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CANADA GOOSE POPULATIONS AND STRIKES WITH CIVIL AIRCRAFT: POSITIVE TRENDS FOR AVIATION INDUSTRY

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Abstract: Canada goose (*Branta canadensis*) populations in North America are subdivided into "migrant-goose" and "large-goose" populations. The "large-goose" populations consist primarily of flocks that are non-migratory (hereafter referred to as resident geese). Estimated migrant and resident geese numbers in the four flyways (Atlantic, Mississippi, Central, and Pacific) are based on mid-winter or breeding period counts. The overall Canada goose population increased five fold from 1970 (1.08 million) to 2005 (5.01 million). Most of this overall increase was due to a 15-fold increase in the population of resident geese (from 0.2 to 3.4 million), especially during the 1990s when the population increased at a mean annual rate of 13.8%. Since 2000, the resident Canada goose population has stabilized at about 3.4-3.6 million. The migrant population has remained relatively stable since 1990 with the population in 2005 estimated at 1.7 million. Resident geese comprised 67% of the total Canada goose population in 2005 compared to 38% in 1990 and only 18% in 1970. Resident Canada geese are of particular concern to aviation because of their large size, flocking behavior, use of airports for grazing, and year-round presence in urban environments. From 1990 to 2005, 1,279 Canada goose and "goose" (unidentified to species but likely Canada geese) strikes with civil aircraft were reported in the USA of which 675 (53%) caused damage. Damage to one or more engines was reported in 163 cases. The number of reported Canada goose and "goose" strikes per year increased, in concert with the increase in the resident population, from 39 in 1990 to 115 in 1998. However, reported strikes declined since 1998 to 70 in 2005 in spite of the continued high overall resident population. This decline is likely due to aggressive Canada goose management programs implemented at many airports and in other urban areas. These programs must be continued and expanded to reduce this significant hazard to aviation.

INTRODUCTION

Canada geese (*Branta canadensis)* are the most massive bird (typically weighing 8-10 lbs) commonly struck by aircraft in North America (Dolbeer and Eschenfelder 2002, Cleary et al. 2006). 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 (Dolbeer et al. 2000). For example, from 1990 to 2005 Canada geese were involved in 5% of all reported bird strikes to civil aircraft in the USA where the bird was identified at least to species group (Cleary et al. 2006). However, these strikes represented 18% of the strikes causing damage, 29% of the reported aircraft down time, and 24% of reported costs attributable to identified birds (Cleary et al. 2006). 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).

The purpose of this paper is to examine trends in Canada goose populations in North America in relation to reported strikes to civil aircraft. This information may prove useful to biologists and others involved in decisions regarding the management of Canada geese at airports (Cleary and

Dolbeer 2005) and the management of populations in urban areas (Smith et al. 1999). The information may also be of interest to engineers and regulators who establish airworthiness standards for aircraft engines and airframes (MacKinnon et al. 2001, Dolbeer and Eschenfelder 2002).

SOURCES OF DATA

Waterfowl in North America are managed in four 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. Population estimates for Canada geese for 1970-2005 were derived from these surveys (U.S. Fish and Wildlife Service 2005*a* and D. Sharp, U.S. Fish and Wildlife Service, unpublished data). For the purpose of this paper, Canada geese are divided into two populations within each flyway, 1) resident or "large" 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.

Data on Canada goose strikes with civil aircraft in the USA were obtained from the National Wildlife Strike Database (Cleary et al. 2006). Strike data were available for 1990-2005.

RESULTS

Trends in Populations of Canada Geese

A summary of estimated population levels from 1970 to 2005 is presented in Table 1. A summary of the current (2005) populations and general trends since 1990 for the four flyways and for North America are presented below.

Atlantic Flyway (2005)

Resident	1,065,000
Migratory	324,000
Total Canada goose count	1,389,000

Comments: The resident population increased dramatically from 1990 to 1996 and has remained stable since 1996. The migratory population (Atlantic Population) was not consistently surveyed on breeding areas until 1993. The population increased during the 1990s and has stabilized between 294,000 and 350,000 from 2001-2005.

Mississippi Flyway (2005)

Resident	1,583,000
Migratory	646,000
Total Canada goose count	2,229,000

Comments: Resident populations increased steadily from 1970 to 2000 and have remained relatively stable from 2000-2005. Migrant populations have remained relatively stable.

Central Flyway (2005)

Resident	622,000
Migratory	578,000
Total Canada goose count	1,200,000

Comments: Resident populations increased during the 1990s but have stabilized since 2000. Migrant populations have fluctuated with no apparent trend since 1990.

Pacific Flyway (2005)

Resident	172,000
Migratory	179,000
Total Canada goose count	351,000

Comments: Resident populations increased during the 1990s but have stabilized since 2000. Migrant populations have fluctuated with no trend since the early 1990s.

North America (2005)

Resident	3,442,000 (67%)
Migratory	1,727,000 (33%)
Total Canada goose count	5,169,000

Comments: In 2005, the estimated total population of North American Canada geese was 7% below the highest level (5.6 million birds in 2003) recorded during the period 1970 to 2005. Based on the mid-winter and nesting season surveys, the total population has increased about five fold since 1970 and two fold since 1990. Most of this increase has come from the resident segment of the population, especially during the period 1990-2000 when the population increased at a mean annual rate of 13.8% (Table 1, Fig. 1). The resident Canada goose population appears to have stabilized at about 3.5 million since 2000. This dramatic population growth of the resident population during the 1990s is corroborated by independent results from the North American Breeding Bird Survey (BBS). Based on BBS results, the resident (non-migratory) Canada goose population in North America increased at a mean annual rate of 7.9% ($P < 0.001$) from 1990 to 2000 (Sauer et al. 2006). In contrast, the resident population showed no growth (mean annual rate was 1.0%, $P = 0.66$) from 2000-2005.

Whereas the resident component of the North America population increased dramatically during the 1990s, the migrant population has shown no consistent trend. The migrant population has fluctuated between 1.5 and 2.1 million birds from 1990-2005 (Table 1, Fig. 1). The resident population of Canada geese comprised only about 18% of the total population of 1.2 million birds in 1970 compared to 38% of the total population of 2.4 million in 1990 and 67% of the total population of 5.2 million in 2005. The resident population has outnumbered the migratory population since 1993 (Fig. 1).

Trends in Canada Geese Strikes with Civil Aircraft

Canada geese were identified in 965 reported bird strikes to civil aircraft from 1990 to 2005 (Table 2). The birds in an additional 314 strikes were simply identified as "geese" and the birds in 80 other strikes were identified as other species of geese. Because Canada geese represented 92% of the geese identified to species, we believe it reasonable to assume that most of the 314 unidentified geese were in fact Canada geese. We have merged the 1,279 strikes for the two groups (Canada geese and unknown geese) for the following analysis. We also note that strike reporting is voluntary for civil aviation in the USA; previous analyses have indicated that about 80% of strikes are not reported to the Federal Aviation Administration (Cleary et al. 2005, Wright and Dolbeer 2005). Thus, these strike data should be considered as indices to the actual number of goose strikes and not as absolute values.

Overall, 675 (53%) of the 1,279 reported Canada goose and unknown goose strikes to civil aircraft, 1990-2005, caused damage to the aircraft (Table 3). Damage to one or more engines was reported in 163 (24%) of the 675 strikes with damage (Table 4). Multiple birds were struck in 534 (42%) of the 1,279 strikes involving Canada geese and unknown geese (Table 2).

There was a positive correlation between the annual increase in the resident Canada goose population and the annual number of reported Canada goose and unknown goose strikes from 1990 to 2000 (Fig. 2). The number of reported Canada goose and unknown goose strikes with civil aircraft increased from 39 in 1990 to 112 in 2000 while the resident Canada goose population increased from about 1 million to 3.5 million. However, reported strikes declined from 112 in 2000 to 70 in 2005 whereas the resident population of geese has remained relatively stable (Fig. 2). Trends for strikes per 1 million civil aircraft movements (Fig. 2) and strikes with damage and strikes with engine damage (Tables 3, 4) followed a pattern similar to that for overall strikes.

DISCUSSION

The resident Canada goose population increased dramatically (3.5 fold) in North America from 1990 to 2000 whereas the migratory population has remained relatively stable since 1990. Resident geese comprised 67% of the total Canada goose population in 2005 compared to only 38% in 1990 and 18% in 1970. This dramatic increase in the resident population of Canada geese should be of particular concern to the aviation industry because of the following four attributes of these geese: 1) large size (typically 8-10 lbs) which greatly exceeds the 4-lb bird certification standard for engines and airframes (MacKinnon et al. 2001, Dolbeer and Eschenfelder 2002), 2) flocking behavior which increases the likelihood of multiple bird strikes (42% of Canada goose strikes, 1990-2003), 3) attraction to airports for grazing and resting, and 4) year-round presence in urban environments near airports.

The dramatic increase in the resident Canada goose population has come at a time when the number of transport jet (turbofan and turbojet) aircraft in operation has also increased. The number of USA- and Canadian-based commercial jet aircraft increased 41% from 5,007 in 1990 to 8,542 in 2003. Worldwide, the number of commercial jet aircraft doubled from 8,936 in 1990 to 17,991 in 2003. Passenger airline companies operated 16,145 of these jets (C. Francoeur, Jet Information Services, Personal Communication). Over 80% of these jets are two-engine aircraft, and the engines have not been designed for or tested against 8- to 10-lb birds (Dolbeer and Eschenfelder 2002).

The decline in reported goose strikes from 2000 to 2005 may be related in part to a slight (<6%) decline in commercial air traffic after the events of September 2001 (Cleary et al. 2006 and Table 1). However, the decline is also likely related to aggressive management programs at airports and other areas throughout the USA that are targeting resident Canada geese and other hazardous or nuisance wildlife species (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*b*). As one specific example, a special "early" goose season has been phased in over the past 15 years in the USA to target resident birds before the Canadian migrants arrive. Over 500,000 resident Canada geese are now annually taken by hunters in 38 USA states during September (U.S. Fish and Wildlife Service 2005*b*). New federal regulations for managing resident Canada goose populations issued in August 2006 (Federal Register 2006) should enhance management options.

Although there are some indications that the strike rate may be leveling off or even declining for Canada geese, 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). Although management actions to reduce goose and other wildlife strikes are being implemented at many airports, much work remains to be done to reduce strikes. We recommend a continued annual analysis of data on goose strikes, the resident Canada goose population, 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). New federal regulations for managing resident Canada goose populations issued in August 2006 (Federal Register 2006) should enhance management options.

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Table 1. Estimated Canada goose populations (x 1,000) in North America (resident and migratory) from 1970-2005 by the four administrative flyways used in waterfowl management--Atlantic (AF), Mississippi (MF), Central (CF), and Pacific (PF)[a].

	Resident (large) Canada geese[b]					Migratory Canada geese					Total
Year	AF	MF	CF	PF	Total	AF	MF	CF	PF	Total	pop.
1970	11	51	134	26	222	121	539	284	43	987	1,209
1971	12	64	135	25	236	121	545	281	44	991	1,227
1972	14	56	131	37	238	121	537	322	43	1,023	1,261
1973	18	54	146	37	255	121	535	407	42	1,105	1,360
1974	23	58	137	43	261	121	534	314	49	1,018	1,279
1975	26	57	159	47	289	121	549	258	58	986	1,275
1976	31	62	182	52	327	121	637	446	57	1,261	1,588
1977	35	58	203	54	350	121	772	381	59	1,333	1,683
1978	40	60	205	59	364	121	936	350	61	1,468	1,832
1979	51	77	184	65	377	121	676	352	90	1,239	1,616
1980	60	86	229	76	451	121	694	379	149	1,343	1,794
1981	71	103	261	93	528	121	612	426	110	1,269	1,797
1982	83	108	257	65	513	121	501	441	72	1,135	1,648
1983	100	150	318	71	639	121	589	345	43	1,098	1,737
1984	116	104	190	63	473	121	518	409	36	1,084	1,557
1985	138	152	306	92	688	121	764	386	40	1,311	1,999
1986	165	180	185	72	602	121	972	379	63	1,535	2,137
1987	190	232	422	75	919	121	848	354	67	1,390	2,309
1988	223	226	339	76	864	121	933	455	82	1,591	2,455
1989	396	252	430	87	1,165	121	760	498	89	1,468	2,633
1990	237	284	377	82	980	121	808	525	122	1,576	2,556
1991	306	345	507	77	1,235	121	557	814	117	1,609	2,844
1992	439	235	483	93	1,250	121	709	896	167	1,893	3,143
1993	647	811	437	106	2,001	182	637	563	181	1,563	3,564
1994	648	1,003	437	130	2,218	80	697	658	164	1,599	3,817
1995	780	1,031	527	140	2,478	58	674	943	170	1,845	4,323
1996	933	1,132	571	137	2,773	92	664	826	145	1,727	4,500
1997	1,013	1,039	602	96	2,750	126	709	724	216	1,775	4,525
1998	970	1,213	673	138	2,994	84	541	773	170	1,568	4,562
1999	999	1,234	587	156	2,976	156	798	951	184	2,089	5,065
2000	1,024	1,497	866	173	3,560	186	709	496	191	1,582	5,142
2001	1,017	1,371	936	169	3,493	294	647	313	193	1,447	4,940
2002	966	1,612	927	142	3,647	330	579	666	145	1,720	5,367
2003	1,083	1,635	767	140	3,625	314	695	769	182	1,960	5,585
2004	980	1,601	838	159	3,578	350	668	663	145	1,826	5,404
2005	1,065	1,583	622	172	3,442	324	646	578	179	1,727	5,169

[a] Data from U.S. Fish and Wildlife Service (2005*a*), plus unpublished data, D. Sharp, U.S. Fish and Wildlife Service. AF migratory population was not consistently surveyed before 1993. Population assumed to be the mean of 1993-2000 estimates for 1970-1992 years.

[b] Resident (large) Canada geese defined as Atlantic Flyway resident geese, Mississippi Flyway population of giant Canada geese, Central Flyway Hi-Line population and Western Prairie/Great Plains population, and Pacific Flyway Rocky Mountain population.

Table 2. Reported goose strikes to civil aircraft in USA, 1990 to 2005.[a]

	Number of reported goose strikes							
Year	Brant	Canada	Un-known species	Greater white-fronted	Snow[b]	Total	Aircraft move-ments (x 1 million)[c]	Canada goose[d] strikes/ 1 million movements
1990	0	29	11	0	2	42	68.76	0.58
1991	1	37	13	0	3	54	66.79	0.75
1992	0	40	14	0	1	55	66.87	0.81
1993	2	53	18	1	4	78	66.24	1.07
1994	0	60	16	0	2	78	67.19	1.13
1995	2	58	28	0	1	89	67.16	1.28
1996	1	55	18	0	3	77	68.86	1.06
1997	0	49	27	0	1	77	69.88	1.09
1998	2	80	35	0	4	121	71.84	1.60
1999	0	83	28	0	10	121	73.30	1.51
2000	1	84	28	0	7	120	74.59	1.50
2001	2	68	11	0	3	84	73.37	1.08
2002	1	75	17	1	8	102	71.70	1.28
2003	1	76	26	1	3	107	70.84	1.44
2004	0	54	18	1	5	78	71.73	1.00
2005	0	64	6	3	3	76	71.59	0.98
Total	13	965	314	7	60	1,359	1,120.73	1.14
Multiple birds[d]	6 (46)	423 (44)	111 (35)	5 (71)	32 (53)	577 (42)		0.51

[a] Data from Federal Aviation Administration National Wildlife Strike Database (Cleary et al. 2006).

[b] Includes 1 emperor goose struck in 1991.

[c] Departures and arrivals by commercial and general aviation at 3,527 airports in USA (Federal Aviation Administration 2006).

[d] Includes the unknown goose strikes which are assumed to be primarily Canada geese.

[e] Strikes (% of total) involving multiple birds hit by aircraft.

Table 3. Reported goose strikes to civil aircraft in USA indicating damage, 1990 to 2005.[a]

	Number of reported goose strikes with damage					
Year	Brant	Canada	Unknown species	Greater white-fronted	Snow	Total
1990	0	15	7	0	1	23
1991	1	19	7	0	2	29
1992	0	24	6	0	0	30
1993	2	21	9	1	3	36
1994	0	28	11	0	1	40
1995	2	31	18	0	1	52
1996	0	25	13	0	2	40
1997	0	27	13	0	1	41
1998	0	39	28	0	3	70
1999	0	50	11	0	9	70
2000	0	46	16	0	3	65
2001	0	36	4	0	3	43
2002	0	37	9	1	5	52
2003	1	41	13	0	2	57
2004	0	32	11	1	5	49
2005	0	24	4	3	3	34
Total	6	495	180	6	44	731

[a] Data from the Federal Aviation Administration National Wildlife Strike Database (Cleary et al. 2006).

Table 4. Goose strikes with reported engine damage to civil aircraft in USA, 1990 to 2005.[a]

	Number of reported goose strikes with engine damage					
Year	Brant	Canada	Unknown species	Greater white-fronted	Snow	Total
1990	0	3	0	0	1	4
1991	1	5	1	0	0	7
1992	0	4	1	0	0	5
1993	1	5	1	1	1	9
1994	0	5	1	0	0	6
1995	1	9	4	0	1	15
1996	0	5	3	0	2	10
1997	0	5	3	0	0	8
1998	0	17	8	0	2	27
1999	0	15	0	0	6	21
2000	0	13	3	0	0	16
2001	0	7	0	0	1	8
2002	0	12	1	1	1	15
2003	1	12	2	0	0	15
2004	0	9	1	1	0	11
2005	0	6	2	2	3	13
Total	4	132[b]	31[b]	5	18	190[c]

[a] Data from the Federal Aviation Administration National Wildlife Strike Database (Cleary et al. 2006).

[b] In the 163 engine-damaging strike incidents involving Canada geese or unknown-species of geese (assumed to be primarily Canada geese), a total of 174 engines were damaged (i.e., there were 11 incidents in which two engines were damaged).

[c] In the 190 engine-damaging strike incidents involving all species of geese, a total of 203 engines were damaged (i.e., there were 13 incidents in which two engines were damaged).

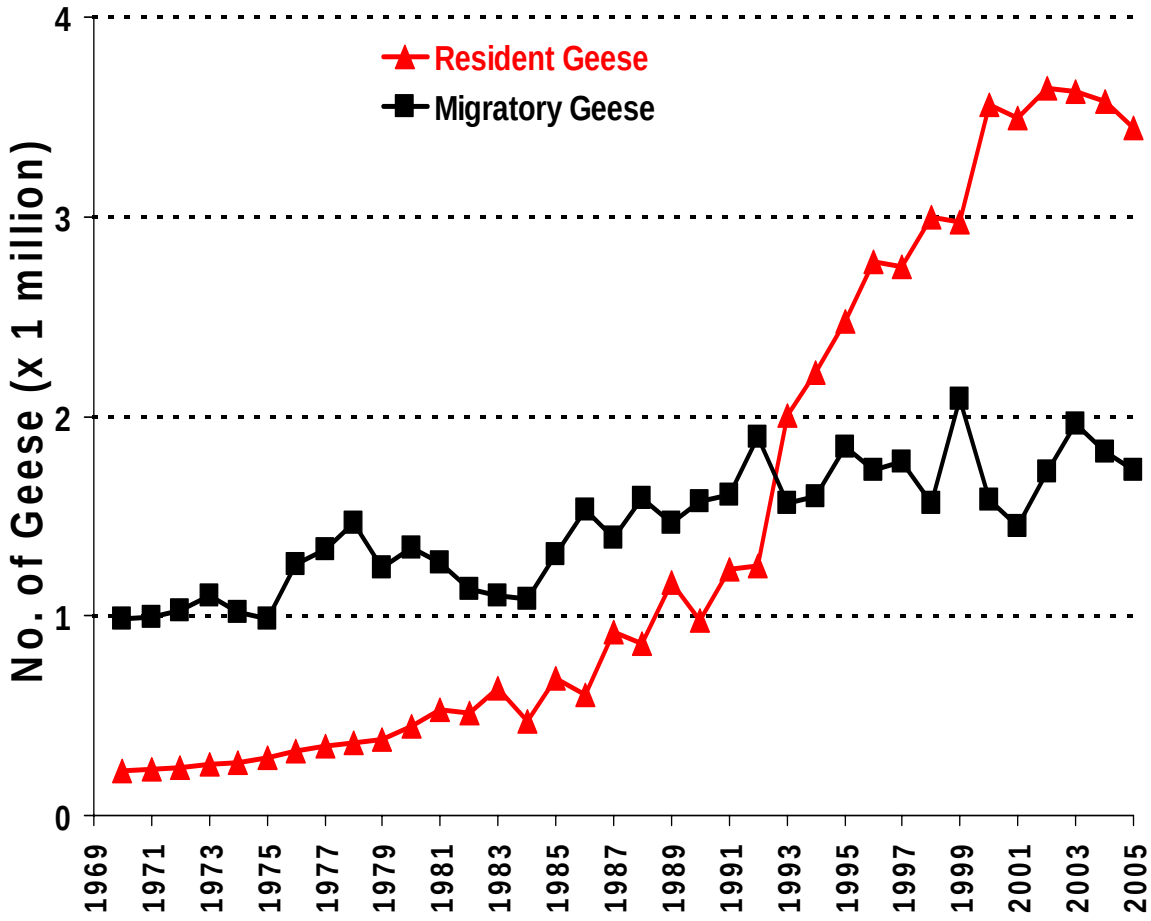

Figure 1. The resident (non-migratory) Canada goose population in North America has been stable from 2000-2005 after showing a dramatic population increase from 1 million to about 3.5 million during the 1990s. In contrast, the migratory population has fluctuated between about 1.4 and 2.1 million from 1986 to 2005. The resident population has exceeded the migratory population since 1993 (see Table 1).

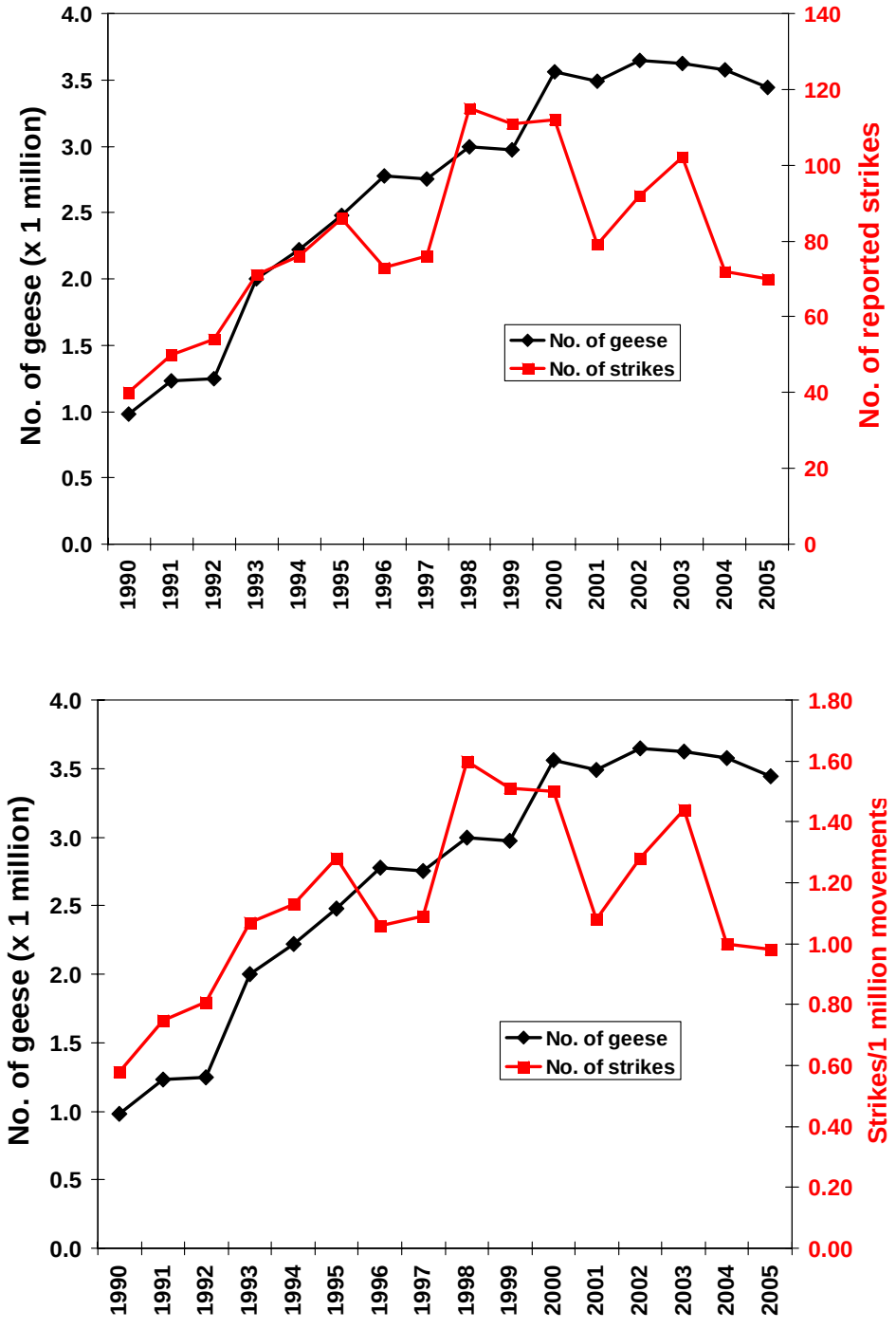

Figure 2. The number of reported Canada goose strikes with civil aircraft (top graph) and the number of strikes per 1 million civil aircraft movements (bottom graph) both increased in parallel with the increase in the resident (non-migratory) population from 1990 to 2000. Since 2000, the number of strikes and number of strikes per 1 million movements have suggested a downward trend (see Table 1).