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Migratory Canada geese cause crash of US Airways Flight 1549

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Migratory Canada geese cause crash of US Airways Flight 1549

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In the United States alone, over 7400 bird–aircraft collisions (birdstrikes) were reported in 2007. Most of these strikes occurred during takeoff or landing of the flight, and it is during these flight phases that aircraft experience their highest risk of substantial damage after colliding with birds. Birdstrikes carry enormous potential costs in terms of lives and money. Using feather remains and other tissue samples collected from the engines of US Airways Flight 1549, which crash landed in the Hudson River in New York City on 15 January 2009 after a birdstrike, we apply molecular tools and stable hydrogen isotopes to demonstrate that migratory Canada geese were responsible for the crash. Determining whether the geese involved in this birdstrike event were resident or migratory is essential to the development of management techniques that could reduce the risk of future collisions. Currently, the US civil aviation industry is not required to report birdstrikes, yet information on frequency, timing, and species involved, as well as the geographic origin of the birds, is critical to reducing the number of birdstrikes. Integrating this information with bird migration patterns, bird-detecting radar, and bird dispersal programs at airports can minimize the risk of such collisions in the future.

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Human–wildlife conflicts can include the introduction of zoonotic diseases, direct confrontations with people, crop damage, and birdstrikes with commercial and military aircraft (Vercauteren *et al*. 2005; Messmer 2009). Such conflicts often result in the death of both humans and wildlife, cost hundreds of millions of dollars, and have far-reaching implications for conservation, management, and research (Conover 2001). In many cases, more precise identification, and information on the biology of the wildlife species involved, could help to mitigate such risks in the future.

Because airports are often constructed in lowland areas that were originally wetlands, bird collisions with aircraft occur with alarming regularity. Millions of people around the world depend on air travel without realizing the risks associated with such events, especially during the takeoff run and initial climb phases of flight (Dolbeer 2008). More than 7400 birdstrikes with civil aircraft were reported in the US in 2007 alone, including 110 that caused substantial damage to the aircraft (Dolbeer and Wright 2008; Figure 1). This is likely an underestimate, because the Federal Aviation Administration (FAA) estimates that only 20% of strikes are reported (Cleary *et al*. 2006). Worldwide, birdstrikes are estimated to cost the commercial airline industry a minimum of $1.1 billion per year (Allan 2002) and have resulted in more than 210 aircraft destroyed and 229 deaths since 1988 (Richardson and West 2000; Thorpe 2003; Dolbeer and Wright 2008).

On 15 January 2009, US Airways Flight 1549, an Airbus 320 aircraft originating from New York's LaGuardia Airport (LGA), experienced a birdstrike involving multiple birds at approximately 2900 feet (~884 m) aboveground and 5 miles (~8 km) from the airport, causing both engines to fail (Figure 2). Only through the skill of an experienced flight crew did all 155 people on board survive the crash landing on the Hudson River. Using feathers and tissues extracted from both engines, we used molecular genetic techniques and feather samples from museum collections to determine the species involved (Dove *et al*. 2008), and stable isotopes to ascertain if these birds were from resident or migratory populations (Caccamise *et al*. 2000). Stable hydrogen isotopes (δD) in growing-season precipitation vary with latitude, and birds incorporate these signatures into their feathers via the supporting food web (Chamberlain *et al*. 1997; Hobson and Wassenaar 1997). Because most migratory birds molt their feathers on or close to the breeding site, feathers obtained from US Airways 1549 engines allow inferences to be made about where these birds nested in the summer of 2008.

Determining the species and origin of the birds involved in this event is essential to the development of management techniques that could reduce the risk of future birdstrikes (Cleary and Dolbeer 2005). Resident birds near airports may be managed by population reduction, habitat modification, harassment, or removal (Smith *et al*. 2000; Dolbeer *et al*. 2003), whereas migratory populations require more extensive approaches, such as

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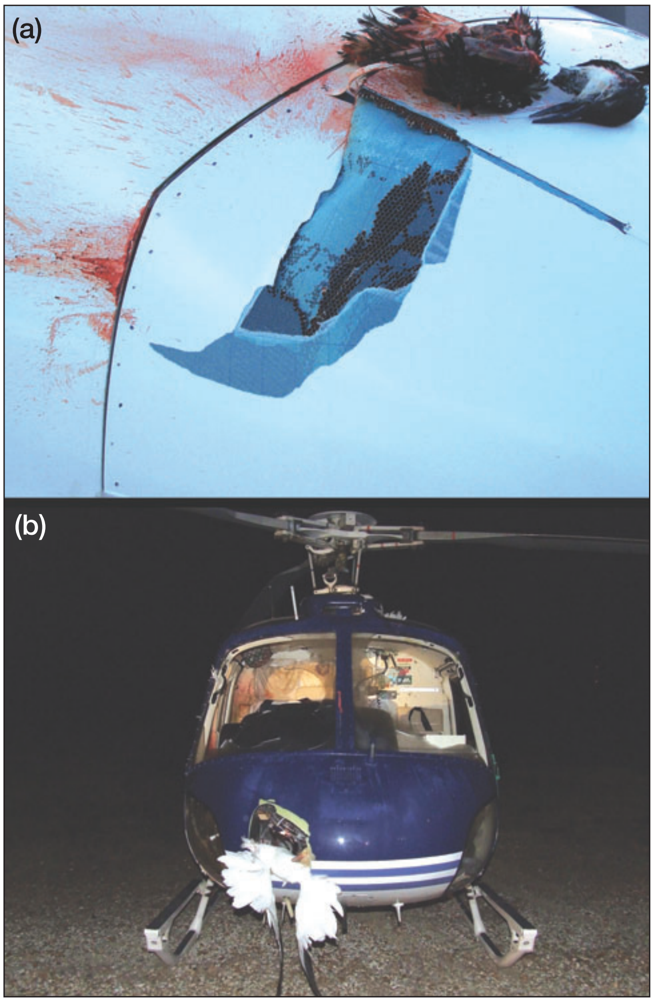

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Figure 1. *Examples of what birds can do to jet aircraft and helicopters. (a) Damage caused by a common loon (*Gavia immer*) to an Airbus 320 on 7 November 2007, New York. (b) Snow goose (*Chen caerulescens*) embedded in an AS 350 helicopter, 21 January 2009, Tennessee.*

improved radar technology and the monitoring of bird movements (Lovell and Dolbeer 1999; Klope *et al.* 2009).

Methods

Feather extraction from the engines

Cumulatively, nearly 100 samples, including tissue, whole feathers, and feather fragments, were extracted from both engines of Flight 1549 (Figure 3). The number one engine (mounted under the left wing of the aircraft) detached from the wing on impact and was recovered from the bottom of the Hudson River 9 days later. The number two engine remained attached to the right wing, but was submerged in the Hudson River for 3 days.

Molecular analyses

DNA barcoding is routinely used by the Smithsonian Institution's Feather Identification Lab in Washington, DC, to identify the remains from birdstrikes. The technique uses a 650 base-pair portion of the mitochondrial gene (*cytochrome c oxidase subunit 1* [*CO1*]) for comparison to a public acccess database of known genetic material and has proven effective for identifying degraded samples such as those obtained from birdstrikes (Dove *et al.* 2008) and for use to distinguish species of North American birds (Kerr *et al.* 2007). Mitochondrial DNA was extracted from 18 separate muscle or tissue samples, via the Qiagen DNeasy Blood and Tissue Kit (Qiagen Inc, Valencia, California). The 10.0 μl polymerase chain reaction (PCR) reaction contained: 1.0 μl of genomic DNA; 1.0 μl Bioline deoxynucleotide triphosphate mix (BioLine USA, Randolf, Massachusetts) at 10 μM; 1.0 μl 5X Promega Flexibuffer (Madison, Wisconsin); 0.3 μl Bioline 50 mM $MgCl_2$ solution; 0.2 μl Promega Taq Polymerase; and 5.5 μl deionized H_2O, 0.5 μl standard *CO1* barcode primers at 10 μM. The thermocycler program consisted of: denaturation at 94°C, 2 minutes; 94°C, 20 seconds; 48°C, 45 seconds; and 72°C, 30 seconds for 25 cycles, then 72°C, 3 minutes; and held at 10°C. PCR products were cleaned with diluted (1:10) ExoSAP-IT (USB, Affymetrix, Cleveland, Ohio); 1 μl for each 10.0 μl PCR sample and heated to 37°C for 30 minutes, and at 80°C for 15 minutes. Cycle-sequence follows methods in Dove *et al.* (2008) and *CO1* sequences were checked by way of Sequencer 4.7 (Gene Code Corp, Ann Arbor, Michigan) and identified via the Barcode of Life Database (BoLD, www.barcodinglife.org).

Direct feather analysis

We analyzed whole feathers or feather fragments using methods of direct comparisons with museum research specimens and examination of the microscopic characteristics of the plumulaceous (downy) barbs (Dove 2000).

Stable hydrogen isotope analysis

Stable hydrogen isotope analysis was carried out according to the methods described by Wassenaar and Hobson (2003). Feather samples were collected from voucher specimens of two known migratory Canada goose (*Branta canadensis*) subpopulations stored at the Field Museum of Natural History in Chicago, Illinois. Approximately 2 cm was cut from the tip of the first primary feather from 13 Canada goose specimens (catalog numbers FMNH 379767–379777, 379780, 379786) collected in Labrador, Canada (54°14'N, 62°13'W). These samples range over an area encompassing approximately 100 000 km^2. Four additional samples (catalog numbers FMNH 379709–379712) were taken from specimens collected in the southern region of Newfoundland, Canada (47°25'N, 54°19'W). The US Department of Agriculture (USDA) wildlife biologists working at LGA provided primary feather tips in late January 2009 from six resident Canada geese previously banded for local study. Four feather samples (body and partial flight) removed from both engines of Flight 1549 had sufficient material for isotope analysis.

Feathers were washed in a 2:1 chloroform:methanol solution and air-dried (fume hood) for 48 hours. Feathers were transported to the Smithsonian Institution Museum Support Center in Suitland, Maryland, and equilibrated with the local atmosphere for 72 hours. Four samples (each 0.30–0.35 mg) were clipped from each feather and loaded into a silver capsule that was crushed, pyrolized at 1350°C in an elemental analyzer (Thermo TC/EA), and introduced to an isotope ratio mass spectrometer (Thermo Delta V Advantage) via a Conflo IV interface. Four standards were run for every ten unknowns. Isotope ratios are reported in delta notation relative to Vienna Standard Mean Ocean Water, where

$$\delta D = \left(\left[\frac{{}^{2}H/{}^{1}H_{\text{sample}}}{{}^{2}H/{}^{1}H_{\text{standard}}}\right] - 1\right) \text{ x } 1000.$$

Analytical error (± 1 SD) was better than 2 per mil (2‰), based on replicate analyses of the same feather ($n = 18$). We ran hydrogen (H) standards provided by the International Atomic Energy Agency (IAEA-CH-7) to monitor machine stability and three keratin standards to correct for the combined exchangeable + non-exchangeable H values. The δD values reported include only non-exchangeable H, as determined by a correction via three isotopically different keratin standards (Wassenaar and Hobson 2003).

Results

Mitochondrial DNA (*CO1*) sequences from tissue samples were compared with samples in the BoLD database to obtain 99–100% species match to *B canadensis*. Samples that contained both DNA and feather fragments were verified with whole feather comparisons to museum specimens, and microscopic analysis of downy feather characters was verified through comparison to a known reference library of microslides.

Results from isotope analyses indicated that δD values from feathers extracted from both engines were similar to δD values from feather samples of populations that are known migrants from the Labrador region, and were significantly different from resident feathers collected in New York City (Figure 4). Canada goose feathers from known New York City resident geese were isotopically heavier (ie they contained more hydrogen when normalized to the international standard) but were not significantly different from those of the Newfoundland subpopulation.

Discussion

The identification of the species and origin of the birds involved are of critical importance in prescribing appropriate management approaches to mitigate future risk of birdstrikes. For example, the identification of the species and the parts of the aircraft that were damaged is vital for engineers to improve birdstrike resistance in aircraft and engine components (MacKinnon *et al.* 2001). More reliable reporting of birdstrikes would provide fundamental information on the frequency and timing of such incidents, and – when combined with molecular testing and information on the species involved – could inform airport managers about bird species that present the greatest risk to aircraft, as well as the time of year when each species poses a threat. Compiling such detailed information into a central database could provide the scientific foundation for minimizing the occurrence of future strikes.


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Figure 2. *US Airways Flight 1549 being pulled from the Hudson River in New York City.*

Although these Canada geese were a migratory as opposed to a resident subspecies, we do not believe that these individuals were actually migrating north to return to breeding areas. Instead, we hypothesize that these birds were undertaking a short-distance movement on their wintering grounds in response to freezing temperatures and snow cover, in an effort to find open water and food, a behavior commonly found in species of birds wintering at temperate latitudes.

Historically, most Canada geese were long-distance migrants, but populations have recently established year-round residency in much of their former wintering range (Smith *et al.* 1999), so that year-round residents now outnumber migrants by about 3:1 (Dolbeer and Seubert 2009). Resident geese inhabiting areas near airports may be managed by population reduction, habitat modification, or harassment and removal (Cleary and Dolbeer 2005), whereas migratory populations might require different approaches, such as improved radar technology, to detect and avoid birds (Klope *et al.* 2009). In addition, making aircraft more detectable to birds through advanced lighting systems may also minimize the occurrence of birdstrikes (Blackwell and Bernhardt 2004). Implementing integrative measures such as these is especially urgent, because birdstrike events could become more common. Thirteen of the 14 species of large-bodied birds (>8 pounds or >3.6 kg) in North America have

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Figure 3. *(a) USDA biologists M Begier (inside engine) and A Gosser recover bird remains from US Airways Flight 1549. (b) Samples of feather remains extracted from the number one engine of Flight 1549.*

experienced significant population increases over the past 35 years (Dolbeer and Eschenfelder 2003).

In 1999, the National Transportation Safety Board (NTSB) recommended that the FAA require birdstrikes to be reported (NTSB 1999), but only the US Air Force currently requires such reporting (US Air Force Instruction 2006). In the US, reporting of birdstrikes involving civil aircraft to the FAA is voluntary, and it is estimated that only about 20% of such events are reported and entered into the national database (Cleary *et al.* 2006). Furthermore, only 43% of the 80 000 birdstrikes reported from 1990 to 2007 included any information on the species or groups of birds involved. Increased reporting of birdstrikes with improved information on the exact species involved and other aspects of the event is critical to developing a more comprehensive national program to mitigate the risk of strikes.

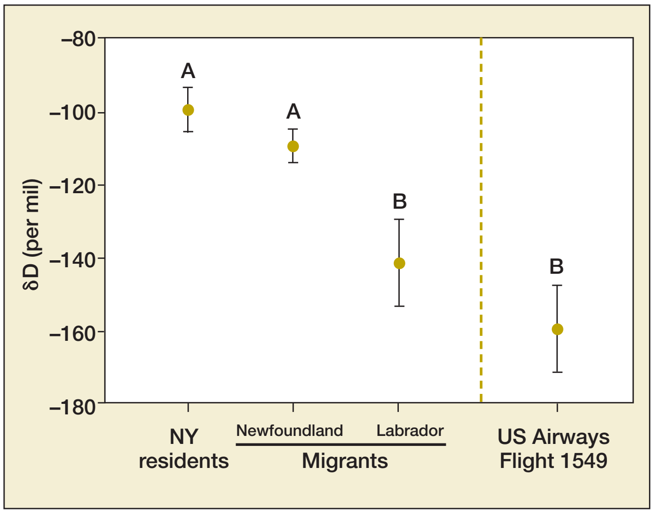

Figure 4. *Mean stable hydrogen isotope signatures (δD) from Canada geese (Branta canadensis) of known migratory status (New York residents, n = 6; Newfoundland migrants, n = 4; Labrador migrants, n = 13) are compared to feather remains of unknown origin obtained from the two engines of US Airways Flight 1549 (n = 4). Error bars indicate 95% confidence intervals. Values with different letters are significantly different using Tukey-Kramer post-hoc mean comparisons (nested analysis of variance;* F = 17.23, P = 0.000004*).*

Finally, our paper demonstrates how molecular genetic tools and stable hydrogen isotope analyses can be applied in a forensic fashion to provide essential, detailed data on the species involved and their geographic origin – information that will be critical in developing strategies to avoid such human–wildlife conflicts in the future. We believe that these forensic approaches, if combined with more efforts to collect data on dead birds, would also enhance the tracking of avian diseases (eg West Nile virus, H5N1 influenza virus) and our ability to predict disease outbreaks, and minimize the numbers of birds (and bats) that collide with and are killed by cell phone towers, wind turbines, buildings, and oil drilling platforms. In the case of the latter, more precise information on the species, their origin, and timing of their collisions can help us to modify these structures either in terms of their location or when they might be operating.

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