Articles

Harvest Distribution and Derivation of Atlantic Flyway Canada Geese

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Abstract

Harvest management of Canada geese *Branta canadensis* is complicated by the fact that temperate- and subarctic-breeding geese occur in many of the same areas during fall and winter hunting seasons. These populations cannot readily be distinguished, thereby complicating efforts to estimate population-specific harvest and evaluate harvest strategies. In the Atlantic Flyway, annual banding and population monitoring programs are in place for subarctic-breeding (North Atlantic Population, Southern James Bay Population, and Atlantic Population) and temperate-breeding (Atlantic Flyway Resident Population [AFRP]) Canada geese. We used a combination of direct band recoveries and estimated population sizes to determine the distribution and derivation of the harvest of those four populations during the 2004–2005 through 2008–2009 hunting seasons. Most AFRP geese were harvested during the special September season (42%) and regular season (54%) and were primarily taken in the state or province in which they were banded. Nearly all of the special season harvest was AFRP birds: 98% during September seasons and 89% during late seasons. The regular season harvest in Atlantic Flyway states was also primarily AFRP geese (62%), followed in importance by the Atlantic Population (33%). In contrast, harvest in eastern Canada consisted mainly of subarctic geese (42% Atlantic Population, 17% North Atlantic Population, and 6% Southern James Bay Population), with temperate-breeding geese making up the rest. Spring and summer harvest was difficult to characterize because band reporting rates for subsistence hunters are poorly understood; consequently, we were unable to determine the magnitude of subsistence harvest definitively. A better understanding of subsistence hunting is needed because this activity may account for a substantial proportion of the total harvest of subarctic populations. Our results indicate that special September and late seasons in the United States were highly effective in targeting AFRP geese without significantly increasing harvest of subarctic populations. However, it is evident that AFRP geese still are not being harvested at levels high enough to reduce their numbers to the breeding population goal of 700,000.

Keywords: Canada goose; derivation; distribution; harvest management

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Introduction

Waterfowl harvest in North America is managed in four administrative flyways that have their biological basis in annual waterfowl migration routes: the Atlantic, Mississippi, Central, and Pacific flyways (Figure 1). The Atlantic Flyway consists of 17 states, six provinces, two U.S. territories, and one Canadian territory, each of which is represented on the Atlantic Flyway Council, a body that helps plan and implement waterfowl management activities in the flyway. The Atlantic Flyway Council has developed harvest and habitat management plans for Atlantic brant *Branta bernicla bernicla*, greater snow goose *Chen caerulescens atlantica*, and the four populations of Canada goose *B. canadensis* that occur in the Atlantic Flyway (Atlantic Flyway Council 2009; Atlantic Flyway Council 2011a, Archived Material in Dryad, Reference S1, http://datadryad.org/handle/10255/dryad.38309). Three of those Canada goose (hereafter goose or geese) populations nest in subarctic portions of eastern

Figure 1. North America's four waterfowl flyways.

Canada (Figure 2): the North Atlantic Population (NAP), the Southern James Bay Population (SJBP), and the Atlantic Population (AP). The flyway's temperate-breeding geese (Atlantic Flyway Resident Population [AFRP]) nest in all 17 states and southern portions (<48°N) of the Canadian provinces (Figure 2).

The AFRP has been designated as overabundant relative to a current population goal of 700,000 (Atlantic Flyway Council 2011b, Archived Material in Dryad, Reference S2, http://datadryad.org/handle/10255/dryad.38309), and most Atlantic Flyway states and provinces have special hunting regulations that are designed to reduce the number of AFRP geese (U.S. Department of the Interior 2005, Archived Material in Dryad, Reference S3, http://datadryad.org/handle/10255/dryad.38309). However, the goal of reducing AFRP geese through hunting is complicated by the fact that they occur in the same areas as subarctic-breeding geese during much of the fall and winter hunting season and that harvest strategies for NAP, SJBP, and AP geese prescribe limited harvest to ensure that those populations are sustained. Temperate- and subarctic-breeding geese cannot readily be distinguished from each other based on appearance, thus, hunters cannot target temperate-breeding geese nor purposely avoid subarctic-breeding geese. Consequently, the Atlantic Flyway uses temporal and spatial restrictions during regular hunting seasons to maintain the harvest of subarctic-breeding populations at desired levels and to further concentrate hunter effort on temperate-breeding geese (Atlantic Flyway Council 2008a, Archived Material in Dryad, Reference S4, http://datadryad.org/handle/10255/dryad.38309; Atlantic Flyway Council 2008b, Archived Material in Dryad, Reference S5, http://datadryad.org/handle/10255/dryad.38309).

Information on Canada goose harvest distribution and derivation is needed to evaluate the efficacy of the

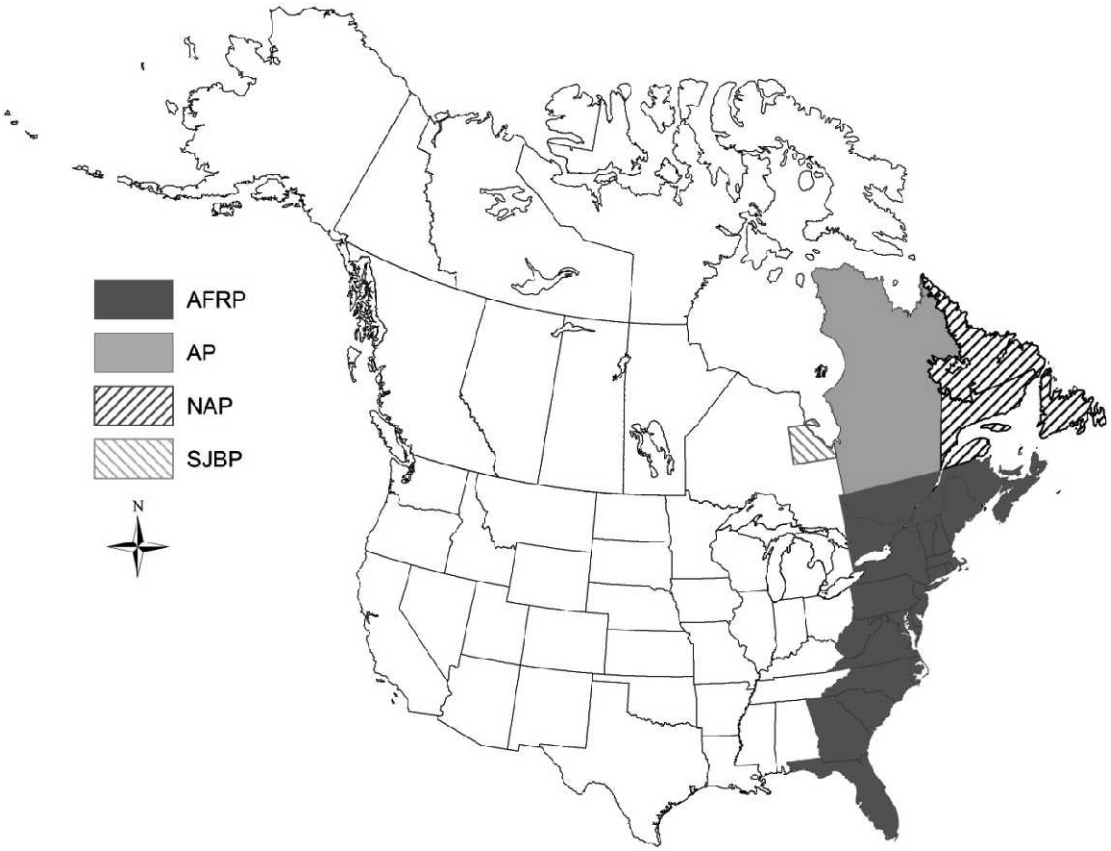

Figure 2. Breeding ranges of Atlantic Flyway Resident Population (AFRP), Atlantic Population (AP), North Atlantic Population (NAP), and Southern James Bay Population (SJBP) Canada geese *Branta canadensis*.

Atlantic Flyway's population-specific harvest strategies and the hunting regulations used to implement them. Harvest distribution refers to the proportion of birds from a particular breeding area that was harvested in each of several defined harvest areas of interest (Munro and Kimball 1982, Archived Material in Dryad, Reference S6, http://datadryad.org/handle/10255/dryad.38309). Harvest derivation refers to the proportion of harvested birds that each population of interest contributed to the total harvest in each harvest area (Munro and Kimball 1982, Archived Material in Dryad, Reference S6, http://datadryad.org/handle/10255/dryad.38309).

Several methods have been used to examine Canada goose harvest distribution and derivation, including use of morphometrics (e.g., Thompson et al. 1999), genetic markers (e.g., Pearce et al. 2000), and band recovery data (e.g., Rusch et al. 1998, Archived Material in Dryad, Reference S7, http://datadryad.org/handle/10255/dryad.38309), but each method has its limitations. Studies involving measurements of morphology (culmen and tarsus) are subject to bias resulting from measurement error (Rasmussen et al. 2001), and they typically have limited scope because it is difficult to obtain representative samples in adequate numbers over large harvest areas. Tail feathers contributed by hunters participating in Canada's Species Composition Survey or the U.S.'s Parts Collection Survey can be the source of samples for genetic marker studies (e.g., Inman et al. 2003), but genetic analyses are expensive compared with the other methods available. In the Central and Pacific flyways, goose tail feathers received through the Parts Collection Survey are measured to distinguish the sizes of the geese in the sample; combined with information on where each bird was harvested, those measurements provide population-level harvest distribution and derivation information (R. E. Trost and D. E. Sharp, U.S. Fish and Wildlife Service [USFWS], personal communication). However, such methods cannot be applied to the Atlantic Flyway Parts Collection Survey sample because geese in the flyway's four populations are of similar size.

Previous goose distribution and derivation analyses based on band recoveries from sport harvest (e.g., Sheaffer 2005) were complicated by the fact that estimates of contemporary band reporting rates were unavailable, but this limitation has since been resolved (Zimmerman et al. 2009). Therefore, we used band recovery data to estimate the distribution of adult ($\geq$1-y-old) and juvenile ($<$1-y-old) geese harvested in the Atlantic Flyway during the 2004–2005 (hereafter 2004) through 2008–2009 (hereafter 2008) fall and winter hunting seasons. We used band recovery and population size data to estimate the derivation of adult geese harvested during those periods and to estimate the magnitude of subsistence harvest that occurs during spring and summer in some parts of Canada.

Methods

We used standard distribution and derivation methods described in detail previously (Munro and Kimball 1982, Archived Material in Dryad, Reference S6, http://datadryad.org/handle/10255/dryad.38309). A sample of adult and juvenile geese from each Atlantic Flyway population was banded annually, and direct recoveries of those banded geese showed how the harvest of each population was distributed across various harvest regions. A direct recovery is a banded goose that was recovered in the first hunting season after it was banded.

We divided the population estimates for each year by the number of adult geese that were banded that year, to calculate a population- and year-specific weighting factor for each band recovery. Summing the weighted recoveries for each harvest region yielded population-specific harvest estimates that we used to characterize the derivation of the goose harvest in each region and flyway-wide. We defined six harvest regions: 1) eastern Canada (New Brunswick, Newfoundland, Nova Scotia, Ontario [the portion east of 80°W], Prince Edward Island, and Quebec); 2) New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont); 3) mid-Atlantic (New Jersey, New York, and Pennsylvania); 4) Chesapeake Bay (Delaware, Maryland, and Virginia); 5) southern Atlantic Flyway (Georgia, North Carolina, South Carolina, and West Virginia); and 6) the Mississippi, Central, and Pacific flyways combined.

Atlantic Flyway states use September hunting seasons to target overabundant AFRP geese before subarctic-breeding geese arrive, and some states have established late hunting seasons to exert harvest pressure on AFRP geese after subarctic-breeding geese have moved through the state (U.S. Department of the Interior 2005, Archived Material in Dryad, Reference S3, http://datadryad.org/handle/10255/dryad.38309). These late hunting seasons are termed special seasons because they are allowed in addition to more restrictive regular goose hunting seasons that are allowed when subarctic-breeding geese are present. Regular goose seasons in the U.S. portion of the Atlantic Flyway begin as early as October and extend into January in some areas, lasting from 45 to 80 d. Special late seasons are only allowed in parts of six states during the period January 15 to February 15. We estimated harvest distribution and derivation separately for special September, regular, and special late seasons in the United States.

Banding and band recovery data

Most NAP goose banding took place in Prince Edward Island during March and April, when NAP geese use this area as a primary stopover point during spring migration. Southern James Bay Population geese were banded in July on Akimiski Island and at various sites along the Ontario mainland's southern James Bay coastline from the Quebec border to the Attawapiskat River (Abraham et al. 2008, Archived Material in Dryad, Reference S8, http://datadryad.org/handle/10255/dryad.38309). Because of the presence of molt-migrants, banders used morphometric criteria to identify temperate-nesting Canada geese from SJBP geese (Hagey et al. 2008). Atlantic Population geese were captured and banded in July and August along the northern coast of Hudson Bay and the southern and western coasts of Ungava Bay (Cotter 2010). Most Atlantic Flyway states and provinces banded AFRP geese, but effort was highly variable among jurisdictions and years. Two states (North Carolina and Delaware) and one province (Prince Edward Island) did not band any AFRP geese during the 5-y period analyzed.

Only standard bands were placed on NAP and SJBP geese during the study period, whereas some AP and AFRP geese in the 2004 and 2005 samples were marked with reward bands (Zimmerman et al. 2009). Reward banding allows estimation of reporting rates for standard bands (Henny and Burnham 1976) provided that the financial incentive is sufficient to ensure that all recovered reward bands are reported (Nichols et al. 1991). Reward bands placed on AP geese in 2004 and 2005 and AFRP geese in 2004 offered US$100 rewards (Zimmerman et al. 2009), a sum that elicited reporting rates near 1.0 in previous studies (e.g., Nichols et al. 1991). Although reward bands placed on AFRP geese in 2005 had values ranging from US$10 to $100 (Zimmerman et al. 2009), we assumed the reporting rate for all reward bands was 1.0.

We used the population-specific reporting rate estimate reported by Zimmerman et al. (2009) for AP (0.593) and AFRP (0.775) geese to adjust reported recoveries of standard bands for reporting rate. North Atlantic Population and SJBP reporting rates have not been estimated, so we used Zimmerman et al.'s (2009) composite, overall goose reporting rate of 0.737 for those two populations. Recovery data used for fall and winter analyses were restricted to direct recoveries of geese shot or found dead from September 1 through March 10.

To estimate spring and summer subsistence harvest in Canada, we assumed that all geese alive after the fall and winter hunting seasons survived until the spring and summer subsistence hunting periods. Band reporting probabilities for subsistence hunters are probably lower than for sport hunters but are not well documented. In 2000 and 2001, the Ontario Ministry of Natural Resources implemented a band solicitation program in the Hudson Bay Lowlands that was designed to increase band reporting rates by Cree subsistence hunters (K. F. Abraham and R. W. Brook, Ontario Ministry of Natural Resources, personal communication). The program seemed to result in a doubling of band recovery reports where most subsistence harvest of SJBP geese occurs. This finding suggests a maximum baseline (unsolicited) reporting rate of 0.5, assuming that the solicitation program resulted in a reporting probability of 1.0. However, experienced investigators familiar with the area reported that the unsolicited band recovery reporting rate in the Hudson Bay Lowlands is probably $\leq$0.1 (K. F. Abraham, personal communication). We are aware of no reporting rates estimates for Canadian subsistence hunters in the spring and summer range of NAP, AP, or AFRP geese. Because of this uncertainty, we estimated an upper and lower limit for the annual spring and summer harvest of each population, with the upper limit based on a reporting probability of 0.1 and

the lower limit based on a maximum reporting probability of 0.5.

Population delineation and abundance

The sources of the population size estimates varied, but in each case we used the estimated total number of geese in the spring population, including nonbreeding geese. North Atlantic Population and SJBP estimates were obtained from the Waterfowl Breeding Population and Habitat Survey (USFWS 2010). Atlantic Population estimates were obtained from an annual survey conducted during mid to late June in the AP breeding range (see Harvey and Rodrigue 2011 for methods). Previous work has indicated that AP geese that spend the breeding season along the Hudson Bay coast exhibit different migration and wintering patterns than those from the Ungava Bay coast (Malecki et al. 2001). Furthermore, the Hudson Bay coast group is increasing in numbers while the Ungava Bay coast group is declining (Harvey and Rodrigue 2011, Archived Material in Dryad, Reference S9, http://datadryad.org/handle/10255/dryad.38309). Therefore, we divided the AP estimates into Ungava Bay (east of 74°W) and Hudson Bay geese (west of 74°W) and treated them as separate groups. The Hudson Bay coast is well known as a destination for molt-migrant, temperate-breeding geese (Luukkonen et al. 2008), but the rest of the Ungava Peninsula is thought to be relatively free of molt migrants. Consequently, we estimated the number of nonbreeding Hudson Bay geese based on the ratio of nonbreeding to breeding geese on the Ungava Bay coast (W. F. Harvey, Maryland Department of Natural Resources, personal communication).

We obtained AFRP estimates from the Waterfowl Breeding Population and Habitat Survey for Maine, New Brunswick, Nova Scotia, Prince Edward Island, and Quebec (USFWS, unpublished data). Annual surveys of southern Ontario provided temperate-breeding goose estimates for the entire province (Canadian Wildlife Service, unpublished data), and 75% of Ontario's temperate-breeding geese breed in the Atlantic Flyway portion of the province (J. Hughes, Canadian Wildlife Service, personal communication); thus, we based our Ontario AFRP estimates on that fraction of the total estimates for southern Ontario. Eleven states (Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia) participated in the annual Atlantic Flyway Breeding Waterfowl Plot Survey (Heusmann and Sauer 1997), and we obtained state-specific AFRP estimates from results of that survey. Georgia and South Carolina used Lincoln's (1930) method to derive indirect annual population estimates from harvest estimates and harvest rates. We used population estimates based on expert opinion for North Carolina (J. C. Fuller, North Carolina Wildlife Resources Commission, personal communication) and West Virginia (S. Wilson, West Virginia Division of Natural Resources, personal communication).

Analysis

The proportion of adults banded varied among years for each subarctic population and group, and it varied among years and jurisdictions for AFRP geese. Consequently, we used harvest estimates derived from weighted band recoveries to represent average adult harvest distribution and derivation (complete raw data available in Data S1, Archived Material in Dryad, http://datadryad.org/handle/10255/dryad.38309). Annual weights (W) were calculated as the estimated breeding population or group size i divided by the number of adults of that population or group that were banded (Munro and Kimball 1982, Archived Material in Dryad, Reference S6, http://datadryad.org/handle/10255/dryad.38309). The estimated average annual harvest (H) of subarctic geese from population or group i that occurred in harvest region j was estimated as follows:

$$\hat{H}_{i,j} = \sum_{i,j,t} \hat{W}_{i,t} \left[\left(\frac{S_{i,j,t}}{\hat{\lambda}_i} \right) + R_{i,j,t} \right]$$

where $S_{i,j,t}$ is the number of standard-banded geese from population or group i reported as direct recoveries in harvest region j during year t; $\hat{\lambda}_i$ is the estimated population-specific band reporting rate; $R_{i,j,t}$ is the number of reward-banded geese banded from population or group i reported as direct recoveries in harvest region j during year t; and $\hat{W}_{i,t}$ is the weight assigned to geese from population or group i banded during year t. Similarly, we estimated the average annual harvest of adult AFRP geese in each harvest region as follows:

$$\hat{H}_j = \sum_{l,j,t} \hat{W}_{l,t} \left[\left(\frac{S_{l,j,t}}{\hat{\lambda}_i} \right) + R_{l,j,t} \right]$$

where l is state or province in which AFRP geese were banded. For the three jurisdictions that did not band AFRP geese, we used other states or provinces in their harvest regions as surrogates for their harvest, and we estimated regional, 5-y average harvest rates that we applied to the individual year-specific population estimates. For example, we estimated the annual harvest of Delaware's AFRP geese by calculating the average harvest rate for Maryland and Virginia combined over the entire 2004–2008 period, and then we multiplied that harvest rate by Delaware's population estimate for each year. Next, we estimated the proportion of Maryland's and Virginia's AFRP harvest that occurred within the state of banding, and we applied that proportion to the total harvest of Delaware's AFRP geese to estimate the number of those geese that were harvested in Delaware.

For each population and group, we represented the average adult harvest distribution as the proportion (p_j) of the harvest that occurred in each harvest region:

$$p_j = \frac{\hat{H}_{i,j}}{\sum_j \hat{H}_{i,j}}$$

We represented the derivation of each region j's harvest as the proportion (p_i) of its adult goose harvest ($\hat{H}$) that consisted of population or group i geese:

$$p_i = \frac{\hat{H}_{i,j}}{\sum_i \hat{H}_{i,j}}$$

Table 1. Bandings, band recoveries, and population estimates for adult Atlantic Flyway Resident Population (AFRP), Atlantic Population [Hudson Bay group; AP (HB)], Atlantic Population [Ungava Bay group; AP (UB)], North Atlantic Population (NAP), and Southern James Bay Population (SJBP) Canada geese *Branta canadensis*, 2004–2008.

	AFRP	AP (HB)	AP (UB)	NAP	SJBP
Bandings					
2004 (Standard)[a]	11,404	614	502	372	1,143
2004 (Reward)[b]	990	612	426		
2005 (Standard)	10,066	604	523	237	1,263
2005 (Reward)	1,454	602	483		
2006 (Standard)	11,699	1,673	1,234	144	1,089
2007 (Standard)	11,278	1,041	1,050	226	1,352
2008 (Standard)	11,195	1,169	1,011	229	967
Recoveries					
2004 (Standard)	1,134	30	24	30	74
2004 (Reward)	138	46	38		
2005 (Standard)	991	25	33	11	98
2005 (Reward)	187	26	36		
2006 (Standard)	1,021	63	55	13	73
2007 (Standard)	1,017	47	48	23	88
2008 (Standard)	1,350	62	51	22	67
Breeding population estimates					
2004	1,442,547	710,068	268,147	197,200	101,000
2005	1,629,316	627,163	279,962	129,900	46,300
2006	1,662,971	690,990	228,711	118,000	160,400
2007	1,817,753	812,157	286,651	166,800	98,000
2008	1,677,764	714,917	260,300	108,400	110,400

[a] A regular U.S. Fish and Wildlife Service butt-end aluminum band identifying an individual bird.
[b] A band offering a monetary reward to hunters for reporting the band.

Abundance estimates were not available for juvenile geese, so we used unweighted, direct band recoveries, pooled across years, to approximate the harvest distribution of each population and group *i* juvenile geese as the proportion (p_j) of recoveries that occurred in each harvest region:

$$p_j = \frac{\frac{S_{i,j}}{\lambda_i}}{\sum_j \left(\frac{S_{i,j}}{\lambda_i}\right)}.$$

Without abundance estimates, we were unable to derive the weighted band recoveries needed to estimate the derivation of the juvenile harvest.

Results and Discussion

We examined 76,652 bandings of adult geese in total, 4,567 of which were reward bands placed on AP and AFRP geese, and 6,921 direct recoveries, 471 of which were AP and AFRP reward-banded geese (Table 1). Annual banded samples consistently constituted approximately 0.2% of the NAP and Hudson Bay AP adults and 0.4% of the Ungava Bay AP adults, but the samples were more variable for the SJBP, averaging 1.4% (Table 1). Although the overall banded sample of AFRP geese was approximately 0.7% of the adults each year (Table 1), there was more annual variability in banding effort and success at the state and province level, primarily because some states and provinces did not attempt to band AFRP geese every year.

Fall and winter harvest distribution

North Atlantic Population. Nearly all (99%) of the annual adult NAP harvest occurred in the eastern Canada, New England, and mid-Atlantic regions of the Atlantic Flyway, primarily during the regular season. No NAP geese were harvested during the special September seasons, but 5% of the geese harvested were taken during special late seasons, all in the New England region (Table 2). The NAP was the only migrant population for which the harvest was split almost evenly between the United States and Canada (Table 2), perhaps due to their comparatively late migration that occurs mainly in November and December (Hestbeck and Bateman 2000). Historically, this population wintered as far south as North Carolina, but in recent years it has been restricted mainly to the New England and mid-Atlantic regions (Atlantic Flyway Council 2008a, Archived Material in Dryad, Reference S4, http://datadryad.org/handle/10255/dryad.38309). In the eastern Canada region, most of the harvest took place on Prince Edward Island; in recent years, Prince Edward Island has been an important fall staging area for

Table 2. Average percentage of distribution of adult (≥1-y-old) North Atlantic Population Canada geese *Branta canadensis* based on band recoveries during the 2004–2005 through 2008–2009 hunting seasons.

Region	Early season[a]	Regular season	Late season[b]	Total
Eastern Canada[c]	0	50	0	50
New England[d]	0	23	5	28
Mid-Atlantic[e]	0	20	0	20
Chesapeake Bay[f]	0	0	0	0
Southern Atlantic Flyway[g]	0	0	0	0
U.S. Atlantic Flyway	0	44	5	48
Other flyways[h]	0	1	0	1

[a] September seasons designated as "special early Canada goose seasons" in the United States.
[b] Late January and February seasons designated as "special late Canada goose seasons" in the United States.
[c] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[d] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[e] New Jersey, New York, and Pennsylvania.
[f] Delaware, Maryland, and Virginia.
[g] Georgia, North Carolina, South Carolina, and West Virginia.
[h] The Mississippi, Central, and Pacific flyways combined.

NAP geese (Atlantic Flyway Council 2008a, Archived Material in Dryad, Reference S4, http://datadryad.org/handle/10255/dryad.38309). Results should be interpreted with caution due to the low proportion of juveniles and adults banded, and we recommend an increased banding effort on the NAP in the future.

Southern James Bay Population. Most (60%) of the adult SJBP geese harvested were taken in the Mississippi Flyway, compared with 28% in eastern Canada and 11% in Atlantic Flyway states (Table 3). Although few geese were shot during special late seasons, 12% of the adult harvest took place during special September seasons, mostly in the Mississippi Flyway (Table 3). In the Atlantic Flyway, most of the harvest occurred in the eastern Canada, mid-Atlantic, and Chesapeake Bay regions. Both temporal and spatial harvest distributions of juveniles were similar to those of the adults (Table 3).

Atlantic Population. Ninety-nine percent of harvested adult and juvenile AP geese originating from the Hudson Bay area were shot during regular seasons (Table 4). The Chesapeake Bay region accounted for the highest amount of both adult (51%) and juvenile harvest (52%) followed by eastern Canada (27% of both adults and juveniles) and the mid-Atlantic region (15% of the adults and 19% of the juveniles) (Table 4).

All of the harvest of adult Ungava Bay AP geese and >99% of the juvenile harvest occurred in the Atlantic Flyway, and only 1% of the geese harvested were shot during special September and late seasons (Table 5). Like Hudson Bay AP geese, both adults and juveniles were shot primarily in the Chesapeake Bay region (43 and 46%, respectively), eastern Canada (27 and 26%), and the mid-Atlantic region (26 and 25%) (Table 5). However, the percentage of Ungava Bay AP geese harvested in the mid-Atlantic was greater, and the percentage taken in the Chesapeake Bay region lower, compared with the Hudson Bay group. Thus, the overall distribution of the harvest was farther north and east than that of the Hudson Bay group. Although the southern terminus for both groups is the Chesapeake Bay region, their migration patterns are different (Malecki et al. 2001), and this difference was reflected in their different harvest distributions.

Atlantic Flyway Resident Population. Ninety-three percent of the adult and approximately 86% of the juvenile AFRP harvest occurred in the United States, mainly in the mid-Atlantic region (Table 6). The U.S. Atlantic Flyway harvest of adults was evenly split between special and regular seasons, with the September season accounting for the majority of the special-season harvest.

Table 3. Average percentage of distribution of adult (≥1-y-old) and juvenile (<1-y-old) Southern James Bay Population Canada geese *Branta canadensis* based on band recoveries during the 2004–2005 through 2008–2009 hunting seasons.

	Early season[a]		Regular season		Late season[b]		Total	
Region	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile
Eastern Canada[c]	0	0	28	34	0	0	28	34
New England[d]	0	0	0	5	0	0	0	0
Mid-Atlantic[e]	2	1	5	5	0	0	7	7
Chesapeake Bay[f]	0	0	2	2	1	0	3	2
Southern Atlantic Flyway[g]	0	0	1	<1	0	0	1	<1
U.S. Atlantic Flyway	2	1	8	7	1	0	11	9
U.S. Mississippi Flyway	10	4	48	51	2	2	60	56
Other flyways[h]	0	0	<1	0	0	0	<1	0

[a] September seasons designated as "special early Canada goose seasons" in the United States.
[b] Late January and February seasons designated as "special late Canada goose seasons" in the United States.
[c] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[d] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[e] New Jersey, New York, and Pennsylvania.
[f] Delaware, Maryland, and Virginia.
[g] Georgia, North Carolina, South Carolina, and West Virginia.
[h] The Central and Pacific flyways combined.

Table 4. Average percentage of distribution of adult (≥1-y-old) and juvenile (<1-y-old) Atlantic Population Canada geese *Branta canadensis* (Hudson Bay group) based on band recoveries during the 2004–2005 through 2008–2009 hunting seasons.

	Early season[a]		Regular season		Late season[b]		Total	
Region	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile
Eastern Canada[c]	0	0	27	27	0	0	27	27
New England[d]	1	0	<1	0	0	0	1	<1
Mid-Atlantic[e]	<1	0	15	19	0	<1	15	19
Chesapeake Bay[f]	0	0	51	52	<1	<1	52	53
Southern Atlantic Flyway[g]	0	0	1	0	0	0	1	0
U.S. Atlantic Flyway	1	0	67	71	<1	1	69	72
Other flyways[h]	0	0	4	1	0	0	4	1

[a] September seasons designated as ''special early Canada goose seasons'' in the United States.
[b] Late January and February seasons designated as ''special late Canada goose seasons'' in the United States.
[c] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[d] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[e] New Jersey, New York, and Pennsylvania.
[f] Delaware, Maryland, and Virginia.
[g] Georgia, North Carolina, South Carolina, and West Virginia.
[h] The Mississippi, Central, and Pacific flyways combined.

Atlantic Flyway Resident Population band recoveries were reported in the Mississippi, Central, and Pacific flyways, but these recoveries made up only 1% of the total adult harvest and <1% of all juvenile band recoveries (Table 6).

Nearly all of each state's special September season AFRP harvest consisted of geese that were banded in that state, consistent with previous findings (e.g., Heusmann 1999). During the regular season, however, the harvest distribution of geese banded in each state or province followed a north–south gradient; where the proportion of AFRP geese harvested in the same province or state in which they were banded increased from approximately 50 to >95%. This increase could be the result of AFRP geese joining migrant geese on their way south. Alternatively, perhaps AFRP geese in northern latitudes move more frequently or extensively than they do further south because of colder temperatures, or snow or ice cover that forces them to search for open water and feeding opportunities. Although Heusmann (1999) found that resident geese moved more during late seasons compared with other seasons, we did not find the same north–south trend for the special late season, possibly because sample sizes (both number of states and band recoveries) were small.

Fall and winter harvest derivation

Special September season. The Atlantic Flyway's average estimated annual harvest of adult Canada geese during the special September season was approximately 89,000 birds, of which 98% were AFRP geese, 1% were temperate-breeding Mississippi Flyway geese, and only 1% were subarctic-breeding geese (Table 7). The New England and Chesapeake Bay regions both derived some of their September harvest from Hudson Bay AP geese but at very low levels (3 and 2%, respectively). Some Ungava Bay AP and SJBP geese were harvested in the mid-Atlantic region, but they made up <1% of that region's harvest.

Table 5. Average percentage of distribution of adult (≥1-y-old) and juvenile (<1-y-old) Atlantic Population Canada geese *Branta canadensis* (Ungava Bay group) based on band recoveries during the 2004–2005 through 2008–2009 hunting seasons.

	Early season[a]		Regular season		Late season[b]		Total	
Region	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile
Eastern Canada[c]	0	0	27	26	0	0	27	26
New England[d]	0	0	4	2	0	0	4	2
Mid-Atlantic[e]	1	1	26	25	0	0	27	26
Chesapeake Bay[f]	0	0	43	46	0	0	43	46
Southern Atlantic Flyway[g]	0	0	<1	0	0	0	<1	0
U.S. Atlantic Flyway	1	1	72	73	0	0	73	74
Other flyways[h]	0	0	0	0	0	0	0	0

[a] September seasons designated as ''special early Canada goose seasons'' in the United States.
[b] Late January and February seasons designated as ''special late Canada goose seasons'' in the United States.
[c] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[d] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[e] New Jersey, New York, and Pennsylvania.
[f] Delaware, Maryland, and Virginia.
[g] Georgia, North Carolina, South Carolina, and West Virginia.
[h] The Mississippi, Central, and Pacific flyways combined.

Table 6. Average percentage of distribution of adult (≥1-y-old) and juvenile (<1-y-old) Atlantic Flyway Resident Population Canada geese *Branta canadensis* based on band recoveries during the 2004–2005 through 2008–2009 hunting seasons.

	Early season[a]		Regular season		Late season[b]		Total	
Region	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile	% Adult	% Juvenile
Eastern Canada[c]	0	0	8	13	0	0	8	13
New England[d]	4	9	4	11	1	<1	9	21
Mid-Atlantic[e]	23	24	21	30	1	<1	45	55
Chesapeake Bay[f]	6	2	8	4	3	2	17	8
Southern Atlantic Flyway[g]	9	1	13	2	0	0	16	3
U.S. Atlantic Flyway	41	36	46	47	5	3	92	86
Other flyways[h]	<1	<1	1	<1	0	0	1	<1

[a] September seasons designated as ''special early Canada goose seasons'' in the United States.
[b] Late January and February seasons designated as ''special late Canada goose seasons'' in the United States.
[c] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[d] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[e] New Jersey, New York, and Pennsylvania.
[f] Delaware, Maryland, and Virginia.
[g] Georgia, North Carolina, South Carolina, and West Virginia.
[h] The Mississippi, Central, and Pacific flyways combined.

Regular season. In the United States, most of the estimated annual regular season harvest of approximately 157,000 was AFRP geese (62%), followed by Hudson Bay AP (23%), Ungava Bay AP (10%), NAP (5%), SJBP (1%), and temperate-breeding Mississippi Flyway (1%) geese (Table 7). All U.S. regions except for the Chesapeake Bay derived the majority of their harvest from temperate-nesting geese. Most of the Chesapeake Bay region's harvest was AP geese (66%; 49% Hudson Bay group and 17% Ungava Bay group), highlighting the importance of this population to that region. Atlantic Population geese also were important in the mid-Atlantic region, making up 22% (13% Hudson Bay group and 9% Ungava Bay group) of that region's harvest. In the New England region NAP geese were an important component, contributing 29% of the harvest.

Eastern Canada's annual harvest of approximately 47,000 adult geese consisted mainly of AP (42%; 30% Hudson Bay group and 12% Ungava Bay group), AFRP (32%), and NAP geese (17%); SJBP (6%) and temperate-breeding Mississippi Flyway (3%) geese made up the remainder (Table 7). However, our estimates omitted the harvest of molt-migrant AFRP and temperate-breeding Mississippi Flyway geese because the number of molt migrants was not estimated annually. Thus, we probably underestimated the harvest of AFRP and temperate-breeding Mississippi Flyway geese in eastern Canada, particularly in Ontario where molt-migrant Canada geese are common (Luukkonen et al. 2008).

Special late season. The average annual harvest during the special late season was approximately 10,000 adult geese (Table 7), or approximately 4% of the total annual U.S. Atlantic Flyway harvest of almost 255,600 during all seasons combined. Although all three regions with late seasons derived the majority of their harvest from temperate-nesting geese, 33% of the New England region's harvest was NAP geese. However, the estimated annual NAP harvest there was based on only five band recoveries reported during the entire 5-y period.

Spring and summer harvest

Few spring and summer band recoveries were reported, primarily from geese taken in April (SJBP geese) or May (NAP, AP, and AFRP geese). The range of the estimated annual SJBP harvest, based on 28 direct band recoveries reported during the 5-y period, was 950–4,750 geese. Most of the recoveries came from along the coast of southern James Bay, but some recoveries were taken farther south in Ontario. Estimated annual NAP harvest, based on just three recoveries (two along Quebec's western shore of the Gulf of St. Lawrence and one in central Labrador), was 636–3,181 geese. In total, 25 recoveries of Hudson Bay AP geese resulted in an annual estimated harvest range of 4,638–20,552 geese. The majority of those recoveries occurred on the northeast shore of Hudson Bay in Quebec, with a few others reported from southwestern Quebec. Subsistence hunters annually harvested an estimated 1,913–8,869 Ungava Bay AP geese (21 recoveries), taken primarily along Quebec's Ungava Bay coast (14 recoveries) and in southwestern Quebec (four recoveries), in the same area as several AP Hudson Bay bird recoveries. There were 16 direct recoveries of AFRP geese reported by Canadian subsistence hunters: six from southern Ontario; three from Quebec's shore of the James Bay; four from Quebec's southern shore of the Hudson Bay; and one from southwestern Quebec. The range of annual estimated AFRP harvest was 2,517–12,476 geese. Atlantic Flyway Resident Population recoveries were from geese banded in Ontario (11), Quebec (one), New York (two), Pennsylvania (one), and Maryland (one).

Conclusions

Using banding and band recovery data, we estimated that almost 255,600 adult geese were harvested annually in the U.S. portion of the Atlantic Flyway. This is considerably less than the average annual harvest of approximately 507,800 adult geese estimated by the U.S. National Waterfowl Harvest Survey for the same years (USFWS

Table 7. Total estimated average annual region-specific harvest ($\hat{H}$) of adult (≥1-y-old) Canada geese *Branta canadensis* in the Atlantic Flyway during the early September, regular, and late seasons from 2004–2005 to 2008–2009, and the percentage of each region's adult Canada goose harvest that was Atlantic Flyway Resident Population (AFRP), Atlantic Population [Hudson Bay group; AP (HB)], Atlantic Population [Ungava Bay group; AP (UB)], North Atlantic Population (NAP), Southern James Bay Population (SJBP), and Mississippi Flyway temperate-breeding (MF) Canada geese.

			% of regional harvest					
Season	**Region**	**Total ($\hat{H}$)**	**AFRP**	**AP (HB)**	**AP (UB)**	**NAP**	**SJBP**	**MF**
September[a]								
	New England[b]	8,076	97	3	0	0	0	0
	Mid-Atlantic[c]	49,457	98	0	<1	0	<1	1
	Chesapeake Bay[d]	12,457	98	2	0	0	0	<1
	Southern Atlantic Flyway[e]	18,665	99	0	0	0	0	<1
	Total	88,657	98	1	<1	0	<1	1
Regular								
	Eastern Canada[f]	47,558	32	30	12	17	6	3
	New England	13,310	64	2	6	29	0	0
	Mid-Atlantic	61,731	71	13	9	5	1	1
	Chesapeake Bay	54,340	33	49	17	0	<1	<1
	Southern Atlantic Flyway	27,476	97	2	<1	0	<1	1
	U.S. total	156,856	62	23	10	5	1	1
	Total	204,414	55	24	11	8	2	1
Late[g]								
	New England	2,373	67	0	0	33	0	0
	Mid-Atlantic	1,508	100	0	0	0	0	0
	Chesapeake Bay	6,185	95	3	0	0	2	0
	Total[h]	10,066	89	2	0	8	1	0

[a] September seasons designated as "special early Canada goose seasons" in the United States.
[b] Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont.
[c] New Jersey, New York, and Pennsylvania.
[d] Delaware, Maryland, and Virginia.
[e] Georgia, North Carolina, South Carolina, and West Virginia.
[f] New Brunswick, Newfoundland and Labrador, Nova Scotia, eastern Ontario, Prince Edward Island, and Quebec.
[g] Late January and February seasons designated as "special late Canada goose seasons" in the United States.
[h] The entire Atlantic Flyway combined.

Division of Migratory Bird Management, Branch of Harvest Surveys, unpublished data). However, if we apply the bias correction factor recommended by Padding and Royle (in press) to the harvest surveys estimate, that estimate is reduced to approximately 304,700, a value that is much closer to our estimate. Furthermore, we recognize that our estimate for AFRP geese was incomplete because some states did not band AFRP geese, and we were unable to fully account for the harvest of AFRP geese from those states. Thus, we believe that analysis of band recovery data does provide useful estimates of harvest distribution and derivation in the United States, but accuracy of results would be significantly improved if all states banded AFRP geese every year.

Our average annual fall and winter harvest estimate for eastern Canada (excluding Ontario) of approximately 23,600 adult geese was also much lower than the annual mean harvest of approximately 81,700 geese that Canada's national harvest survey estimated for the same period (Gendron and Collins 2007). Canada's national waterfowl harvest survey is very similar to the U.S. survey (Cooch et al. 1978; Padding et al. 2006; Archived Material in Dryad, Reference S10; http://datadryad.org/handle/10255/dryad.38309); thus, the two surveys are probably subject to the same types and sources of bias. Therefore, although some of the discrepancy between our estimate and Canada's harvest survey estimate was due to limited banding effort on AFRP geese in some provinces and omission of the harvest of molt-migrant AFRP and Mississippi Flyway temperate-breeding Canada geese, we suspect that 1) as in the United States, Canada's harvest survey estimates were biased high, 2) band reporting rates were lower in Canada than they were in the United States, or 3) both. The band reporting rates could bias distribution and derivation results, particularly if band reporting rates varied among provinces.

Spring and summer harvest estimates were more difficult to interpret because of uncertainty about band reporting by subsistence hunters. We estimated total annual spring and summer harvest in eastern Canada to be approximately 11,000–50,000 adult geese, amounting to 4–16, 9–33, 8–28, 8–29, and 1–6% of the total annual adult harvest of NAP,

SJBP, Hudson Bay AP, Ungava Bay AP, and AFRP geese, respectively. The lower limit estimates were small fractions of total harvest for each population, but the upper limit estimates seemed more realistic, and they represented significant proportions of the SJBP and AP harvests. Accurate, current estimates of subsistence harvest are needed to determine the relative magnitudes of spring and summer harvest versus fall and winter harvest.

In the Atlantic Flyway states, it is evident that both the special September and late seasons are effective in targeting AFRP geese (combined they accounted for half of the AFRP harvest in the United States) with minimal harvest of subarctic-breeding populations. However, despite expansion of those seasons and longer regular seasons in AFRP zones, Atlantic Flyway managers are still faced with an overabundant resident goose population (U.S. Department of the Interior 2005, Archived Material in Dryad, Reference S3, http://datadryad.org/handle/10255/dryad.38309). The desire to minimize impacts on subarctic-breeding geese reduces options for further increasing hunting pressure on AFRP geese, either by expanding areas or time periods during which geese may be hunted. Furthermore, often managers cannot target temperate-breeding geese in urban and suburban areas because of local firearm ordinances, which is problematic given that geese in those areas typically have high survival rates (Balkcom 2010; J. Hughes and S. Iverson, Canadian Wildlife Service, unpublished data). The high survival rates can make reducing population size difficult given that reducing adult survival is one of the most effective methods of controlling overabundant geese (Ankney 1996). Given a current annual population estimate of well $>$1 million, it is unlikely that harvest alone will be able to affect a reduction of AFRP geese to the Atlantic Flyway's population goal of 700,000 (Atlantic Flyway Council 2011b, Archived Material in Dryad, Reference S2, http://datadryad.org/handle/10255/dryad.38309).

Archived Material

To cite this archived material, please cite both the journal article (formatting found in the Abstract section of this article) and the following recommended format for the archived material.

Klimstra JD, Padding PI. 2012. Data from: Harvest distribution and derivation of Atlantic Flyway Canada geese, Journal of Fish and Wildlife Management, 3(1):43.-55. Archived in Dryad Digital Repository: http://datadryad.org/handle/10255/dryad.38309

Data S1. All data for the analysis of all populations is contained in the zip file titled Distribution and Derivation. Abbreviations of the goose populations occurring in the Atlantic Flyway: AFRP, Atlantic Flyway Resident Population; AP, Atlantic Population; NAP, North Atlantic Population; SJBP, Southern James Bay Population. (518.2 KB ZIP)

Reference S1. Atlantic Flyway Council. 2011a. Atlantic brant management plan.

Reference S2. Atlantic Flyway Council. 2011b. Atlantic Flyway Resident Population Canada Goose Management Plan. (2.253 MB DOC)

Reference S3. U.S. Department of the Interior. 2005. Final Environmental Impact Statement: Resident Canada goose management. U.S. Department of the Interior, Washington, D.C. (1.252 MB PDF)

Reference S4. Atlantic Flyway Council. 2008a. Management plan for the North Atlantic Population of Canada geese. (654.3 KB DOC)

Reference S5. Atlantic Flyway Council. 2008b. A management plan for the Atlantic Population of Canada geese. (2.871 MB DOC)

Reference S6. Munro RE, Kimball CF. 1982. Population ecology of the mallard: VII. Distribution and derivation of the harvest. U.S. Fish and Wildlife Service Resource Publication 147. U.S. Fish and Wildlife Service, Washington, D.C. (5.837 MB PDF)

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All found at: http://datadryad.org/handle/10255/dryad.38309

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