Movements, habitat selection, associations, and survival of giant Canada goose broods in central Tennessee

Eric M. Dunton,[1] Department of Biology, Tennessee Technological University, 1100 N. Dixie Avenue, Box 5063, Cookeville, TN 38505, USA   *eric.dunton@state.mn.us*

Daniel L. Combs, Department of Biology, Tennessee Technological University, 1100 N. Dixie Avenue, Box 5063, Cookeville, TN 38505, USA

Abstract: The brood-rearing period in giant Canada geese (*Branta canadensis maxima*) is one of the least-studied areas of goose ecology. We monitored 32 broods in Putnam County, Tennessee, from the time of hatching through fledging (i.e., when the goslings gained the ability to fly) and from fledging until broods left the brood-rearing areas during the spring and summer of 2003. We conducted a fixed-kernel, home-range analysis for each brood using the Animal Movement Extension in ArcView® 3.3 GIS (ESRI, Redlands, Calif.) software and calculated 95% and 50% utilization distributions (UD) for each brood. We classified 25 broods as sedentary (8 ha 95% UD), three as shifters (84 ha 95% UD), two as wanderers (110 ha 95%UD); two were unclassified because of low sample size. We measured 5 habitat variables (i.e., percentage of water, percentage of pasture, percentage of development, number of ponds, and distance to nearest unused pond) within a 14.5-ha buffer at nesting locations. We used linear regression, using multi-model selection, information theoretic analysis, to determine which, if any, habitat variables influenced home-range size at a landscape level. The null model was the best information-theoretic model, and the global model was not significant, indicating that landscape level habitat variables selected in this study cannot be used to predict home-range size in the Upper Cumberland region goose flock. We analyzed associations among broods, using a coefficient of association of at least 0.50, and determined association areas by overlaying individual home ranges. Overall gosling survival ($\hat{S}$) during the brood-rearing period was 0.84 (95% CL = 0.78, 0.92), using a staggered-entry Kaplan-Meier survival curve. We believe that abundance of quality forage and pond habitat, high survivorship, and a lack of movement corridors (i.e., rivers, lakes, and reservoirs) were responsible for the relatively small home ranges of geese in the Upper Cumberland region. Associations formed during brood rearing may reduce predation risks and serve as a template for lifelong social bonds with family members and unrelated geese that are reared in the same locations.

Key words: brood associations, brood movements, *Branta canadensis*, Canada goose, home range, human–wildlife conflicts, survival, Tennessee

Giant Canada geese (*Branta canadensis maxima*) were established across the United States and Canada in the 1960s and 1970s, primarily to provide hunting opportunities where migratory populations had declined or never existed (Fritzell and Soulliere 2004, Griggs and Black 2004). The U.S. Fish and Wildlife Service estimates that 3.6 million giant Canada geese exist in the United States (Haas 2002), with the Mississippi Flyway supporting the largest number (Nelson and Oetting 1998). Increasing populations of giant Canada geese have resulted in an increase in the number of human–goose conflicts. Understanding the ecology of giant Canada geese plays a crucial role in managing urban–suburban problems.

Brood-rearing is among the least understood areas of goose ecology, particularly brood movements and habitat use (Eberhardt et al. 1989). Previous approaches to study movements and habitat use by broods have included color-marking goslings (Geis 1956, Culbertson et al. 1971), neck-banding adults (Martin 1964, Zicus 1981, Mercer 1999), and placing radiotelemetry transmitters on goslings' parents (Lebeda and Ratti 1983, Eberhardt et al. 1989, Didiuk and Rusch 1998). Movement data of broods provide information about the distribution of problem geese during critical periods (i.e., summer) and provide an estimate of productivity, which can be used to determine changes in flock density.

Our objectives were to estimate home-range size and movement patterns, test the influence of landscape-level habitat variables on home-range size, determine gosling survival rates, document the extent and circumstances

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[1]Present address: Minnesota Department of Natural Resources, 35365 800th Avenue, Madelia, MN 56062, USA

surrounding formation of brood associations, and better understand their function and effect on home-range size and movements.

Study area

We conducted this study in the Highland Rim province of Putnam County, Tennessee (Van West 1998). Of the 105,198 ha in Putnam County, 40% was farmland (mostly pastures), 40% was forestland, and 20% was urban environment (Van West 1998). National Wetland Inventory maps indicated that there are 2,292 palustrine open-water habitats in Putnam County, and most were farm ponds (<1 ha). There were 3 large water bodies in Putnam County: Boring Pond (14 ha), Cane Creek Lake (23 ha), and Old City Lake reservoir (37 ha). We did not include these large water bodies in this study because they were not representative of the common nesting habitat types within the study area (i.e., farms ponds <1 ha and pastures) and previous studies have documented disrupted nesting patterns at one of these locations because of high nesting densities (Mukherjee 2001, Christensen 2002, White 2002). Although records were not available for verification, we suspected that the Upper Cumberland (UC) flock was established in the late 1970s when birds were released on farm ponds in the region, perhaps on the Boring Pond (E. L. Warr, Tennessee Wildlife Resource Agency, personal communication). The best estimate of the size of the giant Canada goose population in the UC region was 1,233 (White 2002).

Methods

We monitored 32 broods during spring and summer 2003 from hatching through fledging (i.e., when the goslings gained the ability to fly) and from fledging until broods flew away from rearing areas. We assumed that goslings fledged at 70 days (Yocom and Harris 1965). We obtained nesting locations, clutch sizes, and hatch dates from Carbaugh (2004), who conducted a concurrent nesting ecology study. We monitored all pairs known to have successfully hatched ≥1 gosling within Putnam County except for geese using the 3 large water bodies. At least 1 parent in 29 broods was marked with a white neck collar bearing a unique black, 4-digit alphanumeric code, but 3 broods were completely unmarked. These

broods occurred in areas not used by other broods, and the number and size of goslings were consistent among observations, providing strong evidence that we observed the same broods despite the lack of individual marks. We observed broods daily or every other day throughout the brood-rearing period.

We established a driving route for brood observations that began at the last known location of broods. We recorded detailed descriptions of brood locations, including the distance from nearest major landmarks (e.g., ponds, houses, or roads), time of observations, and indications of disturbance (e.g., dogs, mowing, cutting, or other human activities). If we did not locate broods at previously-observed sites, we searched all nearby suitable habitats and ponds in increasing concentric circles either until we located broods or the search became too time-consuming (i.e., we searched several km^2). We established an *a priori* sample size of 30 to 50 observations per brood to provide accurate home-range calculations (Seaman et al. 1999, Millspaugh and Marzluff 2001). If we did not locate a brood at least once in 7 consecutive days, it was classified as missing, and we restricted searches to once a week at last known locations and surrounding habitat. We considered broods absent after a month of once-a-week searches failed (i.e., all goslings died) or broods had moved sufficiently far enough away that they could not be located.

We observed broods once a week from the time of capture until they flew from their pre-fledging home ranges to determine how long they utilized brood-rearing areas once they gained the ability to fly. If we were unable to locate broods during post-fledging searches, we searched surrounding areas (i.e., all ponds and pastures within a few square kilometers of last known locations) for 2 consecutive days. We assumed broods not observed during these searches had left brood-rearing areas.

Home-range analysis

We conducted home-range analyses by plotting daily brood locations on digital-ortho-quarter quads (DOQQ) within ArcView 3.3 GIS software (ESRI, Redlands, Calif.). We used a fixed-kernel home-range estimator for each brood using 50 and 95% utilization distributions (UD). We selected the Least Squares Cross

Validation (LSCV) as the smoothing parameter (Seaman et al. 1999, Millspaugh and Marzluff 2001).

Habitat analysis

We used linear regression to determine if landscape level variables could predict home-range size. We plotted nesting locations on DOQQ maps, and generated circular buffers of 215-m radii, which is equivalent to mean home-range size 14.5 ha, in ArcView and centered at each nest. Within each buffer, we digitized area polygons to determine the percentage of 3 habitat types: water (e.g., ponds), pastures and lawns, and development (e.g., buildings and roads). We calculated the number of ponds occurring within each buffer and the distance from each nest site to the nearest pond outside the buffer not used by that brood. We employed a linear regression analysis that included percentage of water, percentage of pasture, percentage of development, number of ponds, and distance to the nearest unused pond to predict home-range size. We used information theoretic analysis for selecting models of all possible combinations of independent variables (Burnham and Anderson 1998). In addition, we generated both a null model that included no regression variables and a global model that contained all variables (Long 1997). We selected the model with the lowest biased-corrected Akaike Information Criterion (AIC_c), and considered all models within 2 AIC_c points of the best model as competing models (Burnham and Anderson 1998). We excluded 6 broods in this analysis because 5 broods had unknown nesting locations, and we considered 1 brood an outlier because of an excessively large home range, probably related to access to the Falling Water River that served as a movement corridor. We used Statistical Analysis System (SAS Institute, Cary, N.C.) for all statistical tests.

Brood associations

We defined brood associations as groups of broods that were commonly near each other and exhibited synchrony in movements. However, individual broods were usually distinguishable within associations. We calculated brood association areas for broods that joined other broods during the brood-rearing period. To do so, we overlaid home ranges of all broods in that association, and digitized polygons around overlapping areas. We did not conduct fixed-kernel home-range estimates for brood associations because brood sample sizes were inadequate (i.e., <30), thereby violating a critical assumption (Millspaugh and Marzluff 2001). We calculated coefficients of association (Cole 1949) for all brood associations to determine how often they were intact. We calculated coefficients of association by dividing the sum number of observations of broods when associated with other broods by the sum total number of observations of those same broods. Coefficients of associations >0.5 (i.e., 50% associations) are generally considered to be ecologically meaningful (Knight 1970, Millspaugh and Marzluff 2001). During individual observations, we considered broods away from their association if no other broods were in the immediate vicinity. However, we did not treat sightings impaired by nearby landforms (e.g., hills or trees) as indications of disassociation. We considered associations consisting of 3 or more broods intact if at least 2 broods were together at an observation.

Survival analysis

We calculated gosling survival for the entire brood-rearing period using a staggered entry Kaplan-Meier survival curve (Kaplan and Meier 1958). We discovered 5 broods post-hatch that had unknown nesting locations. We determined back-dated hatch dates using gosling plumage characteristics (Yocom and Harris 1965). We assigned the mid-point between observation dates as the mortality date for mobile broods and broods that we did not observed daily (n = 11). We conducted a sensitivity analysis to determine the importance of these assumptions, by perturbing unknown (estimated) hatch dates ±3 days and setting unknown mortality dates to the left and right endpoints of each observation interval. We conducted a cluster-level bootstrap using 5,000 bootstrap samples to account for correlated survival within a brood. We used the 0.025 and 0.975 quantiles of the bootstrap distribution to produce a 95% confidence interval for the Kaplan and Meier (1958) estimate.

Results

Home-range analysis

We recorded 1,340 brood observations from April 21, 2003, to July 29, 2003, and drove >8,000 km along the observation route. Brood movement patterns and home ranges demonstrated 3 patterns of movement (i.e., sedentary, shifters, and wanderers), which Hughes et al. (1994) described as: (1) sedentary broods that had 1 small, well-defined area of activity; (2) shifters that commonly had 2

Falling Water River (i.e., a movement corridor) and had the largest home range in the study (138.5 ha). The average age that broods left brood-rearing areas was 76.5 days, indicating that broods leave brood-rearing areas soon after they gain the ability to fly (Table 1).

Habitat analysis

Mean habitat within 14.5-ha buffers around 26 goose nests consisted of 58% pasture or lawns, 32% woods, 7% development, and 3% water.

Table 1. Movement pattern and home-range size for the brood-rearing period for 32 giant Canada goose broods in the Upper Cumberland region, Tennessee, 2003.

Movement pattern	Number of broods	95% Utilization distribution		50% Utilization distribution	
		$\overline{X}$ (ha)	SE	$\overline{X}$ (ha)	SE
Sedentary[a]	25	7.6	1.5	1.6	0.3
Shifter[b]	3	84.0	17.6	15.0	3.9
Wanderer[c]	2	109.9	28.6	19.1	1.9
Unclassified[d]	2	7.6	0.7	1.7	0.3

[a] Sedentary broods had 1 small, well-defined area of activity.
[b] Shifters commonly had 2 distinct areas of concentrated use occupied sequentially over the course of the brood-rearing season.
[c] Wanderers ranged widely, having poorly-defined areas of use and no concentrated center of activity.
[d] Two broods went missing during the brood-rearing season but appeared later.

Table 2. Best information theoretic habitat model and the 3 competing models (i.e., within 2 AIC points) for giant Canada geese in the Upper Cumberland region, Tennessee.

Models	R^2	AIC[a]
Null		145.5257
Development	0.0568	146.3594
Distance to pond	0.0524	146.4804
Development + Distance to pond	0.1542	146.0945

[a] AIC corrected for small sample size.

distinct areas of concentrated use occupied sequentially over the course of the brood-rearing season; and (3) wanderers that ranged widely, having poorly-defined areas of use, and no concentrated center of activity. We classified 25 broods as sedentary, three as shifters, and two as wanderers. We did not classify 2 broods due to low sample size. Mean 95% utilization distribution for sedentary broods was <10% the size of the home range of shifter broods (Table 1). One of the wanderer broods had access to the

Mean number of ponds was 2.3, and mean distance to the nearest pond not used was 429 m. The global model to predict home-range size using all variables was not significant ($P = 0.37$, $R^2 = 0.22$). The best approximating model was the null model ($AIC_c = 145.52$), which contains no regression variables. Only 3 models were within 2 AIC_c points and considered competing (Table 2). There was a weak relationship between home-range size and the amount of development and distance to the nearest pond not used by the brood, but we determined no other measured variables to be important.

Brood associations

Eighteen broods formed an association with ≥1 other broods during the brood-rearing period, with a mean gosling age of 15 days (SE = 3.6) at the time of group formation. In most cases, brood associations formed immediately after hatch and consisted of broods from nests in close proximity to each other. Mean 95% UD for sedentary and broods that shifted brood-rearing areas were similar, and coefficients of

Table 3. Movement pattern, number of giant Canada goose brood associations, association home range size, and coefficient of association in the Upper Cumberland region, Tennessee during summer 2003.

Movement pattern	Number of broods associated	95% UD[a] (ha)	50% UD[a] (ha)	Coefficient of association[b]
Sedentary	15	8.1	1.6	0.88 (0.96)
Shifters	3	8.6	2.6	0.79 (0.90)
Wanderers	0			

[a] UD = utilization distributions. We determined association home ranges by overlaying each brood in the association on each other and creating area polygons around overlapping areas. We did not conduct kernel home range estimations for brood associations because brood association sample sizes were inadequate (i.e., <30) and would have resulted in an inflated home-range estimate.
[b] Coefficient of association = sum of observations of broods when associated ÷ sum of total observations of broods. Association values in parentheses represent coefficients after associations were formed.
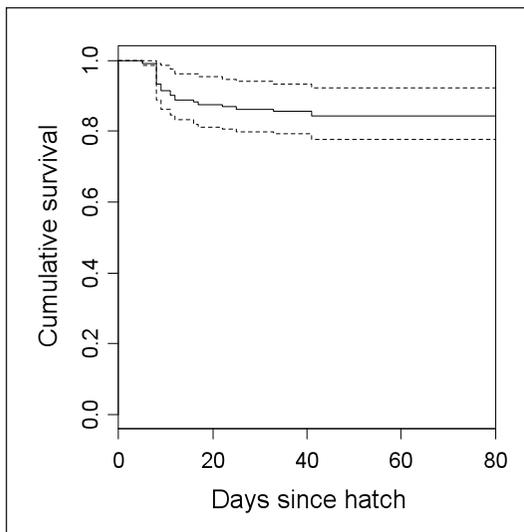

Figure 1. Kaplan-Meier survival distribution for the brood-rearing period for 32 Canada goose broods in the Upper Cumberland region, Tennessee, 2003.

association were similar (Table 3). The 3 broods that shifted brood-rearing areas and formed a brood association moved to a communal brood-rearing area that was >1 km overland from their nest sites (Tables 2 and 3).

Survival analysis

One hundred fifty-six goslings hatched in the study area, and 132 goslings fledged successfully. Overall survival ($\hat{S}$) during the brood-rearing period was 0.84 (95% CL = 0.78, 0.92; Figure 1). Eighteen of the 32 broods successfully fledged all goslings, and only 5 broods lost >50% of their goslings. We did not detect changes in gosling numbers after approximately 5 weeks (i.e.,

between 33 and 41 days post-hatch), indicating that all gosling mortality occurred within the first 5 weeks post-hatch, with most mortality occurring in the first 2 weeks. The overall shape and ending survival estimate were not sensitive to assumed hatch or mortality dates.

Discussion

Home-range sizes of waterfowl broods are influenced by 3 primary factors. Foremost, sufficient food must be available to young waterfowl to meet energetic and nutritional demands of initial rapid physical growth (Sedinger 1986, MacInnes 1998, Mowbray et al. 2002) and growth and replacement of feathers during initial molts, which occur simultaneously (Sedinger 1986). Second, brood movements often are influenced by predation risks because young waterfowl are highly vulnerable due to their small size and inability to fly (Ball et al. 1975, Talent et al. 1983, Rotella and Rath 1992). In addition, social interactions among broods, especially in geese, may contribute to movement patterns. We believe Canada goose brood movements in the UC region are influenced by all of these factors and the interaction effects among them.

Optimal brood-rearing habitat for Canada geese consists of gently sloping banks, nearby water reserves, few disturbances, and abundant plant food in the form of short grasses, semi-aquatic plants, or emergent vegetation (Hanson and Eberhardt 1971, Bellrose 1980, Sedinger and Raveling 1986, Bruggink et al. 1994). Foraging habitat in the UC appears to be evenly distributed in sufficient quantities to meet growth demands on goslings, perhaps

explaining why proportion of land in pastures was not linked to home-range size.

Habitat conditions influence movement patterns and home-range size in waterfowl and many other animals (Eberhardt et al. 1989, Dzus and Clark 1997, Didiuk and Rusch 1998, Yerkes 2000). Movements and or increased home ranges are sometimes caused by a deficiency of specific habitat requirements within a concentrated or localized area (Mauser et al. 1994, Mizutani and Jewell 1998, and Yerkes 2000). Regression analysis conducted in this study indicates that portions of Putnam County used by nesting geese are relatively uniform in habitat conditions. Sedentary broods used habitats similar to those of geese that shifted brood-rearing areas. Limited brood mobility observed in this study was undoubtedly influenced by the landscape of the study area. Scattered farm ponds in a rural–suburban setting provide excellent brood-rearing habitat, but on a localized basis. Shortage of water corridors necessitated overland travel, and parents appeared reluctant to move their broods, especially during the first few weeks post-hatch. Brood movements and fidelity will vary in different landscapes, as shown by greater movements along shorelines of reservoirs (Eberhardt et al. 1989, Mercer 1999). The brood with the largest home range in this study (138.5 ha) used a water corridor, supporting this conclusion.

Because habitat was relatively uniform, we believe differences in movement patterns and home-range size among broods in this study were influenced by other factors more than foraging habitat. If Canada geese survive their first year, their annual survival rates become higher, a key reason for exponential growth of urban flocks (Smith et al. 1999). Survival rates of other Canada goose flocks varied from 5 to 95% during the brood-rearing period (Martin 1964, Combs et al. 1984, Baker 1989, Huskey et al. 1998). High survival rates (i.e., 84%) in this study indicate that there is low predation risk and that survival during the brood-rearing period is not limiting population growth in the UC region.

Canada geese are highly social and have a well-developed social system (Raveling 1969, 1970; Combs 1989; Christensen et al. 2002). Parental desire to form brood associations probably contributed to increased home-range size and shifting or wandering movement patterns for some broods in this study, but only after goslings reached the critical age that reduced predation risks (i.e., 4 to 5 weeks). Parents may form brood associations with siblings or with adults with which they were previously associated. Canada goose broods often associate with other broods, sometimes moving from their natal area to communal brood-rearing areas (Geis 1956, Zicus 1981, Eberhardt et al. 1989, Didiuk and Rusch 1998). Although little is known about social interactions during brood-rearing (Mulder et al. 1995), various theories have been proposed for why geese form brood associations. Most often cited explanations are dominance relationships and competition for food among various-sized groups, reduction in predation risks, and inadvertent mixing of young among broods (Gosser and Conover 1999). Brood associations may simply reflect brood-site fidelity by parents (i.e., use of the same location by several broods; Zicus 1981, Didiuk and Rusch 1998, Lindberg and Sedinger 1998). Although advantages of belonging to brood associations are not fully understood, short-term benefits to young in close family associations seem clear: they are attacked less often, feed more, and have access to food and space in relation to the dominance status of their parents (Raveling et al. 2000). Many urban goose problems are associated with large congregations of geese throughout the summer, and the propensity for broods to associate contributes to the problem. Most broods in the UC region formed associations soon after hatching, but they generally dispersed from brood-rearing areas within a week of fledging, providing evidence that management activities should be utilized prior to nest initiation.

A key component of any management strategy is monitoring and evaluation. Due to the reduced mobility during the brood-rearing period, Canada goose broods are easily observed, providing a mechanism both to easily index annual productivity and determine changes in flock density. In Georgia, Powell et al. (2004) used a postcard survey of golf courses to monitor urban subpopulations of Canada geese and found the technique to be a cost-effective tool to provide information on a segment of the population that is hard to quantify with other

techniques. A well-designed brood survey based on a thorough understanding of Canada goose brood-rearing ecology (e.g., movement patterns, social biology, and site fidelity) can provide biologists with critical information in a timely and relevant manner (Powell et al. 2004). Because most geese exhibit a high degree of site fidelity and most urban goose conflicts are highly localized, a brood route survey of brood-rearing areas would provide an index of changes in flock density and evidence of effectiveness of management activities.

Urban goose problems are often complex and involve an integrated management approach that provides short-term and long-term solutions to managing goose populations at or below target levels (Smith et al. 1999). Urban populations are often difficult to survey and monitor because they are widespread and scattered (Powell et al. 2004). Although human populations in the UC region are not directly comparable with large metropolitan areas, habitat conditions (e.g., numerous ponds and abundant grasslands) are reflective of giant Canada goose habitat in many suburban areas that experience goose problems. Nonlethal management techniques such as eliminating nesting structures, anti-feeding ordinances, physical barriers, chemical repellents, habitat modification, harassment, sterilization, and translocation can provide short-term solutions to localized problems. Generally, however, these techniques do not have long-term effects on population levels (Cooper 1987, Conover and Kania 1991, Cummings et al. 1995, Smith et al. 1999). Lethal management techniques, such as firearms hunting, food donation programs, landowner kill permits, nest manipulation, and removal of nesting females can be effective control techniques, but they must both gain public acceptance and require public education and effective local laws and ordinances that allow managers and municipalities to control nuisance and overabundant wildlife species (Ankney 1996, Smith et al. 1999, Coluccy et al. 2004).

Canada goose problems are often socially defined, and public acceptance of management actions are influenced by past experience and tolerance for wildlife (Loker et al. 1999, Smith et al. 1999, Coluccy et al. 2001). Limited brood mobility creates problems in areas where geese are considered undesirable (e.g., golf courses, parks, and manicured lawns). Most landowners in the UC region have a rural background and have expressed little animosity toward geese unless they accumulate in large numbers. Many landowners are protective of geese, especially broods that are reared on their property. However, many farms in the region are now being sold and subdivided, and homeowners in subdivisions generally are less tolerant of geese. Fidelity of geese to specific ponds is likely to cause future conflicts in a changing landscape. Such changes should be considered when developing management strategies, especially if they involve releasing or translocating geese.

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ERIC M. DUNTON is a wildlife research biologist with Minnesota Department of Natural Resources. His current research involves ecology and management of wild turkeys and turkey hunt management. He received his B.S. degree from Michigan State University and his M.S. degree from Tennessee Technological University and is a certified associate wildlife biologist with The Wildlife Society.

DANIEL L. COMBS is a professor and the chair of the Department of Biology at Tennessee Technological University. His primary research interest is ecology and management of waterfowl, especially Canada geese. He received his B.S. and M.S. degrees from Auburn University and his Ph.D. degree from the University of Missouri. He is a certified wildlife biologist and a past president of the Tennessee Chapter of The Wildlife Society.