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Population trends of resident and migratory Canada geese in relation to strikes with civil aircraft

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Abstract: Canada geese (*Branta canadensis*) are of particular concern to aviation in the USA because of their large size, flocking behavior, attraction to airports for grazing, and, for the resident population, year-round presence in urban environments. We documented trends in resident and migrant Canada goose populations in North America from 1970 to 2012, and for 1990 to 2012 examined these trends in relation to trends in reported civil aircraft collisions (strikes) with Canada geese. The overall Canada goose population increased 4.5 fold from 1.26 million in 1970 to 5.69 million in 2012. Most of this overall increase was due to a 15.6-fold increase in the population of resident geese (from 0.25 to 3.85 million), especially during the 1990s when the population increased at a mean annual rate of 12.7%. From 2000 to 2012, the resident population has stabilized, fluctuating between 3.36 and 3.85 million birds. The migrant population has remained relatively stable since 1990, with the population in 2012 estimated at 1.84 million. Resident geese comprised 68% of the total Canada goose population in 2012 compared to 41% in 1990 and 20% in 1970. From 1990 to 2012, 1,403 Canada goose strikes with civil aircraft were reported in the USA, of which 704 (50%) caused damage. The strike rate and damaging strike rate for all geese and for resident geese only (strikes in May to September) increased in parallel with the increase in the total Canada goose population (resident and migratory combined) and resident population, respectively, from 1990 to 1999. From 1999 to 2012, the strike rate and especially the damage strike rate exhibited a downward trend, especially for strikes involving resident geese during May to September. We hypothesize that this decline is due to Canada goose management programs implemented at many airports and in other urban areas.

Key words: aircraft, airport, aviation safety, bird strike, *Branta canadensis*, Canada goose, flyway, goose, human–wildlife conflicts, population, resident geese

Canada geese (*Branta canadensis)* are the most massive bird (typically weighing 3.6 to 4.5 kg; Dunning 2008) commonly struck by aircraft in North America (Dolbeer and Eschenfelder 2003). Because of their size and flocking behavior, Canada geese have been responsible for a disproportionate amount of damage to civil and military aviation since 1990. For example, from 1990 to 2012, Canada geese were involved in 3.1% of all reported bird strikes to civil aircraft in the United States where the bird was identified to species (Dolbeer et al. 2013). However, these strikes represented 19.5% of the strikes causing damage, 26.8% of the reported aircraft down time, and 29.1% of reported costs attributable to identified birds. Canada geese were responsible for the crash of a U.S. Air Force AWACS aircraft (modified Boeing 707 valued at $190 million) in 1995 that killed 24 airmen (Richardson and West 2000) and, more recently, for the forced landing of an Airbus 320 with 155 passengers and crew in the Hudson River in January 2009 (Marra et al. 2009, National Transportation Safety Board 2010).

Our objective in this paper is to document trends in resident and migratory Canada goose populations in North America and examine these trends in relation to reported strikes to civil aircraft. This information may prove useful to biologists, regulators, and the public involved in decisions regarding the management of resident and migratory Canada geese in the vicinity of airports (Cleary and Dolbeer 2005, Dolbeer and Franklin 2013) and in urban areas in general (Smith et al. 1999, Woodruff et al. 2004). The information should also be of interest to engineers and regulators

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who establish airworthiness standards for aircraft engines and airframes (MacKinnon et al. 2001, Dolbeer and Eschenfelder 2003, Federal Register 2013).

Methods

Waterfowl in North America are managed in 4 administrative flyways: the Atlantic, Mississippi, Central, and Pacific. Goose numbers by designated populations in these flyways are based on mid-winter or breeding period counts coordinated by the U.S. Fish and Wildlife Service (USFWS). Mid-winter or breeding season population estimates for Canada geese for 1970 to 2012 were derived from these surveys (U.S. Fish and Wildlife Service 2012; D. Sharp, U.S. Fish and Wildlife Service, unpublished data; Appendix 1). For the purpose of this paper, Canada geese are divided into 2 populations within each flyway: (1) resident Canada geese that are generally the "giant" (*Branta c. maxima*) and the "western" (*B. c. moffitti*) subspecies (Table 1); and (2) the migratory population that primarily nests in Canada and Alaska.

We obtained data on Canada goose strikes with civil aircraft in the United States from 1990 to 2012 from the National Wildlife Strike Database (Dolbeer et al. 2013). Strike data are not available for years previous to 1990. We examined trends in strikes in relation to the total Canada goose population (resident and migratory) by comparing strikes for each year with the total population in that year. We examined trends in strikes in relation to the resident Canada goose population by comparing strikes for May to September each year (when only resident birds would be present in United States; U.S. Fish and Wildlife Service 2005) with the total resident population in that year. Aircraft movement data in the United States from 1990 to 2012 (departures and arrivals by commercial and general aviation aircraft) were obtained from the Federal Aviation Administration (2013).

Results

Trends in populations of Canada geese in North America

Resident geese. In 2012, the estimated population of resident Canada geese (3.85 million) was the highest recorded, 3% higher than the next highest level recorded (3.72 million) in 2008. Based on the mid-winter and nesting season surveys, the total resident population has increased about 15.6 fold since 1970 and 3.6 fold since 1990. Most of the numerical increase came during the period 1990 to 2000 when the resident population increased at a mean annual rate of 12.7%, adding about 2.5 million birds (Table 1; Figure 1). This period of rapid increase was observed in all flyways but was most pronounced in the Atlantic and Mississippi flyways (Table 1). From 2000 to 2012, the resident population has stabilized, fluctuating between 3.36 and 3.85 million birds.

This mean annual increase of 12.7% in the resident population of Canada geese from 1990 to 2000, based on USFWS waterfowl surveys, is corroborated by independent results from the North American Breeding Bird Survey (BBS). Based on BBS results, the resident Canada goose population in North America increased from a mean of 13.0 to 36.7 birds per survey route (1990 to 2000), a 10.9% increase (Sauer et al. 2012).

Migratory geese. Whereas the resident component of the North American population increased dramatically during the 1990s, the migrant population has shown no consistent trend. The migrant population has fluctuated between 1.35 and 2.13 million birds from 1990 to 2012 (Table 1; Figure 5). The combined resident and migrant population in 2012 (5.69 million birds) is 2.2 times the 1990 population of 2.63 million birds and 4.5 times the 1970 population of 1.25 million birds. The resident population of Canada geese comprised only about 20% of the total population of 1.25 million birds in 1970 compared to 41% of the total population of 2.63 million birds in 1990 and 68% of the total population of 5.69 million birds in 2012. The resident population has outnumbered the migratory population since 1993 (Figure 1).

Trends in Canada goose strikes with civil aircraft

Canada geese were identified in 1,403 reported bird strikes to civil aircraft from 1990 to 2012 (Table 2). Canada geese represented 89% of the 1,578 geese struck by civil aircraft (1990 to 2012) that were identified to species (5 species; Table 2, footnote). We also note that strike reporting is voluntary for civil aviation

Table 1. Estimated Canada goose populations (resident and migratory) × 1,000 in North America from 1970 to 2012 by the 4 administrative flyways used in waterfowl management: Atlantic (AF), Mississippi (MF), Central (CF), and Pacific (PF)[a]. See Appendix 1 for estimated numbers in the sub-populations of each flyway and methods used to derive numbers in years in which surveys were not conducted.

	Resident Canada geese[b]					Migratory Canada geese					Total population
Year	AF	MF	CF	PF	Total	AF	MF	CF	PF	Total	
1970	11	51	149	35	246	137	545	284	45	1,011	1,257
1971	12	64	195	47	318	137	532	280	46	994	1,312
1972	14	56	153	34	257	137	507	321	45	1,009	1,266
1973	18	54	140	38	250	137	514	407	44	1,101	1,351
1974	23	58	147	43	271	137	511	312	51	1,010	1,281
1975	26	57	147	42	272	137	527	249	59	972	1,244
1976	31	62	167	30	290	137	589	444	58	1,228	1,518
1977	35	58	176	30	298	137	719	378	60	1,294	1,592
1978	40	60	180	43	323	137	867	345	63	1,412	1,735
1979	51	77	201	59	387	137	650	344	92	1,223	1,610
1980	60	86	213	36	396	137	628	368	151	1,284	1,680
1981	71	103	218	60	452	137	566	413	112	1,228	1,680
1982	83	108	230	66	486	137	465	425	75	1,102	1,588
1983	100	150	316	50	616	137	527	339	47	1,049	1,665
1984	116	104	256	48	524	137	495	404	40	1,076	1,600
1985	138	152	322	50	662	137	712	376	59	1,284	1,946
1986	165	180	217	68	630	137	903	370	67	1,477	2,108
1987	190	232	419	70	912	137	791	350	88	1,365	2,277
1988	223	226	403	107	959	187	861	445	103	1,597	2,556
1989	396	252	455	95	1,198	137	655	498	109	1,398	2,596
1990	237	284	457	92	1,069	137	774	525	129	1,565	2,634
1991	306	345	538	86	1,275	137	495	814	114	1,560	2,834
1992	439	235	510	102	1,286	137	670	897	174	1,878	3,164
1993	647	779	476	116	2,019	162	598	564	181	1,505	3,524
1994	648	909	433	139	2,129	112	614	658	250	1,634	3,764
1995	780	942	587	148	2,457	103	561	943	265	1,873	4,329
1996	933	1,037	604	146	2,720	151	575	825	277	1,828	4,548
1997	1,013	957	661	104	2,735	137	644	724	329	1,832	4,567
1998	970	1,141	740	147	2,997	103	482	772	263	1,620	4,618
1999	999	1,163	672	165	2,999	181	713	951	288	2,133	5,131
2000	1,024	1,437	882	181	3,524	154	561	496	296	1,507	5,031
2001	1,017	1,296	945	177	3,435	193	516	313	326	1,348	4,783
2002	966	1,415	949	151	3,481	244	494	666	242	1,646	5,127
2003	1,127	1,416	800	149	3,492	236	573	769	317	1,894	5,385
2004	1,073	1,430	831	165	3,499	260	497	662	292	1,711	5,210
2005	1,167	1,367	661	167	3,362	227	549	578	323	1,676	5,038
2006	1,144	1,575	662	148	3,530	235	648	735	353	1,971	5,501
2007	1,128	1,455	756	154	3,492	277	621	871	366	2,135	5,627
2008	1,025	1,460	1,018	221	3,724	216	559	615	404	1,793	5,517
2009	1,006	1,464	935	132	3,536	241	478	530	316	1,565	5,101
2010	977	1,600	740	150	3,468	220	588	708	392	1,908	5,375
2011	1,015	1,630	773	112	3,530	265	490	737	294	1,785	5,314
2012	880	1768	1045	156	3,849	262	480	744	351	1,836	5,685

[a] Resident (large Canada geese) are defined as the following subpopulations in the 4 flyways: Atlantic: AR; Mississippi: MFG; Central: H-L, WPGP; Pacific: RM (D. Sharp, U.S. Fish and Wildlife Service, personal communication; see Appendix 1).

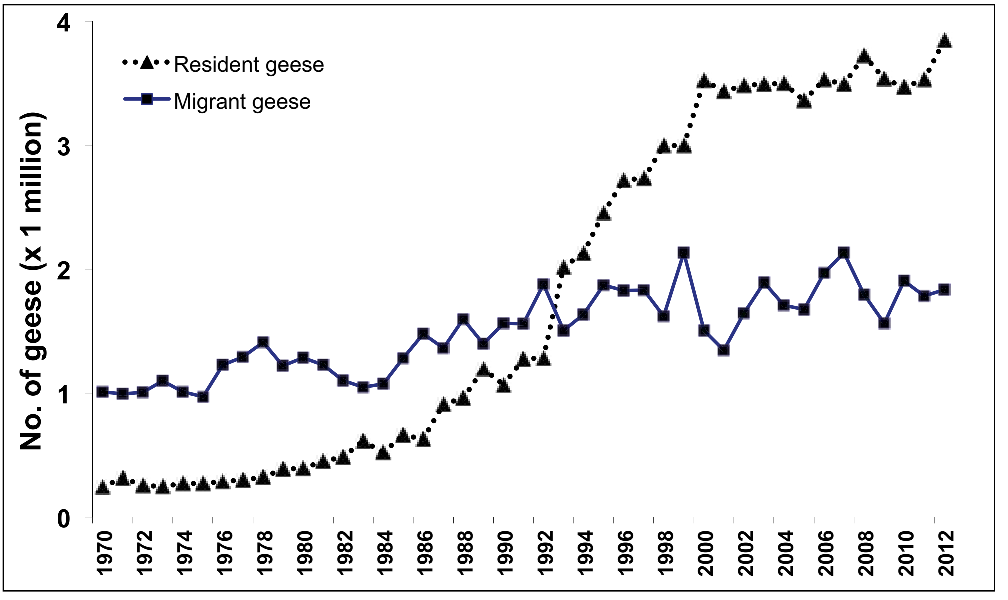

Figure 1. Population trends for resident (non-migratory) and migrant Canada geese in North America, 1970 to 2012. The resident population has exceeded the migratory population since 1993 (Table 1).

in the United States; analyses indicated that from 2004 to 2008 about 58% of strikes were not reported to the Federal Aviation Administration (Dolbeer 2009). However, it is likely that goose strikes were reported more often than strikes with smaller bird species that only rarely cause damage. Still, the strike data should be considered as indices to the actual number of Canada goose strikes and not as absolute values.

Overall, 704 (50%) of the 1,403 reported resident and migratory Canada goose strikes to civil aircraft (1990 to 2012) caused damage to the aircraft (Table 2). During May to September when only resident geese were present, 293 (41%) of the 704 strikes caused damage. Strikes involving multiple birds occurred in 598 (43%) of the 1,403 total strikes involving resident and migratory Canada geese and 316 (49%) of the 640 strikes in May to September involving resident geese only (Table 2).

Strike rate—resident and migratory geese. The strike rate and damage strike rate for resident and migratory Canada geese (i.e., number of reported strikes and strikes causing damage per 1 million civil aircraft movements) increased in parallel with the increase in the total Canada goose population (resident and migratory combined) from 1990 to 1999 (Table 2; Figure 2). However, from 1998 to 2012, the strike rate declined 32% from 0.77 to 0.52; from 1999 to 2012, the damage strike rate declined 43% from 0.44 to 0.25 (Figure 2). The number of strikes with Canada geese causing damage to engines peaked in 1998 at twelve; the number has ranged from six to nine from 2009 to 2012 (7 strikes in 2012; Table 2).

Strike rate—resident geese (May to September). Similar to the pattern exhibited for total strikes each year involving both resident and migratory geese, the strike rate and damage strike rate for resident Canada geese during May to September increased in parallel with the increase in the resident Canada goose population from 1990 to 1999 (Table 2; Figure 3). However, the decline in strikes, including strikes causing damage, for resident geese in May to September has been more pronounced compared to yearly totals for resident and migratory geese combined. From 1998 to 2012, the strike rate declined 56% from 0.90 to 0.40; from 1999 to 2012, the damage strike rate declined 69% from 0.48 to 0.15 (Figure 3). The number of strikes with resident Canada geese during May to September that caused damage to aircraft engines peaked in 1998 at twelve; the number has ranged from two to five from 2009 to 2012 (3 strikes in 2012; Table 2).

Discussion

The 3.5-fold increase in the resident population of Canada geese from 1.1 million

Table 2. Reported Canada goose strikes with civil aircraft in USA, 1990 to 2012.[a, b] Strikes during the months of May to September involve resident Canada geese only.

	All strikes		Strikes causing damage		Strikes causing engine damage		Aircraft movements (× 1 million)[c]
Year	Total	May–September only	Total	May–September only	Total	May–September only	
1990	33	19	18	9	3	1	100.8
1991	38	19	19	9	5	4	108.3
1992	46	17	27	7	6	0	107.5
1993	57	28	21	9	5	1	106.0
1994	62	36	28	13	6	2	105.8
1995	66	30	34	16	9	7	104.3
1996	60	32	25	10	5	2	106.6
1997	52	29	28	15	5	2	107.8
1998	87	42	42	22	17	12	112.3
1999	84	40	50	23	15	8	114.2
2000	85	33	47	16	13	5	116.7
2001	72	33	38	17	7	4	115.1
2002	81	36	39	13	12	3	113.5
2003	80	34	43	15	12	4	111.4
2004	58	31	34	17	10	5	111.6
2005	65	26	24	9	5	0	110.5
2006	57	19	32	8	9	2	108.5
2007	45	18	25	8	9	1	108.8
2008	70	28	32	15	9	6	106.1
2009	56	29	27	15	6	2	99.3
2010	54	21	29	13	7	3	96.6
2011	45	24	18	8	8	5	96.0
2012	50	16	24	6	6	3	95.7
Total	1,403[d]	640[d]	704	293	189	82	2,463.3

[a] Data from National Wildlife Strike Database (Dolbeer et al. 2013); includes 3 damaging strikes in 2010 involving cackling geese (*Branta hutchinsii*), which were classified as a subspecies of Canada goose until 2004.
[b] Birds in an additional 333 strikes were identified simply as "geese," and birds in 175 other strikes were identified as snow geese (*Chen caerulascens*; 111), greater white-fronted geese (*Anser albifrons*; 37), brant (*Branta bernicula*; 27), and emperor geese (*Chen canagica*; 2).
[c] Departures and arrivals by civil aircraft at 3,393 airports in USA (Federal Aviation Administration 2013). For calculations of strike rates for resident geese during May to September each year (Figure 3), the number of movements was multiplied by 5/12 (to estimate movements for the 5-month period).
[d] Multiple geese were reported as struck in 598 (43%) of the 1,403 reported incidents involving all Canada geese and in 316 (49%) of the 640 reported incidents involving resident Canada geese from May to September.

in 1990 to 3.8 million in 2012 should be of particular concern to the aviation industry in North America because of the following 4 attributes of these geese: (1) large size (typically 3.6 to 4.5 kg), which exceeds the bird certification standard for airframes and most aircraft engines (MacKinnon et al. 2001, Dolbeer and Eschenfelder 2003); (2) flocking behavior, which increases the likelihood of bird strikes by multiple birds (i.e., 43% of all Canada goose strikes and 49% of resident Canada geese during May to September, 1990 to 2012); (3) attraction to the large open spaces at airports for grazing and resting; and (4) year-round presence in urban environments, often near airports. In addition, the 1.8 million migrant Canada geese pose a threat of their own to aviation, because these birds annually migrate to and from northern nesting grounds in Canada to the United States and intermingle with resident birds during fall through early spring.

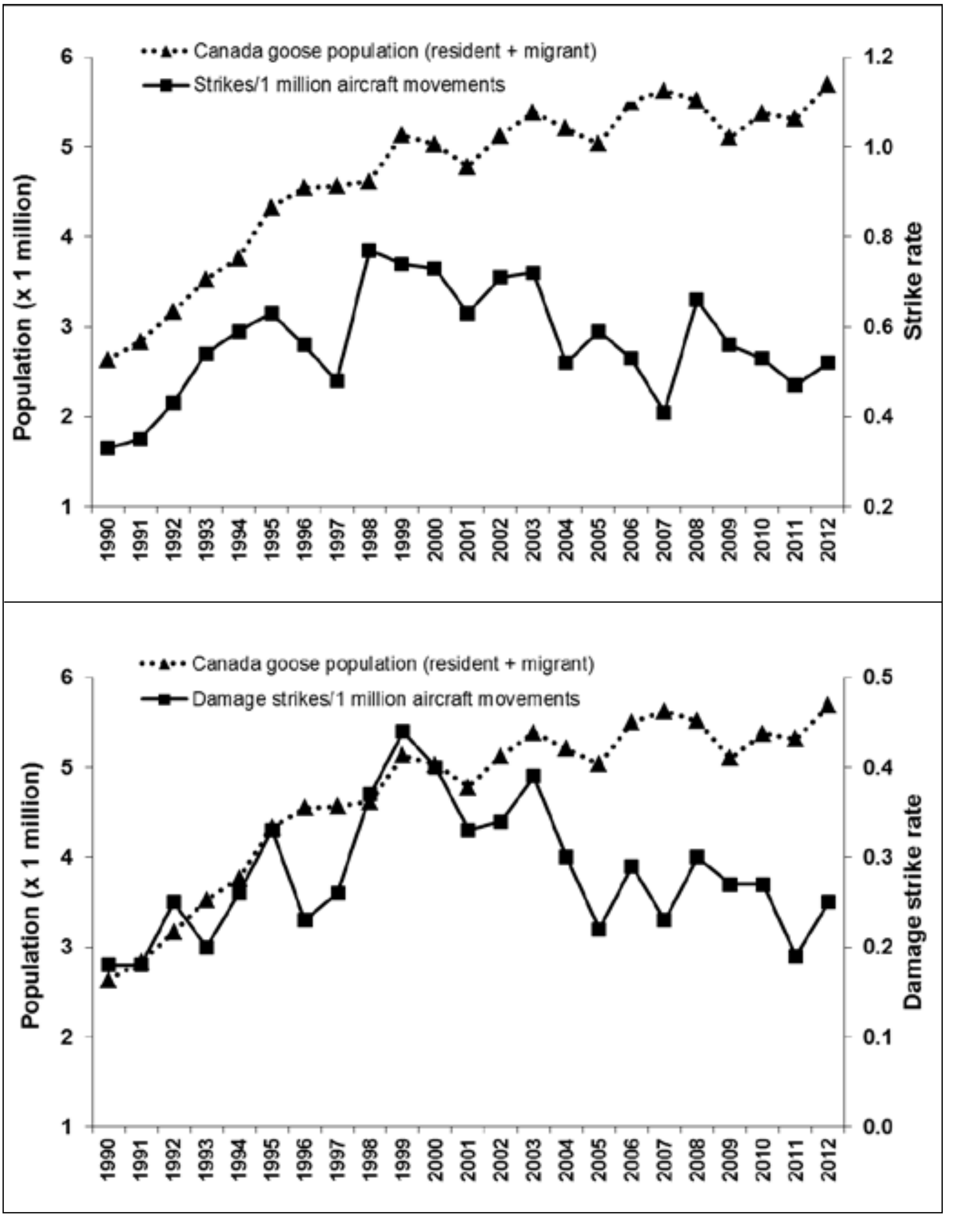

Figure 2. The strike rate (top graph) and damage strike rate (bottom graph) for Canada geese (number of reported strikes and strikes with damage each year per 1 million civil aircraft movements) in relation to the total Canada goose population (resident and migratory combined) from 1990 to 2012 (Tables 1 and 2).

The 3.5-fold increase in the resident Canada goose population came at a time when the number of transport jet (turbofan) aircraft, which are more vulnerable to bird-induced engine damage than slower, piston-powered aircraft (MacKinnon et al. 2001), also increased. The number of USA-based commercial jet-powered aircraft increased 61% from 4,148 in 1990 to 6,670 in 2008 (U.S. Department of Transportation 2012). Further, in 1990 45% of these jet-powered aircraft had 3 or 4 engines and 55% had 2 engines. By 2008, 91% of these jets were 2-engine aircraft, such as the Airbus 320 that ingested Canada geese in both engines, resulting in a forced landing in the Hudson River in 2009 (Marra et al. 2009). As

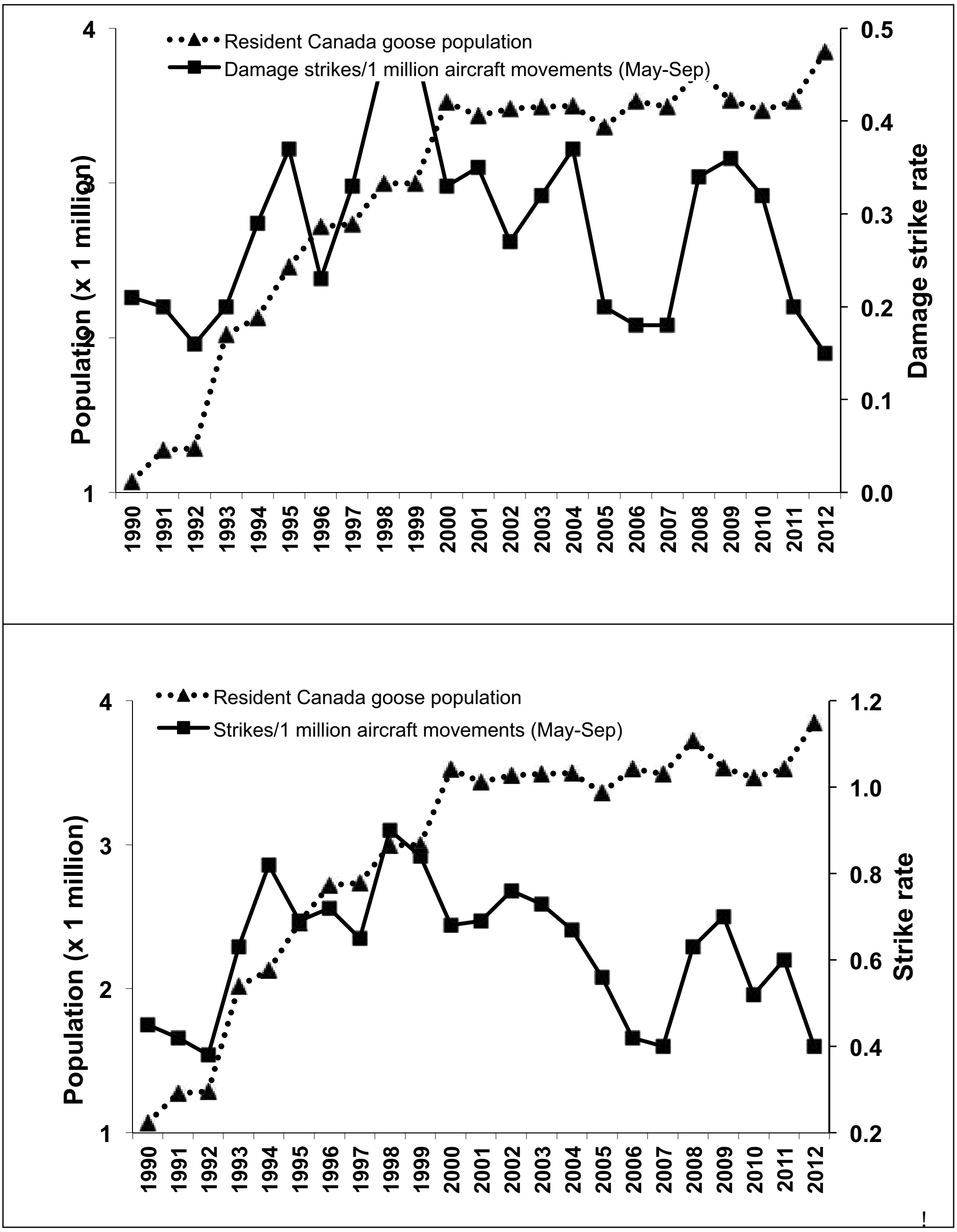

Figure 3. The strike rate (top graph) and damage strike rate (bottom graph) for resident Canada geese (number of reported strikes and strikes with damage during May to September per 1 million civil aircraft movements) in relation to the resident Canada goose population from 1990 to 2012 (Tables 1 and 2).

documented above, 49% of the resident Canada goose strikes during May to September involvd multiple birds.

Regarding engine certification standards for turbofan engines, the Federal Aviation Administration (FAA) has required since the 1970s a "large single bird test" involving a 1.8 kg bird. In recent years, this requirement has been increased to a 2.8- and 3.6-kg bird for new engines with inlet areas >1.35 m^2 and >3.90 m^2, respectively (U.S. Code of Federal Regulations 2013). Most engines on commercial aircraft today were certified under the 1.8-kg bird test. It is important to recognize that certification standards require only that the damage be contained within the cowling and that the engine can be shut down safely. The complete loss of engine power or thrust is acceptable (14CFR Part 33.75[g][1]; Federal Aviation Administration 2001; Dolbeer and Eschenfelder 2003).

We hypothesize that the stabilization of the resident Canada goose population in the past decade and the decline in reported strikes and damaging strikes between aircraft and resident Canada geese from 1998 to 2012 is related to aggressive management programs at airports and other areas throughout the USA that have targeted resident Canada geese (e.g., Smith et al. 1999, Dolbeer et al. 2000, Wenning et al. 2004, Woodruff et al. 2004, U.S. Fish and Wildlife Service 2005, Dolbeer and Franklin 2013). For example, a special, early Canada goose hunting season has been phased in over the past 21 years in the USA to target resident birds before the Canadian migrants arrive. About 450,000 to 650,000 resident Canada geese were taken each year by hunters in 38 U.S. states during the 2001 to 2011 early (September) seasons (Raftovich et al. 2012). As another example, biologists from the U.S. Department of Agriculture, Wildlife Services (WS) provided assistance at 772 to 838 airports nationwide in 2010 to 2012 to mitigate wildlife risks to aviation, compared to only 42 airports in 1991 and 193 airports in 1998 (Begier and Dolbeer 2013). The number of resident Canada geese euthanized by WS because of conflicts with humans (including aviation safety) increased from about 6,000 in 2001 to 24,000 in 2011 (U.S. Department of Agriculture 2013).

Although this analysis indicates that the strike rate has declined, Canada goose strikes still pose a significant economic and safety risk for civil and military aviation in the USA and Canada (Dolbeer et al. 2000, Dolbeer and Wright 2009, National Transportation Safety Board 2010). Although management actions to reduce goose and other wildlife strikes have been implemented at many airports in the past 20 years, much work remains to be done. We recommend continued collection and analyses of data on goose strikes, migrant and resident Canada goose populations, and management efforts at airports and other locations to determine if this encouraging trend in strikes in relation to population levels is sustained. Meanwhile, integrated Canada goose management programs should be aggressively continued on and in the vicinity of airports to reduce this hazard (Cleary and Dolbeer 2005, Dolbeer and Franklin 2013). Federal regulations that expand options for managing resident Canada goose populations issued in August 2006 (Federal Register 2006) should be beneficial in reducing strikes. Finally, we note that management actions at and in the immediate vicinity of airports do little to mitigate the risk of off-airport strikes during departure and approach (Dolbeer 2011). Thus, new technologies, such as the use of bird-detecting radar (Klope et al. 2009) and methods to enhance aircraft detection by birds (Blackwell and Bernhardt 2004, Blackwell et al. 2009), should be pursued more vigorously.

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Richard A. Dolbeer was a scientist with the U.S. Department of Agriculture (USDA) from 1972 to 2008 where he led a series of research projects to resolve conflicts between humans and wildlife in North America, Africa, and Asia. He has published >200 scientific papers. He has received numerous recognitions by wildlife and aviation organizations for his research efforts, including the Federal Aviation Administration's "Excellence in Aviation Research" award, The Wildlife Society's Caesar Kleberg Award for Applied Wildlife Research, and the Lifetime Achievement Award from the Jack H. Berryman Institute. Among his accomplishments, he helped design a program to keep gulls away from the World Trade Center recovery site on Staten Island, New York, in the aftermath of the 9/11 terrorist attacks. He also assisted the National Transportation Safety Board and testified before the U.S. Congress in the investigation of the US Airways Flight 1549 "Miracle on the Hudson" accident in 2009. A native of Tennessee, he received degrees from the University of the South (B.A., biology, 1967), the University of Tennessee (M.S., zoology, 1969), and Colorado State University (Ph.D., wildlife biology, 1972). He currently manages his small farm "Bluebird Haven" in Ohio, and works as a consultant in the aviation industry and as science advisor to USDA. He has been married to Saundra for 47 years and has 2 children and 6 grandchildren.

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Appendix

Appendix 1. North American Canada goose population trends (× 1,000) by subpopulation[a] within each flyway from 1970 to 2012, adapted from Table D.1 (U.S. Fish and Wildlife Service 2012).[b c d e f g]

	Atlantic			Mississippi				Central				Pacific			
Year	AR	A	NA	SJB	MV	EP	MFG	WGP	TG	SG	H-L	RM	DSK	CAK	ALUT
1970	11	68	69	107	325	113	51	90.0	133.0	151.2	58.8	35.0	22.0	21.0	1.6
1971	12	68	69	127	292	113	64	95.0	131.1	148.5	99.6	46.9	20.0	24.0	1.6
1972	14	68	69	118	294	95	56	100.0	159.6	160.9	53.0	33.8	18.0	25.0	1.6
1973	18	68	69	101	296	116.6	54	110.0	147.2	259.4	30.1	37.9	16.0	26.0	1.6
1974	23	68	69	136	278	96.7	58	113.0	158.5	153.6	33.9	42.7	19.0	30.0	1.6
1975	26	68	69	101	304	121.5	57	118.0	125.6	123.7	29.1	42.3	26.0	32.0	0.8
1976	31	68	69	116	305	168.4	62	126.0	201.5	242.5	40.5	30.2	23.0	34.0	0.9
1977	35	68	69	130	478	110.8	58	135.0	167.9	210.0	40.9	29.5	24.0	35.0	1.3
1978	40	68	69	180	576	111.2	60	140.0	211.3	134.0	39.8	43.1	24.0	37.0	1.5
1979	51	68	69	143	434	72.8	77	150.0	180.5	163.7	50.5	58.6	26.0	64.1	1.6
1980	60	68	69	127	395	106	86	162.0	155.2	213.0	51.2	36.3	22.0	127.4	1.7
1981	71	68	69	120	367	78.9	103	167.0	244.9	168.2	51.0	60.3	23.0	87.1	2.0
1982	83	68	69	118	251	96.4	108	175.0	268.6	156.0	54.5	65.9	18.0	54.1	2.7
1983	100	68	69	130	304	92.8	150	242.0	165.5	173.2	74.1	49.7	17.0	26.2	3.5
1984	116	68	69	130	253	112	104	150.0	260.7	143.5	105.8	48.3	10.0	25.8	3.8
1985	138	68	69	129	477	105.6	152	230.0	197.3	179.1	92.3	49.9	8.0	46.8	4.2
1986	165	68	69	158	619	126.4	180	115.0	189.4	181.0	101.8	68.4	17.1	45.2	4.3
1987	190	68	69	130	515	145.9	232	324.0	159.0	190.9	95.4	70.4	15.8	66.7	5.0
1988	223	118.2	69	159	565	137.0	226	272.1	306.1	139.1	131.3	107.0	16.0	82.0	5.4
1989	396	68	69	170	352.5	132.1	252	330.3	213.0	284.8	124.8	95.0	17.4	85.3	5.8
1990	237	68	69	92.1	518.8	163.4	284	271.0	146.5	378.1	185.8	91.5	16.3	106.4	6.3

Appendix 1 continued on next page...

	Atlantic			Mississippi				Central				Pacific			
Year	AR	A	NA	SJB	MV	EP	MFG	WGP	TG	SG	H-L	RM	DSK	CAK	ALUT
1991	306	68	69	72.4	254.8	167.4	345	390.0	305.1	508.5	148.3	85.6	10.7	96.6	7.0
1992	439	68	69	73	438.9	158.4	235	341.9	276.3	620.2	168.0	102.1	17.8	148.6	7.7
1993	647	93.0	69	50.7	411.2	136.2	779.4	318.0	235.3	328.2	158.0	116.4	16.5	153.2	11.7
1994	648	43.2	69	45.7	432.2	136.2	909.4	272.5	224.2	434.1	160.9	138.5	16.3	217.8	15.7
1995	780	34.0	69	74.1	348.2	139.0	941.6	352.5	245.0	697.8	234.6	148.2	12.1	234.1	19.2
1996	933	51.5	99.6	71.1	362.4	141.0	1,037.3	403.3	264.0	561.2	200.5	145.7	12.0	249.8	15.4
1997	1,013	72.1	64.4	87	426	130.5	957.0	453.4	262.9	460.7	208.0	103.5	13.5	294.8	20.4
1998	970	48.6	53.9	70.3	312.5	99.3	1,140.5	482.3	331.8	440.6	257.7	146.7	14.5	216.4	32.4
1999	999	83.7	96.8	108.1	465.5	139.5	1,163.3	467.2	548.2	403.2	204.5	164.6	10.5	241.8	35.5
2000	1,024	95.8	58.0	78.7	352.6	130.0	1,436.7	594.7	295.7	200.0	287.7	180.8	10.3	251.2	34.3
2001	1,017	135.2	57.8	68.4	325.4	122.2	1,296.3	682.7	149.1	164.1	261.9	177.3	11.1	253.3	61.4
2002	966	182.4	62.0	55.2	286.5	152.0	1,415.2	710.3	504.7	160.9	239.0	150.9	12.4	168.1	61.4
2003	1,127	174.9	60.8	90.2	360.1	122.4	1,416.3	561.0	611.9	156.7	239.1	148.7	9.8	234.0	72.8
2004	1,073	191.8	67.8	75.2	276.3	145.5	1,430.4	622.1	458.7	203.6	208.4	165.4	11.2	172.1	108.5
2005	1,167	175.7	51.3	42.2	344.9	161.6	1,367.0	415.1	400.8	177.2	245.4	167.0	16.1	219.4	87.1
2006	1144	186.1	49.2	128.9	384.4	134.8	1,575.2	444.4	499.8	234.7	217.6	148.4	12.1	241.1	100.1
2007	1128	207.3	69.9	64.8	402.6	153.4	1,454.7	446.0	680.3	190.5	309.5	153.6	10.2	248.4	107.5
2008	1024.9	174.0	41.9	92.3	305.2	161.1	1,459.8	669.5	402.7	212.4	348.2	221.3	9.1	283.7	111.0
2009	1006.1	186.8	53.7	69.2	239.6	169.2	1,463.7	628.0	309.9	220.3	306.7	131.5	6.7	225.9	83.8
2010	977.1	165.1	54.6	76.4	339.3	172.6	1,599.9	462.8	417.0	290.7	277.6	150.1	9.5	275.3	107.2
2011	1015.1	216.0	48.5	86.9	269.8	133.1	1,629.8	499.0	427.1	309.6	274.0	111.7	11.8	180.2	101.7
2012	879.8	190.3	71.6	94.9	268.9	116.3	1,767.9	550.8	450.8	292.8	494.4	156.1	13.7	202.3	134.7

[a]AR = Atlantic resident; A = Atlantic; NA = North Atlantic; SJB = Southern James Bay; MV = Mississippi Valley; EP = Eastern Prairie; MFG = Mississippi Flyway Giant; WGP = Western Prairie and Great Plains; TG = Tall Grass Prairie; SG = Short Grass Prairie; HL = Hi-Line; RM = Rocky Mountain; DSK = Dusky; CAK = Cackling; ALU = Aleutian.

[b] Regression growth techniques were used to estimate population sizes in years that data were not available for AR Canada geese, 1970 to 1988; CAK, 1970 to1979; WGP, 1970 to 1981 (D. Sharp, U.S. Fish and Wildlife Service, personal communication).

[c] AR: 1970 to 1988 is winter estimate; 1989 to present is breeding estimate. A: 1993 to present is breeding estimate. NA: 1996 to present is breeding estimate. SJB and MV: 1970 to 1988 is winter estimate, 1989 to present is breeding estimate; MFG 1970 to 1992 is winter estimate, 1993 to present is breeding estimate; DSK: 1970 to 1985 is winter estimate, 1986 to present is breeding estimate; SG is winter estimate; H-L, EP, and RM are spring surveys; CAK, fall survey through 1998; 1999 to present, fall index predicted from breeding ground surveys.

[d] Data were not collected for 1970 to 1987, 1989 to 1992 for A and for 1970 to 1995 for NA. The mean values for the first 8 years when data were collected (1988, 1993 to 1999 for A and 1996 to 2003 for NA) were used as extrapolations for the missing years.

[e] Data were not collected in 1970 to 1971 and in 1980 for EP. The mean value for the first 8 years when data were collected (1972 to 1979) was used for 1970 to1971 and the mean value for the 4 years before and after 1980 was used for 1980.

[f] Data were not collected in 1970 and 2012 for RM. The mean value for first 8 years when data were collected (1971 to1978) was used for 1970; the mean for the 8 preceding years (2004 to 2011) was used for 2012.

[g] Data were not collected in 1970 to 1974 and 2001to 2002 for ALU. The mean for following 8 years (1975 to 1982) was used for 1970 to 1974; for 2001to 2002, the mean of preceding and following 4 years (1997 to 2000, 2003 to 2006) was used.