1-1-2008

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Human–Wildlife Conflicts 2(2):240–247, Fall 2008

Mammalian hazards at small airports in Indiana: impact of perimeter fencing

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Abstract: Fences are used at many airports and small airfields to exclude wildlife from entering critical areas. However, not all fences exclude hazardous mammals reliably, and effective fences can be too expensive for small airports to purchase and maintain. In this study, we evaluated fencing at 10 small airports in Indiana and documented the presence and relative abundance of wildlife within airport boundaries using remote cameras and spotlight surveys. Only 4 airports were completely fenced, and four were <50% fenced. All airports had openings in their fence lines that would allow hazardous wildlife access to the airfields. We encountered either white-tailed deer (*Odocoileus virginianus*) or coyotes (*Canis latrans*) at nine of the airports with remote cameras and during spotlight surveys. There were fewer coyotes and white-tailed deer encountered during spotlight surveys at completely-fenced airports ($\bar{x}$ = 0.40 individuals/km across 8 surveys; SE = 0.24) than were encountered at airports that were not completely fenced ($\bar{x}$ = 6.15; SE = 2.32; P = 0.032). Our study suggests that complete enclosure of airfields and regular fence maintenance is vital for effective wildlife-strike management at small airports.

Key words: airport, coyote, hazard, human–wildlife conflicts, Indiana, *Odocoilus virginianus*, white-tailed deer, wildlife strike

Collisions between wildlife and aircraft (wildlife strikes) are a serious concern both for economic and safety reasons. Wildlife strikes cause >580,000 hours of aircraft downtime each year and cost the civil aviation industry >$556 million annually (Cleary et al. 2006). Furthermore, >350 people have been killed in wildlife strikes worldwide since the inception of aviation 100 years ago (Sodhi 2002). Unfortunately, the probability of wildlife strikes is expected to increase as (1) air travel increases, (2) wildlife populations grow, and (3) commercial air carriers replace 3- and 4-engine aircraft with quieter, more efficient 2-engine aircraft that are more vulnerable to catastrophic strikes (Cleary et al. 2006). It is clear that understanding the causal factors contributing to wildlife-aircraft collisions and developing solutions to reduce the likelihood of such collisions are critical challenges currently facing wildlife managers and aviation employees.

Although high-altitude collisions between aircraft and large soaring birds can be catastrophic (DeVault et al. 2005), collisions in the airport environment are much more common. Commercial and general aviation airports, which commonly are located in close proximity to water bodies and large grasslands, can harbor populations of white-tailed deer (*Odocoileus virginianus*), coyotes (*Canis latrans*), birds, and other wildlife that are potentially dangerous to aircraft (Dolbeer et al. 2000). The combination of abundant wildlife populations and frequent aircraft take-offs and landings at airports commonly leads to unacceptable levels of wildlife strikes; over 90% of wildlife strikes to civil aircraft occur in the airport environment (Cleary et al. 1999). Birds account for approximately 97% of all aircraft collisions with wildlife, although most bird collisions do not cause aircraft damage (Cleary et al. 2006). Mammals also present significant hazards in

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the infield airport environment—652 white-tailed deer collisions and 198 coyote collisions were reported in the United States from 1990 to 2005 (Cleary et al. 2006).

Wildlife biologists have studied wildlife-strike hazards in many venues, but most research has been conducted at large international airports (e.g., Dolbeer et al. 1993). Relatively few researchers have considered wildlife problems at regional airports and smaller airfields. However, because small regional and municipal airports often are located in rural areas, the potential for wildlife strikes is usually significant. Every airport that receives grants-in-aid from the Federal Aviation Administration, regardless of its size and the type of air traffic it accommodates, is required to ensure a safe operating environment with respect to wildlife hazards (U.S. Federal Aviation Administration 2004). Thus, to prevent wildlife strikes it is necessary for all airports to sufficiently identify potential problems with hazardous wildlife.

Habitat management is central to effective wildlife-hazard abatement programs at airports (Barras and Seamans 2002, Seamans et al. 2007, Washburn et al. 2007). Airport habitats can provide food, cover, water, and loafing areas for wildlife. Thus, the goal of habitat management at airports is to reduce or eliminate such attractants without compromising vital airport operations. Most airports use fencing to deter large mammals from accessing critical areas. However, not all commonly-used fence designs exclude deer and other large mammals reliably (VerCauteren et al. 2006), and effective fences often can be too expensive for small airports to purchase and maintain (DeVault, personal observation).

In this study we evaluated fencing at small airports in Indiana. Our objectives were to describe the extent, type, and condition of fencing used at our study airports and to document the presence and relative abundance of potentially hazardous species within the airport boundaries.

Study area

Ten airports were chosen for study (Table 1). Nine were classified as general aviation airports, and one carried commercial air traffic. Although our subset of airports was not a random sample of all small airports in Indiana, we attempted to represent the entire spectrum of aircraft traffic, proximity to large urban areas, and current extent of wildlife hazard management programs exhibited by small airports in the state. In addition, focal airports were distributed equally among northern, central, and southern regions of the state to help account for any regional differences in wildlife populations (e.g., species composition and density) that might exist.

Methods

Fencing evaluations

We made a general assessment of the effectiveness of fences at each airport based on fence type, proportion of airport perimeter fenced, and number and type of fence openings present. Endpoints for each fence type were documented using a handheld Global

Table 1. Characteristics of 10 airports chosen as study sites for an investigation of wildlife hazards at small airports in Indiana, 2005 and 2006.

Airport	Area (ha)	Runway length (m)	Based aircraft[1]	Spolight transect length (m)
1	202	5400	81	5334
2	170	3899	135	6429
3	243	5000	56	2009
4	60	4300	107	1644
5	194	5000	33	4720
6	202	6600	105	7929
7	78	5000	25	1633
8	284	5500	32	4941
9	627	4300	58	7339
10	225	6000	49	2783

[1] Total number of aircraft (single engine, multi-engine, jet) permanently based at the airport.

Positioning System (GPS) unit. We classified 7 types of fencing based on height and construction (Table 2).

For each airport with chain-link fencing around >25% of the airport perimeter, we used a handheld GPS unit to document fence openings that could be exploited by wildlife for entry onto the airfield. We documented all fence openings ≥7.6 cm, based on our assumption that such openings would allow many medium-sized mammals to pass through. Generally, we did not document openings in or under wire-mesh (Type G; Table 2) fences because the mesh size itself was large enough to allow passage by animals. For all other fence types, we classified 7 types of openings (Table 3). Locations of fence openings were downloaded from our GPS unit and uploaded onto digital maps. We used ArcMap (ESRI, Inc.) to calculate the length of each fence type, proportion of airport perimeter for each fence type, and number of openings per 100 m of fence for each airport.

Wildlife inventories

We used spotlight surveys and remote cameras to observe wildlife inside airport properties (within fence lines, where present) during each of 4 seasons (spring, summer, and fall 2005 and winter 2006). Because we did not capture and mark individual animals, it was not possible to estimate absolute abundances. Thus, we used our surveys primarily to detect wildlife presence and to assess the effectiveness of perimeter fences.

We conducted 2 spotlight surveys during each season at each airport (>1 week apart), for a total of 8 spotlight surveys per airport. Survey routes were designed to cover as much of the airport property as practical, given the specific conditions present at each airport (i.e., habitat, topography, access), and ranged from 1,633 to 7,929 m in length (Table 1). Spotlight surveys began between 0.5 hours after sunset and 2330 Eastern Standard Time. During each survey, a team of 1 to 3 observers drove slowly (~10 km/hr) in a truck or ATV along the established route and shined a 1,000,000 candle-power spotlight on both sides of the route. When an animal was observed, we recorded the number and species on a standardized data sheet.

We used digital infrared remote cameras (Stealth Cam, Inc.), designed to trigger upon movement of a heat source in front of the camera sensor, as an additional means of detecting wildlife on airport properties. We placed cameras in locations where animals were likely to travel, such as fence holes, openings of culverts, small wetlands, woodlots, and wildlife trails. During each season at each airport, 3 to 4 cameras were placed within the property

Table 2. Percentage of perimeter fenced at 10 airports in Indiana, 2005 and 2006.

	Fence Type[a]							
Airport	A	B	C	C	E	F	G	Total
1					4	24	49	77
2				43				43
3				23				23
4[b]					98		1	99
5				1		1	42	44
6[b]		83	2		1		7	93
7	25						27	52
8				3		5		8
9[b]	78			13				91
10				2	96	2		100

[a]Type A: 244 cm–305 cm chain-link, 3 strands of barbed wire on top; Type B: 213 cm–244 cm chain-link; Type C: 183 cm–213 cm chain-link, plus 30 cm–61 cm buried; Type D: 183 cm chain-link, 3 strands of barbed wire on top; Type E: 183-cm chain-link; Type F: 91- to 137 cm chain-link; Type G (other): 213 cm plastic mesh (5 cm squares), 183 cm wood-panel, 91 cm–137 cm wire mesh (15 cm squares), 5 strands barbed wire (137 cm tall).
[b]Buildings accounted for a portion of the perimeter of the airport; thus, it was considered to be completely fenced.

Table 3. Type and number of fence openings at 10 airports in Indiana in 2005 and 2006. Airports 3, 5, 7, and 8 were not evaluated because they had <25% of the perimeter fenced with chain-link fencing.

	Type of fence opening								
Airport	Break[a]	Culvert	Dig-hole	Gap	Hole	Warp	Other	Total	Total/100 m
1	1			8				9	0.2
2	3	3	3	5				14	0.5
4				13		2		15	0.3
6		2	16	35	59	14		126	1.3
9			35	27		5		67	0.5
10	2		7	22		8	3	42	0.5

[a]Break: opening between 2 segments of a fence line (e.g., where a driveway or pedestrian corridor occurred); Culvert: open culvert underneath fence; Dig-hole: hole excavated underneath fence; Gap: open space between bottom of fence and the ground or between doors of a gate in the fence line; Hole: missing portion of a fence created by gnawing or other destructive action; Warp: open space between bottom of fence and the ground caused by warping or other physical damage to bottom of fence; Other: actions outside the fence line that essentially have eliminated effectiveness of the fence in preventing larger mammals from jumping over it (e.g., by raising the height of a road or filling a ditch with gravel).

boundary and lightly baited with a commercial wildlife attractant (skunk essence). Each camera operated for an average of 245 hours (SE = 5) during each of the spring, summer, and fall seasons. In an effort to increase performance, we equipped cameras with larger batteries during the winter, resulting in an average operating time of 935 hours (SE = 27) per camera. We attempted to use the same camera locations each season, although occasionally it was necessary to establish new camera locations (e.g., when cameras were subject to flooding or tampering). Photographs were downloaded and analyzed at the end of each season.

Statistical analysis

We used a 2-group Mann-Whitney U test to determine whether the number of coyotes and white-tailed deer encountered at completely-fenced airports ($n = 4$) differed from the number encountered at airports that were not completely fenced ($n = 6$; Table 2). The total number of coyotes and white-tailed deer encountered was summed across all seasons and standardized by the length of the spotlight survey at each airport. We chose to use spotlight survey data rather than remote camera data for the analysis because spotlight survey data could be standardized across airports more precisely, and because the use of wildlife attractant at camera locations may have influenced the number of some species surveyed via camera.

Results

Fencing evaluations

Each airport used chain-link fencing (Types A through F) along at least a portion of its perimeter, and 5 airports used only that type (Table 2). Eight airports had ≥1 type of fence present. The proportion of airport perimeter fenced ranged from 8% to 100% among all airports. Four airports were <50% fenced, and four were completely fenced (including perimeter buildings; Table 2). Several airports with incomplete fencing appeared to have fence lines only where roads or woodlots occurred adjacent to the airfield. All airports, even those that were completely fenced, had openings in their fence lines that would allow coyotes and perhaps deer access to the airfields (Table 3, Figures 1, 2). Most airports with >25% of the perimeter fenced with chain-link fencing had 0.2 to 0.5 openings per 100 m of fence, with gaps and dig-holes being the most common openings (Table 3). Only 1 airport had a buried fence (Type C), and that fence constituted only 2% of the perimeter of that airport (Table 2).

Wildlife inventories

Numbers of potentially hazardous species observed during spotlight surveys varied greatly among airports (Table 4). We observed up to 50 deer (across all surveys; up to 20 on any individual survey) and 9 coyotes during spotlight surveys at individual airports. Only

Figure 1. Culverts through a fence line can create large passageways for wildlife at airports. (*Photo by J. E. Kubel*)

Figure 2. Coyotes are proficient at digging under airport fences that are not buried.

3 airports had no deer observed inside the property boundaries during spotlight surveys, and 6 airports had no coyotes observed (Table 4). There were significantly fewer (P = 0.03) coyotes and white-tailed deer encountered during spotlight surveys at completely-fenced airports ($\bar{x}$ = 0.40 individuals/km across surveys; SE = 0.24) than were encountered at airports not completely fenced ($\bar{x}$ = 6.15; SE = 2.32). Encounters of raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) also varied considerably among airport properties (Table 4).

We observed with remote cameras at least 10 mammal species on airport properties; we were unable to identify 25 individuals observed on camera (Table 5). Coyotes were observed at 7 airports (the greatest number of observations at an individual airport was 15), and white-tailed deer were observed at 6 airports (the greatest number of observations at an individual airport was 39). We recorded more observations of white-tailed deer and coyotes during winter (92 for deer; 35 for coyotes) than during the other seasons combined (50 for deer; 5 for coyotes), likely because cameras operated for a longer period during winter.

Discussion

Deer and coyotes represent the top mammalian hazards at airports in the United States (Dolbeer et al. 2000), and exclusion (fencing) is the preferred method (and in many cases, the only effective method) of preventing deer and

Table 4. Mammals observed during 8 spotlight surveys at each of 10 airports in Indiana during 2005–2006. Values represent number of individual observations of the species totaled across 4 seasons; "Deer (high)" = the highest count of white-tailed deer during any single survey.

Airport	Coyote	White-tailed deer	Deer (high)	Raccoon	Virginia opossum	Other[1]
1		50	20	8	2	3
2	9	26	7			5
3		18	5	4	1	5
4				1		1
5	2	4	4	1		6
6					1	2
7		19	7	4		2
8		1	1	2		6
9	2	7	4		4	7
10	1			1	1	12
Total	14	125	48	21	9	49

[1]Striped skunk (*Mephitis mephitis*), domestic cat (*Felis catus*), red fox (*Vulpes vulpes*), and eastern cottontail (*Sylvilagus floridanus*)

Table 5. Mammals observed with remote cameras at 10 airports in Indiana, 2005–2006. Values represent number of individual observations of the species totaled across four seasons.

Airport	Coyotes	White-tailed deer	Raccoons	Other[1]	Unidentified
1	15	39	26	21	18
2	8	28	6	5	6
3		37	7	4	2
4	4		68	5	5
5	5	12		7	3
6					5
7	4	23	3		5
8	2			4	
9		3	15	20	1
10	2		2	3	1
Total	40	142	127	69	46

[1]Domestic cat (*Felis catus*), domestic dog (*Canis familiaris*), eastern cottontail, American mink (*Neovison vison*), fox squirrel (*Sciurus niger*), Virginia opossum (*Dedelphis virginiana*) and woodchuck (*Marmota monax*).

coyotes from accessing large areas (Conover 2002). Researchers have demonstrated that a 2.4-m fence usually can exclude nonstressed deer on level ground (Falk et al. 1978). However, motivated deer can clear a 2.4-m fence (Sauer 1984). Thus, 3-m fencing may be the most effective regime in airport environments where complete exclusion is desired (VerCauteren et al. 2006). Even so, proper installation and maintenance of fencing may be more important for exclusion of large mammals than fence height alone. A 25-cm gap at the bottom of a fence can allow an adult deer to pass through (Falk et al. 1978, Feldhamer et al. 1986), and when sufficiently motivated, adult deer can pass through a 19-cm gap (Feldhamer et al. 1986). This may explain why we recorded several observations of coyotes and deer at 3 of 4 completely enclosed airports.

Extent of fencing also is critical to successful exclusion of deer and coyotes because incomplete fencing allows animals to simply walk around the end of the fence to gain access to an airfield. For example, 2 airports in our study had only 1.8-m fencing (Type D) that surrounded <43% of the perimeter. Not coincidentally, white-tailed deer and other mammals were observed on those airfields frequently. At airport seven, we observed a well-established deer trail leading around one end of a 3-m fence (which surrounded 25% of the perimeter) and directly through the airfield, across the runway, and into a cornfield. Conversely, deer and coyotes were relatively uncommon at the 4 airports with completely fenced airfields, even though fencing was as short as 1.8 m. Anecdotally, we observed deer and coyotes regularly outside those fences, thus the low number of observations of these animals (relative to other airfields) within the fences was not likely a result of regional differences in population density or habitat availability.

Our methods did not allow us to estimate abundance of white-tailed deer or coyotes on airport properties, but the densities are high in many rural and suburban areas (Hussain et al. 2007, DeNicola et al. 2008). Our observations did make clear that these species can occur regularly within airport boundaries and pose a hazard to safe operation of aircraft in the airport environment. Although other mammals observed during our surveys (e.g., raccoon, Virginia opossum, domestic cat [*Felis catus*]) rarely cause substantial damage to aircraft (Cleary et al. 2006), their presence was noteworthy and should be considered hazardous because such species are struck regularly by aircraft (Cleary et al. 2006). Deer, coyotes, and other mammals appeared to be less common on airfields completely enclosed by fencing than those only partially enclosed; however, none of the focal airports had fencing adequate enough to ensure that animals could not enter a runway area. Hence, managers of small airports (e.g., general aviation airports) in Indiana and perhaps elsewhere in the Midwest should consider upgrading their current fencing regimes.

Many of the fences at our study airports probably were installed for purposes of human security rather than for reducing wildlife hazards. However, the frequency of occurrence of white-tailed deer and coyotes certainly suggests that fences capable of excluding wildlife on such airports are needed and should be part of an integrated management program. Fence installation is expensive (e.g., 2.4-m chain link fencing costs >$20/m; VerCauteren et al. 2006), and many small airports operate on limited funds. Thus, it seems prudent that new fences at small airports should be designed both for human security and wildlife exclusion. In particular, we suggest new fences be buried to reduce the number of dig-holes and other openings that occur over time. At minimum, complete enclosure of airfields and regular fence maintenance (e.g., immediate repair of damaged fences or filling in of holes dug by animals) is vital for effective wildlife-strike management at airports.

Acknowledgments

This study was funded by the Joint Transportation Research Program of the Indiana Department of Transportation and Purdue University, the Aviation Association of Indiana, and the Purdue University Department of Forestry and Natural Resources. We thank all of the airport managers who agreed to participate in this study and allowed us access to their properties. We also thank J. A. DeWoody for providing help with various aspects of the project.

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Jacob E. Kubel (photo unavailable) grew up in the state of Maine and earned a B.S. degree in wildlife and fisheries biology at the University of Vermont and an M.S. degree in wildlife and fisheries science at Pennsylvania State University. Between degrees, he was involved in a variety of avian research projects throughout the eastern United States, focusing mainly on ecology of yellow-rumped and golden-winged warblers, piping plovers, and ruffed grouse. In addition, he spent several years conducting inventories of terrestrial vertebrates at national parks. At Purdue University he assisted with investigations of wildlife hazards at airports, ecology of mesocarnivores in agricultural landscapes, and ecology of the Allegheny wood rat, which is endangered in Indiana. His primary interests include endangered species management and forest ecology. As part of the Massachusetts Natural Heritage and Endangered Species Program, he now develops guidelines for protection of rare species in areas of proposed forest harvesting.

Olin E. (Gene) Rhodes is a professor of wildlife ecology and genetics in the Department of Forestry and Natural Resources at Purdue University. He has published >110 peer-reviewed research articles and currently is designated as a Purdue University Faculty Scholar. His research focus is in wildlife ecology and genetics, including studies of the genetic consequences of species reintroduction programs, the use of genetic markers in applied wildlife management and conservation programs, the use of genetic markers to elucidate mating systems, movement behavior, and population structure of wildlife species, and sustainability of wildlife species in human-dominated landscapes with an emphasis on the resolution of human–wildlife conflicts.

David J. (Dave) Glista received B.S. and M.S. degrees in wildlife from Purdue University. He is currently employed as a research technician for the Department of Forestry and Natural Resources at Purdue where he works with raccoons and Allegheny wood rats. His interests include predator ecology, road ecology, and management of human–wildlife conflicts.