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SATELLITE TELEMETRY OF NORTHERN GOSHAWKS BREEDING IN UTAH—I. ANNUAL MOVEMENTS

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Abstract. Irruptive movements exhibited by Northern Goshawks (*Accipiter gentilis*) can make determining year-round movements of these birds difficult. Recent advancements in satellite telemetry have made these units useful in assessing movements of various raptor species. Studies documenting individual winter movements of Northern Goshawks in North America are limited and detailed studies examining winter ecology of Northern Goshawks have been largely restricted to the European subspecies (*A. g. gentilis*). Adult females (N = 36) were fitted with platform transmitter terminals (30 g in 2000 and 32 g in 2001) within the six national forests throughout Utah. Our data indicate that females breeding in Utah are partially migratory and are capable of extensive movements. Migratory birds traveled distances of 100–613 km. Smaller movements were observed by dispersing birds traveling between 49 and 85 km. We suggest that yearly variants such as prey availability and local weather conditions influence the degree of movement as indicated by a previous study.

Key Words: *Accipiter gentilis*, migration, Northern Goshawk, satellite telemetry.

TELEMETRÍA SATELITAL DE GAVILANES AZOR REPRODUCTORES EN UTAH—I. MOVIMIENTOS ANUALES

Resumen. Movimientos interrumpidos presentes en el Gavilán Azor (*Accipiter gentilis*), pueden dificultar la determinación de los movimientos anuales. Avances recientes en telemetría satelital han hecho útiles estas unidades para estimar los movimientos de varias especies rapaces. Estudios los cuales documenten movimientos individuales de inverno del Gavilán Azor en América del Norte son limitados, y estudios detallados que examinen la ecología en el invierno del Gavilán Azor han sido restringidos en gran parte a las subespecies de Europa (*A. g. gentilis*). Hembras adultas (N = 36) fueron adaptadas con terminales transmisoras de plataforma en el 2002 de 30 g y en el 2001 de 32 g, dentro de seis bosques nacionales a lo largo de Utah. Nuestros datos indican que las hembras reproductoras en Utah son parcialmente migratorias y son capaces de realizar amplios movimientos. Aves migratorias viajaron distancias de 100–613 Km. Movimientos más pequeños fueron observados por aves dispersas viajando entre 49 y 85 Km. Sugerimos que variantes anuales, tales como disponibilidad de presa, y condiciones locales del clima, influyen el grado de movimiento como lo indica un estudio previo.

Fragmentation of forests throughout North America has been perceived as detrimental to Northern Goshawk (*Accipiter gentilis*) populations because forest corridors may no longer be able to facilitate movement of goshawks over broad regions. Additionally, fragmentation is thought to inhibit goshawk movement between forest patches, as birds are unable to travel over non-forested landscapes (Kennedy 1997, Graham et al. 1999b). Breeding adults are relatively sedentary in summer, whereas in winter, they need to forage over large areas in search of prey (Palmer 1988). Studies documenting individual winter movements of Northern Goshawks in North America are limited (Squires and Ruggiero 1995, Stephens 2001). To date, detailed studies examining winter ecology of Northern Goshawks have been restricted to the European subspecies (*A. g. gentilis,* Kenward et al. 1981b, Widén 1984, 1985b, 1987, and 1989, Tornberg and Colpaert 2001). These studies indicated that Northern Goshawks in Sweden can be highly migratory, partially migratory (a population that is composed of migratory and resident individuals), or resident (Kenward et al. 1981b, Widén 1985b). In Finland, goshawks exhibit dispersal patterns similar to those in Sweden (Tornberg and Colpaert 2001). Within the Swedish population, adult females typically migrated longer distances to wintering grounds than adult males. Additionally, adult females migrated more often than adult males (Kenward et al. 1981b, Widén 1985b).

Within North America, Northern Goshawks exhibit a wide variety of movement types in winter or are resident (Evans and Sindelar 1974, Squires and Ruggiero 1995, Squires and Reynolds 1997, Stephens 2001, Sonsthagen 2002). Squires and Ruggiero (1995) studied winter movements of Northern Goshawks breeding in south-central Wyoming using radio telemetry. Their data indicated that Northern Goshawks (N = 4) breeding in Wyoming were migratory (traveling 65–185 km), and inclement weather may have initiated these movements, although a larger sample would be required to confirm that pattern. Stephens (2001) monitored movements of Northern Goshawks breeding in the Ashley National Forest, Utah, using radio telemetry during winters of 1998–1999 and 1999–2000. His data suggest that this population is composed of partial migrants. Of the seven individuals trapped in 1998, six were considered migratory (traveling 14 to >100 km). The remaining bird stayed on its breeding territory. In 1999, 14 individuals were monitored. Eight migrated with distances ranging from 8–100 km, three were considered residents, and no data were collected for the remaining individuals.

Irruptive movements exhibited by Northern Goshawks (Mueller et al. 1977, Kennedy 1998) can make determining year-round movements difficult. Satellite telemetry, however, has become useful in assessing movements in migratory birds (Brodeur et al. 1996, Fuller et al. 1998, Ueta et al. 1998, 2000; McGrady et al. 2000, 2002). However, Britten et al. (1999) warned that satellite telemetry units were not suitable for describing movements on small scales (<35 km). Using satellite telemetry, we describe the year-round movements of Northern Goshawks breeding in Utah in 2000 and 2001 and address the concern that current levels of habitat fragmentation inhibit goshawk movement between forest patches. We hypothesized that Northern Goshawks breeding throughout Utah would exhibit movement patterns similar to those observed by Squires and Ruggerio (1995) and Stephens (2001), because our study area is in close proximity to these previous studies, with some individuals migrating long distances in winter months while others being resident.

METHODS

Field Techniques

Thirty-eight adult female and six adult male Northern Goshawks were captured at nest sites during the breeding seasons of 2000–2001; Ashley National Forest (N = 14), Dixie National Forest (N = 12), Fishlake National Forest (N = 7), Manti LaSal National Forest (N = 6), Wasatch-Cache National Forest (N = 4), and Uinta National Forest (N = 1). A live Great Horned Owl (*Bubo virginianus*) was used to lure breeding Northern Goshawks (Rosenfield and Bielefeldt 1993) into a modified dho-gaza net trap (Clark 1981), which was set according to McCloskey and Dewey (1999).

Birds were banded with USGS Bird Banding Laboratory aluminum bands and plastic alphanumeric violet color bands. Standard measurements including mass, flattened wing length from the wrist to wing tip, tail length (central retrix), tarsus length, and hallux length were recorded to the nearest 0.1 millimeter, along with eye color. Body mass was important to ensure that the transmitters did not exceed 4.5% of the mass of a bird and measurements might provide additional insight into migration patterns, e.g., birds with longer wings relative to body mass may be more likely to migrate. Nests were revisited to determine number of fledglings and observe behavior of the transmitter-equipped female.

Satellite Telemetry Data

Adult females (N = 36) were fitted with a 30 or 32 g platform transmitter terminals (PTT) manufactured by North Star Science and Technology, Columbia, Maryland. Only adult females were fitted with PTT units, because of transmitter weight and high first-year mortality observed in juveniles (Kenward et al. 1999, Kenward 2002). The units were attached with a backpack harness constructed with Teflon ribbon (Snyder et al. 1989). The PTT units were programmed to have a duty cycle of 6 hr of transmission followed by 68 hr without transmission, which allows the transmitters to transmit for approximately 1 yr.

Data were sent to the USDA Forest Service District Station, Cedar City, Utah, by Argos satellite systems, along with a corresponding accuracy estimate for each location. Data points were input into ArcView version 3.2, a geographic information system (GIS) computer program (ESRI 1996). Only data points with accuracy estimates of 3, 2, or 1, which is based on the position of the PTT unit relative to the satellite as it passes over the transmitter to estimate the location (Fuller et al. 1998). These estimates represent an actual transmitter location within 150, 350, or 1,000 m, respectively, of the estimated location. Location estimates with an accuracy estimate of 3, 2, or 1 were removed when distances between successive location estimates were greater than a flight speed of 80 km/hr, which is based on the maximum flight speed observed in the Peregrine Falcon (*Falco peregrinus*; Cochran and Applegate 1986, Chavez-Ramierez et al. 1994).

Based on our observations in this study, young fledged between mid-July and early-August and birds that migrated returned to their territories between mid-March and late-April (Appendix 1). Thus, we used a two-season designation consisting of breeding and non-breeding seasons. Data points received from 1 May–31 August were considered as breeding season. To ensure all birds had returned to their breeding territories, we classified all points received from 1 September–30 April as non-breeding.

Kernel home range and distances between points were calculated using an ArcView extension, Animal Movement Analysis version 1.1 (Hooge et al. 1999). Home-range was calculated using a least squares cross validation kernel estimate (Silverman 1986) as modified by Hooge et al. (1999) using smoothing parameters provided. Area was calculated for 95% probability polygons. Because Northern Goshawks are highly mobile, we defined females as migratory if they traveled >100 km from their nest site, dispersive if they moved to a different area that was distinct from their breeding territory but was <100 km from their nest site, and resident if their winter range extended out from their nest site with no distinct foraging areas. These definitions differ from those used by Stephens (2001). We describe an additional movement pattern for dispersing birds, which, based on what we observed, better fit the movement types utilized by Northern Goshawks in our study.

Along with location estimates, transmitters also provided temperature readings, which we used to assess the status of the transmitter and bird. When transmitters gave warm temperature readings (>25°C), we knew the transmitter was still attached to a live bird. However, when the transmitter gave cold temperature readings (<25°C), the transmitter may have malfunctioned or come off of the bird, or the bird had died. While we do not have data to demonstrate the fate of all goshawks carrying transmitters that went cold, we know some of those hawks died because we found goshawk remains when we recovered transmitters (42%, N = 8). Harnesses were constructed and attached so that they would remain on the bird and would likely not be lost. Therefore we assume the 12 remaining transmitters that sent cold temperatures and were not recovered were likely attached to dead birds.

Statistical Analysis

Data were analyzed in SAS, version 9.1 (SAS 2004) and Minitab version 13.2 (Minitab 2000). Home-range data were natural-log transformed to achieve normality. A general linear model (GLM, $\alpha = 0.05$) was used to compare home-range areas (the 95% probability polygons) and morphological characteristics (mass, tail length, and wing length) between individuals that dispersed or migrated and individuals that were residents. A GLM was also used to compare morphological characteristics (mass, tail length, and wing length) between individuals with transmitters that sent warm temperature readings throughout the course of the study and those that lost their transmitters or died. A regression was used to test if a significant ($\alpha = 0.05$) increase in home-range size occurred throughout the course of the study. In addition, a chi-square test was used to determine if a difference occurred in the number of migrants between years.

RESULTS

Female Northern Goshawks breeding in Utah exhibited a variety of movement patterns in winter (Appendix 1). Of the 36 females tagged during the course of the study, 13 females exhibited movements >100 km (N = 8 in 2000; N = 5 in 2001). In 2000, 10 of 25 (40%) of the females migrated or dispersed and nine of 14 (64%) migrated or dispersed in 2001, which was not a significant difference ($\chi^2 = 2.11$, df = 1, P = 0.2).

In 2000, eight birds migrated. Two females (Ashley 1 and Ashley 7) from the Ashley National Forest migrated to wintering areas approximately 100 and 191 km from their breeding territories (Fig. 1). Female Ashley 1 continued to provide data through winter 2001. She used the same winter range as in 2000, approximately 191 km from her nest site. Dixie 7 was assumed to be a migrant. No data were received prior to her transmitter sending cold readings approximately 115 km south of her breeding site (Appendix 1). Fishlake National Forest females 1 and 2 migrated 104 and 174 km to their winter ranges (Fig. 2). Fishlake 2 continued to send data through the winter of 2001. She wintered in the same area as in 2000, approximately 174 km from her nest site. One female (Manti 3) from the Manti LaSal National Forest migrated 180 km to her wintering area in 2000 (Fig. 3). Two transmitters (Manti 3 and Manti 4) continued to send data through winter 2001. Both females migrated in 2001, traveling 156 (resident in 2000) and 544 km to their winter ranges (Fig. 3). Manti 3 and Manti 4 did not winter in the same area in 2001 as they did in 2000. One female was studied on the Wasatch National Forest in 2000; she traveled 527 km to her wintering area (Fig. 3).

In 2001, five birds migrated. Ashley 11 moved to a winter range approximately 144 km from her nest site (Fig. 4). On the Dixie National Forest, all females (Dixie 8, Dixie 9, and Dixie 10) migrated, traveling 114, 277, and 384 km to their winter ranges (Fig. 4). Of the two females studied on the Wasatch National Forest, one (Wasatch 3) migrated 613 km to her winter range (Fig. 5); the other transmitter sent unusable data.

Three females dispersed from breeding territories throughout the course of the study. In 2000, Dixie National Forest 4 and 6 moved to wintering areas

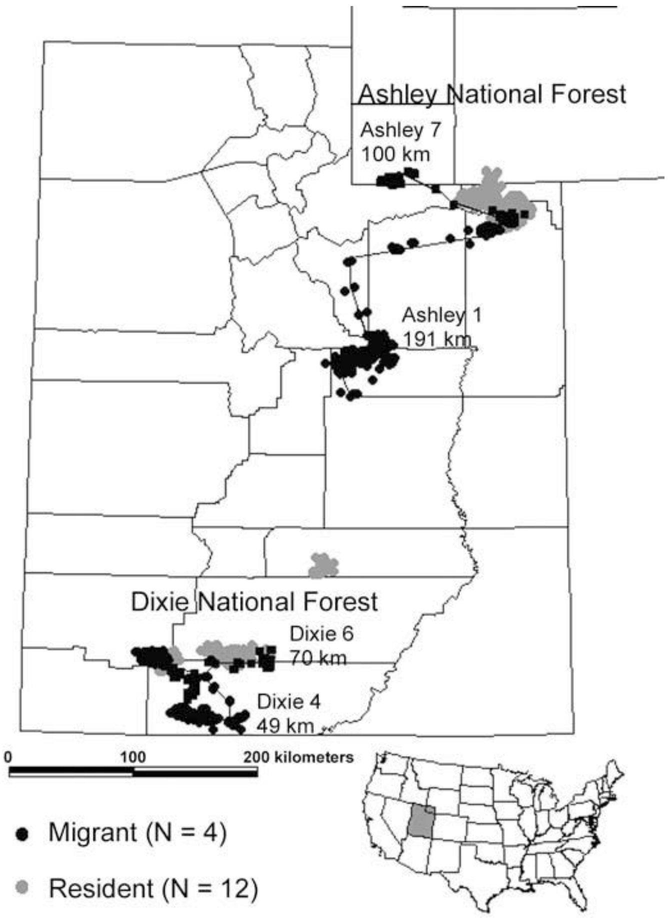

FIGURE 1. Map of Northern Goshawks breeding on the Ashley and Dixie National Forests in 2000. Resident females (Ashley 2, 3, 4, 5, 6, 8, and 9, Dixie 1, 2, 3, and 5) are shown in gray. Migratory females (Ashley 1 and 7, Dixie 4 and 6) are shown in black, with the flight path from their breeding territory to wintering area denoted with a black line. Distances for migratory birds are shown at their wintering areas.

approximately 49 and 67 km from their nest sites (Fig. 1). In 2001, one female dispersed from the Manti LaSal National Forest (Manti 5) 85 km to her wintering range (Fig. 5). The remaining 20 birds studied were residents in 2000 and 2001; Ashley National Forest (Fig. 1; N = 7 in 2000; Fig. 4, N = 2 in 2001), Dixie National Forest (Fig. 1; N = 5 in 2000), Fishlake National Forest (Fig. 5; N = 2 in 2001), Manti LaSal National Forest (Fig. 3; N = 3 in 2000), and Uinta National Forest (Fig. 2; N = 1 in 2000). Two transmitters sent unusable data (accuracy estimates other than 3, 2, or 1). Additionally, 21 of the 36 transmitters did not move and sent cold temperatures prior to the completion of the study.

Home-ranges of female goshawks across all national forests significantly increased throughout the course of the study (R^2 [adj.] = 30.8%, $P < 0.000$; Table 1). In summer 2001, only nine of 19 females bred and two of those breeding attempts failed during incubation, resulting in an overall high average size of home-range. During non-breeding months, females that migrated or dispersed had larger kernel home-range 95% probability polygons than resident females, though they were not statistically significant (Table 2). Also, females that migrated had a slightly larger wing length (6.9 mm, $F = 2.98$, $df = 1$, $P = 0.09$) than residents (Table 3). No significant differences in morphological measurements were found between individuals that had warm transmitters and those who had cold transmitters when data were averaged across years (Table 4). Nonetheless, a significant difference occurred in tail length between individuals that were trapped in 2000 that had warm transmitters versus those that had cold transmitters

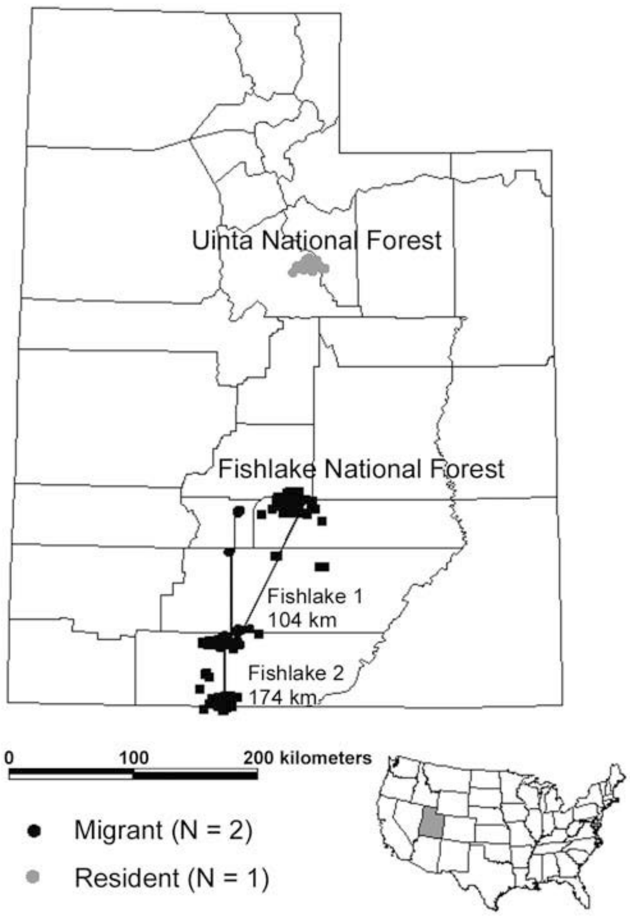

FIGURE 2. Map of Northern Goshawks breeding on the Fishlake and Uinta National Forests in 2000. Resident females (Uinta 1) are shown in gray. Migratory females (Fishlake 1 and 2) are shown in black, with the flight path from their breeding territory to wintering area denoted with a black line. Distances for migratory birds are shown at their wintering areas.

TABLE 1. COMPARISON OF THE AVERAGE KERNEL HOME RANGE (KM^2) 95% PROBABILITY POLYGONS (SILVERMAN 1986) AS MODIFIED BY HOOGE ET AL. (1999) FOR FEMALE NORTHERN GOSHAWKS RESIDING IN EACH OF UTAH'S NATIONAL FORESTS.

National forest	Breeding 2000 Home range (km^2)	Non-breeding 2000 Home range (km^2)	Breeding 2001 Home range (km^2)	Non-breeding 2001 Home-range (km^2)
Ashley	91.7 (N = 9)	204.5 (N = 9)	158.4 (N = 7)	265.9 (N = 6)
Dixie	151.7 (N = 6)	297.2 (N = 6)	270.7 (N = 4)	368.2 (N = 5)
Fishlake	-	75.3 (N = 2)	299.5 (N = 3)	570.2 (N = 3)
Manti LaSal	149.0 (N = 3)	216.9 (N = 4)	215.4 (N = 5)	487.6 (N = 5)
Uinta	96.6 (N = 1)	106.0 (N = 1)	-	-
Wasatch	48.3 (N = 1)	262.5 (N = 1)	293.5 (N = 1)	1,088.6 (N = 1)
Overall average home range (km^2)	116.4	217.9	223.0	433.7

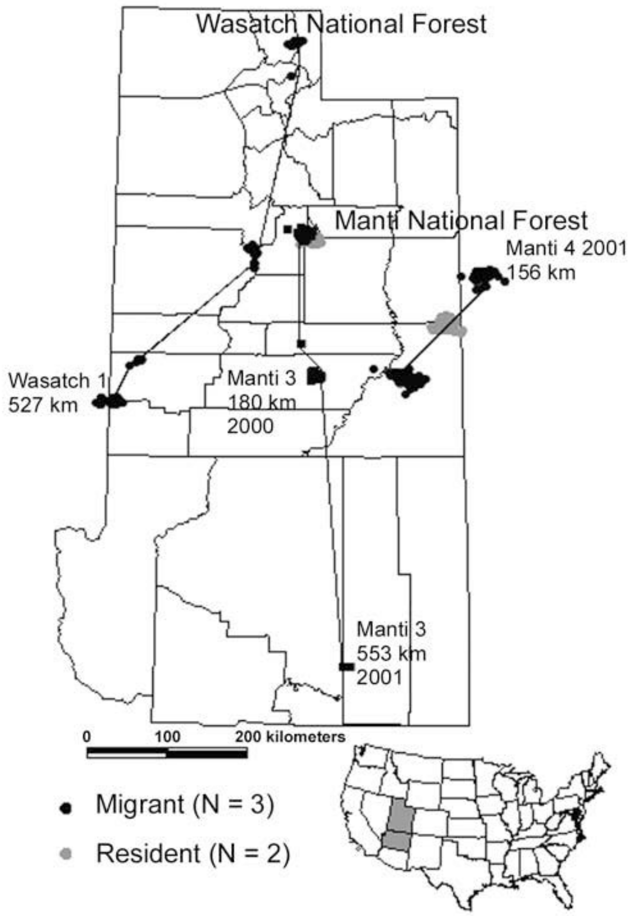

FIGURE 3. Map of Northern Goshawks breeding on the Manti and Wasatch National Forests in 2000. Resident females (Manti 1 and 2) are shown in gray. Migratory females (Manti 3 and 4, Wasatch 1) are shown in black, with the flight path from their breeding territory to wintering area denoted with a black line. Distances for migratory birds are shown at their wintering areas.

TABLE 2. COMPARISON OF THE MEAN KERNEL HOME RANGE 95% PROBABILITY POLYGONS (SILVERMAN 1986), AS MODIFIED BY HOOGE ET AL. (1999), MEAN STANDARD ERROR (SE), AND P-VALUES BETWEEN INDIVIDUALS THAT MIGRATED AND THOSE THAT WERE RESIDENTS ACROSS YEARS USING A GLM ($\alpha = 0.05$).

	Breeding	SE	Non-breeding	SE
Mean area (km^2) for migrants	176.5 (N = 16)	35.5	303.0 (N = 14)	75.9
Mean area (km^2) for residents	101.4 (N = 16)	20.4	149.7 (N = 18)	33.1
P-value	0.24	-	0.18	-

(11.8 mm, F = 5.77, df = 1, P = 0.03; Table 5). This pattern was not observed in 2001.

DISCUSSION

Our data indicate that female Northern Goshawks breeding in Utah are partially migratory, i.e., the population is composed of migratory and non-migratory individuals, and are capable of extensive movements over broad regions of non-forested landscape, as we have observed several instances where females have migrated over non-forested areas. Dixie 7 migrated 115 km from her natal site on the Kaibab Plateau, Arizona, to breed on the Dixie National

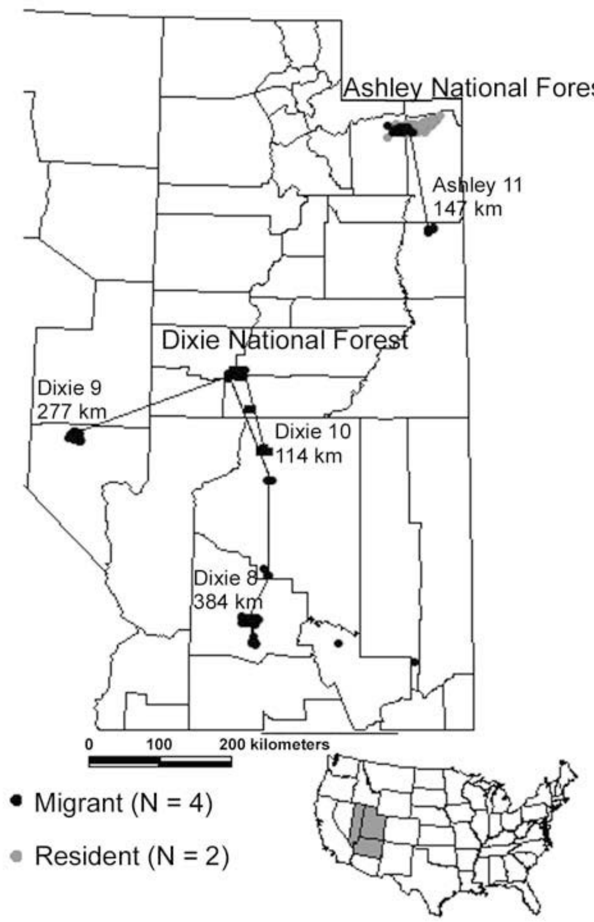

FIGURE 4. Map of Northern Goshawks breeding on the Ashley and Dixie National Forests in 2001. Resident females (Ashley 10 and 12) are shown in gray. Migratory females (Ashley 11, Dixie 8, 9, and 10) are shown in black, with the flight path from their breeding territory to wintering area denoted with a black line. Distances for migratory birds are shown at their wintering areas.

TABLE 3. Comparison of mean, mean standard error (se), and P-value of morphological characters of female Northern Goshawks sampled in 2000 and 2001 between individuals that migrated (N = 16) and those that were residents (N = 18) using a GLM (α = 0.05).

	Mean	se	P-value
Mass			
migrant	951.5 g	18	
resident	982.2 g	14	0.18
Tail length			
migrant	267.2 mm	3.3	
resident	262.6 mm	2.9	0.31
Wing length			
migrant	368.6 mm	3.3	
resident	361.7 mm	2.3	0.09

Forest, Utah, over a large non-forested patch of land between the two forests. Additionally, she returned to that area in winter 2000. Manti La Sal 3 made a similar migration as Dixie 7 over the non-forested habitat between the Dixie National Forest and Kaibab Plateau. She continued on with her migration to central Arizona. Two females from the Wasatach National Forest (females 1 and 3) migrated long distances, 527 and 613 km respectively, over non-forested areas to their winter ranges in Nevada (Appendix 1).

Annual variables such as prey availability and local weather conditions, likely influenced the degree of movement, as indicated by Squires and Ruggiero (1995). We had four individuals (Ashley 1, Fishlake 2, Manti 3, and Manti 4) with successive years of data; two of them wintered in the same

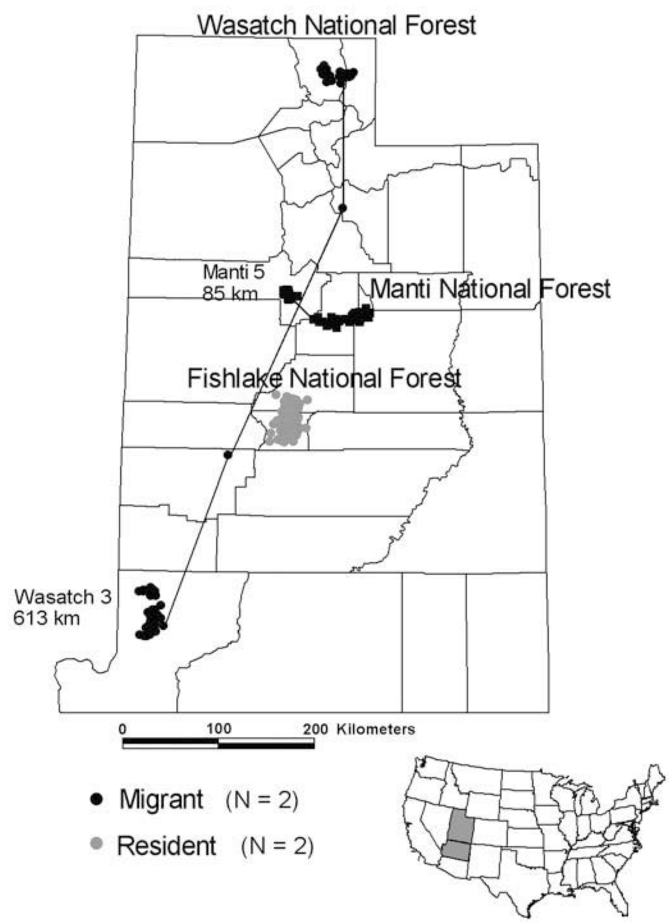

FIGURE 5. Map of Northern Goshawks breeding on the Fishlake, Manti, and Wasatch National Forests in 2001. Resident females (Fishlake 4 and 5) are shown in gray. Migratory females (Manti 5 and Wasatch 3) are shown in black, with the flight path from their breeding territory to wintering area denoted with a black line. Distances for migratory birds are shown at their wintering areas.

TABLE 4. COMPARISON OF MEAN, MEAN STANDARD ERROR (SE), AND P-VALUE OF MORPHOLOGICAL CHARACTERS OF FEMALE NORTHERN GOSHAWKS SAMPLED IN 2000 AND 2001 BETWEEN INDIVIDUALS WITH TRANSMITTERS SENDING WARM TEMPERATURES (N = 15) AND TRANSMITTERS SENDING COLD TEMPERATURES (N = 19) USING A GLM ($\alpha = 0.05$).

	Mean	SE	P-value
Tail length			
cold transmitters	261.6 mm	2.6	
warm transmitters	268.7 mm	3.5	0.16
Wing length			
cold transmitters	364.4 mm	3.2	
warm transmitters	365.6 mm	2.4	0.77
Mass			
cold transmitters	968.1 g	14	
warm transmitters	967.3 g	19	0.58

TABLE 5. COMPARISON OF MEAN, MEAN STANDARD ERROR (SE), AND P-VALUE OF MORPHOLOGICAL CHARACTERS OF FEMALE NORTHERN GOSHAWKS TRAPPED IN 2000 BETWEEN INDIVIDUALS WITH TRANSMITTERS SENDING WARM TEMPERATURES (N = 12) AND THOSE SENDING COLD TEMPERATURES (N = 11) USING A GLM (α = 0.05).

	Mean	SE	P-value
Tail length			
cold transmitters	259.9 mm	4.1	
warm transmitters	271.7 mm	3.4	0.03[a]
Wing length			
cold transmitters	367.3 mm	4.7	
warm transmitters	363.8 mm	2.7	0.56
Mass			
cold transmitters	957.2 g	18	
warm transmitters	975.8 g	23	0.50

[a] Denotes a significant P-value.

winter range both years and two moved to different wintering areas. This differs from the findings of Stephens (2001), who suggested that Northern Goshawks utilize the same areas each winter (N = 3). In addition, 10 of 25 (40%) females migrated in 2000 and nine of 14 (64%) migrated in 2001, indicating a non-significant year-to-year difference (χ^2 = 2.11, df = 1, P = 0.2). The idea of an annual effect on winter movements is supported by observations of periodic invasions of Northern Goshawks, which are correlated with 10-yr population declines in Ruffed Grouse (*Bonasa umbellus*) and snowshoe hare (*Lepus americanus*) (Mueller et al. 1977, Palmer 1988).

The increase in kernel home-ranges between seasons was expected, because during summer females primarily guard nests while males hunt. The significant increase in kernel home ranges throughout the course of the 2-yr study, however, was unexpected. Some potential explanations for this steady increase of home-range sizes may be attributed to a drought occurring throughout the West that started in about 1999 and continued throughout our study. The severity of the drought increased annually, potentially reducing prey abundances and resulting in larger foraging areas. Newton (1986) and Kenward (1982) reported that range size of accipiters is inversely dependent on prey abundance. In addition, we observed reduced nesting activity within our study areas (>50% of known nest territories occupied in 2000 to <10% occupied in 2001). Reynolds et al. (1998) reported that annual fluctuation in Northern Goshawk demography and nesting density are related to abundances of main prey species, mainly the red squirrel (*Tamiasciurus hudsonicus*). Birds trapped in 2001 were in poor body condition as indicated by lack of pectoral muscle mass, which we attributed to poor conditions of the range and its affect on prey availability.

We hypothesize that food plays a part in the process of migration (sensu, Squires and Reynolds 1997). Females that migrated or dispersed had larger home-ranges in winter (Table 2) than individuals that remained on breeding territories. We suggest a larger home range reflects a less rich or less dense local prey base causing the hawks to range farther, which has been noted in several raptor species involved in predator-prey cycles (Newton 1979a). We had 11 birds with successive breeding season data. Only two of these birds attempted to nest the following year and both were resident birds the previous winter (Appendix 1). Since studies indicate that winter food supply affects subsequent breeding densities (Newton 1998), we speculate that migratory females did not nest as a result of lower prey availability on the winter range, relative to resident birds, as indicated by significantly larger home ranges and its effect on their breeding condition. Additionally, females may migrate to reduce competition for resources. A study conducted in Michigan monitored a mixed-species community of raptors during two winters of differing prey densities in a 96 km^2 farmland (Craighead and Craighead 1956). Craighead and Craighead (1956) results indicate that prey availability influenced the number of individuals and species present in a particular area and interactions between them. Degree of winter territoriality may be related to prey numbers such that high prey densities reflect lower incidence of aggressive behavior (Eurasian Kestrel [*Falco tinnunculus*], Cavé 1968). Although the increase in the number of migrants was not significant across years, more females are likely migrating or forced to migrate as a result of increased territoriality between wintering raptors thus reducing local competition.

Females that migrated had slightly longer wings (Table 3) than those that did not. Migratory populations of many birds (Horned Larks [*Eremophila alpertris*], Behle 1942; Cooper's Hawks [*Accipiter cooperii*], R. Rosenfield, pers. comm.) have longer, more attenuated wings than non-migratory populations of the same species. If wing length is an inherited trait, female goshawks that make successful migrations year after year may pass onto offspring the behavioral tendency to migrate and the morphological traits associated with that behavior. Whether such a difference has genetic underpinnings is unknown.

Lastly, an important characteristic that comes from our data dealt with tail length. Although, we do not have data to demonstrate the fate of all goshawks carrying transmitters that sent cold temperature readings, we know some of those hawks died because we recovered transmitters (N = 8). In 2000, all hawks that carried transmitters that sent cold temperature readings had a statistically shorter tail by an average of 11.8 mm than hawks whose transmitters continued to send warm readings (Table 5). Based on continual yearly trapping and measuring of individual birds, tails become shorter annually (B. Woodbridge, pers. comm.). Perhaps the added weight of transmitters was enough of a factor to cause already old goshawks to die. Although, not all territories of females that had cold reading transmitters were reoccupied, we do not believe unoccupied territories were a result of mortality observed in our study. New females reoccupied territories that were occupied by females whose transmitters sent cold readings the previous year (N = 3) and territories that were not used in this study and active in 2000 were not reoccupied in 2001. In addition, by providing extra winter food, studies have indicated that winter food supply may affect subsequent breeding densities (Newton 1998). Therefore, we hypothesize that unoccupied territories reinforce the notion that prey densities were low due to drought conditions and the low nesting density or re-occupancy rate was an artifact of this and not an artifact of mortality observed in our study.

Female Northern Goshawks observed in our study were capable of extensive movements (613 km), despite concerns that current levels of forest fragmentation maybe limiting Northern Goshawk migrations (Kennedy 1997, Graham et al. 1999a). Our data suggest that forest fragmentation does not have a detrimental effect on goshawk movement and notions that current levels of fragmentation are inhibiting goshawk movements are likely overstated as indicated by our four birds that dispersed and migrated over non-forested areas to breeding and wintering areas (Appendix 1). Additionally, partial migratory behavior observed in Northern Goshawks presents a need for researchers to examine breeding territories as potential wintering sites and determine what characteristics provide suitable winter range conditions. Although forest fragmentation does not appear to limit female Northern Goshawk movement, it is important to keep in mind that fragmentation may reduce goshawk numbers by limiting breeding and wintering habitat. This is especially important since raptors are already at lower densities than other birds (goshawks, 3.6–10.7 pairs/ 100 km^2, Squires and Reynolds 1997) without added pressure of contending with habitat fragmentation (Newton 1998).

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APPENDIX 1. Description of female Northern Goshawk movement that were trapped on Utah's National Forests in 2000 and 2001. Hawks are listed by forest with a numerical identification.

Individual	Year	Description
Ashley 1	2000	Bird migrated. Data were received from 15 June 2000–25 April 2002. She remained near her breeding territory in a 90.3 km^2 area until 9 September 2000. She traveled 191 km southwest to a 943 km^2 area near Price, Utah, 21 September 2000–16 April 2001, 28 April 2001–25 October 2001, and 18 November 2001–9 April 2002. She returned to her breeding territory 19 April 2001, 3 November 2001, and 12 April 2002–25 April 2002. She traveled the same route between territories. She did not attempt to breed in 2001.
Ashley 2	2000	Bird was a resident. Data were received 16 June 2000–20 July 2001. She remained near her breeding territory in a 38.0 km^2 home-range. She attempted to breed in 2001 in the same territory, nest failed during incubation.
Ashley 3	2000	Bird was a resident. Data were received 8 August 2000–9 October 2000. She remained near her breeding territory in a 22.0 km^2 area until 12 September 2000. On 18 September 2000, she traveled 28 km northwest to an 11.0 km^2 area. Her transmitter stopped moving and sent cold temperatures after 9 October 2000.
Ashley 4	2000	Bird was a resident. Data were received 16 June 2000–12 January 2001. She remained near her breeding territory in a 252.4 km^2 area until 12 November 2000. She traveled 14 km northeast to a 2.7 km^2 area 14 November 2000–24 November 2000. On 27 November 2000, she returned to her breeding territory until 6 January 2001. She traveled to a 24.7 km^2 area 12.5 km south of her nest site 9 January 2001. Her transmitter stopped moving and sent cold temperatures after 12 January 2001.
Ashley 5	2000	Bird was a resident. Data were received 14 June 2000–4 March 2001. She remained near her breeding territory in a 124.6 km^2 area. Her transmitter stopped moving and sent cold temperatures after 4 March 2001.
Ashley 6	2000	Bird was a resident. Data were received 20 June 2000–17 September 2001. She remained near her breeding territory in a 235.4 km^2 area. She did not attempt to breed in 2001.
Ashley 7	2000	Bird migrated. Data were received 15 June 2000–7 November 2000. She remained near her breeding territory in a 102.9 km^2 area until 4 October 2000. She traveled 100 km west to a 290.5 km^2 area near Robertson, Wyoming, 10 October 2000–4 November 2000. Her transmitter stopped moving and sent cold temperatures after 7 November 2000, 36 km east of winter area 1.
Ashley 8	2000	Bird was a resident. Data were received 20 June 2000–9 October 2000. She remained near her breeding territory in a 104.6 km^2 area. Her transmitter stopped moving and sent cold temperatures after 9 October 2000.
Ashley 9	2000	Bird was a resident. Data were received 16 June 2000–22 October 2001. She remained near her breeding territory in a 240.0 km^2 area. She did not attempt to breed in 2001.
Ashley 10	2001	Bird was a resident. Data were received 6 August 2001–10 April 2002. She remained near her territory in a 287.6 km^2 area.
Ashley 11	2001	Bird was a migrant. Data were received 8 August 2001–15 November 2001. She remained near her breeding territory in a 205.2 km^2 home-range until 5 November 2001. She traveled 147 km southeast to a 115.0 km^2 area. Her transmitter stopped moving and sent cold temperatures after 15 November 2001.
Ashley 12	2001	Bird was a resident. Data were received 8 August 2001–9 March 2002. She remained near her breeding territory in a 341.8 km^2 area. Her transmitter stopped moving and sent cold temperatures after 9 March 2002.
Dixie 1	2000	Bird was a resident. Data were received from 3 September 2000–28 October 2001. She remained in her breeding territory in a 68.9 km^2 home-range until 10 November 2000. She moved frequently between her breeding territory and an adjacent 349.4 km^2 area 22.6 km west. She did not attempt to breed in 2001.
Dixie 2	2000	Bird was a resident. Data were received 2 September 2000–24 November 2000. She remained near her breeding territory in a 204.9 km^2 area. Her transmitter stopped moving and sent cold temperatures after 24 November 2000.
Dixie 3	2000	Bird was a resident. Data were received 5 September 2000–18 September 2000. She remained near her breeding territory in a 9.5 km^2 area. Her transmitter stopped moving and sent cold temperatures after 18 September 2000.
Dixie 4	2000	Bird was dispersive. Data were received 3 September 2000–27 September 2001. She remained near her breeding territory in a 191.7 km^2 area until 25 September 2000 and 18 July 2001–20 September 2001. She foraged in a 341.3 km^2 area, 49 km north of Kanab, Utah. She moved between these two areas 15 times. From 22 October 2000–10 November 2000, she was in a 117.4 km^2 area 39 km east of winter area 1. She did not attempt to breed in 2001.

APPENDIX 1. CONTINUED.

Individual	Year	Description
Dixie 5	2000	Bird was a resident. Data were received 12 September 2000–1 January 2001. She remained near her breeding territory in a 92.1 km^2 area. Her transmitter stopped moving and sent cold temperatures after 1 January 2001.
Dixie 6	2000	Bird dispersed. Data were received 2 September 2000–10 January 2001. She foraged in a 308.3 km^2 area near her breeding territory until 12 November 2000 and 7 December 2000–19 December 2000. She traveled 67 km west to a 106.6 km2 area 18 November 2000–1 December 2001 and 26 December 2000–4 January 2001. From 22 December 2000–23 December 2000 and 7 January 2001–10 January 2001, she foraged in a 96.6 km^2 area 67 km west of her nest site and 22 km east of winter area 1. Her transmitter stopped moving and sent cold temperatures after 10 January 2001.
Dixie 7	2000	Bird was assumed to migrate. No data were collected before her transmitter stopped moving and sent cold temperatures after 30 September 2000, 115 km south of her nest site near Jacob Lake, Arizona. She was banded as a nestling on the Kaibab Plateau, Arizona.
Dixie 8	2001	Bird migrated. Data were received 8 August 2001–28 April 2002. She remained near her breeding territory in a 238.5 km^2 area until 9 October 2001, 25 February 2002–28 February 2002, and 22 March 2002–28 April 2002. She traveled 354 km south to a 201.6 km^2 area near Prescott, Arizona, from 21 October 2001–16 December 2001, 7 January 2002–31 January 2002, 6 February 2002–13 February 2002. She traveled to a 61.9 km^2 area 30 km south of winter area 1 22 December 2001–3 January 2002 and 3 February 2002.
Dixie 9	2001	Bird migrated. Data were received 6 August 2001–10 February 2002. She remained in a 197.5 km^2 area, 277 km west of her nest site in the Sheep Mountain Range, Nevada.
Dixie 10	2001	Bird migrated. Data were received 24 August 2001–18 October 2001. She remained near her breeding territory in a 242.3 km^2 area until 18 September 2001. She traveled 114 km south to a 153.3 km^2 area near Jacob Lake, Arizona. Her transmitter stopped moving and sent cold temperatures after 18 October 2001.
Fishlake 1	2000	Bird migrated. Data were received 5 September 2000–28 October 2000. She remained near her breeding territory in a 15.9 km^2 area until 8 September 2000. She traveled 104 km south to a 221.6 km^2 area near Tropic, Utah, 18 September 2000–28 October 2000. Her transmitter stopped moving and sent cold temperatures after 28 October 2000.
Fishlake 2	2000	Bird migrated. Data were received 1 September 2000–21 December 2001. She remained near her breeding territory in a 182.2 km^2 area until 5 November 2000 and 30 March 2001–19 September 2001. On 8 November 2000, she was 124 km south near Cannonville, Utah. She traveled 49 km south to a 51.1 km^2 area 11 November 2000–24 March 2001. She returned to her breeding site twice during this time. She returned to winter area 1 25 September 2001–23 October 2001 in a 192.9 km^2 area. She traveled to a second winter area 1 November 2001–21 December 2001. She did not attempt to breed in 2001.
Fishlake 3	2000	Bird was assumed to be a resident. No data were collected due to poor signals. Transmitter stopped moving and sent cold temperatures after 1 March 2001. Transmitter was found near her breeding territory.
Fishlake 4	2001	Bird was a resident. Data were received 12 September 2001–4 January 2002. She remained near her breeding territory in a 364.2 km^2 area. Transmitter stopped moving and sent cold temperatures after 4 January 2002.
Fishlake 5	2001	Bird was a resident. Data were received 7 August 2001–24 January 2002. She remained near her breeding territory in a 663.9 km^2 area. After 24 January 2002, her transmitter stopped moving and sent cold temperatures.
Manti 1	2000	Bird was a resident. Data were received 18 July 2000–24 October 2001. She remained near her breeding territory in a 88.1 km^2 home-range. She attempted to breed in 2001, her nest failed during incubation.
Manti 2	2000	Bird was a resident. Data were received 10 July 2000–22 November 2001. She remained near her breeding territory in a 366.4 km^2 home-range. She did not attempt to breed in 2001.
Manti 3	2000	Bird migrated. Data were received 22 July 2000–26 February 2002. She remained near her breeding territory in a 99.4 km^2 area until 1 November 2000. She traveled 179 km south to a 59.0 km^2 area east of Boulder, Utah, 10 November 2000–13 March 2001. She returned to her breeding territory 25 March 2001–12 October 2001 foraging in a 257.4 km^2 area. From 1 December 2001–16 February 2002, she migrated to a 35.9 km^2 area 544 km south near Winslow, Apache Sitgreaves National Forest, Arizona. She did not attempt to breed in 2001.

APPENDIX 1. CONTINUED.

Individual	Year	Description
Manti 4	2000	Bird migrated. Data were received 5 September 2000–24 April 2002. She remained near her breeding territory in a 373.4 km^2 area until 15 April 2001, 24 April 2001–14 October 2001, and 27 March 2002–24 April 2002. From 18 April 2001–21 April 2001 and 23 October 2001–24 March 2002, she traveled 156 km northeast to a 116.6 km^2 area near Glade Park, Colorado National Monument, Colorado. She did not attempt to breed in 2001.
Manti 5	2001	Bird dispersed. Data were received 12 July 2001–4 January 2002. She remained near her nest site in a 235.9 km^2 area until 11/22/01. She traveled 30 km west to 412.6 km^2 winter area near Ephraim, Utah, 25 November 2001–11 December 2001. From 14 December 2001–4 January 2002, she foraged in a 113.7 km^2 area near Levan, Utah, 55 km west of winter area 1. After 7 January 2002, her transmitter stopped moving and sent cold temperatures.
Uinta 1	2000	Bird was a resident. Data were received 10 July 2000–11 March 2001. She remained near her breeding territory in a 102.2 km^2 area.
Wasatch 1	2000	Bird migrated. Data were received 17 July 2000–20 March 2001. She remained near her breeding territory in an 82.7 km^2 area until 29 September 2000. She traveled to a 31.1 km^2 area 261 km south near Scipio, Utah, 1 November 2000–26 November 2000. From 2 December 2000–8 March 2001, she wintered in a 65.8 km^2 area 258 km southwest of winter area 1 near Enterprise, Utah. She traveled to a 75.1 km^2 area 20 km west in Nevada 11 March 2001. Her transmitter stopped moving and sent cold temperatures after 20 March 2001.
Wasatch 2	2001	Too few data points collected to determine movement type. Two data points were collected on 20 Sept 2001 and 3 December 2001 located 30 km apart within 22 km of nest location. Bird Banding Lab recovered her band after 3 December 2001.
Wasatch 3	2001	Bird migrated. Data were received 3 August 2001–13 January 2002. She remained near her nest site in a 392.8 km^2 area until 31 October 2001. She traveled to a 499.1 km^2 area 613 km south near Mt. Trumbull, Arizona, 9 November 2001–28 November 2001. She traveled to a 147.2 km^2 area 36 km north to winter area 2 near Wolf Hole, Arizona, 1 December 2001–7 December 2001. She returned to winter area 1 10 December 2001–7 January 2002. She returned to winter area 2 10 January 2002. After 13 January 2002, her transmitter stopped moving and sent cold temperatures.