with wildlife surveys locally conducted during wildlife hazard assessments and ongoing monitoring programs (e.g., Schafer et al. 2007) to proactively prioritize management actions to those species posing the greatest risk. For example, if wildlife surveys recorded an extremely hazardous species (e.g., deer; Table 1) within the air operations area, this species obviously is posing a much higher risk (i.e., hazard level multiplied by probability of strike) to aircraft than a low-hazard species (e.g., killdeer [*Charadrius vociferous*]) observed in the same area. Management priorities should reflect this risk assessment.

The database also can be used reactively to complement the proactive approach described above in prioritizing management actions to reduce risk. The database can be used to rank the wildlife species involved in damaging strikes at the airport during the most recent 1-year and 5-year periods based on the number of damaging strike incidents they caused. This ranking provides empirical data on species known to pose a safety risk at the airport in recent years. This ranking of damaging strikes listed by species already is automatically provided for all FAA-certificated airports under a wildlife strike summary report, which is part of the on-line database at <http://wildlife-mitigation.tc.faa.gov> (Dolbeer et al. 2007). The current system allows any airport to access its wildlife strike summary report for the most recent 5-year period and since 1990.

When the reactive ranking of species that have caused damage locally is used in conjunction with the proactive risk assessment based on the nationally determined hazard levels of wildlife observed on the airport, an airport can better prioritize management activities and refine the WHMP. This process guides airport management to focus on those species known to pose the greatest risk based on national and local strike statistics and local conditions.

Table 1. Bird and other wildlife species with 25 or more reported strikes with civil aircraft in the United States, 1990–2007, ranked by percentage of strikes resulting in damage to aircraft.

Rank	Hazard (severity) level	Wildlife species	Total reported strikes	Percentage of strikes: Causing damage	Causing negative EOF[1]	Involving multiple animals
1	Extremely high	Mule deer (*Odocoileus hemionus*)	36	86	56	8
2		White-tailed deer (*Odocoileus virginianus*)	712	82	49	9
3		Snow goose (*Anser caerulescens*)	68	78	38	54
4		Northern pintail (*Anas acuta*)	41	66	39	51
5		Turkey vulture (*Cathartes aura*)	289	52	34	4
6		Black vulture (*Coragyps atratus*)	37	51	46	14
7		Canada goose (*Branta canadensis*)	1,109	51	27	43
8		Brown pelican (*Pelecanus occidentalis*)	41	46	39	12
9		Bald eagle (*Haliaeetus leucocephalus*)	101	45	28	9
10		Double-crested cormorant (*Phalocrocorax auritus*)	51	41	29	16
11	Very high	Sandhill crane (*Grus canadensis*)	71	39	27	35
12		Wild turkey (*Meleagris gallopavo*)	38	32	24	21
13		Domestic dog (*Canis familiaris*)	27	30	56	0
14		Mallard (*Anas platyrhynchos*)	424	26	13	22
15		Glaucous-winged gull (*Larus glaucescens*)	48	25	13	19
16		American coot (*Fulica americana*)	57	23	9	9
17		Great blue heron (*Ardea herodias*)	193	22	17	2
18		Osprey (*Pandion haliaetus*)	135	22	14	2
19		Laysan albatross (*Phoebastria immutabilis*)	28	21	18	0
20		Ring-necked pheasant (*Phasianus colchicus*)	50	20	16	10
21		California gull (*Larus californicus*)	35	20	17	17

Table 1, continued.

22	High	Great egret (*Egretta alba*)	36	19	17	17
23	High	Great horned owl (*Bubo virginianus*)	68	18	9	1
24	High	Red-tailed hawk (*Buteo jamaicensis*)	851	17	13	2
25	High	Mew gull (*Larus canus*)	31	16	13	13
26	High	Western gull (*Larus occidentalis*)	55	13	7	13
27	High	Rock pigeon (*Columba livia*)	1,459	12	11	36
28	High	Herring gull (*Larus argentatus*)	623	12	11	12
29	High	Great black-backed gull (*Larus marinus*)	61	11	8	7
30	High	Cattle egret (*Bubulcus ibis*)	150	11	15	27
31	High	Coyote (*Canis latrans*)	252	11	22	0
32	High	Ring-billed gull (*Larus delawarensis*)	716	10	9	21
33	High	Franklin's gull (*Larus pipixcan*)	30	10	10	47
34	High	American crow (*Corvus brachyrhynchos*)	221	10	9	14
35	Moderate	Snowy owl (*Nyctea scandiaca*)	43	9	9	0
36	Moderate	Common grackle (*Quiscalus quiscula*)	46	9	11	26
37	Moderate	Black-crowned night-heron (*Nycticorax nycticorax*)	25	8	0	8
38	Moderate	Northern flicker (*Colaptes auratus*)	25	8	0	0
39	Moderate	Swainson's hawk (*Buteo swainsoni*)	39	8	8	3
40	Moderate	Laughing gull (*Larus articilla*)	214	7	7	17
41	Moderate	American robin (*Turdus migratorius*)	251	7	6	9
42	Moderate	Black-bellied plover (*Pluvialis squatarola*)	32	6	6	16
43	Moderate	Peregrine falcon (*Falco peregrinus*)	116	6	2	4
44	Moderate	Spotted dove (*Streptopelia chinensis*)	52	6	6	8
45	Moderate	Upland sandpiper (*Bartramia longicauda*)	77	5	6	10
46	Moderate	Eastern cottontail (*Sylvilagus floridanus*)	41	5	10	0
47	Moderate	Barn owl (*Tyto alba*)	459	5	4	1
48	Moderate	European starling (*Sturnus vulgaris*)	1,868	4	6	40
49	Moderate	Raccoon (*Procyon lotor*)	47	4	6	4
50	Moderate	Mourning dove (*Zenaida macroura*)	2,483	4	6	22
51	Moderate	Western sandpiper (*Calidris mauri*)	27	4	4	59

Table 1, continued.

Rank	Hazard (severity) level	Wildlife species	Total reported strikes	Percentage of strikes: Causing damage	Percentage of strikes: Causing negative EOF[1]	Percentage of strikes: Involving multiple animals
52	Low	Short-eared owl (*Calidris mauri*)	117	3	3	0
53		Purple martin (*Asio flammeus*)	67	3	1	25
54		Common myna (*Acridotheres tristis*)	35	3	3	26
55		Bank swallow (*Riparia riparia*)	71	3	1	51
56		Black-tailed jackrabbit (*Lepus californicus*)	73	3	1	0
57		American golden-plover (*Pluvialis dominica*)	38	3	8	29
58		Killdeer (*Charadrius vociferus*)	1,107	3	3	12
59		Woodchuck (*Marmota monax*)	77	3	1	0
60		Red-winged blackbird (*Agelaius phoeniceus*)	80	3	8	16
61		Northern mockingbird (*Mimus polyglottos*)	40	3	5	0
62		Zebra dove (*Geopelia striata*)	88	2	2	13
63		House sparrow (*Passer domesticus*)	48	2	0	17
64		Snow bunting (*Plectrophenax nivalis*)	99	2	13	70
65		Western meadowlark (*Sturnella neglecta*)	227	2	3	20
66		Northern harrier (*Circus cyaneus*)	59	2	2	2
67		Burrowing owl (Athene cunicularia)	59	2	0	0
68		Brown-headed cowbird (*Molothrus ater*)	65	2	3	35
69		Horned lark (*Eremophila alpestris*)	659	2	2	27

Table 1, continued.

Rank	Hazard (severity) level	Wildlife species	Total reported strikes	Percentage of strikes: Causing damage	Causing negative EOF[1]	Involving multiple animals
70	Very low	Cliff swallow (*Hirundo pyrrhonota*)	204	1	1	17
71		Savannah sparrow (*Passerculus sandwichensis*)	68	1	0	7
72		Chimney swift (*Chaetura pelagica*)	69	1	1	7
73		American kestrel (*Falco sparverius*)	1,533	1	2	4
74		Eastern meadowlark (*Sturnella magna*)	342	1	1	9
75		Common nighthawk (*Chordeiles minor*)	118	1	0	8
76		Barn swallow (*Hirundo rustica*)	649	1	0	19
77		Pacific golden-plover (*Pluvialis fulva*)	401	1	1	17
78		Tree swallow (*Tachycineta bicolor*)	145	0	2	37
79		Opossum (*Didelphus virginianus*)	59	0	0	0
80		Striped skunk (*Mephitis mephitis*)	52	0	0	2
81		Red fox (V*ulpes fulva*)	46	0	9	0
82		Yellow bittern (*Ixobrychus sinensis*)	43	0	0	5
83		Scissor-tailed flycatcher (*Tyrannus forficatus*)	38	0	5	11
84		Western kingbird (*Tyrannus verticalis*)	35	0	3	9
85		Chestnut mannikin (*Lonchura malacca*)	33	0	3	52
86		Merlin (*Falco columbarius*)	30	0	7	0
87		Least sandpiper (*Calidris minutilla*)	29	0	10	45
88		Song sparrow (*Melospiza melodia*)	26	0	0	23
89		Nutmeg mannikin (*Lonchura punculata*)	25	0	0	60

[1] EOF = effect on flight. Examples of negative EOF are aborted take-off, engine shutdown, and precautionary landing.

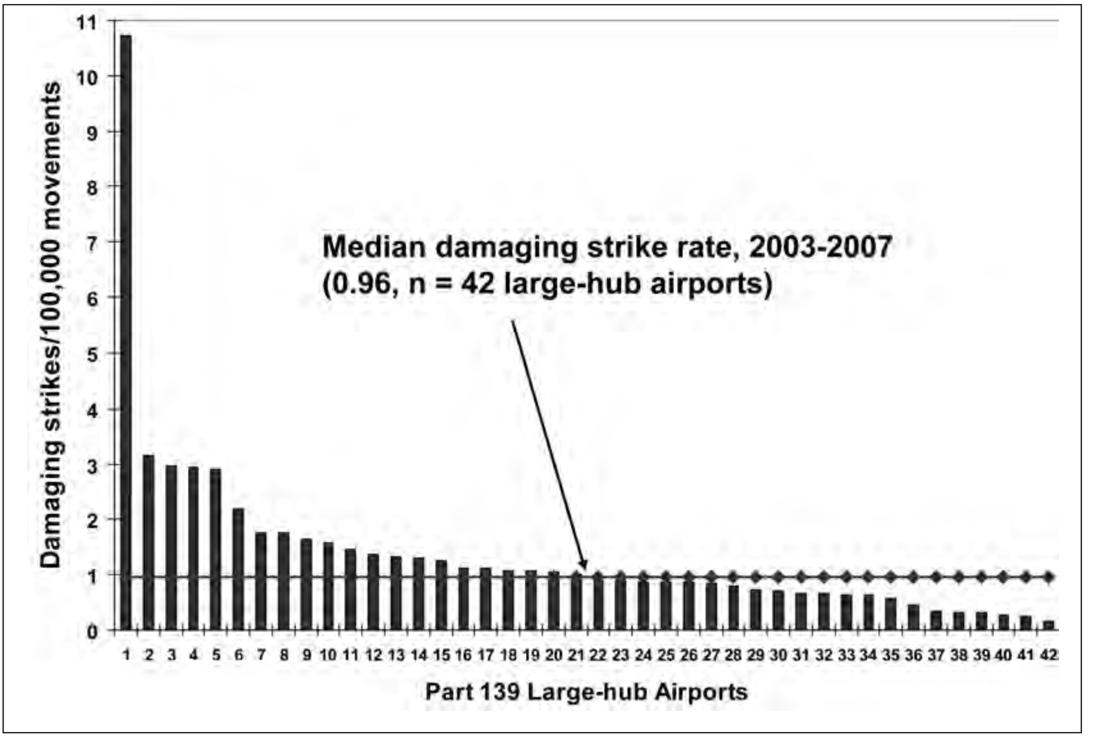

Figure 1. The mean number of damaging strikes per 100,000 aircraft movements per year (n = 5 years, 2003–2007) for each of the 42 large-hub, primary airports certificated for passenger traffic in the USA under 14 CFR, Part 139. The median damaging strike rate for the 42 airports was 0.96.

Providing a benchmark to evaluate WHMPs

Two questions frequently posed by airport operators are: "How effective is my airport's WHMP?" and "How does the strike rate at my airport compare to that of other airports?" Essentially, the airport operator is asking: "How well are we managing the risk posed by wildlife strikes?" Under an SMS, it is important to have identified safety performance indicators and targets (FAA 2007). We propose the following use of the database as 1 means of answering these questions and providing an identified performance target.

Of the 570 passenger-certificated airports in the United States, forty-two are designated as Group 1, or Large Hub Primary Airports (FAA 2006, Dolbeer et al. 2007). Each of these airports handles 1% or more of all United States passenger enplanements. We used strike statistics from these 42 larger airports to develop our proposed benchmark as part of an SMS because these airports are more likely to have sufficient resources devoted to WHMPs and better reporting rates of strikes, especially damaging strikes, than smaller airports (Dolbeer et al. 2008).

We calculated the mean number of damaging strikes per 100,000 aircraft movements per year for each of these 42 Group 1 airports for the most recent (2003–2007) 5-year period. This was done to coincide with the ranking of species causing damage at these airports as described above. With 1 exception, the 5-year mean of damaging strike rates for these airports was distributed normally, ranging from 0.16 to 3.14 (Figure 1). One airport had an unusually high mean rate of 10.72 (>3 times the next highest rate). If we exclude the outlier airport, the mean 5-year damaging strike rate for the 41 remaining airports was 1.14 (standard deviation [SD] = 0.76) with a median (50% of airports above and 50% below) rate of 0.90. Including the outlier, the mean (SD) and median rates were 1.37 (1.66) and 0.96, respectively.

We propose that a benchmark or threshold rate of 0.96 damaging strike per 100,000 aircraft movements per year, which is the median rate for the 42 Large Hub Primary Airports, be established for annually evaluating an airport's WHMP. Ideally, all airports should strive for 0 damaging strikes every year. However, given the abundance, diversity, mobility, and adaptability of wildlife species that are a threat to aviation in the United States, achieving a damage rate of 0 every year may not be practical for most airports. This benchmark provides a realistic risk-reduction goal for airports with rates above the national median. Any airport exceeding this median damaging strike rate of 0.96 in a given year should reevaluate its WHMP. This focuses on those species posing the greatest risk, both nationally and within that specific location, to reduce the rate below this benchmark level. Likewise, airports whose rates are already at or below the national median should continually strive to lower their rates even further. Finally, we propose that this national benchmark be recalculated yearly to adjust for changing numbers of damaging strikes and aircraft movements for the most recent 5-year period. Ultimately, as wildlife risk management becomes more focused and effective at the nation's airports under SMSs, the benchmark rate (0.96 for 2003–2007) should decline.

Improvements needed in database for SMS

We believe that the National Wildlife Strike Database now contains sufficient data for civil aviation in the United States to be used developmentally in SMSs for airports. However, improvements are needed in the quantity and quality of reporting of wildlife strikes to enhance the utility of the database in a SMS. Under the present voluntary reporting system in the United States, an estimated 20% of strikes is reported at passenger-certificated airports, and perhaps only 5% of strikes at general aviation airports is reported (Linnell et al. 1999, Dolbeer et al. 2008, Dolbeer and Wright 2008). It is likely that the number of damaging strikes reported is much higher, especially at the large-hub airports (Yearwood, unpublished data), but this reporting rate is unknown. With the looming advent of formal SMSs at passenger-certificated airports in the United States that require consistent reporting of safety-related incidents without fear of reprisal (FAA 2007), there is a need to reevaluate the current voluntary reporting system. The NTSB (1999) has recommended that strike reporting be mandatory for civil aviation in the United States.

In addition to improved rates of reporting, improved efforts are needed to obtain correct identification of the wildlife species involved in strikes, especially when damage occurs. As noted above, only about 43% of the reported bird strikes was identified to the species group level, and 61% of these incidents was identified to the species level. Appropriate management actions to discourage or remove wildlife from an airport and its immediate surroundings can vary dramatically, depending on the targeted species. Wildlife risk management at airports needs to focus on those species posing the greatest risk. This requires an accurate database of strikes identified to species. Advances in the identification of wildlife remains through morphological examination of fragments (e.g., feathers, hair, bones, and other elements), as well as DNA analyses, provide the framework for achieving a much higher rate of species identification (Dolbeer and Wright 2008). This service is provided by the Smithsonian Institution Feather Lab at no cost to the civil aviation industry in the United States. Finally, improvements are needed in strike report completeness and accuracy of data on height above ground level, phase of flight, time of day, effect on flight, extent of damage, and the part of aircraft damaged.

Conclusions

During the past 13 years, the National Wildlife Strike Database for Civil Aviation in the United States has provided a scientific foundation for the various efforts that are underway to reduce the problem of bird strikes and other wildlife strikes with aircraft. With the impending requirement for airports in the United States to manage safety risks through a formal safety management stystem approach, we propose that the database can be a key element for prioritizing wildlife risks and for providing objective benchmarks of the effectiveness of WHMPs. Improvements in the quantity and quality of reporting will make the database even more useful as part of an SMS to enhance safety at airports nationwide.

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