

# Harvest demographics of temperate-breeding Canada geese in South Dakota, 1967–1995

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**Abstract:** In South Dakota, breeding giant Canada geese (*Branta canadensis maxima*) have increased substantially, and harvest management strategies have been implemented to maximize hunting opportunity (e.g., special early-September seasons) on local, as well as molt-migrant giant Canada geese (*B. c. interior*) while still protecting lesser abundant Arctic-breeding Canada geese and cackling geese (e.g., *B. hutchinsii*, *B. minima*). Information on important parameters, such as survival and recovery rates, are generally lacking for giant Canada geese in the northern Great Plains. Patterns in Canada goose band recoveries can provide insight into the distribution, chronology, and harvest pressures to which a given goose population segment is exposed. We studied spatial and temporal recovery patterns of molting Canada geese during annual banding efforts in South Dakota between 1967 and 1995. Recovery rates (% ± SE) for Canada geese increased over time in both western South Dakota (0.034 ± 0.005 [1967 to 1976], 0.056 ± 0.009 [1977 to 1986]) and eastern (0.026 ± 0.002 [1967 to 1978], 0.058 ± 0.003 [1987 to 1995]) South Dakota. Although recovery rates for Canada geese west of the Missouri River (WR) and east of the Missouri River (ER) were relatively similar, recovery distribution and harvest chronology indicate spatial and temporal differences for geese banded in these 2 geographic regions. Overall, Canada geese banded in South Dakota were recovered in 23 states and 5 Canadian provinces, and recovery distribution varied relative to banding region. Distribution of recoveries suggests a south-southwesterly movement for WR-banded geese compared to a south-southeasterly movement for ER-banded geese. For WR-banded geese, 40 to 52% and 30 to 34% of direct and indirect recoveries, respectively, occurred in December. In contrast, for ER-banded geese, 19 to 38% and 15 to 19% of direct and indirect recoveries, respectively, occurred in December. Waterfowl managers need to consider that recovery rates and harvest chronology of banded giant Canada geese may vary geographically within a state or province. Refinement of harvest management strategies at multiple spatial scales may be required

**Key words:** *Branta canadensis maxima*, Canada geese, distribution, harvest chronology, human–wildlife conflicts, recoveries, recovery rate, South Dakota, status

**MANAGEMENT OF MIGRATORY** populations presents numerous challenges to waterfowl managers, including harvest management of white-cheeked geese (*Branta canadensis* spp. and *Branta* spp.); Ankney 1996, Rusch et al. 1996). One of the challenges faced by both federal and state waterfowl managers is maximizing harvest opportunity and total harvest for temperate-breeding (also referred to as resident) Canada geese (*Branta canadensis maxima*; Figure 1),

while at the same time maintaining, reducing, or, in some cases, eliminating harvest on Arctic-breeding populations of cackling geese (*B. hutchinsii*) and Canada geese that overlap temporally and spatially with resident geese at some point during the migration (Hindman et al. 2004, Kraege et al. 2004, Leafloor et al. 2004, Vrtiska et al. 2004). The efficacy of August depredation orders or control hunts and special early September Canada goose

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hunting seasons (U.S. Fish and Wildlife Service 2005, Dieter et al. 2010a, Groepper et al. 2012) may be limited due to a proportion of some temperate-breeding Canada goose populations exhibiting molt-migrations (Abraham et al. 1999, Luukkonen et al. 2008, Dieter and Anderson 2009). Dieter et al. (2010b) documented that ~45% of the Canada geese marked in eastern South Dakota (2000 to 2003) with VHF transmitters or platform transmitting terminals actually departed their study area prior to the start of the early September Canada goose hunting season. In South Dakota, at least, some fraction of the target population (resident geese) are, therefore, unavailable

for harvest during the state's current Canada goose hunt. Prior to the departure of South Dakota's molt-migrants, there is an influx of nonresident giant Canada geese into the state; primarily in the eastern-northeastern tier counties with relatively abundant and stable wetland conditions (Naugle et al. 1997) and easily accessible row-crops, such as, soybeans (*Glycine max*) and corn (*Zea mays*; Radtke and Dieter 2010).

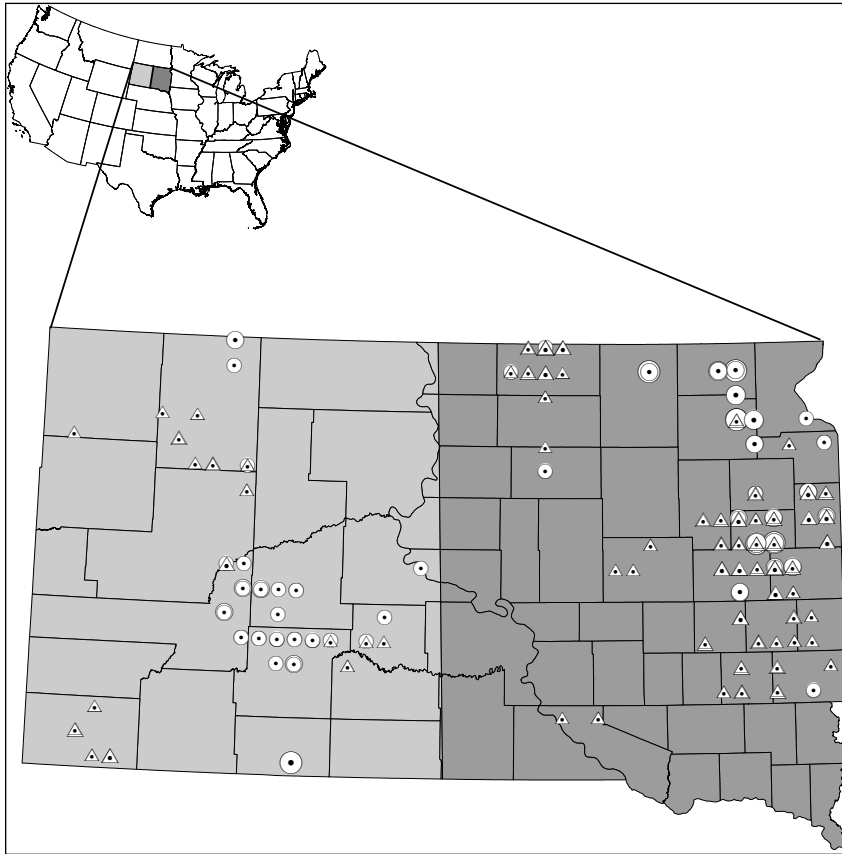
Restoration of large-bodied Canada geese (hereafter, geese) to their former breeding range is considered a great achievement in wildlife management (Nelson and Oetting 1998, Mowbray et al. 2002). Reports of geese being extinct were poorly founded, and, even in 1963, Harold Hanson provided a population estimate of ~55,000 wild geese, primarily on refuges and private lands in the United States and Canada, plus >7,000 geese held by individuals (Hanson 1997). Through successful restoration efforts, geese now occur throughout their former breeding range, even extending outside what was considered their core range (Rusch et al. 1996, Nelson and Oetting 1998). In 1996, Rush et al. (1996) estimated that there were >1 million geese in the Mississippi Flyway alone, plus an additional ~1 million geese in the other 3 flyways. More recently, Gabig (2000) and Vrtiska et al. (2004) estimated the population size for the Western Prairie and Great Plains population (considered *B. c. maxima*) in the



**Figure 1.** Pair of Canada geese and their brood.

Central Flyway to be 644,000 to 700,000 geese. The spring 2012 Western Prairie and Great Plains population index was 1,551,500, which is slightly, but not significantly, lower than the 2011 estimate of 2,046,100, an increase of 11% per year since 2004 (U.S. Fish and Wildlife Service 2013).

Restoration of geese by the South Dakota Department of Game, Fish and Parks (SDGFP) began in the 1960s, though captive flocks were established and maintained at Waubay National Wildlife Refuge (Day County) and, before then, Sand Lake National Wildlife Refuge (Brown County; Nelson 1963, Lee et al. 1984, Gabig 2000). Restoration efforts through the 1970s included primarily free-flyer-release of flightless goslings (7 to 8 weeks old and some yearling and 2-year-old geese) from captive flocks; the first release ( $n = 32$ ) occurred in Mellette County (1967) in western South Dakota (Vaa et al. 2010). Much of the early restoration efforts (1967 to 1977) in South Dakota occurred in counties with suitable stock-pond habitat west of the Missouri River (Lengkeek 1973, Bultsma 1976, Steiffel 1980). The priority for giant Canada goose restoration efforts in South Dakota changed to releases in counties east of the Missouri River in 1978 (Hilley 1976, Clausing 1979). There were 4,189 and 8,089 geese released in western and eastern South Dakota, respectively, not including trapped-and-transported geese related to depredation



**Figure 2.** Geographic regions used to delineate Canada geese banded during the pre-season (June–September) banding period in South Dakota, 1967 to 1995. Circle with dot = Status 3, normal, wild. Triangle = Status 2, 4, and 6. West of the Missouri River = light shading. **NOTE:** In some cases, similar, but different sized symbols may occur in the same 10' block or different symbols may occur in a 10' block, reflecting temporal separation of banding effort or different status groups banded in the same location. Thus, the smallest symbol = 1–10 banded geese; the largest symbol = >100 banded geese.

complaints or city-related nuisance-geese transfers (Vaa et al. 2010: Appendix 1). As part of the restoration efforts to maximize the potential for successfully establishing wild flocks, the SDGFP implemented a 5-year closure of goose hunting in counties of release. At the end of the 5-year period, counties were assessed to determine if an open season with a limited quota of tags was a viable management option. By 1999, almost all of the original release areas were included under a full framework of 95 days and a daily bag limit of 3 geese (Vaa et al. 2010). In 1996, the first early September goose season in the Central Flyway was established in South Dakota; 10 counties in the eastern portion of the state. An estimated >12,800 geese were harvested during this inaugural season. By 1999, 3 Central Flyway states (Kansas, South Dakota, and North Dakota) had implemented

early September Canada goose hunting seasons in some portions of their respective states (Gagib 2000: Appendix 5). For additional information on the restoration of geese in South Dakota and throughout the Central Flyway, refer to Nelson (1963), Lee et al. (1984), and Vrtiska et al. (2004).

Waterfowl managers and policy makers require information on geographic distribution and timing of waterfowl movements to properly apply harvest management strategies for a given species or target population (Baldassarre and Bolen 1994, Nichols et al. 1995). We investigated the geographic distribution of band-recoveries and timing of movements of pre-season banded geese in South Dakota. Specifically, we investigated recovery rates, distributions, and harvest chronology with respect to banding region, status, age, sex, and year. This study (1967 to 1995) represents a comprehensive

statewide assessment of hunter-based band recoveries for geese over a long time frame (28 years) under more conservative, or traditional, hunting regulations prior to (1) implementation of early September hunting seasons and August Management Take, or control hunts, and (2) changes in band inscriptions (Vrtiska et al. 2004: Table 2). Gabig (2000) established a list of data analyses and research needs and this study addresses a number of those objectives (see also Powell et al. 2004, Dieter et al. 2010a, Groepper et al. 2012).

## Methods

### Sorting procedures

We *a priori* sorted restored flocks from normal, wild (Status 3) banded geese. Restored flocks included geese banded as Status 4 and 6 in western South Dakota and Status 2, 4, and 6 in eastern South Dakota (refer to status codes in North American Bird Banding Manual, in Gustafson et al. 1997). Recovery records were obtained from the U.S. Geological Survey's, Bird Banding Laboratory, Laurel, Maryland. We used as our minimum sample size 100 banded individuals per year for deriving recovery rate estimates for all comparisons. Recoveries represent only those geese shot or found dead (i.e., how-obtained codes = 00 and 01, respectively) during the hunting season (i.e., recovery months = 01-02, 09-12). Recoveries were sorted with respect to the 2 broad geographic banding regions in South Dakota (Figure 2). The west river (WR) region included all counties west of the Missouri River, and the east river (ER) region included all counties east of the river. We also assessed recovery information with respect to 3 banding periods (WR and ER; period 1 [1967 to 1976], period 2 [1977 to 1986], and period 3 [1987 to 1995]; Gleason et al. 2003, Vaa et al. 2010: Appendix A). Sample periods selected for WR and ER represent roughly the 3 goose harvest management periods (historic, restrictive, and liberal) in South Dakota prior to initiation of the first early September goose hunting season in 1996 (see Gabig 2000, Vaa et al. 2010). We recognize that, given liberalization of harvest management policies and strategies in place in South Dakota to reduce burgeoning temperate-breeding geese during the mid-late 1990s (U.S. Fish and Wildlife Service 2005), our use of the

term liberal to define a harvest management period for this study would be considered conservative in a broader context (Gabig 2000: Appendix 5; Vrtiska et al. 2004). Sorted recovery files were put into Program Band Analysis System (BAS; Geissler and Powell 1994), and further selection criteria were used to discriminate among age, sex, and status cohorts (Gleason 1997: Tables 6 through 8). Final sorting was conducted to identify recoveries by region banded, recovery type (i.e., direct or indirect), location, and month. In general, the number of banded geese was not equal across the 2 banding regions or among 3 periods (Gleason et al. 2003).

### Recovery rates

Recovery rates were calculated using band-recovery matrix output generated from program BAS. Because cohort-specific samples were highly variable across regions, we used programs ESTIMATE and INTERVAL to derive survival and recovery rates (Conroy et al. 1989). INTERVAL was used only when intervals between banding periods varied, such that banding data for consecutive years were not available (Brownie et al. 1985). In cases where we were interested in a long interval (>10 years), we modified the recovery portion of the band-recovery matrix so that a maximum of 10 years of recoveries was included. This procedure does not increase bias in estimators, because, in most cases, column and row values in the matrix were either 0 or 1 (M. J. Conroy, U.S. Geological Survey, personal communication). Within programs ESTIMATE or INTERVAL, all 3 models (M1/IN1 = time-specific survival [ $S$ ] and recovery [ $f$ ] rates, M2/IN2 = constant survival rates, but time-specific recovery rates, M3/IN3 = constant survival and recovery rates; Brownie et al. 1985) were evaluated for each of the age, sex, status, and region cohorts. Models within MULT (Conroy et al. 1989) are hierarchical in nature with model M1 being the most general. We recognize that Program MARK is robust to simultaneously testing multiple competing hypotheses (Lebreton et al. 1992, White et al. 2001), includes a diverse suite of available models, and allows incorporation of important main effects and covariates that could influence recovery rates and survival (e.g., Balkcom 2010, Groepper et al. 2012).

**Table 1.** Mean annual recovery rates ( $f$ ; %) by year period, banding region, age, sex, and status for geese banded in South Dakota, 1967 to 1995. Only recovery estimates obtained from the best approximating model are included.

| Period <sup>a</sup> | Region     | Age <sup>b</sup> | Sex <sup>c</sup> | Status <sup>d</sup> | Model <sup>e</sup> | $f$   | 95% CI <sup>f</sup> |
|---------------------|------------|------------------|------------------|---------------------|--------------------|-------|---------------------|
| 1967–1976           | West River | P                | P                | 3                   | IN3                | 0.034 | 0.025–0.043         |
| 1977–1986           | West River | P                | P                | 3                   | IN3                | 0.056 | 0.039–0.074         |
| 1968–1979           | West River | AD               | P                | 4,6                 | M3                 | 0.067 | 0.060–0.075         |
| 1976–1978           | West River | SU               | P                | 4,6                 | M2                 | 0.081 | 0.059–0.103         |
| 1967–1978           | East River | P                | P                | 3                   | M1                 | 0.026 | 0.023–0.029         |
| 1987–1995           | East River | P                | P                | 3                   | M1                 | 0.058 | 0.053–0.064         |
| 1977–1986           | East River | P                | P                | 2,4,6               | M1                 | 0.074 | 0.060–0.088         |
| 1987–1995           | East River | P                | P                | 2,4,6               | IN2                | 0.040 | 0.033–0.047         |

<sup>a</sup> Year period was defined based on sufficient (>100 individuals) number of banded Canada geese and roughly, reflect the 3 goose-management periods (historic, restrictive, and liberal) in South Dakota (see Methods; refer also to Gabig 2000, Vrtiska et al. 2004, and Vaa et al. 2010 for additional information regarding goose management in South Dakota).

<sup>b</sup> Age: AD = adult, SU = subadult (local and hatch year), and P = adult and sub-adult pooled based on nonsignificant ( $P > 0.05$ ) survival comparisons using Program CONTRAST (Hines and Sauer 1989, Sauer and Williams 1989).

<sup>c</sup> Sex: P = males and females pooled after nonsignificant ( $P > 0.05$ ) survival comparisons using Program CONTRAST (Hines and Sauer 1989, Sauer and Williams 1989).

<sup>d</sup> Status: 3 = normal, wild; 2 = transported to different 10' block; 4 = hand-reared; and 6 = formerly experimental, color-marked (Gustafson et al. 1997).

<sup>e</sup> Program MULT models tested: M1/IN1 = time-specific survival and recovery rates, M2/IN2 = constant survival rates, but time-specific recovery rates, M3/IN3 = constant survival and recovery rates. Only recovery estimates from the best fitting model are included.

<sup>f</sup> CI represents 95% confidence intervals generated in Program MULT (Conroy et al. 1989).

However, due to the retrospective nature of this study and the restricted set of specific objectives, we believe that use of Program MARK was not necessary (White and Burnham 1999). Therefore, we considered the use of Program MULT (Conroy et al. 1989) and its various routines (e.g., BROWNIE, ESTIMATE, and INTERVAL) appropriate for the analysis of live-dead encounters of goose band-recovery data (Brownie et al. 1985). Model selection was conducted using quasi-likelihood Akaike's Information Criterion (QAIC) for over-dispersed data, because geese generally mate for life, and male-female pairs and associated young behave like an individual unit. Thus, banded individuals are not independent (Pollock and Raveling 1982, Anderson et al. 1994). QAIC was generated after having calculated a variance inflation factor ( $\hat{c}$ ) using the equation

$$\hat{c} = \chi^2/df, \quad (1)$$

where both  $\chi^2$  and  $df$  were generated from

global models. Models were ranked using  $\Delta\text{QAIC}$  (Burnham and Anderson 2002) and were calculated as  $\Delta\text{QAIC} = \text{QAIC}_i - \text{QAIC}_{\min}$  where  $\text{QAIC}_i$  was for the  $i^{\text{th}}$  model from the candidate set. Akaike weights,  $w_{\text{QAIC}_i}$  were derived (Burnham and Anderson 2002) as evidence in favor of model  $i$  being the best model, given the data using the equation

$$w_i = \exp(-.5*\Delta\text{QAIC}_i) / \sum \exp(-.5*\Delta\text{QAIC}_i), \quad (2)$$

where model weights sum to 1. We also calculated all related criteria functions (i.e.,  $\hat{c}$ ,  $\Delta\text{QAIC}_i$ , and  $w_i$ ; Burnham and Anderson 2002). For some models, QAIC reduced to AIC because  $\hat{c} \leq 1$  and over-dispersion was not present (Burnham and Anderson 2002).

Recovery rates included unadjusted direct and indirect recoveries (i.e., not adjusted for reporting rates). Period, age, sex, and status comparisons of recovery estimates using the best models were conducted using program CONTRAST (Hines and Sauer 1989, Sauer and Williams 1989). In all cases, only 2

**Table 2.** Model selection criteria used to evaluate recovery rate models by year period and banding region for Canada geese banded in South Dakota, 1967 to 1995. For each candidate model, included is the number of parameters ( $K$ ), variance inflation factor ( $\hat{c}$ ), quasi-likelihood Akaike Information Criterion ( $\Delta\text{QAIC}_c$ ), and model weight ( $w_{\text{QAIC}}$ ). Only those models with  $\Delta\text{QAIC}_c$  values  $< 4$  were considered of interest. West River = west of the Missouri River. East River = east of the Missouri River.

| Period <sup>a</sup> | Region     | Model <sup>b</sup> | $K$ | $\hat{c}$ <sup>c</sup> | $\Delta\text{QAIC}_c$ | $w_{\text{QAIC}}$ |
|---------------------|------------|--------------------|-----|------------------------|-----------------------|-------------------|
| 1968–1979           | West River | M3                 | 2   | 3.5573                 | 0.0000                | 0.9926            |
| 1976–1978           | West River | M2                 | 4   | $\leq 1$               | 0.0000                | 0.7164            |
| 1976–1978           | West River | M1                 | 5   | $\leq 1$               | 1.8932                | 0.2780            |
| 1967–1976           | West River | IN3                | 2   | 1.4334                 | 0.0000                | 0.6964            |
| 1967–1976           | West River | IN2                | 7   | 1.4334                 | 2.7367                | 0.1772            |
| 1967–1976           | West River | IN1                | 11  | 1.4334                 | 3.4132                | 0.1264            |
| 1977–1986           | West River | IN3                | 2   | 1.5330                 | 0.0000                | 0.9766            |
| 1967–1978           | East River | M1                 | 23  | 1.1623                 | 0.0000                | 1.0000            |
| 1987–1995           | East River | M1                 | 17  | 2.1924                 | 0.0000                | 1.0000            |
| 1977–1986           | East River | M1                 | 19  | 1.4586                 | 0.0000                | 0.9850            |
| 1987–1995           | East River | IN2                | 9   | 1.3944                 | 0.0000                | 0.8170            |
| 1987–1995           | East River | IN3                | 2   | 1.3944                 | 4.0163                | 0.1097            |

<sup>a</sup> Year periods were defined based on sufficient ( $>100$  individuals) numbers of banded geese and reflect the 3 goose management periods (historic, restrictive, and liberal) in South Dakota (see Methods).

<sup>b</sup> Program MULT models tested: M1/IN1 = time-specific survival and recovery rates, M2/IN2 = constant survival rates, but time-specific recovery rates, M3/IN3 = constant survival and recovery rates. Only those models with  $\Delta\text{QAIC}_c < 4.0$  are considered of interest, providing strong ( $<2.0$ ) and some support ( $2.0$ – $4.0$ ), respectively.

<sup>c</sup> Value  $<1$  represents a situation in which overdispersion did not exist; thus, QAIC reduced to AIC (Burnham and Anderson 2002).

recovery estimates were used for each period, age, sex, and status comparison. Pooling of sex-age classes was conducted only when a nonsignificant chi-square value ( $P \geq 0.05$ ) was derived for a given comparison (Gleason 1997).

### Distribution of recoveries

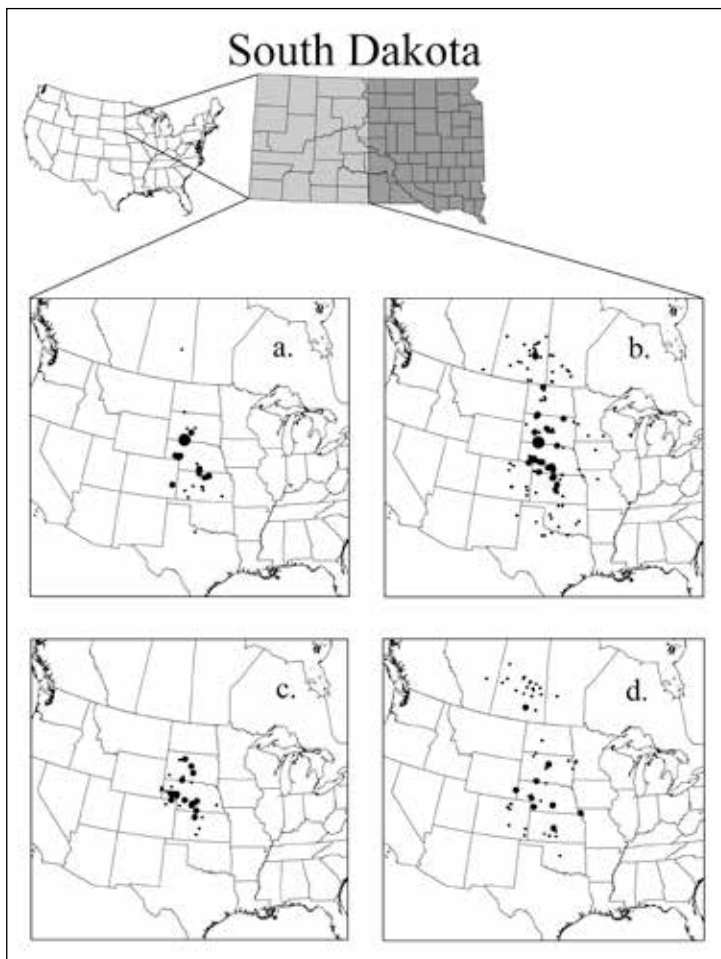
Program CENTROID was used to test for differences in recovery distributions for both direct and indirect recoveries within a specific cohort. This program tests the null hypothesis that 2 samples of recoveries belong to the same bivariate distribution using the Mardia's  $U$ -test (Mardia 1967, Batschelet 1972). We used Method 4 from CENTROID, which averages the ranks of recoveries with the statistic computed as suggested by Robson (1968; see also Chu et al. 1995, Johnson et al. 1995, Fritzell and Soulliere 2004). For geese banded ER and WR, 12 separate distribution tests were conducted.

We compared both direct and indirect recovery distributions independently for each status group (normal, wild and restored flocks) among the 3 periods (i.e., 1967 to 1976, 1977 to 1986, and 1987 to 1995) for which we had sufficient recovery records. Direct and indirect recovery distributions for geese banded in WR and ER for normal, wild (1967 to 1995, ages and sexes pooled), and restored flocks (1967 to 1995, sub-adults only) also were compared. Direct and indirect recovery distributions were plotted using converted (to center of  $10'$  block) recovery latitude-longitude information from the original banding files. Location of banding sites and recoveries of South Dakota banded Canada geese were plotted using a Geographical Information Systems (ESRI® ArcMap™ Version 10.1, Environmental Systems Research Institute, Redmond, Calif.). Location of banding sites and recoveries in the

banding files are not precise locations, but rather are interpolated based on data available in the banding file (BLAT = 3 digit, BLONG = 4 digit) that were then converted to decimal degrees representing the center of 10' blocks prior to being imported into ArcMap™. A similar process was used to plot banding-site locations using a South Dakota base map with county outlines included. Records were summarized for banding latitude-longitude to indicate relative contribution of each banding site to the total banded sample within a region.

### Chronology of recoveries

Frequency of monthly recoveries during the hunting season was calculated for direct and indirect recoveries. Statistical comparisons of the number of recoveries among months during the hunting season is confounded by the initial banded sample size (Gleason et al. 2003), temporal and spatial variation in hunting effort, variation in distribution of geese within and among hunting seasons, and variation in band reporting rates (Zimmerman et al. 2009b: Table 2). In particular, the number of observed frequencies was sparse (<5) for some cells (Manly 1994), particularly for WR-banded geese. Goodness-of-fit tests were used to examine differences in number of monthly recoveries by region, status, and recovery type (direct versus indirect; e.g., Dieter et al. 2010a). Recognizing constraints of the data, this approach seemed reasonable, given the relatively large differences in observed frequencies (Agresti 2012). A Bonferroni adjustment to account for multiple comparisons was applied to all goodness-of-fit tests where  $\alpha = 0.05/5$  (number of months; adjusted  $\alpha = 0.01$ ) to guard against committing a Type I error (Johnson 1998).



**Figure 3.** Distribution of hunter-reported band recoveries for normal, wild (direct [a] and indirect [b]) and restored flocks (direct [c] and indirect [d]) of geese banded in western South Dakota, 1967–1995. Relative size of dots indicates number of recoveries within a 1' block. Thus, smallest dots = 1 recovery; largest dots = >10 recoveries.

We used an *a priori* hierarchical approach to model development and hypothesis testing that included both null hypothesis testing and information theoretic approaches. Though some have cautioned against this analytical approach, i.e., mixing statistical paradigms (Lukacs et al. 2007, Doherty et al. 2012), while others have argued that a combination of null hypothesis testing and information theoretic methods may be beneficial or that null hypothesis testing still has a place in ecological studies (Stephens et al. 2005, 2007). Overall, we do not believe that: (1) our model-based recovery rate estimates are biased or (2) our best-fitting model or interpretation(s) would have differed had we used Program MARK (White and Burnham 1999). Similar to Balkcom

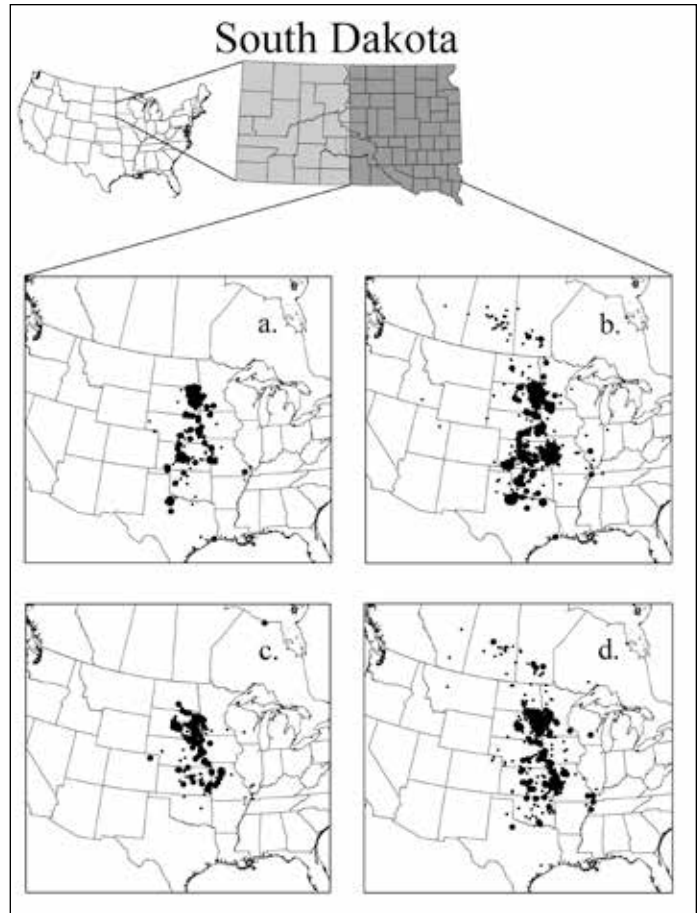
(2010, 2011), we assumed either no band loss over the period studied or that band loss was similar among age, sex, status, and region cohorts (but, see Coluccy et al. 2002, Zimmerman et al. 2009a).

## Results

The starting sample size of recovery records available for all recovery types, regions, status, and cohorts was 5,429, with WR ( $n = 532$ ) and ER ( $n = 4,897$ ) representing 3,317 and 21,987 banding records, respectively. Sample sizes for analyses of recovery distributions and harvest chronology were reduced because latitude-longitude (location of recovered bird) and recovery month, respectively, were not available for some records. For recovery distributions, the number of recovery records available for use was: WR ( $n = 529$ ) and ER ( $n = 4,876$ ). For harvest chronology, the number of recovery records available for use was: WR ( $n = 532$ ) and ER ( $n = 4,895$ ). However, for the harvest chronology analysis, some records had recovery month codes (93 or 94) not associated with specific months depending on when the bird was recovered, and, thus, these records (i.e., WR [93,  $n = 9$ ; 94,  $n = 28$ ] and ER [93,  $n = 56$ ; 94,  $n = 175$ ]) were not considered in our analyses.

## Recovery rates

Recovery rates varied by period, status, and region affiliation (Table 1). Recovery rates (%) for normal, wild geese banded WR increased across the 2 periods (0.034, 1967 to 1976, and 0.056, 1977 to 1986; Table 1). For this same status group, ER recovery rates increased from 0.026 (1967 to 1978) to 0.058 (1987 to 1995). Too few restored geese were banded WR to allow for a period by age and sex comparison. However, period 1 adult and period 2 sub-adult recovery rates for restored flocks were 0.068 and 0.081,



**Figure 4.** Distribution of hunter-reported band recoveries for normal, wild (direct [a]) and indirect ([b]) and restored flocks (direct [c]) and indirect ([d]) of geese banded in eastern South Dakota, 1967-1995. Relative size of dots indicates number of recoveries within a 10° block. Thus, smallest dots = 1 recovery; largest dots = >10 recoveries.

respectively. Increases in recovery rates occurred for most period comparisons except for restored flocks banded ER. The highest and lowest recovery rates documented were for sub-adult, restored geese banded WR (0.081, 1976 to 1978) and normal, wild geese banded ER (0.026, 1967 to 1978).

Because some cohorts of interest did not meet the minimum banded sample of 100 geese, some period by sex, age, and status comparisons could not be done (see Gleason et al. 2003: Table 1). Over-dispersion did not influence model fit or model structure. Anderson et al. (1994) indicated that one would expect  $\hat{c} > 1$ , but the variance inflation factor should not exceed four (see also Eberhardt 1978). In our study, the variance inflation factor was  $< 2$  in most cases (80%), reduced to AIC ( $\hat{c} < 1$ ) in



**Table 3.** Recovery rate estimates from band-recovery studies of Geese (*Branta canadensis maxima*) and other large-bodied (*B. c. hoffitti* and *B. c. interior*) geese in the United States and Canada. In most studies considered, geese were banded pre-season (identified as resident in Location column), but in some cases, geese were banded during the staging or wintering period (identified as migrant in Location column).

| Location   | Year(s) <sup>a</sup>   | Sex <sup>b</sup> | Age <sup>c</sup> | Estimate (f) <sup>d</sup>             | Temporal trend <sup>e</sup> | Source                        |
|--|------------------------|------------------|------------------|---------------------------------------|-----------------------------|-------------------------------|
| Eastern South Dakota, resident                   | 1967–1978<br>1987–1995 | P                | P                | 0.026<br>0.058                        | ↑                           | This study                    |
| Western South Dakota, resident                   | 1967–1976<br>1977–1986 | P                | P                | 0.034<br>0.056                        | ↑                           | This study                    |
| Nebraska, resident<br>northeast versus southeast | 2006–2010              | P                | Effect           | NE: 0.148–0.061<br>SE: 0.081–0.151    | TV                          | Groepper et al. (2012)        |
| Eastern South Dakota, resident                   | 2000–2003              | P                | Ad./Imm.         | Ad.: 0.131–0.185<br>Imm.: 0.142–0.229 | TV                          | Dieter et al. (2010a)         |
| Georgia, resident<br>(rural versus urban)        | 2001–2006              | P                | Ad.              | 0.021–0.1147                          | TV                          | Balkcom (2010)                |
| New York, resident<br>(transported)              | 2003–2004              | P                | Ad./Imm.         | Ad.: 0.033–0.066<br>Imm.: 0.010–0.050 | NT                          | Holevinski et al. (2006)      |
| Mississippi Flyway, resident                     | 1982–1994              | P                | Ad./Imm.         | Ad.: 0.031–0.069<br>Imm.: 0.034–0.129 | TV                          | Sheaffer et al. (2005)        |
| Eastern prairie population                       | 1985–1993              | P                | Ad./Imm.         | Ad.: 0.024–0.067<br>Imm.: 0.038–0.071 | TV                          | Sheaffer et al. (2004)        |
| Iowa, resident<br>(Michigan translocated)        | 1996–2001              | P                | Ad./Imm.         | Ad.: 0.086–0.173<br>Imm.: 0.087–0.144 | TV                          | Fritzell and Soulliere (2004) |
| Nebraska, resident                               | 1990–1995<br>1996–2000 | P                | Ad./Imm.         | Ad.: 0.186–0.196<br>Imm.: 0.259–0.389 | ↑                           | Powell et al. (2004)          |
| Illinois, resident                               | 1974–1989              | P                | Ad./Imm.         | Ad.: 0.053<br>Imm.: 0.038             | TV                          | Lawrence et al. (1998)        |
| Atlantic population                              | 1986–1989              | P                | Ad./Imm.         | Ad.: 0.033<br>Imm.: 0.061             | NT                          | Sheaffer and Malecki (1995)   |
| New Jersey, resident                             | 1984–1989              | P                | Ad./Imm.         | Ad.: 0.056–0.030<br>Imm.: 0.027–0.015 | TV                          | Castelli and Trost (1996)     |
| Wisconsin, migrant                               | 1974–1980              | P                | Ad./Imm.         | Ad.: 0.016–0.013<br>Imm.: 0.070–0.052 | TV                          | Samuel et al. (1990)          |
| Michigan, resident                               | 1969–1974              | P                | Ad./Imm.         | Ad.: 0.036–0.092<br>Imm.: 0.044–0.110 | ↓                           | Tacha et al. (1980)           |

Table 3 continued on next page.

several cases, and was considered high ( $\hat{c} < 3.6$ ) for only 1 model (Table 2). In most instances, only single models were considered in making inferences regarding recovery rates. The best model ( $\Delta Q A I C_c = 0.00$ ) varied with each of the 3 model classes considered and were represented equally.

Seven separate recovery estimate comparisons out of 12 possible comparisons were conducted to determine differences in

recovery rates by period (1, 2, or 3), status (normal wild versus restored), and region (WR versus ER) cohorts. There was a significant ( $\chi^2 = 5.13, df = 1, P = 0.02$ ) period (1967 to 1976 versus 1977 to 1986) difference in recovery rates for normal, wild geese banded WR. The recovery estimate (0.067) for restored flocks banded WR (1968 to 1979) was higher ( $\chi^2 = 31.04, df = 1, P \leq 0.001$ ) than the recovery estimate (0.034) for normal, wild geese banded WR (1967 to 1976).

**Table 3 continued.**

- <sup>a</sup> Years: reflects interval of time specific to each study. In some cases, recovery rate estimates were year-specific, and in other cases, recovery rate estimates reflect a single-point estimate for the entire interval; these varied depending on the study.
- <sup>b</sup> Sex: in some cases, researchers tested for sex-effects, and in other cases, sexes were assumed to have equal survival and recovery rates, which may be an appropriate assumption, given similar plumage characteristics and inability of hunters to discriminate sexes based on plumage.
- <sup>c</sup> Age: Ad. = adult; Imm. = banded as goslings; not capable of flight or as hatching-year geese. Effect = an age-effect detected. In some studies, there was a statistical test to determine age effects in the models used, and results indicated that an age effect was present. In some studies, only adults were included in the analyses. In our study, we tested for an age effect, but after determining age effects were not present we pooled the banded sample to increase sample size for a given region  $\times$  status  $\times$  year period cohort (see Gleason 1997, Gleason et al. 2003).
- <sup>d</sup> Estimate ( $f$ ) = recovery rate estimate(s). In some cases, recovery rates were generated for individual years  $\times$  ages, and in other cases, a single point estimate was generated for a given age class over an interval. When available, for a given study that provided a range of recovery estimates over a period of years, we selected the low- and high-point estimates within the range of recovery rates provided.
- <sup>e</sup> Temporal trend: represents our interpretation of the recovery estimates ( $f$ ) for a given study if estimates were provided for a span of years or across time periods (see column 4);  $\uparrow$  increasing trend;  $\downarrow$  declining trend; TV = time variant or estimates varied with year; NT = no trend detected.

**NOTE:** In some studies, where comparisons were made between leg-banded only and neck-collared geese, we considered only recovery rate estimates derived for leg-banded geese. In some studies, comparisons were made between rural versus urban geese or trapped and transported versus normal, wild geese; we used only recovery rate estimates identified as controls or normal, wild geese banded and released in the same 10' block. Sample sizes, analytical methods, software (Program MARK, Program MULT, Program Brownie), models (M1 through M3) and model selection strategies (log-likelihood, AIC, QAIC) all varied, depending on the study. We recommend reviewing individual studies identified herein for additional information.

Even though the recovery estimate for normal, wild geese banded WR was numerically higher than for normal, wild geese banded ER (0.026), the difference was not significant ( $\chi^2 = 2.70$ ,  $df = 1$ ,  $P = 0.10$ ). There was a significant period difference for both normal, wild geese (1967 to 1978 versus 1987 to 1995;  $\chi^2 = 100.94$ ,  $df = 1$ ,  $P \leq 0.001$ ) and restored flocks (1977 to 1986 versus 1987 to 1995;  $\chi^2 = 18.36$ ,  $df = 1$ ,  $P \leq 0.001$ ) banded ER. Contrary to the results obtained WR, a status comparison of normal, wild versus restored

flocks indicated that normal, wild geese had significantly (1987 to 1995;  $\chi^2 = 16.85$ ,  $df = 1$ ,  $P \leq 0.001$ ) higher recovery rates. Recovery rates documented in this study, regardless of region or cohort affiliation are toward the low end of the recovery rate estimate range for large-bodied geese (Table 3).

## Recovery distribution

Number and proportion of direct and indirect recoveries occurring within individual states and provinces varied by both banding region and status (Figures 3 and 4). In general, geese banded WR had the fewest number of in-state recoveries regardless of status. The lowest number of in-state recoveries was for restored flocks of geese banded WR; only 18% of direct (Figure 3c) and 19% of indirect (Figure 3d) recoveries occurred in South Dakota. Nebraska contributed substantially to both direct (66%) and indirect (21%) recoveries, while Saskatchewan accounted for approximately 30% of indirect recoveries. South Dakota hunters accounted for a higher proportion of normal, wild geese banded WR with 43% of direct (Figure 3a) and 50% of indirect (Figure 3b) recoveries occurring in-state. Recovery distribution for geese banded ER varied by status, but South Dakota hunters harvested a greater proportion of geese banded in this region (Figure 4). Sixty-seven percent of direct (Figure 4a) and 61% of indirect (Figure 4b) recoveries occurred in-state for normal, wild geese banded ER. Kansas ranked second in number of direct (12%) and indirect (13%) recoveries. South Dakota hunters accounted for 51% of direct and 47% of indirect (Figures 4c and 4d) recoveries for restored flocks banded ER. Nebraska, Kansas, Missouri, and Minnesota were important harvest states for restored flocks of geese banded ER. Overall, 57% of all geese banded in South Dakota were recovered in-state, with Kansas and Nebraska ranking second and third, with 12% and 8% of all recoveries, respectively. Recovery distributions for normal, wild geese banded WR did not differ for any of the period comparisons ( $P \geq 0.14$ ). In

**Table 4.** Harvest chronology for both direct and indirect band recoveries (sexes and ages pooled) by status (normal, wild versus restored flocks) for geese (*Branta canadensis maxima*) banded during the pre-season period in eastern (ER) and western (WR) South Dakota, 1967 to 1995.

| Cohort                | Recovery month |               |               |               |                   | Total <sup>a</sup> |
|-----------------------|----------------|---------------|---------------|---------------|-------------------|--------------------|
|                       | September      | October       | November      | December      | January– February |                    |
| WR S3                 |                |               |               |               |                   |                    |
| Direct <sup>a</sup>   | 0 (0%)         | 12 (16.9%)    | 22 (31.0%)    | 37 (52.1%)    | 0 (0%)            | 71                 |
| Indirect <sup>b</sup> | 13 (4.7%)      | 76 (27.3%)    | 76 (27.3%)    | 95 (34.2)     | 18 (6.5%)         | 278                |
| WR S4 and S6          |                |               |               |               |                   |                    |
| Direct <sup>c</sup>   | 0 (0%)         | 4 (5.1%)      | 43 (54.4%)    | 32 (40.5%)    | 0 (0%)            | 79                 |
| Indirect <sup>d</sup> | 6 (9.0%)       | 19 (28.4%)    | 15 (22.4%)    | 20 (29.8%)    | 7 (10.4%)         | 67                 |
| ER S3                 |                |               |               |               |                   |                    |
| Direct <sup>e</sup>   | 4 (0.5%)       | 450 (51.7%)   | 254 (29.2%)   | 162 (18.6%)   | 0 (0%)            | 870                |
| Indirect <sup>f</sup> | 43 (1.7%)      | 1,190 (47.5%) | 605 (24.1%)   | 380 (15.2%)   | 288 (11.5%)       | 2,506              |
| ER S2,4,6             |                |               |               |               |                   |                    |
| Direct <sup>g</sup>   | 8 (2.1%)       | 115 (29.6%)   | 117 (30.2%)   | 148 (38.1%)   | 0 (0%)            | 388                |
| Indirect <sup>h</sup> | 30 (3.3%)      | 369 (41.0%)   | 217 (24.1%)   | 174 (19.4%)   | 110 (12.2%)       | 900                |
| ∑ WR                  | 19 (3.8%)      | 111 (22.4%)   | 156 (31.5%)   | 184 (37.2%)   | 25 (5.1%)         | 495                |
| ∑ ER                  | 85 (1.8%)      | 2,124 (45.6%) | 1,193 (25.6%) | 864 (18.5%)   | 398 (8.5%)        | 4,664              |
| ∑ (%)                 | 104 (2.0%)     | 2,235         | 1,349 (26.2%) | 1,048 (20.3%) | 423 (8.2%)        | 5,159              |

\* Row and columns totals in this table are not equal to the total number of recovery records for each of the 8 different time period × region × status × recovery type comparisons primarily due to the exclusion of recovery month = 1993 (fall) and 1994 (hunting season; see below). Status codes are: Status 2 (transported to different 10' block); Status 3 (normal, wild); Status 4 (hand-reared); and Status 6 (experimental, color-marked).

<sup>a</sup> WR S3 (direct recoveries for normal, wild Canada geese banded in western South Dakota, 1967–1995): 77 recovery records were used; September ( $n = 0$ ), October ( $n = 12$ ), November ( $n = 22$ ), December ( $n = 37$ ), January ( $n = 0$ ), February ( $n = 0$ ), 93 ( $n = 4$ ), 94 ( $n = 2$ ).

<sup>b</sup> WR S3 (indirect recoveries for normal, wild Canada geese banded in western South Dakota, 1967–1995): 293 recovery records were used; September ( $n = 13$ ), October ( $n = 76$ ), November ( $n = 76$ ), December ( $n = 95$ ), January ( $n = 14$ ), February ( $n = 4$ ), 93 ( $n = 4$ ), 94 ( $n = 11$ ).

<sup>c</sup> WRS4 and 6 (direct recoveries for restored flocks of Canada geese banded in western SD, 1967–1995): 87 recovery records were used; September ( $n = 0$ ), October ( $n = 4$ ), November ( $n = 43$ ), December ( $n = 32$ ), January ( $n = 0$ ), February ( $n = 0$ ), 93 ( $n = 1$ ), 94 ( $n = 7$ ).

<sup>d</sup> WR S4 and 6 (indirect recoveries for restored flocks of Canada geese banded in western South Dakota, 1967–1995): 75 recovery records were used; September ( $n = 6$ ), October ( $n = 19$ ), November ( $n = 15$ ), December ( $n = 20$ ), January ( $n = 7$ ), February ( $n = 0$ ), 93 ( $n = 0$ ), 94 ( $n = 8$ ).

<sup>e</sup> ER S3 (direct recoveries for normal, wild Canada geese banded in eastern SD, 1967–1995): 910 recovery records were used; September ( $n = 4$ ), October ( $n = 450$ ), November ( $n = 254$ ), December ( $n = 162$ ), January ( $n = 0$ ), February ( $n = 0$ ), 93 ( $n = 8$ ), 94 ( $n = 32$ ).

<sup>f</sup> ER S3 (indirect recoveries for normal, wild Canada geese banded in eastern SD, 1967–1995): 2,605 recovery records were used; September ( $n = 43$ ), October ( $n = 1,190$ ), November ( $n = 605$ ), December ( $n = 380$ ), January ( $n = 276$ ), February ( $n = 12$ ), 93 ( $n = 26$ ), 94 ( $n = 75$ ).

<sup>g</sup> ER S2,4,6 (direct recoveries for normal, wild Canada geese banded in eastern SD, 1967–1995): 410 recovery records were used; September ( $n = 8$ ), October ( $n = 115$ ), November ( $n = 117$ ), December ( $n = 148$ ), January ( $n = 0$ ), February ( $n = 0$ ), 93 ( $n = 8$ ), 94 ( $n = 14$ ).

<sup>h</sup> ER S2,4,6 (indirect recoveries for normal, wild Canada geese banded in eastern SD, 1967–1995): 968 recovery records were used; September ( $n = 30$ ), October ( $n = 369$ ), November ( $n = 217$ ), December ( $n = 174$ ), January ( $n = 102$ ), February ( $n = 8$ ), 93 ( $n = 14$ ), 94 ( $n = 54$ ).

contrast, direct recovery distributions differed for restored flocks banded WR during 1967 to 1976 versus 1987 to 1995 ( $U = 10.171$ ,  $P = 0.006$ ) and 1977 to 1986 versus 1987 to 1995 ( $U = 23.079$ ,

$P \leq 0.001$ ) periods. Similarly, indirect recoveries also differed for restored flocks banded WR during these same periods ( $U = 9.277$ ,  $P = 0.01$  and  $U = 10.171$ ,  $P \leq 0.001$ , respectively). In

contrast to the lack of period effects in recovery distributions for normal, wild geese banded WR, differences existed in 3 of 6 comparisons ER. For direct recoveries, distributions differed for 1967 to 1976 versus 1987 to 1995 ( $U = 18.781$ ,  $P \leq 0.001$ ) and indirect recoveries distributions differed for 1967 to 1976 versus 1987 to 1995 ( $U = 19.509$ ,  $P \leq 0.001$ ) and 1977 to 1986 versus 1987 to 1995 ( $U = 8.861$ ,  $P = 0.01$ ). No difference ( $U = 0.686$ ,  $P = 0.7$ ) was found when we conducted the only period comparison (1977 to 1986 versus 1987 to 1995) that was possible for direct recoveries of restored flocks ER. In comparison, 2 of 3 period comparisons for indirect recoveries indicated differences (1967 to 1976 versus 1977 to 1986 [ $U = 5.779$ ,  $P = 0.06$ ]; 1977 to 1986 versus 1987 to 1995 [ $U = 6.037$ ,  $P = 0.05$ ]). Recovery distributions also differed ( $U = 51.362$ ,  $P \leq 0.001$ ) when we compared direct recoveries (1967 to 1995) for normal, wild geese banded ER versus normal, wild geese banded WR (Figures 3a and 4a). Similarly, indirect recovery distributions also differed ( $U = 118.163$ ,  $P \leq 0.001$ ) for normal, wild geese banded in ER and WR, respectively (Figures 3b and 4b). For restored flocks, banded samples were adequate only for comparing recovery distributions of sub-adults (1967 to 1995), and both direct ( $U = 58.736$ ,  $P \leq 0.001$ ) and indirect ( $U = 79.942$ ,  $P \leq 0.001$ ) recovery distributions differed with respect to region (WR versus ER; Figures 3c, d, and 4c, d).

Number of individual recoveries by 10' recovery blocks was assessed to determine the maximum number associated with any single block (Figures 3, 4). Single 10' blocks accounted for 2 to 32% of all recoveries WR (Figures 3a–d), but only 2 to 7% of all recoveries ER (Figure 4a–d). For WR-banded geese, Bennett County, South Dakota was the single most important 10' block for: (1) restored flock-indirect recoveries; (2) normal, wild direct recoveries; and (3) normal, wild indirect recoveries (Figure 3a–d). Custer County, NE represented the most important 10' block for restored flock-direct recoveries (Figure 3c). For ER-banded geese, Day County was the single most important 10' block for: (1) normal, wild direct recoveries, and (2) normal, wild indirect recoveries (Figure 4a, b). The single most significant contributing 10' block for restored flock direct recoveries was Yankton County, and for indirect recoveries was Kingsbury County (Figure 4c, d).

## Harvest chronology

Frequency of monthly recoveries during the hunting season indicated temporal variation in harvest by status and region cohorts (Table 4). For WR-banded normal, geese, 52% of direct ( $n = 37$ ) and 34% of indirect ( $n = 95$ ) recoveries occurred during December, the highest harvest month for this status group. For restored flocks banded WR, 54% ( $n = 43$ ) and 40% ( $n = 32$ ) of direct recoveries occurred in November and December, respectively. For this cohort, indirect recoveries were more uniformly distributed throughout the hunting season; October ( $n = 19$ ), November ( $n = 15$ ), and December ( $n = 20$ ; Table 4). Conversely, for ER-banded normal, wild geese, 51.7% ( $n = 450$ ) and 47.5% ( $n = 1,190$ ) of direct and indirect recoveries, respectively, occurred during October, the first month of the hunting season. Both direct and indirect recoveries for ER-banded normal, wild geese showed declines throughout the season (Table 4). Similar to the restored cohort banded WR, ER-banded restored flocks exhibited fairly uniform frequency (115 to 148 recoveries, 29.6 to 38.1%) of direct recoveries (Table 4). Indirect recoveries for this cohort peaked in October (41%,  $n = 369$ ) and steadily declined throughout the season (Table 4). September recoveries, irrespective of region, status, or recovery type represented a small frequency of recoveries during the hunting season (Table 4). Goodness-of-fit tests comparing frequency of recoveries by month indicated differences; WR versus ER (direct recoveries only;  $\chi^2 = 70.52$ ,  $df = 4$ ,  $P \leq 0.001$ ), WR versus ER (indirect recoveries;  $\chi^2 = 95.37$ ,  $df = 4$ ,  $P \leq 0.001$ ), and WR versus ER (status and recovery type combined;  $\chi^2 = 148.59$ ,  $df = 4$ ,  $P \leq 0.001$ ). Overall, harvest chronology for WR-banded geese indicated greater proportion of recoveries in December (37%) compared to October (45%) for ER-banded geese.

## Discussion

We employed a hierarchical approach to describe variability in recovery rates and concomitant changes in recovery distribution and harvest chronology for banded geese over a large temporal scale for 2 distinct banding regions in South Dakota. We do not account for potential issues associated with reporting rates, hunter numbers, regulations, weather, and habitat that may have varied within or among

years or within or among flyways and states and provinces within flyways. We further recognize that banding effort changed dramatically over the period studied (Gleason et al. 2003). Early goose restoration and banding efforts in South Dakota occurred nearly exclusively WR and only recently shifted to ER (Vaa et al. 2010). In general, the banded sample of geese in the WR region represented a shorter span of years and fewer banded geese than the ER banded sample.

### Variation in recovery rates

Recovery rates for South Dakota banded Canada geese tended to be on the lower end of the range of recovery rates reported in other studies, particularly those conducted under more liberal harvest management frameworks (Table 3). Recovery rates from South Dakota banded geese increased over the period studied. Recovery rates for WR-banded geese were higher than recovery rates for ER-banded geese for a given cohort (period\*status). In general, recovery rates for restored flocks were higher within and among banding regions. We hypothesized that banded geese with status codes other than Status 3 will behave similarly to normal, wild geese, and their harvest characteristics and survival should approximate that of normal, wild geese once these individuals have completed their first migration. Overall, recovery rate estimates from our study generally exceeded the minimum (>5%) proposed threshold value as defined by Scheaffer and Malecki (1995) for band-recovery studies. Recovery rates documented in our study were similar to or higher than those from goose band-recovery studies in other areas that roughly overlap temporally with our study. For example, Tacha et al. (1980) derived recovery rates (1966 to 1974) of 0.036 to 0.084 for pre-season banded geese in several counties in Michigan. Samuel et al. (1990) generated direct recovery estimates (1974 to 1980) of 0.016 to 0.044 and 0.052 to 0.108 for leg-banded only adult and subadult geese, respectively, at Horicon Marsh National Wildlife Refuge, Wisconsin. Hestbeck and Malecki (1989) generated an annual recovery estimate (1983 to 1986) of 0.037 for winter-banded geese from several Atlantic Flyway states. Further, Castelli and Trost (1996) generated direct recovery estimates (1984 to

1989) of 0.028 to 0.056 and 0.015 to 0.063 for pre-season, leg-banded-only adult and subadult geese, respectively, in New Jersey. Differences within and among studies of recovery rates for geese may be due to multiple factors, including spatial and temporal variation in season length, bag limits, hunter numbers, band retention, band inscriptions, reporting rates, and harvest rates (Hestbeck et al. 1990, Royle and Dubovski 2001, Zimmerman et al. 2009*a, b*), as well as geographic differences in behavior of Canada geese that may influence migration timing, molt migration, direction, and staging and wintering area fidelity.

We did not attempt to generate harvest rate estimates for 2 primary reasons. First, there were no goose-specific reporting rates available for the timeframe studied, and we did not consider it appropriate to use reporting rates generated for mallards (Nichols et al. 1991, 1995; Boomer et al. 2013) or for other species of geese (Martinson and McCann 1966). Second, the use of more recent estimates of reporting rates (Zimmerman 2009*b*) applied to our recovery rate estimates would likely result in biased harvest rate estimates due to our banded sample of geese being marked with either traditional bands (AVISE BIRD BAND WRITE WASHINGTON DC USA) or bands with only an address inscription (WRITE BIRD BAND LAUREL MD 20708 USA). More recently, geese banded in South Dakota (and elsewhere) are marked with bands that include an inscription with a phone number (1-800-327-BAND), thus, increasing the probability of reporting for this type of band (Zimmerman et al. 2009*b*, Boomer et al. 2013, Garretson et al. 2014). Zimmerman et al. (2009*b*) derived reporting and harvest probabilities (2003 to 2005) for the Great Plains population of geese; rates were 0.842 and 0.159, respectively, on the high end of the range reported for all goose species and populations considered. Since our study was completed, recovery rates for South Dakota geese seem to have increased dramatically (Dieter et al. 2010*a*). We predict that with far more liberalized goose hunting opportunities, including increased number of days and increased bag limits in South Dakota along with spatially expanded early September seasons, implementation of an August Management Take beginning in 2010, and an apparent increase in goose hunter

efficiency (South Dakota Game and Fish, unpublished data), recovery rates will continue to increase for resident geese in South Dakota (Dieter et al. 2010a).

### Variation in recovery distribution

Giant Canada geese banded in South Dakota were recovered in 24 U.S. states and 5 Canadian provinces. Direct and indirect recovery distributions varied by banding region and status, with a greater proportion of ER-banded individuals recovered in-state (>50%) compared to WR-banded geese (<50%). This high proportion of in-state recoveries in ER is typical of a harvested population that delays departure from the banding region (see Raveling 1978). Tacha et al. (1980), studied giant geese banded near Pontiac, Michigan; they determined that >77% of recoveries occurred within the study area, with an additional 8.7% recoveries elsewhere in the state. Naugle et al. (1997) concluded that wetland abundance and water permanency were factors influencing distribution of geese breeding in eastern South Dakota. We attribute the higher proportion of in-state recoveries for ER-banded geese to an abundance of open water and available forage, a large goose population (Solberg 1996), and high public interest in waterfowl hunting (Gleason and Jenks 1997). In contrast to ER, <50% of normal, wild banded geese were recovered in-state with a large number of WR-banded geese recovered in Nebraska and Kansas. Bultsma (1976) found that neck-collared geese began moving out of western South Dakota in late September, with most sightings of neck-collared geese in Nebraska and Kansas. Harvest pressure is likely greater on WR-banded geese that migrate early out-of-state in search of open water and forage. Conflicting hunting interests (i.e., waterfowl versus big game) in western South Dakota, a comparatively small goose population (Vaa et al. 2010, U.S. Fish and Wildlife Service 2013), and limited access to public hunting areas with wetlands (i.e., Game Production Areas and Waterfowl Production Areas) apparently contribute to reduced interest in goose hunting in this region (Gleason and Jenks 1997). Fewer geese banded in South Dakota are now being harvested in more southerly Central Flyway states, as geese now seem to be overwintering in-state with

significant numbers also wintering in Kansas, Nebraska, and Missouri (Dieter et al. 2010a). A similar northward shift in wintering areas has been documented for lesser snow geese (*Chen caerulescens caerulescens*), which traditionally wintered along the coastal marshes of Texas and Louisiana, but can now be found as far north as Iowa, Missouri, Nebraska, Kansas, and Arkansas (Alisauskas et al. 1988), with recent later fall departures from the Canadian prairies (Alisauskas et al. 2011).

Comparisons of recovery distributions for geese banded WR and ER are indicative of differential migration for these 2 spatially discrete populations. In addition, there seem to be differences in migration tendencies within a region, depending on status. ER-banded restored geese displayed an east-southeast migration tendency, with large numbers of direct and indirect recoveries occurring in Minnesota (Lac Qui Parll area) and Missouri (northwestern Squaw Creek). Overall, hunters in the Mississippi Flyway accounted for approximately one-fifth of all recoveries for restored flocks. The first leg of migration is in an easterly direction into western Minnesota continuing south through Iowa en route to their migration destination on refuges in Missouri. For normal, wild geese ER, the migration follows a more southerly course into northeastern Nebraska, eastern and central Kansas, and northwestern Missouri. A generally similar pattern of recovery distribution (2000 to 2004) was reported by Dieter et al. (2010a) for pre-season banded geese in 7 eastern South Dakota counties. In contrast, WR-banded geese regardless of status follow a south-southwesterly course, wintering in south-central South Dakota, south-central Nebraska, and north-central Kansas. Some mixing of WR and ER banded geese may occur on more southerly wintering areas in Nebraska, Kansas, and Missouri.

Our study provides limited evidence for a northerly movement of banded geese into Canada during the late-summer. Our most robust banding data set is for normal, wild geese banded in eastern South Dakota, and analysis of recoveries from these data indicates <1% of direct and ~3% of indirect recoveries occurred north of South Dakota. The most parsimonious explanation for the difference in our results and

the much higher proportion of banded geese exhibiting molt-migration as documented by Dieter et al. (2010a, 2010b) is that early-September goose hunting seasons were not implemented until after our study. Therefore, there is a much lower probability of banded geese being harvested and reported during September, except in Canadian provinces, where waterfowl hunting seasons typically open in early September, though Canadian resident hunter numbers are lower than in the U.S. (Kruse 2005). South Dakota banded geese could have completed a molt-migration cycle without having been detected just from band-recovery data (Dieter and Anderson 2009).

### Harvest chronology

Monthly recovery patterns for geese banded WR versus ER were quite different with WR-banded geese recovered in greater proportion late in the hunting season (Table 4). In comparison, most ER band recoveries occurred in the first month (i.e., October) of the regular hunting season. In most years, eastern South Dakota glacial lakes are ice covered by the second or third week of November. However, flocks of geese often are observed loafing, preening, and resting in open-water pockets on larger semi-permanent wetlands or glacial lakes, with morning and evening feeding flights to cornfields occurring well into December. In western South Dakota, geese are more apt to be displaced by lack of available wetlands and forage crops rather than temperature extremes. Timing of migration, differing migration routes, and differences in hunter numbers or hunting pressure in WR compared to ER likely are causal mechanisms for the variation in harvest chronology. Monthly recovery patterns documented for ER-banded geese were similar to that documented for geese banded in Michigan (Tacha et al. 1980) in that nearly 75% of all recoveries in their study occurred by the end of October. In a study of Great Basin geese (*B. c. moffitti*) banded in Utah, Tautin (1976) found that 46% of the goose harvest in northern Utah occurred in the first 2 weeks of the hunting season. More recently, Dieter et al. (2010a) documented that 49% and 44% of adult and subadult recoveries, respectively, occurred in the month of September. During the period of our study, banded geese were only rarely

reported as shot in the month of September (only in) because there was no early September hunting seasons (Gabig 2000, Vrtiska et al. 2004). In South Dakota, goose harvest estimates increased over the 28-year period of our study, and tail-fan data indicated that the proportion of geese harvested in the state also has increased (Gleason 1997; see also Gabig 2000, Vrtiska et al. 2004, Kruse 2012).

### Management implications

Our results indicate that resident geese in South Dakota that actually depart from the state during the fall southbound migration may behave as  $\geq 2$  distinct sub-flocks. In addition, it appears that there have been recent changes to eastern South Dakota resident goose behavior, with a large segment of the population now exhibiting a northward molt-migration (Dieter and Anderson 2009, Dieter et al. 2010b), which is different from what we documented. Further, geese banded in the eastern and western regions of the state differ with respect to migration chronology, migration direction, and wintering area affiliation. Thus, geese from these 2 different geographic regions almost certainly are faced with differing harvest pressures. Unfortunately, current banding efforts in the western banding region are insufficient to detect changes to important population parameters, even as the resident goose population continues to increase principally east of the Missouri River (Gleason et al. 2003, U. S. Fish and Wildlife Service 2013). We recommend that state and federal agencies charged with pre-season goose banding operations consider expanding operations to include banding sites outside traditional areas to fill knowledge gaps associated with the lack of effort in formerly untargeted geographical regions. Specifically, we recommend that pre-season goose banding efforts be resumed in the WR-banding region of South Dakota to assess temporal and spatial changes in recovery rates and distribution of recoveries. Given funding constraints, we believe that it is important for agencies to continue banding operations for resident geese, specifically targeting smaller brood flocks, rather than large aggregations of molting adults, to ensure that banded geese represent their target population (Gleason et al. 2003).

We documented a fairly limited sample of

direct (<1%) and indirect (~3%) recoveries occurring north of the origin of banding, which is indicative of a molt-migration for geese banded in eastern South Dakota during 1967 to 1995. These results are far more conservative compared to more recent estimates of molt migration by resident geese documented by Dieter et al. (2010b). Using telemetry, Dieter et al. (2010b) estimated that almost half (45%) of their marked resident South Dakota goose population exhibited major movements (>100 km) from their natal areas; this was considered a minimum value. Based on VHF and satellite-transmitted resident geese, Dieter and Anderson (2009) estimated that 50 to 60% of eastern South Dakota geese may molt-migrate. This disparity is not surprising, given differences in information gained from band-recovery data versus geese marked with satellite or VHF transmitters. In addition, it appears that there has been a change in behavior of resident geese in eastern South Dakota; geese are now departing from the state on long-distance movements, likely due to the much earlier hunting pressure (Dieter and Anderson 2009, Dieter et al. 2010b). We recognize that in South Dakota (Dieter and Anderson 2009, Dieter et al. 2010b) and likely elsewhere (Lawrence et al. 1998, Nichols et al. 2004, Sheaffer et al. 2007, Luukkonen et al. 2008) where molt-migration behavior is prevalent by resident geese, the nonbreeding segment (largely sub-adults and failed breeders) may be missed by banding operations because they depart from the state or province on northward molt migrations prior to banding. Missing this segment of the population has a tendency to bias recovery rate and survival estimates particularly for the subadult cohort (Heller 2010). However, we believe that during our study, this was not a major concern, given the limited sample of band-recoveries occurring north of South Dakota (see Gleason 1997). We recognize that in some years in the eastern banding region a large fraction of the banded sample may have been comprised of nonresident molt migrant geese. It appears that in some areas within the range of giant geese, the early September hunting season may be disproportionately impacting the molt migrant segment of the resident populations, as well as nonresident molt migrants much more than resident breeding geese that are

successful, even though the latter cohort is the target for population reduction (Coluccy et al. 2004, Hauser et al. 2007, Iverson et al. 2014).

Results from this study indicated that recovery rates for the 2 status groups were not similar and that handling and marking methods, transportation, or separation of goslings from adults prior to transport and release may be influencing recovery rates (and harvest) of these geese. Most studies of goose band-recovery data consider only normal, wild (Status 3) individuals or geese with other color-markers, i.e., neck-collars or colored leg-bands. In cases where data exist, robust tests for differences in status effects on recovery rates and survival may provide valuable information regarding potential effects of geese that are banded and held, and trapped, transported, and released in different 10' blocks. Based on our results, we hypothesize that for subadult, restored flocks of geese, recovery rates will approach that of normal, wild geese once marked individuals geese have completed their first migration or reach sexual maturity (i.e., >2 years of age). Prior to that, however, recovery rates are apparently higher and annual survival is lower for these geese (see Fritzell and Soulliere 2004). In New York, Holvevinski et al. (2006) documented much higher harvest rates during the September hunting season for trapped and transported adult (0.238) and subadult (0.229) geese compared to controls (0.066 adult, 0.0500). The authors suggested that trap-and-transport of nuisance geese may represent a viable management alternative in alleviating human–goose conflicts. In Georgia (2000 to 2009), Balkcom (2011) documented nearly identical recovery rates, 0.084 and 0.082, respectively, for adult normal, wild geese and those that were trapped, transported, and released. In an earlier study, Balkcom (2010) documented vastly different recovery rates for adult resident geese banded in Georgia (2000 to 2006) in rural (0.147) versus urban (0.021) settings. Therefore, we recommend that future studies consider a comparison of recovery rates and recovery distribution for trapped-and-transported resident giant geese versus normal, wild geese banded in the same 10' block or banding region. In addition, comparisons of recovery rates and recovery distribution for urban-banded Canada geese to those of geese



banded in rural settings, particularly in the northern portion of the breeding range of giant geese would further elucidate the efficacy of trap-and-transport as a possible management option for burgeoning local goose populations.

### Acknowledgments

We thank P. Geissler and B. H. Powell of the U.S. Geological Survey. Canada Geese were banded under Permit #06897 issued to the South Dakota Department of Game, Fish and Parks. We recognize state and federal personnel and the numerous volunteers for their efforts during annual Canada goose banding operations and numerous private landowners who participated in the early Canada goose restoration efforts. F. Quamen, B. Schulz, and T. Sanders assisted with preparation of this manuscript. We thank J. Schmutz and 2 anonymous reviewers for commenting on a previous version of this manuscript. This manuscript benefitted from reviews by M. Conover and 2 anonymous reviewers. Funding for this project was provided by the Federal Aid in Wildlife Restoration Program, Project W-75-R, No. 7569 through the South Dakota Department of Game, Fish and Parks. Support was provided by the U.S. Fish and Wildlife Service, U.S. Geological Survey, South Dakota State University, and the Wildlife Management Institute. Any mention of trade names is purely coincidental and does not represent endorsement by the funding agencies or the government. The findings and conclusions in this paper are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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Dakota State University (SDSU). His master's thesis research was on South Dakota giant Canada geese, working closely with the SDGF. He was the second author on the first South Dakota Resident Canada Goose Management Plan, completed in May 2010. He remains passionate about ecology and management of waterfowl and other migratory birds, including purple martins. Recently, his collaboration with several other biologists and researchers nationally resulted in papers appearing in the *Proceedings of the Royal Society of London* (2012) and the *Auk* (2013), which were based on efforts to describe dispersal and long-range migratory behavior of purple martins.

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