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Changes in distribution of Canada geese nesting in Arkansas

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Abstract: The reintroduced Canada goose (*Branta canadensis*) population in Arkansas has grown in range and abundance in recent decades. We determined the geographic range of Arkansas resident Canada geese from 2004 to 2012 using volume contour maps from citizen science observations using eBird, a citizen science website, and hunter recovery locations from the U.S. Geological Survey Bird Banding Laboratory. Resulting maps indicate an increase in Canada goose encounters toward northwestern and southwestern Arkansas from the original relocations in the Arkansas River valley. We examined movement of Canada geese banded and recovered in Arkansas by determining the distance and angle of movement between initial and final encounter locations; 25% moved east, and 17% went west. The average distance moved from banding to recovery was 50 km (SE = 1 km). Recoveries of Canada geese banded in Arkansas were greatest in the Mississippi Flyway (58% of all geese) followed by the Central Flyway (37%) with some representation in both the Atlantic (4%) and Pacific flyways (0.9%). Movement from Arkansas to other states and Canada was influenced by goose age and sex. Older individuals traveled longer distances than younger ones, and females traveled longer distances than males. Our findings suggest that recently established Canada geese in Arkansas have slowly expanded within the state to the northwest and southwest with the expansion to the east being important now. Movement of Arkansas resident Canada geese on molt-migration can contribute to management issues in other states and provinces.

Key words: Arkansas, *Branta canadensis maxima*, dispersal, molt-migration, movements

Reintroduced populations of giant Canada geese (*Branta canadensis maxima*) are expanding throughout the Mississippi and Atlantic flyways. Management of temperate-nesting geese has evolved to address this continuing growth, especially as geese move from original rural reintroduction sites into suburban and urban areas (Conover and Chasko 1985, Nelson and Oetting 1998). Farm ponds, golf courses, and public parks have provided refuges with abundant food and minimal risk of predation, but increased goose presence in suburban habitats has become an increasingly controversial public relations issue (Conover and Chasko 1985; Smith et al. 1999).

The Mississippi Flyway Council (1996) giant Canada goose committee's management plan for giant Canada geese includes specific goals regarding population control and alleviation of negative human–goose conflicts in portions of the reintroduced populations' ranges within urban and suburban environments. The Mississippi Flyway Council (1996) strategies for temperate-nesting Canada geese in sites where hunting or firearm use is restricted include nonlethal abatement techniques, habitat manipulation, and, if necessary, other methods, such as egg destruction or lethal control of adults captured during the summer when the geese are flightless. However, limited funding, public concerns, and insufficient information about goose ranges and dispersal patterns hinder management strategies to achieve individual state goals regarding reintroduced populations (Ankney 1996).

Molt migrations further complicate management. Subadults and failed nesting Canada goose adults will frequently perform molt migrations, flying northward around May to June and return to temperate regions in August to September, although >25% of these birds may not return until after October 1 (Zicus 1981, Luukkonen et al. 2008, Dieter et al. 2010, Dunton and Combs 2010, Radtke and Dieter 2010). The distance moved by molt-migrating females may be up to 2,500 km, with geese moving from temperate zones to as far north as the 64th Parallel (Luukkonen et al. 2008). Molt migrants can deminish the effectiveness of targeted harvest efforts to reduce nuisance Canada goose issues in northern areas (Iverson et al. 2014).

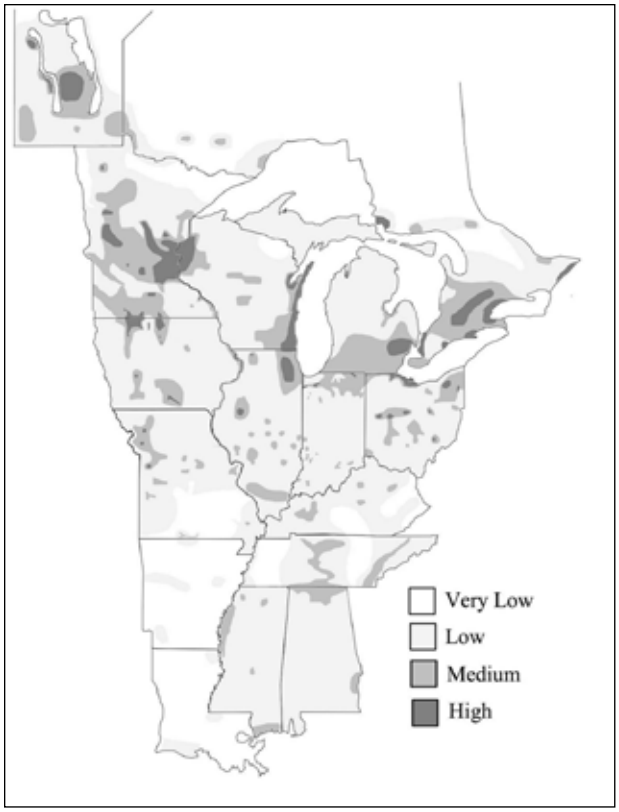

Figure 1. Approximate range of resident Canada geese in the Mississippi Flyway in 1995. Adapted from Mississippi Flyway Giant Canada Goose Management Plan, by Mississippi Flyway Council Giant Canada Goose Committee, 1996, Mississippi Flyway Council Technical Section, Laurel, Maryland.

The Arkansas Game and Fish Commission (AGFC) reintroduced a population of Canada geese to Arkansas for harvest and viewing opportunities beginning in 1981 with continuing supplements through 1983 (Moser 1996). Release of geese occurred primarily at Lake Dardanelle State Park near Russellville and a secondary location southeast of Little Rock. Isolated subpopulations of temperate-nesting Canada geese likely occurred in the northeastern and southwestern portions of the state and at the north-central border between Arkansas and Missouri near the White River-Cache River Drainage Basin (Figure 1; Mississippi Flyway Council 1996, Moser 1996). In the 1990s, the AGFC developed a strategic plan outlining needs for banding, monitoring, and researching the population's demographics and movements (Moser 1996). Its strategic plan outlined the needs for banding, monitoring, and researching the population's demographics and movements (Moser 1996).

Harvest of Canada geese (hereafter, geese)began during late fall of 1992 in northwestern Arkansas (Moser 1996). By 2001, there were regular hunting seasons for geese (after September 15) across Arkansas, with the exception of the southeastern region. In 2007, AGFC initiated a special early hunting season for geese (September 1 to 15) in the northwestern and southwestern regions to target Arkansas resident geese. The early hunting season continued only in the northwestern region from 2008 to 2011. The AGFC opened the early hunting season in the entire state in 2012 in response to the apparent growth in abundance and range of the Arkansas resident goose population. To date, hunter recoveries occur throughout much of the state.

The objectives of our study were: (1) to examine changes in the geographic range of resident geese in Arkansas; (2) estimate average dispersal distance and direction of geese nesting in Arkansas between initial capture and final recapture or recovery within Arkansas; (3) document movements of Arkansas's resident geese and between Arkansas and other states or Canada; and (4) determine if distance traveled by Arkansas resident geese moving outside of Arkansas is related to age and sex.

Methods

Banding of temperate-nesting geese in Arkansas began in 1988, but efforts were sporadic through 2000. Increased banding by AGFC in the 2000s took place in numerous banding locations across the Arkansas River Valley and northwestern and southwestern Arkansas at public parks, AGFC facilities, and private lands (Figure 2). Changes in banding locations by the AGFC over time were in response to increases in goose nesting populations at different locations. Molting geese nesting at these locations were herded into enclosures where they were banded, and the sex and age of each bird were determined. From 2001 to 2011, AGFC banded approximately 13,000 geese with federal aluminum leg bands. We used banding

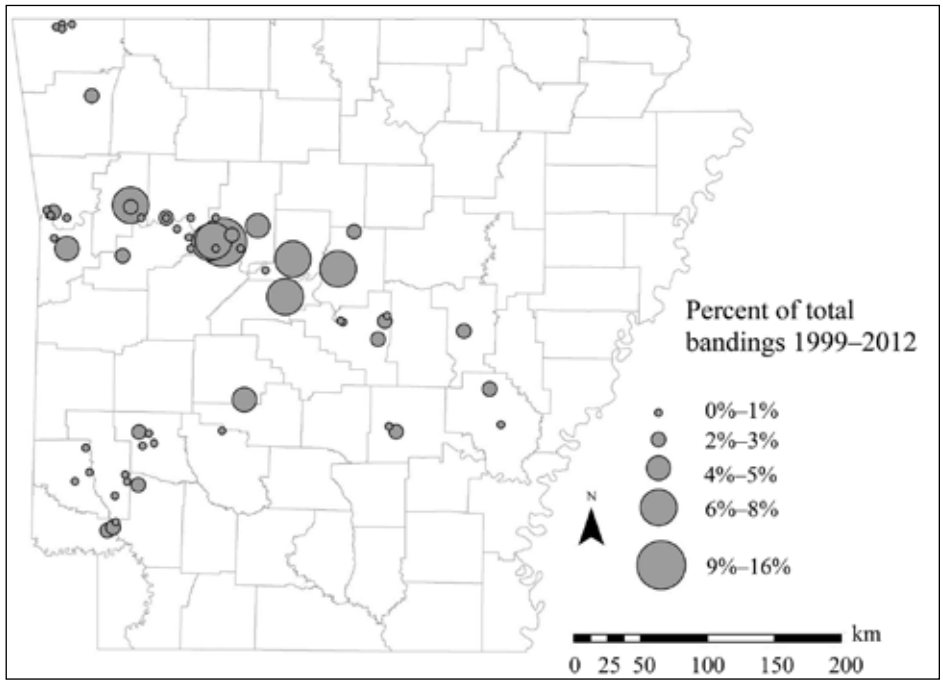

Figure 2. Locations of Canada goose breeding season bandings in Arkansas from 1999 to 2012. Circle size indicates the percentage of the total number of banded Canada geese from those locations.

and recovery data on the Arkansas banded geese from 2001 to 2011 from U.S. Geological Survey Bird Banding Laboratory (BBL) and recovery data for 2001 to 2012 for analysis. We retrieved data on live recaptures of Arkansas banded geese for the years 2006 to 2011 from AGFC. We also retrieved live goose breeding season observations in Arkansas for the years 2004 to 2012 from eBird, a citizen science website organized by Audubon and Cornell Lab of Ornithology (Sullivan et al. 2009).

Geographic distribution

We created distribution maps of geese in Arkansas for 2004 to 2012 using coordinates of geese recovered by hunters that were banded in Arkansas from the BBL and sightings during the breeding season from eBird. We excluded years before 2004 from analysis because eBird reported <30 observations in those years. After producing shapefiles of the observation points in ArcGIS (Environmental Systems Research Institute 2012) for each year, we created kernel density estimates in program R (R Foundation for Statistical Computing, Vienna, Austria) using the home range estimation package, adehabitatHR (Calenge 2011). Kernel density estimation assumes that observations are independent and evenly distributed. However, the resulting utilization distributions can be biased due to sampling methods and spatial auto-correlation. Observations from eBird were concentrated on areas of high human population and included few rural locations. Similarly, banding harvest records were concentrated on the Arkansas River Valley and were less representative of southern Arkansas. We, therefore, combined the 2 datasets to help us address the shortcomings in each and achieve a more comprehensive sample across the state.

We used for each year a smoothing parameter based on the reference bandwidth equal to:

$$h = \sigma \times n^{-1/6}$$

where

$$\sigma = 0.5 \times (\sigma_x + \sigma_y)$$

and σ_x and σ_y are the x and y coordinate standard deviations (Calenge 2011). Though the reference bandwidth method can result in over-smoothing, successive trials revealed this

method as the most appropriate to produce visually useful maps (Calenge 2011). We used adehabitatHR to convert the kernel density output into volume utilization distribution rasters appropriate for computation of home range contours where contour line values indicate the probability level of given raster pixels falling within the species range (Calenge 2011). We used the series of resulting images to display the change in temperate-nesting goose distribution over time.

Dispersal within Arkansas

Of the 13,118 geese that AGFC banded from 2001 to 2011, 4,469 were encountered again in Arkansas, either as a live recapture at a subsequent goose banding roundup or as a dead recovery that hunters reported to the BBL. We determined the final encounter with each of the 4,469 geese. We examined histograms of the distance between initial and final capture to determine a natural break between apparent local movement and dispersal. A break occurred at the median distance of 15 km. Hence, we excluded from dispersal analysis 3,052 geese that moved <15 km, treating those individuals as residents performing local movements only. We created a wind rose diagram of goose dispersal within Arkansas from 2001 to 2011 using the coordinates of the banding location and final recovery or live recapture location of each of the remaining 1,417 geese. We produced line shapefiles in ArcGIS connecting initial and final encounter points and measured the distance and angle of dispersal (Environmental Systems Research Institute 2012). We used the frequency of distances and directions to create the wind rose diagram with the grammar graphics package (ggplot2) in program R (Wickham 2009).

Movement outside of and into Arkansas

We examined the recovery locations of 114 geese banded in Arkansas and recovered outside of Arkansas from 2001 to 2011 by documenting which states and Canadian provinces recovered the most Arkansas-banded geese. We also determined the origin and relative proportion of banded geese moving to Arkansas. Further, we examined the recoveries from outside Arkansas by creating generalized linear models examining the relationship between distance traveled and sex and minimum age at recovery. We created 4 candidate models: a null model and 3 models that accounted for distance as a function of sex, age, and the interaction of sex and age. We used Akaike's Information Criterion (AIC; Akaike 1973) to select among candidate models. We considered all models within $\Delta AIC \leq 2.00$ to be acceptable for the data to account for model-selection uncertainty.

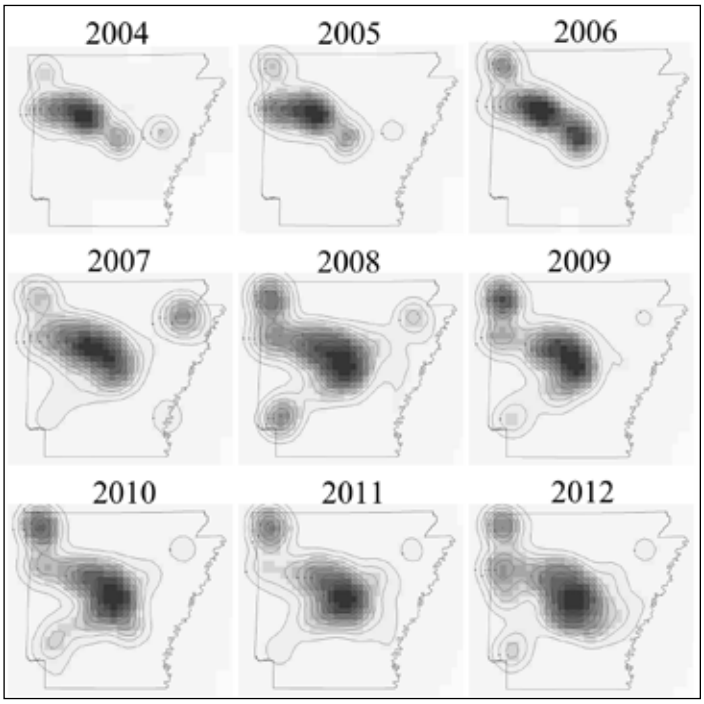

Figure 3. Volume contour maps of Canada goose encounters in Arkansas from 2004 to 2012 from eBird and the U.S. Geological Survey Bird Banding Laboratory combined. Dark tones indicate a higher volume of observations. Light tones indicate a lower volume of observations. The contour interval is 10%.

Results

Geographic distribution

Volume contour maps of both BBL and eBird data show an increase in goose encounters in northwestern Arkansas and along the

Table 1. States and provinces recovering Canada geese banded in Arkansas during the breeding season. Recoveries occurred during normal seasons or during early seasons.

State or province	Recoveries
Minnesota	17
Manitoba	16
Oklahoma	16
Missouri	14
Iowa	10
North Dakota	7
South Dakota	7
Georgia	5
Kansas	4
Texas	4
Colorado	3
Indiana	3
Illinois	2
Michigan	2
Nebraska	1
Saskatchewan	1
Tennessee	1
Utah	1
Wisconsin	1

Arkansas River Valley between 2004 and 2012 (Figure 3). Pockets of geese also occurred in southwestern and northeastern Arkansas. The highest concentrations of temperate-nesting geese consistently occurred in the center and northwestern corners of the state.

Dispersal within Arkansas

Of the 3,052 resident geese that performed only local movements, the average local movement distance was 9.6 km. The wind-rose diagram of temperate-nesting goose dispersal in Arkansas shows the greatest movement in the east (75° to 105°) and west (255° to 285°; Figure 4), with 42% of geese dispersed along the east-west axis (25% east and 17% west). The average dispersal distance was 50.1 km (SE = 1.13 km). The first quartile, median, and third quartile distances were 24 km, 31 km, and 63 km, respectively. The maximum dispersal distance was 344 km. The greatest average distance occurred within the east-northeast directional wedge ($\bar{x}$ = 87.8 km, SE = 10.68 km).

Table 2. States and provinces of origin of Canada geese banded outside Arkansas and recovered in Arkansas.

State or province	Reoveries
Missouri	82
Iowa	37
Tennessee	20
Minnesota	16
Wisconsin	11
Illinois	7
Indiana	5
Michigan	4
Kentucky	3
Nebraska	3
Kansas	2
Ohio	2
Colorado	1

The lowest average distance occurred within the north directional wedge ($\bar{x}$ = 29.9 km, SE = 3.06 km).

Movement outside of and into Arkansas

One-hundred-fourteen geese banded in Arkanssas were recovered across 19 states and provinces (Table 1). Most (66) recoveries occurred in the Mississippi Flyway, with some recovered in the Central Flyway (42), the Atlantic Flyway (5), and Pacific Flyway (1). The 186 geese banded outside of Arkansas and recovered in Arkansas came from 12 states, mostly in the Mississippi Flyway (Table 2).

Both models of distance as a function of age and sex were plausible (Table 3). In both top models, age was positively correlated with distance, with older individuals traveling relatively longer distances than younger individuals. In the model incorporating age and sex, younger males traveled relatively the shortest distances ($\bar{x}$ = 423 km, SE = 151.6 km), and older females traveled relatively the longest distances ($\bar{x}$ = 941 km, SE = 82.3 km).

Discussion

Reintroduction of geese to Arkansas by AGFC has met stated objectives of developing a self-supporting population and providing hunting and viewing opportunities (Yaich

Table 3. Model selection results for distance traveled by Canada geese banded in Arkansas and recovered elsewhere from 2001 to 2011. Covariates represent the minimum age at recovery and sex. Only models with fit better than or equal to the null model are reported.

Model	K*	AIC*	ΔAIC*	w_i*
Distance ~ age	2	1774.9	0.0	0.555
Distance ~ age and sex	3	1775.7	0.8	0.372
Null	1	1780.2	5.3	0.039

*K = number of parameters; AIC = Akaike's Information Criterion; ΔAIC = difference in AIC relative to smallest value; *wi* = AIC weight.

1994, Moser 1996). As the goose population has grown, AGFC has expanded the area open to goose hunting, lengthened the hunting season, and liberalized the bag limit.

Past and present range maps of Arkansas resident geese provide insight about potential future expansion. The Mississippi Flyway Council (1996) reported the approximate range of giant Canada geese in the Mississippi Flyway to include a portion of the Arkansas River Valley and isolated pockets in southwestern, northeastern, and north-central Arkansas (Figure 1). Our range maps display expansion of the population from original release locations at Lake Dardanelle and southeast of Little Rock throughout the Arkansas River Valley and into northwestern Arkansas. Additional pockets occurred in southwestern and northeastern Arkansas, similar to the original range estimate of the Mississippi Flyway Council (1996). The densest concentrations of goose encounters occurred consistently in the center and northwestern corner of the state. No pocket in the White River-Cache River Drainage Basin at the Missouri and Arkansas border appeared in our range maps, despite historic evidence of a subpopulation in the area (Figure 1; Mississippi Flyway Council 1996, Moser 1996).

The absence of the White River-Cache River Drainage Basin subpopulation and the high concentrations around Little Rock and northwestern Arkansas are artifacts of the inherent biases in both BBL and eBird data in Arkansas. Banding of geese has historically been highly concentrated in the Arkansas River Valley, especially around Lake Dardanelle, and hunting of geese is also highly concentrated around Lake Dardanelle and surrounding areas in the Arkansas River Valley. Alternatively, eBird data are biased toward high concentrations of human populations (Sullivan et al. 2009). The areas surrounding Little Rock, Texarkana, and northwestern Arkansas, where human population density is high, produced the greatest number of eBird observations throughout all years. Little to no observations occurred each year in areas of low population density. Combining the BBL data and eBird data

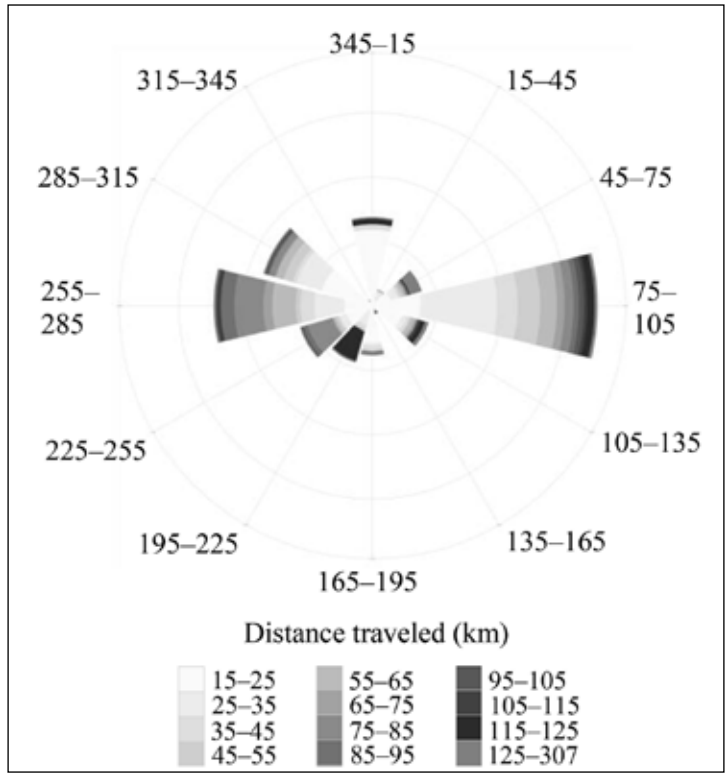

Figure 4. Wind-rose of direction and distance travelled by Canada geese banded in Arkansas from 2001 to 2011 and live-recaptured or hunter-recovered in Arkansas from 2001 to 2012.

helped partially compensate for each dataset's biases, but our resulting range maps remain somewhat uncertain estimates of goose concentrations across Arkansas.

Further evidence of goose expansion along the Arkansas River Valley was apparent in our wind-rose dispersal analysis. The wind-rose data suggest dispersal of geese along the east-west corridor of the valley, with more and longer movements toward the Mississippi Alluvial Valley. If resident geese do not already occur (or occur only at low densities) in the Mississippi Alluvial Valley, we predict that sustained subpopulations will arise in the near future (Figure 5).

Figure 5. We predict that subpopulations of Canada geese will arise in the near future.

Distance analysis of dispersal within Arkansas provides insight about the resident goose population. The average dispersal distance (50 km) was comparable to the average dispersal distance that James and Krementz (2005) reported for the central mixed-grass prairie ($\bar{x}$ = 49.2 km, SE = 6.28 km) and oaks and prairies ($\bar{x}$ = 61.3 km, SE = 14.35 km) bird conservation regions. However, most of our banded geese performed only local movements, remaining within 15 km of their original banding location. Other studies have found that resident Canada geese exhibit little movement between banding sites and subsequent recovery sites. Holevinski et al. (2006) and Powell et al. (2001) found that geese translocated out of urban areas in New York and Georgia, respectively, remained at or near release sites. James and Krementz (2005) encountered similar results in all 6 bird conservation regions, with high proportions of geese both banded and recovered within the same 10-minute block. Conover (2011) also reported minimal movement of resident Canada Geese in Connecticut. Because resident geese frequently move only short distances rather than dispersing long distances into other states or regions, Conover (2011) suggested that populations in different geographic areas are unlikely to have significant interactions with each other and recommended an emphasis on management at the state and local level.

Only 6% of geese recovered in Arkansas originated in other states, and only 4% of geese banded in Arkansas were recovered in other states, suggesting minimal influence of 1 goose population on populations in other geographic areas. James and Krementz (2005) similarly concluded geographically separate subpopulations of temperate-nesting geese are unlikely to have much direct interaction. Conover (2011) reported not only minimal exchange of geese among states, but also an overall decline in the number of out-of-state recoveries over the past 2 decades. Of the Arkansas geese that did move, we found that the greatest exchange occurred between Arkansas and states and provinces in the Mississippi Flyway directly to the north. Northern latitude states and Canadian provinces account for a substantial portion of the total Mississippi Flyway goose harvest, and many states have early season harvests targeting resident geese before the arrival of migrants (Fronczak 2012). Molt migrants from more southern states can experience lower survival due to the early season harvest in higher latitudes (Luukkonen et al. 2008, Dieter and Anderson 2009, Iverson et al. 2014); and a high take of molt migrants in northern regions may aid in alleviation of high goose population issues in temperate latitudes (Luukkonen et al. 2008). Of concern, though, the movement of molt migrants to northern areas may reduce the effectiveness of those early hunting seasons designed to target local resident geese. For example, Iverson et al. (2014) found that molt migrants from southern regions were diluting the effects of early season hunts that target geese produced in Ontario, Canada. Thus, even though the number of

geese harvested in Ontario has increased over time, population growth of temperate nesting geese there has not tapered off.

Our top models of distance travelled by geese banded in Arkansas and recovered outside Arkansas suggested that both older geese and females are likely to travel farther than are younger geese and males, contrary to original theories on molt migrations (Hanson 1965). More recent research suggests that no particular rules apply to molt migrants (Luukkonen et al. 2008). Our model results indicated a higher propensity to disperse or migrate longer distances among females with failed nest attempts rather than nonbreeding subadults or males. Luukkonen et al. (2008) found that approximately 80% of geese with destroyed nests performed molt migrations, which may provide a management option for discouraging reproductive females from remaining in urban nesting habitat.

As the resident Arkansas goose population continues to expand, its harvest and management across Arkansas will become increasingly important, especially in suburban environments. Research specifically exploring translocation of geese from urban to rural areas may provide insight to whether geese in Arkansas would remain in release areas subject to harvest as our local movement data suggest. Additionally, nest destruction to induce molt migration of reproductive females may aid population control in Arkansas but may hinder efforts to control populations farther north.

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