



## Original Article

# Demographic Consequences of Translocation of Overabundant Canada Geese Breeding in Urban Areas

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**ABSTRACT** Translocation is a common tool for managing nuisance Canada geese (*Branta canadensis*) in urban areas across North America. However, no previous research has assessed how translocation affects survival and philopatry at donor and release sites. Such information is required for managers to decide if translocation is a suitable intervention to reach their management objectives. We used a joint multistate–dead recovery mark–recapture analysis to retrospectively measure the effects of translocation on survival and fidelity of immature and adult Canada geese ( $n = 2,946$  marked individuals). Between 2009 and 2013, geese from Wascana Centre, an urban park in Regina, Saskatchewan, Canada, were subject to translocation to Cumberland Lake, a remote lake more than 400 km away. Survival varied between immature (mean annual survival = 0.31, 95% CI = 0.24–0.40) and adult (mean annual survival = 0.72, 95% CI = 0.69–0.75) geese, but translocation had no effect on survival probability. However, translocated immature geese had a lower mean probability of returning to Wascana (0.11, 95% CI = 0.07–0.18) compared to adult geese (0.83, 95% CI = 0.77–0.88). Translocation is unlikely to lead to a reduction in population density in our system given that translocation does not influence survival and adults return at high rates after being moved. If translocation is the only management option available, then the focus should be on immature geese. If translocation is used as a management option to minimize the number of geese that would need to be lethally removed, then managers should translocate immature geese and cull adult geese to reach management objectives. © 2017 The Wildlife Society.

**KEY WORDS** band recovery, *Branta canadensis*, Canada goose, culling, fidelity, goose management, nuisance, population, Saskatchewan, survival.

In numerous urban settings across North America, increasing Canada goose (*Branta canadensis*) population sizes pose a significant challenge to wildlife managers (Groeper et al. 2008, Balkcom 2010, Sanders and Dooley 2014). Managers have a limited number of techniques to deal with urban geese that have varying acceptance by the public. Translocation of geese is one socially acceptable intervention and has traditionally been used to establish populations in locations where they were previously nonexistent (Lee et al. 1984, Fritzell and Soulliere 2004). More recently, translocation has been applied to deal with nuisance geese, but translocation is expensive and may not be a cost-effective approach to reach management objectives compared to other options (Holevinski et al. 2006). To prioritize actions that will maximize the probability of reaching a desired population abundance objective, managers require evidence of how translocation affects survival and philopatry at donor and release sites.

Changes in local population size could arise from effects of local survival and movements of immature and adult geese

among sites (Alisauskas et al. 2012, Norris et al. 2013). Translocation of immature and adult geese could reduce a nuisance population of geese, but this effect may be dampened if a large number of geese return to the original site the following year (Surrendi 1970, Fritzell and Soulliere 2004, Sanders and Dooley 2014). To justify translocation, the population size at the donor site should be expected to stabilize or decline if a large proportion of translocated geese remain at the new site (Fritzell and Soulliere 2004, Sanders and Dooley 2014). Additionally, if translocation subsequently leads to lower survival of geese, it raises doubts about whether translocation is a humane alternative relative to a lethal cull.

To assess the effectiveness of translocation as part of the overall urban Canada goose management program, we applied 5 years of banding data collected during a translocation program in a joint multistate–dead recovery mark–recapture analysis. Our objectives were to 1) determine if the probability of survival of immature and adult Canada geese was influenced by translocation; and 2) assess differences in the probability that immature and adult geese subject to translocation return to the donor site (hereafter philopatry) or to the site of translocation thereafter (hereafter fidelity).

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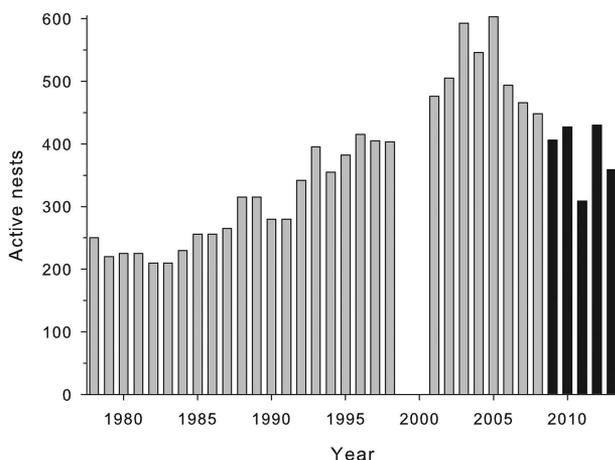
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## STUDY AREA

The study area consisted of 2 locations: the trapping site (Wascana Centre; hereafter Wascana) and translocation release site (Cumberland Lake; hereafter Cumberland). Wascana was a large urban park (810 ha) located within Regina, Saskatchewan, Canada, a city of about 240,000 people (50.4N, 104.6W). Regina was surrounded by agricultural lands, consisting almost exclusively of cropland, with some wetlands. Vegetation in the park was predominately Kentucky bluegrass (*Poa pratensis*) lawns, floral gardens, and forested with American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), and spruce (*Picea* spp.). The park was divided by Wascana Creek, a slow moving prairie creek, which was fed exclusively by snow melt and rainfall (Waiser et al. 2011). The creek was artificially deepened to create 2 large reservoirs (together 120 ha) that contained 6 islands, which provided nesting locations for geese.

Translocation has been used at Wascana for >40 years as part of the Canada goose management program. Similar to many other jurisdictions, a vigorous Canada goose reintroduction program was initiated in Wascana during the 1950s (L. Scott, Wascana Centre Authority, personal communication). Once the population became well established, geese were moved to various locations around Saskatchewan to bolster the provincial goose population size. Beginning in the 1980s, 800–1,200 geese were translocated each year to reduce local goose abundance in Wascana as a way to limit immature recruitment into the breeding population. Despite translocation efforts, the Canada goose population size within Wascana increased from 230 to 604 active nests between 1984 and 2005 (Fig. 1).

The release site for geese that were translocated from Wascana was 426 km to the northeast, at Cumberland Lake, Saskatchewan (53.9N, 102.2W). Cumberland was located within the southern limit of the boreal forest, which was



**Figure 1.** The number of Canada goose nests located within Wascana Centre, Regina, Saskatchewan, Canada, from 1978 to 2013. Nest data were not collected in 1999 or 2000. Translocation was conducted by the Centre starting in 1980 until 2012. The study period in this analysis is shown in black bars.

predominately mixed-wood (*Populus tremuloides* and *Picea glauca*), white spruce (*Picea glauca*), and jackpine (*Pinus banksiana*) communities (Dirschl 1972). The lake was part of the Cumberland Marshes or the Saskatchewan River Delta, which consisted of a large expanse of shallow eutrophic lakes, marshes, and streams (Dirschl 1969).

## METHODS

### Marking and Translocation

Geese were banded in late June or early July from 2009 to 2013 and, beginning in 2010, uniquely coded colored plastic leg bands were placed on some adult geese (Protouch Engraving, Saskatoon, Canada). We captured flightless geese using the drive-trap method. A small corral was set up near a flock of geese, using 4–6 1.4-m × 2.4-m metal framed panels (with thin rope netting), with 2 leads (black plastic mesh, 1 m × 20 m, erected with fiberglass stakes), which extended from the corral in a funnel shape. Birds were baited with bread toward the trap while 2–5 people moved in behind the group, creating a cup around the flock and pushed them into the funnel and corral. We then loaded the birds into a small trailer and transported to a larger permanent fenced holding facility within Wascana. Water, grass, and grain were provided to captured geese. All bands were recorded on previously banded geese and examined for wear. Unbanded birds were aged as either local (hereafter immature) or after-hatch-year (hereafter adult; Pyle 2008). Once the desired number of geese to be translocated were captured and confined in the holding pen (3–5 days), geese were translocated to the release site. Geese were individually loaded into wooden crates, loaded onto a flatbed trailer, transported, and released at Cumberland on the same day. In 2013, geese were not translocated, but the intensity of trapping and banding was consistent to previous years' trapping efforts. Resightings of color-banded individuals were compiled from monthly park-wide surveys from April to September using binoculars and a spotting scope; all surveys were conducted at Wascana and none occurred at Cumberland, which influenced our model structure and parameterization. Cumberland was an unobservable state, but parameter estimates were possible because banded geese that died, predominately from hunting, were recovered and reported (Barker et al. 2005). We obtained band recoveries from the Bird Banding Office (Ottawa, Ontario, Canada) and Bird Banding Laboratory (Laurel, Maryland, USA). We used banding records, recoveries, recaptures, and resightings to construct an encounter history for each individual.

Encounter histories, which are data used to fit statistical models to draw inference, are subject to error if bands cannot be read, are read incorrectly, or are lost (Seguin and Cooke 1983). Only 2 bands, both applied in 2009, had a single numeral that was difficult, but not impossible, to read when recaptured in 2014. Although band loss is known to occur, this is a random effect relative to our translocation treatment; therefore, it should not directionally bias parameter estimates of one particular group. Regardless, band loss was expected to occur at a low rate (~0.5%; Seguin and Cooke 1983) over the

duration of our 5-year study and this effect should be minimized given that supplemental observations of adults were based on color-bands. Therefore, although these errors would minimally bias our survival estimates low, we did not expect this to influence our inference regarding patterns in the transition probabilities. No foreign banded geese were encountered during the study in Wascana.

Authorization to capture and band geese was provided under bird banding permits #10242 (2009) and #10800 (2010–present) issued by the Canadian Bird Banding Office. Authorization to transport geese was granted under Environment Canada permit 15-SK-D006 issued to Wascana Centre Authority. Wascana Centre Authority is a nonacademic and nongovernmental organization and did not require an animal care and use protocol. However, we adhered to the accepted guidelines (Fair et al. 2010) to ensure all geese captured and handled during this project were treated ethically and humanely.

### Statistical Analysis

To retrospectively assess the effects of translocation, we used joint multistate–dead recovery mark–recapture models in Program MARK (Barker et al. 2005). Multistate models, which are first-order Markovian processes, assume translocation influences subsequent demographic parameters in the year following treatment (i.e., not memory models; Brownie et al. 1993). The model provides demographic estimates of 4 parameters: the probability that a dead goose will be recovered and its band reported to authorities ( $r$ ), the probability that a previously marked goose will be recaptured or resighted at Wascana ( $p$ ), the probability of surviving from one annual banding period to the next ( $S$ ), and the probability of moving between sites ( $\psi$ ).

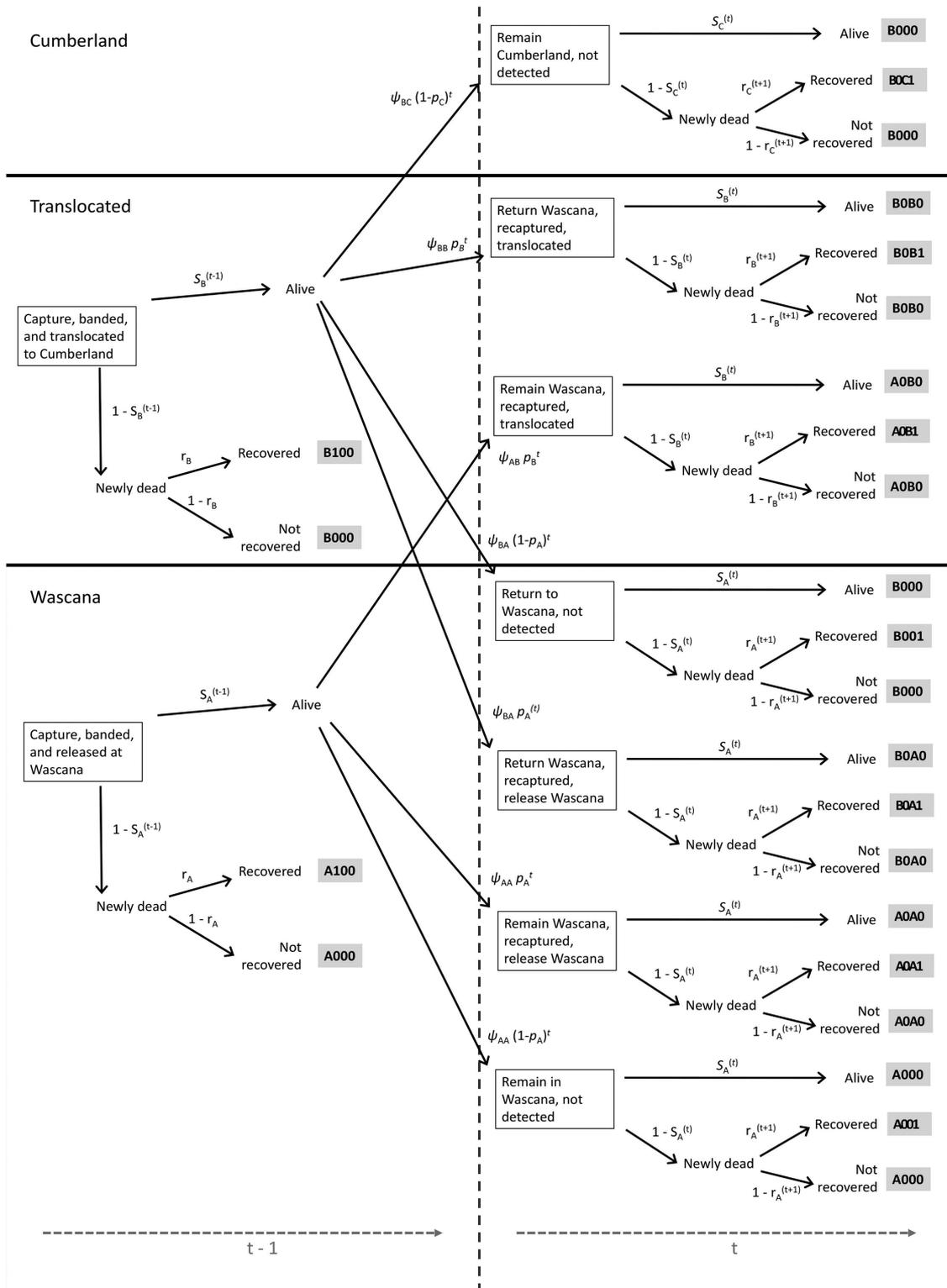
Our analysis centered on the comparison of the survival and transition probability of both immature and adult geese after translocation to return to the donor site (philopatry) or remain at Cumberland (fidelity; Fig. 2). Because our study design sampled birds and applied translocation by convenience, states in the model represented annual demographics at the donor site (state A: Wascana), translocation between sites (state B), and the adopted site (state C: Cumberland). A multistate model was necessary because some geese were translocated repeatedly during their lives; therefore, assigning individuals to a fixed grouping based on experimental treatment was not appropriate. Designating separate states for birds the year they were translocated from birds that remained (adopted) in Cumberland was necessary because we did not survey geese at Cumberland; limited resources often prevent observations at release sites. Therefore, we were primarily focused on the survival of geese the year after they were translocated and those that showed fidelity to Cumberland, in addition to the probability of philopatry or fidelity. We chose our modeling approach specifically because the high rate of band recoveries from geese allows estimation of fidelity and survival at unobserved locations via the likelihood of the model (Barker et al. 2005, Zimmerman et al. 2009). Thus, if they survived, geese that were translocated could return to breed at Cumberland via

adoption caused by the treatment (Fig. 2). Alternatively, translocated birds could show philopatry and return to Wascana to breed and remain faithful to their original location despite being exposed to the treatment (Fig. 2).

Our models used multinomial likelihoods; therefore, any erroneous assumptions made about  $r$  or  $p$  may affect other parameters in the joint likelihood (Barker et al. 2005; Fig. 2 and Table 1). For instance, if we ignore spatial variation in  $r$  when it occurs, we could erroneously conclude apparent spatial variation in  $S$  when it does not exist. The parameters of interest were  $S$  and  $\psi$ , so we took the approach of designating the most general global model possible in  $r$  and  $p$  that converged and provided realistic parameter estimates to avoid making erroneous assumptions about variation in  $S$  and  $\psi$  (Barker et al. 2005). We used a stepwise approach to fit these data to simpler models of each parameter (recovery, recapture, survival, and transition; see Table S1 for complete list of models, available online in Supporting Information). Because modeling parameter estimates in unobservable states requires a large amount of data, we did not consider time-dependent model parameters (except for recapture probability) because we did not expect the direction of these relationships to change over time (Barker et al. 2005).

Our model notation differentiated variation in estimated parameters based on age ( $a$ ), state ( $s$ ), time ( $t$ ), or constancy ( $c$ ). Hence,  $a1$  indicates no age structure and  $a2$  refers to 2 age classes (immature and adults). For models with 1 age class ( $a1$ ), the subscript  $c$  refers to a constant parameter estimate (no age, state, or time dependence),  $s$  refers to variation among states, and  $t$  refers to variation over time. For models with 2 age classes ( $a2$ ), the subscript  $c/c$  refers to no state or time dependence for either age class,  $s/s$  refers to state dependence for both age classes, and  $t/t$  refers to time-dependent variation in each age class. Based on our nomenclature, the additive model component  $S_{a2+s/s}$  indicated state-dependent survival between 2 age categories that was constrained to differ by  $x$  units between immature and adults within each state. The interaction model component  $S_{a2 \times s/s}$  indicated state-dependent survival that was independent between 2 age categories within a given state, whereas the model  $S_{a2 \times s(B=C)/s(B=C)}$  indicated age-dependent survival was equal between states B and C.

Using a time-since-marking approach, we started by parameterizing recovery probability ( $r$ ). The starting model ( $S_{a2 \times s/s}$ ,  $p_{a2 \times t/t}$ ,  $\psi_A: a2 \times c/c$ ,  $\psi_B: a2 \times s/s$ ,  $\psi_C: a1+c$ ,  $r_{a2 \times s/s}$ ), whose structure reflected full parameterization of all variables, was not identifiable and several parameter estimates were singular (SE = 0) such as transition probability for translocated geese and recovery probability for translocated and adopted geese. Therefore, we considered a simplified model that equated recovery probability for translocated (B) and adopted birds (C) but varied between age classes ( $r_{a2 \times s(B=C)/s(B=C)}$ ). This model structure assumes that, for a given age class, the recovery probability is dependent on geographic location (e.g., Barker et al. 2005) and suitable given that band recoveries predominately arise from hunting; hunting pressure varies geographically and temporally across Saskatchewan. This model was



**Figure 2.** An example of the likelihoods of the multistate model for Canada geese in Wascana and Cumberland, Saskatchewan, Canada, over a 2-year period and associated annual demographic rates that include the probability of survival ( $S$ ), the probability of recapture or resighting ( $p$ ), the probability of transition among sites ( $\psi$ ), and the probability that a dead goose would be reported to authorities ( $r$ ). The model consists of 3 states. Geese were captured, banded and observed only in Wascana (state A). Geese captured in Wascana could be translocated to Cumberland (state B) where they could subsequently become permanent residents of Cumberland the year following translocation (state C). Terminal encounter histories for the 2-year period ( $t-1$  to  $t$ ) are shaded boxes with the resulting encounter history (Table 1).

**Table 1.** Example encounter histories, model likelihoods and model descriptions from models of Canada geese translocated in Saskatchewan, Canada, over a 2-year period. The encounter histories have two characters for each year. The first character indicates the state where a goose was detected (A, B, or C) and the second character indicates if the goose was recovered dead where 0 is not recovered dead and 1 is recovered dead. The likelihoods are calculated as products of the probability of survival ( $S$ ), the probability of recapture or resighting ( $p$ ), the probability of transition among sites ( $\psi$ ), and the probability that a dead goose would be reported to authorities ( $r$ ). Subscripts on the variables refer to the 3 states in the model: Wascana (state A), geese captured in Wascana and translocated to Cumberland (state B), and permanent residents of Cumberland the year following translocation (state C).

Encounter history	Description	Likelihood
A0A1	Captured in yr 1, remain in Wascana and recaptured/resighted in yr 2 and subsequently died and was reported dead between yr 2 and 3	$S_A\psi_{AA}p_A(1 - S_A)r_A$
A001	Captured in yr 1, remain in Wascana but not observed in yr 2 and died and was reported dead between yr 2 and 3	$S_A\psi_{AA}(1 - p_A)(1 - S_A)r_A$
B0A1	Translocated in yr 1, survived and returned to Wascana where it was recaptured/resighted alive in yr 2, and it subsequently died and was reported dead between yr 2 and 3	$S_B\psi_{BA}p_A(1 - S_A)r_A$
A0B1	Captured in yr 1 and released in Wascana, survived and returned to Wascana where it was recaptured/resighted alive in yr 2 and translocated and subsequently died and was reported dead between yr 2 and 3	$S_A\psi_{AB}p_B(1 - S_B)r_B$
B0C1	Translocated in yr 1, survived and returned to Cumberland in yr 2 where it subsequently died and was reported dead between yr 2 and 3	$S_B\psi_{BC}(1 - p_C)(1 - S_C)r_C$

identifiable, provided reasonable parameter estimates, and had a difference in quasi-Akaike's Information Criterion corrected for sample size ( $\Delta\text{QAIC}_c$ ) 4.05 units lower with 2 fewer model parameters than the starting model (Table S1), which suggested it explained approximately the same amount of variance in the data as the starting model (Arnold 2010). We fixed recovery probability for adults at Cumberland to 0 in the first year of the study because no individual could adopt to Cumberland until the second year of the study (Fig. 2). We carried forward the top model from this comparison to parameterize recapture probability (Table S1).

We made observations only at Wascana so we fixed recapture probability ( $p$ ) at Cumberland to 0 and assigned geese to the translocation state with certainty (parameter set to 1). To parameterize recapture probability at Wascana, we considered a fully age by time-dependent model ( $p_{a2 \times t/t}$ ), a simpler additive model ( $p_{a2 + t/t}$ ), a time-dependent model that ignored age structure ( $p_{a1 + t}$ ), and finally a model that included only age structure ( $p_{a2 + c/c}$ ). The goal was to allow for an expected increase in resighting probability due to a greater proportion of marked individuals having colored leg bands (Table 2) but to avoid linear time-dependent trend models that could inadvertently force an increase in survival probability over time (Barker et al. 2005). The model that considered only age in resighting probability held no support ( $p_{a2 + c/c}$ ,  $\Delta\text{QAIC}_c = 116.0$ ), which validated that a time-dependent recapture-resighting probability model better explained these data. We carried forward the top model from this comparison to the main evaluation among our parameters of interest: survival and transition probabilities (Table S1).

For survival probability ( $S$ ), we started with a state- by age-dependent model ( $S_{a2 \times s/s}$ ) and considered several reduced combinations of this model (Table S1). We considered an additive model between state and age ( $S_{a2 + s/s}$ ), a model with state-dependence but no age-dependence ( $S_{a1 + s}$ ), and a model that was age-dependent ( $S_{a2 + c/c}$ ). Finally, we considered these same models but substituting equal survival for translocated (state B) and adopted geese (state C) in models that contained state-dependence: interaction model

( $S_{a2 \times s(B=C)/s(B=C)}$ ), additive model between state and age ( $S_{a2 + s(B=C)/s(B=C)}$ ), and a model with state-dependence but no age-dependence ( $S_{a1 + s(B=C)}$ ). Survival probability at Cumberland applied only to adults and thus immature survival at Cumberland and adult survival in the first year of the study at Cumberland were fixed to 0 (Fig. 2). We carried forward the top model during this comparison to parameterize transition probabilities among states (Table S1).

We investigated all combination of models that considered transition probability of Wascana individuals ( $\psi_A$ ) and transition probability of translocated individuals ( $\psi_B$ ). Transition from Wascana was the probability of being translocated ( $\psi_{AB}$ ), given survival and philopatry to Wascana the previous year and entirely under the influence of the researchers. Consequently, birds could not disperse to Cumberland in the absence of translocation ( $\psi_{AC} = 0$ ), which allowed us to test if fidelity and philopatry were mediated strictly via translocation. For  $\psi_A$ , 2 models are possible: the probability of transition to vary between ages ( $\psi_{AB \ a2 \times c/c}$ ) or to be constant between ages ( $\psi_{AB \ a1 + c}$ ). To parameterize transition probability of translocated individuals ( $\psi_B$ ), we considered interactive ( $\psi_{B \ a2 \times s/s}$ ), additive ( $\psi_{B \ a2 + s/s}$ ), and singular effects of age ( $\psi_{B \ a2 + c/c}$ ) and state ( $\psi_{B \ a1 + s}$ ) dependence. We considered all combinations of 2 models of the transition of Wascana individuals ( $\psi_A$ ) and 4 models of transition of translocated individuals ( $\psi_B$ ), equating to 8 different model parameterization of transition in our model set (Table S1). We assumed that fidelity to Cumberland was permanent (i.e.,  $\psi_{CC} = 1$ ) and by default, there was no movement back to Wascana once a bird had adopted ( $\psi_{CA} = 0$ ; Fig. 2). In all cases, we used the default setting in Program MARK to estimate geese returning to a site (i.e.,  $\psi_{AA}$ ) by subtraction. Using parameter estimates from the top model, we calculated the total transition to Wascana (i.e., philopatry) as the sum of  $\psi_{BB}$  and  $\psi_{BA}$  where  $\psi_{BB}$  indicates birds that where philopatric to Wascana after translocation and then translocated again in the subsequent year (Fig. 2).

There are several assumptions that should be met when using mark-recapture models. One assumption is the

**Table 2.** Number of immature and adult Canada geese translocated to Cumberland House, Saskatchewan, Canada, or remaining in Wascana Centre, Regina, Saskatchewan between 2009 and 2013. No geese were translocated in 2013. Total processed is the total number of newly banded and recaptured or resighted geese encountered in Wascana Centre. Recoveries of Canada geese are from 1 September to 1 May.

Year	Wascana		Cumberland Lake		Total translocated	Total processed	Total banded (color banded)	Recoveries					Total recovered
	Immature	Adult	Immature	Adult				2009–2010	2010–2011	2011–2012	2012–2013	2013–2014	
2009	25	136	337	579	916	1,077	1,077 (0)	112	60	41	17	19	249
2010	53	242	398	404	802	1,097	770 (244)		57	36	20	11	124
2011	11	290	294	151	445	746	449 (230)			43	18	4	65
2012	2	368	149	236	385	766	393 (346)				48	20	68
2013	56	651	0	0	0	707	257 (152)					36	36
Total	147	1,687	1,178	1,370	2,548	4,393	2,946 (972)	112	117	120	103	90	542

independence of fates and identity of rates among individuals (the iii assumption), which states that the fate of each marked individual with respect to capture, survival, and transition probability is independent of the fate of any other marked individual (Lebreton et al. 1992). Whether this assumption is met is often dependent upon the biology of the organism under study (e.g., geese migrate in family groups, which will confer some dependence of fates among family members) and study design. In our case, because a goose must be captured to be translocated, there will always be a confounding of  $p\psi_{AB}$  or  $p\psi_{BB}$  and never for  $(1-p)\psi_{AB}$  or  $(1-p)\psi_{BB}$ , which may violate the iii assumption. Violation of the iii assumption does not result in bias of the mean parameter estimates but rather underestimates the variance of the associated parameter estimates (Lebreton et al. 1992). Conducting goodness-of-fit tests can provide a quasi-likelihood adjustment (e.g., c-hat), which is suitable to accommodate extra variation that arises from dependence of fates among individuals (Lebreton et al. 1992, Anderson et al. 1994). Therefore, we assumed that accounting for overdispersion of our dataset would capture extra variation that may arise with potential violation of the iii assumption based on our study design.

To ensure our inference on the effects of translocation were robust with respect to alternate structures on  $r$ , we conducted a *post hoc* comparison of the sensitivity of the parameter estimates of  $r$  and  $S$  from top models. Given our top model (Table S1:  $S_{a2+d/c}$   $p_{a1+t}$   $\psi_A: a2 \times d/c$   $\psi_B: a2 \times s/s$   $\psi_C: a1 + c$   $r_{a2 \times s(B=C)/s(B=C)}$ ), we considered alternative structures where  $r$  varied among all 3 sites ( $S_{a2+d/c}$   $p_{a1+t}$   $\psi_A: a2 \times d/c$   $\psi_B: a2 \times s/s$   $\psi_C: a1 + c$   $r_{a2 \times s/s}$ ), where  $S$  varied among all 3 sites ( $S_{a2 \times s/s}$   $p_{a1+t}$   $\psi_A: a2 \times d/c$   $\psi_B: a2 \times s/s$   $\psi_C: a1 + c$   $r_{a2 \times s(B=C)/s(B=C)}$ ), and where both  $r$  and  $S$  varied among all 3 sites ( $S_{a2 \times s/s}$   $p_{a1+t}$   $\psi_A: a2 \times d/c$   $\psi_B: a2 \times s/s$   $\psi_C: a1 + c$   $r_{a2 \times s/s}$ ). In all comparisons, we retained age-dependence in  $r$  and  $S$  and the structure of  $p$  and  $\psi$  remained as in the best supported model (Table S1). When the parameter estimate remained consistent given these alternative structures, we concluded that our model was performing as intended.

We tested goodness of fit on our global model ( $S_{a2 \times s/s}$   $p_{a2 \times t/t}$   $\psi_A: a2 \times d/c$   $\psi_B: a2 \times s/s$   $\psi_C: a1 + c$   $r_{a2 \times s/s}$ ) with the median c-hat approach using 600 simulations. Results suggested our data were over-dispersed (c-hat = 1.703, 95% CI = 1.656–1.751), so accordingly we adjusted the c-hat

value in Program MARK to the mean estimated value from the goodness-of-fit procedure (White and Burnham 1999). We started with a fully parameterized global model, so at all stages of model development we considered the model with the lowest QAIC<sub>c</sub> as the best, but we also present all models in the supplementary materials (Table S1; Arnold 2010).

## RESULTS

From 2009 to 2013, 2,946 Canada geese were banded (1,325 immature, 1,621 adults), including 972 with color bands; 1,452 encounters were recorded (color band resightings and drive-trap recaptures) and we documented 542 band recoveries (2009–2014; Table 2). A total of 2,222 geese were translocated between 2009 and 2012, but the number varied among years from 385 to 916 geese (Table 2); 721 geese were never translocated (24%), 1,937 geese were translocated once (66%), 236 were translocated twice (8%), 45 were translocated 3 times (2%), and 5 were translocated every year (0.2%).

Models for recovery probability indicated that the probability of band recovery varied between ages and was different between Wascana individuals and a group that considered translocated and Cumberland individuals (Table S1). For recapture probability, the best-supported models (<4  $\Delta$ QAIC<sub>c</sub>) all considered the effects of time and the top-ranked model found no age dependence in recapture probability (Table S1). Of models that considered survival, the best-supported models (<5  $\Delta$ QAIC<sub>c</sub>) considered the effects of age; the top-ranked model found no state dependence in survival probability but rather that adult geese had greater survival probability compared to immature geese (Table S1). For models that considered transition between states, there was overwhelming evidence of an effect of age on transition (Table S1). The best supported model found age- and state-dependent transitions from the translocation state to Wascana or Cumberland and constant transition between age classes of birds from Wascana (Table S1).

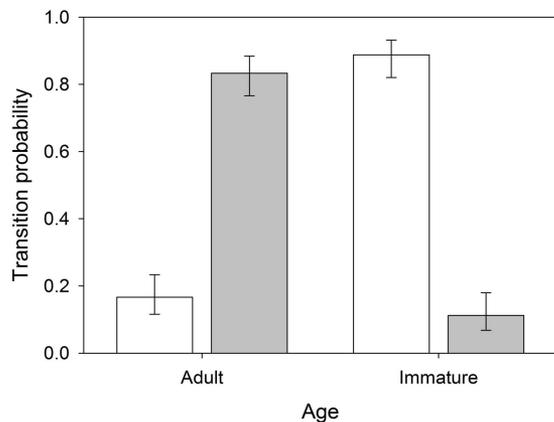
Recovery probability was similar for adults and immatures. Adult geese from Wascana had a recovery probability of 0.29 (95% CI = 0.24–0.34) and immatures had a recovery probability of 0.25 (95% CI = 0.15–0.39). Adult geese that were translocated or permanently adopted at Cumberland had a greater recovery probability (0.32, 95% CI = 0.26–0.38) compared to immatures that were translocated (0.15, 95%

CI = 0.11–0.19). Recapture probability increased over time from 0.39 (95% CI = 0.31–0.47) in 2010, 0.46 (95% CI = 0.40–0.53) in 2011, 0.71 (95% CI = 0.63–0.77) in 2012, and 0.92 (95% CI = 0.83–0.96) in 2013. First-year survival probability of immature geese was lower (0.31, 95% CI = 0.24–0.40) than adult geese (0.72, 95% CI = 0.69–0.75) and model selection suggested that survival did not differ between philopatric, translocated, or site-adopted geese (Table S1). Parameter estimates were largely insensitive to alternative structures on  $r$  and  $S$  in our *post hoc* analysis, suggesting that our model was performing as expected and translocation had little influence on survival (Table S2).

The transition probability after translocation for immature and adult geese was in opposite directions (Fig. 3). Immature geese had a greater probability of showing fidelity to the translocation site (0.88, 95% CI = 0.82–0.93) than being philopatric to the natal site (0.11, 95% CI = 0.07–0.18), whereas adult geese had a significantly greater probability of being philopatric (0.83, 95% CI = 0.77–0.88) than showing fidelity to the translocation site (0.17, 95% CI = 0.12–0.23). Compared to transition probabilities estimated from our multistate model, naïve estimates of return rates to Wascana over the study in at least one summer following translocation were lower for both translocated adult (50%,  $n = 519$ ) than immature geese (3%,  $n = 29$ ).

## DISCUSSION

We found that exposure to translocation did not have a negative effect on immature or adult survival probability. The best-supported model indicated that survival was age-specific but not related to state. In contrast, immature and adult geese that were translocated showed opposite transition patterns in the year following translocation.



**Figure 3.** Mean transition probability (95% CI) of immature and adult Canada geese after translocation from Wascana Centre, Regina, Saskatchewan, Canada, to Cumberland Lake, Saskatchewan from 2009 to 2013. Adults returned to the site of origin at Wascana (Philopatry; gray bars) at a higher rate than immature geese who remained at the translocation site at Cumberland (Fidelity; white bars). Philopatry was the sum of the probability that geese that were philopatric to Wascana after translocation and not translocated again in the subsequent summer ( $\psi_{BA}$ ) and the probability that geese that were philopatric to Wascana after translocation and then translocated again in the subsequent year ( $\psi_{BB}$ ). In other words, philopatry was calculated as  $\psi_{BA} + \psi_{BB}$  and fidelity was calculated as  $1 - \psi_{BA} + \psi_{BB} = \psi_{BC}$ .

Immature geese showed greater fidelity to Cumberland, whereas adults showed greater philopatry to Wascana. Given equal adult survival across sites and the propensity for most adults to return to Wascana, our results suggest that translocation of adult geese is unlikely to have the intended effect of reducing the breeding population abundance, whereas the translocation of immature geese is more likely to be successful, especially if density-dependent recruitment does not occur at Wascana.

Our study used a multistate approach to separately identify survival and transition probabilities after translocation, which provides information on the sources of selection operating in our population (Hestbeck et al. 1991, Norris et al. 2013). Although immature survival in our study was lower than those reported in other portions of the Central Flyway (Dieter et al. 2010), survival of Canada geese from Wascana was not negatively affected by translocation for either immature or adult geese. This result remained despite differences in dead recovery rates between Wascana and Cumberland (geese translocated in the current year and those permanently adopting to Cumberland), which implies differential hunting pressure in the autumn and hunter band reporting rates between study areas. Unlike urban geese in New York (Holevinski et al. 2006) and Georgia (Balkcom 2010), USA, which generally are permanent residents in protected areas and avoid areas where they can be hunted, geese at Wascana leave the park daily to feed in agricultural fields outside the city limits and likely experience high and relatively consistent hunting pressure for 2 months prior to their southern migration.

Adult geese at and migrating from Cumberland had comparable recovery probabilities to adults at Wascana. In contrast, immature geese from Cumberland had lower recovery probabilities, which was surprising because geese travel in family groups during migration. A possible explanation of the difference in recovery probability of immature geese at Cumberland could be the harvest by local First Nations hunters. Given the community knows many young geese are released from Wascana in the same year, reporting of these harvested geese may not occur; hunter familiarity has been suggested as an explanation for low band reporting probability (Henny and Burnham 1976, Zimmerman et al. 2009). All geese from our study have sympatric overwintering distributions, predominantly in Nebraska and South Dakota, USA (J. B. Clarke, Wascana Centre Authority, unpublished data); therefore, we would expect recovery probability to be the same during this period. Overall, this suggests that to determine socially acceptable and effective management plans for migratory populations, we must consider the selection pressures operating on individuals across the annual cycle (Flockhart et al. 2015).

As expected from previous studies and early anecdotal observations from Wascana, fidelity to the release site was higher for immature geese, whereas adult geese exhibited high philopatry to the trapping site (Surrendi 1970, Smith 1996, Iverson et al. 2014, Sanders and Dooley 2014). Because we did not make observations at the release site, we do not know how frequently immature birds returned

specifically to the Cumberland area as opposed to areas nearby. Yet in the release site, geese can be hunted during spring (Mar–Apr) by First Nations residents unlike most hunting in the province, which is restricted only to the autumn. Fourteen spring band recoveries were reported from the Cumberland area during the study period, which occurred 1–4 years after the birds were released. These recoveries support the assumption that immature birds are returning to the translocation site to breed as adults.

Population abundance at Wascana did not decline in parallel with translocation, despite extensive translocation effort. Thus, although we can offer to managers that immature geese are the best candidates for translocation to reduce local abundance via recruitment (or to establish populations via fidelity; Sanders and Dooley 2014), these vacancies were likely filled by immigration from outside sources because the population growth observed at Wascana mirrored that observed for the larger Western Prairie–Great Plains population (Vrtiska et al. 2004). Indeed, translocation alone may be insufficient to reduce local geese abundance if individuals remain in good body condition from feeding in agricultural lands during the wintering period and are released from density-dependent competition upon return to breeding areas (Fox et al. 2005).

## MANAGEMENT IMPLICATIONS

Translocation did not negatively influence survival rate although survival could be reduced if birds are released into an area where hunting pressure is additive relative to the donor site. Translocation of adult geese was an ineffective way to reduce resident goose abundance (except temporarily), given the high fidelity of adult geese to the trapping site in subsequent years. Once moved to the release site, young geese showed high fidelity to that site, instead of the trapping site. In cases where there is concern regarding the number of geese being culled, we recommend to cull adults and translocate immature birds, especially if managers have data to suggest that density-dependent recruitment does not occur at the local site.

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## SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's website. The file includes one table with sequential modeling results and another table presents a *post hoc* comparison of the sensitivity of the parameter estimates of  $r$  and  $S$  from top models.