

FOREST CHARACTERISTICS OF NORTHERN GOSHAWK NEST STANDS AND POST-FLEDGING AREAS IN OREGON

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Abstract: The role of old-growth forest as a component of nesting habitat for northern goshawks (*Accipiter gentilis*) and the effect of timber harvest has come under increased scrutiny in the western United States. We examined the importance of selected elements of old-growth forest as nesting habitat for goshawks by comparing forest structure around 22 nests with 2 sets of random points. Comparisons were made at 6 spatial scales, from the nest stand up to a 170-ha post-fledging area (PFA). Goshawks nested more frequently in stands with dense canopy, late forest structure (i.e., trees >53 cm dbh, canopy closure >50%), and rarely in stands with mid-aged forest structure. Despite the occasional occurrence of goshawk nests in younger, more open-canopied stands, these conditions were less preferred than dense canopy, late forest structure. Late forest structure was more abundant within circles of 12 ha and 24 ha around nests than around random points. At the PFA scale, forest structure around nests was dominated by dense-canopied forest, always contained wet openings, and nests were positively associated with dry openings. Our findings support recent management recommendations for northern goshawks in the western United States, which call for maintaining the PFA in forest conditions intermediate between the high foliage volume and canopy cover of nest stands and more open foraging habitats. These conditions would provide nest sites for goshawks and habitat for a variety of prey species that inhabit late or early seral stage forest.

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The role of old-growth forest as a component of nesting habitat for northern goshawks in the western United States has come under increased scrutiny because timber harvest may reduce or re-distribute breeding populations. Three spatial components of northern goshawk breeding habitat have been recognized: a 10–12-ha nest area, composed of ≥ 1 forest stands or alternate nests; a 120–240-ha ($\bar{x} = 170$ ha) post-fledging area, which is an area around the nest used by the adults and young from the time of fledging to the time when fledglings are no longer dependent upon the adults for food (Kennedy et al. 1994); and a foraging area that comprises the balance of the goshawk's home range, which Reynolds et al. (1992) estimated as 1,500–2,100 ha based on averages from previous studies.

Most studies of goshawk breeding habitat have focused on the nest area, which is typically found in older forest conditions with high canopy closure and abundant large trees (Reynolds et al. 1982, Moore and Henny 1983, Hayward and Escano 1989, Daw et al. 1998). Forest structure in the PFA has not been examined as closely throughout the goshawk's range as that of nest areas. Nonetheless, it has been adopted as a component of management for northern goshawks. Reynolds et al. (1992:16) called for maintaining the PFA in "forest conditions intermediate between the high foliage volume and canopy cover of the nest stands and the more open foraging habitats." The PFA is potentially important to the persistence of goshawk populations, as it provides fledgling hiding cover and foraging opportunities as fledglings learn to hunt, and may correspond to the area defended by the breeding pair (Reynolds et al. 1992, Kennedy et al. 1994). However, the importance of the PFA to the biology and management of northern goshawks remains largely untested throughout most of the species' range.

Our goal was to describe forest structure at

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several spatial scales, from the nest stand to PFA-sized circles, around goshawk nests in eastern Oregon. Understanding habitat selection within nest stands (i.e., contiguous stands of similar forest structure) was necessary to examine larger landscape scales, such as the PFA, around nests. Thus, we first asked, are goshawk nests located randomly on the study area or in relation to specific landscape features, particularly late seral-stage forest structure? We then asked, does the preponderance of late seral stage forest structure diminish with increasing distance from nests and if so, at what point (spatial scale) is this detectable?

STUDY AREA

The study area was located on the Bear Valley Ranger District, Malheur National Forest, near John Day, Oregon. Climate was dry, with cold winters and cool summers. This district was characterized by a mix of forest types including ponderosa pine (*Pinus ponderosa*) stands on dry south slopes, ponderosa pine and Douglas-fir (*Pseudotsuga menziesii*) combinations, and mixed conifer (Douglas-fir, grand fir [*Abies grandis*], western larch [*Larix occidentalis*], lodgepole pine [*Pinus contorta*]) sites on north slopes with little to no ponderosa pine. Hills and moderately steep drainages typified most of the study area, and elevations ranged from 1,460 to 1,920 m. Small openings in the forest (wet and dry meadows) were common, and the district surrounded a large open valley (23,500 ha). Partial cut timber harvest practices (overstory removal, group selection) were standard, while clearcutting was uncommon.

METHODS

Determining Use and Availability

Manley et al. (1993:9) defined 3 sampling protocols for resource selection studies under a use versus availability framework. We used sampling protocols A (used resources compared to available resources) and C (used resources compared to unused resources).

We measured forest structure around 22 goshawk nests active in 1993 on the Malheur National Forest. We found nests using both systematic and opportunistic searches during 1992–93. For the former, we used a grid of transect lines to thoroughly search 2 large (9,000 and 10,500 ha) survey blocks for all goshawk nests ($n = 12$; Kennedy and Stahlecker 1993); for the latter, we used nests that had

been discovered opportunistically during timber stand examinations and wildlife surveys, or found incidentally during other activities ($n = 10$). Comparison of systematically and opportunistically found nests indicated that there was no difference in 2 important variables used to characterize late seral stage forest: high density of large live trees and high percent canopy closure (Daw et al. 1998). We thus combined samples of systematically and opportunistically found nests.

We examined forest structure around goshawk nests at several spatial scales, from the nest stand to 170-ha, PFA-sized circles. To measure availability of forest cover, we generated 44 random points from a list of Universal Transverse Mercator system (UTM) coordinates bounding the study area. We restricted random points to fall in areas with pole-sized or larger (>13 cm diameter at breast height [dbh]) sized trees, as opposed to clearcuts, meadows, or sapling growth, so that our comparisons between nests and random points were in forested areas. We allowed the 170-ha nest and random circles to overlap each other and the edge of the study area, but no center points (UTM coordinates) were duplicated. One other set of random points was a subset of these 44 random points: not-used sites occurred inside our systematically surveyed blocks, but these sites were not occupied by nesting goshawks during the time of our study (1992–93), and there were no records of goshawks having used these sites. The 170-ha circle around not-used points did not overlap the 170-ha nest circles. Used versus available was the primary comparison for which all nests ($n = 22$) and random points ($n = 44$) were used. We then compared nest sites with the subset of not-used random points ($n = 15$).

Habitat Variables

We classified forest structure into 4 categories based on tree size and total percent canopy closure (Table 1). Our division between mid-aged and late forest structure categories for the number of live, large (>53 cm dbh) trees per ha was consistent with U.S. Forest Service forest structural stages (U.S. Department of Agriculture 1994). In addition, we added 4 more features to describe the landscape around goshawk nests and random points: early forest (regeneration or burns), wet openings (riparian corridors flanked by enough open ground to be visible through the canopy), dry openings (grass,

Table 1. Variables used to describe forest structure around northern goshawk nests and random points on the Malheur National Forest, Oregon, 1993.

Forest structure ^a	Trees/ha			Canopy closure (%)			n ^b
	\bar{x}	SE	95% CI	\bar{x}	SE	95% CI	
Late forest-dense canopy	30	4	20–40	59	2	55–64	7
Late forest-open canopy	20	2	15–26	39	3	32–47	7
Mid-aged-dense canopy	8	2	3–12	57	3	51–63	10
Mid-aged-open canopy	10	2	5–15	34	3	27–41	7

^a The terms late and mid-aged refer to structural conditions defined by the density of large trees (>53 cm dbh), not a direct measure of forest

^b Sample size (n) is the number of stands measured for the structural variables.

sagebrush [*Artemisia* spp.], and rock meadows >0.4 ha), and roads (paved and unpaved). These 4 features plus the 4 structural categories comprised 8 habitat categories.

We used 1:30,000 infrared aerial photographs from 1992 to delineate all stands into polygons within a 170-ha circle around nests and random points. Each polygon represented only one of the 8 habitat categories, and we calculated area only within the 170-ha circle. We measured habitat variables in stands that were harvested between 1992 (date of aerial photography) and 1993. We used a zoom transfer scope to transfer polygon overlays of the photographs to planimetrically correct maps, which were then digitized.

To assess the accuracy of the resulting habitat map, we visited and measured a random sample of stands (about 7%) in each of the 4 structural categories. Ground measurements also provided a mean and 95% CI for variables describing each category. As ground measurement progressed, we sampled more stands in categories with high variability with the aim of creating non-overlapping descriptions for each forest structure category. Stands selected for accuracy assessment were >4 ha in size and were not harvested after 1992. We placed plots systematically along straight-line transects to capture the diversity in a stand. Stands 4–16 ha and those >16 ha had 6 and 9 plots, respectively, and all plots were averaged for an overall stand value.

At each plot within the accuracy assessment stands, we used a 20-factor basal area prism to tally the number of large trees in variable-radius plots, and all plots were combined before calculating the number of large trees per ha in the stand. We used a Lemmon spherical densiometer to take canopy closure readings 5 m out from plot centers in each of the 4 cardinal directions, and averaged the 4 readings for each

plot. All plots were then averaged for the stand value. Percent of stands classified correctly from the sample of ground measurements was used to infer the overall accuracy of the habitat map.

Landscape Scales

We compared the amount of dense, late forest structure between nests and random points at 5 scales. We used concentric circles containing areas of 12, 24, 50, 120, and 170 ha. Each successive scale had biological or management significance: 12 ha was recommended for goshawk nest-area management in the Southwest (Reynolds et al. 1992); 24 ha was recommended for goshawk management in Oregon (Reynolds et al. 1982); 50 ha was recommended for protection of goshawk nesting habitat in California (Bloom et al. 1986) and approximates the size of pine marten (*Martes americana*) allocations of old growth forest in most eastern Oregon National Forests (R. Haines, U.S. Forest Service, personal communication); 120 ha was the size of pileated woodpecker (*Dryocopus pileatus*) old growth allocations in eastern Oregon national forests (R. Haines, U.S. Forest Service, personal communication); and 170 ha corresponded to the PFA (Kennedy et al. 1994).

Statistical Analyses

We used a chi-square test of homogeneity to compare proportional use of structural categories between nest stands and random stands. We combined the 2 low-canopy closure categories into the same category (open canopy, late forest structure and open canopy, mid-aged forest structure) because of low sample sizes; in effect, however, this created 1 variable (open canopy forest), which was a primary variable of interest. Nest stand selection was calculated using 95% Bonferroni simultaneous CIs (Pagano and Gauvreau 1993).

At the PFA scale, we used descriptive statis-

Table 2. Area in dense canopy, late forest structure (i.e., trees >53 cm dbh, canopy closure >50%) at 5 landscape scales (circular plots) centered on 22 northern goshawk nests and 44 random points representing available forest on the Malheur National Forest, Oregon, 1993.

Scale (ha)	Nests		Random points		\bar{x} difference		
	\bar{x}_1	SE	\bar{x}_2	SE	$\bar{x}_1 - \bar{x}_2$	90% CI*	P
12	6	1	3	1	3	0.5, 4.0	0.031
24	10	2	7	1	3	0.2, 7.0	0.061
50	19	3	13	2	6	-0.6, 13.0	0.114
120	38	7	30	5	8	-0.6, 22.0	0.279
170	49	9	42	6	7	-10.0, 25.0	0.441

*90% CI for the difference in dense, late forest structure between used and available areas. Numbers are based on untransformed data to provide a meaningful approximation of confidence interval widths.

Table 3. Area in dense canopy, late forest structure (i.e., trees >53 cm dbh, canopy >50%) at 5 landscape scales (circular plots) centered on 22 northern goshawk nests and 15 random points representing areas not used by nesting goshawks on the Malheur National Forest, Oregon, 1993.

Scale (ha)	Nests		Random points		\bar{x} difference		
	\bar{x}_1	SE	\bar{x}_2	SE	$\bar{x}_1 - \bar{x}_2$	90% CI*	P
12	6	1	3	1	3	0.8, 5.0	0.050
24	10	2	6	2	4	0.5, 9.0	0.081
50	19	3	10	3	9	-0.4, 17.0	0.107
120	38	7	22	6	16	-0.6, 31.0	0.210
170	49	9	34	7	15	-6.0, 36.0	0.437

*90% CI for the difference in dense, late forest structure between used and available areas. Numbers are based on untransformed data to provide a meaningful approximation of confidence interval widths.

tics to characterize forest structure. We then tested for habitat associations using logistic regression with forward stepwise variable selection by comparing differences among used, random, and not-used groups. Variables for this analysis were either square-root or natural log transformed (adding 1 to all cases of a variable when zeros were present) when necessary, and included in the model at $P \leq 0.10$ (Hosmer and Lemeshow 1989). Our binary response variable was coded as either nest (1) or random or not-used point (0), and the effect of explanatory variables was to increase or decrease the odds of a nest occurring. We report $\bar{x} \pm SE$ and consider all variables to be significant at $P \leq 0.10$.

RESULTS

Overall classification accuracy for all 4 structural categories was 79%. We were most accurate in classifying dense canopy, late forest structure, with 100% agreement between aerial photo categories and ground measurements, followed by open canopy, late forest structure (86%) and open canopy, mid-aged structure (71%). Although dense canopy, mid-aged forest structure was the least accurate (60%), descriptive data from ground measurements placed the mean for each variable within its correct category and within non-overlapping 95% CIs (Table 1).

Stands with nests (102.8 ± 20.2 ha, range 2.8–375.2) and stands with random points (137.2 ± 19.4 ha, range 5.7–548.8; $t = 1.23$, 54.6 df, $P = 0.220$) were not different in size. Nests were not distributed among stand types in the same proportion as stand types were available ($P = 0.003$); dense canopy, late forest structure was used more than it was available while dense canopy, mid-aged forest structure

was used less than it was available, and use was equal to availability for the open canopy category rarely used for nesting.

When we compared circles around nests with circles around random points, we found more dense canopy, late forest structure around nests in the 12-ha ($P = 0.031$) and 24-ha ($P = 0.061$) circle sizes, with the difference diminishing as circle size increased (Table 2). A similar difference in the association of dense canopy, late forest structure existed when circles around nests were compared with circles around random points that were not used by goshawks for nesting (Table 3). The 12-ha and 24-ha circles around nests contained more dense canopy, late forest structure than circles around random points ($P = 0.050$ and $P = 0.081$, respectively), with a clear trend continuing into the next larger circle size, but diminishing thereafter.

The forest in PFA-sized circles around goshawk nests was a mix of different structural conditions, with a majority in the higher canopy closure categories. The most abundant forest structure was dense canopy, mid-aged forest (37%), followed by dense canopy, late forest (29%). The least abundant was early forest (3%; i.e., regenerating clearcuts with a small [20%] component of burns). Wet openings averaged $7.0 \text{ ha} \pm 1.2 \text{ ha}$ (range 0.8–22.3) and were present near all nests. When we compared forest structure at the PFA scale around nests with available forest structure, we found a positive association between dry openings and nests. Dry openings averaged $3.0 \pm 0.7 \text{ ha}$ (range 0.4–2.4) and were present around 12 of 22 nests (55%), but only around 14 of 44 random points (32%; $\chi^2 = 3.17$, 1 df, $P = 0.075$). The presence of dry openings increased the odds of a nest

occurring an estimated 2.5 times ($P = 0.078$). In addition, when we compared forest structure at the PFA scale around nests to forest structure around random points not used by goshawks for nesting, there was a positive association between roads and nests ($P = 0.034$). The effect was generally small, increasing the odds of a nest occurring by a factor of 1.6 for a 1-km increase in roads.

DISCUSSION

The selective use by goshawks of dense canopy, late forest structure in nest stands reinforces results from other studies throughout the western U.S. (Reynolds et al. 1982, Hayward and Escano 1989, Squires and Ruggiero 1996, McGrath 1997, Daw et al. 1998). The consistency of this pattern across a wide portion of the geographic range of the goshawk and among various forest cover types underscores the importance of this relationship. In eastern Oregon, successful nesting also occurred in dense canopy, mid-aged forest structure, and occasionally, although rarely, in open-canopied stands. Clearly, a dense canopy (occurring at 20 of 22 nests) was important, perhaps because of the hiding cover it provides or its influence on microclimate (Reynolds et al. 1992:13). However, goshawks also showed some versatility in their ability to reproduce successfully in a variety of forest conditions.

In contrast to nest stands, examination of habitat relationships at the PFA scale has not been documented. Dense canopy, late forest structure was clearly important at landscape scales close to the nest, but decreased in relative abundance with distance from the nest. These results are not surprising considering the heterogeneous landscape and the sparsity of remaining large (ca. 170 ha) patches of older forest in eastern Oregon (McGrath 1997), conditions that are common throughout much of the forested lands in the western United States (Federal Register 1998).

Goshawk nests were commonly adjacent to ≥ 1 dry opening, which was typically a rocky meadow with sagebrush and grass. Dry openings were identified as important by Hargis et al. (1994), who found adult goshawks foraging along the edges of pumice flats in eastern California, and by Younk and Bechard (1994), who observed goshawks foraging in open sagebrush and consuming mostly Belding ground squirrels (*Spermophilus beldingi*) at the nest in shrub

steppe communities of Nevada. Biomass of prey remains in our study area (T. Cutler and S. DeStefano, unpublished data) was dominated by sagebrush-inhabiting Nuttall's cottontail (*Sylvilagus nuttallii*) and ground squirrels (*Spermophilus* spp.), including Belding ground squirrels. The importance of cottontails and ground squirrels as goshawk prey in other studies (Boal and Mannan 1994) suggests that dry openings can be an important source of prey for nesting goshawks in some landscapes.

Wet openings were present within PFA-sized circles around all nests and were abundant throughout the study area. Other researchers have found riparian areas in close proximity to goshawk nests (Shuster 1980, Reynolds et al. 1982, Hargis et al. 1994), and this landscape feature may have contributed to the relatively dense (0.07 nests/100 ha) population of goshawks on the Malheur National Forest (DeStefano et al. 1994).

Some caution is appropriate when interpreting the results of landscape patterns within the PFA for several reasons: we could not identify actual areas of use, 170 ha was an average obtained by 1 study in New Mexico (Kennedy et al. 1994), and little information is available on PFAs throughout the goshawk's range. It was possible both to miss important habitat components as well as to identify features in a circular plot that may actually be unimportant from the perspective of a goshawk. However, Lehmkuhl and Raphael (1993) found that habitat patterns in circles around northern spotted owl (*Strix occidentalis*) nests were similar enough to habitat patterns in identified home ranges to support using circles for delineating management areas. Marked adult goshawks in northern Arizona tended to use areas around their nests uniformly, approximating a circular pattern rather than, for example, a linear pattern (R. T. Reynolds, U.S. Forest Service, personal communication). Although adult goshawks often forage long distances from their nest (Hargis et al. 1994), fledgling goshawks stay close to the nest until flying and foraging skills develop, so that habitat components important to their survival during the post-fledging period are likely to be found within our circular PFA-sized plots.

MANAGEMENT IMPLICATIONS

Our findings regarding forest characteristics in goshawk PFAs in Oregon appear to support current recommendations for goshawk management

in the western United States (Reynolds et al. 1992), with the exception that nest stand sizes may need to be larger, depending on the quality of the habitat. A pattern of multiple large stands of older forest with high foliage volume to provide adequate nesting cover, coupled with a mix of age classes and forest seral stages throughout the PFA, to provide hunting cover, protection against predators such as great horned owls (*Bubo virginianus*) and red-tailed hawks (*Buteo jamaicensis*), and habitat for a variety of prey, would benefit goshawks. Our major caution would be to focus management activity away from further reduction and fragmentation of late seral stage forest; this seral stage is important to goshawks, some of their prey, and several other wildlife species, and is the component most affected by recent forestry practices.

Average nest-stand size for nests in older forest on our study area was about 100 ha and ranged from 3 to 375 ha. However, stand quality is more important than stand size, and forest managers need to consider the abundance and distribution of large trees across the landscapes they are managing. Several smaller (i.e., ≥ 12 ha recommended by Reynolds et al. 1992) stands distributed within a PFA will provide cover if those stands are composed of large trees with high foliage volume. For areas where large trees, multiple canopy layers, and high foliage volumes still exist, we recommend maintaining the contiguity of stands, rather than creating smaller patches. Until telemetry identifies specific habitat used by fledglings in a variety of forest cover types, our results suggest that, at a minimum, sufficient dense canopy, late forest structure (i.e., trees >53 cm dbh and canopy closure $>50\%$) in patch sizes of at least 12 ha should be maintained to provide for existing and alternate nest stands, recognizing the potential functions this type of forest structure also serves in the PFA.

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