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NEST PRODUCTIVITY, FIDELITY, AND SPACING OF NORTHERN GOSHAWKS IN ARIZONA

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Abstract. Distribution of nests, nest success and productivity, mate and site fidelity, and diets of Northern Goshawks (*Accipiter gentilis*) were examined on the Kaibab Plateau, Arizona, in 1991–1992. A total of 98 nest attempts was studied, 92 in the Kaibab National Forest and six in Grand Canyon National Park. Of 36 nests in which eggs were laid in 1991, 34 produced young ($\bar{X}$ = 2.15 young/successful nest) and of 59 nests in which eggs were laid in 1992, 49 produced young ($\bar{X}$ = 2.16 young/successful nest). In 1991, 49 adults were banded at nests, including both adults at 21 nests. In 1992 both adults were recaptured at 10 of these 21 nests. At six (60% of 10) of these nests, both adults remained paired and five produced the same or more fledglings in 1992. Three (6% of 49) nesting hawks banded in 1991 moved to new territories in 1992 and each fledged one more young in 1992 than in 1991. The proportion of nesting adults banded in 1991 that were replaced by new hawks at 1992 nests was 23%. In 1992, nine (9.7% of 93) nesting hawks were classed as "young-adult" based on plumage characteristics; young-adults produced significantly fewer fledglings than full adults.

Mean distance between nearest neighboring nests in 1992 was 3.0 km (range = 1.6–6.4 km, N = 59 nests). Alternate nests were used between years in 17 of 34 territories; mean distance between the original and alternate nests was 266.4 m (SD = 157.0 m). Diets in 1991 were composed of 62% mammals and 38% birds by number, and 84% mammals and 16% birds by biomass.

Key Words: *Accipiter gentilis*; Kaibab Plateau; mate and territory fidelity; morphometrics; Northern Goshawk; population; productivity.

The Northern Goshawk (*Accipiter gentilis*) is holarctic in distribution. The North American subspecies (*A. g. atricapillus*) occurs from the northeastern United States across the boreal forests of Canada to Alaska and southward through the montane forests of western United States to northern Mexico (Wattel 1973). The Northern Goshawk nests in most of the coniferous, deciduous, and mixed coniferous-deciduous forests that occur within its range. Northern Goshawks prey on 20 or more species of birds and mammals within nesting home ranges of 15–31 km^2 (Schnell 1958, Meng 1959, Reynolds 1983, Reynolds and Meslow 1984, Bright-Smith and Mannan, this volume).

The Northern Goshawk is listed as a "sensitive species" by the USDA Forest Service Southwestern Region because of potential threats of forest management (e.g., tree harvests, fire suppression, and grazing) to the hawk's nesting and foraging habitats (Reynolds et al. 1982, Herron et al. 1985, Bloom et al. 1986, Reynolds 1989, Crocker-Bedford 1990, Reynolds et al. 1992). In fact, several authors (Herron et al. 1985, Bloom et al. 1986, and Crocker-Bedford 1990) suggest that Northern Goshawk populations have recently declined in Nevada, California, and Arizona due to habitat loss. Crocker-Bedford (1990), for example, estimated that there were 260 pairs of Northern Goshawks on the 120,000 ha North Kaibab Ranger District before timber harvesting began in the 1950s. By 1972, following "light partial" tree harvesting over most of his study area, the number of pairs declined to 130, and to probably half of that in 1988 after the introduction of a more intensive harvesting (Crocker-Bedford 1990).

In 1991 we began a long-term study of individual and population responses of Northern Goshawks to tree harvest and other forest management practices on the Kaibab Plateau. Our objective is to determine the effects of management by measuring Northern Goshawk response variables (e.g., distribution and density of nests, nest success and productivity, diets and prey populations, mate and territory fidelity, time budgets, home range characteristics, and mortality factors) to changes in habitat resulting from forest management. Here we report on nest dispersion, nest success and productivity, mate and territory fidelity, morphometrics, and diets of Northern Goshawks on the Kaibab Plateau in 1991–1992.

METHODS

STUDY AREA

The study area encompassed the coniferous forests on the Kaibab Plateau in northern Arizona. The Kaibab Plateau is an oval-shaped (95 km × 55 km), limestone plateau that rises from a shrubsteppe plain (elevation 1750 m) to a maximum elevation of 2800 m (Rasmussen 1941). It is bounded by escarpments and steep slopes that descend into the Grand Canyon of the Colorado River on its southern half and by more gentle slopes that descend to the shrubsteppe plain on its northern half. Total area covered by forests in the study area, including the Grand Canyon National Park

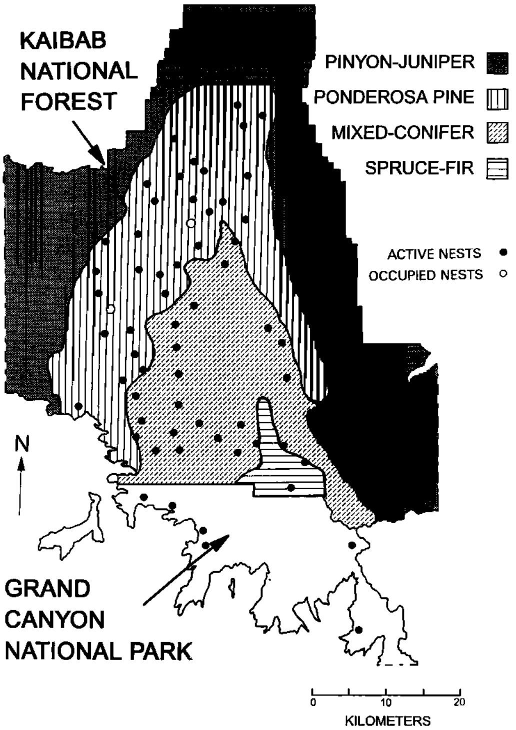

FIGURE 1. Forest types and nest locations of Northern Goshawk on the Kaibab Plateau, including the North Kaibab Ranger District and the Grand Canyon National Park, in 1992 (forest types in the National Park not mapped).

and North Kaibab Ranger District, is about 320,600 ha. Pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands occur at lower elevations (1830–2075 m) on the Plateau and occupy about 176,000 ha. Ponderosa pine (*Pinus ponderosa*) forests occur between 2075–2500 m elevation and occupy about 99,200 ha, and mixed-conifer forests (*P. ponderosa, Abies concolor, Pseudotsuga menziesii, Picea engelmannii,* and *Populus tremuloides*) occur above 2500 m, occupying about 45,400 ha (Rasmussen 1941) (Fig. 1). Annual precipitation averages 67.5 cm, with winter snowpacks of 2.5–3.0 m. Mid to late summers are characterized by frequent (2–4 per week) thunderstorms and heavy showers.

The Kaibab Plateau was isolated from established railroad heads in the late 1800s and early 1900s. Thus, forests on the Kaibab Plateau were not subjected to the heavy logging that typically occurred in montane areas on the Colorado Plateau and elsewhere in the southwestern United States during this period (Pearson 1950, Laudenslayer et al. 1989, J. Hanson, pers. comm.). Organized tree harvests did not begin on the Kaibab Ranger District until 1923 and were limited to single-tree cutting to remove dead and dying trees (sanitation cutting) (Burnett 1991). In the late 1960s clear-cutting began in the mixed-conifer forests (total = 922 ha) but was discontinued in the early 1970s; single-tree cutting in ponderosa pine continued through the mid-1980s. Intensive management at the forest stand level began in the mid-1980s with even-aged silvicultural treatments in the pine and mixed-conifer forests; these even-aged treatments continued until 1991. From the 1940s to 1990, the total volume of wood removed from the Ranger District increased by a factor of 5, from 9077 to 48,412 boardfeet per ha (1992 Kaibab National Forest Timber Atlas, J. Ellenwood, pers. comm.). While the early sanitation cutting occurred over much of the North Kaibab Ranger District, the application of stand level management beginning in 1986 resulted in a reduction of the total area harvested (1986–1991) to 12,632 ha, about 14% of the Ranger District (1992 Kaibab National Forest Timber Atlas, J. Ellenwood, pers. comm.).

The suppression of naturally frequent ground fires on the Kaibab Plateau since the 1910s has resulted in an increase in the number of small trees (≤29.4 cm in diameter at breast height) per ha by a factor of almost eight in ponderosa pine forests and by a factor of 11 in mixed-conifer forests (1992 Kaibab National Forest Timber Atlas, J. Ellenwood, pers. comm.). In 1991, due to concerns for the Northern Goshawk population on the Plateau, the focus of management shifted from the level of the stand to small (0.1–1.6 ha) groups of trees combined with an area-wide thinning of the small, understory trees (Reynolds et al. 1992). The objective of this management was to move the ponderosa pine and mixed-conifer forests on the Ranger District toward the species composition and structure that existed prior to fire suppression and intensive tree harvests (Reynolds et al. 1992).

Nests, Morphometrics, Diets, and Movements

To locate active (containing eggs or young) Northern Goshawk nests, we visited all previously documented nests (Goshawk Nest Records, 1990–1992, Arizona Game and Fish Department, Phoenix, Arizona, and North Kaibab Ranger District, Fredonia, Arizona), searched for new nests on foot (Reynolds 1982), and used a vocalization broadcast technique (Joy et al. *this volume*). Each year nest visits and searches were begun in May and continued through August. Broadcast surveys were conducted daily between 08:00 and 16:30 MDT (Joy et al. *this volume*). All nests of Northern Goshawks, and their potential competitors and predators, Cooper's (*A. cooperii*), Sharp-shinned (*A. striatus*), and Red-tailed (*Buteo jamaicensis*) hawks, and Great Horned Owl (*Bubo virginianus*) found were recorded on 7.5-minute USGS topographic maps. We used the Universal Transverse Mercator (UTM) coordinates of all nests to determine the distances between alternate Northern Goshawk nests (nests used in subsequent years by a pair) and to calculate nearest-neighbor distances among nests. Nearest-neighbor distances were the straight-line distances between each active nest and its closest neighbor. Calculation of nearest-neighbor distance included duplicate measures between reciprocal nearest neighbors (Diggle 1983).

The fates of nests (successful = fledged ≥1 young) and nest productivity (number of fledglings produced) were determined by weekly visits to nests. Adults were captured at nests in dho-gaza traps baited with live Great Horned Owls (Bloom 1987). Away from nests,

TABLE 1. NUMBER OF NESTS OF *Accipiter* FOUND ON THE KAIBAB PLATEAU, 1991–1992

		Nest search technique			
Year	Species	Visits to historic nests	Broadcast survey	Foot search	Total
1991	Northern Goshawk	28	5	4	37
	Cooper's Hawk	0	3	4	7
	Sharp-shinned Hawk	0	7	1	8
1992	Northern Goshawk	40	8	13	61
	Cooper's Hawk	5	2	1	8
	Sharp-shinned Hawk	3	3	2	8

adults and juveniles were captured with 5–6 "falling-end" Swedish goshawk traps (Kenward and Marcström 1983) that were baited with domestic pigeons (*Columba livia*) and placed at about 1 km intervals. Swedish goshawk traps were also placed at nests to capture fledglings. All hawks were fitted with U.S. Fish and Wildlife Service aluminum leg bands and anodized aluminum color leg bands with unique alpha-numeric codes. Bands were read from blinds in nest areas or when the hawks were recaptured. Age classes (immature, young-adult, or adult) were determined by plumage characteristics (Bond and Stabler 1941, Stabler 1943) and sex by body mass (see below). Morphometrics of adults included body mass, wing chord, tail, tarsometatarsal length, and condition (good, moderate, or poor based on breast muscle assessment).

Accipiter remove pelage and plumage from their vertebrate prey in the nesting area and on the nest itself. In addition, these hawks regurgitate pellets that contain keratinous body parts of prey. On each visit to a nest, all prey remains and pellets were completely collected. During identification, remains in a day's collection from a nest were lumped and reconstructed by matching the remiges, rectrices, and bills of birds, and the fur, skull parts, and feet of mammals (Reynolds and Meslow 1984). This procedure estimates the minimum number of individuals of each species in a collection (Reynolds and Meslow 1984). Estimates of body mass of birds and mammals in diets were from the literature and museum specimens. We assigned the mass of young prey to be one-half of their adult mass. The mass of prey that could be identified only to genus was determined by averaging mass of all members of that genus in our study area (Reynolds and Meslow 1984). Prey remains collected in 1992 have not been identified and we present only the 1991 diet data.

To determine post-fledging movements and dispersal of Northern Goshawks, 13 adults and 15 fledglings were fitted with tail-mounted (Kenward 1978) and backpack (Kenward 1985) transmitters weighing 6 g ($\leq$0.8% of body mass). We attempted to locate radio-tagged adults and juveniles once a week from the ground in late summer and early fall and from aircraft during winter (2 flights/year).

RESULTS

NEST NUMBERS, NEST PRODUCTIVITY, AND MORPHOMETRICS

A total of 37 occupied Northern Goshawk nests (nests at which adults were observed on two or more occasions during a breeding season) were located on National Forest lands on the Kaibab Plateau in 1991; 28 (76%) of these were located during visits to historic nests, five (13%) during broadcast surveys, and four (11%) during foot searches (Table 1). Active nests of seven Cooper's Hawks and eight Sharp-shinned Hawks were also located during searches and broadcast surveys. In 1992, 61 occupied Northern Goshawk nests were found, 55 nests on National Forest and six on National Park lands. Of these 61 nests, 40 (66%) were found during visits to historic nest areas (including 1991 nests), eight (13%) during broadcast surveys, and 13 (21%) during foot surveys. Three additional Cooper's Hawk nests and five additional Sharp-shinned Hawk nests were found (Table 1).

Of the 2-year total of 98 occupied Northern Goshawk nests, 83 pairs (85%) fledged young, three pairs (3%) either did not lay a clutch or lost their clutch in early incubation, six clutches (6%) were lost during incubation, and six (6%) nests failed during the nestling period. Among active nests there was no significant difference in the rate of nest failure in the two years (one of 34 [5.6%] nests failed in 1991 and 10 of 59 [16.7%] nests failed in 1992) (Fisher's exact test, $N = 93$, $P = 0.13$), nor were there significant differences in the mean number of young fledged in the two years per occupied (Fisher's exact test, $N = 98$, $P = 0.26$), active (Fisher's exact test, $N = 95$, $P = 0.23$), or successful (Fisher's exact test, $N = 83$, $P = 0.44$) nests (Table 2). For both years modal brood size was two, with one fledgling produced at 13 successful nests (16%), two at 44 nests (53%), and three at 26 nests (31%). All but three (8%) of the 37 occupied nests (or alternate nests) in 1991 were reoccupied in 1992. Broadcast and foot searches for active, alternate nests within 2 km of these three nests in 1992 were unsuccessful.

Nestling Northern Goshawks fledged between 7–25 July and eggs hatched between 31 May and 16 June. Assuming a 30–32 day incubation period (Reynolds and Wight 1978), egg-laying occurred in late April and early May. Combining

TABLE 2. FLEDGLINGS PRODUCED PER OCCUPIED, ACTIVE, AND SUCCESSFUL NORTHERN GOSHAWK NESTS ON THE KAIBAB PLATEAU, 1991–1992

	1991			1992		
	$\bar{X}$	SD	N	$\bar{X}$	SD	N
No./occupied nest	2.0	0.83	37	1.7	1.08	61
No./active nest	2.0	0.77	36	1.8	1.05	59
No./successful nest	2.2	0.61	34	2.2	0.72	49

years, the sex ratio of nestlings just prior to fledging for 23 broods was 23 males to 27 females, not significantly different from a 1:1 ratio (Fisher's exact test, N = 50, P = 0.58).

In 1991–1992 we captured and banded 76 fledglings (hatching year), one second-year hawk (after hatching year), and 93 adults (44 males, 49 females). Three (6.8%) males and six (12.2%) females were in the young-adult plumage class (after second year). All of these young adults nested in 1992, and each was paired to an adult hawk. The mean number of fledglings produced by the young-adult females ($\bar{X}$ = 1.0 fledglings, SD = 0.89, N = 6) was not significantly different from the mean produced by the young-adult males ($\bar{X}$ = 1.3 fledglings, SD = 1.33, N = 3) (Fisher's exact test, N = 9, P = 0.71). However, the production of fledglings at active nests of young-adult to adult pairings was significantly less than the production of fledglings at active nests of adult-to-adult pairs ($\bar{X}$ = 1.1 fledglings, SD = 0.9 vs. $\bar{X}$ = 2.3 fledglings, SD = 0.8, N = 21) (Fisher's exact test, N = 30, P = 0.01).

All but four adults were captured with dhogaza nets. The exceptions (three males, one female) were captured in Swedish traps (98 trap-hours/capture). Four juveniles (one male, three females) were also captured in Swedish traps (77 trap-hours/hawk). There were no significant differences between years in the frequency of adults trapped with either method in the three condition classes (Fisher's exact test: males, N = 50, P = 1.00; females, N = 63, P = 0.51). There was a total of three nesting adult males (one in 1991, two in 1992) and five adult females (two in 1991, three in 1992) in the "poor condition" class. All hawks in poor condition were paired with birds in "moderate" or "good" condition. Mean number of fledglings produced per successful nest of pairs with a hawk in poor condition ($\bar{X}$ = 2.3 fledglings, SD = 0.52, N = 6 pairs) and pairs in which both adults were in moderate to good condition ($\bar{X}$ = 2.2 fledglings, SD = 0.73, N = 38) were not significantly different (Fisher's exact test, N = 44, P = 0.62). Also, nest success of pairs with a hawk in poor condition (six of eight pairs, 75%) did not differ from pairs in which both adults were in moderate to good condition (38 of 40 pairs, 95%) (Fisher's exact test, N = 48, P = 0.12).

Overlap between the sexes occurred for all morphometrics (body mass, wing chord, tail length, tarsometatarsal length) except body mass (Table 3). Mean wing chord and tail length were larger and mass smaller for Northern Goshawks on the Kaibab Plateau than for migrating birds in Wisconsin (Mueller et al. 1976). However, variation in all morphological measurements from hawks on the Kaibab Plateau was less than for Northern Goshawks in Wisconsin. Wing chords of Northern Goshawks on the Kaibab Plateau were also longer than for adults of the

TABLE 3. MEASUREMENTS OF BODY MASS, TAIL, WING, AND TARSOMETATARSUS LENGTH OF ADULT NORTHERN GOSHAWKS ON THE KAIBAB PLATEAU, 1991–1992

Variable	$\bar{X}$	SD	Max.	Min.	N
		Males			
Mass (g)	704.4	32.7	774.0	631.0	45
Tail (cm)	23.5	1.1	28.7	21.3	45
Wing (cm)	34.2	0.7	36.2	32.4	45
Tarsometatarsus (mm)	81.4	3.5	87.7	73.8	45
		Females			
Mass (g)	985.5	51.9	1100.0	907.0	49
Tail (cm)	27.7	0.9	29.0	24.7	49
Wing (cm)	37.3	0.9	38.9	35.0	49
Tarsometatarsus (mm)	88.2	4.4	94.9	79.1	49

subspecies *A. g. laingi* reported by Johnson (1989).

Mate Fidelity, Territory Fidelity, and Nest Productivity

Both members of pairs were banded at 21 nests in 1991. In 1992, both sexes were recaptured at 10 of the 21 nests. At six of the 10 nests both sexes remained paired, at two nests one of the original pair was replaced by a new hawk (one new male, one new female), and at two nests both members of the original pair were replaced by new hawks (at one of these nests both replacement hawks had been banded in 1991 at two different nests).

In 1992, all (six) banded pairs that renested on their 1991 territory (in the same or alternate nest, see below) successfully fledged young in 1991 ($\bar{X}$ = 1.8 fledglings, SD = 0.8), and all but one of these pairs produced the same (two pairs) or more (three pairs) fledglings in 1992 ($\bar{X}$ = 2.3 fledglings, SD = 0.5). The exception produced three fledglings in 1991 and two in 1992. In addition there were ten other nests at which only one adult (either the 1991-banded adult or its replacement) was captured in 1992. At these ten nests, one male and none of the females were replaced. Productivity at the nest where replacement occurred decreased from three to zero fledglings in 1992. Of the females, four produced the same number of fledglings in both years, three produced more in 1992, and two produced less in 1992 (one failed). The overall replacement rate of banded hawks at nests from 1991 to 1992 was 23% (seven replacements for 30 previously banded hawks captured or recaptured in 1992).

Of three banded hawks that moved from their 1991 territory to nest elsewhere in 1992, each fledged two young in 1991 and three young in 1992. In two of these cases, the hawks moved to nests in territories adjacent to their original (male RO, 3.5 km; female EB, 2.6 km). In the third case, female (AH) moved 9.2 km over two territories to pair with male RO.

Distances between Nearest-neighbor and Alternate Nests

Nearest-neighbor distances among a collection of nests provides an estimate of the distribution of those nests. Mean distance between 59 nearest neighboring nests in 1992 was 3 km (SD = 834.2 m, range = 6417–1573 m), and 47% of the nests were within 2.0–3.5 km of each other (Fig. 2). Although by the end of the 1992 season only 50% of the forest on the Kaibab Plateau was searched for Northern Goshawk nests, we think the nearest-neighbor distance is representative of the Plateau. Nest searches were systematically conducted in contiguous areas that expanded (and joined) from the northwest toward the southeast of the Plateau, and few nests were likely to have been missed within this area. Two isolated Northern Goshawk nests in the Grand Canyon National Park, discovered in non-systematic nest searches (B. S. Heslin and J. T. Driscoll, unpubl. data), were excluded from the analysis.

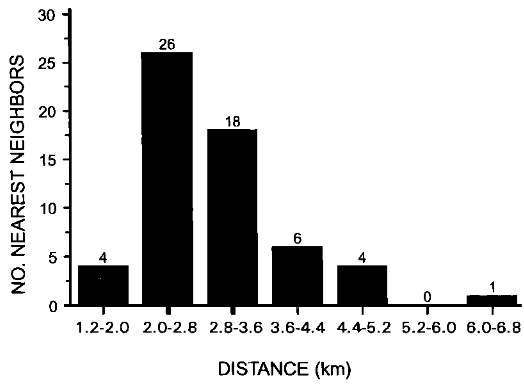

FIGURE 2. Number of occupied Northern Goshawk nests by nearest-neighbor distance in 1992 ($\bar{X}$ = 2.97 ± 0.83 km, N = 59 nests).

Pairs of Northern Goshawks often use alternate nests in different years (Reynolds and Wight 1978, Reynolds 1983). Four pairs of nesting Northern Goshawks banded in 1991 moved a mean distance of 485 m (SD = 130 m, range = 326–635 m) to alternate nests in 1992. In addition, three nesting females banded in 1991 (males not banded) moved a mean distance of 194 m (SD = 50 m, range = 142–241 m) to alternate nests in 1992. Finally, ten unbanded pairs (we presumed one or both sexes to be the same hawks in both years) moved a mean distance of 201 m (SD = 99 m, range = 100–425 m) to alternate nests in 1992. Combining these, the mean distance from 1991 nests to 1992 alternate nests was 266 m (SD = 157 m) (Fig. 3).

Diets

A total of 121 prey items, representing 11 species of birds and eight species of mammals, was identified in prey remains collected at nests in 1991 (Table 4). In descending order of frequency, the most commonly taken species included cottontail rabbit, tassel-eared squirrel, Steller's Jay, red squirrel, black-tailed jackrabbit, and Northern Flicker. By biomass, the most important of the mammals were the cottontail rabbit, tassel-eared squirrel, red squirrel, and jackrabbit and, among birds, Steller's Jay, Northern Flicker, and Williamson's Sapsucker. Overall, mammals con-

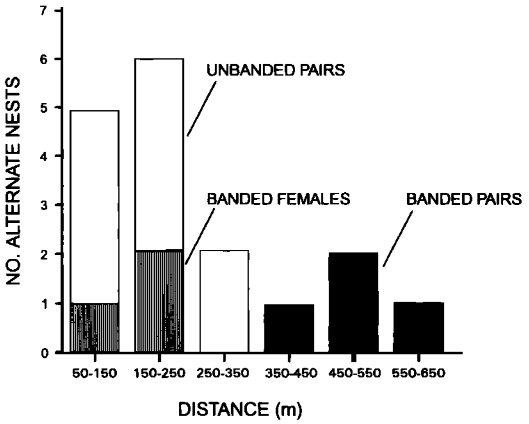

FIGURE 3. Distance between 1991 nests and 1992 alternate nests of Northern Goshawks on the Kaibab Plateau for banded pairs, unbanded pairs, and pairs in which only females were banded.

tributed 62% of number of prey items, while birds contributed 38%.

Post-breeding Movements

Fifteen fledglings were fitted with radio-transmitters in 1991–1992. Dispersal of fledglings from nest areas began in mid August and was completed by late August. Two radio-tagged fledglings in 1991 and four in 1992 could not be relocated after dispersing from nests and two other transmitters, lost by the fledglings, were recovered from the pinyon-juniper woodland on the north end of the Plateau. Five fledglings (two in 1991, three in 1992) were relocated from aircraft one or more times in November and December, and one fledgling was relocated during a March 1993 flight, all on the Plateau. One radio-tagged fledgling was found dead in October 1992, approximately 8 km southeast of Flagstaff, Arizona, a distance of 160 km from its birthplace.

In July and August of 1991 and 1992, five adults (all males) and four adults (two males, two females) were fitted with transmitters, respectively. All adults except one remained on their nesting territories through late October. The exception was a female who left her nesting territory in late August 1992 and spent two weeks in pinyon/juniper woodland on the north end of the Plateau, 13 km north of her nest. The female was relocated in the woodland habitat for two weeks before disappearing. She was again relocated on the Plateau during a March 1993 flight. None of the five males radio-tagged in 1991 were relocated after October 1991, probably because of transmitter failure. Of the other radio-tagged adults, two were relocated from aircraft during a flight in December, both on the Plateau.

TABLE 4. Frequency and % of Total Birds and Mammals in Diets of Northern Goshawks on the Kaibab Plateau in 1991

Species	Frequency	%
Birds		
Cyanocitta stelleri		
Steller's Jay	17	37.0
Colaptes auratus		
Northern Flicker	11	23.9
Sphyrapicus thyroideus		
Williamson's Sapsucker	7	15.2
Accipiter gentilis		
Northern Goshawk	3	6.5
Turdus migratorius		
American Robin	1	2.2
Buteo jamaicensis		
Red-tailed Hawk	1	2.2
Dendragopus obscurus		
Blue Grouse	1	2.2
Corvus brachyrhynchos		
American Crow	1	2.2
Sitta pygmaea		
Pygmy Nuthatch	1	2.2
Siala mexicana		
Western Bluebird	1	2.2
Unknown Emberizidae	1	2.2
Unknown bird	1	2.2
Mammals		
Sylvilagus spp.		
Unknown rabbit	22	29.3
Sciurus aberti		
Abert's Squirrel	13	17.3
Lepus californicus		
Black-tailed Jackrabbit	11	14.7
Tamiasciurus hudsonicus		
Red Squirrel	11	14.7
Unknown Sciuridae	6	8.0
Spermophilus lateralis		
Mantled Ground Squirrel	5	6.7
Spermophilus variegatus		
Rock Squirrel	4	5.3
Eutamius dorsalis		
Cliff Chipmunk	1	1.3
Eutamius umbrinus		
Uinta Chipmunk	1	1.3
Eutamias spp.		
Unknown chipmunk	1	1.3

DISCUSSION

For the North American *Accipiter* species, habitat quality can be regarded as a measure of the abundance and distribution of the structural and floristic elements of forests and woodlands that provide nesting opportunities, hunting perches, and protective cover as well as the accessibility to, and abundance of, suitably-sized prey. Habitat quality can be reflected in a hawk's physical condition (body mass), its nesting success and productivity, its degree of fidelity to territory and mate, the size of its home ranges, and population densities of the hawk and its prey (McGowan 1975; Newton 1976, 1986; Moss 1979; Geer 1981; Newton and Marquiss 1981, 1982; Marquiss and Newton 1982). In many raptors, the age of breeding individuals confounds the investigation of habitat quality because age may affect nesting success and productivity. For example, in European Sparrowhawks (*A. nisus*), the number of young produced per nest attempt increases from yearling-to-yearling pairs, through yearling-to-adult pairs, to adult-to-adult pairs (Newton 1986). Furthermore, individuals of some species can improve their annual reproductive performance by pairing with older, more experienced birds and by moving, with or without a previous mate, to territories of higher quality (Newton 1986, Reynolds and Linkhart 1987).

The mean number of young fledged per active nest on the Kaibab Plateau in 1991–1992 was within the range of values (0.69–3.0 young/nest attempt) for the Northern Goshawk in other areas of western North America, including Alaska (see Reynolds 1989 for review). Although the nest failure rate of pairs in which one adult was in poor condition was not statistically higher than for pairs in which both adults were in moderate or good condition, we anticipate that further sampling will demonstrate that physical condition affects nesting success. Additionally, production of fledglings was significantly related to age of nesting adults; younger hawks produced fewer fledglings. Returning to the same territory and pairing with the same mate in most cases resulted in the same or higher production of fledglings. A few adults, however, increased their production of fledglings after changing territories and mates.

The spacing of Northern Goshawk nests has only been determined for a few areas. On the Kaibab Plateau, the mean distance to nearest nests (3.0 km) was slightly less than half the nearest-nest distance (5.6 km) among four Northern Goshawk nests in Oregon (Reynolds and Wight 1978) and among European Goshawk nests (*A. g. gentilis*) in Sweden (5.5 km) (Hoglund 1964). The Oregon data, however, consist of a small sample of nests and, when compared to the Kaibab data, the nearest-neighbor distance is biased upward because duplicate measures between reciprocal nearest neighbors in Oregon were not used (Reynolds and Wight 1978). Nevertheless, nests of Northern Goshawks on the Kaibab Plateau appear to occur at a density higher than reported for other populations of the subspecies (see Reynolds 1989 for review).

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