Studies in Avian Biology No. 31:228–238

WINTER MOVEMENT AND HABITAT USE OF NORTHERN GOSHAWKS BREEDING IN UTAH

JARED UNDERWOOD, CLAYTON M. WHITE, AND RONALD L. RODRIGUEZ

Abstract. Few studies detail population-wide winter movements of Northern Goshawks (*Accipiter gentilis*) in North America or examine their winter ecology and habitat associations. Using satellite-telemetry transmitters, landscape-habitat models, aerial photos, and field sampling, we assessed movements and wintering habitats of goshawks breeding in Utah. In our study, 42 adult females were fitted with 30 g or 32 g platform transmitter terminals (PTT) between 2000 and 2003. Our data suggest that females in the populations studied were either migrants or semi-migrants that moved randomly throughout the state or residents. Resident birds remained in the general area around the breeding territory but used a wider variety of habitat cover types and commonly moved downward in elevation during winter. In contrast, birds that migrated or semi-migrated from their breeding territories for the winter generally used the pinyon-juniper habitat cover type. This pinyon-juniper habitat tended to be a mosaic of fairly open pinyon-juniper forest and sagebrush ecotones. The wintering areas for each bird were analyzed using vegetative sampling methods in order to determine correlations between habitat structure and goshawk use. Vegetative structure in the winter areas varied widely, but all goshawks used areas of forest-non-forest edge throughout the winter. Many of the selected winter sites showed signs of human manipulation (tree harvest, tree and brush removal by chaining, or fire). These findings increase our understanding of what constitutes goshawk wintering habitat and place new priority on understanding the use of various habitat cover types by wintering Northern Goshawks.

Key Words: *Accipiter gentilis,* diet, habitat, movement, Northern Goshawk, Utah, winter.

MOVIMIENTOS DURANTE EL INVIERNO Y USO DEL HABITAT DEL GAVILÁN AZOR REPROCUCTOR EN UTAH

Resumen. Pocos estudios detallan los movimientos a nivel poblacional del Gavilán Azor (*Accipiter gentilis*) en Norte América, o examinan su ecología durante el invierno y sus asociaciones del hábitat. Utilizando transmisores de telemetría satelital, modelos de hábitat-paisaje, fotografías aéreas, y muestreo de campo, evaluamos movimientos y hábitats de invierno de gavilanes reproductores en Utah. En nuestro estudio, 42 hembras adultas fueron adaptadas con terminales transmisoras de plataforma (PTT) de 30 g ó 32 g, entre 2000 y 2003. Nuestros datos sugieren que las hembras en las poblaciones estudiadas fueron ya sea migrantes o semi-migrantes, las cuales se movieron aleatoriamente por todo el estado, o bien, residentes. Las aves residentes permanecieron en el área general alrededor del territorio de reproducción, pero utilizaron una variedad más amplia de tipos de hábitat de cobertura, y comúnmente se movieron a una elevación más baja durante el invierno. En contraste, las aves que migraron o semi-migraron de sus territorios de reproducción durante el invierno, generalmente utilizaron el hábitat de tipo de cobertura piñón-junípero. Este hábitat de piñón-junípero tendió a ser un mosaico de bosques de piñón-junípero substancialmente abierto y de ecotonos de Artemisa. Las áreas utilizadas durante el invierno de cada ave fueron analizadas, utilizando métodos de muestreo vegetativo, con el fin de determinar correlaciones entre estructura del hábitat y uso del gavilán. La estructura vegetativa en las áreas utilizadas durante el invierno variaron ampliamente, pero todos los gavilanes utilizaron áreas de bordes forestales y no forestales durante todo el invierno. Muchos de los sitios de invierno seleccionados, mostraron señales de manipulación humana (cultivo de árboles, remoción de árboles y arbustos por corta o fuego). Estos hallazgos incrementan nuestro entendimiento sobre qué es lo que constituye el hábitat del gavilán invernando y pone en nueva prioridad el entendimiento en la utilización de hábitats con varios tipos de cobertura por los Gavilanes Azor.

The Northern Goshawk (*Accipiter gentilis*) inhabits mature and old-growth forested regions (Palmer 1988, Squires and Reynolds 1997). It is a predator of small- to medium-sized mammals and birds, and tends to hunt over large ranges (Palmer 1988, Squires and Reynolds 1997). Three putative subspecies breed in North America: the widespread *Accipiter gentilis atricapillus*, and the more geographically isolated *A. g. apache* and *A. g. laingi* (Squires and Reynolds 1997). Goshawks are said to prefer mature to old-growth forest stands with dense canopy cover in which to nest (Squires and Reynolds 1997), consequently their nesting habitat and therefore population numbers may be negatively affected by timber harvest (Crocker-Bedford 1990). Because of this, much like the Spotted Owl (*Strix occidentalis*), the Northern Goshawk has become a flagship animal in the last 15 yr for the preservation of old-growth and mature forests. Although the goshawk remains unlisted under the Endangered Species Act (ESA) it has been designated a sensitive species by many regions of the USDA Forest Service (USFS). This designation generated an increased interest in their biology and habitat requirements in an attempt to protect the goshawk, and prevent the need for listing it under the ESA.

Many studies have attempted to understand the breeding habitat requirements of Northern Goshawks (Bosakowski 1999). Other authors such as Reynolds et al. (1992) and Graham et al. (1999b) have integrated findings of various studies into forest-management recommendations that manage for healthy, sustainable forested landscapes that also benefit the goshawk and their prey. However, to effectively protect a species we must understand its biology not only in the breeding season but also in the non-breeding or winter season (Squires and Ruggiero 1995, Beier and Drennan 1997, Squires and Reynolds 1997). For this study, the winter and the wintering habitat were defined as any area or areas that a goshawk used between mid-September and mid-March, corresponding to the time between dispersal of the current year's young and commencement of a new breeding season (Palmer 1988, Squires and Reynolds 1997).

The few winter studies conducted on the behavior, migration patterns, and wintering habitat of the goshawk in North America have produced limited information (Doerr and Enderson 1965, Squires and Ruggiero 1995, Stephens 2001, Sonsthagen et al. 2002, Boal et al. 2003, Drennan and Beier 2003). It has been difficult to understand migration patterns of the goshawk through these studies because they relied on radio telemetry, which often failed to track goshawks that migrate >25 km from the area they were trapped (Stephens 2001, Drennan and Beier 2003). Winter habitat studies have looked only at winter habitat selection by resident birds (Drennan and Beier 2003) or by birds trapped in a small area (Stephens 2001). Relatively small sample sizes of goshawks (N = 4–12; Squires and Ruggiero 1995, Stephens 2001, Drennan and Beier 2003) also limited the ability to extrapolate these findings to larger population.

We hoped to examine goshawk winter biology and habitat use on a population-wide scale to better evaluate the necessity of incorporating winter biology into goshawk protection and management. The objectives of this study were to: (1) more fully understand the duration, distance, and patterns of winter migration, (2) use geographic information systems (GIS) and other computer tools to identify wintering sites, ascertain winter site fidelity, determine habitat cover types most frequently used, and assess landscape-level habitat selection, and (3) collect data to determine winter diet and importance of vegetative structure (Beier and Drennan 1997) in the selection of wintering areas.

METHODS

Study Site

The study area included six national forests in the state of Utah. The six national forests cover 3,200,000 ha and range from the northern to southern and eastern to western borders of Utah. The elevation of these forests ranges from 1,200–3,300 m with a variety of habitat cover types distributed along an elevational and latitudinal gradient. The most common forest cover types include ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), conifer-quaking aspen (*Abies-Picea-Populus tremuloides*), spruce-fir (*Picea-Abies)*, pinyon-juniper (*Pinus edulis-Juniperus* spp.), and mixed-forest areas where all forest varieties intermingle. The Northern Goshawk is known to breed throughout the study area in all habitat cover types except pinyon-juniper (Graham et al. 1999b). However, most of the nests occur between 1,800–3,000 m in the conifer-quaking aspen cover type (Johansson et al. 1994, Graham et al. 1999b).

Trapping and Tracking

During the months of June through August, 2000–2002, adult female goshawks (N = 42) were trapped at their nests using a live Great Horned Owl (*Bubo virginianus*) to lure the goshawks into a modified dho-gaza net trap (Clark 1981). Britten et al. (1999) suggested a maximum transmitter load of 3–5% of the bird's mass in Peregrine Falcons (*Falco peregrinus*). We assumed this same maximum load would apply to goshawks, another medium-sized raptor, and therefore excluded males from this study because the weight of the transmitters. Goshawks were selected from known territories on various forests corresponding to different regions of the state. This was done to see if winter migration was dependent on location in the state. After the goshawks were trapped, they were fitted with satellite platform terminal transmitters (PTT) manufactured by North Star Science and Technology (Columbia, MD), attached with a backpack harness (Snyder et al. 1989).

The transmitter-marked goshawks were tracked throughout the life of the transmitter, approximately 1 yr, but seven of the transmitters lasted nearly 2 yr. In order to conserve battery life the transmitters were placed on a rotational pattern that consisted of transmitting for 6 hr followed by 68 hr of dormancy. This duty cycle was selected based on extending the life of the transmitter for the desired study length. During the period of transmitter activity it emitted a location signal every 60 sec. These location signals were then processed by the ARGOS satellite company and sent to the USFS with a confidence interval of their accuracy.

The accuracy associated with location estimates varies widely, for this study we only used location estimates (LC: 3, 2) with an associated accuracy buffer of 250 m or 500 m respectively (Argos, pers. comm.). This level of accuracy is similar to that received by aerial tracking of radio-marked raptors and other animals (Marzluff et al. 1994, Samuel and Fuller 1996, Carral et al. 1997, DeVault et al. 2003) and to other published satellite-telemetry studies on raptors (McGrady et al. 2002). The data points received from the PTTs were input into Arc View version 3.3 (ESRI 1996), a GIS computer program, in order to view migration and wintering areas of the goshawks. If a goshawk traveled >100 km and stayed, the length of stay in the wintering area and winter site fidelity between years were recorded. Winter site fidelity was determined for the transmitter-marked goshawks in which the transmitter lasted for two winters. Fidelity was assumed if the bird returned to the same winter area on consecutive winters. The sizes of the winter territories for 2000 and 2001 were analyzed by calculating the kernel home range (95% probability polygons) as described in Sonsthagen (2002).

To determine whether goshawk migration corresponded with inclement weather patterns (Squires and Ruggiero 1995), goshawk movements were compared to the time of the first major winter storm. This was accomplished using storm data (NOAA 2003a) collected statewide on a county basis and individual readings from the closest NOAA weather station to the nest site (NOAA 2003b). The date of the first major winter snow storm for the area in which the bird nested was compared to the date that the bird migrated. Movements that occurred subsequent to the first winter storm were evaluated in relation to the closest preceding major winter storm.

GIS Habitat Analysis

To determine the most frequently used habitat cover types, after each wintering area was identified, we used GIS landscape habitat layers (Utah, Arizona, Nevada, and Wyoming), GAP analysis vegetation layers (USGS GAP Analysis Program 2000), aerial photos (State of Utah 2001), and USGS 1:24 k topographic maps, to assign each location estimate to a habitat cover type. Since finer-scale habitat associations were not permitted due to the accuracy buffer surrounding the location estimates, the vegetative cover associated with each location point was placed in one of four major habitat cover types: ponderosa pine (areas dominated by ponderosa pine but also including in lesser amounts quaking aspen, fir, Gambel oak [*Quercus gambelii*], pinyon, Utah juniper [*Juniperus utahensis*], and rocky mountain juniper [*Juniperus scopulorum*]), pinyon-juniper forests (areas dominated by pinyon, juniper or any combination thereof but also including limited amounts of ponderosa pine, fir, Gambel oak, and big-tooth maple [*Acer grandidentatum*]), grassland-shrubland (any grassland, shrubland, burn, chaining, logged area, or combination thereof), and montane forest (consisting of any areas dominated by a combination of quaking aspen, fir, spruce, and pine). GIS landscape habitat layers and GAP vegetative layers were verified using the aerial photos and field observations. Since each location point was coupled with an accuracy buffer of 250 m or 500 m, multiple habitat cover types were sometimes associated with a particular location estimate. All habitat cover types found within the accuracy buffer were used to label the estimate.

The use of satellite telemetry has inherent flaws. While the specific location for a bird is generally found within the associated accuracy buffer, in some cases the true location of the bird is outside of the reported buffer zone (Britten et al. 1999, McGrady et al. 2002). We occasionally received a location estimate an impossible distance for the bird to have traveled based on estimates received both before and after said estimate. Points such as these were excluded from all analyses.

Field Habitat Analysis

To investigate the importance of vegetative structure in the selection of wintering areas each habitat cover type was also sampled in the field for certain vegetative characteristics: the percent canopy cover of the tree layer, the shrub layer, and the herbaceous-ground layer. These vegetative characteristics were chosen for their connection with prey availability to goshawks (Beier and Drennan 1997). At each site data were also collected on amount of litter and bare ground, elevation, and possible prey species (Squires and Reynolds 1997, Bosakowski 1999) in order to obtain a more complete picture of the winter habitat.

Because of the inaccuracy associated with location estimates we field sampled from areas where clusters of estimates occurred. This approach was taken to mitigate the problem of estimates whose true location might be outside of the associated buffer. By sampling in areas where many location estimate buffers overlapped we hoped to increase the likelihood that a goshawk had actually been using the area sampled. A cluster was defined as a geographically isolated collection of location estimates. The degree of isolation, the number of location estimates, and the geographic area included in a location estimate cluster varied for each bird. Uniform metrics used to define a cluster could not be created due to the variety in the spatial distribution of each bird's location estimates, and total number of location estimates received for each bird. Rather than eliminate some birds from the analysis, these three metrics were used to assess the location estimate data for each bird at the individual's appropriate relative scale.

Many goshawks ranged over a large area, and because we received up to one hundred plus location estimates for each bird, time and personnel constraints did not allow us to examine all clusters in the field. Since only a limited number of clusters for each bird could be sampled, clusters were rated for importance. The process of rating the clusters is described as follows. Clusters with a high density of location estimates when compared to other equally sized geographic areas for the same bird were given highest priority. Of these clusters, those that contained location estimates from varied times during the winter months received higher priority than clusters where estimates spanned only a limited time period. Lastly, clusters situated in the most heavily used habitat cover types were rated more important than those appearing in habitat cover types used only infrequently.

Since the accuracy of our location estimates would not allow fine-scale, micro-habitat data collection, the field data collected only give a general idea of the habitat features found in the wintering areas. After the top-rated clusters for each bird were identified, they were assessed in the field for vegetative structure and other previously mentioned habitat characteristics by establishing a transect within the cluster. Transects were established either between several location estimates or around a particular location estimate within the cluster. This was based on the density and distribution of the location estimates in the cluster. If the location estimates of a cluster were within 0.5 km of each other, transects started at one estimate and ended at another. If the estimates within the cluster were >0.5 km apart, transects were set in a random direction around a central location estimate within the cluster. Approximately every 150 m along the transect line, habitat structure surrounding the transect was surveyed using a modified Daubenmire classification scheme in which each layer of vegetation within a 15-m radius of the sampling point was assigned a value from one–seven (Table 1) corresponding to an ocular estimation of the range of canopy cover (Daubenmire 1952). This sampling allowed the general vegetative structuring of the wintering areas to be described.

Detections of each possible prey species, based on Squires and Reynolds (1997) and Bosakowski (1999), were assigned into one of four categories: (1) sign, meaning that tracks or droppings of the animal were found or its calls were heard, (2) observation, in which the prey item was actually sighted, (3) prey remains found, which referred to prey remains encountered that we could attribute to goshawks, and (4) kill sites, where we actually observed a goshawk take a prey item, or flushed a goshawk from a recent kill. These data were collected opportunistically along the vegetative transects during winter and spring months in which the habitat was sampled.

Field Habitat Data Analysis

To further ameliorate the problem of location estimate accuracy buffers and to allow comparison across individuals, all analyses of the field data were done using 3-km radius sampling areas. Each bird's wintering area was divided in a systematic fashion into these uniform sized sampling areas. The first, and highest rated, sampling area generated for each bird had the greatest possible number of location

Table 1. Modified Daubenmire classification scheme, used in the discussion of cover throughout the analysis.

Classification number	Corresponding % canopy/ground cover
1	0–1
2	1–5
3	5–25
4	25–50
5	50–75
6	75–95
7	95–100

estimates and highly rated clusters. This continued in a systematic fashion until all wintering location estimates and clusters were included in a sampling area. Only the top three rated sampling areas were used in analysis. These top three sampling areas generally contained the majority of the winter location estimates and all of the highest rated clusters. The number of location estimates contained in each sampling area was divided by the total number of winter location estimates received for that goshawk, giving a percentage of winter spent in each sampling area.

Cover data collected for each of the three main vegetative layers (tree, shrub, and herbaceous) were placed by habitat cover type (pinyon-juniper, ponderosa pine, montane forest, and non-forest) in a table showing the number of transect points in which the cover data collected corresponded to each of the seven Daubenmire cover categories. This was done to describe the general vegetative characteristics of the areas in which the goshawks wintered.

To determine if goshawks spent more time in areas with certain vegetative characteristics the data were further analyzed by regression analysis of the percentage of winter spent in a sampling area with the average vegetative cover characteristics of that sampling area. Cover data collected for all transect points within a particular habitat cover type were averaged by sampling area to give a mean cover percentage for each vegetative layer. The average vegetative cover percentage for each sampling area was then regressed against the amount of time a bird spent in each sampling area.

To assess possible preference for specific cover characteristics, the vegetative cover averages for each sampling area and the corresponding time spent in each sampling area were compared with the cover available in each habitat cover type. A line of preference was incorporated into each graph. Preference for a specific cover characteristic was implied if most of the averages for a vegetative characteristic were found to be above this preference line and an avoidance of certain cover characteristics was implied if most of the sampling area averages were found to be below this line. Cover availability was calculated by taking the percentage of all data points found in each cover class (Table 1), for each vegetative layer in a particular habitat cover type.

RESULTS

Satellite Telemetry and Migration

Of the 42 goshawks fitted with PTTs, some winter data were collected on 38 and complete winter data (September–March) on 21; seven birds were tracked for more than one winter. A total of 2,639 location estimates were analyzed for this study (LC 3: N = 946, LC 2: N = 1,693). PTTs did not all perform equally well and some variation existed in the total number of winter location estimates collected for each bird (approximately normally distributed, with a range of N = 11–214, mean of N = 68). Several winter movement patterns were observed. Birds were considered migratory (Squires and Ruggiero 1995) if they flew >100 km from the nest site and then stayed in that area without returning to the nest territory (N = 7). We chose movement of 100 km or greater as the definition of migration for two reasons. First this definition corresponded well with the study of Squires and Ruggiero (1995) which deemed migratory movements as those of >65 km. Second, a natural break appeared in the movement patterns of the goshawks at around 100 km. Birds that flew >100 km from the nest site did so in a couple of days and then stayed in that area without returning to the nest site. We defined goshawks as semi-migratory if they moved within 100 km of the nest site, did so in small bouts of 20 or 30 km, and stayed in each area for several weeks before moving to another area 20 or 30 km away. Resident birds were those that stayed within 25 km surrounding the nest stand throughout the winter.

Of the seven goshawks tracked for >1 yr, five of them were considered migratory—one of these did not migrate the first year but did migrate the second winter. Three birds that migrated the first year migrated to the same location the second winter. The fifth goshawk stopped briefly in the area it used the previous winter and then continued 360 km further south to a new wintering location. Seven other birds migrated to an area >100 km away but were not tracked the entire winter. The total distance traveled to reach the wintering site varied from just over 100 km to >600 km (Fig. 1). The direction of migration was usually to the south or southwest, however, one bird migrated to the northeast.

Semi-migratory birds dispersed over an area of up to 100 km from the nest territory, staying in one area for several weeks and then moving to another (N = 4). Four other birds appeared to start following this pattern but were not tracked the entire winter.

Goshawks considered residents simply expanded their nesting territory by incorporating 5–25 km of the surrounding habitat (N = 10). See Sonsthagen et al. (2002) for a description of nesting and wintering territory size. Of the seven goshawks tracked for >1 yr, two were in this category. These two birds never left the area surrounding their nest territory during

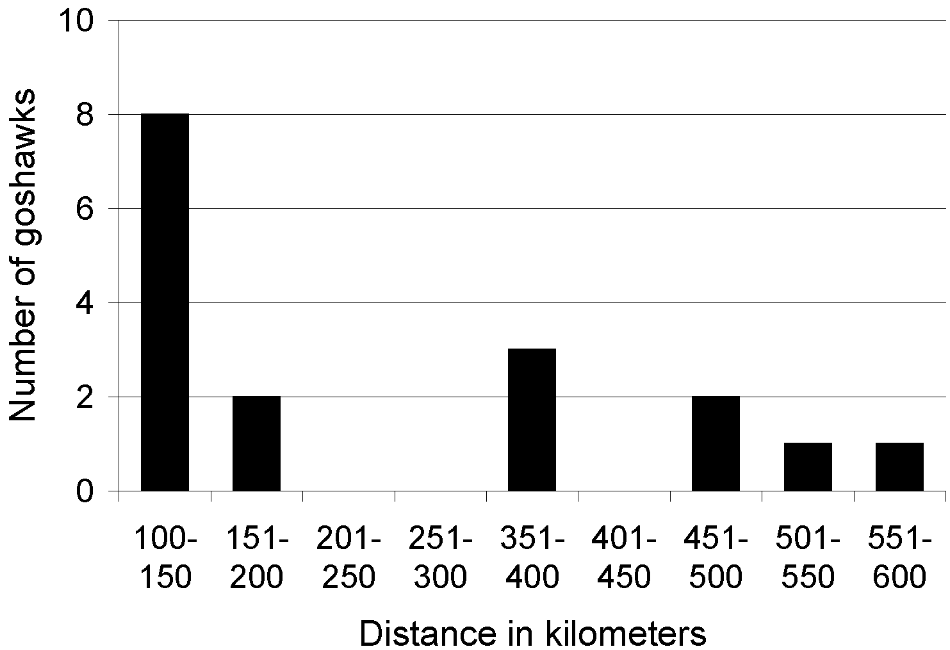

FIGURE 1. Winter migration distances of (N = 17) Northern Goshawks, Utah, 2000–2003.

winter. Six other birds appeared to be residents but were not tracked the entire winter. In summary, of the goshawks in this study 41% were considered resident, 43% were considered migratory, and 16% were considered semi-migratory.

Goshawks that migrated left nesting areas between August and December. Of these goshawks one migrated in August, six in September, two in October, six in November, and four in December. Most of the goshawks returned in March (N = 7) and one returned in February. The length of stay in the wintering area varied from 60–204 d, with an average of 138 d (N = 8). Of the seven birds for which we had multiple years of data, five exhibited winter-site fidelity while the other two wintered in different places on consecutive years but in the same habitat cover type.

We found no association between the time of the first major winter storm and migration. Sixty percent of goshawks that migrated or semi-migrated began before the first major storm of the year. Only two goshawks left within a week after the first major winter storm. The remaining goshawks (32%) moved within 1 wk of a major storm, but this may be an artifact of increased storminess throughout the winter. All four migratory goshawks tracked for multiple years left within 10 d of the date on which they left the first year regardless of the weather.

GIS Habitat Analysis

Seventy-nine percent of the goshawks in this winter habitat study spent time in pinyon-juniper habitat cover type. In areas where no pinyon-juniper habitat exists, they used mountain shrub habitat cover type dominated by maple and Gambel oak. Most goshawks (N = 15) that migrated or semi-migrated, moved exclusively to pinyon-juniper habitat cover type. Those that stayed around their breeding territories used habitat similar to their breeding habitat, which consisted of ponderosa pine or montane forest habitat cover types.

Field Habitat Analysis

The field data collected consisted of 821 transect points spread over all 38 wintering areas. For each bird up to three sampling areas were evaluated for vegetative components. The percent of total location estimates within each sampling area varied according to its rank. The densest sampling areas contained from 17.4–100% of all winter location estimates for a bird with the average being 37.4%. For the second and third ranked sampling areas the average percent of total winter location estimates included was 18.3% and 9.1%, respectively. For some birds only one sampling area was necessary since nearly all their location estimates fell within that sampling area. For each bird a mean of 2.5 sampling areas and 9.6 clusters (approximately normally distributed, range = 3–22) within those sampling areas were analyzed in the field. The data summarized from all transect points included the canopy cover of the tree, shrub, and herbaceous layers, as well as litter cover and the percentage of ground left bare. The percentage of vegetative cover for each of the vegetative layers varied widely within each of the four habitat cover types (Table 2).

Regression analysis found no significant correlation between the time spent in an area and its corresponding vegetative cover. P-values for these relationships ranged from $P = 0.100–0.965$.

The scale and manner of our data collection did not allow us to statistically demonstrate habitat selection; however, possible preference in all habitat cover types was shown for areas with higher herbaceous cover. In the non-forest habitat cover type possible preference was also shown towards areas that had 5–25% tree cover. In all habitat cover types possible preference was shown towards areas that had some degree of shrub cover (5–75%) but were not densely covered (over 75%). Preference for other vegetative cover characteristics sampled could not be shown.

Although winter diet was not empirically assessed, observations of possible prey were recorded in each of the winter areas. We noted common prey observed in winter territories and the number of winter areas in which each prey was found (Fig. 2). Observed winter foraging behavior was similar to hunting tactics observed during the breeding season. Goshawk hunting behavior was observed at multiple kill sites. All of these sites were on the edge of the pinyon-juniper woodlands and sagebrush-grassland openings, or in areas of the pinyon-juniper woodlands that had been thinned by humans and brush piles left on the ground. All kills appeared to be cottontail rabbits (*Sylvilagus* spp.).

Finally, all goshawks exhibited an altitudinal migration during some part of the winter. They either migrated to a lower elevation or simply expanded upon their nesting areas to include surrounding lower elevations. Sonsthagen (2002) found that there was a statistically supported difference between the elevation of the summer habitat and the winter habitat.

DISCUSSION

Migration

The winter movement patterns we observed throughout this study show that goshawks within the same population have various alternative winter movement strategies. To answer the question of why some goshawks migrated or semi-migrated and others did not we looked at weather as suggested by Squires and Ruggiero (1995) and found that it did not appear to drive migration in Utah. Other reasons for winter migration have been suggested by Newton (1986) who stated that the biggest factors in raptor migration patterns appeared to be prey availability and interaction with conspecifics. Additionally Harmata and Stahlecker (1993) suggested that raptor winter movement was based on wintering area fidelity at a location established where the individual survived its first winter. Although our study was not able to empirically assess any of these hypotheses, several observations made throughout the study and certain observed trends in the data are congruent with these statements and would lead us to suggest that the same factors are driving the winter movements of goshawks in Utah.

In agreement with the hypothesis of Harmata and Stahlecker (1993), wintering area fidelity has been observed in Alaskan goshawks (McGowan 1975). In our study many goshawks that migrated passed over habitat similar to that where they eventually wintered. Five of seven goshawks tracked for multiple years showed winter site fidelity both years. Four other goshawks in this study wintered around known breeding territories far from their own. These goshawks may have passed their first winter around their natal nest territory (Tornberg and Colpaert 2001) and then dispersed to find a breeding territory in spring. By returning in subsequent winters to their natal site they too exhibit winter site fidelity. If this conclusion is valid then these four birds provide further support that goshawk wintering areas and migration depend upon the wintering location of the first year.

Our study also seemed to support the hypothesis of Newton (1979a, 1986) that competition or other interaction with conspecifics also may lead to migration. In our study one goshawk did not migrate the first year but did the second year. During the second year, the area it had previously used during winter was occupied by at least one other goshawk; competition with this goshawk may have led to our goshawk's migration. As an additional support for this hypothesis, we observed that when two birds were trapped within several kilometers of each other, one would often migrate or semi-migrate and the other would incorporate both territories into its winter range. This pattern was observed for five pairs.

Finally, although our study did not empirically assess numbers of prey in the wintering territories or in the breeding areas, we would agree with Newton's

TABLE 2. VEGETATIVE AND GROUND COVER PERCENTAGES OF 38 NORTHERN GOSHAWK WINTERING AREAS BY HABITAT COVER TYPE, UTAH, 2000–2003.

	Daubenmire classification category (0–7) and corresponding percent canopy cover							
	0 (0%)	1 (0–1%)	2 (1–5%)	3 (5–25%)	4 (25–50%)	5 (50–75%)	6 (75–95%)	7 (95–100%)
Vegetative/ground cover layer	Percent of transect points where vegetative/ground cover matched each Daubenmire category							
Pinyon-juniper tree layer	0	0	1.21	31.17	53.85	13.77	0	0
Pinyon-juniper herbaceous layer	0	10.12	31.98	40.89	10.93	6.07	0	0
Pinyon-juniper shrub layer	0	8.91	23.48	43.32	22.27	2.02	0	0
Pinyon-juniper litter cover	3.64	0	8.10	47.77	31.17	6.07	2.83	0.40
Pinyon-juniper bare ground	3.64	0.40	1.62	12.55	38.06	37.25	6.48	0
Ponderosa tree layer	0	0	2.20	18.68	30.77	43.96	4.40	0
Ponderosa herbaceous layer	0	1.10	21.98	34.07	29.67	12.09	1.10	0
Ponderosa shrub layer	0	5.49	25.27	37.36	27.47	4.40	0	0
Ponderosa litter cover	0	0	1.10	14.29	13.19	19.78	42.86	8.79
Ponderosa bare ground	13.19	57.14	9.89	8.79	6.59	4.40	0	0
Montane forest tree layer	0	0	0	5.53	30.15	52.76	10.55	1.01
Montane forest herbaceous layer	4.52	3.02	10.55	17.59	25.63	26.13	12.56	0
Montane forest shrub layer	7.04	2.51	16.58	32.16	23.12	15.08	3.52	0
Montane forest litter cover	2.51	0	5.53	19.10	27.14	25.63	16.08	4.02
Montane forest bare ground	26.13	42.71	17.09	10.05	3.52	0.50	0	0
Non-forest tree layer	24.30	38.73	23.94	6.69	2.82	1.76	1.41	0.35
Non-forest herbaceous layer	1.06	3.17	7.04	17.96	25.70	23.59	19.72	1.76
Non-forest shrub layer	3.52	1.41	3.52	19.01	42.25	24.30	5.99	0
Non-forest litter cover	0.35	3.87	17.61	58.10	16.20	3.17	0.70	0
Non-forest bare ground	6.34	9.15	14.08	23.94	30.28	16.20	0	0

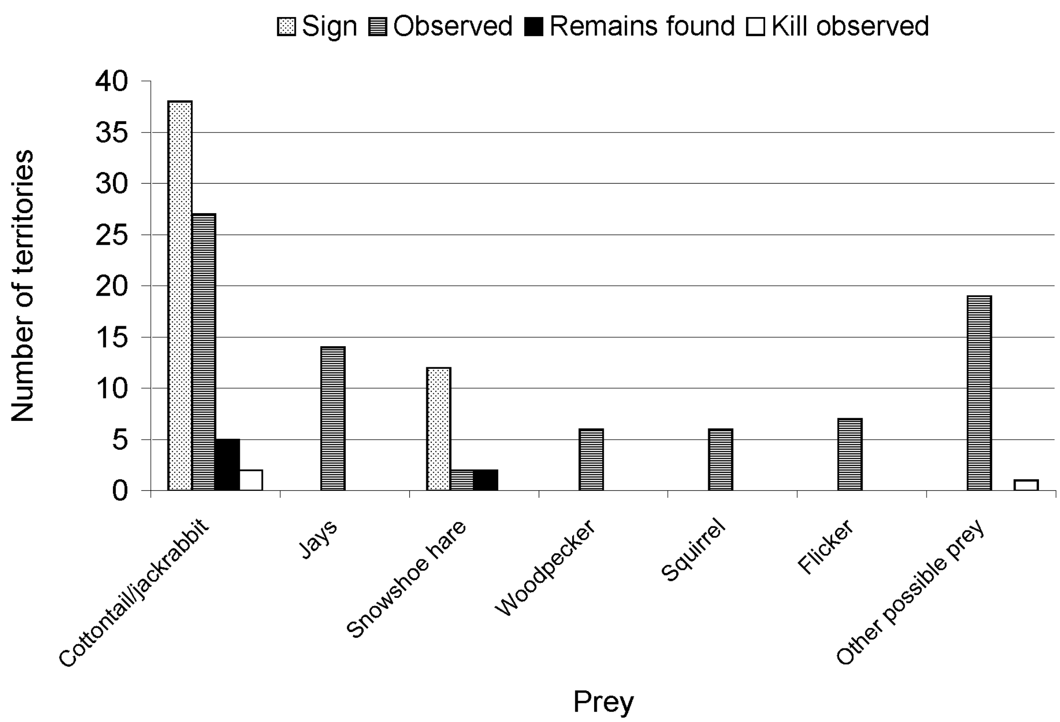

FIGURE 2. Number of Northern Goshawk winter territories in which each possible prey species was observed. Utah, 2000–2003.

(1979a) hypothesis that the most important factor motivating the migration of all raptors was prey availability. This would seem to explain several of the observed winter movement patterns. In our study the length of the stay in winter areas varied by bird, possibly due to the prey abundance in the breeding/nesting area. Variety in prey abundance, or accessibility also may explain the difference in date of departure for the goshawks that migrated. If there were abundant and vulnerable prey then goshawks seemingly would be less inclined to migrate. But as the winter set in, the disappearance of more prey species due to mortality, hibernation, or migration may have prompted the goshawks to move as suggested by Newton (1979a). The differences in movement of goshawks in our study would indicate a behavioral plasticity so that migration occurred when of survival value.

Habitat Analysis

The vegetative analysis of these winter areas showed that goshawks were capable of using a broad variety of habitat cover types and that vegetative cover within those habitats cover types varied widely. These finding are similar to Hargis et al. (1994) and Kenward and Widén (1989). However, possible preference in all habitat cover types was shown toward areas with a high degree of herbaceous cover relative to the available habitat and areas where the shrub cover was neither too dense (>75%) nor too sparse (<1–5%). In the non-forest habitat cover type, areas with some degree of tree cover (5–25%) were preferred over areas with little or no tree cover. Preference toward these areas was probably driven by prey availability and abundance; however this was not empirically assessed. Herbaceous plants such as forbs and grasses act as the most important food resource (Fitzgerald et al. 1994) for cottontail rabbits and other prey commonly taken by wintering goshawks. Protective escape cover, usually in the form of shrubs, is another essential habitat component for these prey items (Chapman and Flux 1990, Fitzgerald et al. 1994). If the shrub cover is too dense, prey availability is limited (Beier and Drennan 1997) and if too sparse, prey abundance would be limited (Chapman and Flux 1990, Fitzgerald et al. 1994). In the non-forest habitat, a preference for areas with higher tree density is probably due to the goshawk's method of hunting (Palmer 1988, Beier and Drennan 1997, Bosakowski 1999). This method consists of the perch-and-wait tactic in which the hawk waits at a perch for a prey to come into sight. Numerous perches would increase the area available for hunting.

Because of the use of the pinyon-juniper habitat cover type by most of the wintering goshawks, a description of this habitat is given based on observations collected at the wintering sites. On a landscape scale, the areas selected generally consisted of a mosaic of pinyon-juniper forest habitat and non-forested openings. Most of the pinyon-juniper areas used had been altered by humans. Anthropogenic modification of these sites commonly included old chained areas, burn areas, or zones of selectively logged trees. Although we do not know what percentage of the total pinyon-juniper habitat cover type in Utah has been altered, human disturbance was found in at nearly all pinyon-juniper wintering areas surveyed. The type and degree of disturbance in the pinyon-juniper habitat varied but most was concentrated on thinning or removing stands of pinyon and juniper trees to open up habitat. Goshawks appeared to stay away from areas where pinyon and juniper trees had grown too dense (>75% cover) or where most of the trees were young and bushy, instead preferring the thinned areas where tall trees provided roost sites (Palmer 1988). As previously discussed, winter foraging areas in this habitat cover type usually consisted of non-forested openings that were surrounded by pinyon-juniper woodlands. Areas used for foraging also consisted of chained mesa tops with pinyon-juniper habitat left in the steep ravines. These steep, tree-covered ravines possibly served as night roost sites.

Results of winter-diet observations are similar to the findings of Drennan and Beier (2003) and Stephens (2001), who found a significant use of cottontails by wintering goshawks. Goshawks that stayed at higher elevations might have been using snowshoe hares (*Lepus americanus*) for food as Palmer (1988), Doyle and Smith (1994), Squires and Reynolds (1997) found. Snowshoe hare prey remains were found but no goshawks were observed in the act of hunting. With cottontail densities higher in edge habitat and disturbed areas and more common in pinyon-juniper woodlands than in montane forest or ponderosa pine habitat (Chapman and Flux 1990, Fitzgerald et al. 1994), use of this prey may explain goshawk migration to pinyon-juniper woodlands.

Some reviewers have expressed concern over the accuracy of the buffers used for analyzing the data. We used values supplied by Argos and the makers of the PTTs, North Star (McGradey et al. 2002). Many times we were able to use the location estimates we received to locate live birds in the field, or to locate birds that had died. In most cases these birds were located within 250–500 m of where the location estimates had placed them. Furthermore, although it is unrealistic to reanalyze all location estimates with larger buffers for the GIS habitat analysis, when a random selection of estimates was reanalyzed and assigned to a habitat cover type using the suggested increase in buffered distance (1 and 3 km) it did not alter in any biological or interpretive manner the results of our findings. If anything, a larger buffer appeared to strengthen our finding that goshawks use a mosaic pattern of habitat during the winter months because more of the location estimates and their associated buffers incorporated a forest and a non-forest habitat type. Finally, because we were only trying to develop a broad definition of the habitat characteristics in the goshawk wintering areas the field sampling data were analyzed using 3-km radius sampling areas, a scale similar to that suggested by the reviewers.

Management Implications

Although management of goshawk breeding areas mandates an absence of human disturbance (Reynolds et al. 1992, Graham et al. 1999b), most wintering areas showed signs of human alteration. Disturbance may contribute to an increase in prey densities or ability for the goshawks to sustain mobility within the forest stand (Kenward and Widén 1989). Therefore, preventing alteration of habitat is probably not as important in the wintering areas used by goshawks as it has been found to be in summer territories (Kenward and Widén 1989); it may even be beneficial by increasing prey densities and availability (Palmer 1988, Chapman and Flux 1990) and creating edge habitat in which goshawks prefer to hunt (Palmer 1988).

When incorporating goshawk winter biology and habitat use into future management plans it would therefore be important to include measures that benefit important goshawk prey species (lagomorphs), a concept similar to that proposed by Reynolds et al. (1992) and Graham et al. (1999b). It would also be important to include all vegetative types used by wintering goshawks in the management plan.

ACKNOWLEDGMENTS

We thank the many USDA Forest Service biologists and wildlife technicians, especially K. Paulin, K. Hartman, K. Rasmussen, M. Madsen, A. Alvidrez, S. Dewey, and T. Hollingshead whose support facilitated many aspects of this project and to V. J. Anderson whose insights and direction made the project possible. Special thanks are also due to those brave souls who worked as field assistants B. Shaheen, L. Bardo, C. Riding, and R. P. Corson and to M.B. Lee and D. B. for making countless maps and managing the satellite data. Lastly we thank S. Sonsthagen for all her advice and help in carrying out the project and the anonymous reviewers who helped better this paper. Funding for this project was provided by the USDA Forest Service.