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Late summer movements by giant Canada geese in relation to a September hunting season

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Abstract: The population of giant Canada geese (*Branta canadensis maxima*) breeding in eastern South Dakota has increased dramatically since reintroduction efforts began in the 1960s. May breeding population levels of giant Canada geese exceeded population management goals set by the South Dakota Department of Game, Fish and Parks (SDGFP) by the mid-1990s, and the population has continued to increase into the 2000s. This population increase was accompanied by an increase in goose-related conflicts such as crop depredation. In 1996, a September hunting season was implemented in select counties in eastern South Dakota in an effort to reduce the giant Canada goose population. After its implementation, some hunters and biologists were concerned that the early September season was causing Canada geese to disperse from areas open to hunting due to hunting pressure. Herein, we describe post-molt movements by geese, particularly in relation to the September hunting season. We caught Canada geese in 7 counties in eastern South Dakota during the summer molting period, 2000 to 2003. We attached VHF (n = 153) and satellite transmitters (n = 43) on adult female geese with broods. We monitored movements of marked geese weekly from July through the fall freezing period. For this study, we considered major movements any post-molt movement ≥40 km from the wetland in which the goose was banded prior to October 15. Forty-six percent of marked geese made major movements from July to September, and 43% moved during the first week of the September season, indicating that the season may have triggered their post-molt movement. Major movements were primarily in a northerly direction, and the longest documented post-molt movement was 474 km north. It appears that the onset of the September hunting season may have caused geese to move immediately before or during the first 10 days of the season. Post-molt movements prior to the September hunting season may simply have been a function of established, learned traditions, but the punctuated movement of geese during the opening weekend of the hunting season may have resulted from geese responding to the hunting season itself.

Key words: Canada geese, human–wildlife conflicts, hunting, post-molt movements, radio telemetry, resident geese, satellite transmitters, September hunting season

Populations of giant resident Canada geese (*Branta canadensis maxima*) have increased dramatically (i.e., 12% per year from 1966 to 1999; Gabig 2000) in eastern South Dakota since reintroduction efforts began, and the population appears to be highly productive (Dieter and Anderson 2009*a*). The population objective for South Dakota, based on aerial surveys conducted in May by the U.S. Fish and Wildlife Service (Smith 1995), was 80,000 to 90,000 geese. But, since 1998, the population estimate has averaged 126,200 (1998 to 2009; Vaa et al. 2010). The population increase has been accompanied by an increase in goose-related problems, primarily crop depredation by geese during the brood-rearing and molting period (Flann 1999, Schaible et al. 2005). From 2000 to 2009, the South Dakota Department of Game, Fish and Parks (SDGFP) annually spent >$325,000 on Canada goose damage management activities in >20 counties in the state (Vaa et al. 2010). A September goose hunting season was implemented in 1996 for 10 counties (expanded to 56 counties in 2007) in eastern South Dakota, largely under the presumption that increased hunting pressure would increase overall harvest of Canada geese, thereby alleviating depredation complaints (Gabig 2000, Sheaffer et al. 2005, Vaa et al. 2010). The early September season (1996 to 2008) resulted in an average annual harvest of ~28,000 Canada geese, ranging from a low of 11,281 geese during 1997 to a high of 51,491 geese in 2001 (Vaa et al. 2010). Even though hunter numbers have declined during the early September season in recent years, an increasing proportion (annual $\bar{x}$ = 22.58 ± SE = 2.00%) of the total annual Canada goose harvest is comprised of geese shot during the early September season (SDGFP, unpublished data). Several years after the September season was initiated, there was a growing concern that the early hunting season was causing geese to disperse from areas open to hunting to areas closed to hunting within the state or to other states (Dieter and Anderson 2009*b*). It appeared that many geese were making considerable post-molt movements early in the autumn, possibly in response to the September hunting season (Anderson and Dieter 2009, Dieter and Anderson 2009*b*).

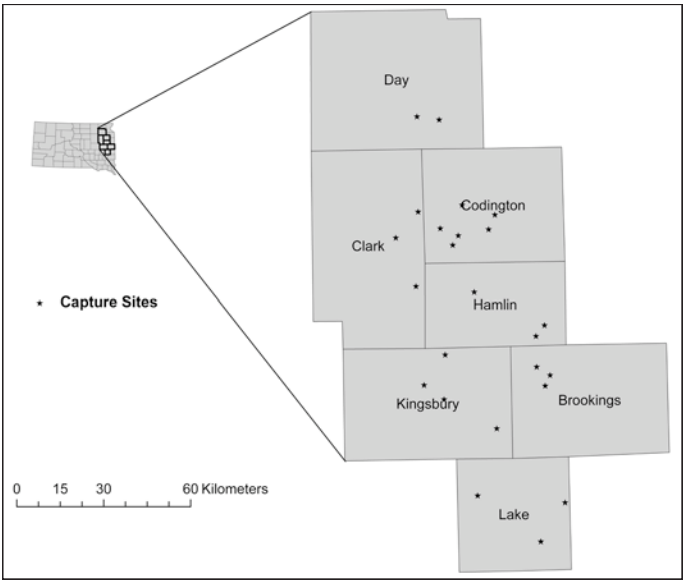

Figure 1. Counties and capture sites (as stars) in eastern South Dakota where Canada geese were captured and fitted with neck-collars with VHF transmitters or PTTs, 2000–2003.

The extent of post-molt movement patterns of Canada geese and their response to hunting have not been studied in many locations (but see Mykut et al. 2004, Luukkonen et al. 2008). Most studies of Canada geese have involved documenting local movements of migrant geese and their subflocking behavior around specific refuge areas (Kennedy and Arthur 1974, Koerner et al. 1974, Zicus 1981, Anderson and Joyner 1985, Schultz et al. 1988). These subflocks exhibited discrete movement patterns and differential harvest rates among subflocks (Koerner et al. 1974, Zicus 1981, Schultz et al. 1988, Powell et al. 2004). For example, Raveling (1978) found that geese banded in Manitoba and migrated through Rochester, Minnesota, sustained much higher harvest rates than those migrating farther west. Using band-recovery data only, Powell et al. (2004) documented subpopulations of Canada geese in Nebraska that differed with respect to movements and survival (but see Groepper et al. 2008). However, none of these studies documented the full extent of post-molt movements of Canada geese. Other than leg-band recoveries (Gleason 1997, Gleason et al. 2003), there has not been any previous research regarding post-molt movements of Canada geese in eastern South Dakota.

Effective management of eastern South Dakota's resident goose population requires an understanding of the extent of subpopulation structure and post-molt movements. The primary objective of this study was to document the extent of post-molt movements made prior to fall freezing period by adult female Canada geese (and their broods). We wanted to describe post-molt goose movements and chronology, particularly in relation to the early September hunting season.

Study area

We captured Canada geese in Brookings, Clark, Codington, Day, Hamlin, Kingsbury, and Lake counties in eastern South Dakota (Figure 1). Waterfowl habitats within the Central Flyway, of which South Dakota is a member, are described in detail by Brewster et al. (1976) and Batt et al. (1989). The 7 counties where we captured geese were within the Coteau des Prairies (hereafter, Coteau), a glaciated region between the James River Lowland to the west and the Minnesota River-Red River Lowland to the east (Gab 1979, Hogan and Fouberg 1998, South Dakota Department of Game, Fish, and Parks 2005). Elevation ranged from 518 m in the southeast to >610 m above sea level in the northeast (Hogan and Fouberg 1998). The elevation of the James River Lowland ranged from 396 m to 426 m, and the Minnesota River-Red River Lowland to the east has as elevation about 244 m lower than the Coteau (Hogan and Fouberg 1998). The large number and diversity of wetlands in the Coteau are used extensively by breeding and staging waterfowl (Brewster et al. 1976, Batt et al. 1989, Naugle et al. 2001, U.S. Fish and Wildlife Service 2009).

The eastern edge of the study area lies within the tall-grass prairie gradually giving way to the northern mixed-grass prairie to the west (Samson et al. 1998). However, because of the rather gentle topography and increasing interest in row-crop agriculture, much of the study area has been converted to crops (Higgins et al. 2002). The major agricultural crops within the study area include corn (*Zea mays*), soybeans (*Glycine max*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), alfalfa (*Medicago sativa*), and prairie-wetland hay. Livestock production also is an important part of the agricultural economy. A more detailed description of the habitat types, vegetation, soils, climate, and topography of the study area is available at SDGFP (2005).

Methods

Trapping

We captured Canada geese (i.e., molting adults, subadults, and goslings) during their summer flightless period (June 23 to July 11) from 2000 to 2003. Prior to capturing geese, we visited sites to ascertain flock size and composition. We selected capture sites with brood flocks because nesting females were our population of interest for marking (Anderson 2006). We captured geese by driving them into corral-type traps (Cooch 1953) placed in shallow bays with gradually sloping shorelines. All trapped geese were banded with standard USFWS aluminum leg bands, unless the geese previously had been banded. We used plumage characteristics and cloacal examinations to determine age and sex of geese (Hanson 1962, Hanson 1997). Adults and goslings were aged and classified as "after hatch year" (AHY) and "hatch year" (HY), respectively. We recorded band numbers of recaptured geese, and then released the geese. We reported recaptured geese to the USFWS Bird Banding Laboratory (BBL). Although we attempted to select only wetlands with concentrations of brood flocks, there was the potential of attaching transmitters to molt migrant females from other areas because unsuccessful females sometimes molt migrate (Sterling and Dzubin 1967, Lawrence et al. 1998, Abraham et al. 1999, Dieter and Anderson 2009*b*), and molt migrants from several states were known to use wetlands in eastern South Dakota (Gleason 1997, Gleason et al. 2003). In some years, an estimated 35% of recaptured geese during banding were molt-migrants from other states (SDGFP unpublished data). However, we selected only adult breeding females, as evidenced by a brood patch to mark with transmitters (Hanson 1959), so we believe most geese were local breeders. During 2000 and 2001, we attached only very high frequency (VHF) transmitters, but during 2002 and 2003, we attached both platform transmitting terminals (PTT), satellite transmitters, and VHF transmitters. At each capture site, we attached transmitters to 5 to 10 female geese.

We used a combination of VHF and PTT telemetry to document post-molt movements. Conventional VHF telemetry has been used extensively to study breeding ecology and movements of various species of waterfowl including Canada geese for >40 years (Cochran et al. 1963, Schultz et al. 1988, Mykut et al. 2004, Hupp et al. 2006). Recent advancements in technology has led to reductions in both the size and weight of PTTs, making them more appropriate for monitoring movements of waterfowl species, including pink-footed geese (*Anser brachyrhynchus*; Glahder et al. 2006), Greenland white-fronted geese (*Anser albifrons flavirostris*; Fox et al. 2003), lesser white-fronted geese (*Anser erythropus*; Lorentsen et al. 1998, Aarvak and Oien 2003), emperor geese (*Chen canagica*; Hupp et al. 2007, Hupp et al. 2008), greater snow geese (*Chen caerulescens atlantica*; Blouin et al. 1999), Canada geese (Malecki et al. 2001, Mykut et al. 2004), and even the small-bodied Atlantic brant (*Branta bernicla hrota*; Gudmundsson et al. 1995). Several authors have cautioned researchers interested in estimating survival of geese marked with neck collars or transmitters (Samuel et al. 1990, Castelli and Trost 1996, Schmutz and Morse 2000, Alisauskas and Lindberg 2002). Due to the short duration of our study (~4 months), we assumed 100% retention of neck-collars (see Coluccy et al. 2002) and that marker effects were negligible.

Telemetry equipment

VHF transmitters were manufactured by Advanced Telemetry Systems (Model 3630, 57 g; Isanti, Minn.) and were attached to black neck collars (made by P. Mammenga, SDGFP) from 2000 to 2002. During 2003, black neck collars were made from Rowmark® plastic (7 cm x 16.5 cm; Spinner Plastics, Springfield, Ill.). VHF transmitters were designed with an antenna (21 cm) that protruded from the top-rear of the collar at a 45° angle and ran down the bird's back. VHF collars had a pulse rate of 50 ppm, a pulse width of 20 ms, and a guaranteed battery life of 300 days. All VHF transmitters had frequencies within the 150 and 151 MHz range, transmitted continuously, and did not have mortality censors. Based on field testing before and after deployment, VHF units had an effective ground and aerial range of approximately 3.2 and 32 km, respectively.

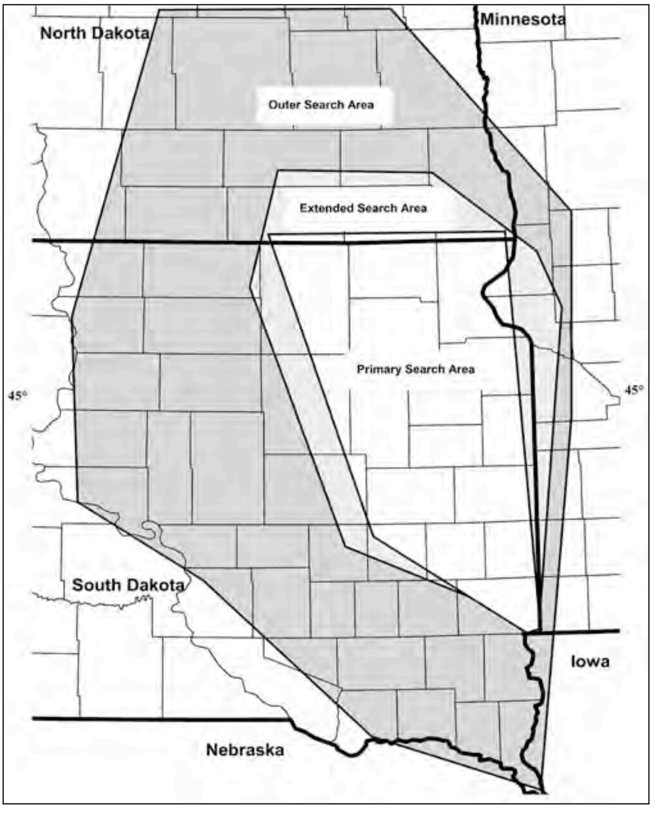

Figure 2. Boundaries of aerial search areas used to locate neck-collared Canada geese with VHF transmitters in eastern South Dakota, 2000 to 2003. The primary area was flown weekly; the extended area was flown every 2 to 3 weeks, and the outer area was flown 2 to 3 times per year.

We attached satellite transmitters (Model ST-19, 74 g; Telonics Inc., Mesa, Ariz.) to black neck collars made from Rowmark plastic (Spinner Plastics, Springfield, Ill.) during 2002 and 2003. The PTT design for 2002 was similar to the redesigned PTT used by Mykut (2002). Satellite transmitters had a specified battery life of approximately 360 hours that was separated over 4 distinct monitoring periods (duty cycles). During 2002, PTTs had a 4-hour transmission on window and then would shut off, which allowed the transmitter to operate a total of 60 times during the 365-day period (D. Crow, Telonics Inc., personal communication). There were problems with data quality used during 2002. Telonics Inc. redesigned transmitters for 2003, and the "on" period was extended to 8 hours, allowing the transmitter to transmit 45 days during the 365-day period. The transmitter duty cycles in 2003 maximized data collected with the limited battery life. Neither the VHF (1.45%) nor PTT (1.80%) packages (including weight of collar) exceeded the 3% of the body mass threshold recommended by Advanced Telemetry Systems (see review by Barron et al. 2010).

We used black plastic collars in an effort to prevent hunters from selectively shooting collared geese out of flocks (Samuel et al. 1990, Castelli and Trost 1996). Both PTTs and VHF transmitters had labels on them that included an address and phone number to contact if someone harvested a collared goose. During 2002, we affixed reward labels for $100 to PTTs to increase the probability of reporting marked geese harvested or found dead. No reward labels were affixed to other transmitters during this study.

VHF monitoring

We monitored VHF-marked geese weekly into November and early December when inclement weather caused geese to migrate south of South Dakota. From July to early August, we used a

4-element, null-peak antenna system mounted on top of a 4-wheel-drive pickup to monitor geese. We used ground telemetry to search for geese within approximately a 13-km radius of the previous week's location. We determined goose locations visually or from triangulation during ground telemetry. We marked locations on detailed maps made in ArcView GIS, Version 3.2, software (Environmental Systems Research Institute, Redlands, Calif.) with themes of wetlands, streams, and roads. We used a Garmin® Rhino 120 GPS to record the Universal Transverse Mercator coordinates. We recorded the date, time, flock size, and general habitat of the location each time we located a VHF-marked goose.

After mid-August, we were often unable to locate marked geese, so we used aerial surveillance to find them. The area where geese were monitored encompassed only counties east of the Missouri River in South Dakota, southeastern North Dakota east of Highway 281 and south of I-94, and 45 km into western Minnesota from the northern South Dakota border south to I-90 (Figure 2). In addition, we collected satellite telemetry and band-recovery data from areas within the Central and Mississippi flyways from as far north as Nunavut, Canada, to as far south as Oklahoma (Anderson and Dieter 2009, Dieter and Anderson 2009*b*). The first few days of each week consisted of ground-based telemetry, with aerial surveillance conducted later during the week to locate geese.

For aerial telemetry, we used a directional, 4-element yagi antenna mounted on each wing strut of a Cessna 172 fixed-wing aircraft (Gilmer et al. 1981). The plane was flown at an elevation of 1,372 to 2,286 m above mean sea level, depending on weather and ceiling conditions. We flew at a target elevation of ~1,829 m under ideal conditions. Aerial surveillance was designed to cover as much area as possible based on the effective ranges of the VHF transmitters. The receiver scanned through all frequencies, cycling from 1 frequency to the next every 4 seconds. Aerial searches for individual geese would start at the last known location. If the goose was not located, we flew north-south transects 32 km apart to locate the goose. We recorded goose locations on detailed maps created with ArcView 3.2 GIS software and UTM coordinates were taken if there was any question about the location.

We flew the primary search area almost weekly, the extended search area roughly every third week, and the outer search area only 2 or 3 times each fall. We flew 4 to15 hours each week between late August and early November, for an annual total of 60 to 120 hours of flight time. The greatest amount of flying time occurred between late August and mid-October.

PTT monitoring

Locations of PTT-marked geese were received by Service Argos Inc. (Largo, Md.), through their Argos System (ARGOS), a satellite-based location and data collection system. PTT location data were sent to us through Service Argos' Automated Distribution Service. ARGOS provides 2 location estimates per PTT during each satellite overpass and designates the location with the best frequency continuity as the best location ("location 1"). We termed the alternate location "location 2". We determined on several occasions that location 2 was the best one, based on flight capabilities of Canada geese. We used a sorting routine to evaluate the location pairs and remove the biologically implausible location (Britten et al. 1999, Malecki et al. 2001). ARGOS assigns each location a location class (LC) based on its accuracy estimates. We used only LCs that were appropriate for accurately indentifying goose locations (Brothers et al. 1998, Britten et al. 1999).

Data analysis

We imported all location information for both VHF and PTT transmitters into ArcView® 3.2 GIS software to document and map movements and distances traveled between consecutive locations. We measured distances that geese moved from banding sites and placed them in 3 distance bins: (1) <40 km; (2) 40 to 100 km; and (3) >100 km. We considered any movement >40 km to be a major movement because a movement of this distance would allow a marked goose to emigrate to an adjacent county potentially outside the hunting zone. We recorded the date, distance, and direction of major movements. The distance reported for each individual goose was the maximum that was documented for a goose away from its capture site during the first autumn following capture. We calculated the maximum distances in ArcView 3.2 GIS software by measuring the distance from an individual's farthest location from its capture site prior to the fall freezing period. We assumed that aerial telemetry would result in a 100% detection probability for VHF-marked geese within the area searched. If a VHF-marked goose was not located by aerial telemetry within the search areas, we assumed the goose had moved outside the search area because only 3 VHF transmitters were confirmed malfunctions during the study (Anderson 2006). We assigned geese that moved out of the aerial search areas a maximum distance reading of ≥100 km for analysis purposes. Aerial search areas often extended well beyond 100 km distance from specific capture sites, and many geese that flew outside the search areas likely moved much farther than 100 km. A Chi-square test was used to compare by year the number of geese that made post-molt movements.

We defined the departure date as the date a marked goose made a major movement from its capture site. We defined the return date as the date a marked goose returned to its capture area. We created maps of goose movements using ArcView 3.2 GIS software for each county where geese were captured during each year.

Many VHF transmitters were operational for 2 autumns after attachment to a goose, allowing comparisons of yearly post-molt movements by individual geese. We compared second year movements of VHF-marked geese in 2000 to 2002 with the individual's prior year's movements to determine differences. We did not include VHF-marked geese from 2003 in this analysis because all monitoring of transmitters ended June 30, 2004. PTT transmitters provided functioning signals only for ≤1 year and, thus, could not be used to determine movements in the second year. We defined a goose that made major movements that varied between years as exhibiting different movements. We considered second year movements different if geese made a major movement during 1 year but not during the other year.

Results

Trapping and equipment

We trapped geese at 25 sites in 7 counties in eastern South Dakota during 2000 to 2003. During 2000 and 2001, we fitted 100 adult female geese with VHF transmitters. In 2002 and 2003, we fitted 53 geese with VHF transmitters and 43 geese with PTTs. We could not use all 196 marked geese for analysis of movements because 11 geese were excluded due to injury, death, or transmitter failure. In addition, we applied leg-bands to 3,839 geese in the study area over the 4 summers.

VHF transmitters performed well during all 4 years, with only 3 transmitters suspected of malfunctioning prior to geese making their first migration south. There was no other evidence of transmitters malfunctioning throughout the first autumn after deployment, and no geese with nonfunctioning transmitters were harvested and reported by hunters. We did not observe any geese with a nonfunctioning VHF transmitter when geese returned the first spring post-capture. In fact, 12 of 17 geese that made major movements to unknown areas in October returned to their capture areas the following spring with functioning transmitters. Most VHF transmitters continued working throughout the second autumn and even into the second spring when geese returned to their nesting grounds.

Average PTT longevity was 7.4 ± 1.13 (SE) and 7.7 ± 0.58 months for 2002 and 2003, respectively. One PTT transmitted only 3 location estimates before failing on September 20, 2002. This bird was excluded from movement analysis. The number of functioning PTTs declined with time, and many were not operational during 2002 and 2003. During 2002 and 2003, 4 geese with PTTs were shot each autumn by hunters. We did not use these birds to plot PTT longevity. During autumn 2002, PTTs began to malfunction shortly after deployment. The location class ratings for geese marked in summer 2002 were poor, and often no messages were provided during transmission periods. Redesign of the PTTs for summer 2003 resulted in a significant improvement. Messages with accurate locations were received for all transmission periods (until PTT failure), and there were no skipped transmission periods during 2003.

Post-molt movements

There was no difference in the proportion of adult females that made major post-molt movements between 2000, 55% (n = 26); 2001, 48% (n = 24); 2002, 47% (n = 20); and 2003, 30%

Table 1. Departure dates of adult female Canada geese fitted with PTT and VHF transmitters in eastern South Dakota, 2000–2003. Geese were grouped into 3 categories: (1) geese departing the week prior to the start of the September season; (2) geese departing during the first week of the September season; and (3) geese departing the second week of the September season.

Year	Week prior to season		First week of season		Second week of season	
	n	(%)	*n*	(%)	*n*	(%)
2000	15 of 26	(61.5)	9 of 26	(34.6)	1 of 26	(3.8)
2001	8 of 24	(33.3)	14 of 24	(58.3)	2 of 24	(8.3)
2002[a]	8 of 20	(45.0)	9 of 20	(45.0)	1 of 20	(5.0)
2003	6 of 14	(42.9)	4 of 14	(28.6)	4 of 14	(28.6)
Total[a] (n = 81)	37 of 81	(45.5)	36 of 81	(44.7)[b]	8 of 81	(9.8)

[a]Does not include goose 102 whose transmitter did not start functioning until September 20.
[b]By the end of the first week of the September hunting season, 89.3% of geese that made significant movements had departed.

(n = 14; χ^2_3 = 6.24, P = 0.10). Our pooled data revealed that 45% of marked geese made a major post-molt movement prior to the beginning of the autumn freezing period. Comparing transmitter types, 22 of 43 (51%) PTT-marked geese and 62 of 142 (42%) VHF-marked geese made major movements. There was a wide geographical distribution of post-molt movements.

Departure dates for geese making major movements did not differ among years (χ^2_6 = 9.22, P = 0.12; Table 1). After we pooled departure dates across years, we found that 45% (n = 37) of geese moved during the last 10 days of August, 45% (n = 36) moved during the first 10 days of September, and 10% (n = 8) moved during September 11 through 20 (Figure 3). Two geese moved at approximately August 20, and 1 goose moved during the third week of the hunting season.

The maximum distance each goose moved prior to the fall freezing period ranged from 2.6 to >100 km (Table 2). The longest documented post-molt movement was by goose 161, which migrated 474 km northward into North Dakota. Twenty geese made long-distance movements to unknown locations, and we assigned them into the >100-km distance category. For analysis, we pooled the directions of major movements by marked geese (n = 84) from 2000 to 2003. Most geese (57%) moved in a northerly direction, while 21% moved in a southerly direction, and 7% moved in a westerly direction. We could not determine which direction the remaining 14% moved. At least 38% of marked geese that made major movements returned to capture areas prior to the fall freezing period during 2000 to 2003. The return rate may have been higher because some geese may have returned briefly and gone undetected.

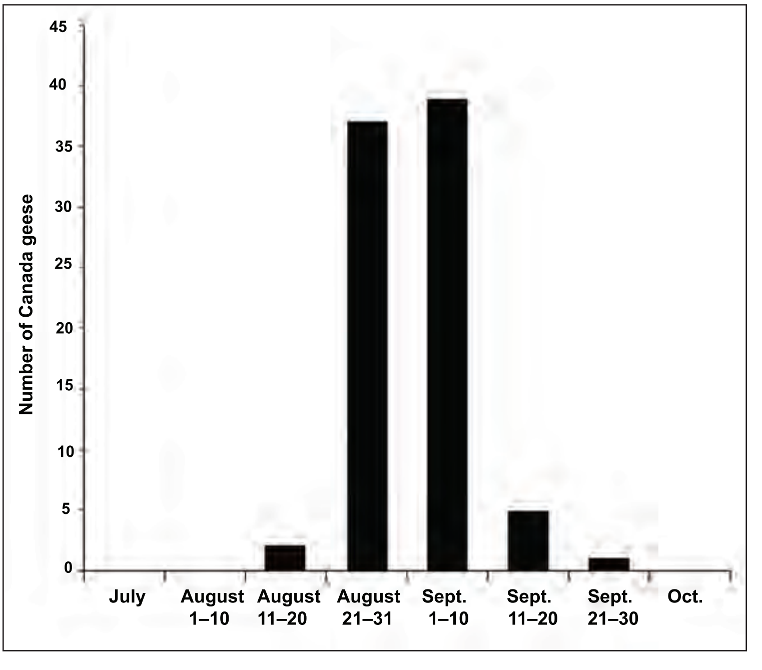

Figure 3. Number of marked adult, female Canada geese that made major post-molt movements and the movement dates in eastern South Dakota, 2000–2003.

Table 2. Maximum documented post–molt movement distances from capture sites for all VHF and PTT marked adult female Canada geese prior to freeze–up from eastern South Dakota, 2000–2003. The >100 column are VHF marked geese that moved outside the aerial search areas to unknown areas representing distances greater than 100 km.

	Maximum documented distance (km)		
Year	<40 (%)	40–100 (%)	>100 (%)
2000	21 (44)	14 (30)	12 (26)
2001	26 (54)	6 (12)	18 (36)
2002	22 (52)	12 (29)	8 (19)
2003	31 (66)	5 (12)	10 (22)
Total	100 (54)	36 (20)	48 (26)

Table 3. Radio-marked adult female Canada geese that were captured and banded from eastern South Dakota that made major movements (> 40 km), by capture site (county) and year, 2000–2003.

County	Year				
	2000[a]	2001	2002[b]	2003[b]	Total
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Brookings	9 (33)	8 (62)	8 (75)	6 (17)	31 (48)
Clark	7 (43)	8 (0)	-	6 (33)	21 (24)
Codington	8 (37)	8 (25)	8 (62)	9 (22)	33 (36)
Day	-	-	9 (44)	7 (14)	16 (31)
Hamlin	8 (87)	9 (56)	-	8 (50)	25 (64)
Kingsbury	8 (62)	9 (56)	9 (11)	10 (40)	36 (42)
Lake	7 (71)	8 (87)	8 (50)	-	23 (70)
Total	47 (55)	50 (48)	42 (48)	16 (30)	185 (45)

[a] Number of geese from each capture site that made a significant post-molt movement out of the total geese marked at that site.
[b] Includes both VHF and PTT transmitters.

The chronology of return dates across years was: 34% (n = 11) prior to September 30; 21% (n = 7) prior to October15; 15% (n = 5) prior to October 31; 22% (n = 7) prior to November 30; and 6% (n = 2) during December. Nine geese that made major northward movements were shot before they were able to return to their capture sites.

The number of marked geese that made major post-molt movements varied by capture site (Table 3). For example, no marked geese (n = 8) from Clark County made major movements during autumn 2001, and the longest distance movement was only 6 km from the capture site. In contrast, 7 of 8 geese made major movements from Hamlin County during 2001 with 6 geese exceeding 100 km. Geese from the same capture site tended to make major movements in the same general direction.

Sixty-two marked geese maintained functional VHF transmitters and survived late into the second autumn after capture, allowing for comparisons between 2 consecutive individual post-molt movements of geese. There was no difference in the number of geese that made different post-molt movement by year (χ^2_2 = 1.97, P = 0.37). Nine marked geese (14.5%) made different post-molt movements during their second autumn of monitoring (Table 4). For example, goose 10 moved a maximum of 3.0 km during autumn 2000, but flew north 231 km to near Lisbon, North Dakota, in 2001, where it remained from roughly September 3 to October 22. Goose 45 made a major movement (>100 km) during autumn 2000, but moved a distance of only 16 km during autumn 2001. In addition, 25 (40%) geese made a molt migration during the first spring after capture (Dieter and Anderson 2009*b*). Over half (55%) of marked geese made differential movements between years (Table 4).

Discussion

VHF and PTT transmitters

Past research on the effect of neck collars on goose survival has been variable. Castelli and Trost (1996) found that neck-collared Canada geese had lower survival rates than geese marked with leg bands only. Schmutz and Morse (2000) reported that emperor geese (*Chen canagica*) marked with neck collars with transmitters had a lower survival rate than leg-banded-only geese. Conversely, Samuel et al. (1990) found that survival rates of neck-collared adult Canada geese were not different from banded-only geese. Menu et al. (2000) reported that neck collars did not affect survival of greater snow geese (*Chen caerulescens atlantica*). Ice accumulation on neck collars has been documented to cause mortality

Table 4. Post-molt movements of VHF–marked adult female Canada geese from eastern South Dakota between their first and second post-molt movements post-capture, 2000-03. Marked geese either made similar movements the second autumn, made different movements, or made a molt migration the second summer. VHF geese marked during summer 2003 were excluded.

Year	Similar post-molt movements %	Different post-molt movements %	Molt migration %
2000 (*n* = 23)	56.5	17.4	26.0
2001 (*n* = 25)	40.0	8.0	52.0
2002 (*n* = 14)	37.5	21.4	42.9
Combined (*n* = 62)	45.2	14.5	40.3

for geese (MacInnes 1966, Craven 1979, Zicus et al. 1983), but we found no evidence of icing on collars even though some of our marked geese wintered in South Dakota (Anderson 2006).

Recovery rates may be higher on geese marked with colored neck collars (Craven 1979, Alisauskas and Lindberg 2002, Sheaffer et al. 2004, Alisauskas et al. 2006). MacInnes (1966) stated that hunters may select geese with colored collars out of flocks, thus, producing potential harvest bias of marked geese. In our study, the use of flat black for the color of neck collars apparently minimized the effect of neck bands on hunter selectivity. Of 20 hunters interviewed, only 2 hunters saw the collar prior to shooting the bird. We found it difficult to locate collared geese within flocks even with the aid of binoculars or a spotting scope, even though we knew via telemetry that a marked goose was present within the flock. We suggest that transmitters in combination with black neck collars be used for future monitoring studies of Canada geese, as long as identification of the alphanumeric code from a distance is not required to address study objectives (Hestbeck et al. 1990).

Problems arose immediately with PTTs that were attached to geese during summer of 2002. The problem was poor LC ratings and entire skipped transmission periods for many PTTs, resulting in less accurate departure and movement dates during 2002. Excessive preening by marked geese was documented, and several PTTs without antennas were returned by hunters. Mykut (2002) stated that reconfiguration of the antenna to prevent excessive preening was the most important factor in improving PTT location class ratings and longevity of functioning transmitters.

Telonics Inc. (Mesa, Ariz.) performed tests with various configurations of antennas and transmitters during spring 2003 and found that problems arose primarily from the 4-hour "on" period, the antenna configuration, and electronics. The PTTs for 2003 resulted in a significant improvement in LC ratings, no skipped transmission periods, and excellent location data. Reconfiguration to a more vertical position and further reinforcement of the antenna resulted in less damage to the antenna from preening geese. However, the greatest improvement in quality of locations for PTTs was probably a direct function of increasing the "on" period to 8 hours (D. Beaty, Telonics Inc., personal communication).

Post-molt movements

The extent of post-molt movements of Canada geese has not been well-documented. While studying post-molt movements of Canada geese in North Dakota, Ross (1995) assumed that any marked goose that could not be located prior to the fall freezing period was dead. However, a number of marked geese not located before the onset of the fall freezing period returned in subsequent years, which indicates that these geese may have made a major post-molt movement (Ross 1995). In west-central Illinois, only 2 direct recoveries from 8,300 young, leg-banded Canada geese were recovered north of Illinois (Lawrence et al. 1998). From these data, Lawrence et al. (1998) concluded that geese usually do not make northward post-molt movements in west-central Illinois. Schultz et al. (1988) also did not report any evidence that a northward post-molt movement had occurred from resident geese monitored in southwest Minnesota. However, our data indicate that geese in this study moved to a much greater extent than indicated by these previous studies. Prior to this study, post-molt movements of Canada geese in South Dakota were unknown, and there was little previous evidence to support a northward movement. Gleason (1997) reported that only 1 direct recovery (a goose harvested and reported to the BBL during the first hunting season after banding) of 16,133 Canada geese banded in eastern South Dakota from 1955 to 1995 was recovered north of South Dakota. In addition, only 53 indirect recoveries (i.e., a goose harvested and reported to the BBL in any hunting season after the first year after banding) of 16,133 banded geese had occurred in North Dakota or Canada (Gleason 1997). We found that almost half (45%) of marked geese made major movements from their natal areas prior to the fall freezing period, many in excess of 100 km. This percentage is a minimum value because some marked geese were shot while making major movements, or may have been shot prior to making major movements.

Almost half (46%) of major movements by geese occurred in late August, and 43% made major movements from their capture wetlands during the first 10 days of the September hunting season (Figure 3). After the first 10 days of the September season, only a few additional geese made major movements. We believe it is likely that the start of the September season in eastern South Dakota triggered a punctuated movement of Canada geese from their breeding areas. Geese that moved during the first 10 days of September likely moved due to hunting pressure and were seeking areas where they would be undisturbed.

Most geese (57%) that made significant movements appeared to have taken a north-northwest route, with multiple geese moving into North Dakota. VerCauteren and Pipas (2004) reported the post-molt movements of 2 Canada geese from south central Nebraska to North Dakota, which appears similar to movements by geese in South Dakota.

All marked geese remained near their capture wetlands through July and into early August, but they initiated major movements after mid-August each year. In general, geese that made major movements from specific capture sites had similar movement patterns. Raveling (1978) documented differential movements and survival rates for 2 flocks banded from the same population in Manitoba. From our data, it was apparent that flocks of geese marked at different sites exhibited differential post-molt movements with some flocks of geese being relatively sedentary, while others exhibited major movements (Anderson and Dieter 2009, Dieter and Anderson 2009*b*). We documented groups of marked female geese from the same capture site making major post-molt movements together, resulting in flocks that consisted of ≥2 families. Geese that moved west or north often briefly returned to capture sites later in autumn prior to initiating fall migration south.

The effects of weather on fall movements of geese have been reported (Koerner et al. 1974, Zicus 1981). Weather has a direct impact on when geese migrate south, but weather probably did not initiate the movements we observed. It was unlikely that Canada geese made major post-molt movements in search of feed. Marked geese from every site were documented feeding in small grain fields within 5 km of their capture site prior to any major movements. In September, geese began to feed in corn silage fields, which were common in the study area. Geese switched to feeding in harvested corn fields later in autumn. The supply of waste grain in eastern South Dakota was in excess of Canada goose requirements. We believe that agricultural crops are not a limiting factor for geese in eastern South Dakota or that a depletion of local food resources caused geese to move.

Influence of tradition on post-molt movements

Hunting pressure influences Canada goose movements and may tend to congregate geese on or near refuges (Raveling 1978, 1979; Craven et al. 1985; Humburg et al. 1985; Bartelt 1987). We believe that some marked geese used their previous experience to avoid hunting pressure by moving to counties that had not previously been open to the September hunting season.

Canada goose tradition can influence goose movements (Craven et al. 1985, Schultz et al. 1988). Schultz et al. (1988) reported that geese from southwest Minnesota flew to the Talcot Lake Wildlife Management Area refuge prior to the start of any hunting season. These breeding-ground refuges developed goose concentrations because geese that formed these patterns had the highest survival rates and returned annually (Schultz et al. 1988). Raveling (1978) also reported similar traditions for other refuge concentrations. These traditions or learned behaviors may have had a large influence on post-molt movements of Canada geese in this study.

Traditions may help explain variable movements from different capture sites. Geese nesting in a specific wetland may have made specific post-molt movements. Juvenile Canada geese follow their parents and probably learn and follow their post-molt movements. Females have a strong attachment to their natal areas, and they return to that specific wetland to breed (Sherwood 1967, Surrendi 1970). After many generations, the wetland contains related females that in turn teach their goslings the same movements creating a tradition. If the tradition leads to a higher relative survival rate, it will expand as the population grows.

Management implications

Many Canada geese nesting in eastern South Dakota made post-molt movements. Most geese making major movements followed a north-northwest route toward or into North Dakota. September hunting seasons are an important tool to manage eastern South Dakota's Canada goose population. Our data suggest that the early September hunting season in South Dakota may at least be partially responsible for movements of Canada geese northward out of state. Most geese (92%) that made major movements left in late August or early September.

We found that South Dakota's Canada geese are not as resident or sedentary as previously thought. We support the efforts of the SDGFP in managing their resident Canada goose population by attempting to maximize recreational hunting opportunities, while at the same time recognizing constraints of habitats and landowner tolerance to an increasing goose population. An early September Canada goose season may simply be ineffective given the relatively large proportion of molt-migrant geese present during the season, buffering resident breeding geese from harvest. We suggest that state and provincial agencies recognize the potential for subflock behavior within resident flocks and that more northerly states and provinces recognize the potential confounding negative impacts of molt-migrant geese. It is important that the resident component of Canada goose populations not be reduced to levels below population objectives in an effort to decrease goose-related complaints, particularly in cases where the segment of the goose population responsible for the damage is actually molt-migrants and not resident breeders.

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