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Original Article

A Comparison of Field Methods to Estimate Canada Goose Abundance

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ABSTRACT We conducted a 2-year study (2014–2015) in North Carolina, USA, to compare precision and efficiency between 2 methods used to estimate Canada goose (*Branta canadensis*) abundance. The first method (i.e., band-return estimation) used hunter band-returns and harvest estimates. The second (i.e., plot survey) used surveys of 1-km^2 plots randomly located across potential goose habitat in the state. To quantify efficiency, we recorded all expenses and time dedicated to goose banding and plot surveys. In June 2014, we banded 2,102 adult geese at 44 sites. During the 2014–2015 hunting season, we received 173 direct band recoveries from birds banded as adults. We used the Lincoln–Peterson formula to calculate an abundance estimate of 148,839 (coeff. of variation = 7.9) and determined the band-return method required US $72,858 and 2,317 person-hours to complete. We surveyed 300 1-km^2 plots across North Carolina in April 2015, and calculated an abundance estimate of 155,655 Canada geese (coeff. of variation = 308.9). We determined the plot-survey method required US $80,767 and 2,857 person-hours to complete. Although population estimates were similar, we recommend the band-return technique to estimate Canada goose abundance because it provided a more precise estimate with similar overall costs and, if continued for multiple years, will allow calculation of additional population metrics including survival, recovery rates, and harvest distributions.

KEY WORDS abundance, band return, *Branta canadensis*, Canada goose, cost, Lincoln–Peterson estimator, North Carolina, plot survey.

At the turn of the 20th century, population densities of Canada geese (*Branta canadensis*; hereafter, geese) across North America were severely depleted by overexploitation and wetland loss (Smith et al. 1999). Laws governing waterfowl harvest and habitat protection have allowed goose numbers to rebound. Increased protection and restocking efforts by state and federal agencies have led to the re-establishment and recovery of temperate-nesting geese in the Atlantic Flyway of the eastern United States. As of spring 2011, the adult Canada goose population in states north of Virginia, USA, was estimated at 1.1 million birds (Atlantic Flyway Council 2011).

In many instances, Canada geese are managed by flyway or stock-specific management plans, with the process of setting waterfowl hunting regulations based on a system of resource monitoring, data analyses, and rule-making (Blohm 1989). A precise and efficient method of estimating the size of goose populations is a critical component of many goose management plans, and the iterative cycle of monitoring, assessment, and decision-making is necessary in any adaptive harvest management program (Williams and Johnson 1995).

Estimates of population size over time provide managers a metric by which effectiveness of management programs can be evaluated. Two common methods of estimating goose abundance are the band-return and plot-survey methods. The band-return method has been used with Arctic-nesting geese, mallards (*Anas platyrhynchos*), and wood ducks (*Aix sponsa*), and often produces estimates 2–4 times greater than count-based methods (Alisauskas et al. 2009, 2013; Zimmerman et al. 2015). However, abundance estimates

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generated from band returns are acceptable to make inferences about long-term trends in the population (Alisauskas et al. 2009). Additionally, plot surveys are conducted during the breeding season and can be used to estimate the number of breeding pairs (Heusmann and Sauer 1997, 2000). The precision and efficiency of the band-return and plot-survey methods have not been compared directly. Hence, our objectives were to 1) assess the precision and evaluate biases of the band-return and plot-survey methods for estimating Canada goose abundance in North Carolina, USA, and 2) compare costs associated with field data collection for each method.

STUDY AREA

We applied band-return and plot-survey methods across North Carolina, which has a total land area of 139,389 km^2. Our goal was to band $\geq$2,000 adult geese at 44 known molt locations across North Carolina (Fig. 1). This banding goal was established based on the financial and logistical resources provided by the North Carolina Wildlife Resources Commission. We included urban (i.e., golf courses and public parks) and rural (i.e., farm ponds and pastures) banding sites to ensure a representative sample of different hunting pressures.

To focus plot surveys in areas most likely to have geese, we defined available goose habitat as 1-km^2 plots with any open water or <80% forest cover. We excluded any plots that were 100% open water and fell outside of a 1-km buffer of the shorelines of the Atlantic Ocean, Pamlico Sound, and Albemarle Sound. We used U.S. Geological Survey National Land Cover Database (2011) to determine percent cover of open water and forest cover (Homer et al. 2015). The number of 1-km^2 plots that met these criteria was 104,001, with the majority of the plots located in the Piedmont and southeastern Coastal Plain physiographic regions (Fig. 2). Eliminating nonhabitat before selecting survey plots eliminated regional effects on goose abundance, and we assumed that goose densities were similar in goose habitat regardless of physiographic region (McAlister et al. 2017). We assigned plots a unique number and used a random number generator to choose 300 plots to survey (Fig. 3). We chose to survey 300 plots because that was the maximum number of plots that could be adequately surveyed with given resources.

METHODS

Goose Capture and Banding

All goose capture and processing efforts were by the North Carolina Wildlife Resources Commission (U.S. Geological Survey, Bird Banding Laboratory permit no. 06557) and met the specifications set forth by the agency's animal handling protocols. We captured temperate-nesting geese from 12 to 27 June 2014, during the flightless period when geese were molting primary feathers. We used a modified version of Cooch's flightless-bird roundup technique to herd and manipulate birds to a desired location (Costanzo et al. 1995). We coaxed flocks of geese out of water using kayaks, grouped them on land, and slowly surrounded them using mobile 3.05-m aluminum panels. After capture, we separated adults and juveniles, divided large groups, and moved captured geese into shaded areas to reduce risk of overheating and other injury during the banding process. We recorded sex and age (cloacal examination and plumage evaluation, respectively) for each bird. Prior to release of each bird, we banded it with a standard size 8 U.S. Fish and Wildlife Service (USFWS) Bird Banding Laboratory aluminum leg band. We

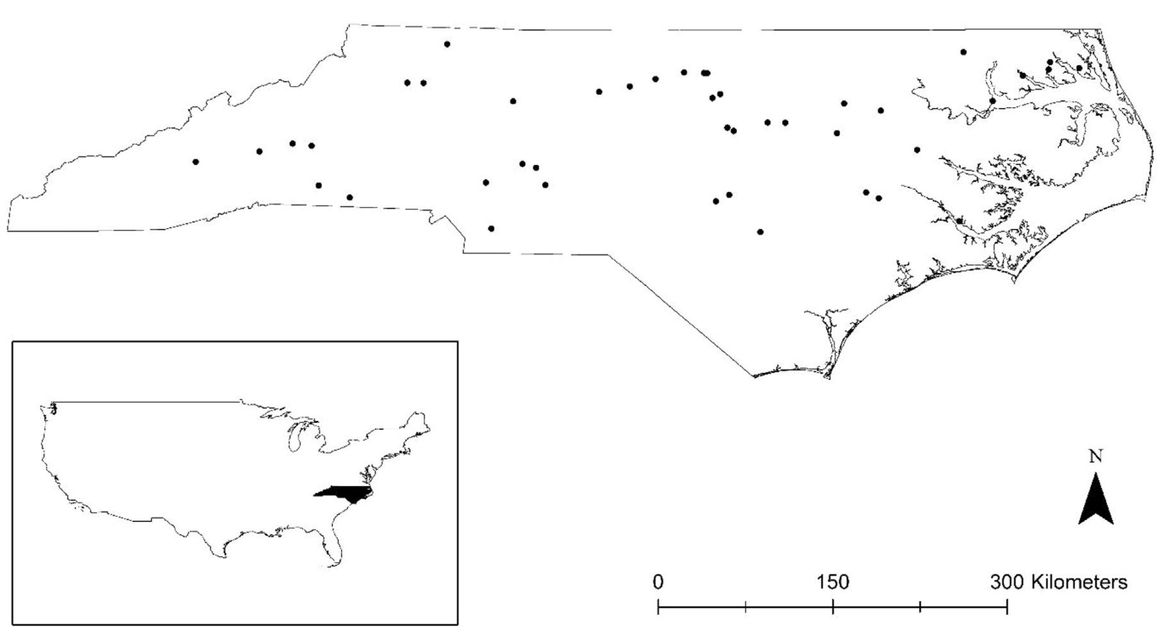

Figure 1. Locations of 44 sites where Canada geese were banded during the June flightless period, North Carolina, USA, during 2014.

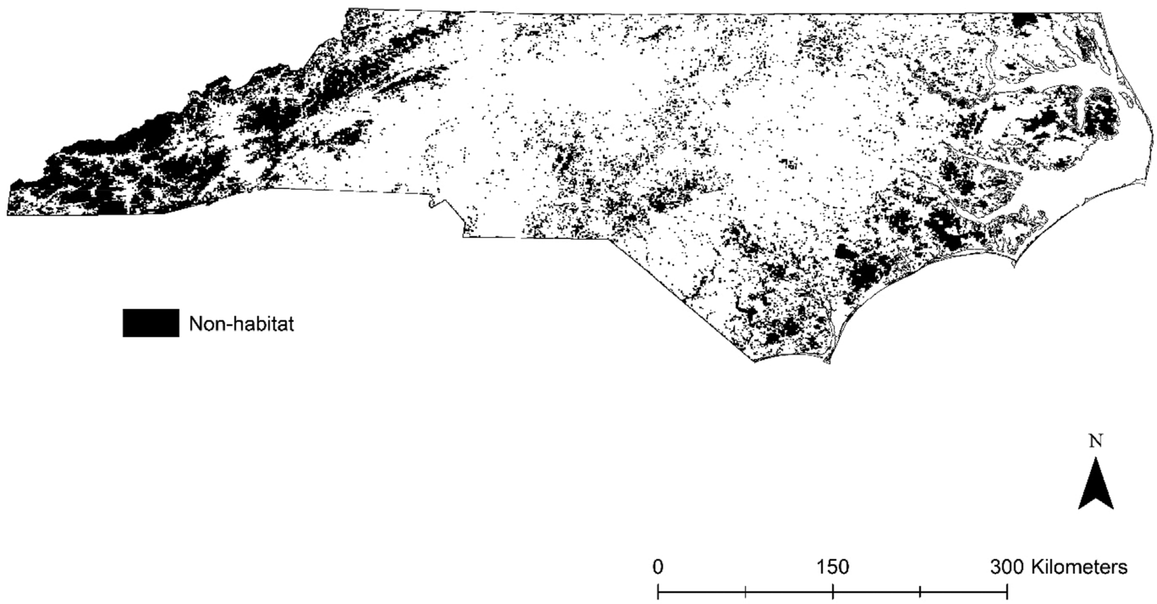

Figure 2. Non-habitat, black area, and potential habitat, white area, for Canada geese identified before the random plot selection, North Carolina, USA, during 2014.

analyzed direct recoveries of adult banded geese that were shot or found dead by hunters from September 2014 to March 2015.

Band-return Abundance Estimation

We used a less biased form of Lincoln's Estimator (Lincoln 1930) for population estimation proposed by Chapman (1951):

$$\widehat{N}* = \left(\frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1\right) \times \widehat{p}$$

This formula used the total number of birds banded for the first sample (n_1) and USFWS federal harvest estimate (n_2) for the second sample, and the number of direct band recoveries by hunters as the number occurring in both samples (m_2). We used the federal hunter parts-collection survey data to estimate the proportion of adult birds in the harvest, and adjusted the harvest estimate to include only adult birds so that final population estimates would be comparable for the band-return and plot-survey methods. Also, we applied a correction factor of 0.61 (95% CI = 0.59–0.64) to federal harvest estimate to correct for a consistent

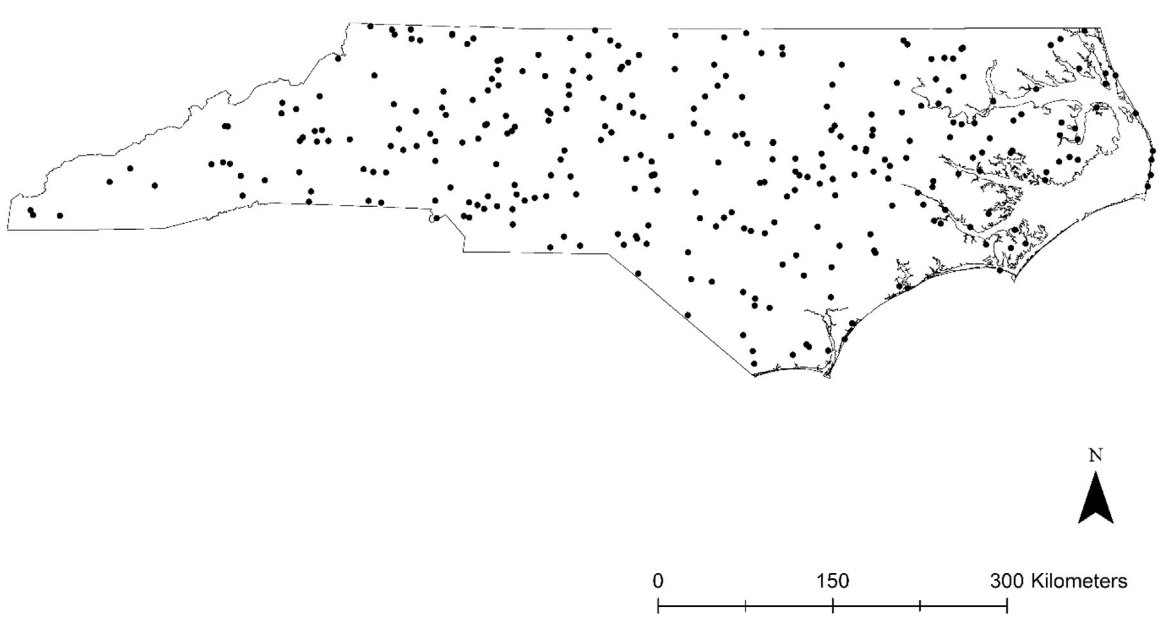

Figure 3. Location of 300 1-km^2 plots surveyed for Canada geese in North Carolina, USA, during April 2015.

overestimation of goose harvest by HIP-based surveys (Padding and Royle 2012). We used the most recent reporting rate estimate available for geese of $\widehat{p} = 0.73$ to account for direct band recoveries not reported by hunters (Zimmerman et al. 2009).

We used a harvest derivation analysis (Munro and Kimball 1982) to estimate the proportion of migrant birds and nonlocal residents in North Carolina's 2014 Canada goose harvest, following methods described by Klimstra and Padding (2012). To conduct this analysis, we obtained population-specific (state- and province-specific for resident geese) banding and recovery data from the U.S. Geological Survey's Bird Banding Laboratory, and 2014 breeding population estimates of Southern James Bay geese (S. Hagey, Ontario Ministry of Natural Resources and Forestry, personal communication), Atlantic geese (Harvey et al. 2014), and resident geese in Ontario, Canada (C. Davies, Ontario Ministry of Natural Resources and Forestry, personal communication) and Atlantic Flyway states (Roberts 2015). Although band recovery records from past years indicate that some harvest of migrant Canada geese likely occurs in North Carolina annually, no direct recoveries from migrant populations were reported during our study period. Therefore, we calculated the average number of direct recoveries of Southern James Bay and Atlantic geese in North Carolina from 2001 to 2015 and used those numbers in the harvest derivation analysis. To account for nonlocal temperate-nesting geese (e.g., birds banded in all other U.S. States in the Atlantic Flyway and southern ON, Canada), we obtained population estimates and banding totals from the Atlantic Flyway harvest and population survey data book (Roberts 2015), and Ontario's temperate-breeding goose estimates (C. Davies, personal communication). Band recovery records from past years indicate that harvest of temperate-nesting Canada geese from other U.S. states and Ontario likely occurs in North Carolina annually, but only direct recoveries from Maryland, USA, and Ontario were reported during our study period. Therefore, we calculated the average number of direct recoveries of all temperate-nesting geese in North Carolina from 2001 to 2015 and used those numbers in the harvest derivation analysis.

As a means of estimating the precision of the band-return estimate, we calculated the variance of the estimate $\left[Var\left(\widehat{N}\right)\right]$ using a formula for variance of a product described below (Goodman 1960):

$$Var\left(\widehat{N}\right) = Var\left(\widehat{N}* \times \widehat{p}\right) = Var\left(\widehat{N}*\right)\left[\widehat{p}\right]^2 + Var\left(\widehat{p}\right)\left[\widehat{N}*\right]^2 + Var\left(\widehat{N}*\right)Var\left(\widehat{p}\right)$$

$$Var\left(\widehat{N}*\right) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)}$$

$Var(\widehat{p})$ = variance obtained from Zimmerman et al. (2009). In this formula, $Var\left(\widehat{N}*\right)$ describes the standard variance calculation for the estimate of abundance and $Var\left(\widehat{p}\right)$ is the variance for the correction factor of unreturned bands reported by Zimmerman et al. (2009). We calculated a coefficient of variation (CV) for the band-return abundance estimate to make a practical comparison of precision between the 2 abundance estimates. We calculated the CV as follows:

$$CV = \left(\frac{\left(\sqrt{Var\left(\widehat{N}\right)}\right)}{\widehat{N}*}\right) \times 100$$

Plot-survey Abundance Estimation

We based the plot-survey protocol on an ongoing breeding waterfowl population survey in the northeastern United States (Heusmann and Sauer 1997, 2000). We surveyed from 1 April to 30 April 2015, to coincide with peak breeding activity of geese in North Carolina. We completed a single observer survey of each plot in its entirety using a variety of methods (i.e., boats, trucks, foot) and recorded any geese observed (Heusmann and Sauer 1997, 2000). The band-return method described above provided an estimate of abundance for 2014, whereas the plot-survey method provided an estimate of abundance for 2015. We believe these 2 estimates are comparable because there has been little annual fluctuation in the Atlantic Flyway temperate-nesting goose population since 1996 (Dolbeer et al. 2014).

We did not limit time of day the plot surveys were completed, because visibility of geese is similar throughout the day (Heusmann and Sauer 2000). Similarly, Rutledge et al. (2015) showed that satellite-tagged geese had relatively constant movement probabilities during daylight hours during the breeding–nesting period.

We separated goose observations into 4 categories depending on behavioral characteristics. Confirmed pairs were 2 geese sighted together, exhibiting paired behavior (i.e., nesting, defending a territory). We assumed that lone males and incubating females had a paired mate and added an additional bird for each solitary goose, resulting in an assumed total count at each plot. We considered groups to be any flocks consisting of ≥ 3 geese (Heusmann and Sauer 2000). All birds we encountered during the plot survey, excluding goslings, were totaled to yield an overall count at each plot (Heusmann and Sauer 2000). We calculated the mean number of geese on each plot and extrapolated those numbers out to the plots containing goose habitat statewide. We calculated the mean number of geese on each plot using the following formula:

$$\bar{y} = \frac{\sum_1^n y_i}{n}$$

In this formula, $\bar{y}$ describes the sample mean number of geese observed, y_i describes the number of geese observed at the ith plot, and n describes the total number of sample plots (300). We multiplied the resulting sample mean by the total number of available plots in the population (N; 104,001) to determine a statewide resident goose abundance estimate ($\widehat{\tau}$; Cochran 1977).

$$\hat{\tau} = N\bar{y} = 104,001 \times \bar{y}$$

We calculated the standard deviation (s_y) and the CV for the plot-survey abundance estimate to make a practical comparison of precision between both methods of abundance estimation using the following formulas (Cochran 1977):

$$s_y = \sqrt{\frac{\sum_1^n (y_i - \bar{y})^2}{n - 1}}$$

$$\mathrm{CV} = \frac{s_y}{\bar{y}} \times 100$$

In these formulas, $\bar{y}$ describes the sample mean number of geese observed, y_i describes the number of geese observed at the ith plot, and n describes the total number of sample plots (300).

Cost Comparison

We used a unique project code to document all North Carolina Wildlife Resources Commission employee time directed at training and completion of each of the abundance estimation techniques. Employees used the same code when making purchases of equipment and fuel. At the conclusion of the project, we compiled all expenses from the discrete project code, which resulted in a side-by-side comparison of person-hours and money spent to complete the 2 methods.

RESULTS

Band-return Estimate

We banded 2,102 adult geese in June 2014 and received 173 (8.2%) adult direct band recoveries from the 2014–2015 goose-hunting season. Before applying correction factors, the initial USFWS harvest estimate for North Carolina was 37,267 (Raftovich et al. 2015). We removed 1,192 birds from the USFWS harvest estimate to account for migratory and nonlocal, temperate-nesting geese included in the estimate. Additionally, we removed 7,923 birds to account for hatch-year birds in the harvest and 11,444 birds to correct the overestimate of the federal Canada goose harvest. This resulted in a final harvest estimate of 16,708. Using this harvest estimate, the band-return abundance estimate was 148,839 (CV = 7.9).

Plot-survey Estimate

We recorded 449 assumed observations, geese observed or assumed to be paired to a solitary goose, at the 300 plot-survey locations. Geese were observed at 67 (22.3%) survey plots. The plot-survey abundance estimate was 155,655 (CV = 308.9).

Cost Comparison

The cost of conducting the band-return method was US$72,858, with US$64,179 for mileage and salaries, US$3,531 for training, and US$5,148 for equipment. The cost of conducting the plot-survey method was US$80,767, with US$57,930 for mileage and salaries, US$19,322 for training, and US$3,515 for equipment. The band-return method required 2,317 person-hours, with 105 hours spent on training and 2,212 hours spent on field work. The plot-survey method required 2,857 person-hours, with 651 hours spent on training and 2,206 hours spent on field work.

DISCUSSION

Although the 2 methods resulted in similar statewide abundance estimates, the plot-survey estimate was much less precise than the band-return estimate. A power analysis of the 2015 data indicated that approximately 1,500 plots would need to be surveyed to generate the same level of precision as the band-return method using the federal harvest estimate. However, increasing survey sample size would result in an increase in survey costs, including the cost of labor, equipment, and travel.

The band-return estimate cost fewer dollars and person-hours than the plot-survey estimation. However, these overall costs do not represent the continued use of these methods on an annual basis because our assessment represented only the initial year of implementation. Future use of these methods will require less annual expenditure for purchasing equipment and less person-hours because only new employees will need to be trained. Excluding initial training expenses and purchase of equipment, these methods required similar overall costs and person-hours.

Additional factors not measured in this study may be incorporated into future comparisons between the band-return and plot-survey methods. The band-return method requires additional data processing (e.g., U.S. Geological Survey banding lab), and abundance results cannot be estimated until the year after banding occurs. Plot-survey data are easily processed and analyzed by the collecting entity; abundance estimates are available soon after surveys are completed. Finally, the plot survey can potentially provide information on goose–habitat relationships, including regional distributions and relative abundance (McAlister et al. 2017).

MANAGEMENT IMPLICATIONS

We recommend that managers use the band-return method with federal harvest estimates for estimating adult temperate-breeding goose abundance because it resulted in a more precise estimate with costs similar to the plot-survey method. Additionally, the band-return method encourages positive agency and public interactions because a large portion of banding occurs in areas where the public can observe and interact with agency employees and many hunters covet the opportunity to shoot banded birds. Finally, we suggest the band-return method because, when performed over an extended time period, it can provide additional population information crucial to the appropriate management of the species, including survival, recovery rates, and harvest distributions (Brownie et al. 1985, Greene and Krementz 2008).

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