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Survival and harvest characteristics of giant Canada geese in eastern South Dakota, 2000–2004

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Abstract: The population of giant Canada geese (*Branta canadensis maxima*) in eastern South Dakota has increased substantially since reintroduction efforts began in the 1960s. Breeding population estimates of Canada geese exceeded the population management objective of the South Dakota Game, Fish and Parks by the mid-1990s and has continued to increase at an estimated rate of 3 to 5% per year. Goose-related crop damage complaints have also increased. In 1996, a September hunting season (September 1 to 15) was implemented in 10 counties in eastern South Dakota and was expanded in 2000 to include most of eastern South Dakota. We initiated this study during 2000 to 2004 to estimate survival, harvest, and recovery rates of giant Canada geese. We captured and leg-banded Canada geese in 7 counties in eastern South Dakota during the summers of 2000 to 2003. Of the total leg-banded sample (n = 3,839), we recovered 648 bands during the same year that they were placed on geese (i.e., direct harvest rate), and we recovered 645 banded geese in later years (i.e., indirect recovery rate). Estimates of annual survival rate (95% CI) for adults and immatures were 0.52 (0.46 to 0.59) and 0.68 (0.57 to 0.79), respectively. Estimates of annual recovery rates (95% CI) for adult and immature geese were 0.16 (0.13 to 0.19) and 0.18 (0.14 to 0.21), respectively. Of the total recoveries, 77 and 69% of direct and indirect band recoveries, respectively, occurred in South Dakota. The composite harvest rate estimate during the period studied was 0.22 (0.20 to 0.24). Forty-nine percent of adult recoveries and 44% of immature recoveries (direct and indirect pooled for both age classes) occurred during the September season. In comparison to a previous band-recovery study of resident giant Canada geese in eastern South Dakota, survival rates for both adult and immature geese have declined, while recovery and harvest rates have increased. Survival estimates for this study were some of the lowest documented for giant Canada geese. However, it appears that even with a September hunting season targeting the local breeding population, declines in adult survival documented during this study are not reducing the population. Alternative management strategies may be necessary to reduce the population to achieve the management objective.

Key words: band analysis, Canada geese, harvest rate, human–wildlife conflicts, hunting, recovery rate, survival rate

Analysis of band and recovery data is an essential part of waterfowl management, and its use in understanding population dynamics in migratory birds has been well-documented (Nichols 1991*a*, 1991*b*; Baldassarre and Bolen 1994; Nichols et al. 1995*a*; Williams et al. 2002; Schmutz 2009). Numerous researchers have used band-recovery data to estimate survival and recovery rates (Francis et al. 1992, Lawrence et al. 1998*a*, Powell et al. 2004, Sheaffer et al. 2004, Calvert and Gauthier 2005, Alisauskas et al. 2006, Eichholz and Sedinger 2007), chronology of migration and harvest (Sheaffer et al. 2004, Sheaffer et al. 2005, Eichholz and Sedinger 2006, Luukkonen et al. 2008), and the derivation and distribution of harvest (Sheaffer and Malecki 1987, Lawrence et al. 1998*b*, Fritzell and Luukkonen 2004, Powell et al. 2004, Alisauskas et al. 2006) for geese. Knowledge of recovery and annual survival rate estimates of geese (*Branta* spp.) can be used in the establishment of harvest regulations (see Nichols 1991*a*, Baldassarre and Bolen 1994, Hestbeck 1994).

Sheaffer and Malecki (1995) stated that low recovery rates of Canada goose (*Branta canadensis*) bands are a problem in many band-recovery analyses across North America. They documented recovery rates for the Atlantic population of Canada geese of only 3.3 and 6.1% for adults and immatures, respectively. However, Sheaffer and Malecki (1995) conducted their study prior to the changes in inscriptions on aluminum leg-bands that have increased reporting rates (Doherty et al. 2002, Royle and Garretson 2005). Reporting, recovery, and survival rates, as well as harvest demography, may vary both spatially and temporally for leg-banded waterfowl (Nichols et al. 1995*b*, Royle and Dubovsky 2001, Calvert et al. 2005, Royle and Garretson 2005, Alisauskas et al. 2006, Zimmerman et al. 2009*b*, Rice et al. 2010). Generating accurate estimates of harvest rates requires a reliable estimate of band-reporting rates. Only recently have reliable band-reporting rates for geese been estimated (Zimmerman et al. 2009*b*), and a region-specific estimate of 0.763 ($\pm$ 0.090) was provided for giant Canada geese (*Branta canadensis maxima*) in Harvest Area 4 that includes South Dakota. Prior to this recent study, reporting rate estimates for mallards (*Anas platyrhynchos*) were used as a surrogate for various populations of geese.

There have been few published studies in which estimates of harvest parameters and annual survival rates have been generated for giant Canada geese banded in the northern Great Plains, even though such information has been identified as important for management decisions (Gabig 2000, Vrtiska et al. 2004). Gleason (1997) conducted an analysis of geographic and temporal trends of the recovery and annual survival rates of banded giant Canada geese from South Dakota during 1955 to 1995. Also, Gleason et al. (2003) completed an analysis of temporal and geographic trends in banded Canada geese in South Dakota, but the authors did not include recovery or survival estimates as part of their analysis. A band-recovery analysis study on Canada geese from South Dakota was conducted during the period when the goose population was being introduced (Kuck 1973).

Populations of giant Canada geese have increased dramatically in South Dakota through the late 1990s and into the early 2000s. The population exceeded management objectives, and the increasing population has resulted in many goose nuisance problems (Gabig 2000). Because of this population increase, South Dakota Department of Game, Fish and Parks (SDGFP) implemented a 2-week hunting season during September in 10 counties in eastern South Dakota during 1996, with a daily limit of either 1 or 2 geese (Vaa et al. 2010). Since that time, the season has been liberalized and now includes 55 counties throughout the state, with a daily limit of 5 geese and a season length from roughly September 5 to 30 (Vaa et al. 2010). The September season was initiated under the premise that hunting mortality is an additive source of mortality for Canada goose populations, and a more liberalized harvest during this time frame would reduce the resident population while minimizing impacts to migrant Canada geese (Rexstad 1992, Gabig 2000, Coluccy et al. 2004, Vrtiska et al. 2004). The September goose-hunting season has resulted in an increase in harvest over time, but high productivity of giant Canada geese is evident (Dieter and Anderson 2009*a*), and extended hunting season appears to be only minimally effective at controlling the increasing population. As part of a larger study, we analyzed band-recovery data for resident giant Canada geese. The objectives for this study were to document spatial and temporal variation of the distribution of band recoveries, harvest chronology, and estimate recovery, survival, and harvest rates of Canada geese banded in eastern South Dakota. In addition, we compared our recovery and survival estimates (2000 to 2003) to estimates from Gleason (1997) from roughly the same geographic area during 1967 to 1995.

Study area and methods

We captured giant Canada geese in Brookings, Clark, Codington, Day, Hamlin, Kingsbury, and Lake counties in eastern South Dakota (Figure 1). These 7 counties were within the Coteau des Prairies (hereafter, Coteau) physiographic region (Gab 1979). The region was characterized by a Humid Continental B climate with average annual temperatures ranging from roughly 6º C in the northern portion of the study area to approximately 8º C in the southern portion (Hogan and Fouberg 1998). The large number and diversity of wetlands on the Coteau were used extensively by breeding and staging waterfowl (Bellrose 1980, Baldassarre and Bolen 1994). Agriculture was the predominant land use in the study area (Hogan and Fouberg 1998).

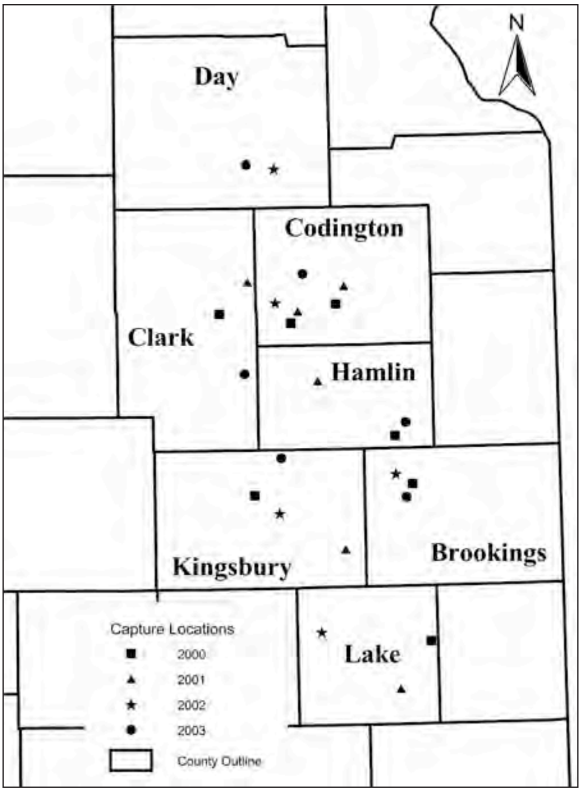

Figure 1. Locations where Canada geese were captured, leg-banded, and released in Brookings, Clark, Codington, Day, Hamlin, Kingsbury, and Lake counties of eastern South Dakota (June 23–July 11, 2000–2003.)

Terms used herein follow definitions described in more detail by Brownie et al. (1985), Nichols et al. (1995*b*), and Gustafson et al. (1997). For our study, assumptions follow those described by Pollock and Raveling (1982) and Brownie et al. (1985) for band-recovery data and estimating recovery and survival rates. A direct recovery is defined as a banded bird found shot or dead during the first hunting season following banding and reported to the U.S. Fish and Wildlife Service Bird Banding Lab (BBL). An indirect recovery is a banded bird shot or found dead during any hunting season following the first hunting season after banding and reported to the BBL.

The recovery rate for year *i* was defined as the probability that a goose alive at the time of banding in year *i* was recovered during the hunting season of year *i*, and was reported to the BBL. The band reporting rate was the percentage of banded birds shot and retrieved by hunters that were subsequently reported to the BBL. In 2000, we used bands that included only an address inscription ("WRITE BIRD BAND LAUREL MD 20708 USA"). From 2001 to 2003, we used bands that had an inscription as well as a phone number (1-800-327-BAND). We recognize that band reporting rates may have been slightly higher for bands with a 1-800 telephone number inscription, but we had no way to control for a potential band-type bias in this short-term study (Doherty et al. 2002). Further, given the limited geographical extent of our banding program, we do not believe that reporting rates would vary substantially within the study area over the period studied (Royle and Garretson 2005, Zimmerman et al. 2009*b*). The survival rate for year *i* was the probability that a bird alive during year *i* at the time of banding survived until the time of banding in year *i* + 1. For sorting purposes of band-recovery data, we defined hunting seasons as the period from September 1 through February 15 (Nichols and Hines 1987, Blandin 1992). We obtained band-recovery data from the BBL in Laurel, Maryland.

Trapping and banding

We captured giant Canada geese of 3 age cohorts (molting adults, subadults, and goslings) during their summer flightless period (June 23 to July 11) by driving them into a corral-type trap (Cooch 1953). We fitted all trapped and unbanded geese with a standard USFWS aluminum leg-band. We used plumage characteristics and cloacal examinations to determine age and sex of geese (Hanson 1965). We classified the age class of geese as adults or as flightless immature or local (hereafter immatures) geese. We recorded band numbers of all previously banded geese recaptured during this study before they were released, and we reported all recaptures to the BBL. We marked some geese with neck-collars and very high-frequency (VHF) transmitters or platform transmitting terminals (PTT; Anderson and Dieter 2009, Dieter and Anderson 2009*a*, 2009*b*). Herein, we limit our analyses only to geese banded with standard aluminum leg-bands and shot or found dead and reported to the BBL during the 2000–2001 through 2004–2005 hunting seasons. Similar to Balkcom (2010), we assumed no band loss during the study period, and we do not include any estimates of band loss in survival or recovery rate estimates (but see Coluccy et al. 2002, Zimmerman et al. 2009*a*).

Distribution of recoveries

We defined the distribution of harvest as the proportion of band recoveries by state or province. We calculated proportions separately for both direct and indirect recoveries. Munro and Kimball (1982) reported that harvest distributions can be estimated by adjusting band recoveries by estimates of differential band-reporting rates. Conversely, Zimmerman et al. (2009*b*) documented little spatial variation in band-reporting rates across the United States for Canada geese during 2003 to 2005. However, we estimated harvest distributions as the proportion of direct and indirect recoveries by state or province, assuming that reporting rates did not vary spatially or temporally because estimates of band-reporting rates have not been generated for all states and provinces (Nichols et al. 1995*b*). We evaluated differences in the number of recoveries (direct and indirect) occurring in different states or provinces with Chi-square goodness-of-fit tests. Only the top 5 states and provinces were used in this analysis because data from other areas were sparse (i.e., <5 returns). Comparisons of recovery distributions between total direct and indirect band-recoveries were evaluated using Program CENTROID (Mardia 1967, Batschelet 1972). This software uses the Mardias *U*-test to test the hypothesis that 2 samples (indirect versus direct recoveries) belong to the same bivariate distributions. We used program CENTROID to compute the mean longitude and latitude for recoveries in each group and then secured a test statistic (*U*) and associated *P*-value. We used ArcView® 3.2 GIS (Environmental Systems Research Institute, Redlands, Calif.) software to plot the overall distribution of all direct and indirect recoveries.

Chronology of harvest

We calculated the proportion of direct and indirect recoveries occurring within months during the hunting season from September through the following February. However, we were most interested in determining the proportion of geese that were harvested during the September hunting season. We also used ArcView® 3.2 GIS software to plot direct and indirect band recoveries by months. We used Chi-square tests to determine differences in number of direct and indirect recoveries among harvest months by age-class (adults versus immatures).

Estimation of recovery and annual survival rates

We generated annual estimates of recovery and survival rates from band-recovery models of Brownie et al. (1985) in Program MARK (White and Burnham 1999). Notation for band-recovery models followed Brownie et al. (1985), where S represented survival and f represented recovery parameters for adults. Immature survival and recovery parameters were denoted by S' and f', respectively. Subscript t on the model parameters represented time-dependence, and subscript i represented a specific year. For example, f'_i represents the recovery rate for geese banded as young in year i.

We used the design matrix in program MARK to develop alternative models. We defined Model 1 ($S_{a*t}\ f_{a*t}$) as the fully parameterized global model. This model assumed that survival and recovery rates were year-specific and band-reporting rates were independent of time since the geese were banded. We also analysed 3 other Brownie models, which were reduced-parameter models that have restrictions in recovery and survival rates. All other parameters were the same as Model 1. Model 2 ($S\ f_t$) assumed that survival rates were constant from year to year, but recovery rates were year-specific. Model 3 ($S\ f$) assumed that both survival and recovery rates did not vary over time. Model 4 ($S_t\ f$) assumed that survival rates were year-specific, but that recovery rates did not vary over time. Due to short duration of the study and our specific objectives, we limited the number of potential competing models and did not include other potential confounding main effects or covariates (Lebreton et al. 1992, Burnham and Anderson 2002, Williams et al. 2002, Mills 2006). We estimated confidence intervals by using the standard error associated with a given recovery or survival estimate from the best approximating model and multiplying by a factor of 1.962 (Zar 2009).

We began model selection by first examining the fit of the fully parameterized model to the data. We assessed the goodness-of-fit (GOF) for this model to the data using a parametric bootstrap approach. We determined if over-dispersion was present in the data by calculating a variance inflation factor (hereafter ĉ; Lebreton et al. 1992). If ĉ > 1, over-dispersion was present. We considered over-dispersion likely, given that the assumption of independent fates of marked individuals is almost certainly violated for Canada geese due to their strong familial bonds, which are retained at least through their first migration (Raveling 1969, 1978, Sulzbach and Cooke 1978, Hestbeck et al. 1990, Gleason et al. 2003). We derived estimates of ĉ by 2 methods, and we used the method resulting in the greatest ĉ-value (i.e., more conservative estimate) in subsequent model selection and parameter estimation. The first method estimated ĉ by dividing the deviance of the global model by the mean of the simulated deviances from the bootstrap GOF bootstrap samples (n = 1000). The second approach involved first dividing the model deviance by the deviance degrees-of-freedom and then dividing this value by the mean ĉ estimated by the bootstrapped simulations. We used a Quasi-Likelihood Akaike Information Criterion ($QAIC_c$) for model selection (Burnham and Anderson 2002) if ĉ > 1. We identified parsimonious models by the relative ranking of the $QAIC_c$ values of the 4 models with the best approximating model having the lowest $QAIC_c$ value. We made model comparisons by taking the ratio of normalized Akaike weights (w_i) between competing models that indicated the relative degree to which a particular model was better supported by the data than the other model (Burnham and Anderson 2002). The second method of calculating direct recovery rates simply involved dividing the number of geese shot and reported during the first hunting season after banding was completed by the total number banded.

We compared our estimates of recovery and survival rates from the best approximating model (lowest $QAIC_c$ value and highest w_i) generated in Program MARK to estimates of recovery and survival rates from Gleason (1997). We compared estimates (GOF test) using Program CONTRAST (Hines and Sauer 1989, Sauer and Williams 1989) by inputting point estimates of recovery and survival rates and their associated standard errors. We restricted our comparisons to those in Gleason (1997) with the lowest AIC value only for normal, wild geese banded in eastern South Dakota, 1967 to 1995.

We compared our estimates of recovery and survival rates from the best approximating model (lowest $QAIC_c$

Table 1. Number of giant Canada geese (*Branta canadensis maxima*) in eastern South Dakota banded (n), recovered, and reported to the BBL as shot or found dead during the hunting seasons of 2000 to 2004.

Age	Year	n	Number recovered					
			2000	2001	2002	2003	2004	Total
Adults	2000	316	42	23	14	10	7	96
	2001	235		40	23	20	11	94
	2002	504			75	45	23	143
	2003	461				80	45	125
Total	2000–2004	1,516	42	63	112	155	86	458
Immature	2000	694	107	85	30	16	11	249
	2001	521		98	58	38	29	223
	2002	545			77	71	32	180
	2003	563				129	54	183
Total	2000–2004	2,323	107	183	165	254	126	835
	∑	3,839	149	246	277	409	212	1,293

Table 2. Distribution of direct recoveries of adult and immature giant Canada geese (*Branta canadensis maxima)* banded in eastern South Dakota, 2000 to 2003.

Adult		State or province of direct recovery							
Year	*n*	SD	KS	NE	MO	IA	OK	ND	MN
2000	42	31	5	2	1	2	1	0	0
2001	40	31	1	0	3	2	2	0	1
2002	75	59	4	3	2	0	4	3	0
2003	80	74	4	1	0	1	0	0	0
Total	237	195	14	6	6	5	7	3	1
(%)		(82.3)	(5.9)	(2.5)	(2.5)	(2.1)	(3.0)	(1.3)	(0.4)
Immature		State or province of direct recovery							
Year	*n*	SD	KS	NE	MO	IA	OK	ND	MN
2000	107	65	20	5	8	4	3	2	0
2001	98	64	7	16	7	2	1	1	0
2002	77	64	9	0	1	1	1	1	0
2003	129	108	13	2	2	1	2	0	1
Total	411	301	49	23	18	8	7	4	1
(%)		(73.2)	(11.9)	(5.6)	(4.4)	(2.0)	(1.7)	(1.0)	(0.2)
∑	648	496	63	29	24	13	14	7	2
(%)		(76.5)	(9.7)	(4.5)	(3.7)	(2.0)	(2.2)	(1.1)	(0.3)

value and highest w_i) generated in Program MARK to estimates of recovery and survival rates from Gleason (1997). We compared estimates (GOF test) using Program CONTRAST (Hines and Sauer 1989, Sauer and Williams 1989) by inputting point estimates of recovery and survival rates and their associated standard errors. We restricted our comparisons to those in Gleason (1997) with the lowest AIC value only for normal, wild geese banded in eastern South Dakota, 1967 to 1995. In addition, we used Program CONTRAST to compare model-averaged estimates of survival and recovery rates from our best approximating model. In the comparison of our survival and recovery rates (adult-only), we used a Bonferonni adjustment to account for multiple comparisons (3-year groups; normal, wild; adult-only from Gleason 1997:table 29), such that the adjusted α level was $P = 0.05 \div 3 = 0.02$. We used the same significance level for recovery rate comparisons between our estimates and those of Gleason (1997). We adjusted the α level to $P = 0.05 \div 4 = 0.013$ in our comparison of model-averaged recovery rates between adults and immatures.

Harvest rates

The 2 primary concerns with recovery analysis for Canada geese are that recovery rates are typically low (i.e., <10%), and, until recently, most studies used band-reporting rates for mallards (Sheaffer and Malecki 1995). We used the 0.763 that was generated from a recent study on Canada geese for our value of reporting rate (Zimmerman et al. 2009*b*). We calculated harvest rates (H) by using the estimated direct recovery rates and the formula H = recovery rate ÷ reporting rate (Henny and Burnham 1976).

Results

Trapping, banding, and distribution of recoveries

We banded 3,839 Canada geese (Table 1) at 25 sites in the 7 counties during the summers of 2000 to 2003. Of the total recoveries (n = 1,293), 648 and 645 were direct and indirect, respectively, from geese that were shot or found dead during the 2000 to 2004 hunting seasons (Table 2). South Dakota accounted for 76.5% direct and 68.5% indirect band recoveries (ages and sexes pooled; Tables 2 and 3). Kansas ranked a distant second, with only 9.7 and 7.1% of direct and indirect recoveries, respectively. The most distant recoveries (13 indirect) detected west of South Dakota occurred in Saskatchewan, Canada. The most-distant recoveries (5 indirect) detected east of South Dakota included 1 adult goose recovered in Indiana and 4 immature

Table 3. Distribution of indirect band recoveries from adult and immature giant Canada geese (*Branta canadensis maxima)* banded in eastern South Dakota, 2000 to 2003.

Adult		State or province of indirect recovery										
Year	*n*	SD	ND	MB	SK	MN	KS	NE	MO	IA	OK	IN
2001	23	17	1	2	0	0	0	1	2	0	0	0
2002	37	25	2	1	0	2	2	1	2	0	1	1
2003	75	59	2	0	0	1	4	4	3	0	2	0
2004	86	70	2	2	2	1	6	0	1	0	2	0
Total	221	171	7	5	2	4	12	6	8	0	5	1
(%)		(76.9)	(3.2)	(2.3)	(0.9)	(1.8)	(5.4)	(2.7)	(3.6)	(0.0)	(2.7)	(0.5)
Immature		State or province of indirect recovery										
Year	*n*	SD	ND	MB	SK	MN	KS	NE	MO	IA	OK	IL
2001	85	54	12	3	1	4	6	4	0	0	1	0
2002	88	56	5	5	3	4	6	2	4	0	1	2
2003	125	88	6	7	1	4	10	4	1	2	1	1
2004	126	74	14	5	6	6	12	1	3	2	2	1
Total	424	272	37	20	11	18	34	11	8	4	5	4
(%)		(64.2)	(8.7)	(4.7)	(2.6)	(4.2)	(8.0)	(2.6)	(1.9)	(0.9)	(1.2)	(0.9)
∑	645	443	44	25	13	22	46	17	16	4	10	5
(%)		(68.5)	(6.8)	(3.9)	(2.0)	(3.4)	(7.1)	(2.6)	(2.5)	(0.6)	(1.7)	(0.6)

geese recovered in Illinois. The most-distant recovery (indirect) to occur north of South Dakota was an adult male goose recovered near The Pas, Manitoba. The most-distant recovery (25 direct and indirect) detected south of South Dakota occurred in Oklahoma. There was a difference in the number of recoveries (both direct and indirect) by state or province (χ^2_4 = 14.22 $P \leq 0.05$).

Program CENTROID indicated that distributions of direct and indirect recoveries were different (U = 11.22, P = 0.004). The mean coordinates for direct recoveries (n = 648) were 43.42° N and 96.86° W, whereas the mean coordinates for indirect recoveries (n = 645) were farther north and west (44.28° N, 97.01° W). Direct recoveries occurred in 8 states (Figure 2), but South Dakota accounted for the greatest proportion of direct recoveries for both adult (82.3%) and immature cohorts (73.2%). Kansas ranked second for both adult (5.9%) and immature geese (11.9%).

Indirect recoveries were documented from 12 states and provinces (Table 3). South Dakota accounted for the greatest proportion of indirect recoveries for both adult (76.9%) and immature geese (64.2%). Kansas ranked second for adults (5.4%), and North Dakota ranked second for immature geese (8.7%). Eighty-six indirect recoveries occurred north of South Dakota (46° N latitude), which accounted for 13.3% of all indirect recoveries (Figure 3). Indirect recoveries from south of South Dakota (n = 99) accounted for 15.3% of the total indirect recoveries. After we plotted both direct and indirect recoveries, it was apparent that the goose migration was south to slightly southeasterly, with relatively few recoveries occurring directly east or west of banding locations (Figures 2 and 3).

Chronology of harvest

We used 1,264 band recoveries in estimating harvest chronology because dates were not assigned for some records (Table 4). There was a difference in the number of direct and indirect recoveries by month (χ^2_8 = 16.44 $P \leq 0.05$) for adult and immature cohorts. Half (49.9%) of direct and 41.4% of indirect recoveries occurred

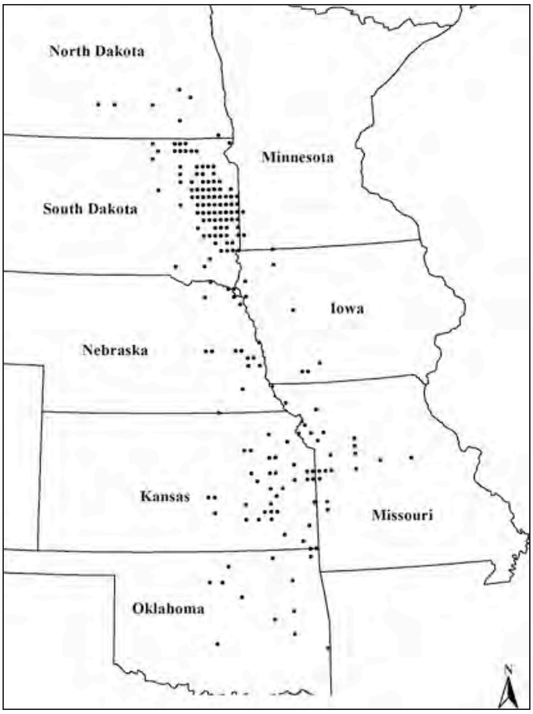

Figure 2. Direct band recoveries (n = 648) from giant Canada geese (ages pooled) shot or found dead during the 2000–2003 hunting seasons and reported to the USGS Bird Banding Laboratory, Laurel, Maryland. Multiple dots in close proximity represent >1 recovery at a given latitude-longitude.

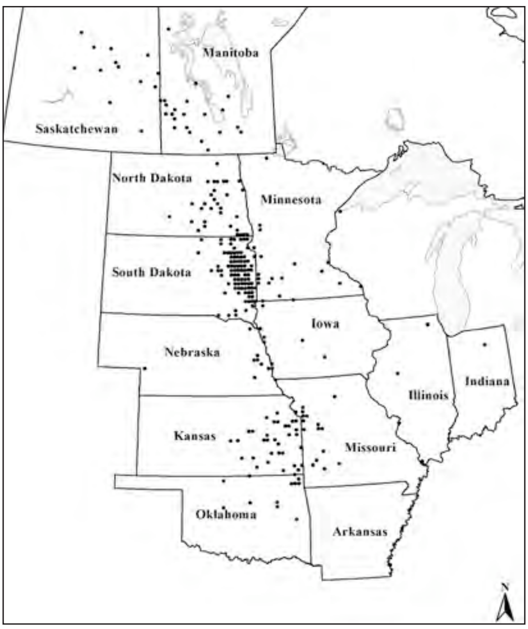

Figure 3. Indirect band recoveries (n = 645) from giant Canada geese (ages pooled) shot or found dead during the 2000 to 2004 hunting seasons and reported to the USGS Bird Banding Laboratory, Laurel, MD. Multiple dots in close proximity represent >1 recovery at a given latitude-longitude.

during the September hunting season. Adults were recovered at proportionally higher rates (49.2%; direct and indirect pooled) as compared to immatures (43.8%) during the September season. Most direct recoveries during the September season occurred in South Dakota. However, indirect recovery encounters during September occurred at a much larger spatial scale and included North Dakota, Manitoba, and Saskatchewan. About 25% of the band recoveries occurred in October with 293 of 325 geese harvested in South Dakota. During November, 99 of 132 recoveries were from South Dakota. Recoveries during December, January, and February were similar, with geese being shot primarily on their wintering areas. Within South Dakota, 523 (55%) of the resident geese harvested were shot in September, with the remaining 45% being harvested during October through December.

Estimates of annual recovery and survival rates

The GOF test of the data to the global model provided evidence of slight lack-of-fit and overdispersion of the data ($\hat{c}$ = 1.33). A comparison of the $QAIC_c$ values of the 4 models indicated that Model 2 (S f_t) had the lowest value (4690.44), with the greatest model weight (0.842); thus, we selected it as the most appropriate model, given the data. Model 1 with a model weight of 0.1371 received some support and was within 3.63 units of Model 2. Model 2 was approximately 6 times better (w_1 to w_2 = 0.84 to 0.14) than the global model. Under Model 2, model-averaged annual survival rates (95% CI) for the adult and immature cohorts were 0.52 (0.46, 0.59) and 0.68 (0.57 to 0.79; χ^2_1 = 5.45 P = 0.02), respectively (Table 5). Model-averaged estimates of recovery rates (95% CI) for adult and immature geese were 0.160 (0.13 to 0.19) and 0.178 (0.14 to 0.21) (χ^2_1 = 0.528 P = 0.47), respectively (Table 5). A comparison of recovery rates for both age-classes among year (2 groups × 4 years) indicated no difference (χ^2_1 = 9.77 P = 0.20; Table 5). The highest recovery rate estimates were derived for the 2003 to 2004 hunting season. Specifically, the recovery rate estimates for adult and immature cohorts were 0.19 (0.16 to 0.21) and 0.23 (0.19 to 0.27), respectively.

Adult survival rates from this study represent one of the lowest survival rates recorded for Canada geese, but were within the range of values reported for immature Canada geese (Table 6). A comparison of survival rates from this study to rates provided in Gleason (1997) indicate major declines in adult survival over time for giant Canada geese banded in South Dakota. A comparison of our adult survival rate (0.523) to adult survival (sexes pooled) estimates (95% CI) for the 1967 to 1976 (0.71; 0.66 to 0.76) (χ^2_1 = 18.57 $P \leq 0.001$), 1977 to 1987 (0.98; 0.92 to 1.04) (χ^2_1 = 100.75 $P \leq 0.001$), and 1988 to 1995 (0.85; 0.49 to 1.20) (χ^2_1 = 3.08 P ≤ 0.08) year periods from Gleason (1997, Table 29) indicate steep declines of approximately 19 to 46%, respectively. Comparisons of recovery estimates from our study (0.160) to those documented by Gleason (1997) for these same year periods (1967 to 1976 = 0.08; 1977 to 1987 = 0.05; 1988 to 1995 = 0.06) were all significant (P ≤ 0.001), indicating major increases in recovery rates.

Harvest rates

Average harvest rates were slightly higher for immatures (0.233) than for adults (0.160), which was likely a function of higher recovery rates for immatures (Table 5). Harvest rates for adults ranged from 0.172 (2000–2001) to 0.224 (2001–2002) and averaged 0.19 (0.16–0.23). Harvest rates for immatures ranged from 0.19 (2002–2003) to 0.300 (2003–2004) and averaged 0.23 (0.19 to 0.27). The average harvest rate (ages pooled, across years) estimated for this study was 0.22 (0.20 to 0.25).

Discussion

Distribution of recoveries

Giant Canada geese banded in eastern South Dakota were recovered in 10 states and 2 provinces, but most direct (0.765) and indirect (0.685) recoveries occurred in-state. Raveling (1978) stated that a high in-state proportion of recovery is typical when the goose population delays departure from the banding state,

Table 4. Harvest chronology for both direct and indirect band recoveries by age-class for giant Canada geese (*Branta canadensis maxima)* in eastern South Dakota, 2000 to 2004.

	Chronology of recoveries					
Cohort	September	October	November	December	Jan.–Feb.	Total
Adult[a]	130	44	21	21	16	232
(%)	(56.0)	(19.0)	(9.1)	(9.1)	(6.9)	
Immature[b]	186	78	37	54	46	401
(%)	(46.4)	(19.5)	(9.2)	(13.5)	(11.5)	
Adult[c]	88	69	24	15	16	212
(%)	(41.5)	(32.5)	(11.3)	(7.1)	(7.5)	
Immature[d]	173	134	50	45	17	419
(%)	(41.3)	(32.0)	(11.9)	(10.7)	(4.1)	
∑	577	325	132	135	95	1,264
(%)	(45.6)	(25.7)	(10.5)	(10.7)	(7.5)	

[a] Direct recoveries for giant Canada geese banded as adults during the summer molting period.
[b] Direct recoveries for giant Canada geese banded as immatures (banded in the same year of hatch) during the summer molting period.
[c] Indirect recoveries for giant Canada geese banded as adults during the summer molting period.
[d] Indirect recoveries for giant Canada geese banded as immatures (banded in the same year of hatch) during the summer molting period.

Table 5. Estimates of survival and recovery rates for giant Canada geese (*Branta canadensis maxima)* banded in eastern South Dakota, 2000 to 2003. Models represent band-recovery models from Brownie et al. (1985) and are ordered based on model weights (w_i) using quasi-likelihood Akaike Information Criterion ($QAIC^c$) corrected for small sample size and overdispersion (Burnham and Anderson 2002).

Model 2[a] ($S\ f_t$)	Adult		Immature		Adult		Immature	
Year	$\hat{S}_i$	SE	$\hat{S}_i$	SE	f_i	SE	f_i	SE
2000–2003	0.523	0.034	0.676	0.056	-	-	-	-
2000	-	-	-	-	0.131	0.022	0.151	0.015
2001	-	-	-	-	0.171	0.017	0.191	0.020
2002	-	-	-	-	0.153	0.014	0.142	0.017
2003	-	-	-	-	0.185	0.015	0.229	0.020
2000–2003	-	-	-	-	0.160	0.017	0.178	0.018
Model 1[b] ($S_t\ f_t$)	Adult		Immature		Adult		Immature	
Year	$\hat{S}_i$	SE	$\hat{S}_i$	SE	f_i	SE	f_i	SE
2000	0.421	0.078	0.534	0.073	0.133	0.022	0.154	0.015
2001	0.642	0.10	0.773	0.109	0.200	0.024	0.188	0.020
2002	0.538	0.091	0.751	0.130	0.145	0.015	0.141	0.017
2003	-	-	-	-	0.174	0.020	0.229	0.020
Model 3[c] ($S\ f$)	Adult		Immature		Adult		Immature	
Year	$\hat{S}_i$	SE	$\hat{S}_i$	SE	f_i	SE	f_i	SE
2000–2003	0.535	0.034	0.688	0.054	0.162	0.010	0.177	0.010
Model 4[d] ($S_t\ f$)	Adult		Immature		Adult		Immature	
Year	$\hat{S}_i$	SE	$\hat{S}_i$	SE	f_i	SE	f_i	SE
2000–2003	-	-	-	-	0.161	0.009	0.177	0.008
2000	0.478	0.072	0.611	0.062	-	-	-	-
2001	0.540	0.064	0.723	0.076	-	-	-	-
2002	0.603	0.062	0.775	0.094	-	-	-	-
2003	-	-	-	-	-	-	-	-

[a] Model 2 ($S\ f_t$) assumed that survival rates were constant from year to year.
[b] Model 1 ($S_{a*t}\ f_{a*t}$) assumed survival and recovery rates are year-specific and band-reporting rates were independent of time since release.
[c] Model 3 ($S\ f$) assumed that both survival and recovery rates did not vary over time.
[d] Model 4 ($S_t\ f$) assumed that survival rates are year-specific, but that recovery rates did not vary over time.

Table 6. Comparison of survival estimates (+SE) from several studies of giant Canada geese (*Branta canadensis maxima)* in the United States and Canada.

Location	Age class		
	Adult *S*	Immature *S*	Source
Eastern South Dakota	0.523 ± 0.034	0.676 ± 0.056	This study
Southeastern Michigan	0.763 ± 0.055[a]	0.802 ± 0.127	Tacha et al. (1980)
Northern Quebec	0.714 ± 0.099[a]	0.67 ± 0.131	Sheaffer and Malecki (1998)
Atlantic Flyway resident-nesting	0.677 ± 0.023[a]	0.696 ± 0.045	Sheaffer and Malecki (1998)
Eastern South Dakota	0.819 ± 0.166[a] (ages and sexes pooled)		Gleason (1997)[d]
Atlantic Flyway	0.655 ± 0.810[a]	0.517 ± 0.764	Johnson and Castelli (1998)[e]
Westcentral Illinois	0.770 ± 0.019[a]	0.819 ± 0.021	Lawrence et al. (1998*b*)
Atlantic Flyway	0.677 ± 0.023[a]	0.696 ± 0.045	Sheaffer and Malecki (1998)
Akimiski Island, Nunavut, Canada	0.846[c]	0.025 ± 0.1.7	Hill et al. (2003)[f]
Central Missouri	0.851 ± 0.020[b]	0.811 ± 0.020	Coluccy et al. (2004)
Nebraska	0.688 ± 0.016[a]	0.611 ± 0.029	Powell et al. (2004)
Alaska	0.68. ± 0.030[b]	0.490 ± 0.050	Eichholz and Sedinger (2007)

[a] Band-recovery estimate.
[b] Mark-resight estimate.
[c] Mark-recapture estimate.
[d] Estimate includes ages and sexes pooled after testing for age and sex effects. This estimate was generated from Model M1 in Program ESTIMATE (Conroy et al. 1989) for geese banded in eastern South Dakota, 1987–1995. Refer to Gleason (1997, table 29) for more detailed information.
[e] Sex-, age, and area-specific variation in survival estimates; represent range of values from 2 areas in the Atlantic Flyway, 1969–1988. Refer to Johnson and Castelli (1998, table 6) for more detailed information.
[f] Estimates based on mark-recapture and recoveries of leg-banded goslings (>1 yr old) and adults (>1 yr old) with precision estimated as confidence limits. The authors documented large differences between gosling survival estimates due to year effects and body size and condition.

which is the case in eastern South Dakota. Powell et al. (2004) reported that approximately 75% of geese banded in Nebraska were recovered in-state. Gleason (1997) also reported a high in-state recovery distribution for direct (0.666) and indirect (0.606) recoveries for geese banded in eastern South Dakota during 1955 to 1995. We attribute the higher proportion of in-state recoveries to the early opening date and liberal bag-limit of the September hunting season, as geese that do not exhibit northward post-molt movements remain in South Dakota during September (Anderson 2006). Over 45% of the total recoveries were from the September hunting season.

Kansas accounted for 9.7% of the total direct recoveries and 7.1% of the total indirect recoveries, compared to 12.9% and 13.6% estimated by Gleason (1997). Gleason (1997) reported that Texas was a relatively important harvest state for both direct (6.8%) and indirect (8.9%) recoveries, though South Dakota ranked first in proportion of direct (66.6%) and indirect (60.6%) recoveries. Because none of our banded geese was recovered in Texas, it appears that geese breeding in South Dakota and their fledged young may be wintering farther north than they did historically. Gleason (1997) reported <2% of total direct and indirect recoveries were from north of South Dakota, but we determined that >13% of band recoveries occurred north of the state. We attribute this change in harvest distribution to an increase in northward post-molt movements as suggested from the direct recoveries north of South Dakota, while indirect recoveries were the result of both northward post-molt movements (Anderson 2006) and northward molt migrations (Anderson and Dieter 2009, Dieter and Anderson 2009*b*). Our data showed that indirect recoveries were made from areas farther north than were direct recoveries. Based on geographic variation in survival rates and recovery distribution, Gleason (1997) proposed that potentially 3 different subflocks of Canada geese breed in South Dakota. In Nebraska, Powell et al. (2004) documented geographic variation in survival and recovery rates, and distribution of recoveries, suggesting subflocking within that population.

Most surviving Canada geese did not migrate to wintering areas south of South Dakota until after inclement weather occurred in South Dakota, causing wetlands and food resources to become unavailable (Anderson 2006, Dieter and Anderson 2009*b*). Based on distribution of band recoveries, it appears that geese follow a south-southeasterly course to their wintering areas (see also Gleason 1997). Based on band-recoveries, most geese appear to follow a migration axis along the Iowa-Nebraska border and then along the Missouri-Kansas border.

Chronology of harvest

The chronology of band recoveries indicated that most geese banded in eastern South Dakota were harvested during the September hunting season. Specifically, 49.9% of the direct and 41.4% of the indirect recoveries occurred during this period. Gleason (1997) reported that 49.7% of the direct and 45.1% of the indirect recoveries for Canada geese banded east of the Missouri River in South Dakota occurred during the month of October. We recognize, however, that there was no September season during the years of band-recovery analysis by Gleason (1997). During his study, the first goose-hunting season (i.e., regular season) implemented in South Dakota did not start until approximately October 1. The high proportion of band recoveries during the September hunting season (i.e., the first open season) that we found is likely a function of the liberal limits of this season. Over half (55%) of the total harvest from the banded sample of Canada geese shot in South Dakota occurred in September. The high proportion of total goose harvest during the September season may be replacing the harvest that traditionally occurred primarily during October and November (Vaa et al. 2010). Sheaffer et al. (2005) found a similar shift in harvest dates in several midwestern states.

Recovery and annual survival rates

Annual survival rate estimates of giant Canada geese during this study were among the lowest reported in the literature (Table 6). Gleason (1997) reported a survival estimate for adult Canada geese banded in eastern South Dakota (sexes pooled) of 0.71 during 1967 to 1976 , 0.98 during 1967 to 1976, and 0.85 during 1988 to 1995. These estimates were much higher than this study's survival estimate of 0.52. Coluccy (2001) reported that survival of giant Canada geese in central Missouri remained high despite liberalized harvest opportunity during Missouri's early October season. In contrast, Sheaffer et al. (2005) found that harvest rates on adult geese from Illinois and Ohio increased by a factor of 1.5 and that harvest rates for immatures increased by a factor of 1.3 to 1.8 after implementation of September hunting seasons.

Our study indicates that survival rates of eastern South Dakota resident geese have decreased after the implementation of the September hunting season. Our low survival estimate coincides with high estimated September season harvests of resident Canada geese in eastern South Dakota, with an estimate of 34,831 to 51,491 during the 2000 to 2003 seasons (Vaa et al. 2010). For our study, survival estimates for adults were lower than estimates derived for the immature cohort. Other studies also have reported higher survival rates for immature geese than for adults (Tacha et al. 1980, Lawrence et al. 1998*b*, Sheaffer and Malecki 1998, Coluccy et al. 2004).

Dieter and Anderson (2009*b*) documented fairly high rates of molt-migration for Canada geese captured in eastern South Dakota for unsuccessful breeders (81%), nonbreeders (56%), and successful breeders (20%). The proportion of band recoveries from north of South Dakota was poorly documented prior to the implementation of the September goose-hunting season (Gleason 1997; P. Mammenga, SDGFP, personal communication). Therefore, it seems likely that the increased rate of molt migration may be influencing current annual survival rates for large Canada geese in South Dakota (see Luukkonen et al. 2008). It has been suggested that geese exhibiting molt migrations may be subject to greater hunting mortality than geese that remain near their breeding areas because geese that remain in familiar areas are probably less susceptible to hunting (Ball et al. 1981, Lawrence et al. 1998*a*, Luukkonen et al. 2008). However, it is questionable whether this was occurring within South Dakota after the implementation of the September hunting season. Hestbeck et al. (1990) stated that different segments of a goose population will be exposed to differential harvest pressure when harvest rates vary or among regions within a state or among states. The number of goose hunters during the September season in eastern South Dakota has shown a significant decline ($F_{1,8}$ = 31.63, P < 0.01) from a high of >26,000 in 2001 to approximately 14,000 in 2007 (Vaa et al. 2010). However, since the bag limit increased to 5 birds daily, the goose harvest has remained relatively stable, indicating that while there are fewer hunters in the field, they are being more successful at harvesting geese. It is not uncommon for some groups of hunters to shoot from 25 to 50 geese per day early in the September season. In contrast, we suspect that hunting pressure would be much less for geese that exhibit a molt migration into Canada due to fairly dramatic declines in Canadian waterfowl hunter numbers (Boyd et al. 2002) even though many provinces open their waterfowl seasons on or about September 1. The peak hunting pressure from U.S. hunters in the prairie provinces of Canada probably does not occur until after the middle of September (Alisauskas et al. 2006).

Most direct recoveries were from geese remaining in South Dakota. However, a proportion of the population of geese responsible for indirect recoveries was north of South Dakota, which we documented as far as 2,080 km north in Nunavut, Canada, during this same time period (Anderson and Dieter 2009). Molt migrants may be experiencing higher hunting mortality on their return migrations to South Dakota (Ball et al. 1981, Lawrence et al. 1998*a*, Coluccy 2001), but we do not know if this hunter mortality compares to the hunting mortality suffered by more sedentary geese during the September season in South Dakota. Many molt migrants are not returning until later in October, with recoveries still occurring in Canada after October 15.

Sheaffer et al. (2005) found recent direct recovery rates for most Canada geese in the Mississippi Flyway ranged from 0.03 to 0.13. The direct recovery rates we found (0.16 to 0.18) were comparable to those reported for Nebraska geese by Powell et al. (2004), with recovery rates ranging from 0.186 to 0.389. Gleason (1997) reported recovery rate estimates for giant Canada geese banded in eastern South Dakota at 0.06 to 0.07 from 1955 to 1995, which are much lower than what we found. Sheaffer and Malecki (1998) reported mean annual recovery rates for Atlantic Flyway resident nesting geese at 0.048 for adults and 0.077 for immatures. In southeastern Michigan, Tacha et al. (1980) reported recovery rate point-estimates that ranged from 0.036 to 0.084. In Illinois, Lawrence et al. (1998*b*) reported mean recovery rate estimates of 0.053 for adults compared to 0.035 for immatures.

Harvest rates

The harvest rate over the 4-year period was 0.222, which was higher than what Zimmerman et al. 2009*b* found for Mississippi Flyway giant Canada geese (0.167) and what Balkcom (2010) found for rural geese in Georgia (0.202). Gleason (1997) reported harvest rates of 0.170 to 0.190 for giant Canada geese using a band reporting rate of 0.36 banded in eastern South Dakota. However, using a reporting of 0.763, the harvest rate would have been 0.08 to 0.09. The harvest rate we documented was near the highest harvest rate for giant Canada geese that has been documented, which was 0.272 to 0.320 near Chesapeake Bay (Hestbeck 1994).

Management implications

Based on band-recovery analyses from our study, it is apparent that Canada goose survival rates have decreased, and recovery and harvest rates have increased compared to those reported by Gleason (1997) from eastern South Dakota. Geese raised in South Dakota also are making considerable northward post-molt movements in the fall (Anderson 2006). It is also apparent that a northward molt migration of immatures, nonbreeders, and even some successful breeders is now more common than previously documented for South Dakota (Dieter and Anderson 2009*b*).

The SDGFP management plan goal for resident Canada geese is a spring breeding population count of 80,000 geese, but the 2005 to 2009 breeding population estimate ranged from 100,000 to 160,000 birds (Vaa et al. 2010). We documented a high harvest rate with a high proportion of banded geese being harvested during the September hunting season. In addition, we documented one of the lowest annual survival rates ever estimated for a population of Canada geese (see Table 6). However, management goals are still not being reached. Hestbeck (1994) found that the population of Canada geese in the Atlantic Flyway still increased, with a harvest rate of 0.23, and the population decreased, with a harvest rate of 0.32. Management goals may not be able to be reached with the current hunting regulations as in other areas of the United States (Ankeny 1996, Hindman et al. 2004, Vrtiska et al. 2004).

South Dakota Department of Game, Fish, and Parks currently has proposed initiating a 9-day August management harvest in 2010. North Dakota had an August management harvest during 2008 and 2009 (with a daily limit of 5 geese), and there was no significant increase in harvest in either year compared to previous years when only the September season was open prior to the regular season (M. Johnson, North Dakota Game and Fish, personal communication). The proposal by SDGFP would allow hunters to harvest 8 Canada geese daily during the August management harvest and also a daily limit of 8 geese during the September season. It is possible that the harvest of Canada geese during the August management harvest will only replace the harvest that has been occurring in the September season (Sheaffer et al. 2005). However, it is also possible that the increase in daily bag limit and longer season may increase harvest sufficiently to reduce or stabilize the population of Canada geese. If not, SDGFP may have to consider using additional management tools to reduce the Canada goose population. A possible alternative would be to increase the Canada goose population goal to a more realistic number from 100,000 to 120,000. The current population goal is related more to landowner tolerance than to available habitat for Canada geese. South Dakota Department of Game, Fish, and Parks already has one of the most successful programs in the United States for reducing crop damage by Canada geese (Radtke and Dieter 2010).

We recommend that SDGFP continue summer-banding operations of Canada geese in eastern South Dakota. The movement of molt-migrant geese out of South Dakota and the immigration of molt-migrant Canada geese into South Dakota from other states should be considered when selecting the timing and location of summer Canada goose banding operations (Gleason et al. 2003, Fritzell and Luukkonen 2004, Nichols et al. 2004). A telemetry study that would provide a comparison of survival rate estimates between more sedentary resident geese and those that make long-distance molt-migrations or post-molt movements would be of particular interest (Groepper et al. 2008). A long-term consistent banding effort selecting wetlands used almost exclusively by brood flocks to reduce potential bias associated with survival and harvest parameters should continue until the effects of the September hunting season and goose movements are better understood.

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