



Management and Conservation Article

Winter Distribution, Movements, and Annual Survival of Radiomarked Vancouver Canada Geese in Southeast Alaska

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ABSTRACT Management of Pacific Flyway Canada geese (*Branta canadensis*) requires information on winter distribution of different populations. Recoveries of tarsus bands from Vancouver Canada geese (*B. canadensis fulva*) marked in southeast Alaska, USA, ≥ 4 decades ago suggested that $\geq 83\%$ of the population was non-migratory and that annual adult survival was high ($\hat{S} = 0.836$). However, recovery distribution of tarsus bands was potentially biased due to geographic differences in harvest intensity in the Pacific Flyway. Also, winter distribution of Vancouver Canada geese could have shifted since the 1960s, as has occurred for some other populations of Canada geese. Because winter distribution and annual survival of this population had not recently been evaluated, we surgically implanted very high frequency radiotransmitters in 166 adult female Canada geese in southeast Alaska. We captured Vancouver Canada geese during molt at 2 sites where adults with goslings were present (breeding areas) and 2 sites where we observed nonbreeding birds only. During winter radiotracking flights in southeast Alaska, we detected 98% of 85 females marked at breeding areas and 83% of 70 females marked at nonbreeding sites, excluding 11 females that died prior to the onset of winter radiotracking. We detected no radiomarked females in coastal British Columbia, or western Washington and Oregon, USA. Most (70%) females moved ≤ 30 km between November and March. Our model-averaged estimate of annual survival ($\hat{S} = 0.844$, SE = 0.050) was similar to the estimate of annual survival of geese marked from 1956 to 1960. Likely $< 2\%$ of Vancouver Canada geese that nest in southeast Alaska migrate to winter areas in Oregon or Washington where they could intermix with Canada geese from other populations in the Pacific Flyway. Because annual survival of adult Vancouver Canada geese was high and showed evidence of long-term consistency, managers should examine how reproductive success and recruitment may affect the population.

KEY WORDS Alaska, *Branta canadensis fulva*, radiotelemetry, survival, Vancouver Canada geese, winter distribution.

Vancouver Canada geese (*Branta canadensis fulva*) nest in coastal regions of southeast Alaska, USA, and British Columbia, Canada (Delacour 1954, Hansen 1962). Previous recoveries of individuals marked with tarsus bands in southeast Alaska suggested that a high proportion ($\geq 83\%$) of the population did not migrate from the region in winter and that the annual adult survival rate was relatively high ($\hat{S} = 0.836$; Hansen 1962, Ratti et al. 1978, Ratti and Timm 1979). However, a reevaluation of winter distribution and annual survival for this population is needed because most (84%) banding of Canada geese in southeast Alaska took place prior to 1966. The population has been poorly monitored since, and comparison of recent rates of survival for adult geese with estimates derived from birds banded > 40 years ago would provide an indication of long-term changes in this important demographic parameter. In the absence of population surveys, an understanding of demographic processes can be useful to evaluate factors that are likely to influence population trajectory (Wisdom et al. 2000, Mills and Lindberg 2002). A reevaluation of winter distribution is also needed because in the last 4 decades there

have been substantial changes in winter distribution of other Canada goose populations in the Pacific Flyway (Jarvis and Cornely 1988, Bromley and Rothe 2003). Whether Vancouver Canada geese have altered their winter distribution is unknown.

Furthermore, interpretation of Vancouver Canada geese winter distribution from band recovery data is difficult due to temporal and spatial differences in harvest intensity in the Pacific Flyway. Although Hansen (1962) noted that 17% of Canada geese marked in southeast Alaska were recovered in Oregon and Washington, USA, Ratti and Timm (1979) estimated that approximately 2% of the population likely migrated from Alaska and concluded that recovery distribution was probably biased due to greater harvest intensity on southern wintering areas. Alternatively, band recoveries could overestimate the proportion of the population that remained in southeast Alaska during winter because 42% of the banded birds harvested in that region were shot in September, before they would have had an opportunity to migrate. Understanding winter distribution of Vancouver Canada geese is especially important because 6 populations of Canada geese and cackling geese (*B. hutchinsii*) winter sympatrically in western Oregon and Washington, and it is necessary to know the source populations of birds harvested there (Jarvis and Cornely 1988). Vancouver Canada geese are morphologically similar to dusky Canada geese (*B.*

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canadensis occidentalis), for which special harvest restrictions are in place due to their small population size (Bromley and Rothe 2003). The presence of Vancouver Canada geese on the Oregon and Washington wintering areas used by dusky Canada geese could inflate harvest estimates and winter population surveys of the latter.

Radiotelemetry can provide unbiased estimates of population distribution and individual survival (Esler et al. 2000a, Kernohan et al. 2001, Hupp et al. 2006). Therefore, we radiomarked adult female Canada geese in southeast Alaska in order to 1) estimate the proportion of radiomarked birds that remained in southeast Alaska in winter versus those that used winter areas in Oregon or Washington, 2) measure the distance radiomarked geese moved in winter, and 3) estimate annual survival rates of radiomarked individuals and evaluate seasonal and annual variation in survival.

STUDY AREA

Southeast Alaska is a complex archipelago of >5,000 islands and the adjacent mainland, 90% of which was federally managed as national forest or national park land (Albert and Schoen 2007). The region is mountainous with a temperate rainforest typically present at elevations <500 m (Stowell 2006). The approximately 30,000 km of coastline in southeast Alaska ranges from rocky, narrow beaches that are exposed to wind and wave action, to broad estuaries and wide protected shorelines with large intertidal areas (Albert and Schoen 2007). Intertidal and shallow water areas often supported diverse marine grass and algal communities and an abundance of benthic invertebrates. Salt marshes often occurred at the heads of bays. Winters were typically cold with average temperatures of approximately 0° C and occasional low temperatures of ≤ -20° C. Rain or snow were frequent. Daily tides averaged approximately 5 m and kept the lower intertidal areas snow free. Canada geese typically wintered in intertidal habitats of estuaries and sheltered shorelines (Fox 2008). Hodges et al. (2008) conducted aerial surveys of almost all shorelines in southeast Alaska between 1997 and 2002 and estimated that approximately 25,000 Canada geese wintered in the region.

METHODS

Field Methods

Prior to marking geese, we conducted aerial surveys in late June 2004 to locate lakes and inlets where geese were molting remiges. The areas we surveyed included molting sites identified by Lebeda and Ratti (1983) and other areas where goose flocks had been reported in summer. We located 4 sites that were accessible by boat or float plane (Fig. 1) where we observed molting geese and had permission from the land management agency to conduct captures. We captured geese at those sites between 7 and 17 July 2004 and 2005. We used an amphibious fixed-wing aircraft to disturb geese and move them from shorelines and forest habitats into open water where we surrounded flocks with inflatable boats and kayaks. We then pushed geese into a corral trap that we established on shore (Robards 1960).

Molting flocks at 2 sites (Harlequin and Icefall lakes) consisted entirely of nonbreeding, adult-plumaged geese. We observed no goslings at those sites. Some family groups with goslings were present at the remaining 2 sites (Fool Inlet and Sumdum Island), indicating that nesting had occurred in those areas. The number of geese that molted at Icefall Lake was relatively small (≤40), and we only captured birds there in 2004. We observed ≥90 geese molting at other sites and captured birds at those locations in both years.

We determined sex of captured geese via cloacal examination (Hanson 1962). We banded adult males and juveniles when conditions permitted and released them immediately after capture. We retained up to 30 adult females for radiomarking at each site and held them in portable pet kennels for up to 12 hours during transmitter deployment. We established a field surgical facility at each capture site and veterinarians implanted a 26-g very high frequency (VHF) radiotransmitter (Holohill Systems, Limited, Carp, ON, Canada) that had a 14-month battery life in the right coelomic air sac of each female (Korschgen et al. 1996). We administered propofol intravenously to induce anesthesia, and monitored heart rate and respiration of geese during surgeries. The 28-cm whip antenna exited the body near the base of the tail. We measured a suite of morphological features on radiomarked females and banded each bird with a United States Geological Survey metal tarsus band. We obtained either a blood sample or a growing feather for genetic verification of gender and to assess genetic variation within the population (M. Sexson, United States Geological Survey, unpublished data). We returned radiomarked females to animal carriers following surgery, held them for at least 1 hour until they had recovered fully from anesthesia, and then released them in groups.

We conducted a tracking flight via fixed wing aircraft near the capture areas 2 weeks (2005) or 4 weeks (2004) after we released birds. Transmitter pulse rate increased in the event of mortality and we monitored all frequencies to determine if any radiomarked females died following release. We considered mortalities that occurred between release and the first tracking flight to be the result of capture and marking (Mulcahy and Esler 1999).

We conducted radiotracking flights throughout southeast Alaska during the fall and winter of 2004–2005 and 2005–2006. In each year we conducted tracking flights during 3 periods; fall (11–24 Nov), midwinter (11–12 Jan in 2005 and 17–18 Feb in 2006), and late winter (17 Mar in both years). We monitored radio frequencies along the coast between Harlequin Lake and the Alsek River during fall radiotracking flights because that area included large estuaries that were potentially suitable as winter habitat. We flew near shorelines of the mainland and major islands from Glacier Bay to the boundary between Alaska and British Columbia in fall and midwinter (Fig. 1). Each tracking interval required 2–3 days of flying.

During the late winter tracking flight, we returned to areas where we had located geese on the earlier flights to assess presence of marked birds and to detect mortality signals. We

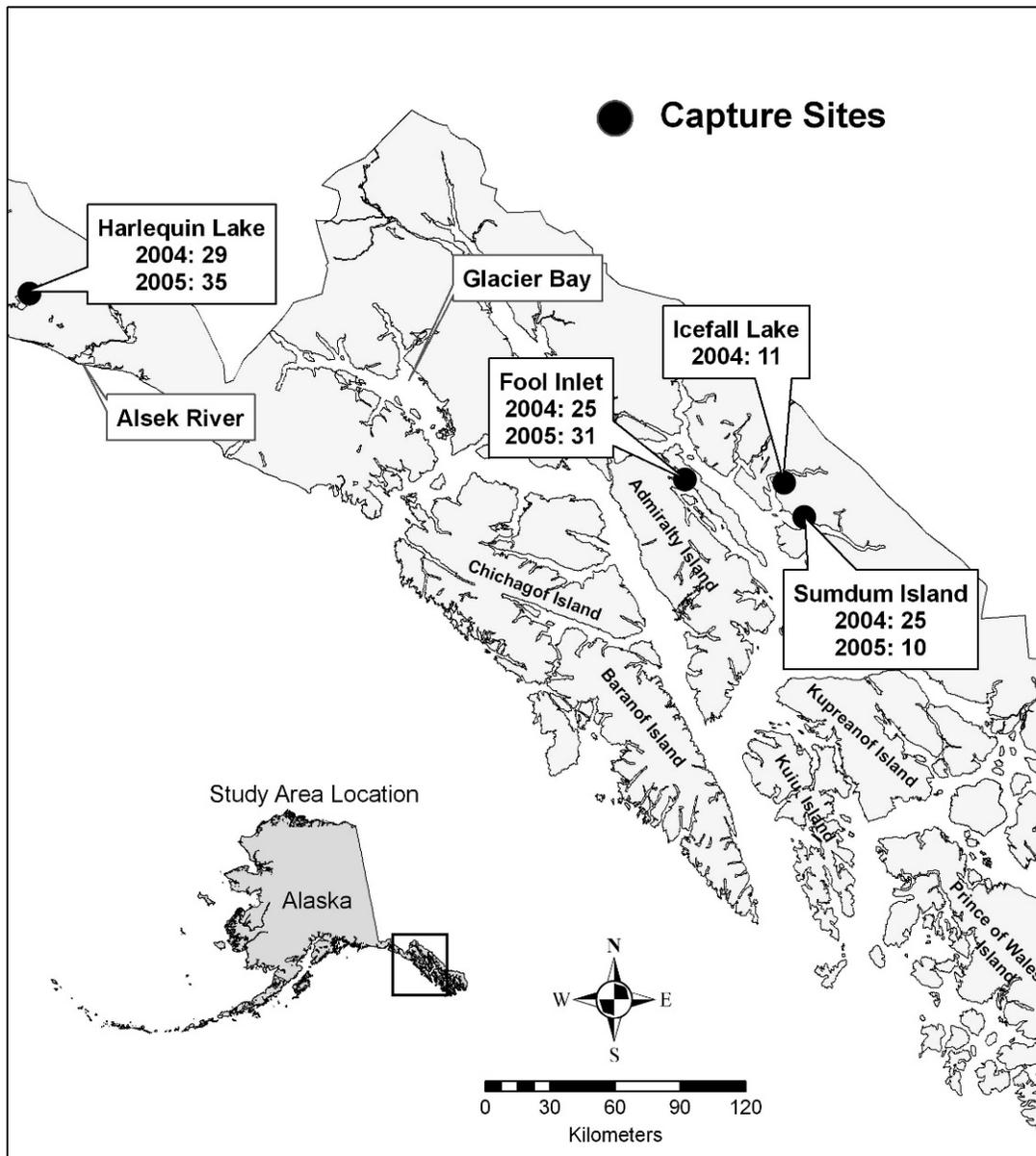


Figure 1. Locations in southeast Alaska, USA, where we captured and radiomarked adult female Vancouver Canada geese during molt, July 2004 and 2005. The number of female geese radiomarked is indicated after each year.

conducted flights using fixed-wing aircraft that were equipped with H-style antennas. Aircraft elevation was usually 1,500–2,500 m above ground level, and reception range of test transmitters was 15–20 km. We recorded the flight track of the aircraft via a Global Positioning System receiver and a modified version of a computer program described by Butler et al. (1995). We used that record to ensure that we had flown near most of the areas in southeast Alaska where Canada geese had been observed by Hodges et al. (2008) during winter aerial surveys.

We monitored radiofrequencies that we did not detect in Alaska during radiotracking flights in northwestern Oregon and southwestern Washington in December and during midwinter waterfowl surveys in January. Those flights covered major wintering areas for Canada geese in the

Willamette Valley and Lower Columbia River of western Oregon and Washington, USA. In addition, we monitored radios that we did not detect in Alaska during ground tracking in the Klamath Basin. We conducted tracking flights along the coast of British Columbia in December and again in either February or March of each winter. Those were straight-line flights when the aircraft was in transit between Prince Rupert and Victoria, British Columbia, and so they did not closely follow the shoreline. Flights near the Queen Charlotte Islands, British Columbia occurred during February or March. We recorded latitude and longitude of the aircraft at each point that we detected a radiotransmitter, but we did not attempt to determine location more precisely than approximately ± 15 km. We noted mortalities based on changes in signal pulse rate.

Following the winter season, we monitored radiotransmitters during tracking flights in southeast Alaska from 26 April to 8 May each year to assess locations of birds at the onset of nesting. Those flights encompassed most areas flown in southeast Alaska during fall and winter. In addition, we relocated geese via aerial relocation and ground tracking multiple times during nesting in May and early June. Between 7 and 12 July we conducted a final tracking flight near molting areas where we originally captured geese the previous year.

Data Analysis

Winter distribution and movements.—We estimated the percentages of radiomarked birds that remained in southeast Alaska during winter versus those detected in Oregon or Washington. We considered a female wintered in southeast Alaska if we detected her radio signal on at least one fall or winter tracking flight in that region, and if we did not detect her elsewhere. We excluded from the analysis any bird that we only detected as dead during fall and winter tracking flights because we did not know if those individuals had died at their wintering site. We detected some radiomarked geese only on 1 or 2 of the fall and winter flights in southeast Alaska, indicating that 1) during a telemetry flight we had an imperfect likelihood of detecting a female that was present in the region with a functional radio, 2) radiotransmitters may have increasingly failed as winter progressed, or 3) some birds moved from the region after the fall tracking flight. To examine those possibilities we tallied the number of geese that we detected at least once during the 3 flights in fall and winter and computed the proportion of those individuals (p) that we detected on each individual tracking flight. The proportion of radios detected would have diminished from fall to late winter if radio failure or movement from the region increased as winter progressed. We computed 95% confidence intervals on p following Zar (1984) to examine if a seasonal decline was evident.

We used logistic regression to assess whether detection of a radiomarked female in southeast Alaska during winter was influenced by year of capture or by capture site. We pooled the latter into breeding areas (Sumdum Island and Fool Inlet) versus nonbreeding areas (Harlequin Lake and Icefall Lake). We examined a suite of 5 candidate models to assess the effects of year and type of capture site on winter presence of marked females, and we evaluated model parsimony using Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002). Annual differences were possible if variation in winter severity affected migration of geese from southeast Alaska. Winter distribution could have varied between birds captured in different sites if Canada geese from other regions conducted summer migrations to molt at nonbreeding sites (Salomonson 1968) but departed southeast Alaska to winter elsewhere.

We computed the distance each radiomarked female moved from her capture site to the site where we detected her most often during winter. For females that we only detected twice in winter, we measured the distance to the

first of those locations. We also measured the total distance radiomarked females moved among winter sites. We constrained that analysis to females located on each of the 3 tracking flights so that we had a more complete measure of total movement. We computed total distance moved during winter to the nearest 30 km.

Seasonal and annual survival.—We used the nest survival module in Program MARK (White and Burnham 1999) to obtain maximum likelihood estimates of monthly survival probability (MSP) of radiomarked female Vancouver Canada geese. We adopted this approach because radiotransmitters were relocated irregularly and nest survival models incorporated uncertainty regarding the timing of death between survey periods (Rotella 2007). Individual encounter histories included information on the month the bird was marked (i), the last month it was observed alive (j), the last month the bird was detected (k), and the bird's fate (alive or dead) when last detected. For individuals whose radios did not indicate mortality, j equaled k , whereas for birds that died, j was $<k$. We marked all birds in July; therefore, we considered July as the start ($i = 1$) of the period; months were scaled relative to the July start (i.e., 1, 2, ..., 13). To avoid bias in our estimates resulting from mortality associated with capture and handling, we included only encounter histories of individuals that survived the interval between capture and the first radiotracking flight 2–4 weeks later (Mulcahy and Esler 1999).

We used an information-theoretic approach to assess support for competing hypotheses about Canada goose survival and to assess variation in survival relative to covariates (Burnham and Anderson 2002). We examined an initial suite of 15 models that included effects of season, year, capture site, and body mass on survival. We then considered 3 additional models that assessed additive effects of year, body mass, and capture site, and the interactive effects of year with the top seasonal model.

We included body mass in some models because it can be positively correlated with survival of female geese (Schmutz and Ely 1999). However, we adjusted body mass for variation due to structural size and molt status. We first conducted a principal components analysis of structural size using the correlation matrix on culmen length, total tarsus length, midwing length, bill width at the nail, and bill width at the base. We then used generalized linear modeling in PROC GLM of SAS (SAS Institute Incorporated 1990) to evaluate models where body mass was influenced by the first principal component of structural size (PC1), 9th primary length, PC1 + 9th primary length, and a model in which body mass was invariant (null model). We assessed the influence of 9th primary length because body mass can be related to the length of time a bird has been flightless (Owen and Ogilvie 1979, Brown and Saunders 1998). We used an information-theoretic approach to compare models, and we concluded that mass was influenced by PC1 and 9th primary length because that model [mass (g) = 3176 + (111.1 × PC1) + (−1.5 × 9th primary length in mm)] received overwhelming support (model wt = 0.99), and explained 35% of the variation in female body mass. We

adjusted mass for the effect of body size and 9th primary length via the equation:

$$m_{\text{adj}} = (m_{\text{obs}} - m_{\text{pre}}) + \bar{m}_{\text{obs}}$$

where m_{adj} = adjusted body mass, m_{obs} = observed body mass, m_{pre} = predicted body mass, and \bar{m}_{obs} = the mean of observed mass across all individuals (Badzinski and Petrie 2006).

We suspected that survival probability might vary seasonally. Therefore, we considered 10 seasonal models in which we assessed variation in survival relative to groupings of months that approximated the seasonal life history events or environmental conditions and reflected timing of telemetry flights. July–November was late summer and fall and included the period when birds were exposed to hunting; December–March was the wintering period when birds were exposed to potentially harsh winter conditions including ice cover, below freezing temperatures, and high winds; April was prenesting when wintering flocks disbanded and birds dispersed to breeding areas; May was the period when nesting females might be exposed to greater predation risk (Anthony et al. 2004); and June and July were the postnesting period when successful breeders reared broods, and failed breeders and nonbreeders may have gone to molting areas. Our most complex seasonal model assessed seasonal specificity in survival among 5 seasonal groupings. We considered 5 seasonal models in which survival in one season was compared to the combined remaining seasons. We also considered 4 seasonal models in which we combined effects of late summer and fall with winter, winter with prenesting, prenesting with nesting, and late summer and fall with nesting, and we compared those combined effects to remaining months.

We assessed annual variation in survival to account for potential yearly variation in environmental conditions. We suspected that survival probability could be related to capture site as a result of potential variation in habitat quality and predator densities among sites. Therefore, we considered a 4-parameter model that estimated capture site specificity in survival. Females captured at the breeding sites may have been older than those at the nonbreeding sites where second-year birds were likely more common. Survival likelihood in geese can be influenced by age and breeding status (Francis et al. 1992, Schmutz et al. 1994); therefore, we considered a second molt site model that contrasted monthly survival of females marked at breeding sites with that of birds marked at nonbreeding sites.

We assessed relative model support among survival models using AIC_c and model weights (w_i ; Burnham and Anderson 2002). We back-transformed parameter estimates from the logit link and calculated estimates of annual survival as the product of 12 MSPs. We used the delta method (Seber 1982) to calculate variances associated with back-transformed survival estimates and model-averaged predicted survival estimates across all models (Burnham and Anderson 2002). We obtained derived model-averaged estimates from Program MARK.

RESULTS

Winter Distribution and Movements

We marked 90 and 76 adult females with VHF radios in 2004 and 2005, respectively. In each year, 2 females died between capture and the first tracking flight 2–4 weeks later, and 7 females had died when first detected on subsequent tracking flights. We excluded these 11 individuals that died from analysis of winter distribution.

Of 155 females used to estimate winter distribution of radiomarked birds, we detected 141 (91.0%) during at least one fall or winter tracking flight in southeast Alaska. We did not detect any radiomarked females in coastal British Columbia, Washington, or Oregon. Among females detected in southeast Alaska, most (65.2%) were detected on each of 3 fall or winter tracking flights, with 9.2% and 25.5% detected on 1 and 2 flights, respectively. Among females located at least once in southeast Alaska, the proportion detected on individual tracking flights ranged from 0.78 to 0.94, and in both years the proportion of birds detected on the late winter flight was comparable to the proportion detected in fall (Fig. 2). In each marked cohort there was one radiomarked bird that we did not detect during fall or winter that we subsequently detected in southeast Alaska during tracking flights in April or May. Also, from November through May we did not detect 3 females marked at Harlequin Lake in 2004, but we heard them at that molting site in July 2005.

Based on logistic regression models, winter detection of a radiomarked Canada goose in southeast Alaska was influenced by the type of capture site and year of capture (Table 1). The best supported model ($w_i = 0.49$) included capture site ($\hat{\beta}_{\text{Site}} = 2.22$, SE = 0.79) and year ($\hat{\beta}_{\text{Year}} = 1.29$, SE = 0.69) effects. During fall and winter flights in southeast Alaska, we detected a higher percentage of females marked at breeding areas (97.7%) than females marked at nonbreeding areas (82.9%), and more of the birds marked in 2005 (95.6%) compared to those marked in 2004 (87.2%). However, the disparity in winter detection of females marked at breeding versus nonbreeding sites was greater for birds marked in 2004 (97.9% vs. 73.7%) than for females marked in 2005 (97.3% vs. 93.4%), resulting in support ($w_i = 0.33$) for a model with an interaction between year and type of capture site. The between-year disparity in detection of females from nonbreeding areas was not related to marking at Icefall Lake in 2004 only. We detected 9 of 11 (82%) females marked at Icefall Lake in 2004, but only 19 of 27 (70%) females marked at Harlequin Lake in that year, suggesting annual disparity was mainly due to differences in detection of birds marked at Harlequin Lake.

The areas where radiomarked geese wintered within southeast Alaska often differed among birds marked at different capture sites. Females marked at a site in different years generally used the same winter areas. Females marked at Harlequin Lake moved a median of 420 km (range 270–540 km) between the capture site and wintering areas, and most (84%) of the birds that we detected used winter sites on Kupreanof and Kuiu islands (Fig. 3). Females marked at

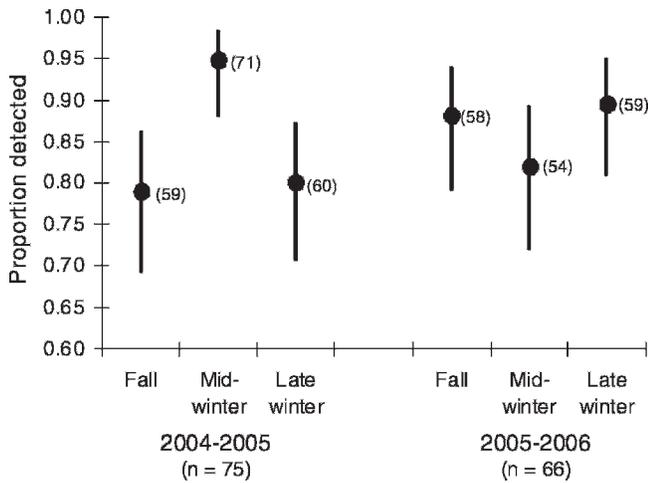


Figure 2. Proportions of radiomarked adult female Vancouver Canada geese that were detected on each of 3 radiotracking flights in southeast Alaska, USA, 2004–2006. We tallied the number of females detected on at least one flight in each year, as indicated in parentheses under the year. Point estimates are the proportion of those individuals detected on each flight. Numbers in parentheses next to the estimate are the number of radios detected on that flight. Vertical lines represent 95% confidence intervals. We excluded females that we only detected as dead during fall and winter tracking flights.

Fool Inlet moved a median of 150 km (range <30 km to 180 km) to winter sites, and 55% of the birds detected used the same areas on Kupreanof and Kuiu islands as females marked at Harlequin Lake. Most other females marked at Fool Inlet remained within 30 km of the capture area. Of the Canada geese marked at Sumdum Island and detected in winter, 95% remained within 30 km of the capture site. Females from Icefall Lake moved approximately 60 km to winter sites on the south end of Admiralty Island. Once at winter sites, Canada geese moved little. Among 45 geese marked in 2004 that we detected on each of the 3 fall and winter tracking flights, 76% moved ≤ 30 km between November and March. Of 45 geese marked in 2005 that we detected on each tracking flight, 64% moved ≤ 30 km during the winter. All movements >30 km were geese that we detected on Kupreanof and Kuiu islands in November that moved to northern Admiralty Island within 30 km of Fool Inlet by late winter. The majority (85%) were birds that we originally captured at Fool Inlet.

Seasonal and Annual Survival

We analyzed encounter histories of 153 radiomarked female Canada geese after excluding 4 birds that died within 4 weeks of capture and 9 birds that were not detected again after they were marked. We detected 9 mortalities of 81 marked birds in 2004 and 11 mortalities of 72 marked birds in 2005 (Table 2).

There was considerable model selection uncertainty in our set of candidate models. All models were within 4 AIC_c values. The top 12 models, including the null model, were within 2 AIC_c values, and the top approximating model accounted for only 12% of the AIC_c model weight (Table 3). Therefore evidence for seasonal or annual variation in MSP, an effect of body mass, or differences in survival among molting sites was equivocal. A separate parameter for survival in late summer and fall (Jul–Oct) versus other months was present in 3 of the top 4 models and had a total model weight of 0.41. However, the difference in MSP between late summer and fall and other seasons was small (0.01). To reduce bias, account for model selection uncertainty, and avoid overestimating precision, we model-averaged predicted MSPs across all models (Burnham and Anderson 2002). That resulted in 7 estimates of annual survival for each molt site and year. We then averaged across predicted survival rates to produce an estimate of average annual survival, 0.844 (SE = 0.050). As predicted by the null model, mean annual survival was 0.851 (SE = 0.031).

DISCUSSION

Winter Distribution and Movements

We detected a high percentage (91%) of radiomarked Canada geese in southeast Alaska during winter and did not find evidence that marked birds wintered elsewhere. By remaining in southeast Alaska, Vancouver Canada geese used a stable, forage-rich environment where there was little human disturbance and where they were able to maintain high rates of overwinter survival. During winter in southeast Alaska, Canada geese exploit marine grasses and salt marsh plants commonly found in intertidal areas (Fox 2008). Because intertidal communities are relatively stable environments, waterfowl that use such habitats often move little during winter, show strong fidelity when returning to winter sites (Robertson and Cooke 1999, Hupp et al. 2008a), and

Table 1. Logistic regression models for the effects of capture year (β_{Year}) and capture site (β_{Site}) on the likelihood that radiomarked adult female Canada geese were detected during winter in southeast Alaska, USA, 2004–2006. Based on 155 Canada geese radiomarked at breeding versus nonbreeding sites in southeast Alaska in 2004 and 2005. We ranked models based on increasing Akaike’s Information Criterion adjusted for small sample size (AIC_c).

Model	K^a	AIC_c	ΔAIC_c	w_i^b	Model likelihood
$\beta_0 + \beta_{Year} + \beta_{Site}$	3	85.17	0.0	0.49	1.00
$\beta_0 + \beta_{Year} + \beta_{Site} + \beta_{Year} \times Site$	4	85.95	0.78	0.33	0.68
$\beta_0 + \beta_{Site}$	2	87.17	2.00	0.18	0.37
$\beta_0 + \beta_{Year}$	2	94.53	9.36	0.004	0.01
β_0 (Intercept only)	1	96.04	10.87	0.002	0.004

^a No. of parameters.

^b AIC_c model wt.

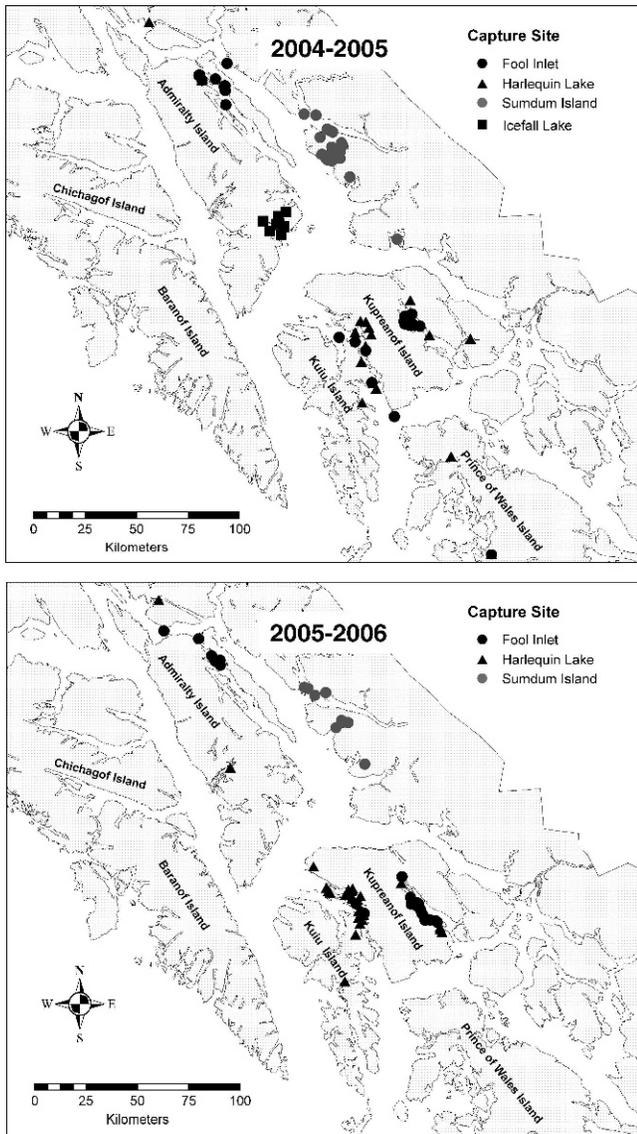


Figure 3. Winter distribution of radiomarked adult female Vancouver Canada geese in southeast Alaska, USA, 2004–2006. Each mark represents the most frequent location of each individual during 3 winter radiotracking flights. Individuals marked at different locations are indicated with different symbols.

Table 2. Fates of 153 radiomarked adult female Vancouver Canada geese during different seasons in southeast Alaska, USA, 2004–2006. Numbers of birds that were detected alive during each season based on radiotelemetry signals are indicated, as are the numbers of birds that were first detected as dead in that season. We did not include radiomarked birds that died ≤ 4 weeks after capture.

Yr of capture	Fate	Aug–Nov	Dec–Mar	Apr	May	Jun–Jul
2004	Detected alive	70 ^a	70 ^b	54	24	31
	Detected dead	1	3	3	0	2
2005	Detected alive	58 ^c	61 ^d	24	55	38
	Detected dead	3	3	0	3	2
Yr combined	Detected alive	128	131	78	79	69
	Detected dead	4	6	3	3	4

^a F detected 5–12 August during radio tracking flights near capture areas and during the fall tracking flight (21–24 Nov).

^b F detected during the midwinter (11–12 Jan) or late winter (17 Mar) tracking flights.

^c F detected during the fall tracking flight (11–12 Nov).

^d F detected during the midwinter (17–18 Feb) or late winter (17 Mar) tracking flights.

can have high overwinter survival (Esler et al. 2000b, Hupp et al. 2008b).

Most radiomarked geese moved little, and we found similar winter distributions within southeast Alaska between geese marked in different years. The longest winter movements we observed were by birds that moved closer to nesting areas by late winter. Unlike most other populations of Canada geese, the winter habitat of Vancouver Canada geese was unaffected by changes in availability of agricultural foods that can prompt midwinter movements (Hestbeck et al. 1991). Furthermore, because annual harvest of Canada geese in southeast Alaska was likely <900 geese/year (T. Rothe, Alaska Department of Fish and Game, unpublished data) and primarily occurred prior to the onset of winter, there was little hunting disturbance that could result in increased movement of geese (Madsen 1998, Béchet et al. 2003).

We could not determine winter location for 9% of the radiomarked birds. Although radiotransmitters of some of those individuals may have failed before the onset of winter tracking flights, radio failure should have been evenly distributed among birds marked at different sites. Instead, we detected a smaller percentage of females marked at nonbreeding sites, especially among birds marked in 2004 at Harlequin Lake. Molt migration away from nesting areas is common in Canada geese and geese at nonbreeding areas may have included molt migrants from different regions (Salmonsén 1968, Luukkonen et al. 2008). No radiomarked geese nested in the vicinity of Harlequin Lake or Icefall Lake (J. W. Hupp, United States Geological Survey, unpublished data), rather they were molting destinations for nonbreeding geese from other areas. Based on mitochondrial DNA and microsatellite allele frequencies in blood and feather samples, there was no genetic evidence that Canada geese marked at nonbreeding sites in southeast Alaska originated from other populations of Canada geese in the Pacific Flyway; however, there was genetic evidence that geese from different molting areas were from different components of the Vancouver Canada goose population (M. Sesson, unpublished data). Vancouver Canada Geese

Table 3. Models of monthly survival probability of 153 radiomarked adult female Vancouver Canada geese in southeast Alaska, USA, 2004–2006. Models are ranked by Akaike’s Information Criterion adjusted for small sample size (AIC_c).

Model	AIC _c	ΔAIC _c	w _i ^a	Model likelihood	K ^b	Deviance
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar, Apr, May, Jun) + Mass ^c }	176.5	0.00	0.12	1.00	3	170.5
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar, Apr, May, Jun)}	176.6	0.10	0.11	0.95	2	172.6
{(Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar, Jun)(Apr, May)}	177.0	0.49	0.09	0.78	2	173.0
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar, Apr, May, Jun) + Molt site}	177.4	0.95	0.07	0.62	5	167.4
{{(Non-breeding sites)(Breeding sites) ^d }	177.5	1.06	0.07	0.59	2	173.5
{(Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar)(Apr, May, Jun)}	177.7	1.19	0.06	0.55	2	173.7
{Constant}	178.2	1.74	0.05	0.42	1	176.2
{Mass}	178.3	1.80	0.05	0.41	2	174.3
{(Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar, Apr, Jun)(May)}	178.3	1.80	0.05	0.41	2	174.3
{(Jul, Aug, Sep, Oct, Nov, May)(Dec, Jan, Feb, Mar, Apr, Jun)}	178.3	1.83	0.05	0.40	2	174.3
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar, Apr, May, Jun) + Year}	178.4	1.90	0.04	0.39	3	172.4
{(Jul, Aug, Sep, Oct, Nov, May, Jun)(Dec, Jan, Feb, Mar, Apr)}	178.5	1.99	0.04	0.37	2	174.5
{(Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar, May, Jun)(Apr)}	178.6	2.10	0.04	0.35	2	174.6
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar, Apr, May, Jun) × Year}	178.8	2.30	0.04	0.32	4	170.8
{(Jul, Aug, Sep, Oct, Nov)(Dec, Jan, Feb, Mar)(Apr)(May)(Jun)}	179.0	2.54	0.03	0.28	4	171.0
{Molt Site}	179.3	2.77	0.03	0.25	4	171.2
{(Jul, Aug, Sep, Oct, Nov, Apr, May, Jun)(Dec, Jan, Feb, Mar)}	179.7	3.18	0.02	0.20	2	175.7
{Year}	180.0	3.51	0.02	0.17	2	176.0
{(Jul, Aug, Sep, Oct, Nov, Dec, Jan, Feb, Mar, Apr, May)(Jun)}	180.2	3.74	0.02	0.15	2	176.2

^a AIC_c model wt.

^b No. of parameters.

^c Mass is corrected for structural size and 9th primary length.

^d Breeding sites: Admiralty Island, Sumdum Island; nonbreeding sites: Harlequin Lake and Icefall Lake.

marked at nonbreeding areas, especially Harlequin Lake, may have originated from a broader range of nesting areas and dispersed more widely during winter, making them less likely to be detected. Birds marked at breeding areas were more apt to remain near molting sites during part of the winter and were more likely to be detected. Annual variation in reproductive success can influence the magnitude of molt migrations and could have influenced the origins of geese that molted at nonbreeding sites (Reed et al. 2003, Hupp et al. 2007). We may have detected a smaller proportion of birds marked at Harlequin Lake in 2004 if lower reproductive success in that year resulted in molting birds that originated from more widely distributed nesting areas. The geese that we did not locate could have remained in southeast Alaska but were in areas that were beyond reception range during tracking flights. When we superimposed the aircraft flight tracks over the distribution of Canada goose winter sites described by Hodges et al. (2008) for southeast Alaska, we found 9% of the sites were >15 km from the flight route. The missing individuals could also have wintered in coastal British Columbia where tracking coverage was less complete.

We detected no radiomarked females in western Oregon or Washington. Assuming we did not fail to detect radiomarked geese and that no birds migrated to Oregon and Washington after the January telemetry flights in that region, that outcome had only a 0.04 probability of occurrence based on a hypergeometric distribution (Zar 1984, Lindberg and Walker 2007) when we used the estimate from Hodges et al. (2008) that approximately 25,000 Canada geese occurred in southeast Alaska, Ratti and Timm’s (1979) estimate that 2% of the population

migrated to Oregon or Washington, and based on our sample of 155 radiomarked geese used to evaluate winter distribution. The likelihood of that outcome increased as the percentage of the population that migrated to Oregon or Washington approached zero, suggesting that the percentage of the population that migrated was even less than proposed by Ratti and Timm (1979). We marked Canada geese at a limited number of sites, and birds marked at a site tended to remain together during winter, making it unlikely we truly had a random sample from the population. However, we have no reason to expect that Canada geese in other parts of southeast Alaska would have a greater tendency to migrate. If Hodges et al. (2008) were correct that approximately 25,000 Vancouver Canada geese wintered in southeast Alaska, and if >98% of the population was nonmigratory, then ≤500 geese likely migrated from that region to Oregon or Washington. Therefore, Vancouver Canada geese from southeast Alaska likely comprised a small component (≤0.3%) of the approximately 160,000 Canada geese and cackling geese observed wintering in western Oregon and Washington in 2008 (Trost and Sanders 2008). However, some Vancouver Canada geese do migrate, because birds marked in southeast Alaska have been recovered in Oregon or Washington, including an adult male banded during our study. Also, we know little about migration behavior of Vancouver Canada geese in the southern part of their breeding range because few birds have been marked in British Columbia. Pearce et al. (2000) found that approximately 10% of Canada geese shot on winter areas in Oregon and Washington and identified as dusky Canada geese based on morphology and plumage were

genetically most similar to Vancouver Canada geese. The origin of those birds was unknown.

Seasonal and Annual Survival

We assumed radiotransmitters did not adversely affect survival of marked geese, and that survival probabilities were the same for birds whose radios stopped transmitting prematurely and those whose fates we could determine. Hupp et al. (2006) found no adverse effects of coelomically implanted radios of the same model used in this study on survival of Canada geese in the first year after marking. Esler et al. (2000a) similarly observed no adverse effects of implanted radios on survival of harlequin ducks (*Histrionicus histrionicus*), and they found that the fate of a bird was unrelated to whether or not a radio failed.

Evidence for seasonal and annual variation in survival of radiomarked geese was equivocal, likely because the detected mortalities were evenly distributed throughout the year and the number of mortalities did not greatly differ between years. Although there was weak support for seasonal variation in survival, estimated differences in MSP among seasons were minimal, suggesting that survival of Vancouver Canada geese did not vary markedly within a year. However, seasonal differences may have been difficult to detect because for 15 of the 20 mortalities, there was a 2–7-month gap between when the bird was last detected as alive and first detected as dead. Furthermore, for 7 individuals, the period when mortality could have occurred spanned >1 season, which likely contributed to model uncertainty. Despite uncertainty regarding seasonal variation, we were able to derive a reliable estimate of annual survival through model averaging.

Ratti et al. (1978) estimated that annual survival for adult-plumaged Vancouver Canada geese was 0.836 based on 351 recoveries of 3,491 geese banded at Glacier Bay National Park between 1956 and 1960. Our estimate of annual survival averaged across models (0.844) indicated no appreciable difference in adult survival compared to >4 decades ago. Environmental heterogeneity can result in temporal variability in adult survival (Sæther and Bakke 2000, Sandercock et al. 2000). Long-term consistency in annual survival suggests that Vancouver Canada geese occupy a relatively stable environment and that the influence of mortality factors on adult survival has not changed over time. This is plausible because the birds nested and reared goslings in forest habitats that were poorly suited to timber harvest and wintered in intertidal habitats where there was little human disturbance (Lebeda and Ratti 1983). Consequently the main seasonal habitats for the population in southeast Alaska have likely remained relatively unaltered in the past 40 years.

Estimates of annual survival of Vancouver Canada geese were in the upper range reported for goose populations (Francis et al. 1992, Sedinger et al. 2007, Hupp et al. 2008b), and are higher than estimates (0.77) of annual survival for adult dusky Canada geese from 1983 to 1990 (Sheaffer 1993). Harvest typically is the greatest source of mortality in exploited goose populations (Francis et al. 1992,

Hestbeck 1994, Alisauskas et al. 2006), and harvest pressure on Vancouver Canada geese in southeast Alaska was relatively light. Adult survival typically has a greater effect on rates of population increase in geese than other demographic parameters (Schmutz et al. 1997, Sæther and Bakke 2000). However, when survival rates of geese are high and invariant, reproductive success is more likely to affect population trajectory (Sedinger et al. 2007). The high rates of survival observed by us and Ratti et al. (1978) suggest that adult survival is likely not limiting rate of increase in Vancouver Canada geese. Rather, factors that affect reproductive success and recruitment may be more apt to influence population increase. This is similar to factors that appear to limit rate of increase in dusky Canada geese (Bromley and Rothe 2003, Grand et al. 2006, Fondell et al. 2008), the Canada goose population that is geographically and taxonomically closest to Vancouver Canada geese (Scribner et al. 2003).

MANAGEMENT IMPLICATIONS

Vancouver Canada geese radiomarked in southeast Alaska remained in that region throughout the year, making protection of intertidal winter habitat especially important to maintenance of the population. Canada geese from southeast Alaska likely contributed little to midwinter surveys or harvest estimates for other populations of Canada geese in Oregon and Washington. However, winter distribution of Vancouver Canada geese from the southern part of their range in coastal British Columbia needs to be evaluated. Because annual survival of adult Vancouver Canada geese was high and showed evidence of long-term consistency, managers should examine how reproductive success and recruitment may affect the population.

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