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NORTHERN GOSHAWK DIETS IN PONDEROSA PINE FORESTS ON THE KAIBAB PLATEAU

CLINT W. BOAL AND R. WILLIAM MANNAN

Abstract. We recorded 385 prey deliveries at a mean delivery rate of 0.25/hr at 20 Northern Goshawk (*Accipiter gentilis*) nests in ponderosa pine (*Pinus ponderosa*) forests on the North Kaibab Ranger District (NKRD), Kaibab National Forest, Arizona, 1990–1992. Golden-mantled ground squirrels (*Spermophilus lateralis*) and cottontail rabbits (*Sylvilagus* spp.) were the most common mammalian prey species (41%). Steller's Jays (*Cyanocitta stelleri*) and Northern Flickers (*Colaptes auratus*) were the most common avian prey species (16%). Mammals and birds accounted for 76% and 24% of the observed prey, respectively. Mammals accounted for 94% of the biomass used by Northern Goshawks, and cottontail rabbits made up the greatest proportion of the biomass (26%). Goshawks on the NKRD fed slightly less equitably upon different prey taxa than goshawks in California, New Mexico, and Oregon, but size of prey taken by goshawks varied little among geographic locations.

Key Words: *Accipiter gentilis*; Arizona; diet; Northern Goshawk; ponderosa pine.

Habitat alteration by timber harvesting is one of the most significant factors affecting Northern Goshawk (*Accipiter gentilis*) populations (Reynolds 1989). Timber harvesting alters the structure of vegetation in mature forests and may reduce the suitability of stands as nest sites for goshawks (Reynolds 1983). Timber harvesting may also influence prey populations by changing the structure and composition of vegetation in areas where goshawks forage (Moore and Henny 1983). For example, densities of Kaibab squirrels (*Sciurus aberti kaibabensis*) are lower in harvested stands of ponderosa pine (*Pinus ponderosa*) than in uncut stands (Patton et al. 1985), red squirrels (*Tamiasciurus hudsonicus*) decrease up to 80% following thinning (Sullivan and Moses 1986), and golden-mantled ground squirrels (*Spermophilus lateralis*) increase in numbers following timber harvesting (Tevis 1956).

Populations of Northern Goshawks on the North Kaibab Ranger District and elsewhere in the western United States may be declining (Bloom et al. 1986, Kennedy, unpubl. data, Crocker-Bedford 1990, Zinn and Tibbitts, unpubl. data, Reynolds et al. 1992), although the evidence is equivocal. Prey abundance influences the reproductive success of raptors (Newton 1979). Northern Goshawks generally nest in areas with high prey densities (Hantage 1980, Kenward and Widén 1989, Kennedy 1988), and in years when availability of prey is low they experience nest failures (Hantage 1980). Other studies also suggest that the abundance of prey has an important influence on goshawk populations. Schnell (1958) found that days of increased food consumption by nestlings did not correspond with an increased delivery rate of prey, suggesting that foraging rate was controlled by prey abundance rather than food requirements. Wikman and Linden (1981) observed that goshawk numbers declined and brood sizes decreased in response to a reduction in grouse (Tetraoninae), their principal prey species, despite adequate available nesting habitat. Finally, sizes of goshawk ranges are inversely related to prey availability (Kenward 1982).

Northern Goshawks are opportunistic foragers with diets reflecting the diversity of available prey species (Opdam 1975, Widén et al. 1987, Kenward and Widén 1989, Kennedy 1991). Diet information is a principal component of management plans, but goshawk prey varies regionally. Diet studies of individual goshawk populations are necessary to understand their food habits on a regional scale (Storer 1966, Kenward and Widén 1989). Little diet information exists for goshawks in the southwestern United States, and our objective was to document the diet of Northern Goshawks during the breeding season on the Kaibab Plateau, 1990–1992.

STUDY AREA AND METHODS

The study area was on the North Kaibab Ranger District (NKRD), Kaibab National Forest, Coconino County, Arizona. The NKRD is approximately 259,000 ha located on the Kaibab Plateau, and is situated along the northern border of Grand Canyon National Park. The Kaibab Plateau ranges from 923 to 2830 m in elevation. The topography of the Plateau is typified by gentle slopes interspersed with shallow to deep drainages. The Plateau descends to sage flats on the north, east, and west sides, and is bounded by the Grand Canyon to the south. Ponderosa pine forests are found between 2075 and 2500 m elevation and comprise approximately 99,200 ha of the District.

All goshawk nests observed in this study were in stands of ponderosa pine or stands dominated by ponderosa pine. Other overstory trees include quaking aspen (*Populus tremuloids*) and white fir (*Abies concolor*). Gambel's oak (*Quercus gambelii*), New Mexico locust (*Robinia neomexicana*), and Utah juniper (*Juniperus* *osteosperma*) were common understory species found along drainages and slopes in all stands.

We observed eight Northern Goshawk pairs each year in 1990 and 1991, and six pairs in 1992. One pair failed each year, and we obtained insufficient data from the failures in 1990 and 1991 to include them in our analyses. We collected dietary data for the remaining 20 nesting goshawk pairs during 1539 hours of observation ($\bar{X}$ = 76.8 hour/nest ± 19.3 SD); we did not study any nesting pair for more than one successful breeding season.

REPRODUCTIVE SUCCESS

We documented nest site productivity for all nests observed in this study. We estimated hatching and fledging dates when not actually observed and we attempted to date and identify causes of nestling mortalities.

PREY DELIVERIES

We determined food habits by directly observing prey brought to the nest by adult goshawks. Observations at the nest are considered the least biased and most accurate way to assess diet of diurnal raptors (Errington 1930, 1932; Mader 1975; Snyder and Wiley 1976; Zeisemer 1981; Marti 1987; Mersmann et al. 1992; Bielefeldt et al. 1992). The technique, however, does have weaknesses, including: (1) it requires considerable time; (2) the probability of identifying different prey types is not always equal because the prey often are plucked, decapitated, or skinned prior to delivery to the nest; and (3) no information can be collected about the items consumed by adults away from the nest.

We located active goshawk nests from mid-May to early June by visiting historic nest sites in ponderosa pine forests on the NKRD. The only constraints on our selection of nesting pairs to study were that the pair had not been used in previous years of the study, and the nest was situated in such a way that it could be observed from ground or tree blinds. The order of nest observations was randomly selected during the first rotation, and followed the initial order during following rotations until fledging except when the nest failed or weather prevented access to nest sites. We began observations at each nest in the afternoon and continued until sundown, resuming at dawn until the time of initiation the previous day. We observed the nests from cloth blinds located on the ground or in trees a mean distance of 53 m (±17.6 SD) from the nest trees. Blinds were constructed over a 2–3 day period to decrease disturbance to the nesting pair (Fyfe and Olendorff 1976, Marti 1987). We initiated our observations during late incubation or early nestling stages. Approximately 5–7 days after fledging we discontinued observations because prey deliveries often occurred away from the nest.

We identified prey deliveries to species with binoculars and 15–45× spotting scopes. We tabulated the identified prey and used an Analysis of Variance for Ranked Data test (Winer 1971) to investigate variance among nests. We used chi-square tests (Sokal and Rohlf 1981) to examine changes in diet composition on basis of mammal and avian prey, and individual species for which there were sufficient samples, through the nesting season.

We categorized prey into a priori size classes based on Storer's (1966) cubic function size class system. We calculated the mean weights for adult mammalian species from the collection weight of museum specimens in the University of Arizona mammal collection; museum specimens were from various regions throughout their ranges in Arizona. We only used adult weights when calculating average mammal biomass. Weights for adult avian species were taken from Dunning (1984). Estimates of avian weights for the age classes of nestling-fledgling, subadult, and unknown age were computed following Bielefeldt et al. (1992).

We categorized unidentified mammals as being small or large and assigned them the average weight of identified mammals occurring in size classes 1–12 ($\bar{X}$ = 164.8 g ± 61.4 SD) for small mammals, and size classes 13–20 ($\bar{X}$ = 676.4 g ± 42.2 SD) for large mammals. We categorized unidentified avian prey as small, medium, or large and assigned them the average weight of identified birds occurring in size classes 1–3 ($\bar{X}$ = 19.8 g ± 0 SD), 4–6 ($\bar{X}$ = 45.6 g ± 14.1 SD), and 7–8 ($\bar{X}$ = 96.7 g ± 7.2 SD), respectively. We also noted when prey was cached or retrieved from a cache, and excluded the cache retrievals from diet assessment (Johnson 1981).

PREY REMAINS

Goshawks often remove plumage and pelage from their prey in the nest area or at the nest structure. We collected prey remains (i.e., feathers, fur, skin, skeletal parts) found in the nest area following each observation period. We also removed prey remains from nests whenever nest trees were climbed to band nestlings.

We cataloged prey remains to nest number and date of recovery on a master list. We packaged samples and assigned each a random identification number to alleviate observer bias when identifying remains. The master list was referred to only after remains were identified.

We reconstructed mammalian and avian remains following Reynolds and Meslow (1984). Remains were identified by comparison to specimens held in the University of Arizona mammal and avian collections. We excluded single feathers from analysis as they may have come from molting birds.

DIET BREADTH

We examined regional variation in diet breadth between Northern Goshawks in Arizona (this study), California (Bloom et al. 1986), New Mexico (Kennedy 1991), and Oregon (Reynolds and Meslow 1984). We used Levins' (1968) equation

$$B = 1/\sum P_i^2$$

to calculate diet breadths for the niche dimensions of prey taxon and prey size. The value P_i is the proportion of prey in each category, and B ranges from 1 to n, n being the number of categories. If B equals n, prey are used equally from all categories. On the other hand, if B is close to 1, the diet breadth is narrower and categories of prey are not used equally. The number of categories varied among studies. To compare diet

TABLE 1. SPECIES CONTRIBUTING ≥5.0% OF THE IDENTIFIED PREY DELIVERED TO NORTHERN GOSHAWK NESTS, NORTH KAIBAB RANGER DISTRICT, KAIBAB NATIONAL FOREST, ARIZONA, 1990–1992

Species	N	Percent observed	Percent biomass
Golden-mantled ground squirrel	86	28.0	14.9
Cottontail rabbit	41	13.3	26.1
Chipmunk	38	12.4	2.0
Steller's Jay	33	10.7	2.7
Red squirrel	31	10.1	5.8
Tassel-eared squirrel	26	8.5	15.0
Rock squirrel	18	5.9	9.8
Northern Flicker	16	5.2	1.5
Total	289	94.1	77.8

breadths among regions we standardized diet breadth values with the equation

$$B_{\text{standard}} = (B - 1)/(n - 1)$$

(Reynolds and Meslow 1984), which allows diet breadths to be compared on a scale of 0 to 1, the larger the value corresponding to increasing breadth of diet.

RESULTS

REPRODUCTIVE SUCCESS

Goshawks had a nestling rate of 2.4 ± 0.7 SD and 2.6 ± 0.5 SD nestlings per active (reached at least incubation) and successful (fledged young) nest, respectively. Forty-two of 53 nestlings survived to fledge, with a fledging rate of 1.9 ± 1.0 SD and 2.2 ± 0.7 SD fledglings per active and successful nest, respectively. We identified Great Horned Owl (*Bubo virginianus*) predation as the principal cause of nestling mortality (45.4%; N = 5) at our study nests, and a likely factor in some of the unidentified causes of death (36.4%; N = 4). The other identified cause of nestling mortality was falling from the nest (18.2%; N = 2).

PREY DELIVERIES

We observed a mean delivery rate of 0.25 prey items/hour, and identified 370 (97%) of the prey items to class. Only mammals (76%) and birds (24%) were delivered to the nest. We identified 241 (89.2%) of the mammal prey items to at least genus. We identified 59 (65.6%) of the avian prey to species, and six to the Family *Picadae* (6.7%); seven mammalian genera and eight avian genera were represented in goshawk diets.

There was no difference in the mean prey rank between nests (χ^2 = 5.0, df = 19, P = 0.99) for prey species contributing ≥5.0% of the diet. Thus, we pooled the data from all nests to characterize the diet of the goshawk population. Mammalian prey contributing ≥5.0% of the identifiable prey were golden-mantled ground squirrels, cottontail rabbits (*Sylvilagus* spp.), chipmunks (*Tamias* spp.), red squirrels, tassel-eared squirrels (*Sciurus aberti*), and rock squirrels (*Spermophilus variegatus*) (Table 1). Steller's Jays (*Cyanocitta stelleri*) and Northern Flickers (*Colaptes auratus*) were the only avian species contributing ≥5.0% of identifiable prey (Table 1).

We found no significant difference in the proportions of mammal and avian prey taken through the nesting season (χ^2 = 8.9, df = 4, P = 0.06) over 10 day intervals. Neither were there significant differences through the nesting season in the proportions of the three most frequent goshawk prey, golden-mantled ground squirrels (χ^2 = 14.9, df = 9, P = 0.09) over 5 day intervals, or cottontail rabbits (χ^2 = 4.1, df = 4, P = 0.39) and chipmunks (χ^2 = 5.6, df = 4, P = 0.23) over 10 day intervals. Insufficient samples prevented analysis of cottontail rabbit and chipmunk use over five day intervals.

PREY BIOMASS

We used only prey delivered to the nest when computing biomass of goshawk prey. Mammals accounted for 94% and birds accounted for 6% of the biomass in goshawk diets. Only mammals contributed ≥5.0% of the biomass, with cottontail rabbits, golden-mantled ground squirrels, and tassel-eared squirrels accounting for most of the biomass (Table 1).

PREY REMAINS

Mammals accounted for 47.5% and birds accounted for 52.5% of the remains collected (N = 179) at the 20 study nests. Cottontail rabbits (N = 49), Steller's Jays (N = 47), and Northern Flickers (N = 22), the three species represented most frequently in remains, accounted for 65.6% of all remains.

DIET BREADTH

Though goshawks from different regions have similar diet breadth, the goshawks on the NKRD use the available prey slightly less equitably than goshawks in the other regions (Table 2). Size class of prey used by goshawks on the NKRD was also

TABLE 2. STANDARDIZED FOOD NICHE BREADTH OF BREEDING NORTHERN GOSHAWKS IN ARIZONA, CALIFORNIA, NEW MEXICO, AND OREGON BASED ON NUMBER OF PREY GENERA

		Food niche breadth		
	Nests	Prey genera[1] (total no. genera)	Size class (total no. classes)	Source
Direct observation				
Arizona	20	0.32 (15)	0.33 (9)	This study
New Mexico	8	0.62 (9)	0.47 (6)	Kennedy (1991)
Prey remains				
Arizona	20	0.29 (18)	0.25 (11)	This study
California	114	0.41 (21)	0.30 (12)	Bloom et al. (1986)
New Mexico	8	0.36 (22)	0.39 (10)	Kennedy (1991)
Oregon	4	0.42 (30)	0.38 (14)	Reynolds and Meslow (1984)

[1] We pooled *Sphyrapicus* and *Picoides* due to difficulty in distinguishing between them during direct observations.

similar to the goshawks from other regions (Table 2).

DISCUSSION

REPRODUCTION

We studied nests that were active and in late incubation or early nestling stages. Thus, our data on reproduction do not take into account goshawk nests that failed prior to reaching at least late incubation. Nor did we determine the frequency of failed eggs in successful nests. Though it is uncommon for accipiters to experience reproductive losses early in the breeding cycle (Snyder and Wiley 1976), there is a potential bias in our observed rate of 1.9 fledglings per active nest.

Nestling goshawks in successful nests on the NKRD have a high probability (84%) of fledging. Mortality at our study nests appeared to be related to factors other than food availability. For example, Great Horned Owl predation was the single greatest factor contributing to nestling mortality. Only one of the three nesting failures we observed was due to factors other than predation. Eggs in this nest failed to hatch in 1990, but the same nest produced 2–3 young in the following years. One possible cause of the failure was disturbance by a slash cutting crew operating within 100 m of the nest for ≥2 days during incubation. This disturbance may have kept the female away from the nest long enough to allow the eggs to chill.

Our data suggest that food availability was not limiting goshawk productivity at the active nests we studied in ponderosa pine forests on the NKRD during 1990–1992.

PREY FREQUENCY AND BIOMASS

Northern Goshawks purportedly possess an inherent inclination to prey on avian species (Sutton 1925). This suspected proclivity has been supported by numerous studies of diet during the breeding season in which avian prey accounted for ≥55% of the diet (Meng 1959, Opdam 1975, Reynolds and Meslow 1984, Bloom et al. 1986, Widén et al. 1987). These studies used the indirect methods of pellet analysis and/or prey remains identification to determine goshawk diets. Many early anecdotal accounts of goshawk nesting behavior, however, suggest that goshawks take a greater proportion of mammals than these studies indicate (Sutton 1925, Gromme 1935, Dixon and Dixon 1938).

Our data, based on direct observations, indicate a 3:1 mammal to avian ratio in the diets of goshawks in our study on the NKRD. To our knowledge, this is the largest proportion of mammals reported in the diet of a breeding goshawk population. In addition, mammals accounted for 94% of the biomass due to the larger body size of most mammalian prey compared to avian prey. The high use of mammalian prey may be a phenomena associated with the forest structure and available prey found in our study area, or it may be common to the species across its range but only apparent through direct methods of diet analysis (Boal and Mannan, unpubl. data).

Reynolds et al. (1992) recommended that habitat for Northern Goshawks be managed for the 14 prey species that are consistently used by goshawks. Although preliminary information from our study was part of the database used to develop the management recommendations, our final results further support this aspect of the recommendations. All 14 of the listed species occurred in goshawk diets on the NKRD. In addition, six of the seven species accounting for ≥5% of the goshawk diets on the NKRD are among the 14 listed prey species in the management recommendations. The single exception is rock squirrels, which the recommendations list as a potential prey species for which importance is unknown (Reynolds et al. 1992).

Goshawks on the NKRD use the available prey less equitably than is reported elsewhere. This is probably a reflection of predation on golden-mantled ground squirrels at a rate of >2:1 over any other species. Ground squirrels are undoubtedly an important part of goshawk diet during the nesting season. A dependence upon one prey species could conceivably lead to a decline in a predator population if that prey species declined (Dymond 1947, Craighead and Craighead 1956, McGowan 1975, Newton 1979). We think this is unlikely on the NKRD because the prey base of goshawks, though inequitably used, is varied (≥19 species) and is likely to buffer affects of individual prey species fluctuations. The inequitable pattern of predation may be a functional response to the most abundant or available prey species, which appears to have been the golden-mantled ground squirrel during this study. It is possible that during periods when ground squirrels are less abundant, goshawks shift to other species that may be more abundant. Long-term studies of goshawk diet and long-term monitoring of the abundance of prey populations will be necessary to address this issue.

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