SURVIVAL RATES AND RECOVERY DISTRIBUTIONS OF CANADA GEESE BANDED IN NEBRASKA

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Abstract: We analyzed banding and recovery data for Canada geese (*Branta canadensis*) banded in Nebraska during 1990–2000. Survival rates were lower during 1996–2000 (adult: 0.688, SE = 0.016; juvenile: 0.611, SE = 0.029), than 1990–1995 (adult: 0.727, SE = 0.011; juvenile: 0.639, SE = 0.024). Average juvenile-to-adult ratio from banding data was 0.834 (SD = 0.485), resulting in an annual population growth rate (λ) estimate for 1990–1995 of 0.995 (95% CI = 0.021), and 0.922 (0.018) for 1996–2000. Our recovery analysis suggests that 67% of geese banded in Nebraska are shot in Nebraska. Over 30% of both juvenile and adult recoveries are obtained in December, and geese banded in Lancaster County are recovered in higher numbers during October than geese banded in the Panhandle and Sandhills regions. Sixty to 70% of geese banded in Lancaster County and the Panhandle region are recovered in their respective region, while less than 20% of geese banded in the Sandhills are recovered in the Sandhills. Our analysis suggests that subpopulations of Canada geese in Nebraska differ in their survival and movements. Thus, area-specific management could be directed at each subpopulation.

Key words: *Branta canadensis*, Canada geese, modeling, Nebraska, recovery distribution, survival.

Recent increases in populations of Canada geese have been considered 1 of the more significant accomplishments in wildlife management in North America (Bellrose 1980). In particular are increases in temperate-nesting geese (e.g., Sheaffer and Malecki 1998), mainly due to restoration or introduction of giant Canada geese (*B. c. maxima*) (Gosser et al. 1997).

The Nebraska Game and Parks Commission (NGPC) initiated restoration programs for locally nesting Canada geese in the late 1960s and continued until the early 1990s. Restoration efforts were conducted primarily in 3 regions: (1) the Salt Valley region in Lancaster County, Nebraska (longitude 96.45° to 96.9° W, latitude 40.52° to 41.05° N), (2) the Sandhills in the north central portion of the state (longitude 98.3° to 102.0° W, latitude 41.0° to 43.0° N), and (3) along the North Platte River Valley in the Panhandle region of western Nebraska (longitude 102.0° to 104.0° W, latitude 41.0° to 43.0° N, Fig. 1). Efforts were successful and have contributed to increases in local populations in all 3 areas.

Canada geese provide abundant consumptive and nonconsumptive recreational opportunities, and most residents are favorable to the presence of Canada geese in their community (Coluccy et al. 2001). Geese can cause problems, however, that may range from minor nuisance (e.g., defecating on sidewalks) to human health and safety issues (e.g., air traffic safety, disease

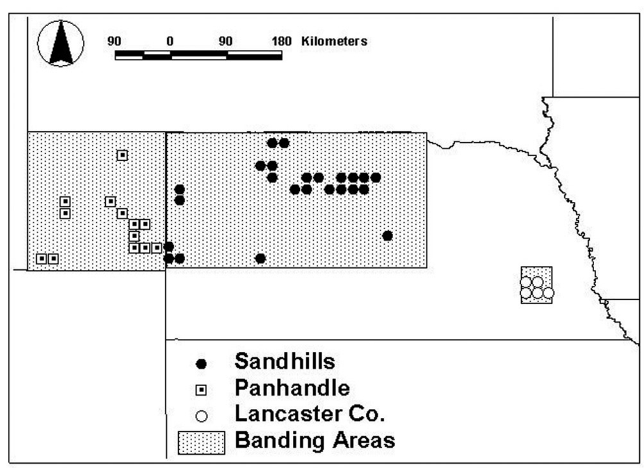

Fig. 1. Canada goose banding sites in Nebraska during 1990–2000. Recovery areas used in analyses are shown as stippled polygons and are distinguished by banding site markers.

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transmission). Management of populations or subpopulations of Canada geese becomes a balance between meeting demands for recreational opportunities and minimizing nuisance and damage problems.

Nebraska has legbanded Canada geese since the early 1970s. No efforts have been made, however, to evaluate the banding and band-return information to determine survival, productivity, or spatial and temporal harvest distribution. Demographic information would be useful in managing populations of resident Canada geese in Nebraska. Our goals were to use banding and recovery data to: (1) estimate survival rates and productivity, and (2) describe patterns of recovery from Lancaster County, Sandhills region, and Panhandle region of Nebraska.

METHODS

Banding

Canada geese were captured by drive trapping during late June and early July when young and molting adults were flightless. Geese were aged by plumage characteristics and sexed by cloacal examination and then classified as either adult (AHY) or juvenile (HY) and marked with a U.S. Fish and Wildlife Service (USFWS) legband. During 1990–1994, the banded sample included birds from the Sandhills and Lancaster County, but not the Panhandle. Banding ceased in the Sandhills during 1995–2000 but commenced in the Panhandle and continued in Lancaster County.

Demographic Parameter Estimation

We obtained Canada goose banding and recovery data (1990–2000) from the Bird Banding Laboratory (Laurel, Maryland). We used program MARK (White and Burnham 1999) to estimate survival and recovery rates for normal, shot, AHY and HY males and females banded in 3 regions in Nebraska (Fig. 1). We used Akaike's information criterion (AIC) to compare individual models. Models considered included age-, sex-, and year-specific survival and recovery rates (White and Burnham 1999). In addition, we compared models that pooled survival and recovery rates by 2 time periods, 1990–1995 and 1996–2000. These time periods correspond generally to a change to more liberal harvest regulations during 1996–2000; the periods are also compatible with the geographic shift in banding effort within Nebraska.

To compare survival among banding areas, we stratified the data by banding area, and used program MARK as above. We used the S(.)f(t) model (pooled survival rate over age, sex, and time; time-specific recovery rate) to allow comparison among banding areas; this model was the fifth best model in the pooled analyis (Table 1, ΔAIC = 18.97), and it always performed better than the S(age)f(t) model (the best model from the pooled analysis in Table 1) when the models were applied to data from individual banding areas. To obtain an estimate of productivity (juveniles produced per adult, *P*), we used the entire banded sample during 1990–2000; this estimate was not adjusted for possible biases of molt migration (Zicus 1981).

Table 1. Model selection for recoveries of Canada geese banded preseason, 1990–2000 in Nebraska. 'Y' indicates survival or recovery rate is age-, sex-, or time-specific; 'N' indicates opposite. Time specificity is indicated as "year" or "period"; models incorporating the latter pool survival or recovery into 2 periods: 1990–1995 and 1996–2000. Models are ordered by lowest (best) QAIC score. The difference in $QAIC_c$ score for each model from the best model is given as $\Delta QAIC_c$, along with the AIC Weight and the number of parameters in the model (N).

Survival (*S*)			Recovery (*f*)					
Age	Sex	Time	Age	Sex	Time	$\Delta QAIC_c$	AIC Weight[a]	N
Y	N	Period	N	N	Year	0.00	0.9649	15
Y	N	Period	Y	Y/N[b]	Year/N[b]	7.34	0.0246	27
Y	N	Period	Y	N	Year/N[b]	9.09	0.0102	16
N	N	Period	N	N	Year	17.76	0.0001	13
N	N	N	N	N	Year	18.97	0.0001	12
Y	Y/N[b]	N	Y	Y/N[b]	Year/N[b]	20.23	<0.0001	26
Y	N	N	Y	Y/N[b]	Year/N[b]	20.70	<0.0001	25
N	N	Year	N	N	Year	24.16	<0.0001	22
N	N	Year	N	N	N	30.13	<0.0001	12
Y	Y/N[b]	Year/N[b]	Y	Y	Year/N[b]	31.33	<0.0001	46
Y	Y/N[b]	Year	Y	Y/N[b]	Year	33.22	<0.0001	66
Y	N	Period	Y	N	Period	76.34	<0.0001	8
Y	N	Period	Y	Y/N[b]	N	127.99	<0.0001	7
N	N	N	N	N	N	213.45	<0.0001	2

[a] AIC Weight is the weight of evidence in favor of the given model being from the set of models considered. AIC Weight is a function of the model's ΔAIC_c value, compared to the other models' ΔAIC_c values (Burnham and Anderson 1998). In this example, the best model is about 39.2 times as likely as the second-best model to be the best model.

[b] Adults and juveniles differ in their sex- or time-specificity; model description is provided in order of adult/juvenile (e.g., Y/N indicates Y for adults and N for juveniles).

We modeled discrete population growth (λ), where $\lambda = S_A + P \bullet S_J$ (Pulliam 1996, Powell et al. 2000). We used our estimates for adult survival (S_A) and juvenile survival (S_J), along with our estimate of P as the parameter inputs for the model. Subadult- and adult-specific survival and productivity estimates were not available from our data; all nonjuveniles were pooled in our estimation procedures. However, this model should provide adequate predictions of population growth unless parameter estimates are biased or proportions of the population in each age class change substantially.

To estimate var(λ), we performed 200 stochastic simulations of λ. During each simulation, values for S_A, P, and S_J were randomly selected from a distribution based on each parameter's associated variance estimate. We randomly selected fecundity rates from a normal distribution, and randomly selected survival rates from a beta distribution to ensure parameter values < 1.0 and > 0.0. We calculated the geometric mean of λ, as suggested by Pulliam (1996), over the 200 simulations during each repetition (Powell et al. 2000). To assess whether $\lambda = 1.0$, we constructed 95% confidence intervals (CI) around the geometric mean, after Powell et al. (2000). If the 95% CI did not include 1.0, the local population could be viewed as growing ($\lambda > 1.0$) or declining ($\lambda < 1.0$).

Recovery Distributions

We compared direct recoveries (shot the first season after banding) with indirect (shot $\geq$2 seasons after banding) recovery distributions of geese banded during 1990–2000 in Lancaster County, the Sandhills region, and the Panhandle region of Nebraska. Recovery data were plotted and analyzed in ArcView version 3.2. We also determined temporal distributions of recoveries for geese from the 3 banding areas, using recovery data subdivided by month.

RESULTS

Nebraska Game and Parks Commission biologists banded 5,021 AHY and 902 HY Canada geese in Lancaster County, 2,488 AHY and 1,493 HY geese in the Sandhills region, and 1,868 AHY and 402 HY geese in the Panhandle region; the 12,174 geese banded in these banding areas represented 88% of Canada geese banded in Nebraska during 1990–2000. Hunters reported 2,832 recoveries of Canada geese banded in Nebraska during 1990–2000, including 1,285 banded in Lancaster County, 1,048 banded in the Sandhills region, and 414 banded in the Panhandle region.

Demographic Parameters

The most likely model with the lowest AIC score incorporated a difference in survival between the 2 time periods (Table 1). Recovery rates were year-specific, providing no justification for collapsing recovery rates into either 1 or 2 pooled time periods. Survival and recovery rates were independent of sex. Although survival differed between age groups, recovery rates were independent of age (Tables 1, 2). The Panhandle's annual survival estimate from the S(.)f(t) model ($\hat{S}$ = 0.635, SE = 0.027, ΔAIC_c = 0.24) was lower than our estimates for Lancaster County ($\hat{S}$ = 0.710, SE = 0.011, ΔAIC_c = 8.94) and the Sandhills ($\hat{S}$ = 0.700, SE = 0.019, ΔAIC_c = 19.15). Juvenile and adult survival estimates did not differ in Lancaster County. However, these rates were slightly different in the Panhandle region, where the S(age)f(t) model was the best model (S(.)f(t) model: ΔAIC_c = 2.13; AHY $\hat{S}$ = 0.638, SE = 0.028; HY $\hat{S}$ = 0.618, SE = 0.056), and markedly different in the Sandhills region (S(.)f(t) model: ΔAIC_c = 6.47; AHY $\hat{S}$ = 0.724, SE = 0.020; HY $\hat{S}$ = 0.615, SE = 0.032).

Table 2. Survival (S) and recovery (f) rate estimates and SE for hatch-year (HY) and adult (AHY) male and female Canada geese, banded in Nebraska during 1990–2000. Estimates are from the best model, selected by Akaike's Information Criterion (see Table 1).

Age	Sex	Parameter	Year	Estimate (SE)
AHY	– [a]	S	1990–1995	0.727 (0.011)
AHY	– [a]	S	1990–1995	0.639 (0.024)
HY	– [a]	S	1996–2000	0.611 (0.029)
– [a]	– [a]	f	1990	0.186 (0.028)
– [a]	– [a]	f	1991	0.239 (0.019)
– [a]	– [a]	f	1992	0.208 (0.017)
– [a]	– [a]	f	1993	0.202 (0.015)
– [a]	– [a]	f	1994	0.269 (0.017)
– [a]	– [a]	f	1995	0.196 (0.013)
– [a]	– [a]	f	1996	0.259 (0.021)
– [a]	– [a]	f	1997	0.209 (0.017)
– [a]	– [a]	f	1998	0.256 (0.016)
– [a]	– [a]	f	1999	0.338 (0.018)
– [a]	– [a]	f	2000	0.389 (0.018)

[a] Model not specific for this parameter.

Mean juvenile-to-adult ratio for banded Canada geese during 1990–2000 was 0.834 (SD = 0.485), and ratios ranged from 0.17 to 1.31. Our model predicted an annual population growth rate for 1990–1995 of 0.995 (95% CI: $\pm$0.021), when the banded sample included mostly Sandhills and Lancaster County geese. The population growth rate for 1996–2000, when the banded sample included Panhandle and Lancaster County geese, was 0.922 (95% CI: $\pm$0.018, Fig. 2).

Recovery Distributions

Approximately 75% of the geese banded in Nebraska were recovered in Nebraska: 814 of 1,073 direct recoveries (75.9%) and 1,291 of 1,759 indirect recoveries (73.4%, Fig. 3). Direct recoveries of geese banded in Lancaster County occurred in Nebraska (448 of 486, 92%), Kansas or Missouri (6%), and Oklahoma (2%); direct recoveries of geese banded in the Panhandle primarily occurred in Nebraska (139 of 141, 99%),

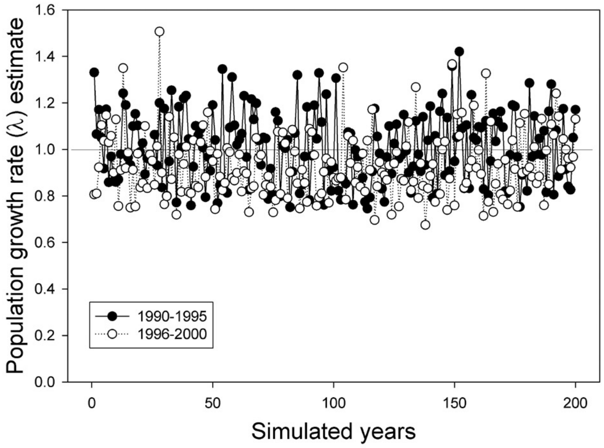

Fig. 2. Estimated annual population growth rate (λ) over 200 simulated years for Canada geese in Nebraska, based on banding analyses for geese banded during 1990–2000.

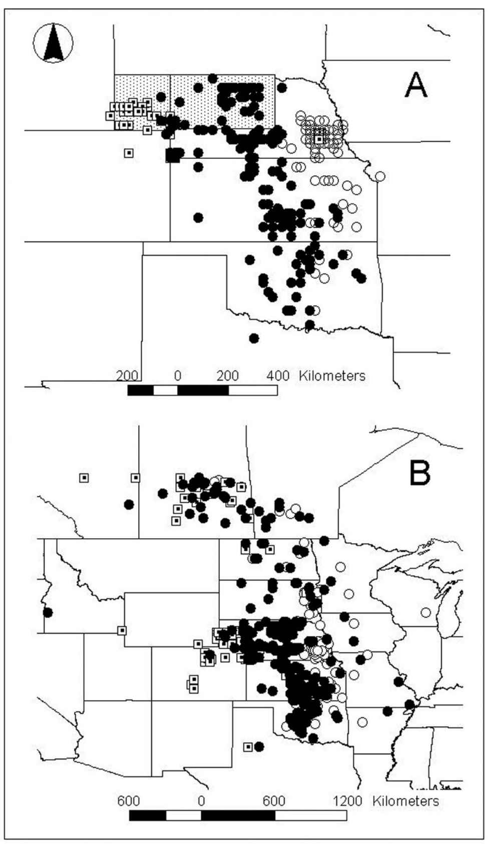

Fig. 3. Recoveries (A: direct recoveries; B: indirect recoveries), within the Central Flyway and western Mississippi Flyway, of Canada geese banded in Lancaster County (hollow circles), the Sandhills region (filled circles), and the Panhandle region of Nebraska (hollow squares with dot) during 1990–2000.

with 2 shot in Colorado and Wyoming. The distribution of direct recoveries of geese banded in the Sandhills differed from the other 2 banding areas (χ^2_4 = 251.5, P < 0.01): only 212 of 411 (52%) occurred in Nebraska, 163 in Kansas (40%), and 36 in Oklahoma (8%, Fig. 3). Although the Sandhills region is the largest recovery area in Nebraska, geese move out of the Sandhills in greater numbers as indicated by direct (χ^2_2 = 325.1, P < 0.01) and indirect recoveries (χ^2_2 = 376.8, P < 0.01). Two-hundred-seventy-six of 486 direct recoveries (56.8%) of geese banded in Lancaster County occurred in the same county; the same was true for 393 of 799 indirect recoveries (49.2%) from Lancaster County. For geese banded in the Sandhills, 95 of 411 direct recoveries (23.1%), and 154 of 637 indirect recoveries (24.2%) occurred in the Sandhills. For geese banded in the Panhandle, 132 of 141 direct recoveries (93.6%), and 215 of 273 indirect recoveries (78.8%) occurred in the Panhandle region (Fig. 3).

Most band recoveries were from geese shot during December (Fig. 4). Recovery dates, by month, were similar across the 3 banding areas, although approximately 30% of the geese banded in Lancaster County were shot in October, compared to less than 20% of geese from other banding areas. Fewer geese banded in Lancaster County were shot in January than geese banded in the Sandhills and the Panhandle (Fig. 4). In October, adult geese were shot at a higher frequency than juveniles from all banding areas; in contrast, more juveniles were shot in December than adults (Fig. 4).

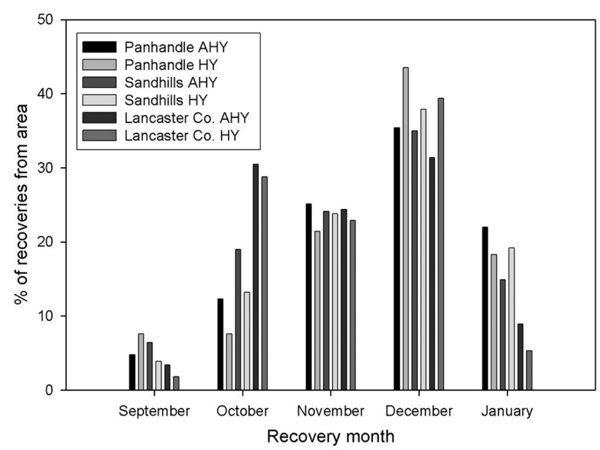

Fig. 4. Proportion of recoveries by month for adult (AHY) and juvenile (HY) Canada geese banded in 3 areas (Panhandle region, Sandhills region, and Lancaster County) in Nebraska during 1990–2000.

DISCUSSION

Our survival estimates were similar to the estimate of 0.726 (SE = 0.015) reported by Hestbeck (1994) for declining populations in the Atlantic Flyway. Similarly, our predicted annual population growth rate for Canada geese in Nebraska was stable (1990–1995) or declining (1996–2000). These estimates should be considered conservative as Nebraska's banding operations are directed at large flocks of flightless Canada geese that contain relatively large numbers of nonbreeding sub-adults or adults. Thus, the actual juvenile-to-adult ratios are likely higher than we reported. Further, our banded samples of Canada geese may represent those that may experience more mortality and hunting pressure.

Nonetheless, our estimates of survival and population growth appear to be consistent with observations of the abundance of Canada geese in all 3 areas. Undoubtedly, Canada geese numbers have increased over the last 30 years. Despite the growth in all populations, particularly in Lancaster County, the number and severity of nuisance problems are not similar to those experienced in other regions of the country (e.g., Minnesota [Cooper and Johnson 1998], Pennsylvania [Hartman and Dunn 1998]) with rapid population growth. In fact, our demographic analysis suggests that Nebraska's populations of Canada geese may be declining in recent years—especially in the Panhandle.

However, our estimates of population growth were not adjusted for rates of immigration or emigration of molt migrants. We were unable to adjust our productivity estimates, as we are not aware of existing data that quantify molt migration within Nebraska or out of the state. Similarly, little is known about molt migration from surrounding states into Nebraska; from the 31,295 Canada geese banded in Oklahoma from 1982–2001, only 55 were shot or found dead in Nebraska during that same time period (M. O'Meilia, Oklahoma Department of Wildlife Conservation, unpublished data). Perhaps molt migration in the Central Flyway is less extensive than the Mississippi Flyway (Zicus 1981, Lawrence et al. 1998); the loss of molt migrants out of Nebraska may be compensated by those migrating into Nebraska.

Although juvenile geese are usually more vulnerable to harvest than adults, we did not have higher rates of recovery for juveniles than adults banded in Nebraska. Our sample of adults may contain mostly sub-adults and adults that are banded during their molt migration. Molting adults or sub-adults may be more similar to juveniles in their susceptibility to harvest (Lawrence et al. 1998). Additionally, juvenile and adult geese from the Lancaster and Panhandle areas likely use similar areas (e.g., refugia) and have similar diurnal patterns that may result in similar patterns of recovery and harvest. Approximately 70% of recoveries of geese banded in Lancaster County and the Panhandle occurred in the respective banding area. Conversely, geese from the Sandhills were more migratory in nature (Fig. 3A), and the Sandhills was the only region in which adults had substantially higher survival rates than their juvenile counterparts.

MANAGEMENT IMPLICATIONS

Prior to this analysis, there was no empirical evidence to suggest distinct subpopulations of Canada geese in Nebraska that differed in their survival and movement patterns. Future management decisions should consider subpopulation differences; evaluation and monitoring programs also should incorporate this knowledge.

Geese banded in the Sandhills have a unique propensity to leave the banding area and be recovered to the south in the first fall. To ensure that analyses of data from the 3 regions are comparable, the origin and movement of Sandhills geese should be investigated. It is possible that we are capturing molt migrants from states to the south. This question might be answered through stable isotope analysis of feathers collected during banding (sensu Hobson 1999), or through cooperative banding programs in Kansas and Oklahoma.

Panhandle geese have significantly lower survival rates than geese from other regions of the state; liberalizing hunting regulations could adversely affect their populations if harvest mortality is additive to natural mortality. Also, Nebraska harvest regulations are most likely to impact populations of geese in the Panhandle and eastern regions, as represented by Lancaster County, while Sandhills geese appear to have the most potential to be affected by harvest in other states. Additionally, the chronology of harvest is region-specific, with Lancaster County having more recoveries early in the season. Hunting seasons for Lancaster County in 1990–2000 contained more days in October than January and relatively large number of recoveries did occur in October. Therefore, a late, extended season in Lancaster County may not lead to the control of urban goose populations, but maintaining a liberal, early season may reach this goal. However, if hunting seasons are extended into January, additional banding and analyses are needed to evaluate the impacts of a later season.

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