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Note

Evaluation of Resident Canada Goose Movements to Reduce the Risk of Goose-Aircraft Collisions at Suburban Airports

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ABSTRACT Resident (non-migratory) Canada goose (*Branta canadensis*) populations in suburban environments pose risks to human health and safety. Specifically, the relatively large size and gregarious behavior of geese combined with an overlap in aircraft flight space pose substantial risk of property damage and human fatalities from goose-aircraft collisions. We estimated home range and core use areas of resident Canada geese and evaluated goose movements to better define the risk of goose-aircraft collisions around Piedmont Triad International Airport in Greensboro, North Carolina, USA. We placed satellite transmitters on 16 of 763 neck- and leg-banded geese to identify and track individuals over an 18-month study period. The frequency of satellite-tagged goose movements peaked daily within the first 2 hours after sunrise (28.1%) and again near sunset (27.2%). All in-flight goose movements occurred $\leq$64 m above ground level. Geese flying at these altitudes posed a risk to aircraft in the take-off and landing phases of flight. For all in-flight movements, the number of movements per day was 0.13 during the molt (1 Jun–15 Jul), 0.42 during early post-molt 2008 (16 Jul–31 Oct), 0.36 during late post-molt (1 Nov–31 Jan), 0.58 during breeding/nesting (1 Feb–31 May), and 0.58 during the early post-molt 2009. Satellite-tagged geese traveled a mean distance ranging from 2.0 km (SE = 0.3) to 4.9 km (SE = 0.4) per day, depending on sex and season, which supports the need for intensive goose management within a minimum distance of 8 km from airports. Mean fixed 95% kernel home range and 50% core use area were 991.8 ha (SE = 241.1) and 120.4 ha (SE = 24.6), respectively. Additionally, we monitored site recolonization of nuisance geese after the controlled removal of 60 resident geese from 1 site, which eliminated 24.2% of those initially banded at the site in 2008, but other geese began to recolonize the site within 27 days. Rapid recolonization of the removal site suggests that lethal removal should be conducted at all molt locations within a minimum distance of 8 km of suburban airports and any additional removal or management resources should be applied to greater distances to prevent recolonization of these sites by geese in close proximity to the removal site. Published 2015. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS airport risk, birdstrikes, *Branta canadensis*, controlled removal, home range, movements, North Carolina, resident Canada geese, survival, telemetry.

Resident Canada goose (*Branta canadensis*) movements across suburban landscapes may increase the number and severity of human-goose interactions. Geese contaminate water sources (Manny et al. 1994, Allan et al. 1995), degrade habitat, can be aggressive toward humans (Smith et al. 1999), and may have the potential to transmit diseases (Graczyk et al. 1998, Smith et al. 1999, Kullas et al. 2002, Rutledge et al. 2013). Additionally, resident Canada geese pose a threat to human safety near airports. To properly manage suburban goose populations and alleviate the risk for goose-aircraft collisions, it is important to know where geese are moving and at what altitude, how often these movements occur, and how much time is spent at sites where geese pose risks to human health and safety.

Wildlife-aircraft strikes have resulted in more than 250 human fatalities and 229 aircraft destroyed since 1988, and birds account for 97% of strikes (Dolbeer et al. 2013). Numerous species (e.g., Canada geese, vultures, gulls, blackbirds, pelicans, herons, and raptors) have been implicated in bird strikes, causing concern for public safety at and near airports (Dolbeer et al. 2013).

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Additionally, populations of many large bird species have increased (Dolbeer and Eschenfelder 2003), and an estimated 80% of bird strikes go unreported (Cleary et al. 2005). Geese have been ranked as the third most hazardous wildlife species to aircraft (Dolbeer et al. 2000), with approximately 240 goose-aircraft collisions occurring in the United States each year (Smith et al. 1999). In 1995, 13 Canada geese were ingested by a United States Air Force jet at takeoff, killing all on board (Smith et al. 1999). In 2009, a commercial plane carrying 155 people made an unexpected landing in the Hudson River in New York after engine failure following the ingestion of Canada geese (Marra et al. 2009).

Resident Canada geese have high survival rates in suburban areas because of ample resources (e.g., water bodies and open areas of grass) and protection from natural predators (McCoy 2000, Rutledge et al. 2015). The adaptability of geese to human-dominated environments and opposition to lethal management have made efforts to control goose populations difficult (Ankney 1996). Between 1990 and 2009, the number of Canada geese in the United States increased from an estimated 2.5 million to more than 5 million birds, intensifying the concern for human safety at or near urban and suburban airports (Dolbeer 2011). Aircraft are particularly vulnerable to goose-aircraft collisions at takeoff and landing (Cleary and Dolbeer 2005) because of the relatively large size of geese (approx. 3.6–4.5 kg), their gregarious behavior, and overlap in altitude with aircraft; 74% of bird strikes occur at <152 m in altitude (based on data collected between 1990 and 2004) and nearly 95% occur at ≤1,067 m (Dolbeer 2006, Martin et al. 2011).

Although management techniques (e.g., scare tactics, lethal removal, bird avoidance mechanisms) have proven effective at reducing the immediate threat of goose-aircraft collisions on airport property, little is known about the movements of resident geese that pose longer-term risk at suburban airports. Quantification of goose movements can be used to determine when and where management practices should occur outside of airport boundaries. Therefore, our objectives were to 1) determine home range and core use areas of resident Canada geese near a suburban airport, 2) evaluate goose movements on and around a suburban airport, 3) conduct an experimental goose removal and monitor recolonization rates, and 4) use study results to guide management of resident Canada goose populations near suburban airports.

STUDY AREA

We conducted our study around Piedmont Triad International (PTI) Airport in Greensboro, North Carolina, which has a human population of approximately 277,000, and covers nearly 344 km^2 (City of Greensboro 2013). The airport (36°06′18″N, 79°56′17″W) is operated by the Piedmont Triad Airport Authority and encompasses more than 1,130 ha (U.S. Department of Agriculture [USDA] 2005). In 2009, the airport accommodated 1.7 million passengers, with an estimated 242 aircraft operations per day (J. Beadle, PTI Airport, personal communication).

The airport property was comprised of mature hardwood and pine stands, areas of open grass, and drainage areas (USDA 2005), with approximately 62 retention (corporate and residential) and recreational ponds within 1.6 km of the airport (Google Earth v. 5.0.11337, Mountain View, CA). The airport enforces a no-goose policy within the approximately 3-m-high perimeter fence, but there have been at least 6 documented Canada goose-aircraft related strikes at PTI Airport since 2002. The most notable occurred in October 2002, when a B-737-300 struck 16 geese (4 were ingested into the engines and 12 collided with the wings and front of the plane) while landing; there was damage to the plane but no human fatalities (USDA 2005).

METHODS

We neck- and leg-banded 763 resident Canada geese at 14 sites within 8 km of PTI Airport in June of 2008 (Fig. 1). Banding sites, selected based on goose presence, consisted of airport property (*n* = 1), local parks and lakes (*n* = 4), a residential area (*n* = 1), corporate landscapes (*n* = 6), a golf course (*n* = 1), and a rock quarry (*n* = 1). We live-captured geese and recorded the sex (cloacal examination), weight, and age (plumage evaluation) of each goose at banding (Pyle 2008). Of the 763 banded geese, 44% were male and 56% were female; 89% were adults (after hatch year) and 11% were juveniles (hatch year). The mean weight for all male and female geese was 4.0 kg (SE = 0.1) and 3.5 kg (SE = 0.1), respectively. To identify and track individual geese, we used auxiliary neck bands (Spinner Plastics, Springfield, IL) with unique 4-character alpha-numeric codes and standard United States Fish and Wildlife Service aluminum bands (size 8; U.S. Geological Survey Bird Banding Lab, Laurel, MD).

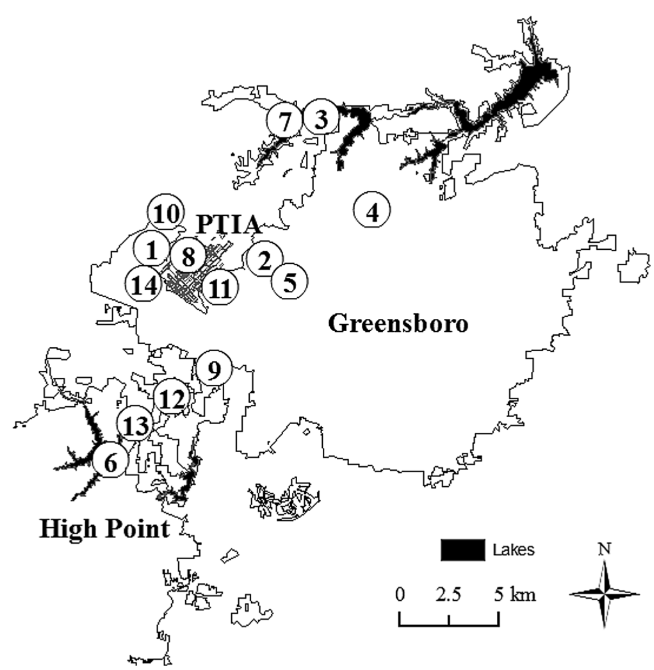

Figure 1. Map of Piedmont Triad International Airport (PTIA) and the location of 14 goose banding sites in and around Greensboro, North Carolina, 2008–2009.

In August 2008, we attached Platform Transmitter Terminal (PTT)-100 70-g solar-powered Argos/Global Positioning System (GPS) satellite telemetry units (Microwave Telemetry, Inc., Columbia, MD 21045) to 16 adult geese that we opportunistically selected from the population of previously banded geese. We placed the satellite transmitters between the wings of each goose and tightly secured them with Teflon straps (Bally Ribbon Mills, Bally, PA) looped across the breast. We set the duty cycle to obtain 19 evenly spaced locations/goose/day during 0500 and 2300 hours Eastern Standard Time (EST). For each GPS location obtained, we received the associated flight speed (kph) and altitude (m above sea level). We minimized capture and handling time, used the most practical technology available for our species and objectives, and used an accepted method of transmitter attachment to reduce stress to the geese in our study.

We conducted all movement analyses using telemetry locations, and we analyzed data for the following 4 predefined seasons: molt (1 Jun–15 Jul), post-molt I (16 Jul–31 Oct), post-molt II (1 Nov–31 Jan), and breeding/nesting (1 Feb–31 May) to evaluate changes in the frequency and distance of movements throughout a goose's annual cycle. Post-molt I represents the time period after the molt has occurred leading up to post-molt II, which is indicative of the potential arrival of migratory geese during the winter months. We analyzed the post-molt I data for 2008 and 2009 for comparison between years.

Flight and Movement Analysis

To quantify the frequency of daily and seasonal goose movements around the airport, we used all telemetry locations that were considered in-flight (i.e., corresponding speed $\geq$6 kph and an altitude $>$1 m; $n = 217$). We calculated the mean altitude for all satellite-tagged geese combined and used the telemetry data to quantify the percent of locations within 8 km of PTI Airport because 8 km is the recommended distance between an airport's air operations area and a hazardous wildlife attractant (Federal Aviation Administration [FAA] 2007). We determined the mean distance of the farthest recorded locations of geese from their banding sites, the maximum distance traveled from each goose's banding site, the average percentage of locations at each goose's banding site, the maximum distance traveled between 2 consecutive telemetry locations, and the mean distance traveled per day (by sex and season). We used 2-way analysis of variance (ANOVA) to determine if the mean distance geese traveled per day varied between sexes or among seasons (Zar 1996). We considered differences significant at $P \leq 0.05$.

We created an altitude occurrence matrix (Avery et al. 2011) using 144 of the 217 in-flight locations to determine the percent of goose movements within designated altitudinal ranges (altitudinal ranges were categorized into 7, 10-m increments from 0–70 m AGL). We removed 73 of the 217 in-flight locations because of inaccurate altitude readings and adjusted all movement data based on sunrise for Greensboro, North Carolina. We determined the frequency of occurrence of goose movements for 217 telemetry locations based on hours after sunrise (0 to 15 hr; −1 represented the hour prior to sunrise).

Home Range Analysis

We used Home Range Tools (HRT; Rodgers et al. 2007) in ArcGIS version 9.3.1 (ESRI, Redlands, CA) to estimate the home range and core use area of each satellite-tagged goose. Prior to analysis, we converted all telemetry data collected between August 2008–November 2009 to EST and Universal Transverse Mercator coordinates. We calculated 95% and 50% utilization distributions (UD) using the fixed-kernel density estimation technique (Seaman and Powell 1996). Least-squares cross-validation frequently is used for kernel density estimation (kde) with animal movements, but HRT was unable to minimize the mean integrated square error for our data sets. Because HRT was unable to calculate a value for the smoothing parameter (h) that minimized the mean integrated square error, we used reference bandwidth (H_{ref}) to maintain the integrity of the data. The H_{ref} method of selecting a smoothing parameter is predefined and based on a known standard distribution, which assumes the data are normally distributed in space (Rodgers et al. 2007). We used the reference bandwidth (H_{ref}) as the primary method of determining the smoothing parameter; however, we used defined proportions of the H_{ref} when HRT was unable to create proper UDs. We rescaled to unit variance as needed ($<$0.5 or $>$1.5 x/y ratio; Rodgers et al. 2007) and used a reference grid-cell resolution of 10 m and a scaling factor of 1,000,000. Additionally, we used HRT to estimate the home range and core use area of each satellite-tagged goose for the following seasons: molt (1 Jun–15 Jul), post-molt I (16 Jul–31 Oct), post-molt II (1 Nov–31 Jan), and breeding/nesting (1 Feb–31 May). We used 2-way ANOVA to determine if the 95% home ranges and 50% core use areas varied between sexes or among seasons (Zar 1996).

Controlled Removal

In June 2009, we conducted a controlled goose removal at an original banding site to evaluate the rate of goose recolonization. We removed all resident geese from the site and determined the rate of recolonization by recording resightings of the neck-banded geese on 13 random sampling days between 30 June and 3 December 2009. We determined the origin of the recolonizing geese based on neckband resightings from prior locations. All field techniques were approved by the North Carolina State University Institutional Animal Care and Use Committee (Protocol 08-038-O) and in accordance with all state and federal permits.

RESULTS

Flight and Movement Analysis

More than 99% of the telemetry locations (approximately 52,000) were within 8 km of PTI Airport, and 5.9% of these locations were on airport property. Based on the satellite telemetry data, geese flew at a mean altitude of 17.1 m (SE = 1.0) AGL with a maximum recorded altitude of 64 m

AGL and a maximum recorded speed of 95 kph. The altitude occurrence matrix revealed that 28.1% ($n = 61$) of in-flight movements occurred within the first 2 hours after sunrise and an additional 27.2% ($n = 59$) occurred within a 2-hour period close to sunset. The remaining 44.7% ($n = 97$) were dispersed throughout the day (Fig. 2). Overall, 37.5% ($n = 54$) of movements occurred within 0–10 m AGL, 25.7% ($n = 37$) within 11–20 m AGL, 27.8% ($n = 40$) within 21–30 m AGL, and 9.0% ($n = 13$) at an altitude >30 m AGL. The frequency of goose movements categorized by hour after sunrise varied by season (Fig. 3). For all in-flight movements, the number of movements per day was 0.13 during the molt, 0.42 during the 2008 post-molt I, 0.36 during post-molt II, 0.58 during breeding/nesting, and 0.58 during the 2009 post-molt I. During the breeding/nesting season, resident geese made localized movements, typically within 2 km of their banding site, at all hours of the day (0–15 hr after sunrise). The frequency of movements during the post-molt I season peaked around 1 hour after sunrise and again between 12 and 14 hours after sunrise (Fig. 3).

The mean of the farthest distance the satellite-tagged geese were recorded from their banding site was 9.5 km (SE = 2.0), and the mean distance traveled per day was as great as 4.9 km (SE = 0.4), with results varying by sex and season (Table 1). We detected a sex by season interaction ($F_{3,\ 1,213} = 14.3$, $P < 0.001$). Geese moved significantly farther during post-molt I and post-molt II than during the breeding/nesting or molt seasons. Males moved greater distances than females during the post-molt I and post-molt II seasons, but the sexes moved similarly during breeding/nesting and molt. The maximum distance a satellite-tagged goose was located from its banding site was 26.1 km and the farthest recorded distance traveled between consecutive locations was 6.2 km, which occurred between 1700 and 1800 hours. The average percent of telemetry locations recorded at each goose's banding site during the study period was 38.6% (SE = 6.7), and 93% of geese used the same site to molt in 2009 as in 2008.

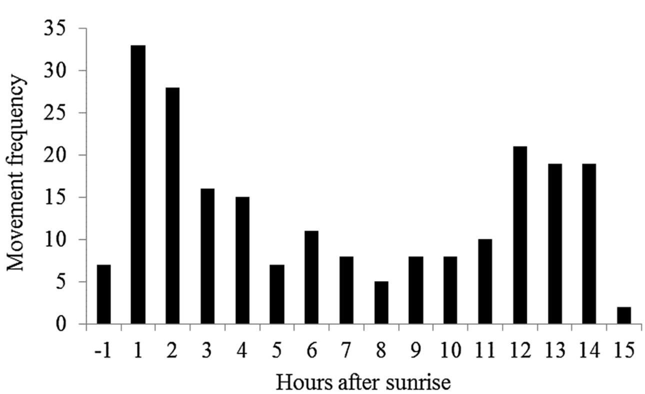

Figure 2. Frequency of resident Canada goose movements categorized by hours after sunrise (1–15 hr; −1 represents the hour prior to sunrise). Telemetry locations ($n = 217$) were in and around Greensboro, North Carolina, 2008–2009.

Home Range Analysis

The telemetry data used in the home range and core use area analysis was collected between June 2008 and December 2009 and ranged from 513 to 5,440 locations per goose (Table 2). Not all transmitters collected data for the entire duration of

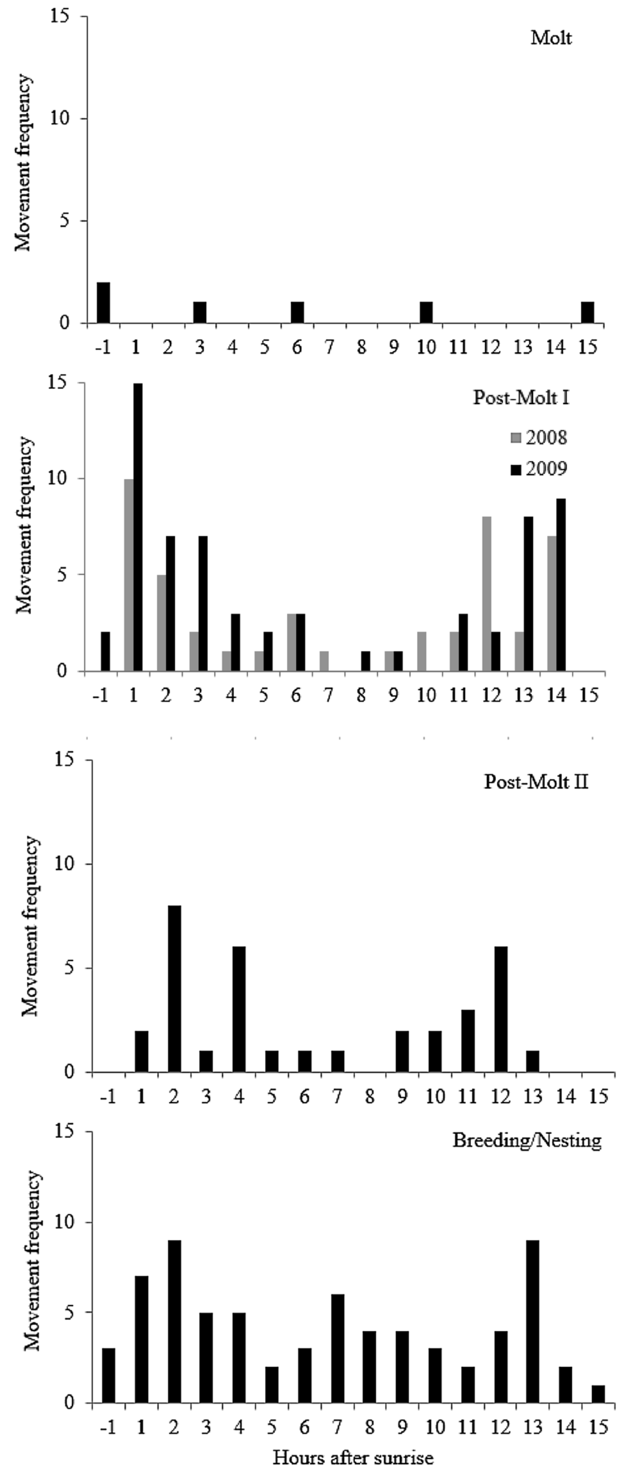

Figure 3. Frequency of resident Canada goose movements categorized by hour after sunrise (−1 representing the hour prior to sunrise) during molt (1 Jun–15 Jul), post-molt I (16 Jul–31 Oct), post-molt II (1 Nov–31 Jan), and breeding/nesting (1 Feb–31 May). We analyzed the post-molt I season by year (2008 and 2009). Telemetry locations ($n = 217$) were in and around Greensboro, North Carolina, 2008–2009.

Table 1. The mean distance geese traveled per day (km) categorized by sex and among 4 seasons (molt [1 Jun–15 Jul], post-molt I [16 Jul–31 Oct; both years], post-molt II [1 Nov–31 Jan], and breeding/nesting [1 Feb–31 May]) in and around Greensboro, North Carolina, 2008–2009. Also, we present the number of days (19 data points/day) evaluated per analysis (n).

		n	Distance (km)	SE
Molt				
	Male	22	2.0	0.3
	Female	30	2.1	0.2
Post-molt I				
	Male	197	4.8	0.2
	Female	302	4.1	0.2
Post-molt II				
	Male	59	4.9	0.4
	Female	98	2.4	0.2
Breeding/nesting				
	Male	188	2.2	0.1
	Female	318	2.6	0.1

the study period. All telemetry data analyses included 16 individuals. The fixed kernel 95% UD for geese ranged from 76.0 to 3,755.6 ha (mean = 991.8 ha, SE = 241.1) and the core use area estimate (50% UD) ranged from 14.2 to 326.2 ha (mean = 120.4 ha, SE = 24.6; Table 2). The mean 95% and 50% UD seasonal estimates ranged from 81.0 (SE = 29.8) to 866.4 ha (SE = 384.7) and 12.1 (SE = 4.3) to 114.2 ha (SE = 51.1), respectively (Table 3). Although the home range ($F_{4,\ 65} = 2.9$, $P = 0.03$) and core use area ($F_{4,\ 65} = 3.5$, $P = 0.01$) sizes varied among seasons, the home range ($F_{1,\ 65} = 0.2$, $P = 0.67$) and core use area ($F_{1,\ 65} = 2.2$, $P = 0.14$) sizes did not vary between male and female geese (Table 4).

Controlled Removal

On 25 June 2009, we lethally removed 60 (22 banded; 38 unmarked) resident Canada geese from 1 site (Fig. 4; site 10). Of the removed geese that were banded, 68.2% ($n = 15$) were banded at site 10 in 2008 and 31.8% ($n = 7$) were banded at sites 1 and 8 in 2008 (Fig. 4). The removal site remained unoccupied for 27 days before geese (7 banded; 10 unmarked) were sighted. During the first 2 resighting events, all banded geese originated from sites 1 or 10 (Fig. 4). Goose presence peaked at 46 days post-removal, with 31 banded and 73 unmarked geese. At that time, 87.0% ($n = 27$) of the banded geese originated from sites 1 or 10 and the remaining 13.0% ($n = 4$) originated from sites 2, 8, and 14 (Fig. 4). Thirteen percent of these geese had not been resighted at the removal site during the previous year. Newly identified banded geese originating from sites 4, 9, and 11 continued to access the removal site from up to 10.5 km (Fig. 4).

DISCUSSION

Results from our study indicate resident Canada geese pose the greatest risk to aircraft at take-off and landing during morning and evening hours as they move to and from foraging and roosting sites, and in-flight movements peaked between mid-July and late October. Therefore, increased awareness of goose movements by airport managers is imperative during these periods when the potential for goose-aircraft collisions is heightened. Sites with abundant grass and water near PTI Airport provided foraging and roosting opportunities for resident geese, which increased the likelihood geese would access PTI Airport airspace while moving freely across the landscape. All resident Canada goose movements were recorded at altitudes ≤64 m AGL. Interestingly, within the last 15 years all 6 documented goose-aircraft collisions at PTI Airport occurred at ≤65 m AGL. Of the 6 previously documented collisions, 2 occurred during take-off, 2 during approach, and 2 during the landing roll phase of the aircraft.

Lethal removal of geese only from airport property will not completely eliminate the risk of goose-aircraft collisions because geese access airport space from distances beyond airport boundaries (Dolbeer 2011). Geese in our study often moved up to a mean distance of 5 km per day and an individual goose from the study traveled 21.8 km in a single day, which suggests geese can access runway departure and landing corridors from distances greater than 5 km; however, these events are less frequent. In a similar study conducted in the highly urbanized area near John F. Kennedy International Airport, almost half (45%) of the 300 neck-banded

Table 2. Home range (95% utilization distribution; UD) and core use area (50% UD; ha) estimates for resident Canada geese ($n = 16$) in and around Greensboro, North Carolina, 2008–2009. We provide the number of points (n) used to determine the home range and core use area estimates (ha), sex, weight (kg), and the collection time period (dates) for each goose.

Goose	Sex	Weight	n	Dates	95%	50%
1	F	3.4	1,745	Aug 2008–Sep 2009	421.6	33.2
2	F	4.1	3,985	Aug 2008–Nov 2009	3,755.6	193.2
3	M	4.1	3,908	Aug 2008–Oct 2009	540.9	97.4
4	F	4.8	2,997	Aug 2008–Jun 2009	2,656.3	326.2
5	M	3.9	3,487	Aug 2008–Oct 2009	1,476.2	174.9
6	F	3.1	3,525	Aug 2008–Aug 2009	1,183.2	219.8
7	M	3.6	4,964	Aug 2008–Oct 2009	1,285.9	294.2
8	F	3.0	2,689	Aug 2008–Aug 2009	514.1	19.4
9	M	4.8	513	Aug 2008–Feb 2009	779.1	74.9
10	F	4.3	4,240	Aug 2008–Oct 2009	572.1	68.8
11	F	3.9	1,528	Aug 2008–May 2009	843.4	171.4
12	F	4.5	1,214	Aug 2008–Oct 2009	297.6	46.4
13	M	3.9	5,240	Aug 2008–Oct 2009	733.9	97.6
14	F	3.6	2,567	Aug 2008–Apr 2009	266.8	32.0
15	F	3.4	4,027	Aug 2008–May 2009	466.3	63.8
16	F	3.4	5,440	Aug 2008–Sep 2009	76.0	14.2

Table 3. Mean home range (95% utilization distribution; UD) and core use area (50% UD; ha) estimates for resident Canada geese ($n = 16$) in and around Greensboro, North Carolina, 2008–2009 by season (molt [1 Jun–15 Jul], post-molt I [16 Jul–31 Oct], post-molt II [1 Nov–31 Jan], and breeding/nesting [1 Feb–31 May]).

Season	95%	SE	50%	SE
Molt	81.0	29.8	12.1	4.3
Post-molt I (2008)	562.1	136.9	87.9	20.9
Post-molt II	222.7	52.8	26.3	6.6
Breeding/nesting	194.6	60.6	34.5	13.0
Post-molt I (2009)	866.4	384.7	114.2	51.1

geese stayed within an 8-km radius of the airport, and were located within an 8-km radius of their banding site 95% of the time (Seamans et al. 2009). The authors suggested geese likely crossed airport airspace while traveling within the 8-km radius of the airport. In combination, these studies reiterate the need for large-scale goose management within a minimum distance of 8 km of all airports with resident Canada geese nearby; the FAA suggests an 8-km buffer between an airport's operations area and any wildlife attractant that may cause movement into or across airspace (FAA 2007).

The rapid recolonization of the site where we removed geese suggests localized lethal removals of resident geese have only short-term benefits. Although the site remained largely unused for 27 days, resident geese began accessing it from a distance of up to 10.5 km. Recolonization likely coincided with the completion of the molt. All new geese recolonizing the site were resighted at other locations during the 12 months prior to removal, suggesting the benefits of 1 removal will be most successful if paired with removals at surrounding locations. Areas of concentrated goose-use (e.g., molt and breeding/nesting sites) within 8 km of suburban airports are ideal locations for lethal removal and habitat modification. The numerous retention ponds and drainage areas near PTI Airport are attractants for waterfowl; therefore, reduction or removal of geese from the landscape surrounding PTI Airport would require frequent and large-scale controlled removal of geese or elimination of these water sources.

Table 4. Home range (95% utilization distribution; UD) and core use area (50% UD; ha) estimates for 5 male and 11 female resident Canada geese in and around Greensboro, North Carolina, 2008–2009 during molt (1 Jun–15 Jul), post-molt I (16 Jul–31 Oct), post-molt II (1 Nov–31 Jan), and breeding/nesting (1 Feb–31 May).

	Sex	95%	SE	50%	SE
Season					
Entire study	Female	1004.8	348.0	108.0	31.2
	Male	963.2	177.8	147.8	40.4
Molt	Female	59.6	33.1	8.3	4.0
	Male	123.9	61.5	19.7	9.9
Post-molt I (2008)	Female	609.1	198.3	90.4	28.1
	Male	468.1	128.4	82.9	32.1
Post-molt II	Female	154.6	37.2	16.6	3.6
	Male	375.7	129.0	48.3	15.8
Breeding/nesting	Female	180.4	77.4	29.5	16.9
	Male	222.9	106.6	44.7	20.9
Post-molt I (2009)	Female	810.2	559.7	73.2	43.6
	Male	964.9	505.0	186.0	120.9

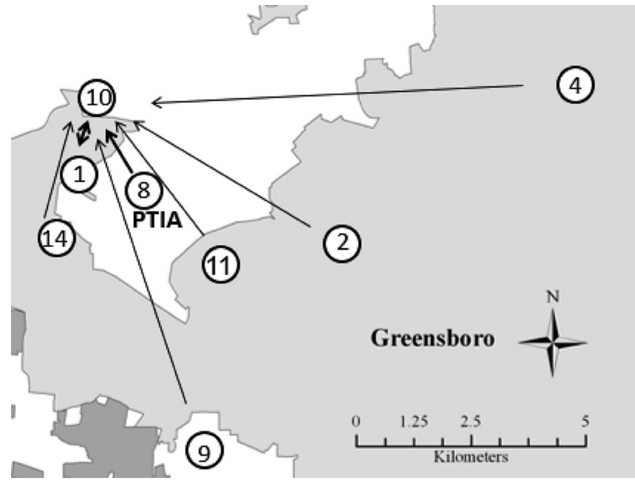

Figure 4. Resident goose movements between banding locations and the removal site (10) in and around Piedmont Triad International Airport (PTIA) in Greensboro, North Carolina, 2008–2009.

Current management techniques (e.g., egg addling, hazing, and nest destruction) are effective at eliminating nuisance individuals (Smith et al. 1999), but ineffective at reducing population numbers (Coluccy et al. 2001). Hence, more intensive management strategies (i.e., annual and large-scale lethal removals, large-scale habitat modification) must be implemented to stabilize local resident goose populations and reduce risks posed to human health and safety. Additionally, the use of non-lethal techniques (e.g., habitat modification, hazing, no-feeding programs) in combination with lethal removals may be an option to further reduce the risk geese pose to aircraft near this suburban airport. Communication among airports and surrounding corporate facilities, local landowners, residents, and city and county park officials is imperative to build public support for lethal removal of geese in suburban areas.

MANAGEMENT IMPLICATIONS

Geese in our study often moved a mean distance of up to 5 km per day, which supports the need for intensive goose management within a minimum distance of 8 km of airports. Our data indicate removal of geese from all molt sites within a minimum distance of 8 km of PTI Airport likely would reduce the risk that geese would traverse runway space and cause goose-aircraft collisions. However, 1-time removal of resident geese, especially at only 1 or a few sites, from areas adjacent to airport property will provide only a short-term reduction in the risk of goose-aircraft collisions because geese quickly recolonize removal sites. Therefore, removal programs should occur frequently and over an extensive land area surrounding an airport to successfully reduce the risk of goose-airport collisions for an extended time period. The majority of resources should be focused within an 8 km radius of the airport, and when possible, management actions should extend farther than 8 km from airport property where geese are likely to still access the airport, but at a less frequent interval. Although our study focused on goose movement around PTI Airport, our results provide insight into the daily and seasonal movements of resident geese and may be applied nationally to airports with similar resident Canada goose presence and comparable habitat composition. We recommend that airport personnel identify and mitigate land-use practices within the surrounding landscape that may encourage wildlife movement across airports. When possible, water sources should be removed from within an 8-km radius of airports and new water bodies should not be constructed.

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