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TERRITORY OCCUPANCY AND HABITAT PATCH SIZE OF NORTHERN GOSHAWKS IN THE SOUTHERN CASCADES OF CALIFORNIA

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Abstract. We monitored annual occupancy of forest patches by nesting Northern Goshawks (*Accipiter gentilis*) in the southern Cascades Mountains in northern California. Goshawks typically used 3–9 alternate nests distributed among 1–5 different forest stands ranging from 4.1 to 115 hectares in size, and showed low fidelity to individual nest trees or stands. Mean distance between alternate nests was 273 ± 68.6 m. Alternate nests and nest stands were grouped into nest stand clusters, which for monitoring purposes were the equivalent of territories. Nest stand clusters ranged from 10 to 114 hectares in size, and were occupied 74% (±5.5) of years monitored. Occupancy of nest stand clusters by nesting goshawks was positively correlated with cluster area, with occupancy of clusters <20 ha typically <50%. Reproductive success was not correlated with habitat area. Two patterns of territory occupancy were distinguishable; traditional territories (23) where nesting by goshawks was predictable within finite nest clusters and ephemeral territories (5) where alternate nests were widely scattered and sporadically used. Despite extensive timber harvesting and forest fragmentation within our study area, goshawks occurred at relatively high densities (0.57–1.07 territories per 1000 ha). However, most goshawk territories were associated with the larger remaining patches of mature forest, and occupancy of these patches was positively associated with patch area.

Key Words: *Accipiter gentilis*; forest fragmentation; nesting habitat; Northern Goshawk; territory occupancy.

Habitat suitability for an animal is a function of the structural characteristics and spatial arrangement of habitat patches, as well as the presence of predators, competitors and adequate food resources (Cody 1981). Fragmentation of habitat can influence habitat suitability even if the structure of the remaining habitat patches remains unchanged (Temple and Wilcox 1986). Assessing the effects of habitat fragmentation on large, mobile species such as birds of prey is further complicated by these species' use of multiple patches in a landscape, often using different types of patches to fulfill different life requisites (e.g., nesting versus foraging or cover) (Harris and Kangas 1988).

The structural attributes of forest stands used for nesting by Northern Goshawks (*Accipiter gentilis*) have been described in a variety of forest ecosystems in North America, including eastern deciduous (Speiser and Bosakowski 1987) and western coniferous (Reynolds et al. 1982, Hall 1984, Crocker-Bedford and Chaney 1988, Hayward and Escano 1989) forests, and Great Basin shrubsteppe communities (White and Lloyd 1965, Younk and Bechard, this volume). Although conducted in different communities, these studies and others (summarized in Reynolds 1989, Reynolds et al. 1992) found that a number of structural features were common to goshawk nest stands in most areas. Nest stands are typically composed of large, densely spaced trees, with higher canopy closure and more open understories than the surrounding landscape. The majority of these studies, however, did not consider spatial relationships such as size and distribution of habitat patches, and none used long-term patterns of occupancy of habitat patches by nesting goshawks to assess habitat quality.

Estimates of stand size given by Reynolds (1983) were based on measurement of areas of intensified activity adjacent to nests (nest areas) and did not necessarily reflect the actual size of the forest stands used for nesting. Crocker-Bedford (1990) described the spacing and occupancy of alternate nests within goshawk territories (nest clusters) and reported a relationship between the size of unharvested buffers surrounding nest sites and subsequent occupancy by nesting goshawks. Kennedy (1991) used the movements of radio-marked goshawk family groups to define the post-fledging family area (PFA), an area of concentrated use by the family group after the young left the nest. It is not clear, however, how PFAs were differentiated from nest stands or clusters of nest stands. Estimating the relationship between patch size of nesting habitat and overall territory quality is further complicated when the effects of foraging habitat quality are considered (Crocker-Bedford 1990, Reynolds et al. 1992).

In this study we describe spatial patterns of habitat use by nesting Northern Goshawks at four levels of resolution: nest trees, nest stands, territories (clusters of nest stands), and spacing between territories. At each level we compare spatial attributes to rates of occupancy by nesting goshawks.

ʼY AREA AND METHODS

s study took place in the southern Cascades ıtains of northern California, on the Goosenest ɜr District of the Klamath National Forest. The vas composed of three major forest types. Sierran ane Forest and Upper Montane Forest (Küchler ı occurred at higher elevations and were domi- by red fir (*Abies magnifica*), white fir (*Abies con-* ı, ponderosa pine (*Pinus ponderosa*), lodgepole (*Pinus contorta*), Douglas-fir (*Pseudotsuga men-*), and incense cedar (*Calocedrus decurrens*). Low- vation forests were comprised primarily of North- ellow Pine Forest (Küchler 1977), dominated by erosa pine and white fir. Most of the study area ɹetween 1400 m and 2330 m elevation and was vely dry, with most precipitation falling as snow ɪter. The area had a long history of timber harvest, intensive harvesting occurring as early as 1900 lenslayer and Darr 1990). The resulting forest cape occurred as scattered patches of unmanaged re forest dispersed in a matrix of thinned or re- ated stands. Suppression of natural fire within this stem resulted in increased density of fire-suscep- conifer species such as white fir in areas formerly nated by fire resistant species (ponderosa pine, ıse cedar; Biswell 1989, Laudenslayer et al. 1989). *: surveyed for nesting northern goshawks each* g and summer from 1984 to 1992. Our initial ·le of territories was derived from Forest Service ds and survey transects conducted in areas of po- ıl goshawk habitat. In 1988 we began using broad- of taped conspecific alarm calls along established ects (Fuller and Moser 1981, Rosenfield et al. 1985, ıedy and Stahlecker 1993) within two 12,000 hect- urvey blocks. We returned annually to all known ories to determine occupancy and reproductive ss. We intensively surveyed an area of 1.6 km ıs surrounding each previously active nest to locate ıate nest sites. Terminology proposed by Postu- .y (1974) and Steenhof and Kochert (1982) was to define occupancy and nesting success of gos- : territories. We defined nest productivity as the ber of large (minimum 5 week old) nestlings. Each that a given territory was monitored was termed ritory-year. Alternate nests within territories were ally clumped and could be distinguished from ad- ıt territories. However, in cases where alternate ı were widely spaced we used simultaneous oc- ncy of both adjacent territories to distinguish be- n them. We measured distances between the geo- ic centers of nest clusters at adjacent territories to ıate nearest-neighbor distances. Locations of oc- ed nests, alternate nests, and habitat boundaries

or reused an existing nest within it. We calculated occupancy rates for individual stands by dividing the number of years the stand was occupied by the total number of years the stand was monitored.

Nest stand clusters were defined as the aggregate area of all stands within a territory that were used for nesting, and for monitoring purposes were the equivalent of territories. Nest stand clusters were considered occupied if goshawks attempted to nest, exhibited defensive behavior, or were sighted repeatedly within them. The occupancy rate of each cluster was calculated by dividing the number of years the cluster was monitored by the total number of years the cluster was monitored.

Comparisons of stand and nest cluster size with occupancy rates were made using the Spearman Rank Correlation (Zar 1984). Only stands (N = 71) or clusters (N = 23) with >5 years of monitoring were used in statistical comparisons. We found that five years of monitoring was sufficient to delineate the area of most nest stand clusters. Mean values in the text are presented with standard errors (±SE).

RESULTS

Monitoring

We monitored 141 territory-years at 28 goshawk territories within the study area. Occupancy by at least one adult goshawk was confirmed in 100 (71%) of monitored territory-years, and breeding attempts were observed in 89 (63%). Rates of occupancy and breeding were likely underestimated due to the secretive behavior (Kennedy and Stahlecker 1993) and annual movements of nesting goshawks observed in this study. The sample of monitored territories increased each year of the study, from 18 in 1984 to 28 in 1992. Six territories were monitored for over 10 years, 17 were monitored 5–9, and five were monitored ≤4 years.

Productivity for 84 nesting attempts averaged 1.93 young per attempt (range = 0–4). Eighty-seven percent of observed nesting attempts were successful. Primary causes of nest failure included failed incubation (cause unknown = 7), severe spring storms (2), and predation by Great Horned Owls (2; *Bubo virginianus*). Brood size was reduced in nine successful nest attempts when nestlings fell from the nest or were killed by siblings. Nest success and productivity were probably overestimated because nesting attempts failing prior to the nestling stage and mortalities occur-

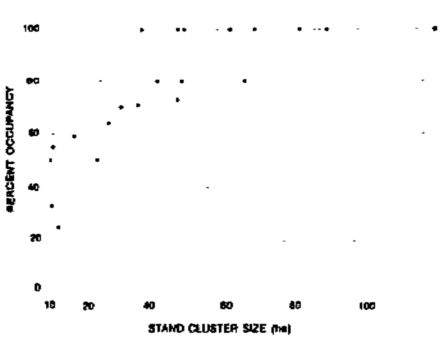

FIGURE 1. Correlation of percent occupancy of goshawk nest stand clusters versus cluster size for 26 territories in the southern Cascades of California, 1984–1992.

used the previous year. The average reoccupancy rate of individual nests at 26 territories over at least 5 years was 49% (±11%). Reoccupancy of alternate nests was highly variable; at some territories goshawks did not re-use the same nest twice in 4–7 years, whereas others used a single nest for 2–6 years and then moved to or built another.

Distribution of Alternate Nests

Spacing and distribution of alternate nests varied widely among territories. Nests in most territories were clumped in two or three adjacent stands, whereas others contained nests scattered in stands up to 2.1 km apart. The mean distance between alternate nests in 65 nest attempts in this study was 273 (±68.6) m, (range = 30–2066 m). This estimate of nest spacing was conservative in that it included only movements actually observed between years. Longer movements were more difficult to detect and were likely underrepresented.

Use of Nest Stands

Goshawk territories typically contained 1–5

individual nest stands were positively correlated with stand size (r_s = 0.85, P = 0.001). Smaller stands (<10 ha) typically contained 1–2 nests and were only occasionally occupied by goshawks, whereas larger stands (>20 ha) often contained several nests and were occupied in a high proportion of territory-years.

Nest Stand Clusters

Nest stand clusters ranged from 10.5 to 114 ha in size ($\bar{X}$ = 41.7 ± 5.89, N = 26 territories). The mean occupancy rate of nest stand clusters was 0.74 (±0.055, N = 26). Occupancy rates of 23 nest stand clusters with at least five years of monitoring was positively correlated with cluster size (r_s = 0.88, P = 0.008). Occupancy rates of clusters of <20 hectares were typically <50%. At approximately 40 ha occupancy rose to 75–80%, and was nearly 100% for stand clusters >61 ha (Fig. 1). We found no significant relationship between stand cluster size and productivity (r_s = 0.052, P = 0.819). The mean number of young produced per occupied territory (minimum five year average) was relatively uniform among territories.

Territory Spacing and Density

Nearest-neighbor distances for 21 goshawk territories within intensive survey blocks ranged from 1.3 to 6.1 km, averaging 3.25 ± 0.34 km. Spacing appeared to be reduced around landscape features such as meadows and riparian systems, where goshawk territories were clumped. Eleven territories were located within a 10,230 ha block of Sierran Montane Forest yielding a density of 1.07 territories per 1000 ha, compared with 0.575 territories per 1000 ha in a 10,440 ha block of Upper Montane Forest.

DISCUSSION

Territory use by goshawks in this study was characterized by alternate use of nest sites up to 2.1 km apart, and low fidelity to any particular nest site. Over time the number of nest sites recorded in most territories increased, as did the area of habitat containing them. From 4 to 6 clusters in this study were made using physical boundaries of nest stands. It is likely that only a small portion of each stand is actually used for nesting in a given year. Reynolds et al. (1992) proposed a hierarchy of spatial components comprising goshawk home ranges: nest area, post fledging family area, and foraging area. Each of these components was based on measurement of goshawk activity and cannot be estimated without radio-telemetry. Estimates of nest habitat area based on observations of nest-tending activities (Reynolds 1983) overlook the possibility that selection of nest sites by goshawks is based at least partially on patch size. Our observations of reduced occupancy in smaller stands suggest that patch size may be an important factor determining quality of nesting habitat.

The post fledging family areas (PFA) described by Kennedy (1991) may be somewhat analogous to nest stand clusters in that the PFA is a larger area encompassing at least one nest site. It is not clear whether the PFAs studied by Kennedy (1991) contained all known nest sites within each territory, or if goshawk pairs moved outside of PFA boundaries in subsequent years. This relationship could be assessed by comparison of PFA boundaries with the distribution of alternate nest sites and the boundaries of nest stands, particularly over a number of years.

Alternate nest sites within most territories appeared as clusters, spatially distinct from nest clusters at neighboring territories. At five territories (18%), however, alternate nests were very widely spaced and territory boundaries were less distinct. Maximum distances between alternate nests at these territories were similar to minimum distances between simultaneously occupied neighboring territories.

Mean occupancy rates of habitat components increased as spatial scale increased from nest trees to nest stands and nest stand clusters. Annual movements of nesting goshawks may have reduced our ability to detect some nest attempts in remote nest sites, resulting in underestimation of occupancy at larger scales (nest stand clusters). Patterns of occupancy at goshawk territories fell into two categories: traditional territories (23), where nesting by goshawks was predictable and typically occurred within finite nest clusters; and ephemeral territories (5), where nesting was sporadic and nest sites were widely distributed. Ephemeral territories were occupied in less than three of five years and appeared to be associated with highly fragmented areas of lodgepole pine and mixed pine stands where extensive tree mortality due to bark beetles (*Dendroctonus* spp.) had occurred. Changes in stand structure in these ar-

to nest in areas where little mature forest habitat was available.

Although occupancy of nest stand clusters was clearly correlated with cluster size, other factors may have affected occupancy of specific clusters by nesting goshawks. Reduction and fragmentation of mature forest habitat may favor early successional competitors and predators such as Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (Moore and Henny 1983, Johnson 1993) and reduce occupancy by goshawks (Crocker-Bedford 1990). Occupancy of traditional goshawk nests or nest stands by Great Horned Owls, Long-eared Owls (*Asio otus*), Northern Spotted Owls (*Strix occidentalis caurina*), Red-tailed Hawks and Cooper's Hawks (*Accipiter cooperi*) was recorded in this study, but was not associated with territory abandonment by goshawks. In three instances, however, goshawks moved outside of their traditional nest cluster after it was occupied by Northern Spotted Owls.

Despite intensive timber harvest and fragmentation of mature forest, our study area supported high densities of nesting goshawks. Goshawk territories, however, were associated with the larger remaining patches of mature forest, and territory occupancy was positively correlated with the size of nesting habitat patches.

Several factors may act to mitigate the effects of timber harvest and forest fragmentation on goshawk habitat quality in our study area. Timber harvests occurring after the early 1960s typically consisted of commercial thinning, shelterwood, and sanitation prescriptions, resulting in less distinction between harvested areas and remaining mature forest than in large clearcut regimes. Golden-mantled Ground Squirrels (*Spermophilus lateralis*), a primary prey species for goshawks in the southern Cascades (Woodbridge, unpubl. data), are abundant in open habitats (Ingles 1965) and were frequently observed in previously harvested areas. This prey resource could act to offset losses of prey species associated with mature forest. Finally, effects of forest fragmentation on goshawk populations may be less important in forest ecosystems such as the southern Cascades that are naturally fragmented by topography, xeric conditions, and wildfire. Comparison of our results with data collected in different forest ecosystems may provide insights into the relative importance of nesting habitat area.

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