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EFFECTS OF RESIGHTING ERRORS ON CAPTURE-RESIGHT ESTIMATES FOR NECK-BANDED CANADA GEESE

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Abstract.—Biologists who study neck-banded Canada Geese (*Branta canadensis*) have used capture and resighting histories to estimate annual resighting rates, survival rates and the number of marked birds in the population. Resighting errors were associated with 9.4% (n = 155) of the birds from a sample of Canada Geese neckbanded in the Mississippi flyway, 1974–1987, and constituted 3.0% (n = 208) of the resightings. Resighting errors significantly reduced estimated resighting rates and significantly increased estimated numbers of marked geese in the sample. Estimates of survival rates were not significantly affected by resighting errors. Recommendations are offered for using neck-band characters that may reduce resighting errors.

EFECTO DE ERRORES DE REAVISTAMIENTOS EN ESTIMADOS DE CAPTURA-REAVISTAMIENTOS DE INDIVIDUOS DE *BRANTA CANADENSIS* ANILLADOS EN EL PESCUEZO

Sinopsis.—Biólogos que estudian gansos del Cánada (*Branta canadensis*) anillados en el pescuezo, han utilizado la captura e historia de reavistamientos para estimar la tasa anual de reavistamientos, tasa de sobrevivencia y el número de aves marcadas en la población. De una muestra de gansos del Cánada anillados en el pescuezo en la Vía de Vuelo del Mississippi, entre 1974–1987, hubo un 3.0% error en los reavistamiento (n = 208) los cuales estuvieron asociados al 9.4% (n = 155) de los gansos en la muestra. Los estimados de la tasa de supervivencia no fueron afectados significativamente por los errores de reavistamientos. Se ofrecen recomendaciones utilizando características de las anillas que pudieran reducir los errores de reavistamientos.

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Visual markers are frequently used to identify individual animals in wildlife studies. These markers are useful because identification can be made without recapture, and handling or disturbance of animals is reduced. Errors associated with reading and recording animal markers may occur, however, and adversely influence estimation of population parameters. Most research methods assume markers are applied, observed and recorded without error. This basic assumption is either implied or stated for a variety of mark-recapture strategies used to estimate survival and recapture rates or to estimate animal abundance (Brownie et al. 1985, Burnham et al. 1987, Jolly 1965, Otis et al. 1978, Seber 1982). Estimates obtained from these methods may be biased by the errors associated with reading and recording the markers. As most of these errors are difficult to identify, the frequency of errors and the bias imparted on population estimates is unknown.

Plastic neck bands have been used in studies of Canada Geese (*Branta canadensis*) to monitor movement (Craven and Rusch 1983, Koerner et al. 1974, Raveling 1978, Trost et al. 1980) and to estimate survival and resighting rates (Hestbeck and Malecki 1989a, Rusch et al. 1985). Since 1974, cooperators from state, federal and Canadian agencies have captured, banded and observed geese at breeding, staging and wintering areas within the Mississippi flyway. Inconsistencies became evident when neck-banded geese were resighted sometime after they were recaptured without neck bands (neck band lost) or were harvested. The objectives of this study were to evaluate the effects of these resighting errors on survival, resighting and population estimates obtained from open population capture-resight methods; identify factors associated with resighting errors; and make recommendations that would reduce resighting errors in future studies.

METHODS

Captured geese were banded with U.S. Fish and Wildlife Service (USFWS) aluminum leg bands and plastic neck bands described by Craven (1979). Codes were engraved 4× around each neck band to facilitate identification, and were legible at ≤500 m using a 60× telescope (Craven 1979). Neck bands used in this analysis were either blue with white characters, orange with white characters or orange with black characters.

We evaluated resighting errors for neck-banded geese in the Mississippi flyway that were reported harvested by hunters or were recaptured without neck bands. Harvest records obtained from the USFWS Bird Banding Laboratory, Laurel, Maryland, were used to identify harvest dates of geese that were reported killed. Harvested birds were primarily those banded at Canadian breeding grounds or Horicon National Wildlife Refuge, Wisconsin, 1974–1987. Records of geese recaptured during banding operations were used to determine the presence of neck bands at time of recapture. Resightings of neck-banded geese were reported to the Wisconsin Cooperative Wildlife Research Unit (WCWRU) by paid observers and refuge personnel at wildlife refuges in the Mississippi flyway (Samuel et al. 1986, Sullivan et al. 1989). Capture, harvest and resighting dates were assigned to annual intervals based on a biological year beginning 1 June. Geese were captured throughout the year, with peaks occurring in July, August, October, November and January. Nearly all resightings (98.0%) of neck-banded geese in our sample were obtained October–February, and >90% of the harvested geese were killed October–January.

Our study was limited to resighting errors made after geese were reported harvested or neck bands were reported lost. Other types of resighting errors also may have occurred. For example, a neck band may have been incorrectly resighted, but the resighting matched a valid neck-band code. We were unable to detect or determine the impact of these errors on mark-resight population estimates. Further, not all of the inconsistencies we detected in capture, recapture, harvest and resighting histories of neck-banded geese were the result of resighting errors. Inconsistencies in the data could have occurred when birds were incorrectly identified (leg bands or neck bands incorrectly reported) at time of recapture or harvest, or when dates of resighting, recapture or harvest were incorrectly reported. We did not attempt to attribute resighting errors to any specific task associated with collection, transcription or computer entry of resighting data. Although we were unable to identify the exact error or errors associated with each inconsistency, we eliminated those inconsistencies that most likely did not result from resighting errors. As it was unlikely that a bird would be resighted >3× after harvest or after recapture without a neck band, we suspected recapture or harvest records for these birds (leg bands or neck bands) were erroneous and all resightings were indeed correct. Thus we defined resighting errors to be those resightings that were made after recapture without a neck band or after harvest, for geese with ≤3 inconsistent resightings. Alternative definitions of resighting errors (geese with 1, ≤2 or ≤4 inconsistent resightings) also were analyzed to determine the robustness of the conclusions obtained from our definition of resighting errors. We believed that errors in observation or recapture dates were small and could be ignored. Reported dates of harvest likely were less accurate. To evaluate the effect that inaccurate harvest dates would have on our conclusions, we also analyzed resighting errors that occurred ≥14 and ≥30 d after the reported date of harvest.

We used program JOLLY (Pollock et al. 1990) to analyze capture and resighting histories of geese, and to determine the most appropriate model for the data. Model selection included tests for constant survival and resighting probabilities, and tests to evaluate differences in survival during the first year of banding. Annual estimates and standard errors of survival and resighting rates, and the number of marked geese in the sample (Seber 1982:219) were obtained from program JOLLY. Separate analyses were conducted on the complete data (all resightings) and the adjusted data for which resighting errors were deleted. We used one-tailed paired t-tests (Joyner 1985) to compare estimates (survival and resighting rates and numbers of marked geese) derived from complete data and estimates derived from adjusted data. Serial correlations between years i and $i + 1$ of the within-year differences were tested for significance (Zar 1984: 418). When significant serial correlations occurred, we applied corrections for non-randomness (Miller 1986:36) to the paired t-test.

We used stepwise logistic regression (Cox 1970, Dixon et al. 1985) to evaluate factors associated with the proportion of geese in our sample of resightings errors (≤3 inconsistent resightings). Covariates tested were neck-band color and 25 alpha-numeric characters used on neck bands (0–9, A, C, E, F, H, J, K, M, P, R, T, U, X, Y and Z). Alpha characters such as B, O, Q and W were not used to code neck bands because observers might confuse these characters with others. For each bird (n = 1644), alpha-numeric characters used to code the neck band were designated present (1) and remaining characters were designated absent (0). A typical neck band with four characters was represented with 1's for each character used and 0's for the ≥21 characters that were not used.

RESULTS

There were 7047 resightings of neck-banded geese that were recaptured without neck bands or were harvested. Recaptured geese (n = 316) comprised 19.2% of our sample and harvested geese (n = 1328) comprised 80.8% of our sample. Preliminary analysis showed that 6.3% (n = 444) of the resightings were made after recapture without a neck band or after harvest. These inconsistent resightings were associated with 11.1% (n = 182) of the geese in our sample (9.5% [n = 30] of the recaptured geese and 11.4% [n = 152] of the harvested geese). The frequency of inconsistent resightings associated with individual geese ranged from 1 to 36 (Fig. 1). Of these geese, 65.4% (n = 119) had 1 inconsistent resighting and 14.8% (n = 27) had >3 inconsistent resightings. Resighting errors (≤3 inconsistent resightings) comprised 3.0% (n = 208) of all resightings, and were associated with 9.4% (n = 155) of the geese in the sample (6.3% [n = 20] of the recaptured geese and 10.2% [n = 135] of the harvested geese).

We found that resighting errors were more likely to occur soon after birds were recaptured without neck bands or were harvested. More than half (54.2%) of all first resighting errors were reported within the same biological year (1 June–31 May) that geese were recaptured without neck bands or were harvested, and 77.4% of the resighting errors were reported within the interval that included the following year (Fig. 2).

A generalization of the Jolly-Seber model that permitted a difference in survival during the first year after banding (Brownie and Robson 1983) was determined to be most appropriate for the capture-resighting histories of the geese in our sample. Selection of this model was consistent with previous analyses that determined survival and resighting probabilities for all geese banded during the present study (Samuel et al. 1986, Sullivan et al. 1989). Parameter estimates (Table 1) were used to assess the bias associated with resighting errors. These estimates were not representative of all geese in the Mississippi flyway because our sample included only recaptured and harvested geese.

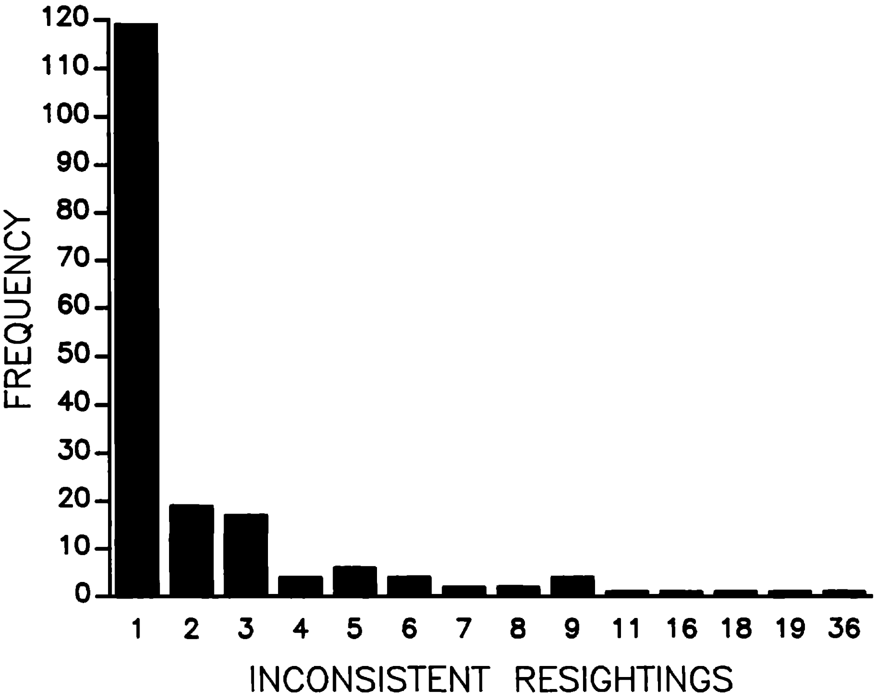

FIGURE 1. Distribution of inconsistent resightings ($n = 444$) associated with harvested or recaptured Canada Geese neckbanded in the Mississippi flyway, 1974–1987.

Annual resighting rates from the complete data were less than those estimated from the adjusted (resighting errors deleted) data ($\bar{D} = -0.105 \pm 0.024$ [SE], paired $t = -4.38$, df = 11, $P < 0.001$, Table 1), and estimated numbers of marked geese from the complete data were greater than those determined from the adjusted data ($\bar{D} = 33.2 \pm 8.54$, paired $t = 2.62$, df = 11, $P = 0.012$). Annual survival rates from the complete data were not significantly greater ($\bar{D} = 0.038 \pm 0.025$, paired $t = 1.51$, df = 10, $P = 0.080$) than those from the adjusted data. Serial correlation of within-year differences for years i and $i + 1$ were significant only for estimates of number of marked geese in the sample ($P < 0.05$). The correction for serial correlation was included in the t statistic reported for this parameter.

Additional analysis based on alternative definitions of resighting errors (geese with 1, ≤2, ≤4 inconsistent resightings, and inconsistent resightings that occurred ≥14 and ≥30 d after harvest) produced parameter estimates similar to those obtained from our initial definition of resighting errors. Thus, our general conclusions regarding the effects of resighting errors on parameter estimates were consistent for the alternative definitions of resighting errors that we examined. With the 30-d adjustment for errors in reported harvest dates, the proportion of harvested birds associated with incorrect resightings was 8.3% ($n = 110$) and was not significantly

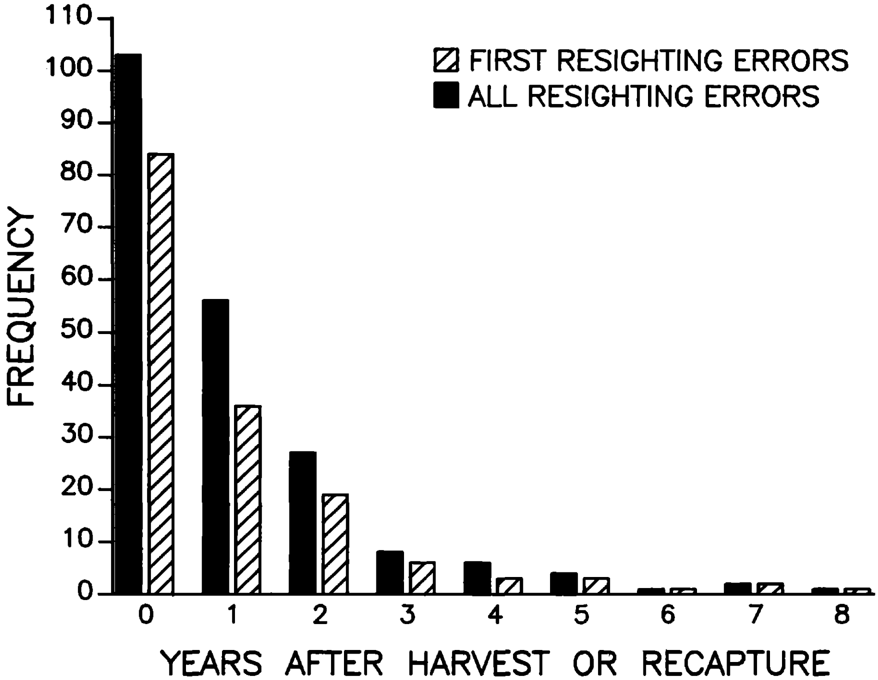

FIGURE 2. First resighting errors (n = 155) and all resighting errors (n = 208) distributed across yearly intervals, for recaptured or harvested geese neckbanded in the Mississippi flyway, 1974–1987. Resighting errors (n = 208) were defined as resightings made after a goose was harvested or recaptured without neck band for geese with ≤three inconsistent resightings.

different from the error rate (6.8%) for recaptured birds (χ^2 = 1.338, df = 1, P = 0.247). Although inaccuracies may have existed in reported harvest dates, these inaccuracies did not appear to bias our conclusions.

Stepwise logistic regression on the adjusted data identified neck-band characters U ($P < 0.001$), J ($P = 0.005$), T ($P = 0.027$), P ($P = 0.018$) and 6 ($P = 0.034$) as significant factors associated with resighting errors of individual geese. The neck-band characters U and 6 were positively correlated with correct resightings, whereas the remaining characters were correlated with resighting errors. Neck-band color ($P = 0.417$) did not enter the logistic regression model.

DISCUSSION

Resighting errors significantly affected estimates of resighting rate and the number of marked geese in our sample. Estimated mean resighting rate determined from complete data was 0.105 less than that determined from adjusted data. This difference resulted because the probability for resighting errors was relatively low, and deletion of these resightings increased the estimated resighting rate for the remaining records. The estimated mean number of marked geese for complete data was 33.2 birds

TABLE 1. Estimated annual survival and resighting probabilities and annual number of neck-banded Canada Geese, obtained from mark-resight[a] methods for neck-banded birds that were harvested or recaptured without neck bands in the Mississippi flyway, 1974–1987. Estimates were based on complete data and adjusted data in which resightings believed to be incorrect were deleted.

Year	Annual survival rate (SE)[b]		Annual resighting rate (SE)		Annual number marked in sample (SE)	
	Complete data	Adjusted data	Complete data	Adjusted data	Complete data	Adjusted data
1975	1.069 (0.043)	1.054 (0.036)	0.500 (0.250)	0.667 (0.272)	4.9 (1.20)	3.5 (0.84)
1976	0.834 (0.145)	0.829 (0.146)	0.818 (0.082)	0.857 (0.076)	34.4 (2.06)	32.8 (1.77)
1977	0.368 (0.079)	0.354 (0.082)	0.667 (0.096)	0.682 (0.099)	65.7 (3.65)	64.8 (3.84)
1978	0.473 (0.067)	0.258 (0.050)	0.761 (0.063)	0.778 (0.080)	117.8 (6.48)	106.7 (6.53)
1979	0.488 (0.056)	0.531 (0.058)	0.676 (0.056)	0.852 (0.048)	166.3 (8.87)	113.1 (4.96)
1980	0.644 (0.052)	0.642 (0.051)	0.673 (0.046)	0.779 (0.045)	172.3 (5.80)	141.5 (4.27)
1981	0.687 (0.054)	0.690 (0.052)	0.792 (0.036)	0.840 (0.034)	243.6 (8.21)	214.7 (7.19)
1982	0.588 (0.059)	0.482 (0.048)	0.629 (0.043)	0.710 (0.045)	277.5 (13.43)	238.3 (11.29)
1983	0.553 (0.092)	0.404 (0.061)	0.663 (0.053)	0.828 (0.050)	255.7 (16.54)	193.7 (11.91)
1984	0.316 (0.069)	0.288 (0.059)	0.460 (0.071)	0.700 (0.084)	222.6 (24.30)	130.3 (15.54)
1985	0.246 (0.066)	0.310 (0.083)	0.630 (0.093)	0.833 (0.088)	136.3 (18.44)	72.9 (9.50)
1986			0.833 (0.152)	0.833 (0.152)	48.8 (9.86)	34.8 (7.48)
Mean	0.570 (0.025)	0.531 (0.025)	0.675 (0.030)	0.780 (0.032)	145.5 (3.46)	112.3 (2.38)

[a] Model of Brownie and Robson (1983) permitting differences in survival during first time interval.
[b] Determined for ≥ 2 time intervals after initial capture and banding.

greater than that determined from adjusted data (Table 1). This difference represented a relative bias of 32.3 ± 7.7% (after Anderson and Burnham 1980:245). Similar resighting errors also may have affected previously reported resighting rates (Hestbeck and Malecki 1989a, Samuel et al. 1986, Sullivan et al. 1989) or population estimates of Canada Geese (Hestbeck and Malecki 1989b, Smith 1989).

The estimated mean survival rate determined from complete data was 0.038 greater than that determined from adjusted data. This difference was not significant ($P = 0.080$), however, and demonstrated that survival estimates were relatively robust to the types of resighting errors identified in this study. Similar findings were reported by Anderson and Burnham (1980), who used simulated data and capture-recovery models (Brownie et al. 1985) to evaluate biases in survival estimates induced by delayed reporting of band recoveries. They concluded that late reporting inflated survival estimates, but capture-recovery estimates of survival were found to be relatively robust.

The effects of resighting errors on parameter estimates would have been greater had resighting errors occurred long after a bird was recaptured or harvested. Instead, resighting errors generally occurred within the first year after birds were harvested or recaptured without a neck band. This pattern was influenced by the manufacture and application of neck bands, bird survival, hunter recovery and loss of neck bands. Many errors associated with the resighting or recording of neck-band codes likely occurred when adjacent characters were transposed or single characters were changed. In such cases, there were similarities between the actual neck-band codes on the geese and the neck-band codes erroneously perceived or recorded by the observers. As codes engraved on neck bands were not manufactured or distributed randomly, geese banded at a common place or time had neck-band codes that usually shared as many as 2–3 common characters. Thus, the probability of observers encountering neck bands with similar codes was greatest immediately after banding and decreased as geese with similar neck bands died or lost neck bands.

We caution against the use of characters J, P and T to code future neck bands, because these characters were positively associated with resighting errors. Although these characters did not necessarily constitute part of the actual neck-band codes of resighted geese, they were the codes erroneously recorded by observers. Thus, there may be other characters that contributed to resighting errors that we were unable to detect. Elimination of these three characters from future neck-band codes, however, may reduce the occurrence of resighting errors and the subsequent effects these errors have on capture-resight estimates.

We have no reason to believe neck-band color influenced resighting errors. Although neck-band colors likely contributed to the maximum distances codes could be perceived (Craven 1979), the reliability of reported resightings appeared to be similar for all neck-band colors.

Our methods only identified resighting errors made after geese were reported harvested or their neck bands were lost. Other errors likely existed, but could not be accurately detected. Therefore, the true incidence of resighting errors could not be determined from our data. Our evaluation revealed that errors also occurred in hunter recovery and banding records. Additional analyses, however, indicated that our conclusions regarding the influence of resighting errors on capture-resight estimates were robust to these sources of error. Our analysis provides a meaningful starting point for examining frequency, effect and nature of resighting errors, and provides useful information for the improvement of neck-band studies and the interpretation of results. Our conclusions regarding the effects of one type of resighting error on capture-resight estimates may apply to other wildlife studies, because other marking techniques share many of the problems associated with correctly identifying and recording neck-band codes. When possible, marker studies should attempt to identify inconsistencies in resighting, recapture or recovery data, and determine if correction of estimates is warranted.

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