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OCCUPANCY, PRODUCTIVITY, TURNOVER, AND DISPERSAL OF NORTHERN GOSHAWKS IN PORTIONS OF THE NORTHEASTERN GREAT BASIN

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Abstract. We determined the occupancy, productivity, turnover, and dispersal distances of Northern Goshawks (*Accipiter gentilis*) in two areas of the northern Great Basin in northeastern Nevada and southern Idaho from 1992–2003. Occupancy of nesting territories declined in both study areas over the 10–11 yr study period but the decline was statistically significant ($P < 0.05$) only in northeastern Nevada where it decreased from a high of 83% in 1997 to a low of only 23% in 2002. The average productivity of goshawk breeding pairs did not change significantly in either study area, but it was lowest in southern Idaho at only 1.5 ± 0.6 young/breeding pair and highest in northeastern Nevada at 2.3 ± 0.8 young/breeding pair. Males bred mostly at 3yr of age and females bred at 2 yr of age with both sexes residing in nesting territories an average of 2 yr. We found no difference in the number of nesting territories used by either sex with 88% of adults using only one nesting territory, 10% using two nesting territories, and 2% using three nesting territories. Turnover of males and females ranged from 12.5–22.9% and 16.2–30.0%, respectively, and did not differ significantly. Breeding dispersal of males and females ranged from only 2.1–5.8 km but natal dispersal was 19.1 km for males and 96.4 km for females indicating that the female segment of the population was the dispersing sex. Several goshawks captured on migration at the Goshutes Mountains in northeastern Nevada were reencountered as breeding adults in both southern Idaho and northern Nevada suggesting that Northern Goshawks in the northeastern section of the Great Basin constitute a large metapopulation consisting of several subpopulations occupying the isolated mountain ranges of Nevada, Utah, and southern Idaho. With dispersal distances of nearly 100 km, female goshawks are capable of being recruited into breeding populations throughout the northeastern segment of the Great Basin.

Key Words: *Accipiter gentiles*, adult turnover rates, dispersal distance, nesting territory occupancy, Northern Goshawk, northern Great Basin, population dynamics.

OCUPACIÓN, PRODUCTIVIDAD, REEMPLAZO Y DISPERSIÓN DEL GAVILÁN AZOR EN PORCIONES DE LA GRAN CUENCA DEL NORESTE

*Resumen*Determinamos la ocupación, productividad, reemplazo y distancia de dispersión del Gavilán Azor (*Accipiter gentilis*), en dos áreas del norte de la Gran Cuenca, en el noreste de Nevada y el sur de Idaho, de 1992–2003. La ocupación de territorios de anidación declinó en ambas áreas de estudio, sobre el período de 10–11 años, pero el descenso fue estadísticamente significativo ($P < 0.05$) solamente en el noreste de Nevada, donde declinó de un elevado 83% en 1997 a tan sólo 23% en el 2002. El promedio de productividad de las parejas reproductivas de gavilanes no cambió significativamente en ninguna de las áreas de estudio, pero fue más baja en el sur de Idaho, con solo 1.5 ± 0.6 crías sobre parejas reproductivas, y más alta en el noreste de Nevada con 2.3 ± 0.8 crías sobre parejas reproductivas. Los machos se reprodujeron hasta casi los 3 años de edad y las hembras a los 2 años, ambos sexos residiendo en los territorios de anidación por un promedio de 2 años. No encontramos diferencia en el número de territorios de anidación utilizados, ya sea por sexo, con 88% de adultos utilizando solo un territorio para anidar, 10% utilizando dos territorios de anidación, y 2% utilizando tres territorios de anidación. El reemplazo de machos y hembras tuvo un rango de 12.5–22.9% y 16.2–30.0% respectivamente, y no diferenció significativamente. La dispersión de machos y hembras reproductivas tuvo un rango de tan solo 2.1–5.8 km, pero la dispersión de las crías fue de 19.1 km para los machos y de 96.4 para las hembras, indicando que la población del segmento de hembras era el sexo dispersor. Algunos gavilanes capturados durante la migración en las Montañas Goshutes en el noreste de Nevada, fueron reencontrados como adultos reproductores, tanto en el sur de Idaho, como en el noreste de Nevada, sugiriendo que los Gavilanes Azor en la sección noreste de la Gran Cuenca, constituyen una gran metapoblación, que consiste en varias subpoblaciones, las cuales ocupan las aisladas cordilleras montañosas de Nevada, Utah y el sur de Idaho. Con distancias de dispersión de cerca de 100 km, las hembras gavilán son capaces de ser reclutadas dentro de las poblaciones reproductivas, a lo largo del segmento noreste de la Gran Cuenca.

The Northern Goshawk (*Accipiter gentilis*) is the largest member of the genus *Accipiter* in North America and it occurs in boreal and temperate forests throughout the continent (Squires and Reynolds 1997). The goshawk is considered a forest habitat generalist with specific habitat requirements associated with nest sites (Dixon and Dixon 1938, Schnell 1958, Kenward 1982, Moore and Henny 1983, Crocker-Bedford and Chaney 1988, Lilieholm et al. 1993, Hargis et al. 1994, Beier and Drennan 1997, Rosenfield et al. 1998). In North America, nests occur in either mature coniferous, deciduous, or mixed conifer-hardwood forests with large trees, high canopy closure, and sparse ground cover (Reynolds et al. 1982, Speiser and Bosakowski 1987, Hayward and Escaño 1989, Siders and Kennedy 1994, Squires and Ruggiero 1996). Goshawks feed opportunistically on a wide diversity of prey species but main foods include ground (*Spermophilus* spp.) and tree squirrels (*Sciurus* spp.), lagomorphs (*Sylvilagus* and *Lepus* spp.), large passerines, woodpeckers, and game birds (Squires and Reynolds 1997). Partially migratory, goshawks winter throughout their breeding range but some individuals do make short movements to lower elevations during winter. Irruptive movements in northern populations to more southern latitudes in winter occur at approximately 10-yr intervals and these apparently coincide with population lows of the snowshoe hare (*Lepus americanus*) and grouse (Squires and Reynolds 1997).

Due to concerns raised over possible declining populations since the late 1980s, the USDI Fish and Wildlife Service listed the goshawk as a category 2 species of concern in 1991 (USDI Fish and Wildlife Service 1992a, 1992b) and it kept that status until the category was eliminated in 1996. It continues to be listed as a sensitive species in Regions 3, 4, and 5 of the USDA ForestService (Kennedy 1997). Information on the breeding biology and status of populations across the goshawks' western range is limited making evaluations of these various listings troublesome. Because of this situation, we undertook a study in the northeastern portion of the Great Basin in an attempt to better document the dynamics of the breeding population of goshawks in this portion of the species' North American range.

STUDY AREA

Our study included portions of two national forests, the Independence and Bull Run Mountains of the Humboldt-Toiyabe National Forest in northeastern Nevada and the Cassia and Sublett Divisions of the Sawtooth National Forest in southern Idaho (Fig. 1). These areas are situated in the northeastern segment of the Great Basin Region of North America. Our study area in northeastern Nevada included most of the Independence and Bull Run Mountains. These mountain ranges are approximately 150 km long and 10–30 km wide and range from 1,700 m on the valley floor to >3,000 m in elevation on the highest peaks. Vegetation in the area is mostly open sagebrush (*Artemisia tridentata*) steppe habitat that contains highly-fragmented stands of mixed conifer (*Pinus albicaulis, Pinus flexilis,* and *Abies lasiocarpa*) and aspen (*Populus tremuloides*) stands at >2,500 m elevation, and aspen stands in riparian areas and natural drainages at lower elevations (Loope 1969). The Sawtooth National Forest is characterized by a very diverse assemblage of physical features that range from broad stretches of flat to rolling semi-arid plains interspersed with shallow to deep canyons, high elevation desert plateaus (>2,500 m), and infrequent mountain ranges in the southern portion of the forest to strongly glaciated valleys, steep terrain, rugged ridges, and mountain peaks with cliffs and talus slopes in the forests' northern areas (USDA Forest Service 1987). Our study areas in the Cassia and Sublett Divisions of the Sawtooth National Forest are mainly classified as shrubsteppe habitat with fragmented stands of conifer trees (either lodgepole pine [*Pinus contorta*] or subalpine fir, 7,181 ha), mixed conifer (subalpine fir and lodgepole pine) and aspens (1,438 ha), and aspen stands (7,572 ha; USDA Forest Service 1980, 1991a). Over 80% of these stands are classified as mature (70–150-yr old), and stand size averages from only 4 ha for conifer stands to16 ha for aspen stands (USDA Forest Service 1980).

METHODS

We annually searched forest patches in each study area that had histories of occupancy by breeding goshawks, which we defined as historic nesting territories. We also searched all nearby forest patches that appeared to support suitable aspen stands for breeding goshawks where alternative nest sites and any possible new nesting territories may have been located. Searches were conducted on foot during May and we thoroughly searched each forest patch for evidence of breeding goshawks. We confirmed that breeding attempts had taken place by observing goshawks showing breeding behaviors such as copulation, incubation, or nest building activity (Postupalsky 1974, Steenhof 1987, Steenhof et al. 1999). Locations of occupied nest trees within nesting territories were recorded using

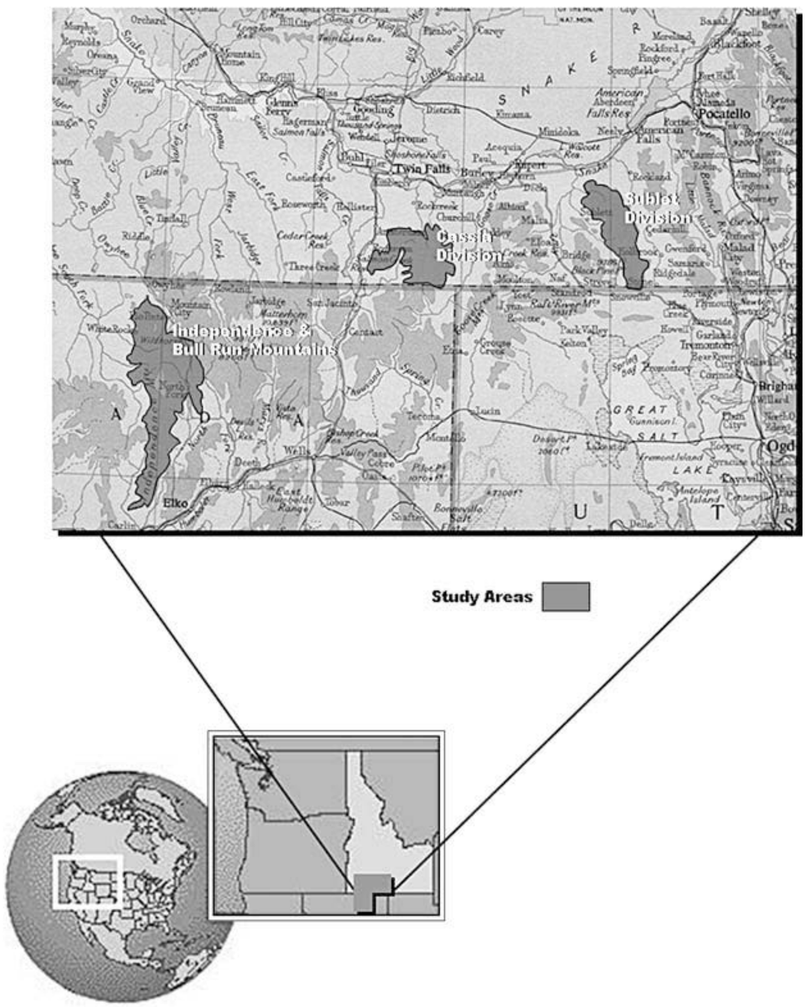

FIGURE 1. Locations of the Independence and Bull Run Mountains study area of the Humboldt-Toiyabe National Forest in northeastern Nevada and the Cassia Division and Sublet Division study areas of the Sawtooth National Forest in southern Idaho from 1992–2003.

global positioning system (GPS) coordinates and marked on topographic maps. In April of 1992 and 1994–1996, the study area in northeastern Nevada was also searched via helicopter prior to emergence of aspen catkins to document early occupancy of nesting territories. Because many adults were individually marked with color bands, we also attempted to identify each adult we observed during occupancy checks using 10× binoculars and 20–60× spotting scopes. During June, we rechecked all nesting territories on foot to verify breeding, record and age nestlings in nests, and identify any breeding adults that were not previously identified. We estimated the productivity of breeding pairs by climbing nest trees and counting young when they were 30–31 d old, or 80% of fledging age (Steenhof 1987). Because of logistical restraints, we did not revisit nesting territories to confirm fledging. Nestlings were banded with USGS aluminum bands and colored, aluminum bands bearing alpha-numeric codes for future identification. Sex of nestlings was determined by tarsus width and age estimates were based on plumage characteristics (Boal 1994). If breeding adults were not marked, we trapped them using a Great Horned Owl (*Bubo virginianus*) lure and dho-gaza net (Bloom 1987) and they were also banded with USGS Bird Banding Laboratory aluminum leg bands and colored, aluminum leg bands with alpha-numeric codes. We did not begin trapping and color-marking goshawks in southern Idaho until 2000.

To determine residency, we used the average number of years individual goshawks were observed in either of the two study areas, and, to estimate nesting territory turnover, we used the percent of territories where individuals were replaced by new goshawks in subsequent years. Natal dispersal distances, or the distance between the natal site and first breeding site (Greenwood 1980), and breeding dispersal distances, or the distances between subsequent breeding sites (Greenwood 1980), were calculated with the point feature distance matrix extension in ArcView GIS v. 3.2a (Environmental Systems Research Institute, Redlands, CA).

For statistical analysis, we considered reproductive measures as continuous variables, which allowed us to compare our results with other studies. However, for analyses through time, we considered reproductive measures as categorical response variables. Occupancy, failure, and turnover were considered binomial (i.e., occupied or not occupied, failed or not failed, same adult or different adult), and productivity was considered a multinomial count, thereby allowing us to model reproductive statistics through time using logistic regression analyses. For modeling, we used the generalized estimating equations (GEE) method in PROC GENMOD (SAS Institute Inc. 2001) with a logit link function and binomial distribution for binomial data, and a log link function and Poisson distribution for count data. Rather than taking an annual average occupancy across all nesting territories and regressing with year, our analysis modeled responses on a nesting territory level. This approach had several advantages in that it allowed us to use all data collected from all nesting territories, regardless of how many years a territory was surveyed, and it solved problems associated with sample independence and the binomial distribution of our data (Allison 1999).

RESULTS

Nesting Territory Occupancy and Productivity

During the 11-yr period we monitored goshawks in the study area in northeastern Nevada, a total of 41 nesting territories were located. Because of years with heavy snowpack, not all nesting territories were surveyed every year but we surveyed an average of 32 ± 4.74 nesting territories annually (range = 24–41; Table 1). Mean annual nesting territory occupancy was 62.3 ± 18.8% and varied from a high of 83.3% in 1997 to a low of 22.6% in 2002. Occupancy of individual nesting territories ranged from 11–100%. There was a significant annual decline (21.5%) in the odds that sites would be occupied over the 11-yr study period (odds = 0.7851, P <0.0001). A total of 22 nesting territories were identified over the 10-yr study period in southern Idaho (Table 1). All 22 of the nesting territories were surveyed each year. Nesting territory occupancy averaged 39.5% and ranged from a high of 59.1% in 1995 and 2000 to a low of 13.6% in 1999. Occupancy of individual nesting territories ranged from 0–100%. We also observed a decline in territory occupancy by Northern Goshawks in southern Idaho, but logistic regression analysis indicated that the decline over the 10-yr period was not statistically significant (odds = 0.9502, P <0.2922).

Table 1. Occupancy of Northern Goshawk nesting territories in the Independence and Bull Run Mountains of the Humboldt-Toiyabe National Forest in northeastern Nevada and the Cassia and Sublet Divisions of the Sawtooth National Forest in southern Idaho, 1992–2002.

	Nevada		Idaho	
Year	N territories surveyed	% occupancy	N territories surveyed	% occupancy
1992	27	81.5	–	–
1993	32	78.1	–	–
1994	37	70.3	15	54.5
1995	37	73.0	22	59.1
1996	41	73.2	22	41.0
1997	24	83.3	22	13.6
1998	33	54.6	22	27.2
1999	33	51.5	22	36.3
2000	33	54.6	22	59.1
2001	30	43.3	22	31.8
2002	31	22.6	22	41.0
2003	–	–	22	31.8

Breeding pairs of goshawks in northeastern Nevada produced a total of 478 young during the 11-yr study period for a mean productivity of 2.27 ± 0.76 (N = 211) young/breeding pair (Table 2). Annual productivity was lowest in 2002 ($\bar{x}$ = 1.43 ± 1.40 young/breeding pair, N = 7) and highest in 2000 ($\bar{x}$ = 3.39 ± 0.78 young/breeding pair, N = 18). We found no significant interaction between location and year on productivity per breeding pair, and no significant trend in overall productivity (odds = 0.9853, P = 0.2020) or the productivity of individual nesting territories (odds = 0.8674, P = 0.1090) over the duration of the study. Breeding pairs of goshawks in southern Idaho produced a total of 72 young during the 10-yr study period for an average productivity of 1.49 ± 0.60 (N = 48) young/breeding pair (Table 2). Despite a decline from an average high of slightly over 2 young/breeding pair in 1999 to a low of 0.83 young /breeding pair in 2002, regression analysis of productivity over the 10-yr period did not show a significant decline (odds = 1.017, P = 0.5598).

The number of young produced by successful breeding pairs of goshawks in northern Nevada and southern Idaho averaged 2.64 ± 0.57 (N = 181) and 2.04 ± 0.65 (N = 65), respectively (Table 2). Here also, we did not detect a significant decline in the productivity of successfully breeding pairs of goshawks in either northern Nevada (odds = 1.003, P = 0.9047) or southern Idaho (odds = 0.9152, P = 0.1913) during the study period.

Demographics, Individual Identity, and Territory and Mate Turnover

We banded 102 adult goshawks (60 females, 42 males) in northeastern Nevada over the 11-yr study period. Fifty-five of the females and 34 of the males were aged at banding. Mean age of breeding females was 2.0 ± 1.06 yr (mode = 3, N = 55) and mean age of breeding males was 3.0 ± 0.24 yr (mode = 3, N = 34). Males were significantly older than females (χ^2 = 14.83, P = 0.0001) and females were more likely to be breeding as 2-yr olds and males as 3-yr olds (G = 21.37, P <0.0001). Based on re-sightings, residence time in the study area averaged 2.0 ± 2.0 yr for females (range = 1–10, mode = 1, N = 59) and 2.0 ± 1.38 yr for males (range 1–7, mode = 1, N = 42), but no significant difference was found between the sexes in the number of years they remained in the study area (G = 5.47, P = 0.2422). Both sexes used from 1–3 different territories for breeding (mode = 1 for both sexes) and, again, we found no significant difference in the number of territories used by either sex (G = 2.27, P = 0.3230). Combining all adults, 88% used one nesting territory, 10% used two different territories, and only 2% used three different territories.

Of the 359 territory years surveyed in northeastern Nevada, we determined individual identities of female breeding goshawks at 151 territories and male breeding goshawks at 93 territories for a total of 244 individually identified breeding goshawks over the 11-yr study period. Of the 109 cases where the identity of either member of breeding pairs was known in two consecutive years, 74 were females and 35 were males. Female turnover occurred 12 times (16.2%/yr) and male turnover occurred 8 times (22.9%/yr), but the difference in turnover rates between the sexes was not significant (Table 3). Combining turnover for both sexes, there was a significant annual increase in the likelihood that a known-identity adult would remain on the same territory the following year (odds = 0.7950, P = 0.0245), but this increase

Table 2. Productivity of Northern Goshawk breeding pairs in the Independence and Bull Run Mountains of the Humboldt-Toiyabe National Forest in northeastern Nevada and the Cassia and Sublet Divisions of the Sawtooth National Forest in southern Idaho, 1992–2002. Numbers in parentheses indicate sample size.

	Nevada		Idaho	
Year	Young/breeding pair	Young/successful pair	Young/breeding pair	Young/successful pair
1992	2.77 ± 0.92 (22)	2.90 ± 0.70 (21)	–	–
1993	2.08 ± 1.14 (24)	2.38 ± 0.86 (21)	–	–
1994	2.47 ± 1.22 (19)	2.76 ± 0.90 (17)	1.58 ± 1.16 (12)	2.11 ± 0.78 (9)
1995	1.84 ± 1.40 (25	2.56 ± 0.92 (18)	1.38 ± 0.96 (13)	1.80 ± 0.63 (10)
1996	2.43 ± 0.94 (30)	2.61 ± 0.68 (28)	1.67 ± 1.00 (9)	1.87 ± 0.83 (8)
1997	2.05 ± 0.85 (19)	2.17 ± 0.71 (18)	1.00 ± 1.00 (3)	1.50 ± 0.71 (2)
1998	2.22 ± 1.17 (18)	2.67 ± 0.62 (15)	1.00 ± 0.00 (2)	1.00 ± 0.00 (2)
1999	1.53 ± 1.33 (17)	2.17 ± 1/03 (12)	2.12 ± 1.13 (8)	2.43 ± 0.79 (7)
2000	3.39 ± 0.78 (18)	3.39 ± 0.78 (18)	1.87 ± 1.55 (15)	2.08 ± 0.92 (10)
2001	1.92 ± 1.55 (13)	2.50 ± 1.27 (10)	1.15 ± 1.21 (13)	2.14 ± 0.69 (7)
2002	1.43 ± 1.40 (7)	2.50 ± 0.58 (4)	0.83 ± 1.11 (12)	2.00 ± 0.71 (5)
2003	–	–	3.00 ± 1.41 (7)	3.50 ± 0.555 (5)

TABLE 3. ANNUAL TURNOVER OF BREEDING GOSHAWKS AT NESTING TERRITORIES IN THE INDEPENDENCE AND BULL RUN MOUNTAINS OF THE HUMBOLDT-TOIYABE NATIONAL FOREST IN NORTHEASTERN NEVADA AND THE CASSIA AND SUBLET DIVISIONS OF THE SAWTOOTH NATIONAL FOREST IN SOUTHERN IDAHO.

	N cases		Same bird		Different bird		Turnover %	
Years	Female	Male	Female	Male	Female	Male	Female	Male
Northern Nevada								
1992–1993	2	2	0	1	2	1	100.00	50.0
1993–1994	3	3	2	2	1	1	33.3	33.3
1994–1995	4	2	4	2	0	0	0.0	0.0
1995–1996	14	7	12	7	2	0	14.3	0.0
1996–1997	13	12	7	5	1	0	12.5	0.0
1997–1998	8	5	9	1	0	0	0.0	0.0
1998–1999	9	1	9	1	0	0	0.0	0.0
1999–2000	10	2	7	1	3	1	30.0	50.0
2000–2001	7	1	7	1	0	0	0.0	0.0
2001–2002	4	0	4	0	0	0	0.0	0.0
Southern Idaho								
2000–2001	3	0	2	–	1	–	25.0	–
2001–2002	5	3	3	3	2	0	40.0	0.0
2002–2003	4	4	3	3	1	1	25.0	25.0

was not significantly related to location (odds = 0.7661, P = 0.5874). Identities of both members of a breeding pair were determined at 26 nesting territories in two consecutive years. Of these, 17 (65.4%) were situations where the same two adults bred in both years, four (15.4%) involved a change in the female partner, three (11.5%) involved a change in the male partner, and two (7.7%) involved changes in both partners. In all cases where both partners were identified, neither member of a breeding pair was ever found breeding with a different partner in a subsequent year when its mate was still in the study area. We combined all mate turnover events for logistic regression analysis. The interaction between year and location was not significant, so the final model included year and location as the main effects without an interaction. The odds of breeding pairs experiencing turnover of a mate the following year did not change significantly over time (odds = 0.9489, P = 0.8952) and was not significantly related to location (odds = 0.6735, P = 0.5876).

During the 3-yr period in which we recorded the identities of breeding adults in southern Idaho, we identified 12 female and seven male breeding goshawks in two consecutive years (Table 3). Because of our limited sample, we did not analyze these data statistically. Female turnover occurred a total of four times for an average annual female turnover rate of 30%. Only one male turnover was recorded over the 3-yr period for an annual male turnover rate of only 12.5%. Here also, we did not record any incidences of mate infidelity.

DISPERSAL AND MOVEMENTS

Only seven goshawks (five females, two males) banded as nestlings in northeastern Nevada were ever found as breeding adults and five were banded as nestlings in 1992 (Table 4). One female banded as a nestling in 1992 returned to breed at 3 yr of age in a nesting territory 7.62 km west of its natal site in 1995 and bred there annually through 2002. A second female banded as a nestling in 1992 returned to breed as at 4 yr of age in 1996, 41.7 km north of its natal site. A third female banded in 1992 was found breeding as at 4 yr of age near Soldier Peak in the Ruby Mountain Wilderness of northeastern Nevada in 1996, 93.8 km south of its natal site. A fourth female banded in 1999 was found breeding at 1 yr of age in our study area in southern Idaho in 2002, 175.3 km northeast of its natal site. The fifth female was also banded in 1999 and was also found breeding as at 2 yr of age in the southern Idaho study area in 2001, 2002, and 2003,163.75 km northeast of its natal site. Overall female natal dispersal averaged 96.4 ± 73.6 km. There were only two observations for male natal dispersal in northeastern Nevada. One male banded in 1992 returned to breed in 1996 as a 4 yr of age, 23.99 km south of its natal site, and a second male also banded in 1992 returned to breed in 1996 as 4 yr of age, 14.17 km southwest of its natal site. Average male natal dispersal was 19.1 km. None of the nestlings banded in the southern Idaho study area were ever reencountered as breeding adults.

TABLE 4. NATAL DISPERSAL DISTANCES OF NORTHERN GOSHAWKS IN THE INDEPENDENCE AND BULL RUN MOUNTAINS OF THE HUMBOLDT-TOIYABE NATIONAL FOREST IN NORTHWESTERN NEVADA, 1992–2002.

Sex	Year banded	Year first breeding	Natal dispersal distance (km)
F	1992	1995	7.62
F	1992	1996	41.68
F	1992	1996	93.84
F	1999	2000	175.30
F	1999	2001	163.75
M	1992	1996	23.99
M	1992	1996	14.17

We recorded nine breeding dispersal events (eight female, one male) by eight different goshawks (seven females, one male) in northeastern Nevada and none in southern Idaho. Breeding dispersal distance in northeastern Nevada averaged 5.37 ± 3.93 km (N = 9). Female breeding dispersal distance ranged from 1.3–10.6 km ($\bar{x}$ = 5.78 ± 3.99, N = 8) and the only male breeding dispersal distance recorded was 2.1 km. None of the adult goshawks that we identified to be breeding in southern Idaho dispersed within the study area over the 3-yr period we made observations. As long as they remained in the study area, both males and females showed 100% fidelity to nesting territories and they were replaced at nesting territories only when they died or disappeared from the study area.

Three goshawks (one male, two females) banded as nestlings in our northeastern Nevada study area in 1996, 1999, and 2000 were captured in the Goshutes Mountains by HawkWatch International (J. Smith, pers. comm.) approximately 200 km east of their natal area as hatch year birds. In addition, two goshawks (one male, one female) banded at the Goshutes Mountains in the fall of 1991 and 1995, respectively, were found breeding at before 3 yr of age in the northern Nevada study area in 1992 and 1997, respectively. One hatch-year male goshawk captured at the Goshutes Mountains in 1997 was subsequently recaptured as a breeding male in the southern Idaho study area in 2002.

DISCUSSION

Overall occupancy of territories by breeding goshawks in the Independence and Bull Run Mountains of northeastern Nevada averaged 62% and 39.5% in the Sawtooth National Forest of southern Idaho. These averages were very similar to average nesting territory occupancies of 63% and 50% reported by Woodbridge and Detrich (1994) for the Klamath National Forest in northern California, by Patla (1997) for the Targee National Forest in southeastern Idaho, and Ingraldi (1998) for the Sitgreaves National Forest of east-central Arizona. Occupancy of nesting territories by goshawks in areas of the Tongass National Forest in southeast Alaska averaged much lower at only 33% (range = 13–62%; Flatten et al. 2001), but it was similar to the nesting territory occupancy of only 39.5% that we recorded in southern Idaho. Occupancy in neither of our study areas approached the average occupancy estimate of 81% reported by Reynolds and Joy (1998) for the Kaibab Plateau in Arizona.

Nesting territory occupancy declined significantly in northeastern Nevada from highs of >80% between 1992–1994 (Younk 1996) to a low of <30% in 2002. A less severe decline occurred in southern Idaho where occupancy decreased from 59% in 1995 to 32% in 2003. In situations where goshawks feed on one particular prey species, declining breeding populations of goshawks have been linked to declines in their preferred prey. For example, in interior Alaska where goshawks feed primarily on snowshoe hares which cycle every 10 yr, the breeding population of goshawks appears to fluctuate with changes in the hare population (McGowan 1975, Doyle and Smith 1994). In the Dixie National Forest of southern Utah, a decline in occupancy has been attributed to a widespread drought in the southwestern US (R. Rodriguez and C. White, pers. comm.). Goshawks in northeastern Nevada and southern Idaho feed mostly on ground squirrels, which can comprise between 50–90% of their diet (Younk and Bechard 1994a), but they also feed on several species of birds including American Robins (*Turdus migratorius*) and Northern Flickers (*Colaptes auratus*). Because the diet of these goshawks was variable from year to year, we felt it unlikely that the decline in the breeding population that we observed was related to a decline in ground squirrel populations. Rather, we feel that such a large scale, regional decline in the breeding population of goshawks in the northern Great Basin was more indicative of the effects of climate on goshawk breeding. We found a significant correlation between average March–April temperature and April–May precipitation in northern Nevada indicating that variations in climatic factors such as cold temperatures and high snowpack and rain in spring may play a major role in determining the number of goshawk pairs that breed annually (Fairhurst and Bechard 2005). Nesting territory occupancy may be related to severe weather (Squires and Reynolds 1997) and colder, wetter springs may negatively influence goshawk reproduction by increasing mortality through chilling of eggs and nestlings (Höglund 1964a, Zachel 1985, Kostrzewa and Kostrzewa 1990, 1991, Bloxton 2002). Cold weather may also affect foraging behavior of males (Zachel 1985) with poor food provisioning to pre-egg-laying females preempting egg laying entirely (Newton 1979a).

Our estimated average of 1.62 young/breeding pair for goshawks breeding in southern Idaho was similar to that reported for other goshawk populations but our estimate for the productivity of goshawks in northeastern Nevada was higher than reported elsewhere. Our mean productivity of 2.27 young/breeding pair in northeastern Nevada was higher than in northern California where breeding pairs average only 1.93 young/breeding pair (Woodbridge and Detrich 1994), in eastcentral Arizona where pairs average only 1.19 young/breeding pair (Ingraldi 1998), in the Kaibab Plateau in Arizona where pairs average only 1.55 young/breeding pair (Reynolds and Joy 1998), and in the Tongass National Forest in Alaska where pairs average only 1.9 young/breeding pair (Flatten et al. 2001). Most breeding pairs in northeastern Nevada that began breeding were successful in raising young to fledging age averaging only 13.5% annual failure of breeding attempts. This failure rate was similar to that reported by Woodbridge and Detrich (1994) who found 13% of breeding pairs failing in northern California, Flatten et al. (2001) who found 7% failing in Alaska, and Reynolds and Joy (1998) who found 18% failing in Arizona. Due to the decline in the number of breeding pairs in the population in northeastern Nevada, overall annual production of young fell from a high of 73 young in 1996 to a low of only 10 young in 2002. Likewise, in southern Idaho annual production of young varied from a high of 28 young in 2000 to a low of only two in 1998. With such marked variation in annual productivity, the recruitment of new breeders into these populations was undoubtedly highly variable over the 11 yr that we studied them. Despite this, two females dispersed nearly 200 km from their natal grounds in northeastern Nevada and settled as breeders in southern Idaho indicating that, rather than settling into their natal areas as new breeders, young may disperse great distances, filling vacancies in remote breeding populations.

An average of 19.3 % and 20% of goshawk nesting territories in northeastern Nevada and southern Idaho, respectively, experienced turnover of at least one breeding adult during our study. Adult females were replaced at 18.7% and 40% of nesting territories, respectively. Adult males were replaced at 20.6% of the nesting territories in northeastern Nevada and only one of the males was replaced in 3 yr in southern Idaho. Squires and Reynolds (1997) have noted that fidelity to breeding territories is often difficult to determine because of the problems associated with finding all of the alternate nests in nesting territories. Nesting territories in northeastern Nevada and southern Idaho are relatively small and nest structures are built in aspen trees and lodgepole pines where they are fairly obvious. We thoroughly searched all territories and, although we cannot assume that our turnover estimates are entirely unbiased, we feel confident that when we did not find a bird on a territory it was because it no longer bred there. Furthermore, our estimate of annual turnover of breeders was similar to that found in the Kaibab Plateau in Arizona (16% for females and 25% for males, Reynolds and Joy 1998), northern California (28.6% for females and 23.5% for males, Detrich and Woodbridge 1994), and Alaska (35.7% for females, Flatten et al. 2001). In the 31 cases where we identified both members of a pair on the same nesting territory in northeastern Nevada and southern Idaho, only 57.5% were situations where both members of the pair remained together on the same territory that had been used in the previous year. Most mate turnovers involved female replacements, indicating that female mate turnover was higher in our study areas than elsewhere. Breeding goshawk pairs were found to retain the same mate at 72% of nesting territories in northern California (Detrich and Woodbridge 1994), 75.9% of the nesting territories in southeast Alaska (Flatten et al. 2001), and 98% of the nesting territories in the Kaibab Plateau (Reynolds and Joy 1998). Because we did not find a member of a breeding pair breeding with a different partner in a subsequent year when its mate was still in the study area, we felt that the occurrence of mate infidelity in this population was probably very low.

Natal-dispersal distance of goshawks in northeastern Nevada was sex-biased with females dispersing nearly five times farther than males (19 vs. 96 km for males and females). Reynolds and Joy (1998) reported a male natal dispersal of 15.9 km, which was similar to our estimate for male natal dispersal distance in northeastern Nevada. Nevertheless, their estimated female natal dispersal of 21.5 km was nearly five times less than our estimate for female natal dispersal in northeastern Nevada. Our estimate for breeding dispersal distance of adult goshawks in northeastern Nevada indicated that, once an adult began to breed in the population, it tended to breed in the same, or near to the same, territory from one year to the next. Our breeding dispersal distances of only 5.8 km for females and 2.1 km for males were much shorter than breeding dispersal distances in northern California where females disperse an average of 9.8 km and males disperse an average of 6.5 km between breeding territories (Detrich and Woodbridge 1994) and in Alaska where adults move 18.5 km between nesting territories in consecutive years (Flatten et al. 2001), but similar to Arizona where breeding females disperse an average of 5.2 km and males disperse an average of 2.8 km (Reynolds and Joy 1998).

Our results indicate that the northeastern Great Basin area of northeastern Nevada and southern Idaho supports a large metapopulation of Northern Goshawks that is comprised of several smaller, populations existing in isolated mountain ranges throughout the area. With their large natal dispersal distances, it appears that juvenile, female goshawks readily move between these isolated populations, which can be separated by hundreds of kilometers. However, once they settle into an area, females remain there and do not return to their natal areas. In view of these large dispersal distances, we feel that to accurately monitor the status of the breeding population of Northern Goshawks in the northeastern Great Basin, it is necessary to monitor all of the isolated populations that are distributed throughout the region including the Ruby and Santa Rosa Mountains and the Jarbidge Wilderness in northeastern Nevada.

We did not identify the cause for the decline in occupancy of goshawk nesting territories in our two study areas. Nevertheless, the fact that both areas experienced simultaneous declines in occupancy indicated that there was a large-scale factor that affected the metapopulation of goshawks in the northeastern Great Basin. While declines in breeding populations in the northern portion of the goshawk's North American range have been associated with 10-yr declines in snowshoe hares, this explanation cannot be used for goshawks in the northeastern Great Basin which feed mostly on ground squirrels which are not known to exhibit population cycles (Van Horne et al. 1997). We feel that other factors that operate on a landscape basis are probably the cause of the decline in goshawk breeding that we observed in the northeastern Great Basin. Kostrzewa and Kostrzewa (1990) and Fairhurst (2004) and Fairhurst and Bechard (2005) have found a significant relationship between goshawk occupancy and spring weather which may play a role in the breeding status of populations of goshawks distributed throughout the Great Basin. Apparently, warm, dry springs are most conducive to goshawk breeding and periods of cold and above average precipitation prevent goshawks from initiating breeding. Further work on the effect of weather on the breeding of goshawks in the Great Basin would increase our understanding of factors that influence populations of goshawks and the status of the species across its western North American range (Kennedy 1997, DeStephano 1998).

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