AN ABSTRACT OF THE THESIS OF

Sonya Kathleen Daw for the degree of Master of Science in Wildlife Science presented on May 7, 1996. Title: Northern Goshawk Nest Site Selection and Habitat Associations at the Post-fledging Family Area Scale in Oregon.

Abstract approved: ____________________________

Stephen DeStefano

Concern is growing about the potential loss of northern goshawk (Accipiter gentilis) breeding habitat caused by timber harvest practices at nest sites and in the areas of use within the home range. Nests typically occur in stands with dense, late forest structure, although non-systematic survey methods may have introduced a bias towards late forest structure. Little is known about forest structure outside of the nest stand. Systematic goshawk nest surveys were conducted in 3 eastern Oregon National Forests during 1992-94 to study habitat at landscape scales between the immediate nest site and the 170 ha post-fledging family area (PFA). To determine if search method biased nest-site descriptions, I compared nests from the Fremont, Wallowa-Whitman, and Malheur National Forests found by systematic (n = 21) versus non-systematic (n = 20) survey methods, and found no difference by search method in the number of live, large (> 53cm diameter at breast height) trees per hectare (2-sided \( P = 0.67 \)) or the total percent canopy closure (2-
sided $P = 0.39$) in 0.4-ha areas surrounding nests. On the Malheur National Forest, forest structure at different landscape scales around 22 nests was compared with 3 groups of random points representing available (randomly located sites; $n = 44$), not-used (randomly located sites that did not overlap with known goshawk nest sites; $n = 15$) and not-used with suitable nest stand (randomly located sites that did not overlap with known goshawk nest sites and included a potentially suitable nest stand; $n = 10$) conditions, to address remaining habitat questions. Nest stands with dense, late forest structure averaged a minimum of 79 ha in size, and this forest structure was used more than it was available ($P < 0.05$) at the nest-stand scale, while dense, mid-aged forest structure was used less than it was available ($P < 0.10$) at the nest-stand scale. At larger landscape scales, dense, late forest structure was significantly more abundant around nests within circles up to 24 ha in size when compared with available random points (2-sided $P = 0.06$) or not-used random points (2-sided $P = 0.08$). PFA-sized circles centered on nests contained a mix of structural conditions dominated by denser-canopied forest, always contained wet openings, and had an average density of 3.4 km/km² of roads. At the PFA scale, dry openings were associated with nests (2-sided $P = 0.07$); dense, mid-aged forest structure was negatively associated with nests (2-sided $P = 0.06$); and an interaction between roads and early forest (clearcuts and burns) (Drop in Deviance $X^2 = 7.5; 1$ df; $P < 0.01$) showed a negative
relationship between nests and early forest, that was most
extreme at low road densities. My results diminish concern
that selection for dense, late forest structure at the nest
site is a biased description; however, non-systematically
found nests had up to 11 more large trees per hectare, and
nests did occur in younger forest, cautioning against
surveying exclusively in late forest structure for goshawk
nests. For goshawk nest stands in eastern Oregon ponderosa
pine (*Pinus ponderosa*) and mixed conifer forest, I recommend
maintaining large trees and dense, 2-layered to multi-
layered canopies, while avoiding excessive fragmentation of
existing nest stands. At the PFA-scale, landscape features
associated with nests in this study, and trends suggesting
the importance of dense, late forest structure need further
clarification using telemetry on fledgling goshawks.
Northern Goshawk Nest Site Selection and Habitat Associations at the Post-fledging Family Area Scale in Oregon

by

Sonya Kathleen Daw

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APPROVED:

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Major Professor, representing Wildlife Science

Redacted for Privacy

Chair of Department of Fisheries and Wildlife

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Dean of Graduate School

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Sonya Kathleen Daw, Author
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DEDICATION

This work is dedicated to my husband, Charlie, for sharing my journey, and to the magnificent raptors, for the joy they inspire in me.
Northern Goshawk Nest Site Selection and Habitat Associations at the Post-fledging Family Area Scale in Oregon

Chapter 1

INTRODUCTION

The northern goshawk is adapted to forest ecosystems in North America and Eurasia (Palmer 1988). Northern goshawks (hereafter goshawk) are adept at maneuvering in forest conditions due to their relatively short wings and long tails. Their foraging strategy has been described as "short-sit-and-wait-short-flight" (Kenward 1982) where ambushing attacks are made from frequently shifting perches. Goshawks prey on small mammals and birds and have been described as foraging zone generalists (Reynolds and Meslow 1984).

Avian habitat selection can be viewed as a hierarchical decision-making process starting at the geographic range (first-order selection), to the home range (second-order selection), to habitat components within the home range (third-order selection), and ending with the choice of particular resource patches (fourth-order selection) (Johnson 1980).

Three spatial components of goshawk habitat have been recognized by Reynolds et al. (1992) corresponding to second and third-order habitat selection. The first, the nest area (third-order selection), is on the scale of 8-10 ha, composed of 1 or more stands or alternate nests. The nest
area has been the primary focus of goshawk habitat studies. Nests are typically found in older forest stands with a high crown closure and dense, large trees (Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984, Crocker-Bedford and Chaney 1988, Hayward and Escano 1989). Also, significant association with northerly aspects and water have been reported. In Oregon, and elsewhere, nesting stands have been found in a variety of forest types (Reynolds et al. 1982, 1992). Researchers often searched for nests in patches of late forest structure because it was considered to be "good" nesting habitat. As a result, it is not clear whether the current description of nest-site structure is biased towards late forest structure.

The second spatial component of nesting habitat is the post-fledging family area (PFA) (also third-order selection). This is an area of concentrated use, serving multiple purposes for goshawks. The PFA was identified through telemetry by Kennedy et al. (1994) as a 120-240 ha ($\bar{x} = 170$ ha) 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. Because PFA size estimates were based on radio-tagged adult females who were hunting during this fledgling-dependency period, it follows that the PFA was also providing adult forage. Reynolds et al. (1992) stated that the PFA provides for fledgling hiding cover and foraging opportunities as fledglings learn to hunt, and confirmed that this area seemed to correspond with the area of defended territory.
Bull (1992) also identified an area of concentrated use by fledglings – all fledgling locations were ≤0.5 km of the nest during the first 6 weeks post-fledging. The forest structure in the PFA has not been examined directly. Nonetheless, Reynolds et al. (1992:16) call for maintaining the PFA in "forest conditions intermediate between the high foliage volume and crown cover of the nest stands and the more open foraging habitats."

The foraging area is the third spatial component (second-order selection), comprising the balance of goshawk home ranges. Several researchers (Austin 1992, Bright-Smith and Mannan 1994, Hargis et al. 1994, Kennedy et al. 1994) have estimated the size of the home range through telemetry as 1,500-2,100 ha.

Limited data are available to characterize the forest structure used by goshawks in foraging throughout the home range. In northern California, Austin (1992) compared forest structure at telemetry locations with available habitat for 10 foraging goshawks. She found trends that goshawks selected mature and late stands with crown closure ≥40%, and avoided meadows and open forest with crown closure ≤40%. In eastern California, Hargis et al. (1994) found goshawks foraging in a wider array of vegetational stages than were generally available in the study area, and selecting areas with higher basal area, greater crown closure, and more trees/ha, especially in the larger diameter classes.
Two re-occupancy studies from Arizona suggest that relatively dense, mature forest is important throughout the home range. Crocker-Bedford (1990) found a high correlation between timber harvest throughout the goshawk home range and reduced occupancy and reproduction. Crocker-Bedford and Chaney (1988) also suggested that dense nesting stands provided goshawks with important foraging habitat. Based on 12 nests, Ward et al. (1992) found that historical nest-sites with high crown closure on areal scales of up to 1,000 ha around the nest area were more likely to be re-occupied than those where crown closure was low. Both studies based evidence of selection on re-occupancy of historic nest sites. This can be misleading for a species which often makes use of alternate nests, sometimes spaced as widely as 2.1 km apart, as has been shown for the goshawk (Woodbridge and Detrich 1994).

Crocker-Bedford's (1990) study provided evidence of a decline in goshawks within his study area. With the goshawk's apparent reliance on dense-canopied late forest structure for nest stands, and possibly for larger areas outside of the nest stand, the loss of such forest throughout the western United States from timber harvest and other factors is a potential threat. In 1991, the U.S. Fish and Wildlife Service listed the goshawk as a Category 2 species, indicating that concern about its status is warranted but information is lacking.

The current management recommendations by Reynolds et al. (1992) were developed in the absence of conclusive data
about PFA and foraging area habitat. Desired structural conditions outside of the nest area are based on their proposed model for optimal goshawk prey habitat and can be viewed as an untested hypothesis.

An alternative approach to providing information about forest structure at larger scales is to analyze landscape patterns within concentric circles of increasing radii around a nest site. This approach has been used by Newton et al. (1977, 1981, 1982) at raptor nest sites in Wales, Ripple et al. (1991) and Lehmkuhl and Raphael (1993) for northern spotted owls (*Strix occidentalis caurina*) in Oregon and Washington, and by Hall (1984) and Allison (1993) for the goshawk in northern California. Using this approach, I studied goshawk habitat at scales up to and including a PFA-sized circle. The goals for this study were to: (1) determine if a bias existed in the current description for nest-site structure; (2) determine if goshawk nests are located randomly on the study area at the PFA scale, or in relation to various landscape features; and (3) examine several landscape scales between the nest site and the PFA for selection of dense, late forest structure. This study does not address why dense, late forest structure may be important to goshawks outside of the nest site; rather it is a first step in determining if this structure is an important habitat association at the PFA level.

I chose the PFA scale for practical and ecologically significant reasons. The 2,100 ha foraging area is more variable, and more likely to contain areas of non-use than
the much smaller 170 ha area of the PFA, and thus may
disguise habitat patterns. The PFA provides not only
forage, but also fledgling hiding cover, and is heavily used
by the adult female during the fledgling dependency period.
The PFA may be providing for more complex, specialized, and
therefore identifiable habitat functions than would the
foraging area, especially for this wide ranging, prey-
generalist species.

Information is lacking about the important structural
components of habitat within the goshawk PFA. Testing for
patterns on this scale will provide information essential to
the management and conservation of the goshawk in
increasingly fragmented forest habitat.
Chapter 2
SURVEY BIAS AND GOSHAWK NEST-SITE STRUCTURE

ABSTRACT

Most nest-site studies of the northern goshawk (Accipiter gentilis) were based on nests found by researchers or timber marking crews searching patches of late forest structure, creating a possible bias in nest-site descriptions away from younger forest. I compared the number of live, large (> 53cm diameter at breast height [dbh]) trees per hectare and the total percent canopy closure in 0.4 ha surrounding nests found by systematic (non-biased) and non-systematic (opportunistic) methods on the Malheur, Wallowa-Whitman, and Fremont National Forests in eastern Oregon. I used multiple linear regression with indicator variables for search method and forest type to determine whether nests in 2 different forest types (ponderosa pine [Pinus ponderosa] and mixed conifer) could be combined to assess whether different search methods resulted in different descriptions for the number of large trees per hectare or the total percent canopy closure around nests. For 41 nests, pooled across both forest types, large trees were not significantly more abundant around non-systematically than around systematically found nests (2-sided P = 0.67) (95% Confidence Interval = -7.4 to 11.4 more abundant), and total percent canopy closure was not significantly higher around non-systematically than around systematically found nests (2-sided P = 0.39) (95%
Confidence Interval = -10 to 4% higher). Nests from both groups were generally found in dense, late forest structure, suggesting that the current model for goshawk nest site habitat is not biased, despite past search methods. However, because non-systematically found nests had up to 11 more large trees per hectare, and nests were occasionally found in younger forest conditions, goshawk surveys occurring exclusively in older forest would be likely to misrepresent the actual distribution of nests among forest types.

INTRODUCTION

Reynolds et al. (1992) identified the nest area as the smallest of 3 spatial components of northern goshawk breeding habitat. It is composed of one or more forest stands or alternate nests on the scale of 8-10 ha, and has been studied more than the 2 larger components, the post-fledging family area, and the foraging area. Nests are typically found in older forest stands with high crown closure, and dense, large trees (Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984, Crocker-Bedford and Chaney 1988, Hayward and Escano 1989). In Oregon, and elsewhere, nesting stands have been found in a variety of forest types (Reynolds et al. 1982, Reynolds et al. 1992).

A potential bias may exist in the current description for forest structure at nest sites because of the difficulty in finding nests for an animal as wide-ranging, uncommon, and elusive as the goshawk. Nests have typically been found
as a result of timber-sale surveys or by researchers searching what they thought to be "good" goshawk habitat – typically drainages and other areas supporting abundant, large trees. This leads to the possibility that some forest structural stages may be under-represented as suitable nesting habitat (Marshall 1992).

Concern that timber harvest of older forest around nests was negatively affecting goshawk populations led to the listing of the goshawk as a Category 2 species by the U. S. Fish and Wildlife Service in 1991, and currently, guidelines are being developed to protect dense, late forest structure for nesting stands (Reynolds et al. 1992). These actions neglect to address the possibility that a bias exists in the current model for goshawk nest site structure.

A systematic survey method (Kennedy and Stahlecker 1993) which can eliminate the possibility of this search bias is currently available. My objective was to compare forest vegetation around goshawk nests found using this survey method with nests found in non-systematic ways to determine if the 2 search methods resulted in different characterizations of goshawk nest sites, and therefore, if a bias existed.

METHODS

Study Area

Goshawk nest surveys occurred on 3 National Forests in eastern Oregon: the Fremont, Malheur, and Wallowa-Whitman.
All 3 forests contained mixed-conifer and ponderosa pine forest types, although the relative proportion and species composition varied. Mixed conifer forest on the Malheur and Wallowa-Whitman National Forests contained Douglas-fir (*Pseudotsuga menzeseii*), grand fir (*Abies grandis*), western larch (*Larix occidentalis*), ponderosa pine, and lodgepole pine (*Pinus contorta*) trees. On the Fremont National Forest, mixed conifer forest also included sugar pine (*Pinus lambertiana*) and incense cedar (*Calocedrus decurrens*) trees. Five systematically-searched survey blocks of 90-130 km² were chosen specifically to contain representative tree harvest intensities and the following forest types: lodgepole pine (Paisely Ranger District [RD]) and mixed conifer (Bly RD) on the Fremont National Forest, ponderosa pine (Bear Valley RD, East side) and mixed conifer (Bear Valley RD, West side) on the Malheur National Forest, and mixed conifer (La Grande RD) on the Wallowa-Whitman National Forest. Nests found in the lodgepole pine survey block were subsequently excluded from analysis because of a small sample size and an uneven distribution between search methods. Although the majority of stands within each survey block consisted of the targeted forest type, the heterogeneous nature of eastern Oregon forests resulted in a mix of forest types at goshawk nest-sites within each block.

The climate in eastern Oregon is dry, with cold winters providing the majority of precipitation in the form of snowfall. Topography on all Forests was typically moderately-sloped hills and ridges, with some deeply-cut
drainages. Elevations ranged between 900-2,000 m. Natural openings included wet meadows, dry grass and sagebrush (Artemisia spp.) meadows, dry scab flats, and burns.

Partial cut timber harvest was typical for mixed conifer and ponderosa pine forest types. By design, study sites on all 3 Forests included some designated old growth set aside units (U.S. Department Agriculture 1990a), ranging in size from approximately 60-160 ha.

Study Design

Nests found within a survey block using the protocol developed by Kennedy and Stahlecker (1993), and adapted to topographic conditions following Woodbridge (1992), were grouped into the "systematic search" category. This method establishes a grid of stations for broadcasting taped goshawk calls, covering approximately 91% of the total area in the survey block. All other nests comprised the "non-systematically" searched category, and included nests found opportunistically incidental to timber cruising, by protocol or non-protocol nest searches in timber-sale units or during wildlife inventories in unique habitats such as in designated old growth set aside units, or historic nest-sites specifically known and searched for inside the survey blocks.

Two variables were used to measure differences in nest site characteristics associated with search method: live, large (> 53cm diameter at breast height) trees per hectare (LTPH) and total percent canopy closure (CC). Because
density of large trees and canopy closure are structural variables used in characterizing merchantable timber, as well as the conditions thought to be ideal goshawk nesting habitat, they are a useful way to measure the type of bias in question. These variables were measured on the ground at 5 plots, (a center nest tree plot surrounded by 4 plots 30 m out from the center in the 4 cardinal directions, for a total coverage from the 5 plots combined of approximately 0.4 ha). I chose 0.4 ha because biologists searching for goshawk nests are often drawn to microsite conditions within stands, such as drainage bottoms, which are reasonably represented by a 0.4 ha area. Using a Lemmon spherical densiometer, I measured CC 5 m out from each plot center in the 4 cardinal directions and averaged the 4 measurements for a plot value. The 5 plots were then averaged. At each of the same 5 plot centers, variable radius plots using a 20-factor basal area prism provided a cumulative measure across all plots of stem density, from which I calculated the number of live, large trees per hectare for the entire 0.4 ha area. All researchers were trained in the field together to minimize observer bias. A total of 41 nest sites, active in 1992 or 1993, were measured in July/August of 1993. I used only 1 nest per territory.

Statistical Analysis

Using multiple linear regression, I analyzed the effect of two explanatory indicator variables, search method and forest type, on each response variable, CC or LTPH,
separately. Including the interaction between both explanatory variables allowed me to determine whether the effect of search method on CC or LTPH around nests differed by forest type, and therefore whether the data could be pooled across forest types.

RESULTS

Nests were distributed approximately evenly between search methods, and most occurred in the mixed conifer forest type (Table 2.1).

Total Percent Canopy Closure

For the 0.4 ha surrounding goshawk nests, differences in mean CC associated with search method were not different between forest types, based on the non-significant interaction term between search method and forest types (Conditional Sum of Squares F-test; 1, 37 df; $P = 0.77$). A 95% Confidence Interval for this interaction term showed that differences in CC associated with search method could be from -14 to 19% different between forest types. I pooled the data across both forest types, for the resulting model:

$$\text{Mean } \% \text{ CC} = 59 + -3(\text{NSS}) + 15(\text{MC})$$

(SE) $(3.71)$ $(3.63)$ $(4.1)$

Estimated population SD = 11.5 on 38 df,

where NSS = non-systematic search, and MC = mixed conifer.
Table 2.1. Distribution of goshawk nests by search method among ponderosa pine (PP) and mixed conifer (MC) forest types on 3 National Forests in eastern Oregon.

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<th>National Forest</th>
<th>Wallowa-Whitman</th>
<th>Fremont</th>
<th>Malheur</th>
<th>Total</th>
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<td>Search method</td>
<td>PP</td>
<td>MC</td>
<td>PP</td>
<td>MC</td>
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<tr>
<td>Systematic</td>
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<td>1</td>
<td>4</td>
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<tr>
<td>Non-systematic</td>
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<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>10</td>
<td>2</td>
<td>7</td>
</tr>
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</table>
The Constant term in this model (indicator variable reference level) represents CC around systematically found nests in ponderosa pine forest, and the remaining terms are interpreted as follows: the coefficient of NSS is the average difference in CC (weighted across both forest types) around non-systematically found nests when compared with systematically found nests, and the coefficient of MC is the average difference in CC around nests in mixed conifer forest (weighted across both levels of the search variable [systematic and non-systematic]) when compared with nests in ponderosa pine forest.

In the chosen model, non-systematically found goshawk nest sites were an estimated 3% lower in CC than nest sites found by systematic search, but there was no statistical evidence of a true difference (2-sided \( P = 0.39 \)). Mean CC at nests found by systematic survey across both forests types was 69% (SD = 12%).

A 95% Confidence Interval for the estimate of the effect of search method is a change in CC of -10 to 4%. A change in CC of 10% is not greater than the smallest unit usually used to categorize CC (10%). I do not consider 10% to be biologically significant, and am therefore comfortable with the adequacy of the data to test this question.

Large Trees per Hectare

For the 0.4 ha surrounding goshawk nests, differences in LTPH associated with search method were not different between forest types, based on the non-significant
interaction term between search method and forest types (Conditional Sum of Squares F-test; 1, 37 df; \( P = 0.91 \)). A 95% Confidence Interval for this interaction term showed that differences in LTPH associated with search method could be from -9 to 8 LTPH different between forest types. I pooled the data across both forest types, for the resulting model:

\[
\text{Mean LTPH} = 18.7 + 2.0(\text{NSS}) + 2.6(\text{MC})
\]

\[
(\text{SE}) \quad (4.76) \quad (4.67) \quad (5.26)
\]

Estimated population SD = 14.80 on 38 df,

where the interpretation of variables and their coefficients with regard to LTPH are the same as in the CC analysis.

Non-systematically found goshawk nest sites had an estimated 2 more LTPH than systematically found nest sites, but the difference was not significant (2-sided \( P = 0.67 \)). Mean LTPH at nests found by systematic survey across both forest types was 20.5 (SD = 14.8).

A 95% Confidence Interval for the estimate of the search effect is a change in LTPH of -7.4 to 11.4. Eleven LTPH is slightly more than 10% of the range of values for LTPH (0 to 69), and might be considered a biologically significant difference.

DISCUSSION

Despite non-systematic search methods commonly used in past studies of goshawk nest site habitat, I found little to
no evidence that the current description for nest site habitat is biased, based on comparing 2 of the most frequently measured vegetative characteristics. In my sample of eastern Oregon ponderosa pine and mixed conifer forests, goshawk nests were most often found in patches of dense, late forest structure, using either search method.

Some caution must be observed in the interpretation of these results. My relatively small sample size provided limited power to justify pooling nests across both forest types, although no extreme differences were observed. Successful nests did occasionally occur in younger forest, suggesting that goshawks exhibit flexibility in their nest site requirements. The possibility that non-systematic search methods found > 11 more LTPH around nests (95% Confidence Interval end point) is suggestive of a biologically meaningful difference. A larger sample size of nests may have resulted in a smaller Confidence Interval for this difference, but it is also possible that a weak tendency for bias exists that would become more apparent if surveys occurred exclusively in old growth forest. My non-systematic nests were found by a mix of methods including miscellaneous wildlife surveys, which probably reflects the average type and degree of bias in past studies. The possibility that a weak bias exists cautions that although searching dense, late forest structure is the most efficient way to find goshawk nests in eastern Oregon, it will not fully represent the distribution of nests among different forest structural stages. If time and money allow,
systematic survey of potential habitat will result in the best information about nest distribution.

REFERENCES


Chapter 3
NORTHERN GOSHAWK NEST STAND SELECTION AND HABITAT ASSOCIATIONS AT THE POST-FLEDGING FAMILY AREA SCALE IN OREGON

ABSTRACT

The role of dense, late forest structure in northern goshawk (Accipiter gentilis) breeding habitat and the structural characteristics of post-fledging family areas (PFAs) are important because of the possibility of population declines in response to timber harvest practices around nest sites and within home ranges. On the Malheur National Forest in eastern Oregon, I examined the importance of dense, late forest structure at the nest-stand scale, and in 5 circular plots (12, 24, 50, 120, 170 ha) centered on 22 active goshawk nests. Nest stands were compared with random points representing available (randomly located sites; n = 44) stands to test for selection, and the 5 circular plots around nests were compared with both available and not-used (randomly located sites within completely surveyed blocks of forest with no overlap of nest circles; n = 15) forest conditions. I examined PFA-scale forest structure using 8 landscape variables. When compared with random points representing available conditions, goshawks nested in stands with dense, late forest structure more than this type of stand was available (P < 0.05), and nested in stands of dense, mid-aged forest structure less than they were available (P < 0.10). At landscape scales within the PFA, dense, late forest structure was significantly more abundant
within circles of 12 ha (2-sided $P = 0.031$), and 24 ha (2-sided $P = 0.06$) around nests than around 44 available random points, and similarly more abundant within circles of 12 ha (2-sided $P = 0.05$) and 24 ha (2-sided $P = 0.08$) around nests than around 15 not-used random points. Forest structure within PFA-sized circles around nests was dominated by denser-canopied forest and always contained wet openings. I found a negative relationship between nests and early forest (clearcuts and burns) that became less negative, though remained strong, as road density increased (Drop in Deviance for the roads and early forest interaction term: $\chi^2 = 7.5$; 1 df; $P < 0.01$). Nests were also negatively associated with dense, mid-aged forest structure (2-sided $P = 0.06$), and positively associated with dry openings (sagebrush [Artemisia spp.] meadows, scab flats) (2-sided $P = 0.07$) and roads (2-sided $P = 0.034$). Despite the occurrence of goshawk nests in younger and occasionally very open stands, these conditions were clearly less preferred than dense, late forest structure at the nest stand scale in my study area. I recommend maintaining large trees and dense, two-layered to multi-layered canopies at goshawk nest stands, and avoiding excessive fragmentation of existing stands. The role of roads, wet and dry openings, and early forest patches, and the significance of trends suggesting the importance of dense, late forest structure in the PFA should be pursued in subsequent telemetry studies of fledgling habitat use within the PFA.
INTRODUCTION

Three spatial components of goshawk breeding habitat have been recognized by Reynolds et al. (1992) corresponding to second and third order habitat selection (Johnson 1980). The goshawk nest area, on the scale of 8-10 ha, is composed of > 1 stands or alternate nests. Most studies have focused on the nest site, which is typically found in older forest conditions with a high crown closure and dense, large trees (Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984, Crocker-Bedford and Chaney 1988, Hayward and Escano 1989).

The second spatial component of nesting habitat is the post-fledging family area (PFA). The PFA was defined by Kennedy et al. (1994) as a 120-240 ha ($\bar{x} = 170$ ha) 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. Reynolds et al. (1992) stated that the PFA provides for fledgling hiding cover and foraging opportunities as fledglings learn to hunt, and it also seemed to correspond with the area of defended territory. These ideas are consistent with recent research in Oregon (Bull and Hohmann 1992). Forest structure in the PFA has not been examined directly. Nonetheless, Reynolds et al. (1992:16) call 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 foraging area is the third spatial component comprising the balance of the goshawk's estimated 1,500-2,100 ha home range. Debate about the importance of dense, late forest structure at this scale has been fostered by research showing a possible decline in goshawk population numbers correlated with timber harvest within home ranges (Crocker-Bedford 1990), and showing that home ranges with high forest crown closure have higher re-occupancy rates (Ward et al. 1992). Also, there is evidence that goshawks forage in stands with denser canopy closure and larger trees (Austin 1992, Hargis et al. 1994).

Evidence of a decline in goshawks (Crocker-Bedford 1990) and their subsequent listing as a Category 2 species in 1991 by the U. S. Fish and Wildlife Service highlighted the need for more information about the role of dense, late forest structure in goshawk breeding habitat. I focused on forest structure surrounding nests at several scales within and including the PFA, using concentric circles of increasing radii. I did not extend my investigation to the home range scale, because without telemetry, areas of non-use at this scale could effectively decrease my power to detect patterns. The goals for this study were to describe forest structure at goshawk nest stands and within PFA-sized circles around nests, and to determine if goshawk nests were located randomly on the study area or in relation to specific landscape features, particularly dense, late forest structure.
METHODS

Study Area

The study area was located on the Bear Valley Ranger District, Malheur National Forest, immediately south of John Day, Oregon. Climate is dry, with cold winters and cool summers. This district is characterized by a mix of forest types from ponderosa pine (*Pinus ponderosa*) stands on dry south slopes, to ponderosa pine and Douglas-fir (*Pseudotsuga menzeseii*) combinations, to dense mixed conifer (Douglas-fir, grand fir [*Abies grandis*], western larch [*Larix occidentalis*], lodgepole pine [*Pinus contorta*]) sites on north slopes with very little to no ponderosa pine. Hills and moderately steep drainages typify the study area, except for a steep-walled major drainage in the northeastern section. Elevations range from 1,460 to 1,920 m. Small openings in the forest (wet and dry meadows, scablands) were common, and the district surrounded a large open valley (23,500 ha). Partial cut timber harvest practices (overstory removal, group selection) were standard, and clear cutting was uncommon.

Sampling Methods

I used 22 goshawk nests, active in 1993 on the Malheur National Forest, to characterize habitat and test for associations. Nests were found using both systematic (2 large [9,000-10,500 ha] survey blocks thoroughly searched...
using a grid of transect lines; \( n = 12 \) and non-systematic
(nests found incidentally to timber stand or other wildlife
surveys, or as a result of searching predetermined
"suitable" habitat; \( n = 10 \)) search methods. I used only 1
nest per territory. Forty-four random points were generated
from a list of UTM coordinates bounding the study area.
Random points were restricted to pole-sized (> 13 cm dbh
[Bell and Dilworth 1988]) or larger forest vegetation, on
U. S. Forest Service land. I 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.

Habitat Classification

I classified forest structure into 4 categories based
on tree size and total percent canopy closure (CC) (Table
3.1). My division between mid-aged and late forest
structure categories for the number of live, large (> 53cm
diameter at breast height) trees per hectare (LTPH) was
consistent with the Malheur National Forest's interpretation
of the U. S. Forest Service, Region 6 forest structural
stages (U. S. Department of Agriculture 1994). In my usage,
the term "late" refers specifically to a structural
condition defined by the density of large trees, and is not
directly a measure of forest age. Four more landscape
features (early forest, wet openings, dry openings, roads)
were added to the 4 structural categories for a total of 8
habitat variables.
Table 3.1. Landscape variables measured around goshawk nests and random points on the Malheur National Forest, Oregon, 1993.

<table>
<thead>
<tr>
<th>Forested Structural Categories</th>
<th>Variables</th>
<th>Category Bounds</th>
<th>n</th>
<th>X</th>
<th>SE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late dense canopy</td>
<td>LTPH (^1)</td>
<td>≥15(^4)</td>
<td>30.1</td>
<td>4.0</td>
<td>20.3 - 40.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC (^3)</td>
<td>≥50%</td>
<td>59</td>
<td>1.8</td>
<td>55 - 64</td>
<td></td>
</tr>
<tr>
<td>Late open canopy</td>
<td>LTPH (^1)</td>
<td>≥15</td>
<td>20.3</td>
<td>2.3</td>
<td>14.6 - 25.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>≤50%</td>
<td>39</td>
<td>3.0</td>
<td>32 - 47</td>
<td></td>
</tr>
<tr>
<td>Mid-aged dense canopy</td>
<td>LTPH (^1)</td>
<td>&lt;15</td>
<td>7.7</td>
<td>2.0</td>
<td>3.0 - 12.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>&gt;50%</td>
<td>57</td>
<td>2.5</td>
<td>51 - 63</td>
<td></td>
</tr>
<tr>
<td>Mid-aged open canopy</td>
<td>LTPH (^1)</td>
<td>&lt;15</td>
<td>9.6</td>
<td>2.0</td>
<td>4.7 - 14.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>≤50%</td>
<td>34</td>
<td>2.7</td>
<td>27 - 41</td>
<td></td>
</tr>
</tbody>
</table>

**Description**

- **Early forest**: Seedling/sapling regeneration or burns
- **Wet openings**: Riparian corridor flanked by enough open ground to be visible through the canopy (most drainages)
- **Dry openings**: Dry grass, scablands, sagebrush meadows >0.4 ha
- **Roads**: Arterial (paved), collector (well-used dirt) and local (sporadically-used dirt) roads

\(^1\) The terms "late" and "mid-aged" refer to a structural condition defined by the density of large trees; they are not a direct measure of forest age.

\(^2\) live, Large (> 53cm diameter at breast height) Trees per Hectare

\(^3\) total percent Canopy Closure

\(^4\) 15 trees/ha = 6 trees/ac
I used 1:30,000 infrared photographs from 1992 to delineate stands into polygons. Stands that were harvested between August 1992 (date of aerial photography) and April 1993 (nest site selection by goshawks) were ground measured. Polygon overlays of the photographs were transferred by eye and with a zoom transfer scope to planimetrically correct maps, that were then digitized using LTPlus software, and stored in an ArcInfo database.

To assess the accuracy of the resulting habitat map, I ground measured a randomly selected sample of approximately 7% of the stands in each of the 4 categories most difficult to interpret consistently. Ground measurements also provided a mean and 95% Confidence Interval for variables describing each category. As ground measurement progressed, I sampled more stands in categories with high variability with the aim of creating reasonably tight, non-overlapping descriptions for each forest category. Stands selected for the accuracy assessment had to be >4 ha in size and not harvested after the 1992 aerial photography. Based on U. S. Forest Service stand level vegetation exam methodology (U. S. Department of Agriculture 1990b) I systematically placed plots along straight line transects aimed at capturing the diversity in a stand. Stands <4 ha, between 4-16 ha, and >16 ha had 3, 6, and 9 plots, respectively, and all plots were averaged for an overall stand value. At each plot, LTPH was measured in variable radius plots using a 20-factor basal area prism. I used a Lemmon spherical densiometer to take CC readings 5 m out from plot center in
each of the 4 cardinal directions, and averaged the 4 readings for each plot. Percent of stands classified correctly from the sample of ground measurements was used to infer the overall accuracy of the habitat map. I made no further adjustments to the map.

ArcInfo provided areas and distances for all landscape variables at all chosen scales. All ArcInfo output was proofed against the original habitat maps for errors in data transfer or manipulation.

Nest Stands and Post-fleging Family Area Habitat

Nest stands were compared with the 44 random points representing available conditions to test for selection. For PFA habitat associations, I made 3 different comparisons between nest sites and random points. Used versus available was the primary comparison for which all nests (n = 22) and random points (n = 44) were used. I also compared nest sites with a subset of random points (n = 15) considered to be not-used in 1993 because they occurred inside systematically surveyed blocks and did not overlap the 170 ha nest circles. Within the subset of not-used random points, I analyzed a further subset of points (n = 10) which landed on "suitable" nesting stands (Not-used/SNS). This last subset asked the question, "Given a suitable nest stand, what is different in the surrounding area at the PFA-scale that may have influenced why the site was not chosen for nesting?" I took 2 approaches to defining a "suitable" nesting stand. The first approach was to identify which
structural categories appeared to be most frequently used by goshawks for nesting. The dense, late and dense, mid-aged forest structural categories were chosen at 20 of 22 nests. The second approach was to calculate the mean LTPH and CC for all nest stands, based on averages from ground measurement in each category, and to include any category that came within 1 standard deviation of those means. This again resulted in choosing dense, late forest structure and dense, mid-aged forest structure as "suitable" for nest stands.

Dense, Late Forest Structure

Five landscape scales were examined for selection of dense, late forest structure around nests. Around all nests and random points, I used concentric circles containing areas of 12, 24, 50, 120, and 170 ha. Each successive scale had biological or management significance. Twelve ha (30 ac) was the size Reynolds et al. (1992) recommended for a typical nest area on the stand level; 24 ha (60 ac) was the size of goshawk allocations in U. S. Forest Service Region 6 (Fremont National Forest); 50 ha (125 ac) was the size of goshawk allocations recommended as a preliminary minimum estimate in California (Bloom et al. 1986), and also roughly corresponds with the size of pine marten (Martes americana) allocations of old growth forest in most eastern Oregon National Forests; 120 ha (300 ac) was the size of pileated woodpecker (Dryocopus pileatus) old growth allocations in eastern Oregon National Forests; 170
30 ha (415 ac) corresponded to the PFA. I also analyzed differences between the 4 successive outer rings, for a more independent comparison of the data.

Statistical Analysis

I used a Chi-square test of homogeneity to compare proportional use of structural categories between nest stands and random points, after lumping the 2 low-canopy closure categories into the same category (open, late forest structure + open, mid-aged forest structure) because of low sample sizes. Nest stand selection or avoidance was calculated using Bonferroni simultaneous confidence intervals. Descriptive statistics were used to characterize forest structure at the PFA scale. Logistic regression with forward stepwise variable selection tested for habitat associations by comparing differences among used, available, and not-used groups at the PFA scale. 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 to normalize the data. In logistic regression, my binary response variable was coded as either nest (1) or random point (0), and the effect of explanatory variables was to increase or decrease the odds of a nest occurring. The area in dense, late forest structure for circles and rings at all landscape scales was square-root transformed and compared using Student's t-tests. I considered all variables to be significant at alpha = 0.10.
RESULTS

Habitat Map Accuracy Assessment

Overall accuracy for all 4 structural categories was 79% (Table 3.2). I was most accurate in classifying dense, late forest structure, with 100% agreement between aerial photo categories and ground measurements. Although dense, 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% Confidence Intervals (Table 3.1).

Nest Stand Selection

Nests were not distributed among stand types in the same proportion as stand types were available in the study area ($X^2 = 11.5$, 2 df, $P = 0.003$) (Table 3.3). Bonferroni simultaneous confidence intervals (Pagano and Gauvreau 1993) provided evidence that dense, late forest structure was used more than it was available ($P < 0.05$), dense, mid-aged forest structure was used less than it was available ($P < 0.10$), and use was equal to availability for the low canopy closure category rarely used for nesting.

Post-fledging Family Area Characteristics

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 (Figure
Table 3.2. Accuracy matrix for habitat categories delineated on 1992 infra-red, 1:30,000 scale aerial photographs of the Malheur National Forest, eastern Oregon, based on a random sample of ground measured stands representing approximately 7% of the area in each category.

<table>
<thead>
<tr>
<th>Aerial Photograph Categories</th>
<th>No. stands sampled</th>
<th>Ground Measurement</th>
<th>Dense, late(^1)</th>
<th>Open, late forest</th>
<th>Dense, mid-aged(^1)</th>
<th>Open, mid-aged forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense, late forest</td>
<td>7</td>
<td></td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Open, late forest</td>
<td>7</td>
<td></td>
<td>0.00</td>
<td>0.86</td>
<td>0.00</td>
<td>0.14</td>
</tr>
<tr>
<td>Dense, mid-aged forest</td>
<td>10</td>
<td></td>
<td>0.20</td>
<td>0.00</td>
<td>0.60</td>
<td>0.20</td>
</tr>
<tr>
<td>Open, mid-aged forest</td>
<td>7</td>
<td></td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
<td>0.71</td>
</tr>
</tbody>
</table>

\(^1\) The terms “late” and “mid-aged” refer to a structural condition defined by the density of large trees; they are not a direct measure of forest age.
Table 3.3. Observed (OBS) and expected (EXP) values for the distribution of goshawk nests and random points among forest stand types on the Malheur National Forest, Oregon, 1993.

<table>
<thead>
<tr>
<th></th>
<th>Dense, late(^1) forest</th>
<th>Dense, mid-aged(^1) forest</th>
<th>Open, late and mid-aged forest</th>
<th>Total OBS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OBS</td>
<td>EXP</td>
<td>OBS</td>
<td>EXP</td>
</tr>
<tr>
<td>Nests</td>
<td>15</td>
<td>8.7</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Random pts</td>
<td>11</td>
<td>17.3</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>Total OBS</td>
<td>26</td>
<td>27</td>
<td>13</td>
<td>27</td>
</tr>
</tbody>
</table>

\(^1\) The terms "late" and "mid-aged" refer to a structural condition defined by the density of large trees; they are not a direct measure of forest age.
3.1). The most abundant forest structure was dense, mid-aged forest (37%), followed closely by dense, late forest (29%), and the least abundant was early forest (regenerating clearcuts)(3%). Wet openings were present at all nests, and road density for paved and dirt roads together averaged 3.4 km/km² around nests.

**Post-fledging Family Area Habitat Associations**

**Used versus Available**

When forest structure around nests was compared with available forest structure, there was a positive association between dry openings and nests. The presence of dry openings increased the odds of a nest occurring an estimated 2.5 times (2-sided $P = 0.07$)(Table 3.4).

**Used versus Not-used**

When forest structure around nests was compared with forest structure around random points not-used by goshawks for nesting, there was a positive association between roads and nests (2-sided $P = 0.034$). The effect was generally small, increasing the odds of a nest occurring by a factor of 1.0005 for a 1 m increase in roads, and by a factor of 1.6 for a 1-km increase in roads (Table 3.4).
Figure 3.1. Distribution of forest structural categories and wet and dry openings in PFA-sized (170 ha) circles around 22 active goshawk nests on the Malheur National Forest in eastern Oregon, 1993.
Table 3.4. Road distance and presence (P) or absence (A) of early forest and dry opening landscape variables measured in PFA-sized (170 ha) circles around goshawk nests and 3 groups of random points on the Malheur National Forest, Oregon, 1993.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Used (n = 22)</th>
<th>Available (n = 44)</th>
<th>Not-used (n = 15)</th>
<th>Not-used/SNS(^1) (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\bar{x}) SE</td>
<td>(\bar{x}) SE</td>
<td>(\bar{x}) SE</td>
<td>(\bar{x}) SE</td>
</tr>
<tr>
<td>Roads (m)</td>
<td>5,885 322</td>
<td>5,258 238</td>
<td>4,704 378</td>
<td>4,859 508</td>
</tr>
<tr>
<td>Early forest</td>
<td>6 16</td>
<td>34 32</td>
<td>7 8</td>
<td>6 4</td>
</tr>
<tr>
<td>Dry openings</td>
<td>12 10</td>
<td>14 30</td>
<td>7 8</td>
<td>6 4</td>
</tr>
</tbody>
</table>

\(^1\) not-used random circles centered on suitable nest stands.
Used versus Not-used/SNS

When forest structure around nests was compared with forest structure around random points centered on suitable nest stands but not-used by goshawks for nesting, the odds of a nest occurring were influenced by the interaction of roads with early forest (Drop in Deviance $X^2 = 7.5$; df = 1; 2-sided $P < 0.01$) (Table 3.4), and the amount of dense, mid-aged forest structure (2-sided $P = 0.06$) (Figure 3.2). At a low level of roads (e.g., 3,000 m) the presence of early forest decreased the odds of a nest occurring by a factor of $2.6 \times 10^9$, but at high levels of roads (e.g., 6,000 m) early forest decreased the odds of a nest occurring by a factor of 12. The odds of a nest occurring decreased an estimated 2% with every 1 ha increase in dense, mid-aged forest structure.

Dense, Late Forest Structure

Used versus Available

When circles around nests were compared with circles around available random points, there was more dense, late forest structure around nests in the 12 ha (2-sided $P = 0.031$) and 24 ha (2-sided $P = 0.06$) circle sizes, with the difference diminishing as circle size (landscape scale) increased (Table 3.5). Potentially large, although statistically non-significant, differences at the larger circle sizes are indicated by the size of their approximate
Figure 3.2. A comparison of forest structure and wet openings in PFA-sized (170 ha) circles around goshawk nests (used sites), with random circles representing available, not-used, and not-used with suitable nest stand conditions, on the Malheur National Forest, Oregon, 1993.
Table 3.5. A comparison, on 5 landscape scales, of dense, late forest structure in circular plots centered on 22 goshawk nests and 44 random points representing available forest on the Malheur National Forest, Oregon, 1993.

<table>
<thead>
<tr>
<th>Landscape Scale</th>
<th>Nests</th>
<th>Available</th>
<th>$\bar{x}_1$(SE)</th>
<th>$\bar{x}_2$(SE)</th>
<th>$\bar{x}_1-\bar{x}_2$</th>
<th>90% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle 1 (12 ha)</td>
<td>6(0.9)</td>
<td>3(0.6)</td>
<td>3   (0.5 - 4)</td>
<td>0.031</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle 2 (24 ha)</td>
<td>10(1.7)</td>
<td>7(1.2)</td>
<td>3   (0.2 - 7)</td>
<td>0.061</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle 3 (50 ha)</td>
<td>19(3.4)</td>
<td>13(2.2)</td>
<td>6   (-0.6 - 13)</td>
<td>0.114</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle 4 (120 ha)</td>
<td>38(6.9)</td>
<td>30(4.6)</td>
<td>8   (-6 - 22)</td>
<td>0.279</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle 5 (170 ha)</td>
<td>49(8.9)</td>
<td>42(6.0)</td>
<td>7   (-10 - 25)</td>
<td>0.441</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring 1 (Circle 2-1)</td>
<td>5(0.9)</td>
<td>3(0.6)</td>
<td>2   (-0.5 - 3)</td>
<td>0.148</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring 2 (Circle 3-2)</td>
<td>9(1.8)</td>
<td>6(1.1)</td>
<td>3   (-1 - 6)</td>
<td>0.189</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring 3 (Circle 4-3)</td>
<td>19(3.7)</td>
<td>17(2.5)</td>
<td>2   (-5 - 9)</td>
<td>0.589</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring 4 (Circle 5-4)</td>
<td>11(2.3)</td>
<td>12(1.6)</td>
<td>-1  (-5 - 4)</td>
<td>0.798</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 90% Confidence Interval 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.

2 After square-root transformation of the variable
90% Confidence Intervals. Although ring differences were not significant, they indicate that differences in dense, late forest structure at the larger scales existed independently; they were not solely a residual of large differences in the two smallest circle sizes.

**Used versus Not-used**

A similar difference in the association of dense, late forest structure existed when circles around nests were compared with circles around random points that were not used by goshawks for nesting (Table 3.6). The 12 ha and 24 ha circles around nests contained more dense, late forest structure than circles around random points (2-sided $P = 0.05$, 2-sided $P = 0.08$, respectively), with a clear trend continuing into the next larger circle size, but diminishing thereafter. Again, approximate Confidence Intervals for differences in the larger scales were large, and the pattern of more dense, late forest structure around nests was visible in all but the outermost ring.

**DISCUSSION**

The selective use by goshawks of dense, late forest structure at the nest-stand scale reinforces results from past studies. The tendency for nests to occur in stands with dense, late forest structure is not an artifact of search method; a majority (12) of the 22 nests in this study
Table 3.6. A comparison, on 5 landscape scales, of dense, late forest structure in circular plots centered on 22 goshawk nests and 15 random points representing not-used forest on the Malheur National Forest, Oregon, 1993.

<table>
<thead>
<tr>
<th>Landscape Scale</th>
<th>Nests</th>
<th>Available</th>
<th>90% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle 1 (12 ha)</td>
<td>6(0.9)</td>
<td>3(0.9)</td>
<td>3 (0.8 - 5)</td>
<td>0.050</td>
</tr>
<tr>
<td>Circle 2 (24 ha)</td>
<td>10(1.7)</td>
<td>6(1.7)</td>
<td>4 (0.5 - 9)</td>
<td>0.081</td>
</tr>
<tr>
<td>Circle 3 (50 ha)</td>
<td>19(3.4)</td>
<td>10(3.1)</td>
<td>9 (0.4 - 17)</td>
<td>0.107</td>
</tr>
<tr>
<td>Circle 4 (120 ha)</td>
<td>38(6.9)</td>
<td>22(5.5)</td>
<td>16 (-0.6 - 31)</td>
<td>0.210</td>
</tr>
<tr>
<td>Circle 5 (170 ha)</td>
<td>49(8.9)</td>
<td>34(7.3)</td>
<td>15 (-6 - 36)</td>
<td>0.437</td>
</tr>
<tr>
<td>Ring 1 (Circle 2-1)</td>
<td>5(0.9)</td>
<td>3(0.9)</td>
<td>2 (-0.5 - 4)</td>
<td>0.171</td>
</tr>
<tr>
<td>Ring 2 (Circle 3-2)</td>
<td>9(1.8)</td>
<td>5(1.6)</td>
<td>4 (-0.3 - 8)</td>
<td>0.113</td>
</tr>
<tr>
<td>Ring 3 (Circle 4-3)</td>
<td>19(3.7)</td>
<td>12(2.8)</td>
<td>7 (-2 - 15)</td>
<td>0.356</td>
</tr>
<tr>
<td>Ring 4 (Circle 5-4)</td>
<td>11(2.3)</td>
<td>12(2.2)</td>
<td>-1 (-6 - 5)</td>
<td>0.522</td>
</tr>
</tbody>
</table>

1 90% Confidence Interval 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.

2 After square-root transformation of the variable.
were found using systematic (non-biased) search methods. It is important to note, however, that successful nesting also occurred in dense, mid-aged forest structure, and very rarely in open-canopied stands. Clearly, dense canopy (occurring at 20 of 22 nests) is important, perhaps because of the hiding cover it provides, or its influence on microclimate. Without data on productivity and nest site persistence over several years, the relative suitability of dense, late structure versus dense, mid-aged structure at the nest stand is not clear.

My investigation of landscape features associated with nests at the PFA scale was limited because I could not identify actual areas of use. Using a circular plot around nests which contained both areas of use and non-use, it was possible both to miss important habitat components as well as to identify features that may actually be unimportant from the perspective of a goshawk. I assumed that patterns emerging despite being diluted by areas of non-use within my circles were important. Lehmkuhl and Raphael (1993) found that habitat pattern in circles around northern spotted owl (Strix occidentalis caurina) nests was similar enough to habitat pattern in identified home ranges to support using circles for delineating owl habitat management areas. Also, although adult goshawks have been shown to forage long distances from the nest (Hargis et al. 1994), fledgling goshawks are tied more closely to the nest until flying and foraging skills develop, so that habitat components important to their survival during the post-fledging period
are more likely to be found within my circular PFA-sized plots.

The negative relationship between nests and early forest, (typically clearcuts, with a small [20%] component of burns) although buffered by an increase in roads, was the strongest pattern to emerge. This relationship appeared in the comparison with not-used random points containing suitable nest stands, which despite having the smallest sample size, most specifically targets PFA-scale contrasts between nests and random points. This is because not-used random points centered on suitable nest stands were not diluted by overlapping nest areas, as were the available random points, or by areas that may in fact be unsuitable because they lacked a nest stand, as was possible with the larger group of not-used random points. Although goshawk nests were occasionally found relatively close to the edge of clearcuts, these kinds of openings are likely to pose a threat by competition or predation from great horned owls (Bubo virginianus) and red-tailed hawks (Buteo jamaicensis), who nest in proximity to openings for foraging purposes (Johnsgard 1988, Johnsgard 1990). Clearcuts also clearly decrease fledgling hiding cover.

Relatively weaker relationships existed between nests and other landscape features. Although I did not expect to find a positive relationship between nests and roads, it may be that the not-used group of random points represented drier, less productive land with little road development, which may have increased the contrast between nests and
random points. It is also possible, however, that the results suggest some degree of tolerance for roads near nests, and successful nesting did sometimes occur within 150 m of well-used dirt or paved roads. Nests were positively associated with dry openings. They were surrounded by an average of 1 dry opening (average size = 3 ha, range = 0.4 to 24 ha), typically composed of sagebrush meadows, with a smaller component of grass and dry scablands. 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 (pers. comm. 1993) in shrub steppe habitat of Nevada, who observed goshawks foraging in open sagebrush, and consuming mostly Belding ground squirrels (Spermophilus beldingi) at the nest. Biomass of prey remains in my study area (Cutler and DeStefano 1993) was dominated by the sagebrush-inhabiting Nuttall's cottontail (Sylvilagus nuttallii), and by ground squirrels (Spermophilus spp.), including Belding ground squirrels. The importance of cottontails and ground squirrels as goshawk prey in other studies as well (Boal and Mannan 1994) suggests that dry openings may be an important source of prey for nesting goshawks. The negative association between dense, mid-aged forest structure and nests is difficult to explain except for its possible inverse relationship to the abundance of dense, late forest, because they were the 2 dominant structures around nests. I noted that wet openings were present within PFA-sized circles (radius 735 m) around all nests, because other
researchers have found riparian areas to be important to goshawk nests (Shuster 1980, Reynolds et al. 1982, Hargis et al. 1994). Wet openings were, however, abundant throughout the study area and may have contributed to the relatively dense (0.07 active terr/100 ha) population of goshawks I encountered.

Dense, late forest structure was clearly important at landscape scales close to the nest, and decreased in relative abundance with distance from the nest. These results are not surprising considering my circular plot study design in a naturally heterogeneous landscape, and the sparsity of remaining large (ca. 170 ha) patches of dense, late forest structure in eastern Oregon. A small sample size also limited my ability to detect differences at the largest scales, where Confidence Intervals contained potentially large, although statistically non-significant, differences. Much of the area in dense, late forest structure was probably contributed by the nest stand and alternate nest stands. Woodbridge and Detrich (1994) described clumping of alternate goshawk nests stands into "nest clusters" ranging in size from 10 to 114 ha, which could therefore be contained in a PFA. Until telemetry identifies specific habitat used by fledglings in eastern Oregon ponderosa pine and mixed conifer forests, my results suggest that, at a minimum, sufficient dense, late forest structure should be left around nests to provide for existing and alternate nest stands, recognizing the
potential functions this type of forest structure also serves in the PFA.

MANAGEMENT IMPLICATIONS

The denser canopied stands selected by goshawks for nesting typically had at least a mature overstory and a pole-sized (13 - 30 cm dbh) mid-canopy layer (17 of 20 ground measured nest stands), and most of these (13 of 17) were dominated by a multi-layered (3+ layers) vertical structure. In eastern Oregon, the mid-canopy layer has been targeted for thinning because of its density in insect damaged forests. A small component of the mid-canopy should remain in nest stands because of its contribution to total canopy closure and nest stand vertical structure. Also, live, large (> 53cm dbh) trees have been thinned extensively in eastern Oregon as a result of selective harvest practices, particularly overstory removal. I recommend against further loss of trees in this size class within the nest stand in order to prevent shifting the nest stand's composition into the questionably suitable mid-aged forest structure category.

Nest stand size is difficult to quantify consistently because selective timber harvest and natural heterogeneity in eastern Oregon have resulted in stands that are not visually distinct. I delineated stands based on broad CC and tree size class categories, thus one nest stand might contain a north facing mixed conifer forest type and a south facing ponderosa pine forest type together. Given this bias
towards delineating larger stands, my average nest stand size for nests in the dense, late forest structure category (n = 15) was a minimum of 79 ha (some stands extended outside my mapped PFA circles and were not completely measured.) This is a much larger contiguously forested area than the 12-ha nest areas recommended by Reynolds et al. (1992). Woodbridge and Detrich (1994) observed reduced occupancy of nest stands by goshawks as stand size decreased, and suggest that patch size may be related to the quality of nesting habitat. I recommend an emphasis on maintaining the contiguity of larger existing nest stands, rather than fragmentation into smaller patches.

REFERENCES


Chapter 4
SUMMARY

Results from these 2 concurrent studies of goshawk habitat in eastern Oregon confirm the importance of dense, late forest structure at the immediate nest site and stand scale, and provide direction towards describing the goshawk PFA.

The possibility for bias in the current description of goshawk nest site habitat is generally refuted for eastern Oregon by the lack of any clear difference in forest structure around nests associated with method of discovery. Evidence from both of my studies indicate that dense, late forest structure is selected by goshawks for immediate nest site conditions, as past studies have shown. Nevertheless, goshawks do not nest exclusively in dense, late forest structure, and surveys should include younger forest, primarily in higher canopy closure, to maximize results.

Bearing in mind that habitat associations are not necessarily equal to selected habitat by an individual, a number of landscape features were identified as potentially important to goshawks at the PFA scale. Compared with not-used random points containing suitable nest stands, nests were negatively associated with dense, mid-aged forest, and with early forest, although increasing road densities buffered the strength of the negative relationship between nests and early forest. Nests were associated with roads when compared with not-used random points, and were also
associated with dry openings when compared with available random points. A general description of forest structure in 170 ha circles around nests included a mix of conditions, dominated by higher canopy closure, and always containing wet openings.

Dense, late forest structure was important at 12 and 24 ha scales around nests, and its decrease in abundance with distance from the nest was likely to be influenced by the natural, as well as timber harvest related, fragmentation of the landscape. The circular study plot design and a small sample size also limited my ability to validate trends at the larger landscape scales. Future telemetry studies of fledgling habitat use within the PFA should seek to clarify the role of roads, wet and dry openings, early forest patches, and the most suitable proportion of early to late forest structure around nests.
BIBLIOGRAPHY


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