ANIMAL AMBUSH AT THE AIRPORT: THE NEED TO BROADEN ICAO STANDARDS FOR BIRD STRIKES TO INCLUDE TERRESTRIAL WILDLIFE

Richard A. Dolbeer, Dr. [1], Sandra E. Wright [2], and Paul E. Eschenfelder, Capt. [3]
[1, 2] United States Department of Agriculture, Wildlife Services,
6100 Columbus Avenue, Sandusky, OH 44870, USA
[1] Tel:419-625-0242, Fax: 419-625-8465, Email: richard.a.dolbeer@usda.gov
[2] Tel: 419-625-0242, Fax: 419-625-8465, Email: sandra.e.wright@usda.gov
[3] Aviation Consultant, 16326 Cranwood, Spring, Texas, 77379, USA
Tel: 281-370-3925, Fax: 281-370-3925, Email: eschenfelder@compuserve.com

Abstract

Birds have long been recognized as a serious threat to aviation safety. However, terrestrial wildlife can also have a serious impact on aircraft. In the USA, 1,243 strikes to civil aircraft involving terrestrial vertebrates (mammals and reptiles [excluding bats]) were reported from 1990-2003. Deer (primarily *Odocoileus* spp., 622) and coyotes (*Canis latrans*, 153) were the most commonly reported terrestrial wildlife struck by aircraft. Whereas 13% of bird and bat strikes resulted in aircraft damage and 8% had a negative effect on the flight, 45% of strikes with terrestrial wildlife caused damage and 33% had a negative effect on the flight. Although terrestrial wildlife represented only 2.4% of the reported strikes in the USA from 1990-2003, 15 (56%) of the 27 civil aircraft that were destroyed due to wildlife strikes were caused by these non-bird species. A survey of other countries also revealed a number of significant strike events involving terrestrial wildlife. When data from all countries were combined, large herbivorous mammals represented 51% of 1,379 terrestrial wildlife strikes. However, these species comprised 93% of the 630 terrestrial wildlife strikes that caused damage and 96% of the strikes that caused substantial damage or aircraft destruction. We conclude that 1) terrestrial wildlife is an important component of wildlife hazards to aviation in the USA and elsewhere; 2) the International Civil Aviation Organization (ICAO) should broaden the existing three standards regarding the management of bird hazards at airports to include terrestrial wildlife; 3) ICAO standards should address minimum requirements for airport fencing to exclude large herbivorous mammals and other hazardous wildlife; 4) terrestrial wildlife strikes should be reported to national aviation authorities and ICAO in the same manner as bird and flying mammal (bat) strikes; and 5) the size limit for reporting terrestrial wildlife strikes should be animals greater than 1 kg (the size of a muskrat [*Ondatra zibethica*] or small rabbit [*Sylvilagus floridanus*]).

Keywords: airport, aviation safety, cattle, coyote, deer, fence, ICAO, mammal, reptile, standards, strike reporting, wildlife strike.

1. Introduction

Aircraft collisions with birds (bird strikes) are an increasingly serious economic and safety problem. Allan and Orosz (2001) estimated that bird strikes annually cost commercial air carriers over $1.2 billion worldwide, 1999-2000. At least 192 people died and 140 aircraft were destroyed as a result of bird strikes with civil and military aircraft from 1988-2004 (Richardson and West 2000; Thorpe 2003; Dolbeer, unpublished data).

Bird strikes have increased in the past 30 years because of expanding populations of many species that are hazardous to aviation. Highly successful programs funded by governmental organizations during the past 30 years (e.g., pesticide regulation, expansion of wildlife refuge systems, wetlands restoration), coupled with land-use changes, have resulted in dramatic increases in populations of many wildlife species in North America (Dolbeer 2000) and Europe (Buurma 1996, Allan and Feare 1996). For example, 24 of the 36 largest (>1.8 kg) bird species in North America have shown significant population increases in the past 30 years and only 3 species have shown declines (Dolbeer and Eschenfelder 2003).

Exacerbating this problem is the fact that these large birds exceed the size standards under which large-commercial aircraft components and engines are certified (MacKinnon et al. 2001). Furthermore, many of these species have adapted to living in urban environments, including airports. Finally, birds are less able to detect and avoid the quieter turbofan-powered aircraft in use today compared to older, noisier aircraft (Burger 1983, Kelly et al. 2001).

To initially address this problem internationally, the 188 member States of the International Civil Aviation Organization (ICAO) adopted in 1990, in Annex 14 to the Convention on Civil International Aviation, three Recommended Practices regarding bird hazards to aviation. Annex 14 recommendations were that 1) authorities assess the extent of the hazard posed by birds on or in the vicinity of airports, 2) take necessary action to decrease the number of birds by adopting measures for discouraging their presence, and 3) eliminate or prevent the establishment of any site in the vicinity of the airport which would be an attraction to birds and thereby present a danger to aviation.

In 2002, because of the increasing concern worldwide with bird hazards to aviation as described above, ICAO member States voted to change these Recommended Practices into ICAO Standards, effective 27 November 2003. These Standards establish the broad mandatory requirements which authorities operating international airports must follow to successfully comply and to demonstrate the exercise of “due diligence” in managing bird hazards to aviation (Dolbeer and Eschenfelder 2004). In addition, ICAO has made the reporting of bird strikes a Recommended Practice.

One potential shortcoming of these ICAO Standards and Recommended Practices (SARPs) is that they do not address or even mention strike hazards caused by terrestrial (non-flying) wildlife such as large mammals. The question we pose is: are terrestrial wildlife a sufficient safety risk and economic problem at airports to warrant inclusion in ICAO SARPs that presently address only birds? Our objective is to summarize available data on terrestrial wildlife strikes, particularly from the USA, and based on this analysis, provide recommendations to ICAO regarding SARPs for terrestrial wildlife hazards.

2. Methods

In the USA, a voluntary system for reporting bird and terrestrial wildlife strikes with civil aircraft has been in place since 1990. These data are maintained in a national Federal Aviation Administration (FAA) database that contained 52,493 strikes from 1990-2003 (Cleary et al. 2004). To obtain data from other countries, we requested information on terrestrial wildlife strikes from various sources (Table 1), and we also compiled information from news media reports and various web sites. We then examined the number and characteristics of reported strikes to civil aircraft by type of terrestrial wildlife and by aircraft takeoff mass category.

Terrestrial wildlife species were classified into four broad categories for analysis (Table 2). Large herbivorous mammals (typical body mass >25 kg) were species from the taxonomic orders Artiodactyla (e.g., deer, cattle), Perissodactyla (horses) and Diprotodontia (kangaroos). Medium

carnivorous mammals (typical body mass 5-25 kg) were from the order Carnivora (e.g., coyotes, dogs, foxes). Medium herbivorous/omnivorous mammals (typical body mass 1-10 kg) were from the orders Rodentia (e.g., marmots, porcupine), Lagomorpha (rabbits and hares), Didelphimorphia (opossum), Xenarthra (armadillo), and Monotremata (echidna). Finally, medium to large reptiles (1-100 kg) were from the orders Crocodylia (American alligator), Testudines (turtles), and Squamata (lizards [green iguana]).

Aircraft were placed into four categories based on the maximum certified takeoff mass (ICAO 1989): Category 1 (<2,250 kg) are typically General Aviation (GA), piston-powered aircraft (e.g., Piper PA-28); Category 2 (2,251-5,700 kg) are typically GA or corporate, turboprop- or turbofan-powered aircraft (e.g., Piper PA-31); Category 3 (5,701-27,000 kg) are typically corporate or commercial passenger (commuter) aircraft (e.g., Saab 340); and Category 4 (>27,000 kg) are large commercial passenger and cargo aircraft (e.g., Boeing 737). Hereafter, Category 1 and 2 aircraft will be referred to as GA aircraft and Category 3 and 4 aircraft will be referred to as commercial transport aircraft.

3. Results

3.1 Numbers of terrestrial wildlife strikes to civil aircraft

We located 1,393 records of terrestrial wildlife strikes to civil aircraft from 23 countries (Table 1). Eighty-nine percent of the strike reports came from the USA. Forty-two species groups of terrestrial wildlife involving at least 55 species were identified as struck (Table 2).

3.2 General characteristics of terrestrial wildlife strikes to civil aircraft in USA

From 1990-2003, terrestrial wildlife strikes comprised only 2.4% of the 52,493 total strikes reported in the USA (Table 3). Mammals and reptiles comprised 95% and 5%, respectively, of the 1,243 terrestrial wildlife strikes. Large herbivores, medium carnivores, and medium herbivores/omnivores comprised 55%, 26%, and 18%, respectively, of the 1,164 terrestrial mammal strikes (Table 4).

Although terrestrial wildlife were involved in only 2.4% of the total strikes, these strikes were responsible for a disproportionate ($P < 0.01$) amount of the negative consequences of strikes (Table 3). Terrestrial wildlife strikes represented 7.4% of all strikes with reported damage and 8.6% of strikes with a negative effect on flight. Terrestrial wildlife strikes were responsible for 46.4% of the resulting aircraft down time and 14.6% of the resulting costs that were reported for all strikes. Whereas 13% of bird and bat strikes resulted in aircraft damage and 8% had a negative effect on the flight, 45% of reported strikes with terrestrial wildlife caused damage and 33% had a negative effect on the flight (Table 3).

3.3 Terrestrial wildlife strikes by species and aircraft mass categories, USA and all countries

Large herbivorous mammals represented 52% of the terrestrial wildlife strikes in the USA; however, these species were responsible for 95% (527) of the 555 terrestrial wildlife strikes that caused damage and 98% of the strikes that caused substantial damage or destroyed the aircraft (Table 4). The general pattern of strikes and resulting damage for terrestrial wildlife from other countries was similar to the pattern found in the larger dataset from the USA. Large herbivorous mammals comprised 41% of the strike reports but represented 75% of the strikes with damage and 87% of the strikes with substantial damage or destroyed aircraft (Table 4).

When data from all countries were combined, large herbivorous mammals represented 51% of the terrestrial wildlife strikes. However, these species were responsible for 93% (583) of the 630 terrestrial wildlife strikes that caused damage and 96% of the strikes that caused substantial damage or aircraft destruction (Table 4). For commercial transport aircraft (Category 3 and 4), these large herbivorous mammals represented 88% (162) of the 186 terrestrial wildlife strikes that caused damage and 96% (55) of the 57 strikes causing substantial damage or aircraft destruction (Table 4).

Only 38 strikes with medium carnivorous mammals and 8 with medium herbivorous/omnivorous mammals caused damage; 21 and 3 of these incidents, respectively, occurred with commercial transport aircraft. Two of these 24 damaging strikes with commercial transport aircraft were substantial-damage incidents, both caused by carnivores (fox and hyena, Table 4).

For terrestrial wildlife, about 1.7 times more strikes occurred during the landing phase of flight (63%) compared to takeoff (39%, Table 5). This pattern is similar to that found for birds and bats in USA where 59% of strikes were in the landing phase.

3.4 Terrestrial wildlife strikes resulting in aircraft destruction, USA and all countries

As noted above, terrestrial wildlife strikes comprised only 2.4% of the total reported bird and other wildlife strikes with civil aircraft in the USA, 1990-2003. However, terrestrial wildlife species were responsible for 56% (15) of the 27 aircraft destroyed as a result of bird and other wildlife strikes (Table 6). Thirteen of the 15 aircraft destroyed (87%) were GA aircraft. All 15 destroyed aircraft struck large herbivorous mammals, primarily white-tailed deer. An examination of the 149 strike reports from other countries revealed an additional two GA aircraft that were destroyed after striking large herbivorous mammals (Table 6).

4. Discussion

For countries other than the USA, Canada, UK, and New Zealand, the data on civil aircraft strikes with terrestrial wildlife were very fragmentary. For example, some international airports in Africa are known to have terrestrial wildlife strikes (FAA 2005), but records of these strikes are not maintained in airport databases because there is no ICAO recommendation or standard regarding the reporting of these non-bird events (E. C. Cleary, FAA Personal Communication). Thus, the data presented in this paper should be construed as a sample of the types of terrestrial wildlife strikes that occur and not as a documentation of the extent of the problem worldwide.

The analyses of these fragmentary data indicate that strikes by terrestrial wildlife, especially by large herbivorous mammals, can have a serious impact on aircraft. We documented 630 cases of damage to aircraft in the aftermath of a strike with terrestrial wildlife; 93% of these damaging strikes involved large herbivorous mammals. Of the 630 damaging strikes, 290 caused substantial damage or destruction of the aircraft; 57 of these cases involved commercial transport aircraft. Of the 57 terrestrial wildlife strikes causing substantial damage to or destruction of commercial transport aircraft, 55 (96%) involved large herbivorous mammals.

Only 6%, 1%, and <1% of the 630 damaging strikes were caused by medium carnivorous mammals, medium herbivorous/omnivorous mammals, and reptiles, respectively. Medium carnivorous mammals did cause 10 substantial damage incidents and 2 of these involved commercial transport aircraft.

We conclude that terrestrial wildlife is an important component of wildlife hazards to aviation in the USA and elsewhere. The primary hazard comes from large herbivorous mammals that gain access to runways. The majority of strikes with these species occur during landing at dusk, dawn or night (Cleary et al. 2004). Airport authorities need to recognize the potential threat to aircraft caused by these large mammals. Airport authorities need to erect adequate fencing with animal-proof gates to exclude these animals from aircraft operating areas (FAA 2004) and have a management program in place to quickly remove animals that obtain access to the aircraft operating area (Wright et al. 1998).

Only a few substantial-damage strikes have occurred with carnivorous mammals, medium herbivorous/omnivorous mammals, or reptiles; however, these species can still pose hazards at airports. Besides having the potential to cause damaging strikes, these species can create problems by burrowing, gnawing on wiring, serving as a food attractant for scavenging or predatory birds, and causing pilots to abort or delay landings and takeoffs. For example, a bird strike that severely damaged the #2 engine of an A-320 departing a French airport in 1998 was directly attributed to a dead hedgehog (*Erinaceus europaeus*) on the runway. About 20 gulls were feeding on the 1.5-kg hedgehog carcass when the mishap occurred. The air carrier sued the French government for negligence in operating the airfield and was awarded 3 million Euros (Agence France Presse 2005). The hedgehog had likely been struck by an earlier flight.

We recommend that ICAO broaden their existing three Standards regarding the management of bird and bat hazards at airports to include terrestrial wildlife. This modification can be done by simply adding the words “and other wildlife” after “birds” in the existing Standards.

Because large herbivorous mammals are such a large component of the terrestrial wildlife hazard, we also recommend that ICAO develop minimum standards for airport fencing to exclude these animals from aircraft operating areas. The USA FAA has developed guidelines for fencing to exclude white-tailed deer (*Odocoileus virginianus*) and other large herbivores at airports. These guidelines (FAA 2004), which could be used as a template by ICAO, state:

- Proper fencing is the best way of keeping deer [and other large herbivores] off aircraft movement areas.

- The FAA recommends a 10-12 foot [3.0-3.6 m] chain link fence with 3-strand barbed wire outriggers.

- In some cases an airport may be able to use an 8-foot [2.4 m] chain link fence with 3-strand barbed outriggers, depending upon the amount of deer activity in a local area.

- All fencing must be properly installed and maintained. The fence line right-of-way must be kept free of excess vegetation.

- The fence line should be patrolled at least daily, and any washouts, breaks or other holes in the fence repaired as soon as they are discovered.

- Gates should close with less than 6-inch [15-cm] gaps to prevent entry by deer.

- When installation of chain link fencing is not feasible due to cost or environmental impacts, other types of fencing may be installed. In some cases, electric fencing may offer a suitable alternative.

We note that white-tailed deer are proficient jumpers and that the fence heights recommended for USA airports may be excessive for countries or locations where only livestock or terrestrial wildlife with lesser jumping ability are present. Fence height should exceed the maximum jumping height of the terrestrial wildlife present in the locale.

Finally, we recommend that terrestrial wildlife strikes should be reported to national aviation authorities and to ICAO in the same manner as bird and flying mammal (bat) strikes. Furthermore, the reporting of bird and bat strikes to ICAO should be upgraded from a Recommended Practice to a Standard and include the reporting of terrestrial wildlife strikes. The size limit for reporting terrestrial wildlife strikes should be animals greater than 1 kg (the size of a muskrat [*Ondatra zibethica*] or small rabbit [e.g., *Sylvilagus floridanus*]).

5. Conclusions

1) Terrestrial wildlife is an important component of wildlife hazards to aviation in the USA and elsewhere that should be addressed by national and international Bird Strike Committees and by ICAO;

2) ICAO should broaden the existing three standards regarding the management of bird hazards at airports to include terrestrial wildlife;

3) ICAO standards should address minimum requirements for airport fencing to exclude large herbivorous mammals and other hazardous wildlife;

4) Terrestrial wildlife strikes should be reported to national aviation authorities and ICAO in the same manner as bird and flying mammal (bat) strikes;

5) The reporting of bird and bat strikes to ICAO should be upgraded from a Recommended Practice to a Standard and include the reporting of terrestrial wildlife strikes; and

6) The size limit for reporting terrestrial wildlife strikes should be animals greater than 1 kg (the size of a muskrat or small rabbit).

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Table 1. Number of terrestrial wildlife strikes with civil aircraft by country used in the analyses for this paper. Because of fragmentary reporting, these data should be considered as only a small sample of terrestrial wildlife strikes that have occurred for the years covered.

	No. of reported strikes			
Country	Total	With damage	Source of information[a]	Years covered
Australia	10	6	UK CAA, NZ CAA, Misc.	1998-Jan 2005
Belize	1	1	UK CAA	1976-Sep 2004
Botswana	1	1	Misc.	2003
Canada	43	5	Canada CADORS	Apr 2003-Nov 2004
China	1	1	UK CAA	1976-Sep 2004
Egypt	1	0	UK CAA	1976-Sep 2004
Ethiopia	1	1	UK CAA	1976-Sep 2004
Finland	5	0	Finnish CAA	Jun 2003-Aug 2004
France	1	1	UK CAA	1976-Sep 2004
Germany	1	1	UK CAA	1976-Sep 2004
Greece	2	2	UK CAA	1976-Sep 2004
Guyana	1	1	UK CAA	1976-Sep 2004
India	3	3	UK CAA	1976-Sep 2004
Indonesia	1	1	Misc.	2005
Kenya	3	3	UK CAA, Misc.	1976-Sep 2004
New Zealand	38	31	NZ CAA	1975-Jul 2004
Portugal	1	0	UK CAA	1976-Sep 2004
South Africa	16	1	ACSA - EWT Database	Jun 2000-Aug 2004
Sudan	1	1	UK CAA	1976-Sep 2004
Switzerland	1	1	UK CAA	1976-Sep 2004
UK	17	15	UK CAA	1976-Sep 2004
USA	1,243	561	Cleary et al. 2004	1990-2003
Venezuela	1	1	UK CAA	1976-Sep 2004
Total	**1,393**	**638**		

[a] UK CAA = United Kingdom Civil Aviation Authority (CAA) Mandatory Occurrence Reporting (MOR) system; NZ CAA and Finnish CAA = New Zealand and Finland National CAA Databases; Canada CADORS = Canada Civil Aviation Damage Occurrence Reporting System; Misc. = Newspaper/internet accounts of incidents or information from airport/airline databases.

Table 2. Species of terrestrial wildlife reported as struck by civil aircraft in USA, 1990-2003, and other countries, 1975-2005 (see Table 1).

Terrestrial wildlife category	Species group	Scientific name or taxonomic group	Reported strikes		
			USA	Other countries	Total
Large herbivorous mammals	Deer/ wapiti	*Odocoileus* spp., *Cervus* spp.	622	13	635
	Sheep	*Ovis aries*		24	24
	Cattle	*Bos* spp.	8	12	20
	Pronghorn	*Antilocapra americana*	7		7
	Moose	*Alces alces*	3		3
	Horse	*Equus caballus*	3		3
	Water buffalo	*Bubalus bubalis*		2	2
	Kangaroo/ wallaby	Diprotodontia		3	3
	Grysbok	*Raphicarus melanotis*		2	2
	Caribou	*Rangifer tarandus*	1		1
	Collared peccary	*Pecari angulatus*	1		1
	Swine	*Sus scrofa*	1		1
	Donkey	*Equus asinus*		1	1
	Goat	*Capra* sp.		1	1
	Giraffe	*Giraffa camelopardalis*		1	1
	Zebra	*Equus burchelli*		1	1
Medium carnivorous mammals	Coyote	*Canis latrans*	153	5	158
	Fox	*Vulpes* spp.; *Urocyon* sp.	59	17	76
	Skunk	Mephitidae	41	4	45
	Raccoon	*Procyon lotor*	29	1	30
	Dog	*Canis domesticus*	18	9	27
	House cat	*Felis domesticus*	8	1	9
	Ringtail	*Bassariscus astutus*	1		1
	White-nosed coati	*Nasua narica*	1		1
	River otter	*Lutra canadensis*	1		1
	Badger	*Taxidea taxus*	1		1
	Hyena	*Hyaena hyaena*		1	1
	Jackal	*Canis sp.*		1	1
	Aardwolf	*Proteles cristata*		1	1
Medium herbivorous/ omnivorous mammals	Rabbits/ hares	Lagomorpha	88	36	124
	Marmot	*Marmota monax*	50	3	53
	Opossum	*Didelphis marsupialis*	30	2	32
	Armadillo	*Dasypus novemcinctus*	14		14
	Muskrat	*Ondatra zibethica*	7	1	8
	Rat	*Rattus* spp.	7		7
	Porcupine	*Erethizon dorsatum*	7	1	8
	Prairie dog	*Cynomys* sp.	3		3
	Ground squirrel	*Citellus* spp.		4	4
	Echidna	*Tachyglossus aculeatus*		1	1
Medium and large reptiles	Turtles	Testudines	50		50
	Alligator	*Alligator mississippiensis*	12		12
	Green iguana	*Iguana iguana*	5		5

Table 3. Number of reported strikes, strikes causing damage, strikes having a negative effect-on-flight (EOF), total reported aircraft downtime, and total reported costs for civil aircraft by flying and terrestrial wildlife category, USA, 1990–2003.

	14–year totals for USA				
	Number of reported strikes			Reported economic losses	
Wildlife category	Total	With damage	With negative EOF	Aircraft down time (hrs)[a]	Reported costs ($USA)[a]
Flying wildlife					
Birds	51,154	6,700	4,316	244,510	163,509,104
Mammals (bats)	96	4	2	72	3,076,015
Total	**51,250**	**6,704**	**4,318**	**244,582**	**166,585,119**
Terrestrial wildlife					
Mammals (except bats)	1,176	560	401	211,349	28,448,816
Reptiles	67	1	7	0	0
Total	**1,243**	**561**	**408**	**211,349**	**28,448,816**
All species	**52,493**	**7,625**	**4,726**	**455,931**	**195,033,935**
Terrestrial wildlife as % of all species	2.4%	7.4%[b]	8.6%[b]	46.4%[b]	14.6%[b]

[a] These reported losses grossly underestimate the actual losses. The USA Federal Aviation Administration estimates that only about 25% of wildlife strikes are reported; furthermore, only about 24% of the strikes that were reported and indicated damage provided information on costs or downtime (Cleary et al. 2004).

[b] The proportion of strikes with terrestrial wildlife resulting in damage and a negative effect on flight are greater ($P < 0.01$, $z \geq 23.83$) than the proportion of reported strikes with terrestrial wildlife. The proportion of aircraft down time and costs resulting from strikes with terrestrial wildlife are greater ($P < 0.01$, $z \geq 10.66$) than the proportion of reported strikes with terrestrial wildlife (Statistix8 2003).

Table 4. Number of reported strikes by four categories of terrestrial wildlife and number of these strikes with reported damage (number of damaging strikes resulting in substantial damage or aircraft destruction[a] is in parentheses) by mass category of civil aircraft in USA and other countries.

Category of terrestrial wildlife (see Table 2)	Total reported strikes	Strike reports indicating damage (substantial damage or destroyed[a]) by aircraft mass category (maximum certified takeoff mass [kg])					
		Cat. 1 (<2,250)	Cat. 2 (2,251-5,700)	Cat. 3 (5,701-27,000)	Cat. 4 (>27,000)	Un-known cat.[b]	All aircraft
USA							
L. herbivores	646	243 (132)	121 (66)	110 (37)	34 (8)	19 (10)	527 (253)
M. carnivores	312	10 (5)	1 (1)	10 (0)	2 (0)	0 (0)	23 (6)
M. herbivores	206	2 (0)	0 (0)	1 (0)	0 (0)	1 (0)	4 (0)
Reptiles	67	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)
Other countries[c]							
L. herbivores	60	21 (12)	9 (2)	10 (7)	8 (3)	8 (2)	56 (26)
M. carnivores	40	1 (1)	2 (1)	4 (0)	5 (2)	3 (0)	15 (4)
M. herbivores	48	0 (0)	2 (0)	0 (0)	2 (0)	0 (0)	4 (0)
All countries							
L. herbivores	706	264 (144)	130 (68)	120 (44)	42 (11)	27 (12)	583 (279)
M. carnivores	352	11 (6)	3 (2)	14 (0)	7 (2)	3 (0)	38 (10)
M. herbivores	254	2 (0)	2 (0)	1 (0)	2 (0)	1 (0)	8 (0)
Reptiles	67	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)
Total (all species)[d]	**1,379**	**278 (151)**	**135 (70)**	**135 (44)**	**51 (13)**	**31 (12)**	**630 (290)**

[a] Damage is categorized as Substantial when aircraft incurs damage or structural failure that adversely affects structure strength, performance, or flight characteristics and that would normally require major repair or replacement of affected component (specifically excluded are bent fairings or cowlings; small dents or puncture holes in skin; damage to wing tips, antenna, tires, or brakes; and engine blade damage not requiring blade replacement); Damage is categorized as Destroyed when damage sustained makes it inadvisable to restore the aircraft to an airworthy condition (ICAO 1989).
[b] Carcass found on runway that showed evidence of being struck by aircraft, but specific aircraft that struck the animal was unknown; or aircraft type could not be determined from strike report.
[c] See Table 1.
[d] Totals do not include 14 strikes (8 with damage) in which mammal species was not identified.

Table 5. Reported phase of flight at time of terrestrial wildlife strikes to civil aircraft in USA, 1990-2003, and other countries (see Table 1).

	Number of strikes (% of total) by phase of flight		
Country	Takeoff	Landing	Total
USA	345 (38)	562 (62)	907
Other countries	40 (33)	83 (67)	123
All countries	**385 (37)**	**645 (63)**	**1,030**

[a] For comparison, when en-route strikes are excluded, 41% and 59% of 36,663 bird and bat strikes in USA occurred during the takeoff and landing phases of flight, respectively (Cleary et al. 2004).

Table 6. Comparison of reported strikes by flying (birds and bats) and terrestrial wildlife that resulted in aircraft destruction, classified by mass category of civil aircraft, USA, 1990-2003.

		Strike reports indicating aircraft destroyed[a] by aircraft mass category (maximum certified takeoff mass [kg])				
Category of wildlife	Total reported strikes	Cat. 1 (<2,250)	Cat. 2 (2,251-5,700)	Cat. 3 (5,701-27,000)	Cat. 4 (>27,000)	All aircraft
Birds and bats	51,250	7	4	1	0	12
Terrestrial wildlife	1,243	10	3	2	0	15[b]
Total (all species)	**52,493**	**17**	**7**	**3**	**0**	**27**

[a] Damage is categorized as Aircraft Destroyed when damage sustained makes it inadvisable to restore the aircraft to an airworthy condition (ICAO 1989).
[b] In addition to these 15 aircraft destroyed in USA, two of the 150 strike reports from other countries (Table 1) indicated the aircraft (both Category 1) were destroyed after striking terrestrial wildlife. All 17 destroyed aircraft struck large herbivorous mammals: deer (12), cattle (2); and giraffe, wapiti, and zebra (1 each).