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Tracking Canada geese near airports: using spatial data to better inform management

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Abstract: The adaptation of birds to urban environments has created direct hazards to air transportation with the potential for catastrophic incidents. Bird–aircraft collisions involving Canada geese (*Branta canadensis*; goose) pose greater risks to aircraft than many bird species due to their size and flocking behavior. However, information on factors driving movements of geese near airports and within aircraft arrival/departure areas for application to management are limited. To address this need, we deployed 31 neck collar-mounted global positioning system transmitters on Canada geese near Midway International Airport in Chicago, Illinois, USA during November 2015 to February 2016. We used the movement data obtained to model environmental and behavioral factors influencing the intersection of goose movements (i.e., transition from 1 location to another) with air operations areas (i.e., aircraft flight paths). Of 3,008 goose movements recorded, 821 intersected a 3-km buffer around the airport representing U.S. Federal Aviation Administration recommended distances from wildlife attractants, and 399 intersected flight paths for approaching and landing aircraft. The effects of weather (i.e., snow cover, temperature, wind speed) on the probability of geese flying varied with different air operation areas while certain habitat resources greatly increased the probability of intersection. For example, the juxtaposition of foraging (railyards with spilled grain) and loafing areas (rooftops) near the airport led to a higher probability of movements intersecting important air operations areas. The average altitude of flying geese was 29.8 m above the ground, resulting in the greatest risk of collision being within 0.5 km of the end of runways. We suggest airport goose collision mitigation management actions, such as reducing habitat resources near the airport and using focused nonlethal harassment or physical modifications, when guided by animal movement data, may further mitigate bird-strike risks.

Key words: aviation safety, bird–aircraft collision, *Branta Canadensis*, Canada geese, human–wildlife conflicts, global positioning system satellite transmitters, Illinois, risk mitigation, spatial data

Canada geese (*Branta canadensis*; geese) are among the largest and most frequently struck birds by aircraft in North America (Dolbeer 2011). Over 1,400 reported collisions between geese and civil aircraft (hereafter goose strikes) occurred from 1990 to 2012, although more strikes likely went unreported (Dolbeer and Eschenfelder 2003, Dunning 2008, Dolbeer et al. 2014). Since 1988, wildlife collisions with aircraft have led to 262 human fatalities worldwide (U.S. Federal Aviaion Administration [FAA] 2016). In 1995, 24 crew members perished in the crash of a military aircraft following the ingestion of geese into both engines during take-off from Elmendorf Air Force Base in Alaska, USA (U.S. Air Force 1995, Dolbeer et al. 2000, Richardson and West 2000). In 2009, the emergency landing of U.S. Airways 1549 into the Hudson River following take-off from LaGuardia Airport captivated national attention and was attributed to a collision with Canada geese (Marra et al. 2009, National Transportation Safety Board

2010). Goose strikes result in greater monetary loss than any other species due to their size and flocking behavior (FAA 2016). Given the increased risk that geese pose to air traffic, a better understanding of goose behavior is needed to reduce risk of goose strikes.

The abundance of geese wintering in the Greater Chicago Metropolitan Area (GCMA) in Illinois, USA and the large volume of air traffic at the city's 2 international airports pose considerable risk of goose strikes (Dorak et al. 2017). In particular, thousands of geese use parks, wetlands, river corridors, rooftops, and other urban habitats near Chicago's Midway International Airport (Midway) during winter (Dorak et al. 2017). The GCMA population of temperate breeding geese exceeds 30,000 adults (Paine et al. 2003). This population is augmented by migrants from other areas in the United States and Canada, resulting in a substantially greater number present during winter (Paine et al. 2003). Midway is a hub for major commercial airlines, averaging 1,010 flight operations daily in 2016 (FAA 2017). Although there are active wildlife hazard mitigation procedures in place at Midway to help prevent wildlife–aircraft collisions, Canada geese commonly use urban habitat resources near Midway and consequently pose a risk to aircraft (Dorak et al. 2017).

Information on factors driving movements of geese near airports and within aircraft arrival/departure areas are limited (Rutledge et al. 2015). Advancements in global positioning system (GPS) transmitter technologies may provide insights to goose movements and their distribution relative to air operations that were previously unattainable (Avery et al. 2011, Rutledge et al. 2015). For example, if only a small proportion of goose movements pose a risk to aircraft, understanding what specific locations and conditions may increase these risks can help wildlife managers implement more effective management approaches. If specific locations or habitat resources that result in birds flying across air operation areas can be identified, managers can implement management actions to make sites less attractive to geese (Washburn and Seamans 2012).

Nonlethal harassment involving the use of pyrotechnics, dogs, or human disturbance (Castelli and Sleggs 2000, Marra et al. 2009) could be used to increase perceived risks or increase energy expenditure associated with particular locations, and in turn, reduce goose movements that intersect focal departure and arrival areas for aircraft (Rutledge et al. 2015). The effectiveness of these techniques is contingent on the composition of habitat resources in the surrounding landscape and the scale at which selection occurs (Martin et al. 2011). Improving our understanding of how movements of geese across focal air operations areas vary according to specific habitat resource use patterns, over time, and with weather conditions will allow wildlife managers to reduce the risk of goose strike risks to aircraft.

We investigated the movements of Canada geese in the vicinity of Midway to understand the frequency at which their movements intersect air operation areas. Our study objectives were to: (1) quantify the intersection of goose movements (i.e., transition from 1 location to another by flight) with 4 focal air operations areas (e.g., runways), (2) determine the altitude of geese when crossing focal air operations areas, and (3) identify weather (e.g., temperature, snow cover, wind) and behavioral factors (e.g., movements between habitat resources) that influence the probability of goose movements intersecting focal air operations areas. The ultimate goal of the study was to identify factors associated with flights of geese through areas near Midway and identify key locations or habitat resources that could be managed to reduce the probability of goose strikes.

Study area

Our study focused on the area surrounding Midway (41°47′6.5″N, 87°45′6″W), a major commercial airline hub with >22.5 million travelers in 2016 (Chicago Department of Aviation 2016). Midway is in Cook County, a portion of the GCMA of northeastern Illinois. The area surrounding Midway consists mostly of dense residential areas, commercial buildings, factories, and large railyards. Within 8 km of Midway, <2% of the landscape consists of water (i.e., rivers, ponds, canals) and approximately 5% consists of greenspaces (i.e., city parks, cemeteries). The GCMA averages 43 days annually below freezing, with 7 days below -18 °C. The average high temperature in

November is 9 °C with a low of 0 °C. December has an average high of 2 °C with a low of -6 °C, and January has an average high of 0 °C and a low of -9 °C. February has an average high of 2 °C and low of -7 °C (National Oceanic and Atmospheric Administration [NOAA] 2015). Chicago averages approximately 93 cm of snowfall annually (NOAA 2015). The GCMA has a human population of 9.4 million, including the city of Chicago and surrounding suburbs (United States Census Bureau 2013), and a breeding population of Canada geese exceeding 30,000 individuals (Paine et al. 2003).

Methods

We live-captured geese from November 14, 2015 through February 29, 2016 at parks, cemeteries, housing complexes, and a water treatment plant within 12 km of Midway. We chose these sites due to the abundance of geese and their proximity to Midway (Figure 1). Geese were captured using cast nets (commonly used for baitfish) and MagNet™ small animal net-guns (Wildlife Capture Services, Flagstaff, Arizona, USA). We attached U. S. Geological Survey leg bands and GPS Global System for Mobile (GSM) transmitters (Cellular Tracking Technologies [CTT], Somerset, Pennsylvania, USA) mounted on neck collars with unique alphanumeric codes (Spinner Plastics, Springfield, Illinois, USA) on geese selected for study. The GPS-GSM transmitters were solar-powered CTT Generation 3 transmitters (CTT-1000-BT3; $\bar{x}$ = 62.2 grams, SE = 0.2). Transmitters were remotely programmable, scheduled to record a GPS location and altitude (meters above ground level [AGL]) every hour, and connected to GSM networks to upload location data 3 times per week.

Transmitters (n = 31 in 2015–2016) were deployed during 4 time periods each year (mid-November, early December, mid-December, and early January) and across 7 different capture locations that were an average of 7.2 km from Midway (range = 3.7 – 12.0 km; Figure 1). We excluded data from 4 transmitters that failed within 10 days of deployment and redeployed 3 transmitters obtained from hunters. Transmitters were <2% of the body mass of geese ($\bar{x}$ = 4,713 grams, SE =10.6) and all geese were captured and handled using methods approved by the University of Illinois Institutional Animal Care and Use Committee (protocol no. 14155) and Illinois Department of Natural Resources (permit no. W17.6079).

Data analysis

We quantified intersections of goose movements and air operation areas at and nearby Midway during winter from November 16, 2015 to February 28, 2016. We defined a goose movement as the straight line between 2 consecutive GPS locations in which a change in habitat resource type occurred. Goose movements between locations of the same habitat resource type (e.g., moving across a park) were not analyzed because we assumed altitude would have been low and flight time minimal. Movements of geese with location fixes derived from only 1 satellite or with a horizontal dilution of precision of >4 were removed from the dataset in order to maintain locational accuracy (CTT 2015). We also removed goose movements that included a location with a speed of >25 km/hour to exclude in-flight locations for our models of intersecting movements.

We classified movements by the habitat resource types in which they originated and ended. Habitat resource types included: greenspace, open water, rooftop, railyard, or miscellaneous and were classified using available aerial imagery and ancillary information following Dorak et al. (2017). Greenspaces were typically large parks, cemeteries, and other large areas that contained a mixture of trees and shrubs, large sports fields, and golf courses that offered foraging and loafing sites, as well as ponds that may be used as roost areas within their boundaries. Our observations suggest that greenspaces were used primarily for foraging and loafing. Water included large, permanent waterbodies that remained ice free throughout the year (e.g., shipping canals and rivers) as well as smaller wetlands and impoundments that froze during cold periods. Water was used by geese primarily for roosting and loafing. Rooftops were the tops of large commercial buildings including retail stores, factories, distribution centers, and other commercial buildings with flat roofs. Geese used rooftops as loafing locations during winter (Dorak et al. 2017). Railyards included areas used for railroad operations, such as switching yards,

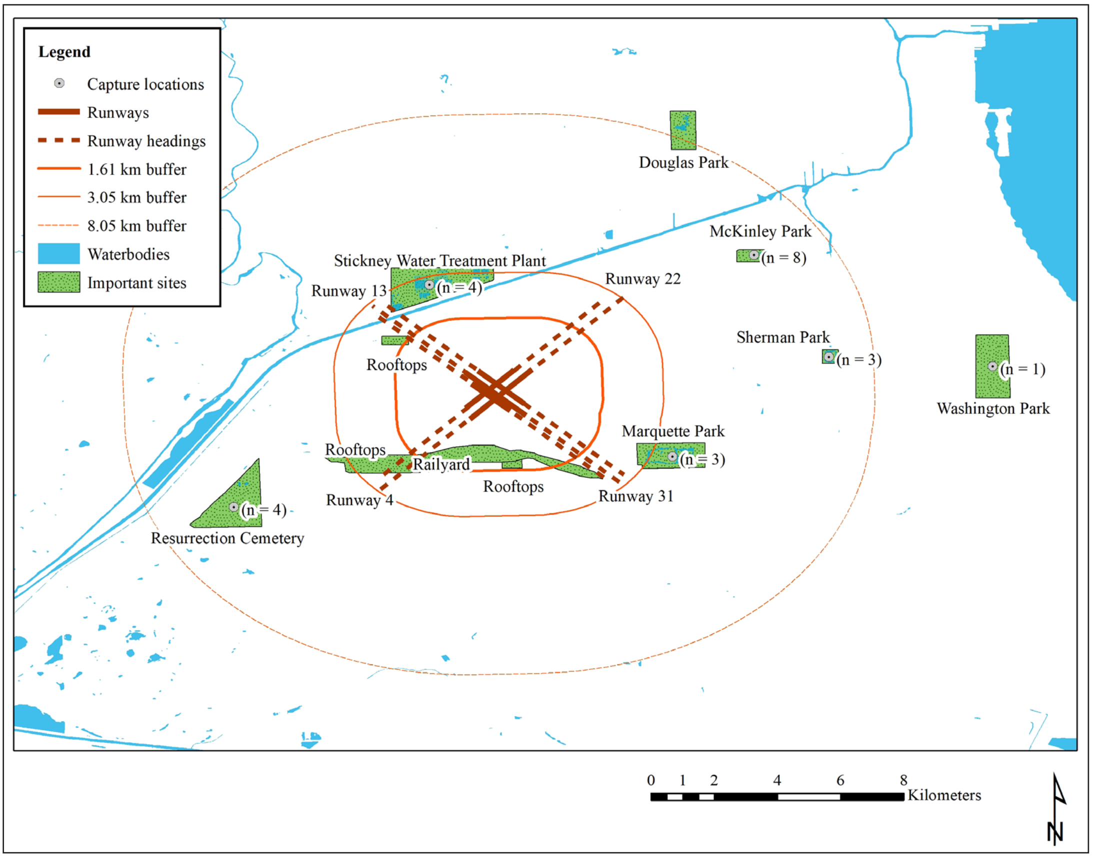

Figure 1. Map of study area surrounding Midway International Airport in Chicago, Illinois, USA with important sites used by Canada geese (*Branta canadensis*) in winter, water bodies, and capture sites.

loading yards, and depots. Railyards likely served as foraging sites due to the existence of grain spilled from train cars loaded with corn (Dorak et al. 2017). Miscellaneous areas mostly consisted of paved or gravel lots within industrial areas.

We chose 4 areas to represent focal air operations areas near Midway. The FAA recommends separation distances between land use practices that attract wildlife (i.e., parks, waterbodies) and airports to reduce risks to air traffic (FAA 2007). The FAA-recommended separation distance is 1.6 km from the edge of airports (i.e., perimeter) serving piston-powered aircraft and 3 km for those serving turbine-powered aircraft (FAA 2007). The FAA also recommends a separation distance of 8 km between airports and habitat resources that cause wildlife movement across approach and departure paths (Cleary and Dolbeer 2005). However, given most geese captured in this study were within 8 km of Midway, we focused on the smaller buffers recommended by the FAA.

We analyzed the intersection of goose movements with runway thresholds based on these separation distances and runway headings extending for 3.2 km from the ends of runways 13/31 and runways 4/22 (hereafter, runway extensions) as an approximation for aircraft approach and departure paths (Figure 1). We estimated the altitude of aircraft per kilometer from the end of runways based on approach charts for runway 31 center (i.e., the most used runway; https://aeronav.faa.gov/d-tpp/1902/00081ILD31C.PDF) to evaluate if the altitude of geese in-flight would pose a risk to air traffic. We used an estimate of 51.5 m AGL per kilometer from the end of runways to compare aircraft altitudes to all in-flight GPS locations of transmitter-marked geese.

We examined the number of daily movements as a function of month using a 1-way analysis of variance (Program R, R Foundation for Statistical Computing, Vienna, Austria). The

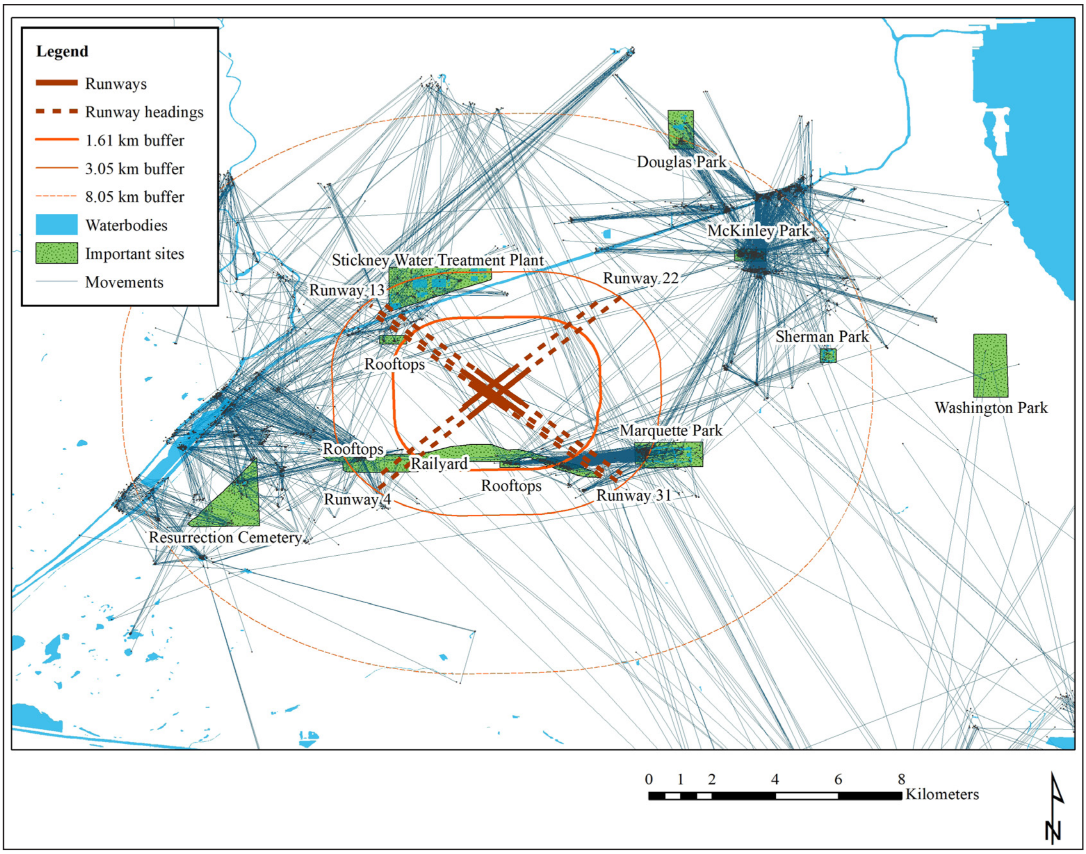

Figure 2. Movements of Canada geese (*Branta canadensis*) in relation to Midway International Airport and runway headings in Chicago, Illinois, USA during November 2015 to February 2016.

binary outcome of movements, intersection or no intersection, were modeled using mixed effect, logistic regression modeling (GLMER) in package lme4 in Program R (Bates et al. 2014). We tested for correlation between predictor variables using a Pearson pairwise correlation (r) analysis and excluded 1 variable in the pair if correlation existed ($|r| \geq 0.7$). We used a suite of biologically plausible predictor variables based on existing literature, which included habitat resource type, temperature (C°), wind speed (km/hour), and snow cover (cm).

Continuous predictor variables (i.e., snow depth, temperature, wind speed) were standardized to 2 standard deviations from the mean values (Gelman 2008). We designated individual goose ID as a random effect to account for subject-specific effects. We ranked the models against a null model using Akaike's Information Criterion (AIC) to identify the most parsimonious model from the candidate model set (Burnham and Anderson 2002) using package MuMIn in Program R. We reported model outcomes for our top ranked model as odds ratios, which approximates the relative probability of a movement intersecting with 1 unit change in the predictor variable. We used predicted probabilities for fixed effects to explore the influence of a specific variable on the probability of a movement intersection by holding all other variables at their means (Muller and MacLehose 2014). We did not fit a model for intersections of runway 4/22 extensions because too few intersections occurred, while too many intersected the 8.05 km buffer for model convergence. We detected no correlation between parameters; thus, all parameters were included in models (Pearson, $P < 0.15$).

Results

We recorded 3,008 movements from 24 GPS transmitter-marked geese (Figure 2). Geese traveled an average of 1.48 (±0.20 SE, range 0.07–

Table 1. Percentage of intersecting movements by associated habitat resource types of global positioning system transmitter-marked Canada geese (*Branta canadensis*; n = 24) intersecting buffers (1.61 km and 3.05 km) and extensions of runways at Midway International Airport, Chicago, Illinois, USA during November 16, 2015 to February 28, 2016.

		Intersecting				Movements
Habitat type	n	1.61 km	3.05 km	Runway 13/31	Runways 4/22	Total
Greenspace/miscellaneous	24	4%	6%	2.8%	21.1%	168
Greenspace/railyard	22	32%	30.8%	47.4%	9.2%	557
Greenspace/rooftop	24	34.7%	22.3%	28.8%	14.5%	340
Greenspace/water	17	12%	11.9%	6.5%	30.3%	1,331
Railyard/miscellaneous	17	2.2%	7.3%	1.8%	1.3%	67
Railyard/water	21	8.9%	10%	6%	9.2%	213
Rooftop/water	20	4%	5.2%	3.5%	7.9%	90
Water/miscellaneous	23	2.2%	6.5%	3.3%	6.6%	242
Total intersections	24	225	821	399	76	3,008

Table 2. Logistic regression models of the effects of time of day, snow cover (cm), temperature (C°), habitat resource types (type), and wind speed (km/hour) on the probability of Canada goose (*Branta canadensis*) movements intersecting extensions of runways 13/31 and 3-km buffer at Midway International Airport in Chicago, Illinois, USA between November 16, 2015 and February 28, 2016. Models are ranked from best to worst based on Akaike's Information Criteria (AIC), delta (Δ_i), and Akaike weights (w_i); AIC is based on -2 x log likelihood (L) and the number of parameters in the model (K).

Area	Models	AIC	ΔAIC	w_i	K	Log-likelihood	Evidence ratio
3-km buffer	snow cover + temperature + type + wind speed	1045.94	0.00	0.73	12	-510.92	0
	temperature + type + wind speed	1047.98	2.04	0.26	11	-512.95	2.78
	type	1054.70	8.76	0.01	9	-518.32	79.91
	type + temperature	1056.50	10.56	0.00	10	-518.21	196.64
	null	1266.56	220.62	0.00	2	-631.28	8.06×10^{47}
Runways 13/31	temperature + type + wind speed	908.49	0.00	0.69	11	-443.20	0
	snow cover + temperature + type + wind speed	910.15	1.66	0.30	12	-443.02	2.29
	type + temperature	919.36	10.87	0.00	10	-449.64	229.47
	type	920.94	12.45	0.00	9	-451.44	504.5
	null	1002.14	93.65	0.00	2	-499.07	2.17×10^{20}

3.69) movements per day. The average number of movements varied by months ($F_{3, 2.7}$ = 17.27, $P < 0.001$) and was greatest in January (1.91 movements ± 0.21 SE), followed by February (1.71 ± 0.22 SE), December (0.76 ± 0.20 SE), and November (0.22 ± 0.12 SE). Across individuals and months, 821 (27.3%) movements intersected the 3-km buffer and 225 (7.5%) movements intersected the 1.6-km buffer around Midway. Extensions of runways 13/31 were intersected more frequently (13.3% of movements, n = 399) than extensions of runways 4/22 (2.52% of movements, n = 76). We recorded an average of 0.23 (± 0.05 SE, n = 1,824) intersections with extensions of runway 13/31 per bird per day. Only 18 instances of movements intersecting the Midway airfield were recorded during our study (0.6% of movements).

Greater than 70% of the intersections with each air operations area originated from goose movements associated with greenspaces (Table 1). Movements of geese between greenspaces and railyards had the most intersections with the 3-km buffer (30.8%, n = 253), followed by movement between greenspaces and rooftops (22.3%, n = 183) and greenspaces and water (11.9%, n = 98; Table 1). For runway 13/31 extensions, goose movement between greenspace and railyards contributed the highest percentage of the intersecting movements (47.4%, n = 189), followed by movement between greenspace and rooftops (28.8%, n = 115; Table 1).

We fit models only for extensions of runways 13/31 and the 3-km buffer. Too few intersections of extensions of runway 4/22 and 1.6-km buffer and too many intersections with the 8-km buffer occurred for model fitting. The global model including the effects of temperature, snow depth, wind speed, and habitat resource type was the most supported model for the 3-km buffer (ΔAIC $\leq$ 2; Arnold 2010; Table 2). The top supported model for runways 13/31 was similar except for the exclusion of snow depth; however, the global model was closely ranked so we report those results for ease of interpretation (Table 2). The log odds ratios can be interpreted as change in likelihood based on 1 unit increase in the parameter with all other variables held at their mean. For example, movements between water and rooftops were 1.78 times more likely to intersect the 3-km buffer than not (Figure 3).

Goose movements associated with rooftops and railyards were more likely to intersect both the 13/31 runway extensions and the 3-km buffer (Figure 3). Conversely, many of the goose movements associated with water to miscellaneous habitat resources and greenspace to water led to movements that were less likely to intersect with air operation areas (Figure 3). Increased wind speed had a negative effect on the intersection of movements for both 13/31 runway extensions a 3-km buffer, whereas increased snow cover had a positive effect but confidence intervals overlapped zero.

Altitudes of geese (n = 23) in-flight ranged from 1–149 m AGL, with an average altitude of 29.8 m (n = 377; Figure 4). We estimated the altitude of commercial aircraft at 0.5 km from the end of a runway to be 25.7 m AGL, 51.5 m AGL at 1 km from the end of the runway, and 102.9 m AGL at 2 km from the end of the runway. Therefore, at 2 km from runway 31, only 1.1% of flying geese would be at an altitude to pose a risk of a strike, whereas 13.3% of flying geese would pose a risk at 1 km, and 49.9% of flying geese at 0.5 km from the end of the runway.

Discussion

More than a quarter of goose movements we detected intersected focal air operations areas in our study, despite ongoing wildlife management efforts to dissuade geese from using areas on and near Midway. These intersections are driven by novel habitat resources (i.e., rooftops and railyards) that facilitate overwintering of geese near Midway.

Our results suggest there is a 22.5% chance that an individual goose in our study area would intersect the 3-km buffer on given day. Assuming a conservative estimate of 10,000 geese in our study area (C. Pullins, U.S. Department of Agriculture - Wildlife Services, personal communication), that would result in 2,250 potential intersections of geese with extensions of runways 13/31 a day during the 2015–2016 winter. Encouragingly, <1% of the intersections were over Midway, and average altitude of geese in flight was lower than air traffic except immediately prior to landing and after take-off.

We attribute the relatively low number of intersections to wildlife management efforts to reduce wildlife conflicts at Midway, similar to those conducted at other airports in the United States (Cleary and Dolbeer 2005). The altitudes at which geese make local movements appears to be below the flight paths of aircraft using Midway. At 0.5 km, we estimated the altitude of an aircraft at 25.7 m, and the average altitude of geese was 29.8 m; thus, the greatest risk occurs in areas 0.5 km from the runways. A previous description of altitude distribution of temperate-breeding geese reported a slightly lower average altitude with only 9% of movements occurring above 30 m AGL (Rutledge et al. 2015), compared to 38% in our study.

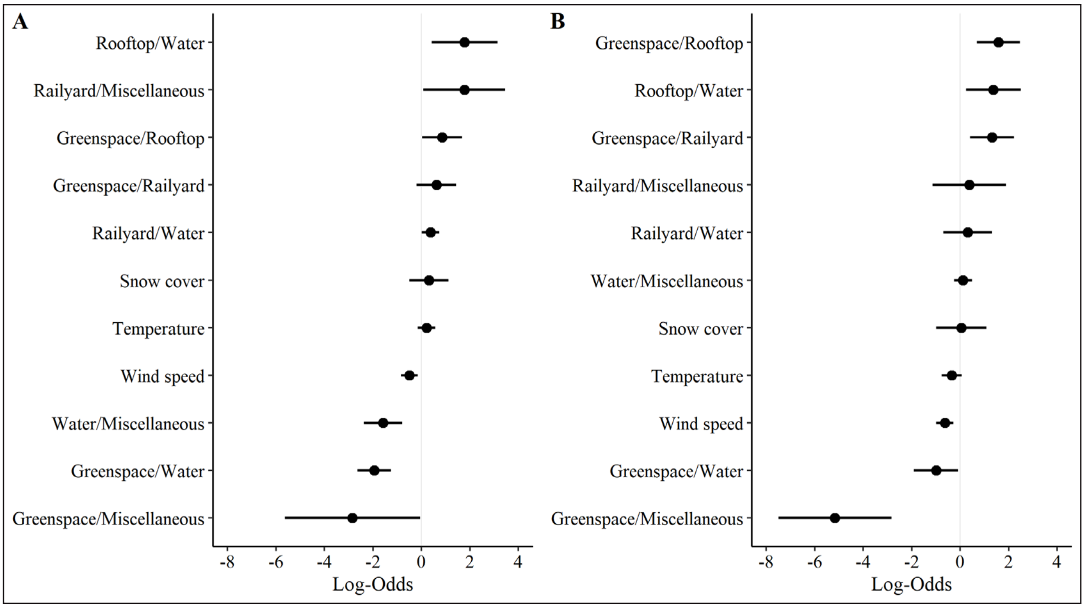

Figure 3. Log-odds of fixed effects in logistic regression mixed models of Canada geese (*Branta canadensis*) movements intersecting (A) 3.05-km buffer and (B) extensions of runway headings 13/31 at Midway International Airport in Chicago, Illinois, USA during November 2015 to February 2016.

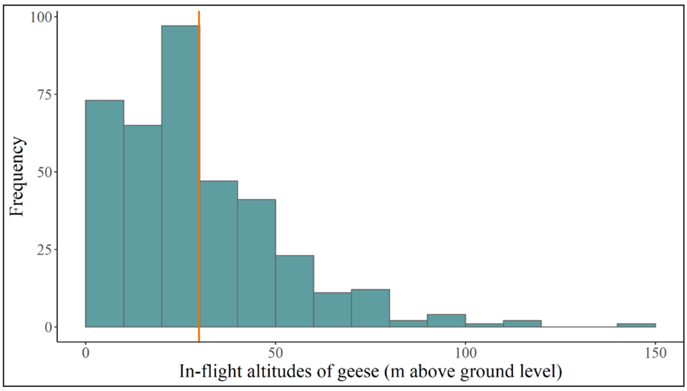

Figure 4. Frequency distribution of in-flight altitudes (m AGL) from global positioning system (GPS) fixes (n = 377) of GPS transmitter-marked Canada geese (*Branta canadensis*) during November 2015 to February 2016 in Chicago, Illinois, USA. The mean altitude of in-flight GPS fixes ($\bar{x}$ = 29.8 m AGL) is denoted by the vertical orange bar.

Bird strike data suggests that around 50% of damaging goose strikes occurred above 152.5 m AGL between 2005 and 2009 (Dolbeer 2011), and Flight 1549 was at 884 m AGL when it struck a flock of Canada geese (Marra et al. 2009). These goose strikes are likely associated with migratory movements that are not influenced by local habitat resources (Marra et al. 2009). Although we don't dismiss the risk of goose strike associated with migratory movements, we suggest that understanding local movements and associated weather and habitat resources provides actionable information for wildlife managers.

Traditionally, much of the research and management associated with wildlife–aircraft strike risks has been focused within the airport boundary; however, researchers and managers are increasingly considering landscape composition and context near airports (Dolbeer 2006, Martin et al. 2011). Understanding the interplay among environmental factors, landscape composition, and the juxtaposition of habitat resources for wildlife is necessary to guide effective management actions (Martin et al. 2011).

Several habitat resource types commonly used by geese occur near Midway, particularly a large railyard and industrial rooftops just south of the airport. Nearly 50% of intersections of the 3-km buffer and >50% of intersection with extensions of runways 13/31 are associated with this railyard. Railyards have not traditionally been considered a habitat resource for geese and are relatively limited on the landscape compared to greenspaces and permanent water.

However, geese likely use railyards to forage on spilled grain, highlighting the adaptability of geese under limited resource conditions.

The use of industrial rooftops as roosting and loafing sites has only recently been described (Dorak et al. 2017), but 35% of the intersections with the 1.6-km buffer in this study were birds moving to or from rooftops. Given the large number of rooftops available for geese in the area surrounding Midway, it would be difficult to effectively manage every rooftop to dissuade use. However, goose movements that intersect important air operations areas in this study were associated with a limited number of rooftops located primarily south and northwest of Midway. By reducing the goose use of these rooftops through habitat alteration (e.g., wire grids; Smith et al. 1999) and decreasing the accessibility of food in railyards, the probability of goose–aircraft strikes could likely be reduced.

Similar to rooftops, geese appeared to use the Chicago Shipping Canal in order to avoid disturbance and conserve energy (Dorak 2016). Nonlethal harassment and other deterrent methods could be used there to potentially reduce goose use of the canal but is unlikely to be very effective due to the large area and the fact that relatively few goose movements to and from water intersected with air operation areas.

Although weather conditions are beyond the control of managers, their effect on goose movements and habitat use may have important implications regarding the timing and location of management actions. The relationship between weather variables and the intersection of goose movements with important airspaces is complex and likely interrelated with landscape composition, food availability, and levels of disturbance in the vicinity of Midway (Dorak et al. 2017).

Geese wintering near Midway are remaining north of their traditional wintering grounds (Gates et al. 2001) and may become energetically stressed during cold weather, especially if food is limited. Scarce resources (i.e., waterbodies freezing, snow cover decrease food availability) likely force geese to move more frequently and to habitat resources where food and water remains accessible. Increased movements during periods of scarce resources is supported by a greater number of movements in January and February. In our study area, spilled and waste grain in the railyards and the ice-free waterbodies of the Chicago Shipping Canal appear to concentrate geese during colder periods.

Our study was limited to a single area and season, but our results and findings are likely informative to airports in highly urbanized areas of North America. Other studies have suggested that effective large-scale management would require sustained efforts within an 8-km radius to reduce the abundance of geese that pose risks to air traffic (Holevinski et al. 2007, Seamans et al. 2009, Rutledge et al. 2015). We suspect goose abundances within an 8-km radius around Midway would be extremely challenging despite the relatively discrete patches of available habitat resources.

Management implications

Our results highlight how high-resolution data on the movements of geese (or other wildlife) may help focus management on sites and weather conditions that are most impactful. Wildlife managers should consider nontraditional urban habitat resources, such as rooftops and railyards, as these accounted for most intersections with focal air operation areas. Integrated goose management programs have the potential to mitigate the risk of goose strikes associated with local movements. Continued research examining goose movement in conjunction with management actions is important to determine if geese move to new locations that reduce risks or whether they simply move to other locations that maintain or increase potential intersections with air operations areas.

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