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SATELLITE TELEMETRY OF NORTHERN GOSHAWKS BREEDING IN UTAH—II. ANNUAL HABITATS

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Abstract. Irruptive movements exhibited by Northern Goshawks (*Accipiter gentilis*) can make determining year-round habitats of these birds difficult. Recent advancements in satellite-received transmitters and habitat modeling of landscapes have become useful in assessing movements and habitats of Northern Goshawks breeding in Utah. Studies documenting individual winter movements of Northern Goshawks in North America are limited, and detailed studies examining winter ecology have been largely restricted to the European subspecies. Adult females (N = 36) were fitted with 30 or 32 g platform transmitter terminals in 2000 and 2001 within the six national forests throughout Utah. Resident birds used forest habitat types and elevations similar to their breeding areas throughout winter. In contrast, birds that migrated or dispersed used pinyon-juniper habitat and lower elevations. In addition, migratory individuals had significantly larger home range sizes, suggesting lower prey availability within pinyon-juniper forests for Northern Goshawks.

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

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

Resumen. Movimientos interrumpidos presentes en el Gavilán Azor, pueden dificultar la determinación de sus hábitats, que utilizan durante todo el año. Avances recientes en transmisores de recepción satelital y en modelación del hábitat del paisaje, se han vuelto útiles para la estimación de los movimientos y hábitats del Gavilán Azor reproductor en Utah. 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. 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. Aves residentes utilizaron tipos de hábitat forestal y elevaciones similares a sus áreas de reproducción a través del invierno. En contraste, aves que migraron o se dispersaron, utilizaron hábitat de piñón-junípero y elevaciones más bajas. Además, individuos migratorios tuvieron un rango en el tamaño del hogar significativamente más amplio, sugiriendo que existe menor disponibilidad de presa para el Gavilán Azor dentro del bosque de piñón-junípero.

Population viability of Northern Goshawks (*Accipiter gentilis*) is a concern because habitat fragmentation is thought to reduce overall habitat quality for goshawks (Kennedy 1997, Graham et al. 1999a). Knowledge of breeding habitat alone is not adequate to understand biological requirements of goshawks, therefore non-breeding habitats need to be defined to determine relationships between habitat types and goshawk abundance (Kennedy 1997). Breeding habitat for Northern Goshawks has been well defined in the literature (Reynolds et al. 1982, Moore and Henny 1983, Hayward and Escano 1989, Hargis et al. 1994), but the winter ecology of Northern Goshawks is well known only in Europe (Kenward et al. 1981b, Kenward 1982, Widén 1987, Tornberg and Colpaert 2001). Few studies have examined winter habitats of Northern Goshawks in North America (Squires and Ruggiero 1995, Stephens 2001). Squires and Ruggiero (1995) studied four migratory individuals in southeastern Wyoming, where winter ranges contained quaking aspen (*Populus tremuloides*) with mixed conifer, Engelmann spruce-subalpine fir (*Picea engelmannii-Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), and cottonwood (*Populus* spp.) groves surrounded by sagebrush (*Artemisia* spp.). Stephens (2001) reported goshawks using three main habitat types in the Ashley National Forest, Utah, including mixed lodgepole pine, subalpine fir, and Douglas-fir (*Pseudotsuga menzieseii*) stands, pinyon-juniper (*Pinus edulis, Juniperus osteosperma,* and *Juniperus scopulorum*) stands, and lowland riparian areas. Although these studies provided valuable information about winter habitat use of Northern Goshawks near their breeding grounds, more data on goshawks that moved greater distances are needed to adequately assess habitat use.

In this study, we used satellite telemetry to assess annual habitat use by Northern Goshawks breeding in southwestern North America. Satellite telemetry had been used successfully to assess movements of various raptors (Brodeur et al. 1996, Fuller et al. 1998, Ueta et al. 1998, Ueta et al. 2000, McGrady et al. 2002), but none of these studies expanded the use of satellite technology to determine habitat types. Earlier studies (Britten et al. 1999) warned against using satellite telemetry for small-scale movements (<35 km) because actual locations may be several hundred meters from the recorded location. Though we understand the potential limitations in the accuracy of satellite telemetry locations estimates when considering small-scale movements, given the limited amount of data describing annual habitat use by Northern Goshawks, we feel it is important to broaden our understanding of annual habitat types used by goshawks at a landscape scale.

Using satellite telemetry, we determined the year-round habitats of Northern Goshawks breeding throughout Utah at a landscape scale. We hypothesized that Northern Goshawks would use habitats consistent with those described in previous studies during breeding months with birds breeding in mature to over-mature forest stands (Reynolds et al. 1982, Speiser and Bosakowski 1987, Hayward and Escano 1989). During winter, however, individuals would exploit a variety of habitat types, as described by Squires and Ruggiero (1995) and Stephens (2001), including those used during the breeding season.

METHODS

Field Techniques

Adult female Northern Goshawks (N = 36) were trapped at their nest sites in six national forests (Ashley, Dixie, Fishlake, Manti LaSal, Uinta, and Wasatch national forests) in Utah. These forests span about 720 km from north (Wasatch National Forest, ca. 41° 45' N) to south (Dixie National Forest, ca. 37° 25' N) and 540 km east (Manti LaSal National Forest, ca. 109° W) to west (Dixie National Forest, ca. 113° W). We used a live Great Horned Owl (*Bubo virginianus*) to lure birds 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 violet alphanumeric color bands. Females were fitted with a 30 or 32 g platform terminal transmitter (PTT) manufactured by North Star Science and Technology, Columbia, Maryland. We used a backpack harness made with Teflon ribbon (Snyder et al. 1989) to attach PTTs. We recorded standard measurements including mass, wing chord, tail length (central retrix), tarsus length, and hallux length to the nearest 0.1 mm along with eye color to assess bird's age. To limit potential transmitter effects, PTT units did not exceed 4.5% of the bird's body mass.

Satellite Telemetry Data

North Star Science and Technology programmed PTTs with a duty cycle of 6 hr of transmission followed by 68 hr without transmission. Data were sent to the USDA Forest Service District Station, Cedar City, Utah, by Argos satellite systems along with a corresponding location class for each location. Data points were input into ArcView version 3.2, a geographic information system (GIS) (ESRI 1996). We only used data points with location classes 3, 2, and 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 of the estimated location, respectively (McGrady et al. 2002). Estimated locations with a class 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 maximum flight speed observed in the Peregrine Falcon (*Falco peregrinus*; Cochran and Applegate 1986, Chavez-Ramierez et al. 1994).

Location estimates were characterized as day or night to determine potential differences between day and roost habitats. Data were considered daytime at sunrise through 1 hr before sunset at 40° latitude (U.S. Naval Observatory 1999). Times were rounded to the nearest 5 min. Data received 1 March–30 April were considered spring, 1 May–31 August as summer, 1 September–30 November as autumn, and 1 December–28 February as winter.

Habitat type and elevation for each point were determined in ArcView with Utah Forest Inventory and Analysis (USDA Forest Service 1988a), Arizona, Nevada, Utah, and Wyoming GAP analysis vegetation layers (USGS GAP Analysis Program 2000), Utah Contours (State of Utah 2000), Arizona 90 meter Digital Elevation Model (USGS 2000), and Wyoming 90 meter Digital Elevation Model (USGS 1997) elevation layers. Buffers were placed around each estimated location according to its accuracy estimate because the actual location of the transmitters would be within 150–1,000 m (radius) of estimated location. We assessed and recorded all habitat types within each buffer. Buffers containing multiple habitat types were categorized as conifer, conifer-aspen, non-forest, and non-forest-forest. We defined conifer as a buffer containing any combination of alpine fir, Douglas-fir, Engelmann spruce, lodgepole pine, pinyon-juniper, ponderosa pine, or white fir (*Abies concolor*); conifer-aspen as any combination of previously mentioned conifer types with aspen; non-forest as any combination of a non-forest habitat such as perennial grass and sagebrush; and non-forest-forest as any combination of non-forest habitat types and forest habitat types. Assuming birds are relatively sedentary at night, data received during the same night were considered one estimate. If night locations had more than one elevation or habitat type for a particular night, each estimate was weighted proportional to its occurrence that night. Total weighted values for each night summed to one. No habitat data were available for Colorado (3.2% of points) and no elevation data were available for Colorado and Nevada (4.3% of points). Location estimates along with their corresponding buffer will be referred to as location estimates throughout the rest of this manuscript.

Some researchers have indicated at error distances for location estimates provided by Argos underestimate the actual error associated with a given location estimate (Craighead and Smith 2003). In an attempt to address these concerns, we characterized habitat within use areas for individual goshawks for each season. Use areas were defined by a kernel home range 95% polygon calculated in ArcView version 3.2 using extension Animal Movement (Hooge et al. 1999). Habitats were categorized as described above.

Statistical Analysis

Habitat and elevation data collected from summer 2000 through summer 2001 were analyzed in SAS release 8.2 (SAS Institute, Inc. 2001). Habitat types were categorized as conifer, deciduous, non-forest, pinyon-juniper, or any combination of these categories, using definitions described above. Data were not stratified based on day or night locations. Data were normally distributed and had equal variances. A logistic regression was used to determine potential differences in habitat categories among seasons in 2000, accounting for bird and breeding location. A regression with repeated measures (PROC MIXED) was used to determine potential differences in elevation among seasons in 2000, accounting for bird and breeding location. Buffers categorized as conifer-deciduous-non-forest-pinyon-juniper, conifer-non-forest-pinyon-juniper, conifer-pinyon-juniper, deciduous-non-forest-pinyon-juniper, and deciduous-pinyon-juniper were removed from the regression because of low sample size.

RESULTS

We received 5,557 (LC3 N = 940, LC2 N = 1,665, LC3 N = 2,952) location estimates from units attached to the 35 birds used in this study. Habitats used varied with national forest and migratory behavior. Detailed descriptions of habitats exploited by individual birds are described in Sonsthagen (2002). On the northern national forests (Ashley, Uinta, and Wasatch national forests), five of 15 individuals migrated, whereas, on the southern national forests (Dixie, Fishlake, and Manti LaSal national forests) 11 of 20 females migrated. Most individuals (79%) that migrated or dispersed used primarily pinyon-juniper and non-forest habitat in winter, whereas, most residents (93%) used alpine fir, Douglas-fir, Engelmann spruce, lodgepole pine, ponderosa pine, quaking aspen, white fir, or any combination of these in winter. Proportion of location estimates in each habitat type and elevation varied between day and night. No distinct habitat use pattern was found due to high variability between locality, seasons, and years.

Females breeding in the northern national forests used the same habitat types throughout most of the year, but percent of use varied between breeding and non-breeding periods (Table 1). In summer, autumn, and spring, females used mainly Douglas-fir (0–16.3%), Douglas-fir-aspen (2.5–25.0%), Engelmann spruce-lodgepole pine (4.7–20.6%), lodgepole pine (0–14.4%), lodgepole pine-aspen (6.4–25.2%), and quaking aspen (5.1–25.0%). In winter, females used habitat types similar to those in other months but in differing frequencies. Females increased their use of pinyon-juniper habitat from an average of 2.6% in all other seasons to 15.4% in winter 2000 and 20.6% in winter 2001 (Table 1). Two females from the Wasatch National Forest used pinyon-juniper habitat almost exclusively in winter and migrated 527 km and 613 km to their winter ranges. In autumn and spring, birds used a wider range of habitats. In general, more points were in non-forest and non-forest-forest habitats in non-breeding months. Additionally, in 2001, only three of seven females bred, which may have affected our results.

Females breeding on the southern national forests used a variety of habitat types with frequency of use varying between seasons and years (Table 2). In summer 2000, females used mainly alpine fir (27.8%) and quaking aspen (56.9%). In 2001, however, birds used alpine fir (13.3%), pinyon-juniper (10.5%), quaking aspen (21.6%) and non-forested (11.1%) habitats. Only one-half of the females studied in summer 2001 bred, which may have affected our results. In autumn, females used similar habitat

TABLE 1. PERCENT OF LOCATION ESTIMATES THAT OCCURRED BY HABITAT TYPE FOR FEMALE GOSHAWKS BREEDING IN THE NORTHERN NATIONAL FORESTS (ASHLEY, UINTA, AND WASATCH NATIONAL FORESTS), UTAH, BY YEAR AND SEASON FROM 2000–2001. NIGHT LOCATIONS WERE WEIGHTED PROPORTIONAL TO THEIR OCCURRENCE SO THAT EACH NIGHT'S ESTIMATES SUMMED TO ONE.

Habitat type	Summer 2000	Autumn 2000	Winter 2000	Spring 2001	Summer 2001	Autumn 2001	Winter 2001	Spring 2002
Alpine fir	0.2	0.1	0.2	-	-	-	-	4.8
Alpine-aspen	-	-	0.1	-	-	-	0.1	-
Douglas-fir	14.4	11.0	6.3	16.3	14.1	12.6	0.7	-
Douglas-fir-aspen	2.5	4.0	4.5	5.8	5.0	12.6	13.2	25.0
Engelmann spruce	-	-	-	-	-	-	-	-
Engelmann-lodgepole	8.2	9.4	10.1	16.5	20.6	4.7	7.0	7.1
Lodgepole pine	14.4	12.2	9.8	4.9	8.6	1.5	-	-
Lodgepole-aspen	25.2	14.2	15.4	6.4	12.7	23.1	18.2	7.1
Pinyon-juniper	0.4	3.6	15.4	3.0	5.9	2.9	20.6	-
Ponderosa pine	0.4	0.5	0.1	0.2	-	0.8	-	-
Quaking aspen	8.9	10.6	8.5	5.1	14.1	10.9	19.8	25.0
White fir	5.0	6.5	6.5	5.1	-	-	-	-
Conifer	0.4	-	0.3	0.6	1.3	3.1	0.2	4.8
Conifer-aspen	9.7	8.6	5.9	8.0	7.9	6.7	2.4	-
Non-forest	4.1	7.2	8.0	16.1	5.1	8.8	6.9	14.3
Non-forest-forest	6.4	12.1	8.9	11.8	9.7	12.0	10.3	11.9
N locations	278	367	400	177	330	191	145	42
N individuals	11	11	8	7	8	7	4	3

TABLE 2. PERCENT OF LOCATION ESTIMATES THAT OCCURRED BY HABITAT TYPE FOR FEMALE GOSHAWKS BREEDING IN THE SOUTHERN NATIONAL FORESTS (DIXIE, FISHLAKE, AND MANTI LASAL NATIONAL FORESTS), UTAH, BY YEAR AND SEASON FROM 2000–2001. NIGHT LOCATIONS WERE WEIGHTED PROPORTIONAL TO THEIR OCCURRENCE SO THAT EACH NIGHT'S ESTIMATES SUMMED TO ONE.

Habitat type	Summer 2000	Autumn 2000	Winter 2000	Spring 2001	Summer 2001	Autumn 2001	Winter 2001	Spring 2002
Alpine fir	27.8	9.9	2.6	12.3	13.3	28.5	25.3	2.3
Alpine-aspen	6.9	1.6	2.0	3.6	4.1	4.4	4.7	-
Douglas-fir	-	1.5	1.2	3.1	1.6	2.1	-	-
Douglas-fir-aspen	2.8	0.5	1.3	0.7	-	-	-	-
Engelmann spruce	-	4.3	1.1	6.2	6.8	5.1	-	8.0
Engelmann-lodgepole	-	-	-	-	0.2	-	-	-
Lodgepole pine	-	-	-	-	-	-	-	-
Lodgepole-aspen	-	-	-	-	-	-	-	-
Pinyon-juniper	2.8	19.2	46.1	25.6	10.5	10.2	17.7	-
Ponderosa pine	-	12.2	5.3	3.8	6.6	5.4	13.2	47.7
Quaking aspen	56.9	12.2	12.1	12.1	21.6	11.8	-	-
White fir	-	8.5	8.8	4.7	6.9	7.9	0.5	2.3
Conifer	2.8	9.3	3.6	3.4	6.5	6.7	4.3	30.7
Conifer-aspen	-	0.3	1.7	0.4	2.5	1.3	0.9	2.3
Non-forest	-	9.4	7.3	11.4	11.1	6.3	17.5	4.5
Non-forest-forest	-	11.1	7.7	12.5	8.1	10.8	15.8	2.2
N locations	36	361	355	222	368	319	108	44
N individuals	3	12	9	7	11	12	7	2

types between years with an increase in the percent of points occurring in alpine fir (9.9% in 2000 to 28.5% in 2001; Table 2). In winter 2000, birds used mainly pinyon-juniper (46.1%) and quaking aspen (12.1%). Conversely, in winter 2001, females used a wider range of habitat types; alpine fir (25.3%), pinyon-juniper (17.7%), ponderosa pine (13.2%), non-forest (17.5%), and non-forest-forest (15.8%) habitat types. In spring 2000, birds used a wider range of habitats with pinyon-juniper (25.6%), quaking aspen (12.1%) and non-forest-forest (12.5%) habitats having the highest frequency of use, whereas, in spring 2001 goshawks used ponderosa pine (47.7%) and conifer (30.7%) habitats almost exclusively. In general, a higher percentage of locations were in pinyon-juniper, non-forest, and non-forest-forest habitat types in the non-breeding period.

Though we received data for approximately 1 yr from most of our transmitters, four transmitters continued to send data for 2 yr. From the northern national forests, Ashley 1 was migratory and wintered in the same location each year using mainly Douglas-fir and quaking aspen habitat (Sonsthagen 2002). We had three birds with 2 yr of data from the southern forests (Fishlake 2, Manti 3, and Manti 4; Sonsthagen 2002). Fishlake 2 wintered in the same area each year and also used pinyon-juniper habitat almost exclusively with frequencies ranging between 83.3–92.9%. Manti 3 and Manti 4 did not winter in the same area in 2001 as they did in 2000, but both used pinyon-juniper habitat almost exclusively (70.6–100%) each winter. Manti 4 migrated 156 km in 2001 to Colorado National Monument, her winter range was composed of pinyon-juniper with corridors of sagebrush (J. Underwood, pers. comm.). No vegetation layers are available for Colorado, so we were unable to determine the percentage of points in each habitat type. Habitats within each use area, as determined by kernel home range 95% polygons, did not differ from those described above for location estimates in a given season and year.

We detected significant differences in habitat use among seasons (Table 3). Logistic regression indicated significant differences in the number of locations among seasons in conifer, deciduous, non-forest, pinyon-juniper, conifer-deciduous, and non-forest-pinyon-juniper for the 2000 habitat data after accounting for individuals and breeding locality. Significant differences in the number of locations that occurred in conifer habitat were detected among all seasons except autumn–winter, where summer had highest number of estimates in conifer and spring the lowest. Of location estimates in deciduous habitat, significant differences occurred between spring-summer, spring-autumn, and spring-winter. We found lower numbers of location estimates in spring in deciduous habitats than in all other months. Non-forested locations differed significantly among all seasons except summer-autumn. Summer had the highest number of estimates and winter the lowest. Pinyon-juniper locations differed significantly among all seasons except spring-winter, where spring had the highest number and summer the lowest number of locations. Significant differences in the number of locations

TABLE 3. PAIRWISE SEASON COMPARISON AMONG HABITAT TYPES FOR DATA COLLECTED IN SUMMER 2000 TO SPRING 2001 IRRESPECTIVE OF NATIONAL FOREST USING A LOGISTIC REGRESSION ($\alpha = 0.05$) WITH SLOPES FOR EACH SEASONAL COMPARISON.

Pairwise season comparison	Conifer slope	Deciduous slope	Pinyon-juniper slope	Non-forest slope	Conifer/ deciduous slope	Conifer/ pinyon-juniper slope	Conifer/ Non-forest slope	Deciduous/ pinyon-juniper slope	Deciduous/ Non-forest slope	pinyon-juniper / Non-forest slope
Spring-summer	-1.0[a]	-0.6[a]	2.6[a]	-1.1[a]	0.2	0.4	0.5	-18.7	1.0	-0.2
Spring-autumn	-0.5[a]	-0.4[a]	1.7[a]	-0.9[a]	0.4[a]	-0.2	0.2	-19.9	0.4	-1.3[a]
Spring-winter	-0.4[a]	-0.6[a]	0.2	0.7[a]	-0.1	18.8	27.4	-4.1	9.7	-1.7[a]
Summer-autumn	0.5[a]	0.1	-0.9[a]	0.2[a]	0.2	-0.6	-0.3	-1.2	-0.6	-1.1[a]
Summer-winter	0.6[a]	-0.1	-2.4[a]	1.8[a]	-0.3	18.4	27.0	14.6	8.7	-1.5[a]
Autumn-winter	0.1	-0.2	-1.5[a]	1.6	-0.5[a]	19.0	27.2	15.8	9.3	-0.4

[a] Significant slopes ($\alpha = 0.05$).

that occurred in conifer-deciduous habitat were among spring-autumn and autumn-winter. Spring had more estimates than autumn and autumn less than winter. Of the locations in non-forest-pinyon-juniper, significant differences occurred among all seasons except spring–summer and autumn-winter. Autumn and winter had more locations than spring and summer.

Individuals were observed at elevations ranging from 1,525–3,505 m. Elevation ranges used by Northern Goshawks varied with locality, but two general trends existed (Tables 4, 5). Birds from the northern forests remained at relatively the same elevation range throughout the year (Table 4). Birds from the southern forests used a wide range of elevations in autumn and spring and dropped to lower elevations in winter (Table 5). Birds residing on the same forest did not exhibit the same trends each year, which may be attributed to movement type (migratory versus resident) exhibited by individuals. In general, migratory individuals moved to lower elevations and residents remained at elevations similar to their breeding territory. We found a significant difference ($P = 0.044$) among elevations that individuals occurred at and season in the 2000 data, after accounting for the region in which the birds were located. Elevations used in summer were higher than in winter.

DISCUSSION

These habitat data provide information on the common habitat types used throughout the year. Two general trends characterized habitat types and elevations exploited by goshawks. Northern Goshawks that migrated or dispersed from their nest sites used pinyon-juniper and non-forest habitat types and lower elevation ranges than representative of their breeding site. In contrast, individuals that remained residents used habitats common to their breeding territory and remained at relatively the same elevation throughout the year. Not all individuals, however, displayed these trends. Females breeding on the Ashley National Forest used habitats similar to their breeding sites across all movement types. One female on the Manti LaSal National Forest (Manti 4, 2000) used pinyon-juniper habitat and lower elevations while remaining near her nest site. Additionally, we had four birds (Ashley 1, Fishlake 2, Manti 3, and Manti 4) with 2 yr of data. Although, not all of these individuals wintered in the same area each year, they used the same habitats as the previous winter.

We are aware of potential limitations in accurately estimating satellite telemetry locations (Britten et al. 1999, Craighead and Smith 2003) and do not suggest that these values presented here are absolute. Rather, we present these data heuristically to illustrate

TABLE 4. PERCENT OF LOCATION ESTIMATES THAT OCCURRED BY ELEVATION FOR FEMALE GOSHAWKS BREEDING IN THE NORTHERN NATIONAL FORESTS (ASHLEY, UINTA, AND WASATCH NATIONAL FORESTS), UTAH, BY YEAR AND SEASON FROM 2000–2001. NIGHT LOCATIONS WERE WEIGHTED PROPORTIONAL TO THEIR OCCURRENCE SO THAT EACH NIGHT'S ESTIMATES SUMMED TO ONE.

Elevation (meters)	Summer 2000	Autumn 2000	Winter 2000	Spring 2001	Summer 2001	Autumn 2001	Winter 2001	Spring 2002
1,525	-	0.1	-	-	-	0.9	4.2	-
1,675	0.4	1.2	0.6	-	-	1.9	3.6	-
1,830	0.2	2.7	15.4	-	-	2.6	13.2	-
1,980	0.9	3.1	4.0	5.6	0.4	0.3	3.7	2.2
2,135	4.3	4.3	5.4	7.7	1.0	2.1	2.1	13.0
2,285	7.3	4.7	8.2	11.5	2.9	8.6	7.3	13.0
2,440	13.1	15.0	19.8	34.9	20.1	14.7	5.8	10.9
2,590	31.2	34.5	24.9	27.7	37.9	21.2	17.4	38.0
2,745	21.3	25.2	16.9	10.5	21.8	25.5	26.1	14.1
2,895	18.3	7.9	4.0	0.2	11.1	15.7	9.8	4.3
3,050	2.6	1.3	0.7	1.2	4.5	4.8	6.6	4.3
3,200	0.3	0.2	0.2	0.7	0.3	0.9	0.2	-
3,355	-	-	-	-	-	0.6	-	-
3,505	-	-	-	-	-	-	-	-
3,660	-	-	-	-	-	-	-	-
3,810	-	-	-	-	-	-	-	-
3,965	-	-	-	-	-	-	-	-
N estimates	278	373	402	162	313	164	143	46
N individuals	11	11	8	7	8	7	4	3

TABLE 5. PERCENT OF LOCATION ESTIMATES THAT OCCURRED BY ELEVATION FOR FEMALE GOSHAWKS BREEDING IN THE SOUTHERN NATIONAL FORESTS (DIXIE, FISHLAKE, AND MANIT LASAL NATIONAL FOREST), UTAH, BY YEAR AND SEASON FROM 2000–2001. NIGHT LOCATIONS WERE WEIGHTED PROPORTIONAL TO THEIR OCCURRENCE SO THAT EACH NIGHT'S ESTIMATES SUMMED TO ONE.

Elevation (meters)	Summer 2000	Autumn 2000	Winter 2000	Spring 2001	Summer 2001	Autumn 2001	Winter 2001	Spring 2002
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1,675	-	5.8	7.8	10.1	3.5	2.8	18.0	2.2
1,830	-	11.1	21.5	8.9	10.6	9.4	22.8	-
1,980	2.6	10.4	26.1	11.0	7.6	10.4	10.2	11.4
2,135	2.6	10.7	12.6	15.7	3.7	8.8	10.7	15.9
2,285	5.1	10.5	6.0	3.8	7.0	8.3	7.3	20.5
2,440	3.1	10.4	3.4	6.4	10.5	14.6	3.4	18.2
2,590	9.0	15.7	2.6	8.8	15.2	14.0	3.5	29.5
2,745	32.9	7.1	5.4	5.4	12.3	14.8	12.2	-
2,895	16.2	9.8	5.5	7.9	15.8	8.7	4.3	2.3
3,050	11.1	5.4	5.6	15.1	8.6	5.6	2.7	-
3,200	14.1	1.8	2.2	4.3	3.2	1.6	-	-
3,355	2.6	0.8	0.5	1.7	0.7	0.6	-	-
3,505	2.6	0.3	0.4	0.9	1.1	0.1	-	-
3,660	-	-	0.3	-	-	-	-	-
3,810	-	-	0.2	-	-	-	-	-
3,965	-	-	-	-	-	-	-	-
N estimates	39	359	358	219	351	319	110	44
N individuals	3	12	9	7	11	12	7	2

habitat use of goshawks on an annual basis. While researchers have expressed concern about the error estimates we used in this study, we used current published error distances for the location estimates provided by Argos (McGrady et al. 2002). In addition, habitats within each use area did not differ from those described for location estimates. Underwood et al. (*this volume*) increased buffers (1 and 3 km) around location estimates and did not detect any biological difference in their results. Finally, in several instances we used location estimates to locate live birds or retrieve transmitters from birds that had died. In these cases we were able to locate birds and transmitters within 500 m of where the location estimates placed the transmitters. Therefore, the error estimates that we used in this study do not appear to alter the biological or interpretive significance of our findings.

We hypothesize that prey availability may be a driving factor in Northern Goshawks using an area. Availability of prey depends on prey abundance, but also habitat characteristics that influence accessibility of prey (Widén 1994). In Sweden and Northern Finland, goshawks in boreal forests hunted in mature forests (Widén 1987, Tornberg and Colpaert 2001). Conversely, goshawks studied in the farmland-forest mosaics of Sweden appeared to favor foraging on forest-edge zones (Kenward 1982). In both landscapes, suitable prey abundances were greater in areas exploited by goshawks. Additionally, large tracts of land may not be used by raptors because of the lack of perch availability. Widén (1994) suggested perch availability is the limiting factor for the exploitation of clearcuts by pause-travel-foraging raptors, like Northern Goshawks. Habitat fragmentation, therefore, may affect the ability of individuals to use an area rather than reduce habitat quality for potential prey.

Finally, winter home ranges of individuals that migrated were larger than residents and main habitat utilized by migratory individuals was pinyon-juniper (Sonsthagen 2002). Because home-range size in accipiters is inversely proportional to prey abundance (Kenward 1982, Newton 1986), this outcome indicates that individuals wintering in pinyon-juniper and non-forest habitats are moving to areas with lower prey abundance. Winter density and territoriality of raptors vary according to prey availability (Craighead and Craighead 1956, Cavé 1968). Therefore, females may be moving to reduce local competition or females that are more aggressive secured territories forcing birds to migrate to areas with lower prey availability.

The nature of our data clearly defined wintering habitat currently used by Northern Goshawks and highlighted two completely different landscapes, one similar to that used during breeding and the other pinyon-juniper habitat. Because of the spatial scale of our data, we could not further address the finer points of the habitats nor did it allow us to speculate on the effects that increased habitat fragmentation might have on Northern Goshawks. Additionally, effects of fragmentation on population numbers are difficult to assess because effects of habitat loss depend on the quality of the area lost (Newton 1998). In migrant populations, breeding and non-breeding habitat loss may have different effects on population levels depending on the strength of density-dependence in the two areas (Sutherland 1996, Newton 1998). The strength of density-dependence in winter ranges is measured by the rate of increased mortality with increased population size or habitat loss, whereas, the strength of breeding area density-dependence is measured by the rate of decreased reproduction in relation to increased population size or habitat loss. Therefore, habitat loss will have a larger impact on population size in the range with the larger slope (Newton 1998). Also, size of the remaining patches may influence bird density (Newton 1998). This is especially important because goshawks normally exist at a low density (3.6–10.7 pairs/100 km^2; Squires and Reynolds 1997). So the question of habitat loss or fragmentation becomes circular reasoning because while small patches may facilitate prey capture, prey are usually present at lower densities (Tornberg and Colpaert 2001) requiring greater risk to the goshawk in trying to fulfill nutritional needs.

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