J. Raptor Res. 40(1):76–80

Collisions of Red-tailed Hawks (*Buteo jamaicensis*), Turkey Vultures (*Cathartes aura*), and Black Vultures (*Coragyps atratus*) with Aircraft: Implications for Bird Strike Reduction

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Key Words: *Black Vulture;* Coragyps atratus; *Red-tailed Hawk;* Buteo jamaicensis; *Turkey Vulture;* Cathartes aura; *airport; bird strike.*

From 1990 through 2003, 52 493 wildlife collisions with aircraft were reported to the U.S. Federal Aviation Administration (FAA); 97% of these incidents involved birds. The approximate cost to the civil aviation industry in the U.S.A. due to collisions of birds with aircraft (hereafter referred to as bird strikes) was $163.51 million in direct monetary losses and associated costs for the 14-yr period (Cleary et al. 2004). Strikes with raptors (Falconidae and Accipitridae; including vultures, Cathartidae) accounted for approximately 28% of reported aircraft down time resulting from known-species bird strikes (known species = 182 942 hr; total for all birds = 244 510 hr) and represented a $12.9 million loss to U.S. civil aviation (Cleary et al. 2004). However, these figures are misleading relative to actual costs; of 7265 reports of wildlife strikes involving damage to the aircraft, only 1759 reports provided cost estimates (Cleary et al. 2004).

Because of their size (at least six North American-nesting raptor species have a mean body mass >1.8 kg) and flight behavior (e.g., flocking or soaring), strikes with raptors pose a substantial threat to air safety relative to FAA airworthiness standards for airframes, windshields, and engines (Seamans et al. 1995, Dolbeer and Eschenfelder 2003). Recent work by Dolbeer (2006) shows that for bird strikes (1990–June 2003) ≤152.4 m above ground level (AGL), passerines, gulls/terns (Laridae), doves (Columbidae), and raptors (including vultures) were the species groups most frequently struck. For strikes >152.4 m AGL, waterfowl (Anatidae), gulls/terns, passerines, and vultures were the species groups most frequently struck. Notably, for strikes resulting in substantial damage to the aircraft (Dolbeer et al. 2000, Cleary et al. 2004), 66% occurred at ≤152.4 m AGL (Dolbeer 2006).

More specifically, strikes involving Red-tailed Hawks (*Buteo jamaicensis*) comprised 24.5% of reported raptor strikes to civil aircraft from 1990–2003 (*N* strike reports involving raptors = 1945); strikes of Black Vultures (*Coragyps atratus*), Turkey Vultures (*Cathartes aura*), and unidentified vultures represented an additional 19.2% of reported raptor strikes (Cleary et al. 2004). Together, strikes of Red-tailed Hawks and vultures accounted for 93.4% of civilian aircraft down time associated with raptor strikes and represented a loss of approximately $7 million to U.S. civil aviation over the 14-yr period (Cleary et al. 2004). Similarly, in an analysis of U.S. Air Force (USAF) strike data, Kelly (1999) reported that Red-tailed Hawks and Turkey Vultures accounted for the majority (64%) of damaging raptor strikes by USAF aircraft (see also Zakrajsek and Bissonette 2005).

Because of the prominence of Red-tailed Hawks and vultures in military (Kelly 1999, Zakrajsek and Bissonette 2005) and U.S. civil aviation (Cleary et al. 2004) bird-strike databases, we questioned whether strike statistics might yield information critical to wildlife and resource management on the air operations area (AOA; areas designated for takeoff, landing, and surface maneuvers of aircraft) of an airport (14 CFR Part 139, Subpart D) and within FAA siting criteria for certificated airports (i.e., within 1.5 km of a runway for airports servicing piston-powered aircraft only and within 3.0 km of a runway for airports servicing turbine-powered aircraft; U.S. Federal Aviation Administration 2004). In general, an aircraft descending on a 3° glideslope would be ≤152.4 m AGL at 3.0 km from the runway (Flight Safety Foundation 2000).

Importantly, we note that a strike report might involve more than one bird, only about 20% of wildlife strikes are reported, not all bird strikes are identified to species, the altitude of a strike is not always reported as m AGL (i.e., the report might be relative to elevation of the airport), and bird strike-related damage and down-time costs are underreported (Cleary et al. 2004). Thus, species-specific losses and the associated costs to aviation due to those bird strikes are highly underrepresented by strike data within

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the FAA National Wildlife Strike Database. In addition, strike reports do not include data by which analyses can be standardized relative to aircraft type and the associated movements (i.e., takeoffs and landings) or hours in use prior to a strike. Our objective was to quantify U.S. civil aviation strike reports within the FAA National Wildlife Strike Database for Red-tailed Hawks, Black Vultures, Turkey Vultures, and unknown vultures relative to number of birds struck, season, and altitude.

METHODS

We used data from the FAA National Wildlife Strike Database for civil and joint-use airports (Cleary et al. 2004). The FAA uses a standard form (5200–7) for voluntary reporting of wildlife strikes to civil aircraft in the U.S.A.; strike reports may also be made directly to the FAA National Wildlife Strike Database via the internet (Cleary et al. 2004). At the time of our analyses, the database contained 55 329 strike reports from U.S. civil aviation (January 1990–19 July 2004). We included only reports where at least one bird was struck (i.e., we ignored reports of evasive action only) and assumed the minimum number of individuals struck when a range (e.g., 2–10 individuals) was reported in a single incident. In addition, we included strike reports for unknown vultures only when the report originated from a U.S. state or Canada, thus indicating that the bird was either a Turkey Vulture or Black Vulture.

The phase within a species' annual cycle (e.g., migration, nesting, incubation, nestling, or fledging) has been suggested as a possible factor contributing to the probability of a bird strike (Kelly 1999); however, assigning strikes to a specific phase is speculative at best because (1) nonbreeding birds are involved in strikes during the breeding season, and their behavior and habitat use might differ markedly from that of breeding adults, (2) not all individuals migrate (e.g., some Red-tailed Hawks are residents; Schafer et al. 2002), and (3) there is variation and overlap of the breeding chronology between years and with latitude (Preston and Beane 1993, Kirk and Mossman 1998, Buckley 1999, Kelly 1999). Therefore, we quantified the number of strikes and altitude of each strike by season (i.e., spring: 22 March–21 June; summer: 22 June–21 September; autumn: 22 September–21 December; winter: 22 December–21 March) within species group and inferred as to the probable phase within the annual cycle. We conducted 1×4 contingency table analyses using the chi-square test for goodness of fit (Conover 1980) to compare the number of strikes among seasons within each species group; we made our statistical comparisons at $\alpha = 0.025$ (i.e., the 0.975 quantile of the chi-square random variable). To assess the degree to which hawk and vulture strikes might be mitigated via wildlife management methods on the AOA and within FAA siting criteria, we quantified the number of strikes by altitude of the strike.

RESULTS

Red-tailed Hawks. For Red-tailed Hawks, we found 508 strike reports comprising 515 individuals struck by aircraft across 40 states and the District of Columbia; 7 strikes involved at least 2 birds. Over 49% of the strikes occurred in Illinois (19.5%), Oregon (14.2%), California

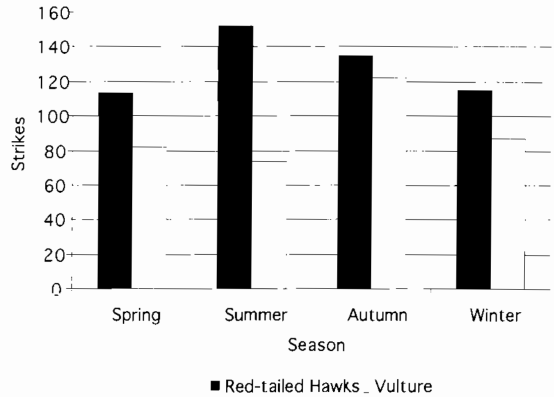

Figure 1. Strike reports by the U.S. civil aviation industry (January 1990–19 July 2004) involving Red-tailed Hawks, Turkey Vultures, Black Vultures, and unknown vultures were taken from the FAA National Wildlife Strike Database and depicted by season.

(10.4%), and Pennsylvania (5.3%). Although more strikes occurred during summer, we found no statistical difference in the number of Red-tailed Hawks struck by season ($\bar{x}$ = 128.8 strikes, SD = 18.4 strikes; χ^2 = 7.9, 0.975 quantile = 9.348, P = 0.048, df = 3; Fig. 1). Further, when time of day was reported, 95% of strikes occurred during daylight hours (dawn = 18 strikes; day = 247 strikes; dusk = 15 strikes; night = 14 strikes; unknown = 214 strikes). In addition, 82% of strikes occurred at or below 30.5 m AGL, whereas nearly 63% occurred while the aircraft was operating on the ground (Table 1).

Vultures. For vultures, we found 334 reports comprising 365 individuals struck by aircraft and representing the loss of 193 Turkey Vultures, 24 Black Vultures, and 148 unidentified vultures; 31 strikes involved at least 2 birds. Vultures were struck in 29 states, the District of Columbia, Mexico, Brazil, and Guatemala; 54.0% of the strikes occurred in Florida, followed by unknown points (i.e., en route; 9.0%), California (8.4%), and Texas (6.6%). When time of day was reported, 99% of strikes occurred during daylight hours (dawn = 2 strikes; day = 259 strikes; dusk = 3 strikes; night = 3 strikes; unknown = 67 strikes). Also, strikes were more frequent during autumn ($\bar{x}$ = 91.2 strikes, SD = 21.2 strikes; χ^2 = 14.8, 0.975 quantile = 9.348, P = 0.002, df = 3; Fig. 1). In addition, approximately 29% of strikes occurred at or below 30.5 m AGL, whereas 17% occurred while the aircraft was operating on the ground (Table 1).

DISCUSSION

Most (63%) strikes involving Red-tailed Hawks occurred on the ground (Table 1). Further, we found that strikes were, on an absolute scale, more frequent during summer months, corresponding to a period when newly fledged birds were common in the population (Preston and Beane 1993, Dolbeer 2006). Surprisingly, even during summer,

Table 1. Bird strike reports by the U.S. civil aviation industry (January 1990–19 June 2004) involving Red-tailed Hawks, Turkey Vultures, Black Vultures, and unknown vultures were taken from the FAA National Wildlife Strike Database and categorized by altitude (i.e., m above ground level; AGL).

	Red-tailed Hawks			Vultures		
Altitude (AGL)[a]	No. Birds Struck	Percent at Known Altitude[b]	Percent of Total	No. Birds Struck	Percent at Known Altitude[b]	Percent of Total
0	185	62.9	35.9	55	17.0	15.1
0.3–30.5	57	19.4	11.1	38	11.8	10.4
30.8–152.4	28	9.5	5.4	64	19.8	17.5
152.7–304.8	9	3.1	1.7	63	19.5	17.3
305.1–609.6	9	3.1	1.7	72	22.3	19.7
609.9–914.4	2	0.7	0.4	20	6.2	5.5
914.7–1219.2	1	0.3	0.2	8	2.5	2.2
1219.5–1524.0	1	0.3	0.2	2	0.6	0.5
>1524.0	2	0.7	0.4	1	0.3	0.3
Unreported	221		42.9	42		11.5
Total	515	100	100	365	100	100

[a] International civil aviation standards require altitude to be reported in units of "feet," units from which the AGL intervals were converted.

[b] Percent of the total number of strikes less strikes at unreported altitudes.

where thermal conditions would be conducive to soaring, 84% of strikes occurred below 30.5 m AGL. These results are indicative that management of food availability and abundance and vegetation structure on airports could reduce airfield use by resident hawks, as well as birds inexperienced in both hunting and avoiding air traffic. However, we note that our findings relative to season of strike contrast with work by Kelly (1999), who showed that strikes involving Red-tailed Hawks and USAF aircraft were more likely during spring, corresponding to migration and the incubation phase of the breeding period. A likely reason for this difference in seasonality of strikes is that the FAA Wildlife Strike Database comprises records of strikes to civil aircraft and flight movements that differ markedly in speed, location, and altitude from those of military aircraft.

For strikes involving vultures, most (68%) occurred at or below 305.0 m AGL, altitudes similar to mean soaring altitudes for Black and Turkey vultures (169 m, SD = 115 and 163 m, SD = 92, respectively) over forested habitat (DeVault et al. 2005). Also, we showed that 88.9% of vulture strikes, when the species was identified, involved Turkey Vultures, a soaring species (Kirk and Mossman 1998). However, we note that a surprising number of vulture strikes (17%) occurred during ground operations.

Our findings relative to the seasonality of vulture strikes (peaking in autumn) contrast to those reported for USAF aircraft (Kelly 1999), in which strikes with Turkey Vultures were more frequent during summer, when fledged birds had entered the population and thermals were prevalent. We suggest that our findings regarding seasonality of strikes relate to autumn migration and contrast to Kelly's (1999) findings, again, because aircraft and air operations differ substantially between civil and military aviation.

Management programs to reduce bird strikes have traditionally concentrated efforts on vegetation structure and other resources (e.g., removing harborage) at airports, but also integrated non-lethal harassment and lethal control on the AOA (Cleary and Dolbeer 2005). Dolbeer's (2006) findings further emphasize the need to focus wildlife-management efforts on the AOA to reduce bird strikes. However, with regard to raptors, particularly large (>1.8 kg) soaring species, the relationship between management on and near the AOA and the potential for a reduction in strikes has been speculative. Our analysis of strike records for Red-tailed Hawks and vultures, species groups prominent in raptor strike statistics (Cleary et al. 2004), suggested that management efforts to both reduce food resources and habitat availability on the AOA could reduce strike frequency.

Specifically, the reduction of raptor food resources on and near the AOA, particularly rodent populations and carrion (e.g., road-killed animals), is likely critical to controlling foraging by both Red-tailed Hawks and vultures (e.g., Baker and Brooks 1981, Coleman and Fraser 1987, DeVault et al. 2003, Cleary and Dolbeer 2005). The open airport environment and its associated high road density might increase food resource abundance, particularly for vultures (e.g., road-killed animals; Coleman and Fraser 1987), as well as increasing thermal updrafts conducive to soaring. For example, Coleman and Fraser (1989) found that home ranges for both Turkey and Black vultures included roads and open habitat in a greater proportion than available within their study area (also see DeVault et al. 2004). Further, DeVault et al. (2005) theorized that daily diet preferences, foraging strategy, and food availability, as well as other physiological and social factors, figured more prominently in vulture flight behavior than climatic variables. Therefore, we suggest that timely removal of road-killed animals will reduce vulture foraging activity and, likely, frequency of soaring through AOAs.

We suggest that airport managers should strive toward an integrated management approach that comprises, in addition to control of food resources, the reduction of perching, loafing, nesting, and roosting habitats (e.g., Coleman and Fraser 1989, Avery et al. 2002, Seamans 2004) on AOAs (Schafer et al. 2002, Teague 2002) and, where necessary, on bordering properties (14 CFR Part 139, Subpart D; Cleary and Dolbeer 2005; Transport Canada 2001; U.S. Federal Aviation Administration 2004, Cleary and Dolbeer 2005). For example, there is evidence that Red-tailed Hawk distribution is linked to a composite of prey, low-density plant cover (i.e., vegetation that increases vulnerability of rodents to predation), and perch availability (Preston 1990). Leyhe and Ritchison (2004) reported similar findings, noting the importance of perches to foraging Red-tailed Hawks in association with use of habitats characterized by low-density plant cover. Therefore, a particular management emphasis for the AOA, within vegetation cover types characterized by low-density plant coverage, should be the control of perching on runway signage and structures proximate to taxiways and runways (see U.S. Federal Aviation Administration 2004).

We emphasize that control of a single habitat feature (e.g., perching sites) on airports, without an integrated wildlife management approach that targets food and other habitat resources, will not necessarily reduce exploitation by hawks and vultures of thermal conditions conducive to aerial foraging. A current habitat-management protocol under consideration for airports and complimentary to reduction in perching, loafing, and roosting habitats is use of tall fescue (*Festuca arundinacea*; Cleary and Dolbeer 2005), a sod grass of temperate environments. Varieties of tall fescue, if infected with the fungus, *Neotyphodium coenophialum*, may be repellent to small mammals (Coley et al. 1995, Conover 1998).

With increasing air traffic world-wide and quieter aircraft with fewer engines, the potential for loss of human lives, property, and birds due to bird strikes is increasing (Cleary et al. 2004, Cleary and Dolbeer 2005). Reducing the potential for bird strikes requires proactive, integrative, and collaborative wildlife management measures involving airport administrations, municipalities, private groups, government agencies, and professional wildlife biologists.

COLISIONES DE *BUTEO JAMAICENSIS*, *CATHARTES AURA* Y *CORAGYPS ATRATUS* CON AERONAVES: CONSECUENCIAS PARA LA REDUCCIÓN DE LOS GOLPES POR AVES

RESUMEN.—*Buteo jamaicensis*, *Cathartes aura* y *Coragyps atratus* estuvieron involucrados en aproximadamente el 37% de los golpes de rapaces (N = 1945) que se registraron contra aviones civiles en los EEUU entre 1990 y 2003, resultando en un 93.4% del tiempo en que los aviones se encontraron fuera de servicio debido a golpes de rapaces en general, y en una pérdida de aproximadamente $7 millones para la industria aérea civil de EEUU. Nos preguntamos si las estadísticas de los golpes de rapaces podrían brindar información crítica para el manejo de la vida silvestre y de los recursos en las áreas de operación (AAO; áreas designadas para el despegue, aterrizaje, y maniobras terrestres de los aviones) de los aeropuertos y dentro del área establecida por la Administración Federal de Aviación de EEUU (AFA) para los aeropuertos certificados (i.e., hasta 1.5 km desde la pista para los aeropuertos que operan solamente con aviones con propulsión a pistón y de 3.0 km desde la pista para aeropuertos que operan aviones con propulsión a turbina). Nuestro objetivo fue cuantificar los informes de golpes a la aviación civil de EEUU usando la base de datos de golpes contra vida silvestre de la AFA (1990–2004) que hayan incluido a *B. jamaicensis*, *C. aura*, *C. atratus* y buitres no identificados. Luego relacionamos esta información con el número de aves golpeadas, la estación y la altitud. Encontramos que el 82% de los golpes que involucraron a *B. jamaicensis* se dieron hasta o por debajo de 30.5 m sobre el nivel del suelo (SNS; dentro de los límites de las AAO), y cerca del 63% se dieron mientras los aviones estaban operando en el suelo. Del mismo modo, encontramos que aproximadamente el 29% de los golpes que involucraron a buitres se dieron hasta o por debajo de 30.5 m SNS, con un 17% ocurrido mientras los aviones estaban operando en el suelo. No hubo una diferencia estacional dentro de los grupos de especies en el número de halcones o buitres golpeados. Sugerimos que los esfuerzos de manejo que reducen los recursos alimenticios de las rapaces en las AAO, así como los esfuerzos que reducen los lugares de percha, descanso, nidificación y refugio nocturno dentro de estas áreas, pueden mejorar la seguridad de la aviación y reducir las colisiones.

[Traducción del equipo editorial]

ACKNOWLEDGMENTS

We greatly appreciate reviews of earlier drafts of this manuscript by M.L. Avery, R.C. Beason, T.L. DeVault, R.A. Dolbeer, J. Gehring, M.S. Lowney, and T.W. Seamans. Our work was supported by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services (WS), WS National Wildlife Research Center, and the FAA, William Hughes Technical Center, Atlantic City, New Jersey, under agreement DTFACT-04-X-90003. Opinions expressed in this study do not necessarily reflect current FAA policy decisions regarding the control of wildlife on or near airports.

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Received 19 November 2004; accepted 26 September 2005