Contents lists available at ScienceDirect

## Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

## Carnivore incidents with U.S. civil aircraft

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#### ARTICLE INFO

Article history: Available online 14 March 2015

Keywords: Aircraft Airport Carnivore Wildlife incident Wildlife management

#### ABSTRACT

Wildlife incidents with aircraft are of concern in the United States as they pose a risk to human safety and economic losses for the aviation industry. Most previous research on wildlife-aircraft incidents has emphasized birds, bats, and ungulates. We queried the Federal Aviation Administration's National Wildlife Strike Database from 1990 to 2012 to characterize carnivore incidents with U.S. civil aircraft. We found 1016 carnivore incidents with aircraft representing at least 16 species, with coyotes (n = 404) being the species most frequently struck. California and Texas had the most reported incidents and incidents were most likely to occur at night from August to November. Overall estimated damage to aircraft incidents increased 13.1% annually from 1990 to 2012 whereas the rate of damaging incidents remained fairly constant. Due to the increase in carnivore-aircraft incidents from 1990 to 2012, we recommend further research on techniques to increase detection of carnivores and implementation and scheduled maintenance of perimeter high fences for exclusion. Additionally, we recommend increasing patrol of runways, especially during peak incident periods (July–November) and at night (2000–0600 h).

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#### Introduction

Wildlife collisions with aircraft pose a threat to human safety and economic losses for the aviation industry (DeVault et al., 2013). From 1990 to 2009, wildlife incidents with U.S. civil aircraft resulted in more than US\$ 1.4 billion in damages and substantial loss of revenue due to the cost of mitigation techniques (Biondi et al., 2011). From 1990 to 2010, more than 100,000 wildlife incidents with aircraft were reported using the Federal Aviation Administration's (FAA) National Wildlife Strike Database (Dolbeer et al., 2012). Birds are the primary group involved in incidents (97.2%), followed by mammals (2.7%) and reptiles (0.1%) (Dolbeer et al., 2012). Increases in wildlife populations and air traffic have contributed to the increased risk and severity of wildlife collisions with aircraft (Khalafallah and El-Rayes, 2006; DeVault et al., 2013).

Though most research on wildlife-aircraft incidents has emphasized birds (e.g., DeVault et al., 2009; Dolbeer, 2011; Blackwell et al., 2012), incidents involving mammals cause a greater proportion of damaging incidents with aircraft (e.g., Dolbeer et al., 2000; Biondi et al., 2011; DeVault et al., 2011). Previous research on mammal incidents with aircraft has focused on ungulates and bats (Parsons et al., 2008; Biondi et al., 2011, 2013); other mammalian taxa have not been studied

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http://dx.doi.org/10.1016/j.trd.2014.12.001 1361-9209/© 2015 Elsevier Ltd. All rights reserved.







in detail. Our objective was to summarize carnivore incidents with U.S. civil aircraft to estimate the frequency and timing of incidents and associated hazards to aircraft. Carnivores use airport runways and surrounding areas to acquire prey (e.g., small mammals), thus posing a threat to aircraft. We predicted overall similar numbers of carnivore incidents annually from 1990 to 2012 due to increased awareness of wildlife hazards at airports and associated reporting, but also consequent increases in management to reduce the frequency of such incidents. We also predicted that carnivore incidents would be greatest during autumn when abundance is greatest and juvenile dispersal typically occurs (e.g., Bekoff, 1977).

#### Methods

We queried the Federal Aviation Administration National Wildlife Strike Database (NWSD; http://wildlife.faa.gov/database.aspx) containing data from 1990 to 2012 for wildlife incidents involving species within the Order Carnivora and U.S. civil aircraft. We included only incidents reported within the 50 U.S. states and Washington, D.C. The National Wildlife Strike Database contains information reported to the FAA by pilots and airport personnel using FAA Form 5200-7 (Dolbeer et al., 2009). Reporting of wildlife incidents for U.S. civil aircraft is voluntary; therefore, some reports were incomplete which resulted in varying sample sizes.

We calculated incident rates as the annual number of incidents/1 million U.S. civil aircraft movements using the FAA Terminal Area Forecast Summary Report (Federal Aviation Administration, 2012a). We also calculated monthly data on aircraft movements from 1996 to 2012 using the Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics (United States Department of Transportation, 2012). Additionally, we summarized incidents by states and species responsible for incidents. We defined an aircraft movement as a take-off or landing by the aircraft. We determined the time of day each incident took place based on the local time reported. Incidents occurring between 0800 to 1800 local time were categorized as 'day', and incidents occurring from 2000 to 0600 were categorized as 'night' (Washburn et al., 2013). 'Dawn' incidents occurred from 0600 to 0800 and 'dusk' from 1800 to 2000 (Washburn et al., 2013).

We summarized phase of flight using the classification of approach, climb, taxi, landing roll, and take-off run. Approach was defined as an aircraft engaged in landing with at least one wheel off the ground whereas climb was defined as an aircraft engaged in take-off with at least one wheel off the ground (Biondi et al., 2011). We defined taxi as an aircraft moving between the gate and runway (Biondi et al., 2011). Take-off run and landing roll were defined as an aircraft having all wheels on the ground during landing and take-off (Dolbeer and Wright, 2009). From the FAA National Wildlife Strike Database, we used the damage classes "none", "minor", "substantial", and "destroyed" to assess the overall extent of damage incurred on the aircraft (Dolbeer et al., 2009). None was defined as no damage to the aircraft. Minor damage required simple repairs and did not require extensive inspection. Damage defined as substantial could not be fixed by simple repairs and required extensive inspection as it affected flight, structural integrity of the aircraft, and overall performance. Damage categorized as destroyed was irreparable, resulting in decommissioning of the aircraft. The estimated damage cost of an aircraft deemed "destroyed" was the cost of replacement for the aircraft.

We estimated damage by averaging reported costs for each damage class, multiplying those averages by the total number of incidents within each respective damage class, and summing the estimates (Biondi et al., 2011). Additionally, we summarized damaged components of aircraft by analyzing damage reports provided by the FAA National Wildlife Strike Database to further assess extent of aircraft damage. The estimated damage cost was the cost of replacement for the component. We used simple linear regression to assess trends in the number of incidents across years and chi-square analyses to compare the number of incidents among months, phase of flight, and incident rates/hour by time of day (e.g., day, night) (program R version 2.13.1, The R Foundation for Statistical Computing, Vienna, Austria).

### Results

Overall, 1016 carnivore–U.S. civil aircraft incidents were reported from 1990 to 2012. The number of incidents increased 13.1% annually (y = 1.98 + 0.20x;  $r^2 = 0.94$ ; P < 0.01) from 1990 to 2012, with the greatest number of reported incidents/1 million movements (n = 101) in 2012 (Fig. 1). The number of reported incidents varied among months ( $\chi^2_{11} = 158.5$ , P < 0.01) and was greatest in October (n = 142) and lowest in April and May (n = 41) (Fig. 2).

At least 16 carnivore species were responsible for reported incidents (Table 1). Overall, canids accounted for 66.2% of all incidents with coyotes (*Canis latrans*), the most frequently reported species (n = 404), accounting for 39.8% of incidents. The second most frequently reported species, red fox (*Vulpes vulpes*) (n = 120), accounted for 11.8% of incidents. Incidents were reported in 48 of the 50 United States and Washington, D.C. California had the most reported incidents (n = 88) followed by Texas (n = 85) and Illinois (n = 77); South Dakota and Wyoming had no reported incidents.

Of the 509 incidents for which the time of day was reported, most ( $\chi_3^2 = 507.7$ , P < 0.01) incidents occurred at night (n = 334), followed by day (n = 129) (Fig. 3). Of the 537 reported incidents which included phase of flight when the incident occurred, landing roll (n = 279) was most common ( $\chi_4^2 = 626.7$ , P < 0.01), followed by take-off run (n = 214) (Fig. 4).

Extent of damage was reported for 501 incidents. Damage reports indicating "none" were most frequent (n = 440), followed by "minor" (n = 42), "substantial" (n = 12), "destroyed" (n = 2), and "uncertain" (n = 5). Damaged components were

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