Civil Aircraft Collisions with Birds and Other Wildlife in Ohio, 1990-1999[1]

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Abstract. Collisions between wildlife and aircraft (wildlife strikes) cost civil aviation more than $380 million annually in the US and pose a safety risk to flight personnel and passengers. We investigated wildlife strike trends and characteristics of strikes at airports in Ohio, 1990-1999, by analysis of data from the Federal Aviation Administration (FAA) National Wildlife Strike Database. Of 903 reported wildlife strikes with civil aircraft in Ohio, 98% were bird strikes and 2% involved mammals (primarily white-tailed deer [*Odocoileus virginiana*] and coyote [*Canis latrans*]). Reported wildlife strikes increased ($P < 0.01$) from 39 in 1990 to 165 in 1999. Species groups most commonly involved in bird strikes were gulls (*Larus* spp., 135), raptors (Falconiformes and Strigiformes, 55), and waterfowl (Anseriformes, 49). The estimated cost of damage (mean = $85,816/aircraft; total = $3,175,192) was provided for only 37 (29%) of the 126 strike reports that indicated damage occurred. Assuming all damaging strikes had comparable mean damage and 20% of all strikes were reported, the total cost of these strikes may have been as high as $54 million. Airport managers in Ohio and elsewhere should develop wildlife hazard management programs to minimize the risk of wildlife strikes, especially with deer, geese, gulls and other large species.

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INTRODUCTION

The first known collision between wildlife and an aircraft (wildlife strike) in the world occurred in Ohio in 1908 when Orville Wright struck and killed a bird near Dayton (Thorpe 1996). From 1990-1999, over 28,000 wildlife strikes to civil aircraft were reported to the Federal Aviation Administration (FAA), costing civil aviation in the United States more than $380 million annually (Cleary and others 2000, Robinson 2000). These events also represent an increasing safety risk to flight personnel and passengers. The first wildlife strike resulting in a human fatality occurred in 1912 in California (Thorpe 1996), and over 400 people have been killed in wildlife strikes worldwide to date (Dolbeer and others 2000).

Since 1990, wildlife strikes to civil aircraft in the United States (USA) reported to the FAA have been entered into a National Wildlife Strike Database. This database has been managed by the US Department of Agriculture's (USDA) National Wildlife Research Center (NWRC) field station in Sandusky, OH, since 1995. Analyses of the wildlife strikes reported to this database, 1990-1999, have enabled the FAA to characterize wildlife strikes and the ecological and operational conditions that contribute to their occurrence (Cleary and others 2000).

Wildlife strikes have been reported for all USA states and territories, and involve birds, mammals, and even reptiles. Although mammal (deer, primarily *Odocoileus virginiana*) strikes inflict the greatest amount of damage per strike, collisions with birds (bird strikes) are by far the most common and inflict the greatest cumulative amount of damage (Cleary and others 2000; Dolbeer and others 2000). Strikes occur year-round, although they are more prevalent in the US in late summer and early fall (Cleary and others 2000). Wildlife strikes involve both propeller- and turbine-driven aircraft of any size, although damage may be more severe to turbine-driven aircraft. Although most strikes (90%) occur in the airport environment during landing or takeoff (below 1000 m), strikes have been reported from 0.0 to 9,000 m altitude (Cleary and others 2000).

We analyzed the FAA National Wildlife Strike Database to determine which species in Ohio were most frequently involved in wildlife strikes. We also compared seasonal and annual wildlife strike trends in Ohio to determine whether or not the wildlife strike problem has increased, 1990-1999, and to determine if seasonal differences in wildlife activity and abundance influence the seasonal timing of the problem. Finally, we used damage estimates from strike reports to characterize the economic impact of wildlife strikes to aviation in Ohio.

MATERIALS AND METHODS

We searched the FAA National Wildlife Strike Database and extracted all records of wildlife strikes that occurred in Ohio, 1990-1999, to determine which wildlife species were most commonly involved in these strikes. Using an online FAA data source (FAA Air Traffic Activity Data System, www.apo.data.faa.gov), we also examined changes in commercial aircraft activity and traffic volume. Safety and financial impacts of strikes in Ohio were estimated using cost estimates from strike reports and published estimates of strike reporting rates and reporting biases (Linnell and others 1999; Barras and Dolbeer 2000; Cleary and others 2000). Because wildlife strike reporting is voluntary and varies among airports, we did not report strike frequency for individual airports. Identification of individual airports with a high reported strike frequency might discourage future reporting, prevent accurate data collection, and thereby hinder effective management of the problem.

We calculated descriptive statistics and used simple correlations and linear regression (using SAS statistical software, Cody and Smith 1991) to help characterize the

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magnitude and temporal trends in wildlife strikes and air travel in Ohio compared to national statistics. We also used linear regression to determine if aircraft movement volume was a significant predictor of wildlife strike frequency. A paired *t*-test was used to compare monthly wildlife strike rates in Ohio to nationwide strike rates. Differences were deemed significant at alpha = 0.05.

RESULTS

From 1990-1999, 903 reported wildlife strikes occurred in Ohio. Ohio ranked 7th among states in total strikes nationally, although it accounted for only 3.2% of all reported wildlife strikes in the USA (28,150 total; Cleary and others 2000). The number of wildlife strikes reported annually in Ohio increased from 39 in 1990 to 165 in 1999 (t = 7.89, df = 1, 9, P <0.01). This increase paralleled the increase in strikes for the total USA, 1990-1999 (t = 6.08, df = 1, 9, P <0.01; Cleary and others 2000). The number of commercial aviation movements (takeoffs + landings) in Ohio increased 12.8% (t = 3.54, df = 1, 9, P <0.01) from 1990-1999, simultaneous with an increase of 15.1% nationwide (t = 10.54, df = 1, 9, P <0.01). The number of aircraft movements was a significant predictor of bird strike frequency nationwide (R^2 =0.73; t = 4.62; df = 1, 9; P < 0.01) and in Ohio (R^2 = 0.57; t = 3.25; df = 1, 9; P = 0.01). We used standardized strike rates (strikes per 100,000 aircraft movements) to compare strike frequency and timing between Ohio and the entire USA. Using this index, we found that annual strike rate in Ohio has been above the national average since 1992 (Fig. 1).

As with strike reports nationwide (Cleary and others 2000), strikes in Ohio were most common in late summer, with most strikes occurring in September (Fig. 2). The monthly strike rate (strikes/100,000 movements) was higher in Ohio than the national average (2.71< t <3.61, df = 9, P <0.02) from July-September, lower in February (t = -5.20, df = 9, P <0.001), and did not differ during the remainder of the year (Table 1).

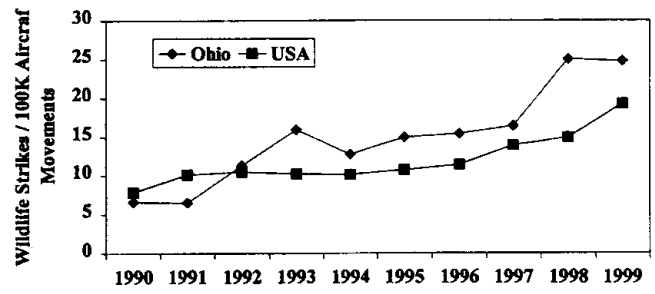

FIGURE 1. Wildlife strike rates (strikes/100,000 aircraft movements) for civil aviation in Ohio and the entire United States, 1990-1999.

Wildlife species involved was reported for only 48.4% (437 of 903) of the Ohio bird strike records (Table 2).

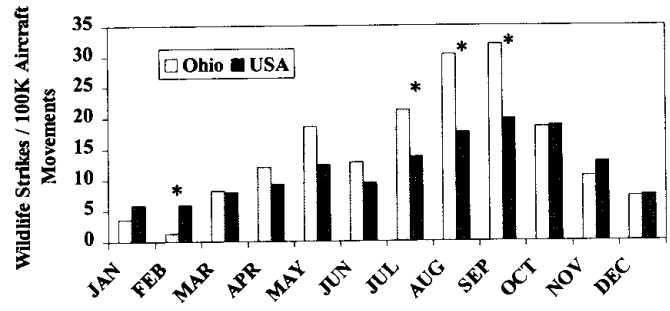

FIGURE 2. Wilflife strike rates (strikes/100,000 aircraft movements) for civil aviation in Ohio and the entire United States by month, 1990-1999. Asterisk denotes statistical significance (P <0.02).

TABLE 1

Major categories of wildlife involved in collisions with civil aircraft in Ohio by month, 1990-1999, as reported to the Federal Aviation Administration.

Month	Species groups								Total
	Blackbirds	Doves	Gulls	Raptors	Waterfowl	Deer	Other	Unknown	
Jan	0	3	7	2	2	0	0	3	17
Feb	0	1	0	0	0	0	1	4	6
Mar	0	3	6	2	3	1	3	23	41
Apr	3	0	22	2	7	0	1	25	60
May	1	2	19	0	4	0	6	64	96
Jun	7	3	7	4	4	0	9	29	63
Jul	11	3	19	14	4	1	15	43	110
Aug	6	8	13	16	13	0	27	77	160
Sep	7	11	16	7	3	2	26	90	162
Oct	5	3	9	2	4	3	8	66	100
Nov	0	1	10	1	3	4	6	26	51
Dec	2	3	7	5	2	1	1	16	37
Total	42	41	135	55	49	12	103	466	903

TABLE 2

Major categories of wildlife involved in collisions with civil aircraft in Ohio, 1990-1999, as reported to the Federal Aviation Administration.

Year	Species groups								Total
	Blackbirds	Doves	Gulls	Raptors	Waterfowl	Deer	Other Species	Unknown Species	
1990	1	1	12	0	2	2	6	15	39
1991	4	0	2	4	1	0	8	17	36
1992	5	0	14	1	3	3	5	30	61
1993	4	2	20	2	6	2	7	41	84
1994	6	2	14	3	3	0	11	36	75
1995	1	5	8	3	4	2	3	57	83
1996	7	5	15	2	8	0	6	51	94
1997	6	3	17	12	8	2	6	51	105
1998	3	16	23	19	5	0	29	66	161
1999	5	7	10	9	9	1	22	102	165
Total	42	41	135	55	49	12	103	466	903

For many records, the species was recorded as a broad taxonomic category (e.g., duck, blackbird) rather than an individual species. Of the known birds struck, gulls were the most frequently struck (135) species group during 1990-1999, followed by raptors (55) and waterfowl (49). Among gulls, 81.5% (110) were recorded simply as gull, and not identified to species. Of those identified to species, 15 were ring-billed gulls (*Larus delawarensis*) and 10 were herring gulls (*Larus argentatus*, Appendix 1). Among waterfowl, 46.9% (23) were not identified to species. Geese were struck 35 times (21 Canada geese, *Branta canadensis*), and ducks were involved in 12 strikes (4 mallards, *Anas platyrhynchos*). Among raptors, 70.9% (39) were identified to species. Twenty-seven of these strikes involved American kestrel (*Falco sparverius*). Others identified were red-tailed hawk (*Buteo jamaicensis*, 6), snowy owl (*Nyctea scandiaca*, 2), turkey vulture (*Cathartes aura*, 2), and red-shouldered hawk (*Buteo lineatus*, 1). Only 2% (18 of 903) of reported strikes involved mammals (Table 2). Among mammals, 12 involved white-tailed deer (*Odocoileus virginiana*), 5 involved coyotes (*Canis latrans*), and 1 involved bats (Chiroptera). A complete list of species struck is presented in Appendix 1.

Most strikes were reported in counties with large cities (Table 3) and large airports with high traffic volume. Most (86%) gull strikes and waterfowl strikes (62%) occurred in counties that border Lake Erie, whereas strikes that involved other species groups (e.g., blackbirds) were more uniformly distributed throughout the state.

There were no reported civil aviation injuries or deaths as a result of wildlife strikes in Ohio, 1990-1999, although 1 aircraft was destroyed and 24 suffered substantial damage. Nationwide, 7 aircraft were destroyed, and 91 injuries and 6 deaths were attributed to wildlife strikes during the same time period (Cleary and others 2000). In Ohio, the estimated cost of damage (mean = $85,816/aircraft; total reported = $3,175,192) was provided for only 37 (29.4%) of the 126 strike reports that indicated damage had occurred. Most (81%) of the damage estimates reported were below the mean, and 22% of reported estimates were <$1,000. Using a mean of $85,816/aircraft, we estimated that up to $10,812,816 in damage might have occurred. Given that only about 20% of bird strikes are reported (Cleary and others 2000), Ohio wildlife strikes may have cost the civil aviation industry up to $54 million, 1990-1999.

DISCUSSION

The wildlife strike problem in Ohio ranks among the worst (7th nationwide) in the United States, with a strike rate higher than the national average since 1992. Several factors may contribute to this problem, including increasing populations of some wildlife species (Ohio Division of Wildlife 1999) and the relatively high volume of air traffic (nearly 6 million aircraft movements). Although the increase in reported wildlife strikes was positively related to increases in air traffic, it was not solely a factor of these increases, as evidenced by increases in adjusted strike rate (strikes/100,000 movements). The increase in abundance in Ohio and the entire USA, of those species commonly involved in wildlife strikes (e.g., gulls [Tyson and others 1999], some waterfowl [US Fish and Wildlife Service 2000], and white-tailed deer [Wright and others 1998]), and the urbanization (increased use of urban habitats such as airport grasslands and water developments) of these species also may have contributed to the problem (Dolbeer 2000). Dolbeer (2000) suggested that reporting rates might have increased as public awareness of the wildlife strike issue has risen. We agree that reporting rates may have increased in Ohio, 1990-1999. However, knowledge of the number of unreported strikes that occurred during the same time period is required to determine if changes in reporting rates alone resulted in

TABLE 3

Major categories of wildlife involved in collisions with civil aircraft in Ohio by county, 1990-1999, as reported to the Federal Aviation Administration.

County	Blackbirds	Doves	Gulls	Deer	Raptors	Waterfowl	Other	Unknown	Total
Butler	1	0	0	0	1	3	1	1	7
Clinton	0	0	1	0	0	1	0	132	134
Coshocton	0	0	0	0	1	0	0	0	1
Cuyahoga	11	29	112	0	36	24	67	81	360
Delaware	0	0	0	0	0	0	0	1	1
Erie	0	0	0	1	0	1	0	0	2
Franklin	11	5	7	1	7	6	12	88	137
Gallia	0	0	0	0	0	1	0	1	2
Greene	1	0	0	0	0	0	0	0	1
Hamilton	6	0	0	1	1	1	4	13	26
Hancock	0	0	1	0	4	0	0	1	6
Hardin	0	0	0	0	0	1	0	0	1
Huron	0	0	0	1	0	0	0	0	1
Jefferson	0	0	0	1	0	0	0	0	1
Lake	0	0	1	2	0	1	1	0	5
Lorain	0	0	2	0	0	1	0	0	3
Lucas	1	2	1	0	4	3	3	16	30
Montgomery	7	4	2	1	1	1	3	46	65
Ottawa	0	0	0	0	0	0	0	1	1
Pike	0	0	0	1	0	0	0	0	1
Portage	0	0	0	1	0	0	0	0	1
Putnam	0	0	0	0	0	0	0	1	1
Richland	0	1	0	1	0	0	4	4	10
Summit	3	0	5	1	0	1	5	11	26
Trumbull	1	0	1	0	0	1	3	4	10
Williams	0	0	0	0	0	0	0	1	1
Wood	0	0	1	0	0	0	0	1	2
En route	0	0	1	0	0	3	0	63	67
Total	42	41	135	12	55	49	103	466	903

the observed increases in reported wildlife strikes. Although these data are non-existent for Ohio, Barras and Dolbeer (2000) found that unreported strikes were positively correlated with reported strikes over 20 years at an airport in New York.

The relative impact of individual species to aviation in Ohio is difficult to characterize because the species involved in strikes was unknown for over half of the reported incidents and all of the unreported incidents. In fact, if only 20% of strikes were reported (Cleary and others 2000), then the actual percentage of strikes for which species was known is 10%. The FAA's system of voluntary wildlife strike reporting undermines efforts to understand the factors contributing to wildlife strikes in several ways. First, data from the relatively small sample of reported strikes may not give a representative sampling of the species involved in wildlife strikes in Ohio. For example, reported bird strikes at John F. Kennedy International Airport in New York underestimated the number of species involved in strikes annually by at least one third (Barras and Dolbeer 2000). Second, reporting rates and frequency of species identification vary greatly among airports. One airport in this study reported 134 wildlife strikes with only 2 of the strike reports indicating species involved. Without species information, habitat or behavioral characteristics contributing to the problem at an individual site cannot be identified or altered to facilitate management of the problem. Finally, data from individual airports that accurately and consistently report wildlife strikes may dominate the database. If these facilities face unique strike problems, the frequency of these unique situations may be overrepresented in the database. Also, diligent reporting at an individual airport may cause the strike problem to appear greater at that facility than at others with low reporting rates and a strike problem of similar severity. Thus, conscientious reporting under the voluntary system may attract unwarranted negative publicity to the facilities that are trying to accurately and responsibly address an issue of human safety.

The species groups most frequently reported struck in Ohio (gulls, raptors, and waterfowl) are representative of those commonly associated with wildlife strikes nationwide (Cleary and others 2000). Gulls were the most frequently struck species in Ohio and the entire USA (Dolbeer and others 2000). As expected, we found that most gull strikes occurred in the counties bordering Lake Erie, where large populations of ring-billed and herring gulls breed, and even greater numbers concentrate in early winter (Tyson and others 1999). The peaks in gull strike frequency that we observed in late spring and late summer did not correspond with previously noted early-winter peaks in gull abundance (Tyson and others 1999; Peterjohn and Zimmerman 1989) along the lakeshore. Instead, one peak in gull strike frequency corresponded with dates of nesting activities of ring-billed and herring gulls in April and May, and a second peak following fledging of young gulls in July and August (Peterjohn and Rice 1991; Peterjohn and Zimmerman 1989).

The dramatic increase in Canada goose populations in Ohio (mean annual increase of 9.7% from 1980-1999; Sauer and others 2000) poses a special hazard to aviation. These geese are increasingly becoming a year-round hazard to aviation due to their large size, flocking behavior, and ability to thrive in urban habitats (Cleary and others 2000; Dolbeer and others 2000). Based on the damage incurred and effect on flight following a strike, Dolbeer and others (2000) ranked Canada geese as the third most hazardous type of wildlife (behind deer and vultures). Continent-wide waterfowl populations have increased dramatically since 1990 (US Fish and Wildlife Service 2000) because of wildlife management initiatives and improved habitat conditions in breeding areas. Increases of species frequently struck, along with increases in aircraft movements suggest that strikes to waterfowl in Ohio and the rest of the nation may continue to increase.

Raptors ranked second among known species groups involved in bird strikes in Ohio and fourth nationwide (Cleary and others 2000). Although this group of birds ranks among the most hazardous nationwide (Dolbeer and others 2000), most of the raptors struck in Ohio were American kestrels, which are relatively small birds (111-120g; Dunning 1993) that hunt for insects and small mammals in grassland habitats. Although these birds have been involved in costly accidents (Cleary and others 2000), kestrels present a much lower hazard than the large, soaring birds of prey such as hawks (buteos) and vultures (Dolbeer 2000).

Deer-automobile collisions have increased recently in Ohio, partly due to increasing populations of white-tailed deer (Iverson and Iverson 1999). We found that aircraft-deer collisions are infrequent in Ohio (12 reported from 1990-1999), but damage to aircraft occurs in up to 87% of deer strikes (Wright and others 1998; Dolbeer and others 2000). Conover and others (1995) reported that over 700,000 deer-automobile collisions cost 211 human lives annually in the USA. However, the same effect could result from a single, catastrophic deer strike to a large, commercial aircraft. Therefore, deer are considered the most hazardous species from a wildlife-strike perspective (Dolbeer and others 2000), and total exclusion of deer from airport environments is recommended (Wright and others 1998).

Although we have focused on the human safety aspects of wildlife strikes, these events also impose economic costs on Ohio's aviation industry. Using mean cost per accident for those estimates provided, and assuming that all damaging strikes had comparable mean damage costs, the total cost of these strikes from 1990-1999 may have been as high as $54 million. Damaging strikes are more likely to be noticed by pilots and maintenance crews, and may be reported more frequently than non-damaging strikes. However, we have no data to support this hypothesis. Instead, we contend that the economic cost estimate is conservative, given that the costs of flight delays and aircraft down time were not included in damage estimates. Furthermore, strike reports were often filed before final damage estimates were complete (Cleary and others 2000).

In conclusion, wildlife collisions with civil aircraft are increasing in Ohio due to increases in some wildlife populations and increasing numbers of aircraft movements. Because of the costs of these strikes and the potential for loss of human lives, airport managers in Ohio and elsewhere should develop wildlife hazard management programs to minimize the risk of wildlife strikes, especially with deer, geese, gulls, raptors and other large species (Cleary and Dolbeer 1999).

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APPENDIX 1

List of known wildlife species involved in collisions with civil aircraft in Ohio, 1990-1999, as reported to the Federal Aviation Administration.

Common name	Scientific name	Number of reported strikes
Birds		
American coot	*Fulica americana*	1
American crow	*Corvus brachyrhynchos*	1
American kestrel	*Falco sparverius*	27
American robin	*Turdus migratorius*	2
Barn swallow	*Hirundo rustica*	8
Canada goose	*Branta canadensis*	21
Chimney swift	*Chaetura pelagica*	2
Common grackle	*Quiscalus quiscula*	2
Common nighthawk	*Chordeiles minor*	1
Eastern Kingbird	*Tyrannus tyrannus*	1
Eastern meadowlark	*Sturnella magna*	3
European starling	*Sturnus vulgaris*	19
Great blue heron	*Ardea herodias*	1
Herring gull	*Larus argentatus*	10
Killdeer	*Charadrius vociferus*	19
Mallard	*Anas platyrhynchos*	4
Northern mockingbird	*Mimus polyglottos*	1
Mourning dove	*Zenaida macroroura*	28
Peregrine falcon	*Falco peregrinus*	1
Red-shouldered hawk	*Buteo lineatus*	1
Red-tailed hawk	*Buteo jamaicensis*	6
Ring-billed gull	*Larus delawarensis*	15
Rock dove	*Columba livia*	6
Savannah sparrow	*Passerculus sandwichensis*	10
Snowy owl	*Nyctea scandiaca*	2
Tree swallow	*Tachycineta bicolor*	1
Tundra swan	*Cygnus columbianus*	1
Turkey vulture	*Cathartes aura*	2
Upland sandpiper	*Batramia longicauda*	1
White-throated sparrow	*Zonotrichia albicollis*	1
Other birds*		220
Unidentified birds		466
Total birds		885
Mammals		
Coyote	*Canis latrans*	5
White-tailed deer	*Odocoileus virginiana*	12
Unidentified mammals		1
Total mammals		18
Grand total		903

*Other birds refers to birds identified to a general taxon but not to species (e.g., blackbirds - 17, crows - 9, doves - 7, gulls - 110, hawks - 10, owls - 3, sandpipers - 2, sparrows - 30, swallows - 5, vultures - 3, waterfowl - 23, wrens - 1).