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In recent years, the northern goshawk (*Accipiter gentilis*) has been the center of controversy due to the potential effects of timber harvest practices and silvicultural regimes on goshawk breeding habitat. As a result, landscape-level conservation plans for goshawk habitat were developed in the Pacific Northwest when very little information about landscape-level habitat relationships were actually known. The objectives of this study were to (1) describe goshawk nesting habitat at multiple landscape levels and (2) develop an appropriate multivariate model to predict site suitability for goshawk nesting habitat, based on a comparison of random vs occupied sites.

This study encompassed four study areas in eastern Oregon and Washington. Eighty-two goshawk nests, in which female goshawks incubated eggs, were examined in 1994, and 95 random sites were examined in 1995. Habitat conditions surrounding all nests and random sites were quantified in concentric circles at four landscape levels: (1) 1-ha nest site, (2) 10-ha nest stand, (3) 83-ha theoretical post-fledging area (TPFA), and (4) 170-ha post-fledging area (PFA). Nest site level information consisted of physiographic, vegetative, and structural characteristics. Nest stand, TPFA, and PFA level information consisted of landscape composition and fragmentation metrics obtained from digitized images of habitat surrounding goshawk nests and random sites on 1:12,000 to 1:16,000 aerial photo stereoscopic pairs. Analyses included two-sample t-tests and logistic regression.

Univariate analysis of 1-ha nest site variables indicate that goshawk nests were associated with north facing slopes ($P < 0.001$), low topographic position ($P = 0.0001$), were not distributed

evenly among stages of forest stand development ($P = 0.0002$), had higher average basal area ($40.6\ m^2/ha \pm 1.3$ [SE] vs. $22.2\ m^2/ha \pm 1.1$, $P < 0.0001$), greater canopy closure ($53.1\% \pm 1.7$ vs. $33.2\% \pm 1.7$, $P < 0.0001$), and had larger quadratic mean diameter for trees within the stand (24.1 cm ± 0.6 vs. 20.8 cm ± 0.7, $P = 0.0011$) than random sites. This information confirms findings of other studies on goshawk nest sites throughout the western United States. Logistic regression analysis indicated that the variables that best discriminated between goshawk nests and random sites were indicators for stage of stand development, topographic position, and basal area. The single most important factor for site determination, in my multivariate analysis at the 1-ha landscape level, was basal area. Analysis of the coefficients for the logistic regression model demonstrated that knowledge of the stand's stage of stand development and topographic position did not provide enough information to successfully discriminate between goshawk and random nest sites. Basal area had the only coefficient in the model with a positive association for goshawk nest sites. Thus, given a stage of stand development and topographic position, increasing the site's basal area would increase the likelihood of that site being suitable for goshawk nesting.

Univariate analysis of the nest stand, TPFA, and PFA levels indicated that stand initiation stands were more abundant at random sites at all three levels (nest stand: $P = 0.0011$, TPFA: $P = 0.0016$, PFA: $P = 0.0040$) and high canopy closure (i.e., total canopy closure within a stand $\geq 50\%$) understory reinitiation stands were more abundant at goshawk sites at all three levels (nest stand: $P < 0.0001$, TPFA: $P < 0.0001$, PFA: $P = 0.0001$). Also, Simpson's evenness index was greater at goshawk sites than at random sites, at both the TPFA ($P = 0.0378$) and PFA ($P = 0.0069$) levels. The logistic regression analysis of all variables across the nest stand, TPFA, and PFA levels indicated that four variables at two landscape levels best discriminated between goshawk and random sites at the landscape level. These variables consisted of the percent of high canopy closure understory reinitiation and high canopy closure stem exclusion at the nest stand level, and Simpson's evenness index and the percent of the landscape in stand initiation between 10 and 83 ha. The percent of the landscape between 10 and 83 ha in stand initiation was negatively related with the likelihood for goshawk sites. The amount of high canopy closure stem exclusion and understory reinitiation at the 10-ha nest stand level, however, explained 75% of the deviance in the model indicating that habitat conditions at smaller landscape levels are likely to be more indicative of site suitability for goshawk than habitat characterizations at larger landscape levels. This relationship between habitat conditions at smaller landscape levels and site suitability for breeding goshawks suggests that forest management activities in close proximity to goshawk nests must be carefully evaluated to determine their effects on future site suitability.

Northern Goshawk Habitat Analysis in Managed Forest Landscapes

by

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Michael Thomas McGrath

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INTRODUCTION

The northern goshawk (*Accipiter gentilis*) is a forest-dwelling raptor with holarctic distribution, occupying much of northern North America and the western United States (Johnsgard 1990). The goshawk nests and forages below the forest canopy, preys upon a wide variety of bird and mammal species, and is considered to be a prey generalist (Reynolds et al. 1992, Boal and Mannan 1994, Cutler et al. 1996). However, being a prey generalist does not necessarily equate with being a habitat generalist, and the goshawk appears to be associated with late forest conditions (Reynolds et al. 1992). It has been categorized as a mid- to late-successional forest indicator species for federal lands in the Mid-Atlantic, New England, Mid-Western, Southwestern, and Pacific Northwest states.

Reynolds et al. (1992) recognized three landscape levels that are biologically relevant for goshawk breeding biology: the nest stand, post-fledging area (PFA), and foraging area. According to landscape ecologic theory, as landscape scale increases from nest stand through foraging area, so should landscape heterogeneity (Forman and Godron 1986). To date, only Daw (1997) has estimated the spatial extent to which late forest conditions are associated with goshawk nest sites. Her analysis suggests that dense, late forest conditions are important to nesting goshawks out to approximately 24 ha surrounding the nest.

Debate in recent years has been focused on the deleterious effects timber harvesting has had on goshawk populations (Crocker-Bedford 1990). Crocker-Bedford (1990) found a high correlation between timber harvesting throughout goshawk home ranges and reduced occupancy and reproduction. One of the many repercussions of the Crocker-Bedford (1990) study was the listing of the goshawk as a Category 2 species by the U. S. Fish and Wildlife Service in 1991, indicating that concern about its status was warranted but information was lacking. Additionally, the Northern Goshawk Scientific Committee was formed by the U. S. Forest Service, Southwestern Region, resulting in management recommendations for the northern goshawk in the southwestern United States (Reynolds et al. 1992). Concepts for these guidelines were based on goshawk ecology, prey, and forest pattern. From these guidelines, the nest stand and PFA levels were incorporated into national forest management in eastern Oregon and Washington (U. S. Department of Agriculture 1994).

Until recently, most goshawk habitat research has focused on the conditions surrounding goshawk nests up to approximately 10 ha, i.e., the nest stand level (Hennessy 1978, Reynolds 1978, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski 1987, Hayward and Escano 1989, Lilieholm et al. 1993, Speiser 1993, Bull and Hohmann 1994, Lang 1994, Squires and Ruggiero 1996), whereas very little research has been done on the PFA (Kenward et al. 1993, Bull and Hohmann 1994, Kennedy et al. 1994, Daw 1997). Kennedy et al. (1994) pioneered the delineation of the PFA in North America, finding juvenile goshawk movements, prior to independence, to be correlated with the core area of the adult female. Adult female goshawk core areas averaged 168 ha (SD = 129, n = 5). However, the functional significance of the PFA is still unknown. It may be an area of high prey availability and may provide fledglings with escape cover from predators and concealment while learning to hunt (Reynolds et al. 1992, Kennedy et al. 1994). However, habitat conditions within the PFA were not analyzed prior to Daw (1997) and habitat use within the PFA has yet to be examined.

Daw (1997) examined the habitat surrounding goshawk and random sites in concentric circles from the nest stand level to the 170 ha PFA. Dense, late forest structure (>15 live trees >53 cm DBH per ha, and >50% canopy closure) was significant ($P < 0.1$) to approximately 24 ha around goshawk nests (n = 22). However, her analysis was essentially univariate in nature and could not account for the potential effects other forest conditions may have on habitat conditions within the PFA.

The objectives of my study were to describe goshawk nesting habitat at multiple landscape levels, and to develop a multivariate site suitability model based on the comparison of random vs occupied sites. Through these objectives I hope to better understand goshawk landscape-level habitat associations and the influence of interactions among landscape components on the apparent suitability of sites for nesting goshawks.

STUDY AREA

The study areas were located in eastern Oregon and Washington: central Washington, northeast Oregon, and the Malheur and Fremont National Forests (Fig. 1). Goshawk nests occurred in a variety of forest types and landscape conditions on lands administered by state and federal agencies, as well as those owned by private timber companies.

Central Washington

The central Washington study area consisted of forested lands on the eastern slope of the Cascade mountains surrounding Cle Elum, Washington and was managed by the Cle Elum Ranger District of the Wenatchee National Forest, Washington Department of Natural Resources, Plum Creek Timber Company, and Boise Cascade Corporation. Topography ranged from greatly undulating to moderately hilly. Elevations ranged between 600 and 1800 m. Due to its proximity to the Cascade crest, this study area received an average of 500 mm precipitation per year and encompassed a diversity of conifer species and forest associations, including Pacific silver fir (*Abies amabilis*), subalpine fir (*A. lasiocarpa*), grand fir (*A. grandis*), western larch (*Larix occidentalis*), Engelmann spruce (*Picea engelmannii*), white pine (*Pinus monticola*), lodgepole pine (*P. contorta*), ponderosa pine (*P. ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*) (Franklin and Dyrness 1973). Silvicultural practices varied from even-aged management techniques near the Cascade crest, to uneven aged management techniques (i.e., overstory removal and group selection) on drier, flatter sites.

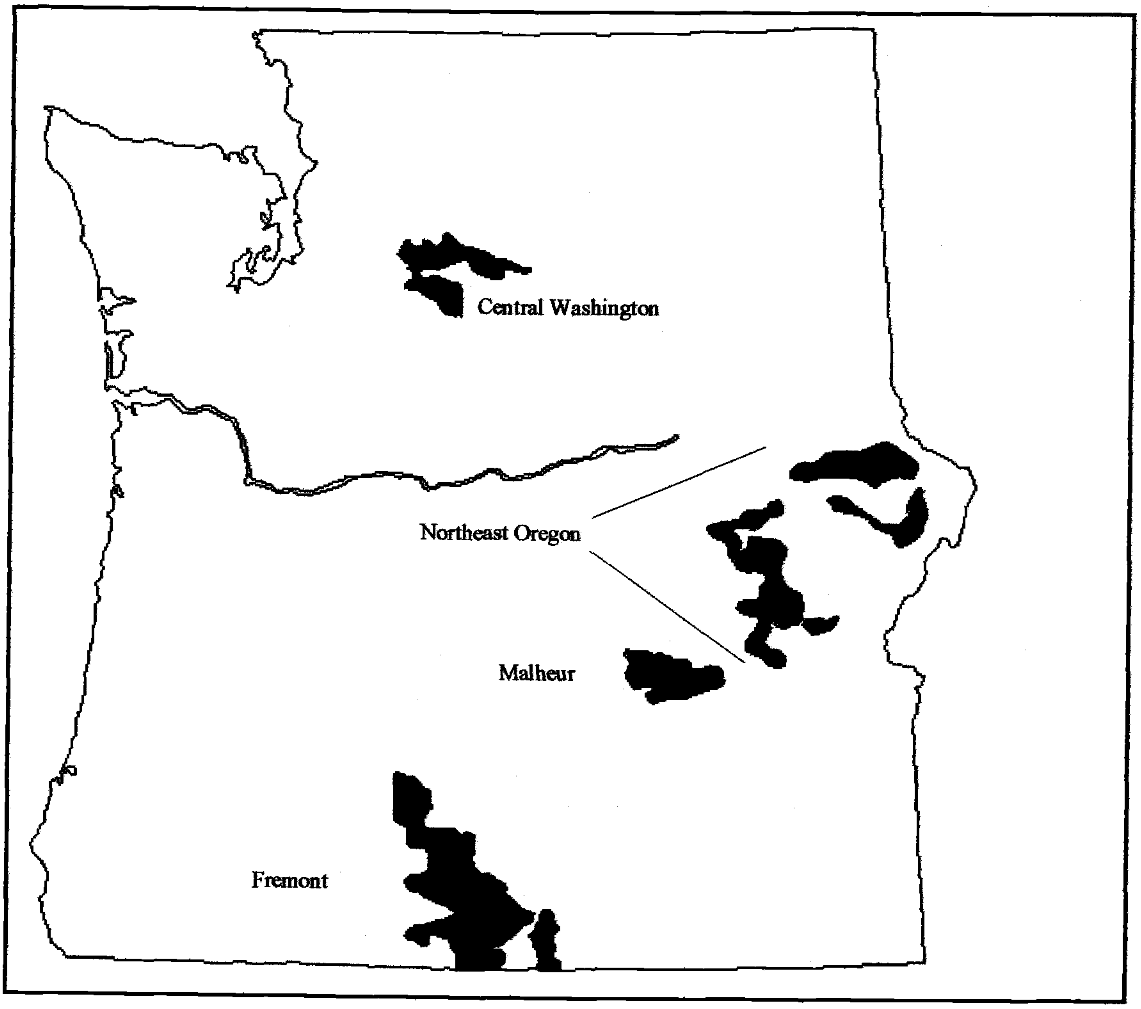

Figure 1. Location of four study areas in eastern Oregon and Washington from which goshawk nests and random sites were sampled, 1994-1995.

Northeast Oregon

This study area included lands administered by the Wallowa-Whitman National Forest, Boise Cascade Corporation, and R-Y Timber lands in northeastern Oregon. This region included several mountain ranges separated by faulted valleys and synclinal basins, causing highly variable topographic relief, from moderate to steep slopes. A mosaic of forest stands occurred throughout this study area's elevational range (between 500 and 2900 m), due to the approximately 400 mm of precipitation it received annually (Franklin and Dyrness 1973). Several of the climax plant communities within northeast Oregon include ponderosa pine, lodgepole pine, grand fir, subalpine fir, and an abundance of mixed conifer stands (e.g., ponderosa pine, Douglas-fir, grand fir, and western larch). Silvicultural practices included a variety of even-aged (e.g., clear cut and shelterwood harvests) and uneven-aged (e.g., thinning from below, overstory removal, group selection) management techniques.

Malheur

The Malheur study area was located on the Bear Valley Ranger District of the Malheur National Forest, immediately south of John Day, Oregon. Elevations ranged between 1300 and 2000 m, with a topography typified by hills and moderately steep drainages. This study area received approximately 350 mm of precipitation annually and supports a mixture of forest types, including ponderosa pine, Douglas-fir, grand fir, western larch, lodgepole pine, mixed conifer stands, and mountain-mahogany (*Cercocarpus ledifolius*) (Franklin and Dyrness 1973). Additionally, the Malheur study area surrounds a large open valley (23,500 ha) (Daw 1997). Silvicultural practices are typified by uneven-aged management techniques (e.g., overstory removal and group selection).

Fremont

This study area included the Fremont National Forest and surrounding lands owned by Weyerhaeuser Corporation in southcentral Oregon (Fig. 1). This area is characterized by fault-blocked mountains and elevations ranging between 1200 and 2500 m. Much of the area has rolling topography with low relief. Precipitation averaged approximately 350 mm annually and is capable of supporting a diversity of tree species, including ponderosa pine, sugar pine (*P. lambertiana*), lodgepole pine, Douglas-fir, grand fir, white fir (*A. concolor*), and incense cedar (*Calocedrus decurrens*) (Franklin and Dyrness 1973). Silvicultural practices were typified by even-aged (i.e., clear cuts) and uneven-aged (e.g., group selection harvests) management practices.

METHODS

This study employed a use versus availability design similar to that of Marcum and Loftsgaarden (1980) to test the general hypothesis that goshawk breeding habitat does not differ from what is available at multiple landscape levels.

The null hypotheses were tested by comparing active goshawk nesting habitat with random sites at biologically relevant landscape levels for goshawk reproduction. Those levels consisted of nest-centered concentric circles including a 1 ha nest site (hereafter 1-ha level), 10 ha nest stand (hereafter 10-ha level) (Reynolds et al. 1992), 83 ha theoretical post-fledging area (TPFA), and a 170 ha post-fledging area (PFA) (Kennedy et al. 1994).

To offset possible environmental differences between the Inland Northwest and New Mexico, where current estimates for goshawk PFA's have been derived (Kennedy et al. 1994), the 83 ha TPFA was created based on the relationship of body mass to home range size (Holling 1992). Following Kennedy et al.'s (1994) derivation of a goshawk PFA, the TPFA was considered to be the core area of a breeding female goshawk's home range. Since telemetry data were not available for my study area, the average weight of 103 female goshawks (Dunning 1984) was used to calculate the theoretical home range size for a breeding female goshawk (Holling 1992:473). Once the theoretical home range was calculated, it was then multiplied by 0.318, the relationship of core area to home range size in Kennedy et al.'s (1994:78) study, to yield the TPFA.

Nests and Random Points

Goshawk nests (n = 82) were located by Oregon Cooperative Wildlife Research Unit, Washington Department of Wildlife, U. S. Forest Service, timber industry, and project personnel in the four study areas (Table 1). Each nest was known to have been used by an incubating female goshawk in 1994. Active goshawk nest sites included in this study were obtained through various methods, including searches of historic nest sites utilizing Kennedy and Stahlecker's (1993) protocol survey, protocol searches of extensive land tracts (DeStefano et al. 1994, Finn 1994, Daw 1997), forest stand exams, and incidental discoveries by forest workers. Of the 82 nests, 8 failed to fledge young and the reproductive status of 4 nests was unknown.

Available landscape habitat, to be used in comparisons with goshawk nesting habitat, was selected by distributing 95 universal transverse mercator (UTM) coordinate pairs, generated by a simple random sample, evenly across the 4 study areas (Table 1). These locations were selected for sampling on the following criteria: (1) that the entire landscape sample fall within a managed landscape (i.e., non-wilderness), (2) that the UTM coordinate pair fall within a forested stand, and (3) that no overlap occur at the 170-ha landscape level with other random points. Additionally, the selected locations had to occur on lands managed by a project cooperator so that project personnel could gain access to the sites. Locations not meeting these requirements were discarded and replaced with a new set of random coordinates. Random points were treated identically to nest sites, in terms of data collected and collection methods, with the exception of 5 random points in which the 1-ha level fell in recent clearcut plantations. At these sites, 1-ha level data was not collected. However, site conditions and other landscape-level data were collected. Habitat variables at goshawk nest sites and random sites were quantified in 1994 and 1995, respectively.

One-hectare Level Characteristics

Goshawk and random 1-ha sites were quantified in the field by their general physiographic, vegetative, and structural characteristics within 1 ha of the nest tree or UTM

Table 1. Number of northern goshawk nests and random sites by study area in eastern Oregon and Washington, 1994-1995.

	Study Area			
	Central WA	Northeast OR	Malheur	Fremont
Nest Sites	14	27	20	21
Random Sites	20	25	25	25

coordinate pair. Random point UTM coordinates were located to within 15 m in the field using a Garmin GPS40™ global positioning system (Garmin International 1994).

Physiographic Characteristics

Physiographic information collected in the field at the 1-ha level included elevation, aspect, slope, topographic position, and proximity to forest change, water, and human disturbance. Changes in forest type occurred if an opening ≥0.1 ha was encountered or a forest stand exhibited a change in dominant tree species composition, ≥20% change in canopy closure, or a change in the stage of stand development (Oliver and Larson 1990). Human disturbance is defined here as a change in 1-ha level conditions of anthropogenic origin (e.g., forest roads, recent silvicultural practices, and human habitations). I obtained elevation and proximity to water from USGS 7.5' topographic maps. In the field, I measured aspect with a compass and percent slope with a clinometer, and I categorized topographic position into 1 of 6 positions: ridge top, upper 1/3 of the slope, middle 1/3, lower 1/3, drainage bottom, or flat. Proximities to forest change and human disturbance were obtained either in the field or from recent 1:12,000 - 1:16,000 aerial photographs.

Vegetative and Structural Characteristics

Vegetative and structural characteristics sampled at each nest site included forest type, stage of stand development (SSD) (after Oliver and Larson 1990), stand age, canopy closure, basal area, live stem density, quadratic mean diameter, and stand density index (Reineke 1933). Vegetation within the 1-ha level was classified into 1 of 5 forest types based on prevalent tree species: (1) ponderosa pine (*Pinus ponderosa*) (ponderosa pine >50%, other tree spp. <10%), (2) mixed conifer/ponderosa pine (10-50% ponderosa pine), (3) mixed conifer (ponderosa pine < 10%), (4) lodgepole pine (*Pinus contorta*) (lodgepole pine >50%, other tree spp. <10%), and (5) other (none of the prior categories). One-hectare level structure was categorized according to Oliver and Larson's (1990) four stages of stand development (i.e., stand initiation, stem exclusion, understory reinitiation, old growth). Following Oliver and Larson's (1990:143) definitions, stand initiation is characterized by young trees of various species following a disturbance. Stem exclusion is characterized by the absence of seedlings and saplings, the onset of self-thinning throughout competition, and the beginning of crown class differentiation into dominant and subordinant species (e.g., Smith 1986:49). Understory reinitiation is characterized by the colonization of the forest floor by advanced regeneration and the continuation of competition in the overstory. Old growth is characterized by the senescence of overstory trees in an irregular fashion and the growth of the understory trees to the overstory (Appendix 1). Stand age was determined as the average number of growth rings from an increment core taken at breast height, obtained from 5 dominant and 5 codominant trees within the 1-ha level, following Smith's (1986:49) definitions for dominance and codominance.

Data for canopy closure, basal area, live stem density, quadratic mean diameter, and stand density index were collected using a nest-centered concentric hexagonal sampling design within the 1-ha level (Fig. 2). The sampling design consisted of 7 nested plots, 18 fixed-radius plots, and 18 sampling points. Nested plots were composed of a variable-radius plot for basal area, an 80 m^2 fixed-radius plot to tally and record diameter at breast height (DBH) for all live trees $\geq$2.54 cm DBH and $\geq$1.22 m tall, and a sample point to record canopy closure. Fixed-radius plots were 80 m^2 in area and used to tally and record DBH for all live trees and included a sample point to record canopy closure. At each of the 18 individual sample points only canopy closure was recorded (Fig. 2).

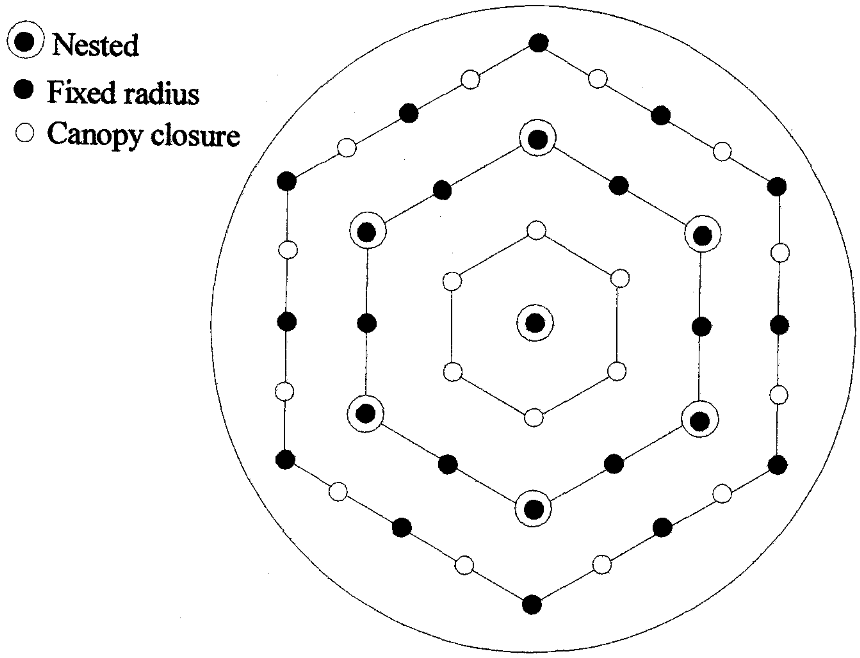

Figure 2. Goshawk 1-ha level sampling design. Distances from nest-centered plot to first, second, and third hexagons were 17, 34, and 51 m, respectively. Live stem density, diameter at breast height, and canopy closure were measured at fixed-radius plots. Nested plots include basal area in addition to fixed-radius plot variables. Canopy closure was measured at all plots.

Canopy closure was estimated at 43 plots within the 1-ha level (Fig. 2) with a moosehorn (Garrison 1949, Bonnor 1967, Bunnell and Vales 1990) constructed of polyvinyl-chloride pipe, with a 25 dot matrix imposed on plexiglass on one end. A moosehorn was used, rather than spherical densiometers, because the latter over-estimate canopy closure (Bunnell and Vales 1990, Cook et al. 1995). Basal area estimates were obtained at the 7 variable-radius plots using a 20 basal area factor prism. Live stem density (LSD), the number of live trees $\geq$2.54 cm DBH and $\geq$1.22 m tall, was estimated from the 25 fixed-radius plots. Quadratic mean diameter (DBH_Q) for each 1-ha level was calculated from the diameters obtained at the fixed-radius plots.

Reineke's (1933) stand density index (SDI) is an expression of the relationship between mean tree size and density (trees/ha) within a forest stand (Long 1985). This relationship has been shown to predict density-dependent mortality for several tree species associated with Yoda et al.'s (1963) "self-thinning rule." As such, SDI provides a basis for understanding the competitive interactions within a stand (Long 1985) that may be relevant to goshawk habitat selection. Stand density index for each 1-ha level was calculated (after Reineke 1933) as:

$$SDI = LSD(DBH_Q/25)^{1.6}$$

Stand density index has also recently been used to illustrate stand management prescriptions for growing and maintaining nest sites with SDI's for goshawk nest sites in Idaho (Lilieholm et al. 1994).

Landscape Characteristics

I used mirror stereoscopes with magnification capabilities and the most recent (1988 - 1994) color and black-and-white aerial photograph stereoscopic pairs (1:12000 - 1:16000 scale) to delineate forest stands within the 170-ha PFA level for goshawk nests and random points. Stands were categorized into 1 of 9 succession-based habitat categories (sensu Oliver and Larson

1990) including stand initiation, high canopy closure (i.e., total stand canopy closure ≥ 50%) stem exclusion (hereafter high stem exclusion), low canopy closure (i.e., total stand canopy closure < 50%) stem exclusion (hereafter low stem exclusion), high canopy closure understory reinitiation (hereafter high understory reinitiation), low canopy closure understory reinitiation (hereafter low understory reinitiation), old growth, wet openings, dry openings, and water. Criteria for stand delineation included crown diameters, number of visible canopy layers, diversity of crown diameter classes, and canopy closure (Appendix 2) (Paine 1981). Minimum stand size, due to photograph scale, was 2.02 ha. Polygon overlays of the photographs were digitized using Tosca software, corrected for photographic distortion using control points obtained from USGS 7.5' topographic maps, and stored in an Idrisi database with 1 m pixel size.

Ground Truthing

Upon completion of stand typing within a study area, a 10% simple random sample of each of the 9 habitat categories was ground truthed to assess classification accuracy and to obtain structural characteristics for each category. Classification accuracy is defined as the percent agreement between aerial photograph classifications and ground measurements for stands in each habitat category. Ground measurements provided a mean and 95% Confidence Interval for variables describing each category. Personnel conducting the ground truthing had no *a priori* knowledge of any stand's classification membership and assessed the structural development of each stand after considering the stand's vertical stratification, herbaceous development, evidence of competition, and advance regeneration (Oliver and Larson 1990). Plots were systematically placed along a single straight line transect aimed at capturing maximum diversity within a stand. Plots alternated between nested and fixed-radius plots, with a minimum of 50 m between nested plots. Nested plots consisted of a variable and fixed-radius plot. At variable-radius plots, DBH and crown class (Smith 1986:49) for all trees, live and dead, detected with a 20 basal area factor prism were recorded. Fixed-radius plots were 80 m^2 in area and used to assess the presence of advance regeneration.

Early ground truthing efforts in the northeast Oregon study area indicated that many of the stands classified as either high or low stem exclusion were in fact wrong, due to the effects of a western spruce budworm (*Choristoneura occidentalis*) epidemic that peaked in 1991. Many stands in these two categories had either been set back successionally, to stand initiation, or enough gaps in the canopy had been created to accelerate succession to understory reinitiation. After overlaying nest and random point locations on U. S. Forest Service "Insect and Disease Activity Maps" (Johnson 1995), I determined that 71% (n = 37) of all nests and random points in northeastern Oregon had been affected to some degree by the spruce budworm infestation since 1988. Coincidentally, 67% (n = 35) of the aerial photographs used were from 1987 - 1991. Hence, these photos could not reliably depict existing forest conditions where forest stands were most susceptible to spruce budworm infestation. Those stands deemed susceptible to infestation, due to physiologic stress and overstocking (Hessburg et al. 1993) were most likely undergoing self-thinning (i.e., stem exclusion). As a result, I walked through every stand classified as either high or low stem exclusion in northeast Oregon (n = 166) and assigned a habitat classification only after visual inspection on the ground.

Landscape Variables

I collected information on 14 variables at the 10-ha, TPFA, and PFA landscape levels, including the 9 habitat categories and 5 fragmentation metrics (Table 2). Values for each variable were generated by the program FRAGSTATS 2.0 (McGarigal and Marks 1994) run on an Idrisi image of each landscape level for each goshawk nest and random point. Values for the percent of

Table 2. Fragmentation metrics calculated from Fragstats 2.0 (McGarigal and Marks 1994) for 10, 83, and 170 ha landscape levels surrounding goshawk nests and random points in eastern Oregon and Washington, 1994-1995.

Fragmentation Metric	Definition
CWED[a]: structure	The sum of the lengths of each edge segment in the landscape multiplied by the corresponding contrast weight for forest structure, divided by total landscape area.
CWED: canopy closure	Same as above with weights based on canopy closure.
Mean nearest neighbor	Average distance to the nearest neighboring stand of the same type, across all types, for those stand types with a neighbor of the same type.
Simpson's evenness index	A measure of the proportional abundances of forest structural categories present in the landscape.
Contagion	A measure of the proportional abundances of each stand type and their interspersion and juxtaposition in the landscape.

[a]Contrast-weighted edge density (McGarigal and Marks 1994).

the landscape exhibiting each habitat category were derived from the class-level statistics variable %LAND (FRAGSTATS 2.0; McGarigal and Marks 1994). McGarigal and Marks (1994) provide formulas for calculation of each fragmentation metric. Appendices 3 and 4 list the values of the contrast weights for both the forest structure and canopy closure contrast-weighted edge density (CWED) fragmentation metrics, respectively. Due to the homogeneous nature of the 10-ha level, the 5 fragmentation metrics were not included in its analysis.

Univariate Analyses

Two-sample t-tests (Zar 1984:126) were used to test continuous variables at all levels for preference by goshawks. Circular data (i.e., aspect) at the 1-ha level were analyzed using the Rayleigh test (Batschelet 1981), which tests for nonrandomness or directedness, and a two-sample testing of angles (Zar 1984:446) to test for differences between nests and random points. The mean angle, angle deviation, and length of the mean vector were calculated. Each variable was screened for normality and homogeneity of variance and transformed when necessary. I transformed variables that did not meet assumptions of equal variances or normality using log, square root, and arcsine square root transformations prior to conducting t-tests. I used an alpha level of ≤ 0.10 to denote statistical significance. Because there was no difference in the results of transformed and untransformed data, all results presented are from untransformed data, unless otherwise noted.

For categorical 1-ha level variables, stage of stand development, forest type, and topographic position, I tested the hypothesis that goshawks select 1-ha level habitat in proportion to its availability through the use of a chi-square test of homogeneity (Marcum and Loftsgaarden 1980). If the null hypothesis was rejected, selection was determined for an overall alpha of 0.10; a Bonferroni approach for determining simultaneous confidence intervals ($\alpha = 0.05$) was used to evaluate selection (Marcum and Loftsgaarden 1980). All univariate tests were performed with the program SAS (SAS Institute Inc. 1988).

Multivariate Analyses

This study employed two types of multivariate analyses, principal components analysis (PCA) and logistic regression. Principal components analysis was used to aid in the description of the habitat characteristics associated with each forest stand type for the landscape data. Logistic regression was used to model habitat variables, at multiple landscape levels, that best distinguished nests from random sites. Logistic regression was used rather than discriminant analysis for several reasons: it does not require the assumption of multivariate normality (Press and Wilson 1978), and it allowed me to analyze first-order interactions among significant main-effect variables, test for study area effects, and to analyze first-order interactions among main effects and study areas to account for geographic differences in the main effect variables.

Principal components analysis is a statistical technique applied to a single set of variables in order to discover which variables in the set form coherent subsets that are relatively independent of one another. Variables that are correlated with one another, but largely independent of other subsets of variables, are combined into components. These components may reflect underlying processes that have created the correlations among variables (Tabachnick and Fidell 1989). Principal components analysis results in a loading matrix, which reflects the correlations between observed variables and individual components. The magnitude of the loadings reflects the extent of the relationship between each observed variable and each component. Each component is then interpreted from the loading matrix by determining which variables correlate with each component through an assessment of the association each variable has with the component (i.e., examining the variable's loading). As a rule of thumb, only variables with loadings ≥ 0.30 are interpreted (Tabachnick and Fidell 1989:640). My objective for using PCA was to reduce a large number of observed variables to a smaller subset. Thus, the first principal component, from a PCA of the habitat characteristics for each forest stand type, was interpreted for a description of the forest stand types. The first principal component was selected for interpretation because it explains the greatest amount of variation in the data set (Tabachnick and Fidell 1989).

Logistic regression analysis describes how a binary response variable is associated with a set of explanatory variables (i.e., habitat variables). In my study, the binary response was 1 for goshawk nests and 0 for random sites. The mean of a binary response results in a probability (Hosmer and Lemeshow 1989). Therefore, a logistic regression model specifies that a probability is related to a regression function of explanatory variables. The fitted multiple logistic response function is estimated as

$$\hat{\pi} = \frac{e^{(\beta_0 + \sum_{j=1}^{p} \beta_j x_j)}}{1 + e^{(\beta_0 + \sum_{j=1}^{p} \beta_j x_j)}},$$

where the response variable, π, is the estimated probability that a site is suitable for goshawk nesting, and the estimated regression coefficients are β_0 for the intercept and β_j for the independent variables x_j, for $j = 1, ..., p$ habitat variables. The response variable π can be practically interpreted as an estimated percent (Hosmer and Lemeshow 1989). The process for constructing a logistic regression model is similar to that for ordinary regression models in that there is a need to judge the adequacy of a reduced model to that of a full model. In logistic regression, this is done through a drop-in-deviance test. This test is based on a sum of squared residuals from the reduced model minus the sum of squared residuals from the full model. The sum of squared residuals is called the deviance residual (Ramsey and Schafer 1997). If the reduced model is adequate, then the drop-in-deviance has a χ^2 distribution with n degrees of freedom (hereafter d.f.) (Hosmer and Lemeshow 1989). Thus, *P*-values for significance tests using the drop-in-deviance test are obtained from the χ^2 distribution (Hosmer and Lemeshow 1989). Once the model has been constructed, the coefficients for individual variables are interpreted in terms of statements about odds and odds ratios. Odds ratios are estimated as $\exp(\beta_j)$, where β_j is the coefficient for variable x_j, and can be practically interpreted as the increase in the odds of the response variable (i.e., goshawk nesting) with a unit increase of a specific habitat variable, keeping other habitat variables constant.

Before analysis of the 1-ha level, categorical data were combined to conserve degrees of freedom. Due to a zero cell occurring in the stand initiation category of stage of stand development for goshawk nest sites, the stand initiation and stem exclusion categories were combined to offset difficulties with logistic regression when a zero cell occurs in categorical data (Hosmer and Lemeshow 1989:84). Additionally, the continuous variable aspect was converted into 8 directional categories (i.e., N, NE, E, SE, etc.) based on the azimuth for the 1-ha level site. Using logistic regression, categorical variables such as aspect (i.e., topographic position and forest type) were reduced from multiple indicator variables to a single indicator variable that is both consistent with the categorical variable's structure and highly related to selection by goshawks through a categorical variable reduction method described by Ramsey et al. (1994:194). This process entails using a logistic regression which includes all indicator variables for the factor (e.g., 7 for aspect), creates all possible indicator variables which are a linear combination of the categories (e.g., 255 for aspect which has 8 categories), and uses logistic regression on each linear combination and assesses the drop in deviance of each reduced model. The linear combination that has the greatest reduction in model deviance and has a small remainder deviance from the full model (e.g., 7 variable model for aspect), in relation to its degrees of freedom, is the variable to use in place of the full model for the particular factor (Ramsey et al. 1994).

Models

Several logistic regression models were constructed to differentiate between available habitat and habitat associated with goshawk nests. These models include (1) a 1-ha level model, based on the vegetation data collected at the nest site, (2) a 10-ha level model, based on the successional habitat categories occurring within the 10 ha circle, (3) an 83 ha TPFA circle model, based on the habitat categories and fragmentation metrics within the 83 ha circle, (4) a 170 ha PFA circle model, based on the habitat categories and fragmentation metrics within the 170 ha circle, (5) a ring model, which models the habitat conditions within the 10-ha level, habitat for the TPFA occurring between 10 and 83 ha (hereafter TPFA ring), and habitat for the PFA occurring between 83 and 170 ha (hereafter PFA ring) (Fig. 3), and (6) a validation model, similar to the ring model, but constructed from 90% of the data after a 10% random sample of the nest and random sites were removed.

The "ring" analysis, put forth in models 5 and 6, is a new concept in spatial modeling using logistic regression, as described by Ramsey et al. (1994:201). Through the use of variables calculated for the ring of a circle, rather than the circle itself, the values for each variable represent values for nonoverlapping levels (Fig. 3). Hence, the values for each variable located within a ring (e.g., TPFA ring) are independent of the next smaller landscape circle (e.g., 10-ha level in this example). Therefore, through the addition of variables from subsequent rings to the base circle (i.e., the 10-ha level), the significance of a variable from a larger level can be separated from

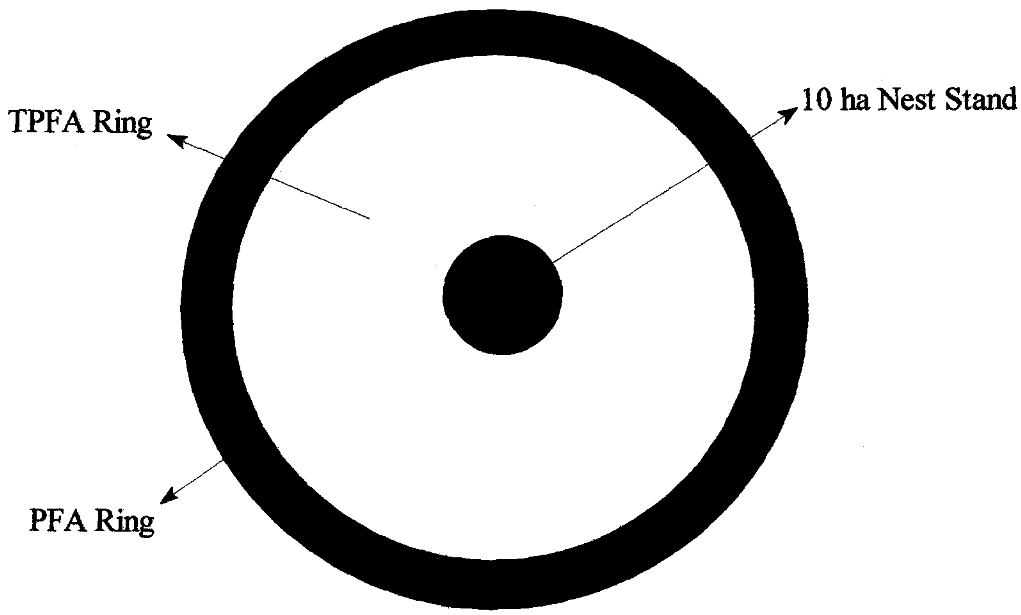

Figure 3. Landscape depiction of the ring and validation models using concentric habitat rings surrounding goshawk nests and random points in eastern Oregon and Washington, 1994-1995. For the TPFA ring, values for each variable were calculated for the region between 10 and 83 hectares. For the PFA ring, values were calculated for the region between 83 and 170 hectares.

its correlation with its counterpart at the smaller level. Thus the spatial extent to which an organism is associated with a particular variable can be estimated (Ramsey et al. 1994).

Model Construction

To reduce the number of variables in the analysis, transformed variables were screened for inclusion using a two-sample t-test at each landscape level. Variables whose *P*-value was ≤ 0.25 were retained for the multivariate analysis. An $\alpha \leq 0.25$ was used because more restrictive levels may fail to identify potentially important variables (Hosmer and Lemeshow 1989:86). Variables were then screened for correlation. Highly correlated variables ($r > \pm 0.70$) were analyzed using univariate logistic regression, and the variable that explained more deviance was retained for the multivariate analysis. Simple linear regression was used to describe the relationship between highly correlated variables. Logistic regression with a "manual" stepwise procedure was used on the remaining untransformed variables for all models except the ring and validation models. A "manual" forward selection procedure, constructing the model from the nest stand level outwards, was used for the multi-level ring and validation models, adding variables from each successive ring after controlling for variables at smaller landscape levels (Ramsey et al. 1994). For a variable to enter a model (e.g., forward selection or forward step in stepwise selection), results of a drop-in-deviance test required a *P*-value ≤ 0.10. For a variable to leave the model (e.g., reducing the model or backward step in stepwise selection), results of a drop-in-deviance test required a *P*-value > 0.10.

Mahrt and Smith (in review) have indicated that traditional stepwise techniques have several problems associated with them. These include potential exclusion of influential variables, inclusion of unnecessary variables, instability of any given subset, and selection of an artificial subset (i.e., variables that appear good on the basis of significance levels to enter and remain in a model, but are not biologically interpretable). For these reasons, "manual" procedures were used to control selection of borderline significant variables for biological interpretation.

After the significant main-effects for each model were determined, a test for study area effects was performed by attempting to add the three indicator variables for study area simultaneously to the model. If a study area effect was detected (i.e., $P \leq 0.1$ from a drop-in-deviance test), the previously described variable reduction method for categorical data (Ramsey et al. 1994:194) was used on the study area indicators, while controlling for the significant main-effects. As a result, divergent habitat conditions among study areas could be determined, based on the data. I then expanded the model to include all first-order interactions among the significant main-effects and study area indicator variables. The drop-in-deviance test was used to determine if any interactions or group of interactions explained a significant amount of model deviance. Only those interactions which significantly reduced model deviance (i.e., $P \leq 0.1$) were retained in the model.

To evaluate the classification accuracy of the resulting ring model, a validation model was constructed from a 90% random sample of nest and random sites. The resulting model's classification accuracy was then evaluated based on its classification of the remaining 10% of the data withheld from construction of the validation model (Verbyla and Litvaitis 1989).

RESULTS

Map Accuracy Assessment

Across 9 habitat categories, classification accuracy via photo interpretation averaged 76.1% (Table 3). Classification accuracy ranged from 44 - 100%. Among forest stages, accuracy was highest for low understory reinitiation and lowest for high understory reinitiation. Twenty-six percent of the high understory reinitiation stands were misclassified as low understory reinitiation based on canopy cover (Table 3). Old growth was misclassified 50% of the time, either as low understory reinitiation (33%) or as high understory reinitiation (17%). Structural characteristics for the forested stand types are located in Tables 4 - 6. Descriptive statistics (i.e., mean, SE, 95% C.I.) for total basal area, stand quadratic mean diameter, basal area by crown class, and tree frequency by diameter class indicated that there was a great deal of overlap among the structural categories.

Analysis of the first principal component for each of the forest habitat categories (Table 7), for descriptive purposes, elucidates some of the differences among the categories. Habitat characteristics associated with stand initiation stands, at the landscape level, included DBH_Q, total basal area, basal area for dominant/codominant trees, and the number of trees in the 0 - 12.7 cm and >25.4 cm diameter classes (Table 8). Variables associated with high stem exclusion stands included DBH_Q, basal area for dominant/codominant trees, and the number of trees in the 38.11 - 63.5 cm diameter classes (Table 8). The number of trees $\leq$12.7 cm was not associated with high stem exclusion stands (Table 7). Low stem exclusion variables consisted of DBH_Q, total basal area, basal area for dominant/codominant trees, and the number of trees in the 25.41 - 63.5 cm diameter classes (Table 8). The number of trees in the $\leq$12.7 cm diameter class was not associated with low stem exclusion stands (Table 7). Variables associated with high understory

Table 3. Accuracy matrix for habitat categories delineated on 1988-1994 color and black-and-white, 1:12,000 - 1:16,000 scale aerial photographs of goshawk nests and random sites in eastern Oregon and Washington. Accuracy was based on a random sample of ground measured stands representing approximately 10% of the stands in each category. All stands classified as water were correctly classified.

Aerial photograph categories	No. stands sampled	Ground Measurement: Stand initiation	High[a] stem exclusion[b]	Low[a] stem exclusion[b]	High understory reinitiation	Low understory reinitiation	Old growth	Wet openings	Dry openings
Stand initiation	16	0.75	0.00	0.19	0.00	0.06	0.00	0.00	0.00
High stem exclusion	30	0.00	0.70	0.17	0.10	0.03	0.00	0.00	0.00
Low stem exclusion	17	0.00	0.06	0.65	0.17	0.12	0.00	0.00	0.00
High understory reinitiation	39	0.00	0.15	0.10	0.44	0.26	0.05	0.00	0.00
Low understory reinitiation	49	0.00	0.00	0.12	0.02	0.86	0.00	0.00	0.00
Old growth	6	0.00	0.00	0.00	0.17	0.33	0.50	0.00	0.00
Wet openings	11	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Dry openings	22	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.95

[a]The terms "high" and "low" refer to total percent canopy closure within a stand, ≥50% and <50%, respectively.

[b]Due to insect infestations in the Northeast Oregon study site, all high and low stem exclusion stands (n = 61 and 22, respectively) were classified on the ground and are correctly classified. These stands are not included in the accuracy assessment.

Table 4. Structural characteristics of forested stand types surrounding goshawk nests and random sites in eastern Oregon and Washington, 1994-1995. Developed from a 10% random sample of each stand type.

Forest stand type	n	Basal Area (m^2/ha)			Quadratic Mean Diameter (cm)		
		Mean	SE	95% CI	Mean	SE	95% CI
Stand initiation	13	2.26	0.97	0.15 - 4.37	16.53	4.25	5.61 - 27.45
High[a] stem exclusion	22	27.32	1.93	23.31 - 31.33	29.44	1.73	25.85 - 33.03
Low[a] stem exclusion	27	19.04	1.26	16.45 - 21.64	30.87	1.72	27.33 - 34.41
High understory reinitiation	25	29.43	1.78	25.75 - 33.10	39.30	1.83	35.54 - 43.07
Low understory reinitiation	62	17.53	1.01	15.52 - 19.55	37.50	1.48	34.53 - 40.47
Old growth	5	39.86	5.37	24.96 - 54.76	53.66	5.56	38.21 - 69.11

[a]The terms "high" and "low" refer to the total percent canopy closure within a stand, ≥ or <50%, respectively.

Table 5. Basal area (m^2/ha) by crown class for forested stand types within 170 ha of goshawk nests (n = 82) and random sites (n = 95) in eastern Oregon and Washington, 1994-1995. Determined from a 10% random sample of each stand type.

		Dominant/Codominant			Intermediate			Suppressed		
Forest stand type	n	Mean	SE	95% CI	Mean	SE	95% CI	Mean	SE	95% CI
Stand initiation	13	1.70	0.76	0.03 - 3.36	0.14	0.14	0 - 0.45	0.42	0.25	0 - 0.96
High[a] stem exclusion	22	16.99	1.83	13.18 - 20.79	7.23	1.15	4.85 - 9.61	3.10	0.51	2.04 - 4.16
Low[a] stem exclusion	27	13.27	1.13	10.94 - 15.59	4.38	0.54	3.27 - 5.49	1.39	0.33	0.71 - 2.08
High understory reinitiation	25	21.23	1.44	18.26 - 24.21	4.85	0.85	3.09 - 6.61	3.34	0.62	2.06 - 4.62
Low understory reinitiation	62	12.67	0.72	11.24 - 14.11	3.38	0.41	2.57 - 4.19	1.48	0.27	0.94 - 2.03
Old growth	5	27.18	4.05	15.94 - 38.43	9.55	1.85	4.41 - 14.69	3.12	1.25	0 - 6.60

[a]The terms "high" and "low" refer to the total percent canopy closure within a stand, ≥ or <50%, respectively.

Table 6. Number of trees per diameter class category per hectare for forested stand categories surrounding goshawk nests and random sites in eastern Oregon and Washington, 1994-1995. Determined from a 10% random sample of each stand type. Number of trees per hectare calculated for the midpoint of each diameter class. For the 63.51+ cm category, number of trees per hectare was calculated for the median of the diameter distribution, of the 63.51+ cm diameter class, for each forest stand type.

		0 - 12.70 cm			12.71 - 25.40 cm			25.41 - 38.10 cm		
Forest stand type	n	Mean	SE	95% CI	Mean	SE	95% CI	Mean	SE	95% CI
Stand initiation	13	334.56	149.90	7.96 - 661.16	24.78	14.20	0 - 55.72	1.78	1.21	0 - 4.42
High[a] stem exclusion	22	1288.31	261.98	743.48 - 1833.13	283.97	33.03	215.28 - 352.66	104.82	18.55	66.24 - 143.40
Low[a] stem exclusion	27	694.96	192.49	299.29 - 1090.64	200.63	26.29	146.59 - 254.67	71.06	8.85	52.87 - 89.25
High understory reinitiation	25	614.70	153.72	297.43 - 931.96	217.79	27.16	161.72 - 273.85	96.96	8.36	79.71 - 114.21
Low understory reinitiation	62	488.71	90.32	308.10 - 669.32	168.23	17.74	132.75 - 203.71	54.58	4.43	45.71 - 63.44
Old growth	5	289.95	183.38	0 - 799.10	238.40	61.63	67.28 - 409.53	102.06	39.91	0 - 212.87

Table 6. continued.

Forest stand type	n	38.11 - 50.80 cm Mean	SE	95% CI	50.81 - 63.50 cm Mean	SE	95% CI	63.51+ cm Mean	SE	95% CI
Stand initiation	13	0.46	0.46	0 - 1.45	0.55	0.55	0 - 1.75	0.30[b]	0.30	0 - 0.95
High stem exclusion	22	26.40	4.75	16.54 - 36.27	6.10	2.00	1.95 - 10.26	3.05[c]	0.75	1.50 - 4.61
Low stem exclusion	27	20.63	3.84	12.73 - 28.54	5.09	1.16	2.70 - 7.49	2.35[d]	0.77	0.76 - 3.94
High understory reinitiation	25	37.40	4.33	28.46 - 46.34	15.03	1.85	11.22 - 18.85	8.97[e]	1.83	5.20 - 12.75
Low understory reinitiation	62	18.44	1.77	14.90 - 21.99	5.76	0.75	4.26 - 7.26	5.30[f]	0.96	3.37 - 7.22
Old growth	5	36.69	14.42	0 - 76.73	24.34	4.30	12.42 - 36.27	23.51[g]	5.81	7.38 - 39.64

[a]The terms "high" and "low" refer to the total percent canopy closure within a stand, ≥ or <50%, respectively.
[b]63.51+ cm diameter class median diameter at breast height (DBH) = 77.7 cm.
[c]63.51+ cm diameter class median DBH = 70.1 cm.
[d]63.51+ cm diameter class median DBH = 73.2 cm.
[e]63.51+ cm diameter class median DBH = 74.7 cm.
[f]63.51+ cm diameter class median DBH = 78.1 cm.
[g]63.51+ cm diameter class median DBH = 80.9 cm.

Table 7. First principal component for each forest structure category for goshawk nests (n = 82) and random sites (n = 95) in eastern Oregon and Washington, 1994-1995. From a principal components analysis of the structural characteristics for each category. Decimal values for each habitat variable represent the loading value, or correlation, each variable has with the first principal component for each forest structure category.

	Stand Initiation	High Stem Exclusion	Low Stem Exclusion	High Understory Reinitiation	Low Understory Reinitiation	Old Growth
No. stands sampled	6	22	27	25	62	5
Variation explained by component (%)	58.0	37.0	36.5	35.0	36.3	56.3
DBH_Q	0.310529	0.440077	0.388890	0.379611	-0.097359	-0.335417
Total basal area	0.366255	0.176889	0.333494	0.360235	0.484845	0.374627
Crown class basal area:						
Dominant/codominant	0.361095	0.388028	0.419611	0.445020	0.350728	0.368459
Intermediate	0.085701	-0.286635	-0.096571	-029808	0.332044	0.075198
Suppressed	0.157127	-0.078234	-0.007271	0.041751	0.372920	0.302567
Frequency of trees by diameter class (cm):						
0 - 12.70	0.300646	-0.365222	-0.324866	-0.086171	0.353607	0.170528
12.71 - 25.40	-0.031686	-0.263087	-0.051569	-0.196465	0.339853	0.142952
25.41 - 38.10	0.353130	0.288812	0.380560	0.114171	0.245561	0.382060
38.11 - 50.80	0.360977	0.367607	0.347806	0.362599	0.202997	0.338893
50.81 - 63.50	0.360977	0.318124	0.336330	0.424961	0.186272	0.381107
63.51+	0.360977	0.117664	0.254920	0.392840	0.079808	-0.242095

Table 8. Summary of structural characteristics that best explain each forest structural category surrounding goshawk nests (n = 82) and random sites (n = 95) in eastern Oregon and Washington. As determined from an analysis of the first principal component for each forest structure category.

Stand Initiation	High[a] Stem Exclusion	Low[a] Stem Exclusion	High Understory Reinitiation	Low Understory Reinitiation	Old Growth
DBH_Q	DBH_Q	DBH_Q	DBH_Q	Total basal area	Total basal area
Total basal area	Dominant/codominant[b]	Total basal area	Total basal area	Dominant/codominant[b]	Dominant/codominant[b]
Dominant/codominant[b]	Diameter class (cm)	Dominant/codominant[b]	Dominant/codominant[b]	Intermediate[b]	Suppressed[b]
Diameter class (cm)	38.11 - 50.80	Diameter class (cm)	Diameter class (cm)	Suppressed[b]	Diameter class (cm)
0 - 12.70	50.81 - 63.50	25.41 - 38.10	38.11 - 50.80	Diameter class (cm)	25.41 - 38.10
25.41 - 38.10		38.11 - 50.80	50.81 - 63.50	0 - 12.70	38.11 - 50.80
38.11 - 50.80		50.81 - 63.50	63.51+	12.71 - 25.40	50.81 - 63.50
50.81 - 63.50					
63.51+					

[a]The terms "high" and "low" refer to the total percent canopy closure within a stand, ≥ or <50%, respectively.
[b]Basal area for trees within this crown class.

reinitiation stands included DBH_Q, total basal area, basal area for dominant and codominant trees, and the number of trees in the ≥38.11 diameter classes (Table 8). Habitat characteristics associated with low understory reinitiation stands consisted of total basal area, basal area in each of the three crown class categories, and the number of trees in the ≤25.4 cm diameter classes (Table 8). Finally, the variables associated with old growth stands included total basal area, basal area for the dominant/codominant and suppressed crown classes, and the number of trees in the 25.41 - 63.5 cm diameter classes (Table 8). Quadratic mean diameter for the stand was not associated with old growth stands (Table 7).

Univariate Analysis

One-hectare Level Selection

Goshawk nests were not distributed proportionately among the four stages of stand development ($\chi^2 = 19.8$, 3 df, $P = 0.0002$). Stem exclusion was used significantly more than expected based on its availability, and stand initiation was used significantly less than expected based on its availability (Table 9). Goshawk 1-ha level sites were not distributed in proportion to topographic position ($\chi^2 = 25.9$, 5 df, $P = 0.0001$). Ridge tops and the upper 1/3 of slopes were used significantly less than expected based on their availability, while lower 1/3 of slopes and drainage bottoms were used significantly more than expected based on their availability (Table 10). Forest types were used by goshawks at 1-ha level sites in proportion to availability ($\chi^2 = 7.0$, 4 df, $P = 0.1333$).

Goshawk 1-ha level sites occurred at lower elevations, and on aspects that were significantly different from random sites, and were closer to human disturbance than random sites (Table 11). Seventy-seven percent (n = 137) of all human disturbances encountered (n = 177)

Table 9. Results of Bonferroni 90% simultaneous confidence intervals (97.5% individual C.I.) for stage of stand development within the 1-ha level for goshawk nests (n = 82) and random sites (n = 90) in eastern Oregon and Washington, 1994-1995. Goshawk 1-ha level sites were not distributed proportionately among the four stages of stand development ($\chi^2 = 19.8$, 3 df, $P = 0.0002$).

Stage of development	Number of nest sites	Number of random sites	Lower C.I.	Upper C.I.	Use
Stand initiation	0	11	0.0449	0.1995	<[a]
Stem exclusion	36	24	-0.3335	-0.0111	>[b]
Understory reinitiation	36	52	-0.0305	0.3081	=[c]
Old growth	10	3	-0.1801	0.0027	=

[a]Used significantly less than expected based on its availability.
[b]Used significantly more than expected based on its availability.
[c]Used in proportion to availability.

Table 10. Results of Bonferroni 85% simultaneous confidence intervals (97.5% individual C.I.) for 1-ha level site topographic position for goshawk nests (n = 82) and random sites (n = 90) in eastern Oregon and Washington, 1994-1995. Goshawk 1-ha level sites were not distributed in proportion to topographic position ($\chi^2 = 25.9$, 5 df, $P = 0.0001$).

Topographic position	Number of nest sites	Number of random sites	Lower C.I.	Upper C.I.	Use
Ridge top	1	11	0.0280	0.1920	<[a]
Upper 1/3 of slope	13	29	0.0211	0.3063	<
Middle 1/3 of slope	17	17	-0.1548	0.1180	=[b]
Lower 1/3 of slope	25	13	-0.3014	-0.0196	>[c]
Drainage bottom	14	3	-0.2397	-0.0351	>
Flat	12	17	-0.0846	0.1698	=

[a]Used significantly less than expected based on its availability.
[b]Used in proportion to availability.
[c]Used significantly more than expected based on its availability.

Table 11. Univariate habitat characteristics of goshawk 1-ha level sites compared to those available in eastern Oregon and Washington, 1994-1995. Results are for untransformed data.

	Goshawk sites (n = 82)			Random sites (n = 90)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Elevation (m)	1419	33.2	728-2131	1504	32.1	695-2036	0.0679
% Slope	22.7	1.9	2.0-75.0	24.7	2.2	0.5-96.5	0.4943
Aspect (°)	0.5	7.1	2-360	164.2	8.1	2-358	0.0008[a]
Basal area (m^2/ha)	40.6	1.3	11.2-67.2	22.2	1.1	2.3-51.5	<0.0001
DBH_Q (cm)	24.1	0.6	12.9-36.9	20.8	0.7	6.9-41.5	0.0011
Live stem density (trees/ha)	862.4	52.9	70-2155	721.4	51.6	5-2595	0.0584
SDI	705.1	29.0	84-1429	458.4	27.4	11-1190	<0.0001
% Canopy closure	53.1	1.7	14.3-89.1	33.2	1.7	2.7-74.1	<0.0001
Age	126.3	4.9	59.9-285.5	115.4	5.2	21.8-306.3	0.0349[b]
Proximity (m) to:							
Forest change	58.2	5.5	0-259	55.5	6.3	0-289	0.7421
Human disturbance	144.1	19.8	0-1358	152.4	21.7	0-1200	0.0538[b]
Water	342.4	34.7	4-1415	375.2	47.7	3-3622	0.5786

[a] *P*-value for two-sample testing of angles.
[b] *P*-value for log-transformed data.

were forest roads and 22% (n = 38) were timber harvests. Goshawk 1-ha level sites also occurred in stands typified by greater basal area, quadratic mean diameter, live stem density, stand density index, mean percent canopy closure, and mean age than random sites (Table 11). Aspects at random sites tended to be random while goshawk 1-ha level sites were nonrandomly distributed, primarily on north-facing slopes (Table 12). Results for individual study areas are found in Appendices 5-8.

Ten-hectare Nest Stand Level

Goshawk 10-ha level sites contained significantly lower proportions of stand initiation and low understory reinitiation than did random sites (Table 13). Goshawk 10-ha level composition never exceeded 35% stand initiation, whereas random sites ranged from 0 - 100% stand initiation. Goshawk 10-ha level sites contained significantly greater proportions of high stem exclusion and high understory reinitiation than did random sites (Table 13). Water occurred at only one random 10-ha level site, yielding no significant difference with goshawk nests (P = 0.3199). Results for individual study areas can be found in Appendices 9-12.

Theoretical Post-Fledging Area Selection

Goshawk TPFA's contained significantly lower proportions of stand initiation and low understory reinitiation than random TPFA's (Table 14). Contagion was also significantly less at goshawk TPFA's than at random TPFA's (Table 14). While the ranges for stand initiation and low understory reinitiation composition in random TPFA's range from 0 to nearly 98% each, goshawk TPFA's never exceeded 44% and 68% composition for either category, respectively. Goshawk TPFA's were composed of significantly greater proportions of high stem exclusion and

Table 12. Mean aspect angle, angular deviation, r, and *P*-value for test of randomness or non-directedness for goshawk and random 1-ha level sites in eastern Oregon and Washington, 1994-1995, using continuous data for aspect.

	Mean Angle	Angular Deviation	r	*P*-value
Goshawk nests (n = 82)	0°	65°	0.36	<0.001
Random sites (n = 90)	164°	77°	0.09	0.471

Table 13. Univariate habitat characteristics of goshawk 10-ha level sites compared to those available in eastern Oregon and Washington, 1994-1995. Values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 82)			Random Sites (n = 95)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	1.6	0.7	0-34.9	11.0	2.7	0-100	0.0011
High[a] stem exclusion	24.7	3.5	0-100	15.0	2.6	0-100	0.0256
Low[a] stem exclusion	6.2	2.0	0-100	8.5	2.1	0-93.5	0.4414
High understory reinitiation	47.1	3.6	0-100	25.3	3.2	0-98.7	<0.0001
Low understory reinitiation	13.9	2.2	0-80.6	32.3	3.4	0-100	0.0001
Old growth	2.2	1.4	0-82.9	1.2	0.6	0-39.8	0.4723
Wet openings	1.4	0.5	0-27.4	2.4	0.9	0-46.5	0.3058
Dry openings	2.8	0.8	0-44.3	4.3	1.0	0-51.1	0.3745[b]
Water	0.0	0.0	0 - 0	0.01	0.01	0-1.2	0.3199

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value is for arcsine square root transformed data.

Table 14. Univariate habitat characteristics of goshawk 83 ha theoretical post-fledging areas compared to those available in eastern Oregon and Washington, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 82)			Random Sites (n = 95)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	3.3	0.8	0-44.3	10.5	2.1	0-98.5	0.0016
High[a] stem exclusion	19.3	2.2	0-86.7	13.1	1.7	0-87.3	0.0291
Low[a] stem exclusion	8.2	1.5	0-70.8	8.3	1.8	0-72.1	0.9506
High understory reinitiation	38.5	2.2	0-97.0	24.9	2.2	0-89.3	<0.0001
Low understory reinitiation	22.4	2.1	0-67.6	32.4	2.6	0-97.2	0.0032
Old growth	1.1	0.5	0-28.8	1.0	0.6	0-45.5	0.9282
Wet openings	1.9	0.4	0-19.8	2.6	0.7	0-44.9	0.4253
Dry openings	5.1	1.0	0-48.4	7.2	1.3	0-54.3	0.1897
Water	0.3	0.2	0-19.2	0.1	0.1	0-5.3	0.4196
CWED[b]: structure (m)	33.3	2.6	1.1-127.5	33.0	2.5	0-131.5	0.9427
CWED: canopy closure (m)	36.5	2.8	0.4-138.5	39.9	2.5	0-127.1	0.3786
Mean nearest neighbor (m)	126.6	10.0	32-607	121.3	7.8	27-477	0.6765
Simpson's evenness index	0.80	0.02	0.09-0.99	0.74	0.02	0.06-0.99	0.0378
Contagion (%)	59.7	0.8	47.7-93.2	62.2	0.9	46.9-94.4	0.0425

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]Contrast weighted edge density.

high understory reinitiation, and greater evenness among stand types present in the landscape, than random site TPFA's. Results for individual study areas can be found in Appendices 13-16.

Theoretical Post-Fledging Area Ring Selection

Like the TPFA circles, goshawk TPFA rings differed significantly from those for random sites by the proportion of the landscape in stand initiation, high stem exclusion, high understory reinitiation, low understory reinitiation, Simpson's evenness index, and contagion (Table 15). Goshawk TPFA rings were composed of significantly less stand initiation and low understory reinitiation, and had significantly lower values of contagion than random site TPFA rings. Conversely, goshawk TPFA rings were composed of significantly more high stem exclusion and high understory reinitiation, and had higher evenness than random site TPFA rings.

Post-Fledging Area Selection

Goshawk PFA's contained significantly lower proportions of stand initiation, and had lower values of contagion than did random PFA's (Table 16). Stand initiation ranged from 0 - 89% of the landscape in random 170-ha circles. In contrast, stand initiation in goshawk PFA's ranged from 0 - 41%, less than half what was in available landscapes. Goshawk PFA's also contained significantly greater proportions of high understory reinitiation, and had greater evenness among stand types than did random PFA's. Results for individual study areas are found in Appendices 17-20.

Table 15. Univariate habitat characteristics of goshawk 73 ha theoretical post-fledging area ring, habitat between 10 and 83 ha, compared to those available in eastern Oregon and Washington, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 82)			Random Sites (n = 95)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	3.5	0.9	0-47.3	10.4	2.0	0-98.3	0.0023
High[a] stem exclusion	18.6	2.1	0-84.8	12.8	1.7	0-85.6	0.0349
Low[a] stem exclusion	8.5	1.5	0-66.8	8.3	1.7	0-74.9	0.9489
High understory reinitiation	37.3	2.2	0-96.6	24.8	2.2	0-89.3	0.0001
Low understory reinitiation	23.6	2.1	0-71.5	32.4	2.6	0-96.8	0.0621[b]
Old growth	0.9	0.4	0-22.8	1.0	0.6	0-49.0	0.9263
Wet openings	2.0	0.4	0-20.5	2.6	0.7	0-45.8	0.4829
Dry openings	5.4	1.1	0-52.8	7.6	1.3	0-56.4	0.2521[b]
Water	0.3	0.3	0-21.8	0.1	0.1	0-5.9	0.4156
CWED[c]: structure (m)	33.6	2.6	1.2-125.5	33.6	2.6	0-132.9	0.9941
CWED: canopy closure (m)	37.0	2.8	0.5-135.7	40.2	2.5	0-126.8	0.4061
Mean nearest neighbor (m)	124.4	9.6	32.3-606.9	115.3	7.7	21.4-477.0	0.4570
Simpson's evenness index	0.81	0.02	0.10-1.00	0.75	0.02	0.07-0.99	0.0247
Contagion (%)	59.2	0.8	47.4-92.5	61.9	0.9	47.1-93.8	0.0309

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value for arcsine square root transformed data.
[c]Contrast weighted edge density.

Table 16. Univariate habitat characteristics of goshawk 170 ha post-fledging areas compared to those available in eastern Oregon and Washington, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 82)			Random Sites (n = 95)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	3.8	0.9	0-41.4	9.8	1.8	0-88.6	0.0040
High[a] stem exclusion	17.6	1.9	0-69.2	13.8	1.6	0-78.5	0.1391
Low[a] stem exclusion	8.3	1.3	0-51.1	7.7	1.5	0-67.9	0.7607
High understory reinitiation	36.2	2.0	0-87.0	24.9	2.1	0-79.1	0.0001
Low understory reinitiation	25.2	2.2	0-77.9	32.9	2.5	0-84.8	0.1181[b]
Old growth	0.8	0.4	0-17.5	0.8	0.5	0-41.03	0.9145
Wet openings	2.1	0.4	0-16.2	2.7	0.7	0-47.7	0.4765
Dry openings	5.7	1.1	0-52.6	7.4	1.2	0-56.2	0.2965
Water	0.4	0.3	0-28.3	0.1	0.1	0-3.8	0.3441
CWED[c]: structure (m)	29.5	2.2	3.5-105.4	28.8	2.0	0-104.6	0.8186
CWED: canopy closure (m)	33.3	2.4	4.0-117.9	35.1	2.0	1.8-96.0	0.5736
Mean nearest neighbor (m)	165.8	11.3	16.7-544.8	158.6	12.6	17.2-952.0	0.6715
Simpson's evenness index	0.82	0.01	0.35-0.97	0.77	0.01	0.28-0.99	0.0069
Contagion (%)	58.6	0.7	49.2-78.4	61.2	0.7	47.0-82.0	0.0102

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value for arcsine square root transformed data.
[c]Contrast weighted edge density.

Post-Fledging Area Ring Selection

Like the PFA circles, variables that differed between goshawk and random PFA rings consisted of the proportion of the landscape in stand initiation, high understory reinitiation, Simpson's evenness index, and contagion (Table 17). Goshawk PFA rings contained significantly less stand initiation and more high understory reinitiation than random PFA rings. Goshawk PFA rings were also characterized by less contagion and by greater evenness among structural types than random PFA rings.

Multivariate Analysis

One-hectare Level

Twelve variables measured within the 1-ha level were significant ($P < 0.25$) from the two-sample t-tests and chi-square analyses (Tables 9 - 11). Among these, mean canopy closure and stand density index were highly correlated with basal area ($r > \pm 0.70$) (Figs. 4 and 5). Basal area had a greater reduction in model deviance (deviance = 31.13, 1 df) than mean canopy closure (deviance = 3.01, 1 df) and SDI (deviance = 0.96, 1 df) and was retained for inclusion in the manual stepwise procedure. Using the categorical variable reduction method, the number of indicator variables necessary for aspect and topographic position were reduced to 1 and 2, respectively. The indicator variable for aspect, where aspects of NW, N, and NE were 1, and all other aspects were 0, described the differences between goshawk and random nest sites as well as the full model which contained 7 indicator variables (drop-in-deviance = 5.895, 6 df, $P = 0.4351$). The two indicator variables for topographic position, where lower 1/3 of slope and drainage bottoms each equal 1, and all others equal 0, or ridge tops and upper 1/3 of slope each equal 1,

Table 17. Univariate habitat characteristics of goshawk 87 ha post-fledging area ring, habitat between 83 and 170 ha, compared to those available in eastern Oregon and Washington, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 82)			Random Sites (n = 95)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	4.4	1.0	0-39.0	9.2	1.7	0-87.4	0.0182
High[a] stem exclusion	15.9	1.8	0-59.7	14.6	1.7	0-71.2	0.6226
Low[a] stem exclusion	8.4	1.4	0-55.8	7.1	1.4	0-65.8	0.4971
High understory reinitiation	34.0	2.1	0-77.5	24.8	2.1	0-77.1	0.0028
Low understory reinitiation	27.9	2.5	0-87.6	33.3	2.7	0-86.0	0.2982[b]
Old growth	0.5	0.2	0-12.5	0.7	0.4	0-36.7	0.6839
Wet openings	2.3	0.5	0-19.0	2.8	0.8	0-50.0	0.5622
Dry openings	6.3	1.2	0-56.6	7.5	1.3	0-62.0	0.4642
Water	0.5	0.5	0-38.0	0.1	0.1	0-2.4	0.3120
CWED[c]: structure (m)	25.9	2.1	4.3-94.4	24.8	1.8	0-87.6	0.6851
CWED: canopy closure (m)	30.1	2.2	5.2-98.2	30.4	1.8	3.6-95.0	0.9238
Mean nearest neighbor (m)	235.3	15.6	33.2-832.2	210.2	13.2	20.6-708.3	0.2170
Simpson's evenness index	0.81	0.01	0.34-0.99	0.77	0.02	0.30-1.00	0.0562[b]
Contagion (%)	59.4	0.7	48.9-78.3	61.3	0.8	47.7-82.5	0.0732

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.

[b]*P*-value for arcsine square root transformed data.

[c]Contrast weighted edge density.

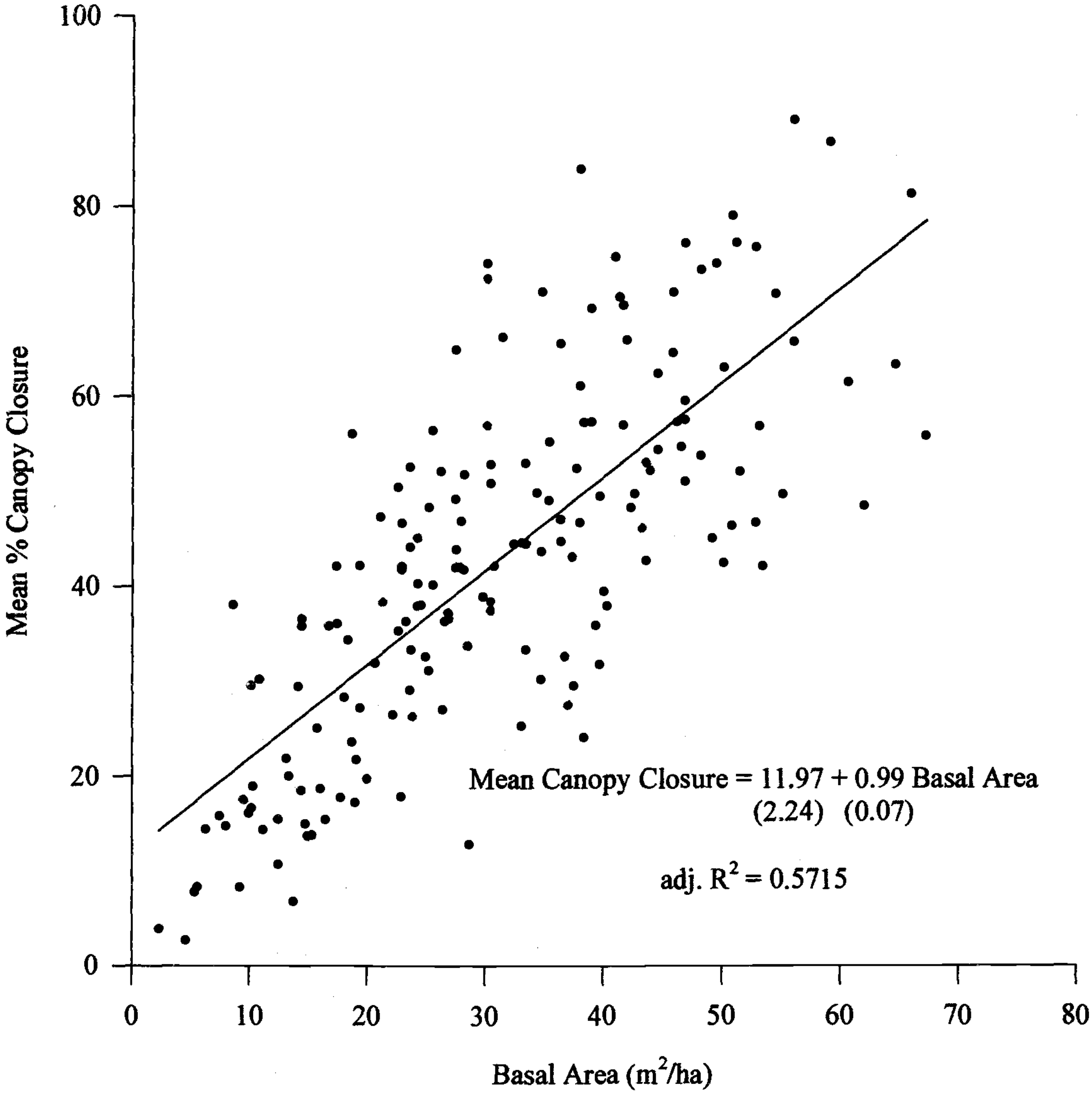

Figure 4. Simple linear regression relationship between basal area and mean canopy closure within the 1 ha nest site level at goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients are in parentheses. The regression equation explains a significant portion of the variation ($F_{1, 170}$, $P = 0.0001$).

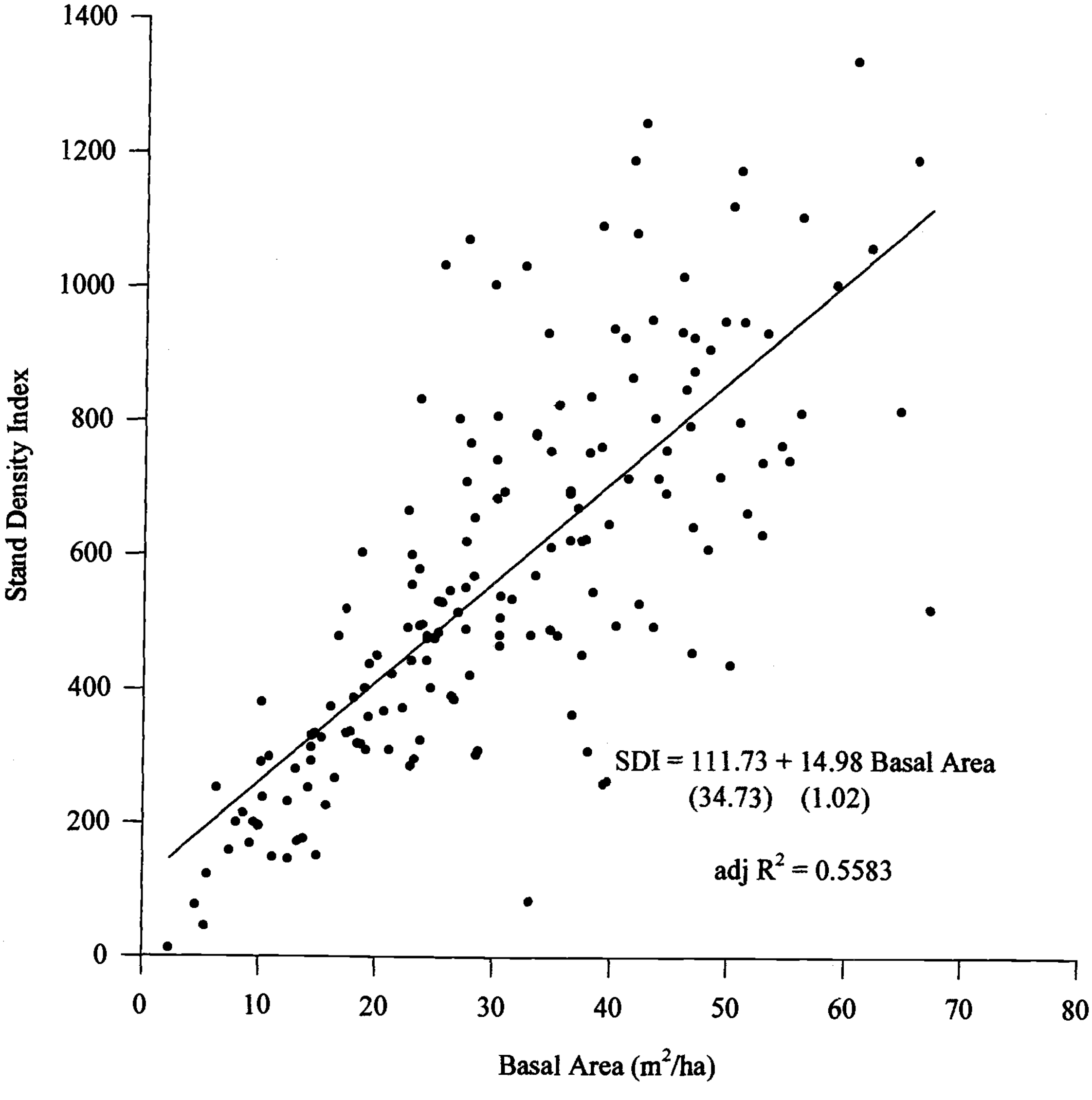

Figure 5. Simple linear regression relationship between basal area and stand density index within the 1 ha nest site level at goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients are in parentheses. The regression equation explains a significant portion of the variation ($F_{1, 170}$, $P = 0.0001$).

and all others equal 0, described differences between goshawk and random sites as well as the full model which contained 5 indicator variables (drop-in-deviance = 6.664, 3 df, $P = 0.0834$).

Of the remaining 10 variables, basal area and indicator variables for stage of stand development and topographic position best described habitat conditions that differ between goshawk and random 1-ha level sites (Table 18). There was no study area effect (drop-in-deviance = 3.435, 3 df, $P = 0.3293$). After expanding the model to include all possible first-order interactions among the main effects, there was a significant drop in deviance (drop-in-deviance = 3.984, 1 df, $P = 0.0459$) for the interaction between low topographic position and basal area. This interaction (Table 18) indicated an association between goshawk nest sites and higher basal area on lower slope positions.

The odds ratios in Table 19 represent how much more likely it is for a site to be a goshawk nest site when the corresponding variable increases by 1 unit. For the indicator variables, the odds ratios indicate how much more likely it is for a site to be a goshawk nest site when the condition is true. If the odds ratio for a single variable are >1, then that variable increases the odds for a nest to occur, while odds < 1 decrease the odds for a nest to occur. For example, if a site occurs on a ridge top (i.e., high topographic position), the odds of that site being a goshawk nest site are 0.43 times as likely as sites that occur on the middle and lower 1/3 of the slope, drainage bottoms, and flats (i.e., high topographic position decreases the odds of a nest occurring). For a site that does not have low topographic position, increasing basal area by 1 m^2/ha would increase the odds of that site being a goshawk nest site 1.16 times. Whereas, increasing basal area by 1 m^2/ha on a site with low topographic position would increase the odds of that site being a goshawk nest site 1.35 times. In general, odds of a 1-ha site being suitable for goshawks increase more rapidly on low topographic positions with increasing basal area (Fig. 6).

Table 18. Six-variable logistic regression model, with interactions, that best discriminated between goshawk and random 1-ha level sites in eastern Oregon and Washington.

Variable	Parameter estimate[a]	SE[a]	χ^{2b}	*P*-value[b]
Intercept	-4.2894	0.9524	20.2833	0.0001
Understory reinitiation indicator [c]	-1.3126	0.5396	5.9169	0.0150
Old growth indicator [c]	-0.5742	0.9144	0.3943	0.5301
Low topographic position[c] indicator	-1.8950	2.4939	0.5774	0.4473
High topographic position[c] indicator	-0.8552	0.5669	2.2763	0.1314
Basal area	0.1443	0.0274	27.7756	0.0001
Low topographic position x Basal area	0.1530	0.0926	2.7313	0.0984

[a]Parameter estimates and standard errors based on the model with all 6 variables included.
[b] χ^2 and *P*-values based on Wald test.
[c]Indicator values for each variable are 1 if stage of stand development is understory reinitiation or old growth, topographic position of the site is either the lower 1/3 of the slope or drainage bottom (low), or is the ridge top or upper 1/3 of the slope (high). Otherwise, the indicator value is 0.

Table 19. Odds ratios for the 6-variable logistic regression model for 1-ha level sites in eastern Oregon and Washington, 1994-1995. For continuous variables, the odds ratio reflects the change in odds for a 1 unit increase in the variable. For categorical variables, the odds ratio reflects that the condition is true.

Condition	Odds Ratio
Stage of stand development is understory reinitiation	0.2691
Stage of stand development is old growth	0.5632
Topographic position is Lower 1/3 of slope or Drainage bottom	0.1752
Topographic position is Ridge top or Upper 1/3 of slope	0.4252
Basal area for sites not on Lower 1/3 of slope or in Drainage bottoms	1.1552
Basal area for sites on Lower 1/3 of slope or in Drainage bottoms	1.3462

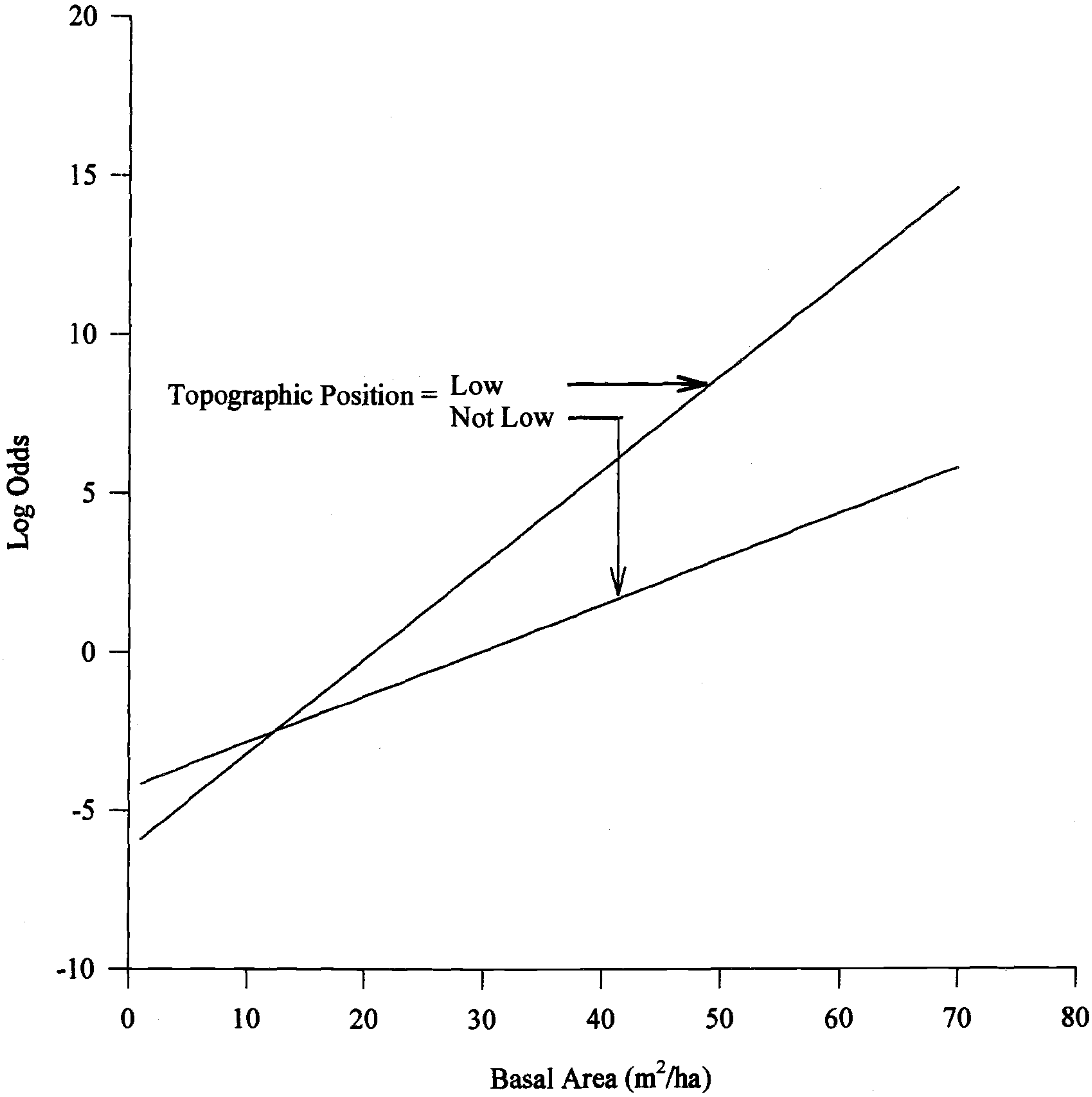

Figure 6. Interaction between basal area and low topographic position at the 1-ha level. Low topographic position occurs on the lower 1/3 of slopes and drainage bottoms. This association is for sites occurring in the stem exclusion stage of stand development.

The effects of the relationship between basal area and topographic position on log odds in stem exclusion, understory reinitiation, and old growth structural stages are represented in Figs. 7-9, respectively.

Ten-hectare Level

Four variables were significant ($P < 0.25$) from the two-sample t-test at the 10-ha level (Table 13) and were retained for the logistic regression analysis. Logistic regression indicated that two variables, percent of the landscape in high stem exclusion and high understory reinitiation, best described differences in habitat between goshawk and random 10-ha level sites (Table 20). Results of the test for a study area effect indicated that habitat conditions do not differ with respect to study area at this landscape level (drop-in-deviance = 4.927, 3 df, P = 0.1772). Model expansion to include the first-order interaction between high stem exclusion and high understory reinitiation did not identify a significant interaction between these main effects (drop-in-deviance = 2.517, 1 df, $P = 0.1126$).

Odds ratios for the two-variable logistic regression model that best described differences in habitat between goshawk and random 10-ha level sites indicated that increasing the amount of high stem exclusion at the 10-ha level by 1%, with high understory reinitiation held constant, increased the odds that the site will be suitable for nesting by goshawks 1.03 times (Table 21). Also, if the amount of high stem exclusion at the 10-ha level is held constant, and the amount of high understory reinitiation is increased by 1%, then the odds of a site being suitable for nesting by goshawks increases 1.03 times.

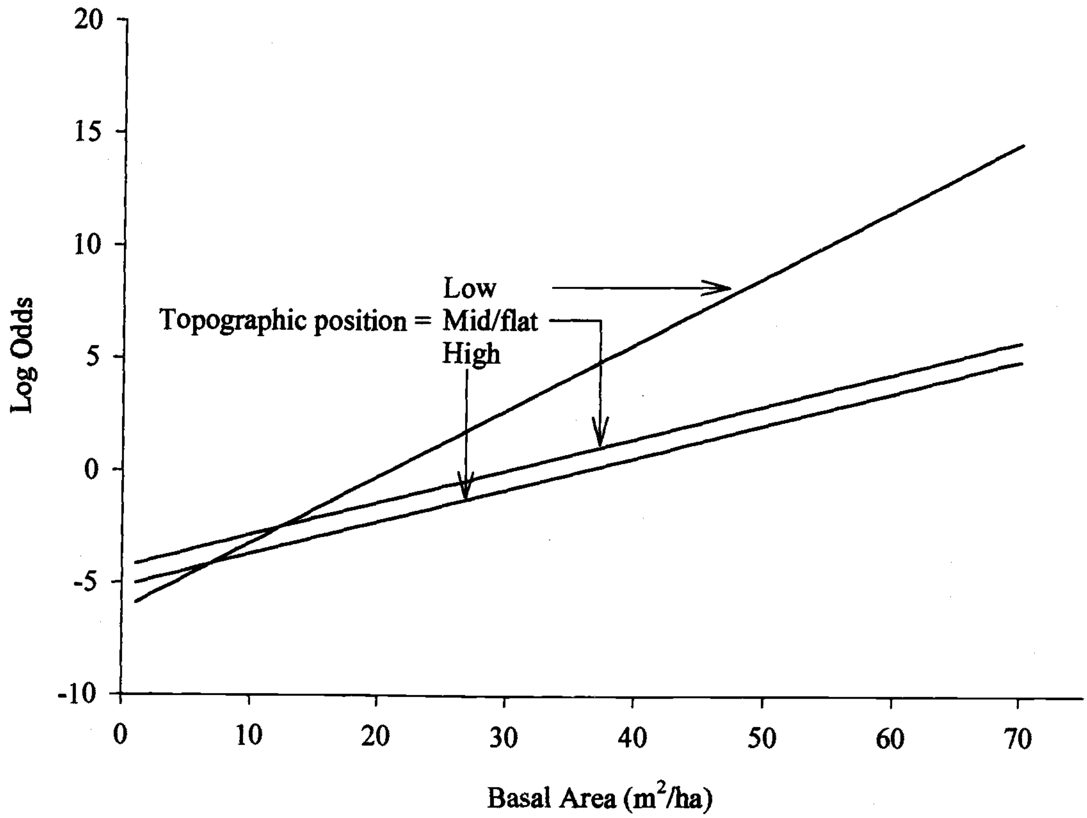

Figure 7. Effect of the relationship between basal area and topographic position on the log odds for sites in stem exclusion stands at the 1-ha level in eastern Oregon and Washington, 1994-1995. Sites on ridge tops or upper 1/3 of slopes have "high" topographic position. Sites on the middle 1/3 of slopes or flats are "mid/flat", and sites on the lower 1/3 of slopes or drainage bottoms have "low" topographic position.

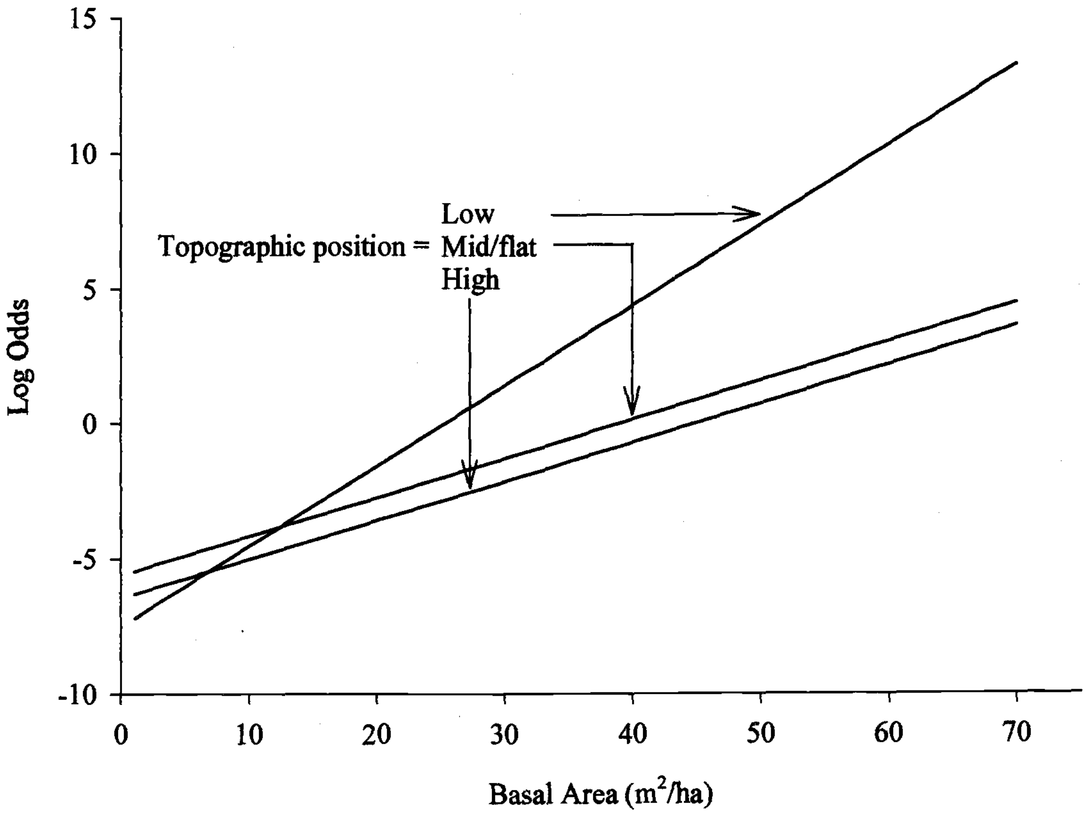

Figure 8. Effect of the relationship between basal area and topographic position on the log odds for sites in understory reinitiation stands at the 1-ha level in eastern Oregon and Washington, 1994-1995. Sites occurring on ridge tops or upper 1/3 of slopes have "high" topographic position. Sites occurring on the middle 1/3 of slopes or flats are "mid/flat", and sites occurring on the lower 1/3 of slopes or drainage bottoms have "low" topographic position.

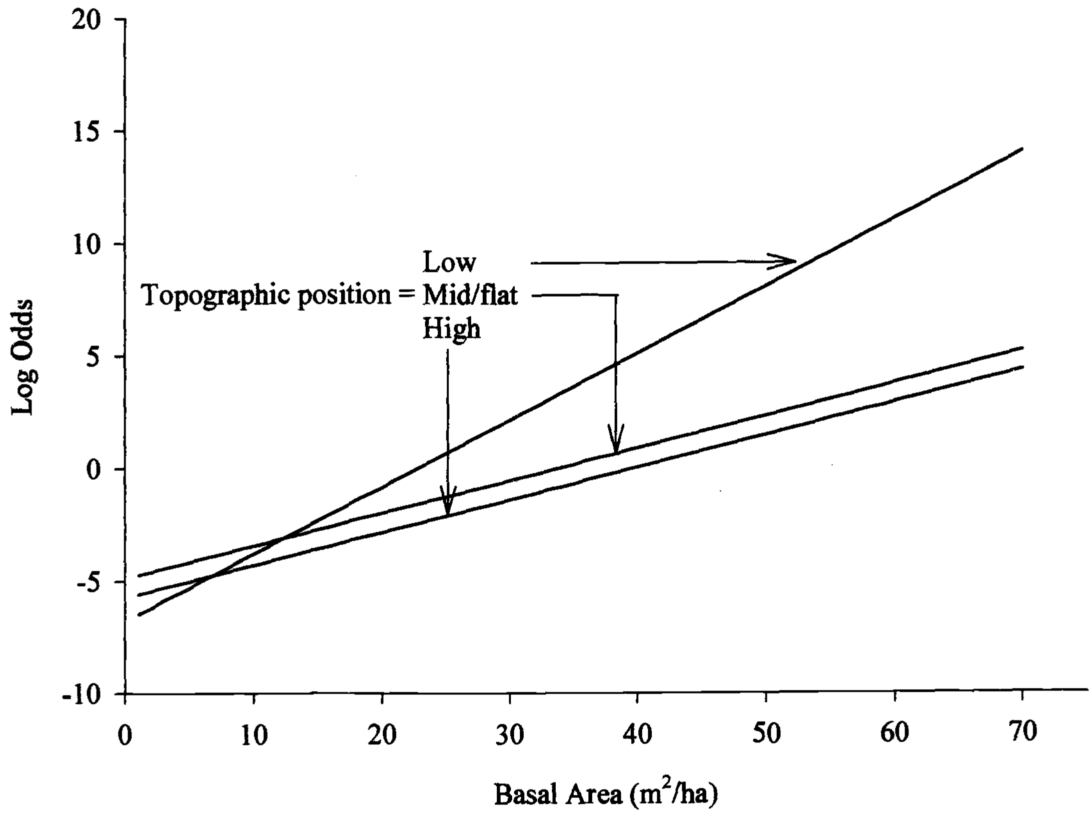

Figure 9. Effect of the relationship between basal area and topographic position on log odds for sites in old growth stands at the 1-ha level in eastern Oregon and Washington, 1994-1995. Sites occurring on ridge tops or upper 1/3 of slopes have "high" topographic position. Sites occurring on the middle 1/3 of slopes or flats are "mid/flat", and sites occurring on the lower 1/3 of slopes or drainage bottoms have "low" topographic position.

Table 20. Two-variable logistic regression model that best discriminated between goshawk and random 10-ha level sites in eastern Oregon and Washington.

Variable	Parameter estimate[a]	SE[a]	χ^2[b]	*P*-value[b]
Intercept	-1.9363	0.3739	26.8242	0.0001
High stem exclusion[c]	0.0289	0.00675	18.3573	0.0001
High understory reinitiation[c]	0.0327	0.00613	28.4723	0.0001

[a]Parameter estimates and standard errors based on the model with both variables included.
[b] χ^2 and *P*-values based on Wald test.
[c]Percent of the landscape in the respective categories.

Table 21. Odds ratios for the 2-variable logistic regression model for 10-ha level sites in eastern Oregon and Washington, 1994-1995. The odds ratio reflects the change in odds for a 1 unit increase in the variable. Continuous variables are measured as the percent of the landscape occupied by that stand type.

Condition	Odds Ratio
High[a] stem exclusion	1.0293
High understory reinitiation	1.0332

[a]"High" denotes total canopy closure within a stand $\geq$50%.

Theoretical Post-Fledging Area

Seven variables were significant ($P < 0.25$) at the 83 ha TPFA level (Table 14). Among these, Simpson's evenness index and contagion were highly correlated ($r > \pm 0.70$) (Fig. 10). Simpson's evenness index provided a greater drop in deviance (deviance = 4.396, 1 df) than did contagion, so only evenness was included in the manual stepwise procedure. In the stepwise analysis 5 variables, the percent of the landscape in stand initiation, high understory reinitiation, low understory reinitiation, dry openings, and Simpson's evenness index, were important to discriminating between goshawk and random sites at this landscape level (Table 22). A study area effect was detected (drop-in-deviance = 10.68, 3 df, $P = 0.0136$), and through the variable reduction procedure was attributed to the northeast Oregon study area (drop-in-deviance = 1.3110, 2 df, $P = 0.5192$).

After determination of significant main effects and the study area effect, the model was expanded to include all possible first-order interactions among the main and study area effects. Three first-order interactions entered the model (drop-in-deviance = 22.483, 3 df, $P = 0.0001$), including interactions between the northeast Oregon study area effect and Simpson's evenness index, stand initiation and high understory reinitiation, and high understory reinitiation and low understory reinitiation (Table 22).

Odds ratios for the nine-variable logistic regression model that best described differences in habitat between goshawk and random 83 ha TPFA's (Table 23) indicated that if a site was located in northeast Oregon, the odds of a site being a goshawk site were increased 0.0005 times (holding all other variables constant). Increasing amounts of either stand initiation, low understory reinitiation, or dry openings by 1% while holding all other variables constant in the model increased odds of a site being a goshawk site 0.80, 0.99, and 0.91 times, respectively. Increasing high understory reinitiation by 1%, while all other variables remain constant, increases

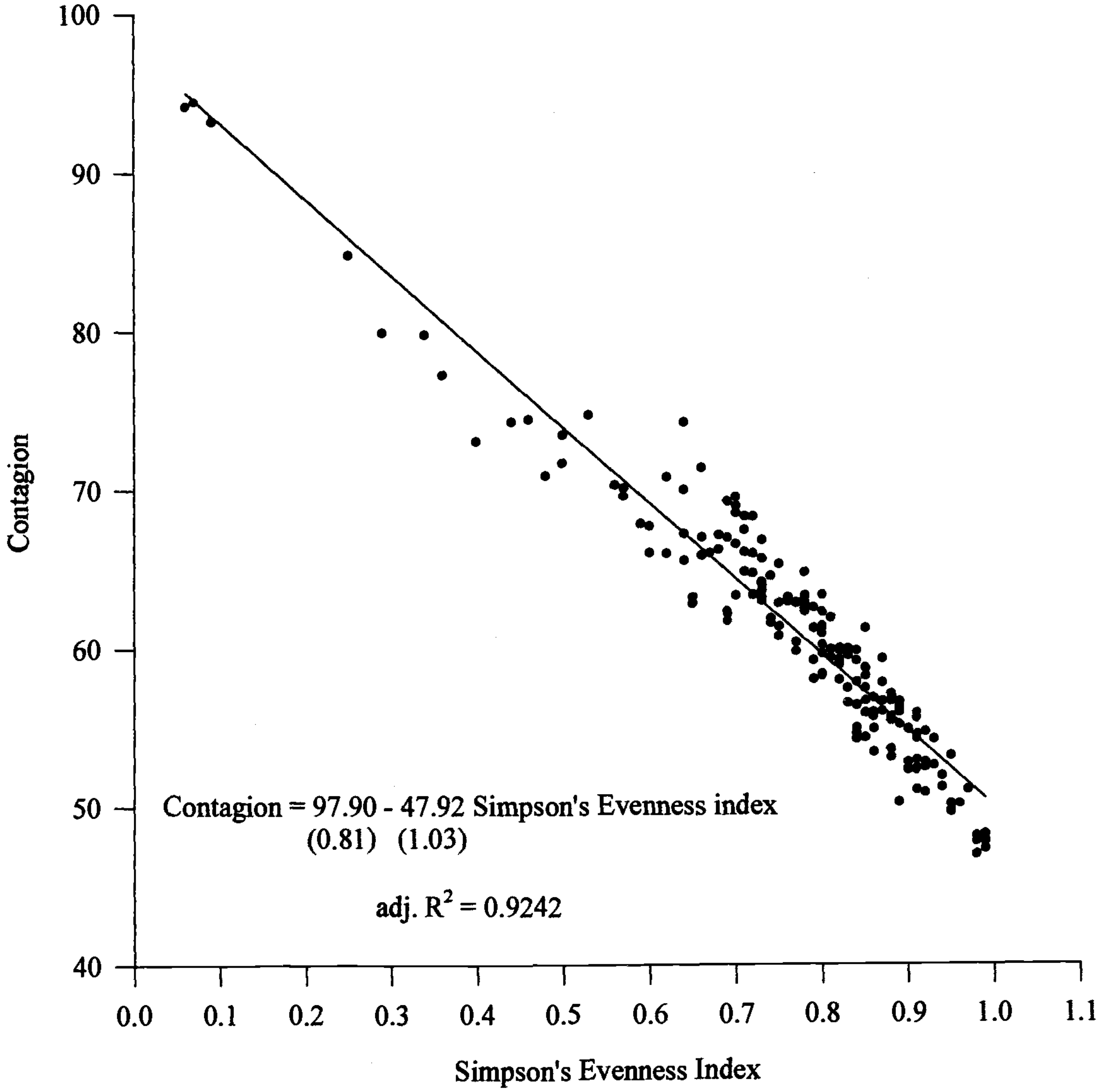

Figure 10. Simple linear regression relationship between Simpson's evenness index and contagion at the 83 ha theoretical post-fledging area level surrounding goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients in parentheses. The regression equation explained a significant portion of the variation ($F_{1, 175}$, $P = 0.0001$).

Table 22. Nine-variable logistic regression model, with interactions, that best discriminates between goshawk and random 83 ha theoretical post-fledging area circles in eastern Oregon and Washington.

Variable	Parameter estimate[a]	SE[a]	χ^2[b]	*P*-value[b]
Intercept	-2.0744	1.5306	1.8367	0.1753
Northeast OR indicator[c]	-7.6609	3.1416	5.9464	0.0147
Stand initiation[d]	-0.2280	0.0655	12.1032	0.0005
High understory reinitiation[d]	0.0348	0.0154	5.0976	0.0240
Low understory reinitiation[d]	-0.00986	0.0148	0.4409	0.5067
Dry openings[d]	-0.0951	0.0261	13.2469	0.0003
Simpson's evenness index	0.0340	0.0172	3.9064	0.0481
Northeast OR x Simpson's evenness index	0.1151	0.0402	8.2038	0.0042
Stand initiation x High understory reinitiation	0.00404	0.00179	5.0993	0.0239
High understory reinitiation x Low understory reinitiation	-0.00117	0.000469	6.2637	0.0123

[a]Parameter estimates and standard errors based on the model with all 9 variables included.
[b] χ^2 and *P*-values based on Wald test.
[c]Indicator value equals 1 if the study area is Northeast OR. Otherwise, the indicator value is 0.
[d]Percent of the landscape in the respective categories.

Table 23. Odds ratios for the 9-variable logistic regression model for the 83 ha theoretical post-fledging area circles in eastern Oregon and Washington, 1994-1995. For continuous variables, the odds ratio reflects the change in odds of occupancy associated with a 1 unit increase in the variable. Continuous variables are measured as the percent of the landscape occupied by that stand type.

Condition	Odds Ratio
Study area is Northeast Oregon	0.0005
Stand initiation	0.7993
High[a] understory reinitiation	1.0384
Low[a] understory reinitiation	0.9890
Dry openings	0.9093
Simpson's evenness index:	
not in Northeast Oregon	1.0346
in Northeast Oregon	1.1608

[a]"High" and "low" denote total canopy closure within a stand ≥ or <50%, respectively.

the odds of the site being a goshawk site 1.04 times. Additionally, increasing Simpson's evenness index by 1 unit, while all other variables remain constant, increases the odds of the site being a goshawk site 1.03 times at sites other than northeast Oregon, and 1.16 times at sites in northeast Oregon.

The interaction between the northeast Oregon study area and Simpson's evenness index indicated that the odds of occupancy were not substantially affected by evenness in the central Washington, Malheur, or Fremont study areas at this landscape level (Fig. 11). Increasing amounts of high understory reinitiation in landscapes with larger amounts of stand initiation (e.g., 10.4%) increases the likelihood of a site being a goshawk site (Fig. 12). Increasing amounts of high understory reinitiation serves to offset negative effects of stand initiation in the landscape (Fig. 12). However, increasing the amount of high understory reinitiation does not offset the effects of larger amounts of low understory reinitiation (32.4%) in the landscape (Fig. 13).

Post-Fledging Area

Six variables were significant ($P < 0.25$) at the 170 ha PFA level (Table 16). Of these, Simpson's evenness index and contagion were highly correlated ($r > \pm 0.70$) (Fig. 14). Simpson's evenness index had a greater drop-in-deviance (deviance = 7.351, 1 df) than contagion and was retained for the manual stepwise logistic regression procedure.

Manual stepwise logistic regression determined that four variables best describe the differences in habitat between goshawk and random 170 ha PFA's (Table 24). Main effects were Simpson's evenness index and percent of the landscape in stand initiation, high stem exclusion, and high understory reinitiation structural stages. Once the main effects had been defined, there was no apparent study area effect (drop-in-deviance = 3.693, 3 df, $P = 0.2966$).

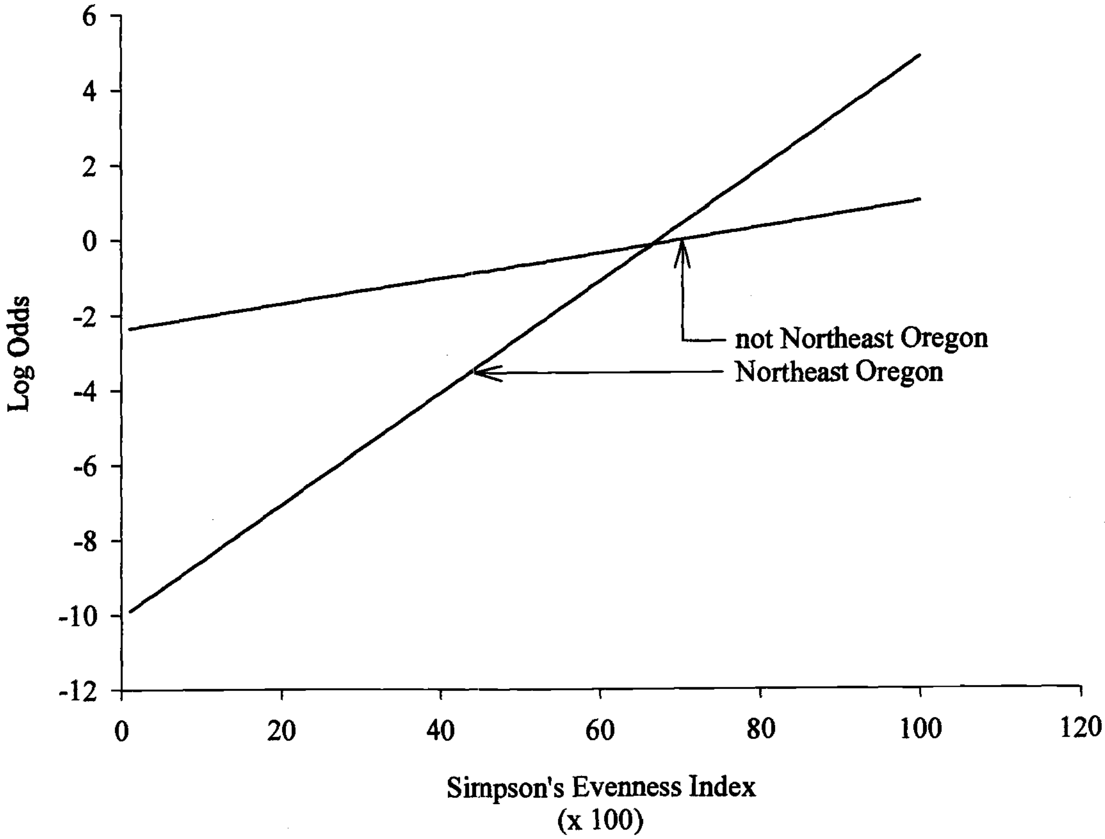

Figure 11. Interaction between Simpson's evenness index and the indicator for the northeast Oregon study area in the logistic regression model for the 83 ha theoretical post-fledging area circle. The interaction shows that Simpson's evenness index is important in discriminating between goshawk and random sites in northeast Oregon.

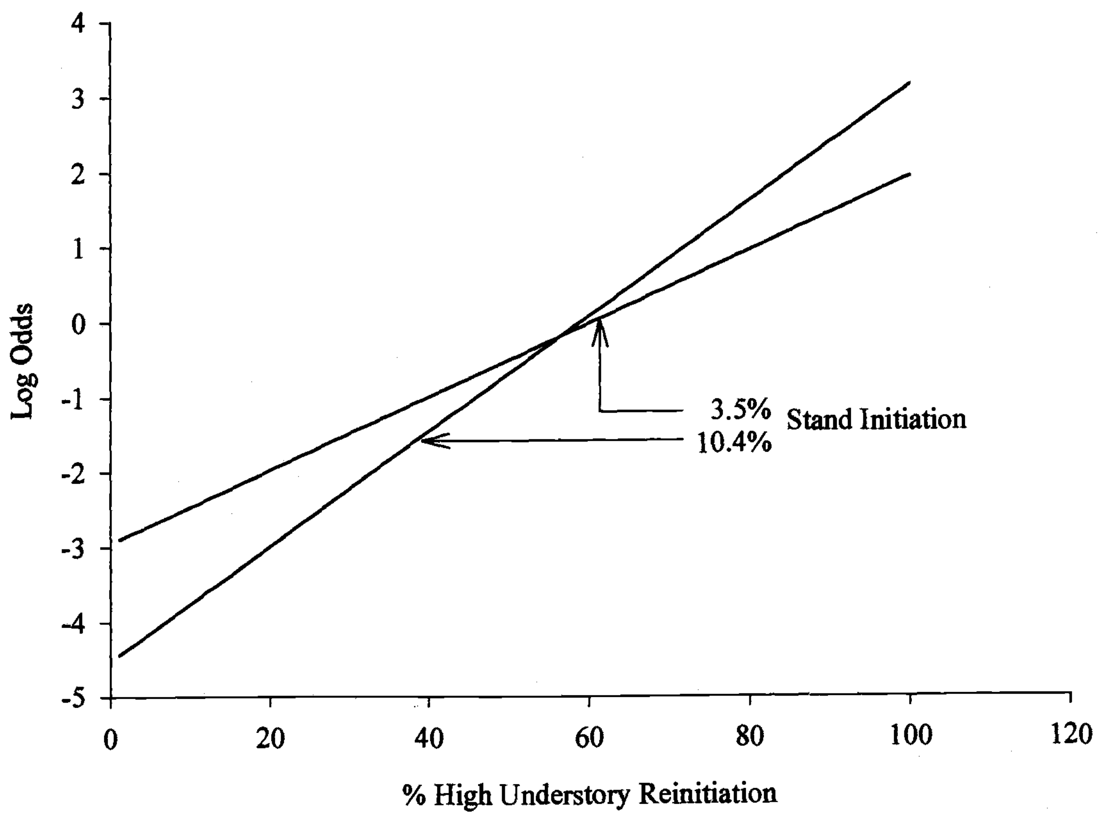

Figure 12. Interaction between high understory reinitiation and stand initiation in the logistic regression model for the 83 ha theoretical post-fledging area circle. The interaction demonstrates how increasing amounts of high understory reinitiation serve to offset negative effects of higher quantities of stand initiation.

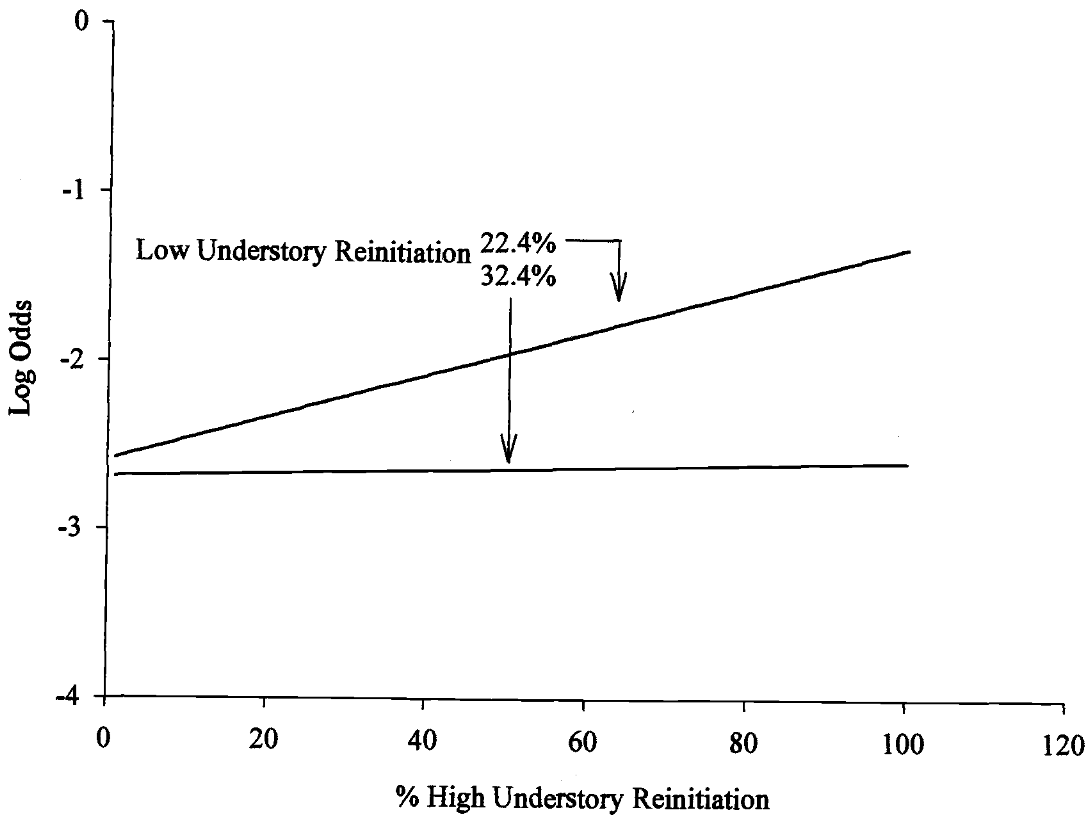

Figure 13. Interaction between high understory reinitiation and low understory reinitiation in the logistic regression model for the 83 ha theoretical post-fledging area circle. The interaction demonstrates how increasing quantities of low understory reinitiation decrease the rate at which high understory reinitiation can improve the odds of a site being a goshawk site.

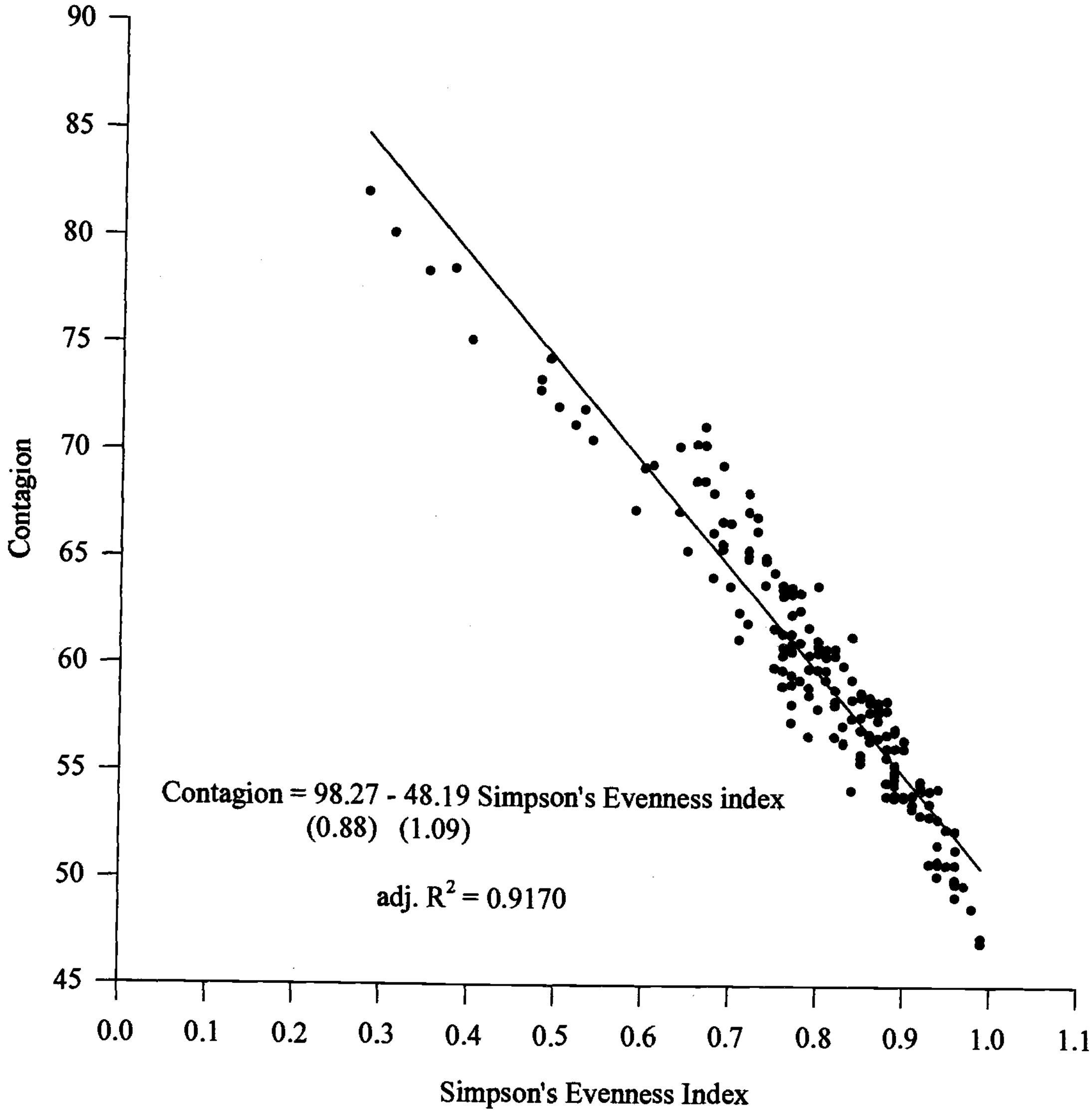

Figure 14. Simple linear regression relationship between Simpson's evenness index and contagion at the 170 ha post-fledging area level surrounding goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients are in parentheses. The regression equation explained a significant portion of the variation ($F_{1,175}$, $P = 0.0001$).

Table 24. Six-variable logistic regression model, with interactions, that best discriminates between goshawk and random 170 ha post-fledging area circles in eastern Oregon and Washington.

Variable	Parameter estimate[a]	SE[a]	χ^{2b}	*P*-value[b]
Intercept	-1.8665	1.5164	1.5151	0.2184
Stand initiation[c]	-1.1791	0.4754	6.1526	0.0131
High stem exclusion[c]	0.0335	0.0124	7.2628	0.0070
High understory reinitiation[c]	0.0177	0.0107	2.7179	0.0992
Simpson's evenness index	0.0122	0.0171	0.5117	0.4744
Stand initiation x High understory reinitiation	0.00653	0.00240	7.4367	0.0064
Stand initiation x Simpson's evenness index	0.0109	0.00485	5.0468	0.0247

[a]Parameter estimates and standard errors based on the model with all 6 variables included.

[b] χ^2 and *P*-values based on Wald test.

[c]Percent of the landscape in the respective categories.

Model expansion to include all first-order interactions among main effects detected 2 significant interactions (drop-in-deviance = 16.605, 2 df, $P = 0.0002$). These included an interaction between percent stand initiation and percent high understory reinitiation, and an interaction between percent stand initiation and Simpson's evenness index. Odds ratios for main effects in the logistic regression model for the 170 ha PFA are in Table 25. The effects of increasing the amount of stand initiation in the PFA by 1%, with all other variables remaining constant, increased the odds of a site being a goshawk site 0.31 times. Increasing the amount of either high stem exclusion, high understory reinitiation, or Simpson's evenness index by 1% or 1 unit, holding all other variables constant, increased the odds of a site being a goshawk site 1.03, 1.02, and 1.02 times, respectively.

The interaction between stand initiation and high understory reinitiation shows that increasing amounts of high understory reinitiation in the landscape slows the rate at which odds decline for a site being suitable for nesting goshawks due to increased amounts of stand initiation (Fig. 15). Similarly, the rate of decreasing odds is lower in landscapes where evenness is relatively high (Fig. 16).

Ring Model

Fifteen variables were significant ($P < 0.25$) among the 10-ha level, 73 ha TPFA ring, and 87 ha PFA ring (Tables 13, 15, and 17, respectively). Of these, Simpson's evenness index and contagion, in both habitat rings, were highly correlated ($r > \pm 0.70$) (Figs. 17 and 18). Simpson's evenness index had a greater drop-in-deviance than contagion at both levels (TPFA ring: deviance = 5.173, 1 df; PFA ring: deviance = 4.393, 1 df) and was retained for the manual forward selection procedure.

Table 25. Odds ratios for the 6-variable logistic regression model for the 170 ha post-fledging area circles in eastern Oregon and Washington, 1994-1995. For continuous variables, the odds ratio reflects the change in odds for a 1 unit increase in the variable. Continuous variables are measured as the percent of the landscape occupied by that stand type.

Condition	Odds Ratio
Stand initiation	0.3130
High[a] stem exclusion	1.0341
High understory reinitiation	1.0245
Simpson's evenness index	1.0234

[a]"High" denotes total canopy closure within a stand ≥50%.

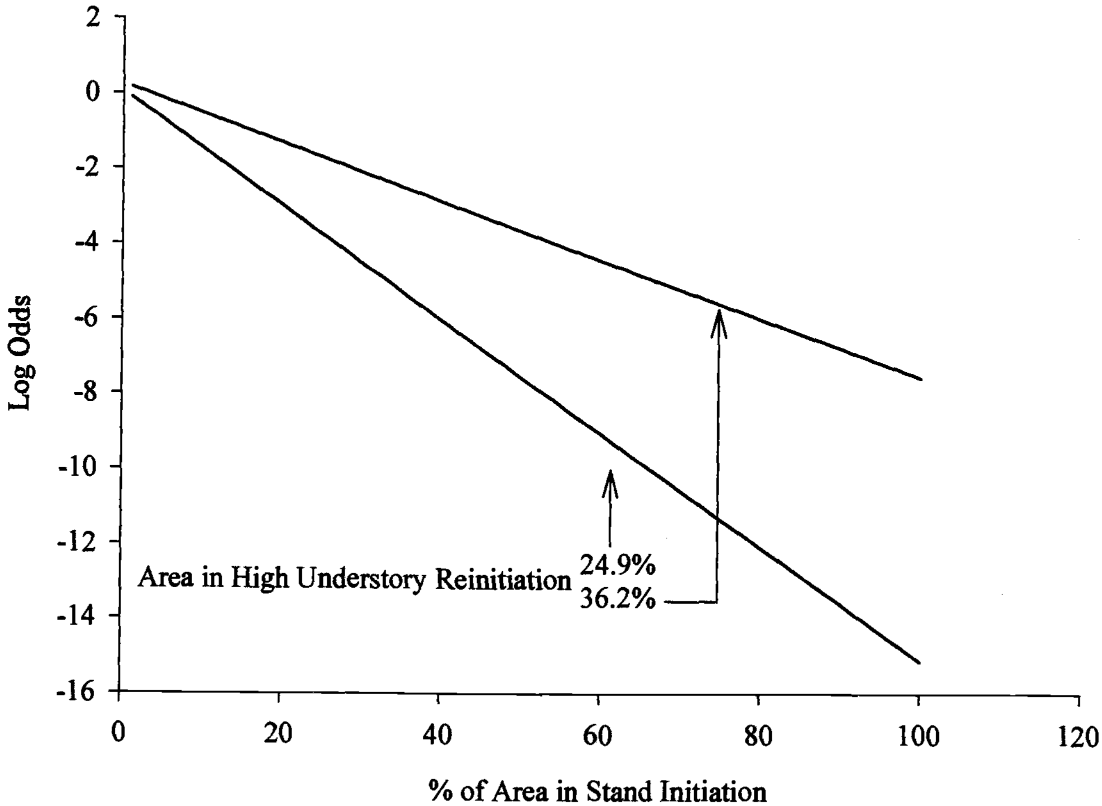

Figure 15. Interaction between stand initiation and high understory reinitiation in the logistic regression model for the 170 ha post-fledging area circle. The interaction indicates that the rate of decreasing odds due to stand initiation's negative effects is lower in landscapes with relatively high amounts of high understory reinitiation.

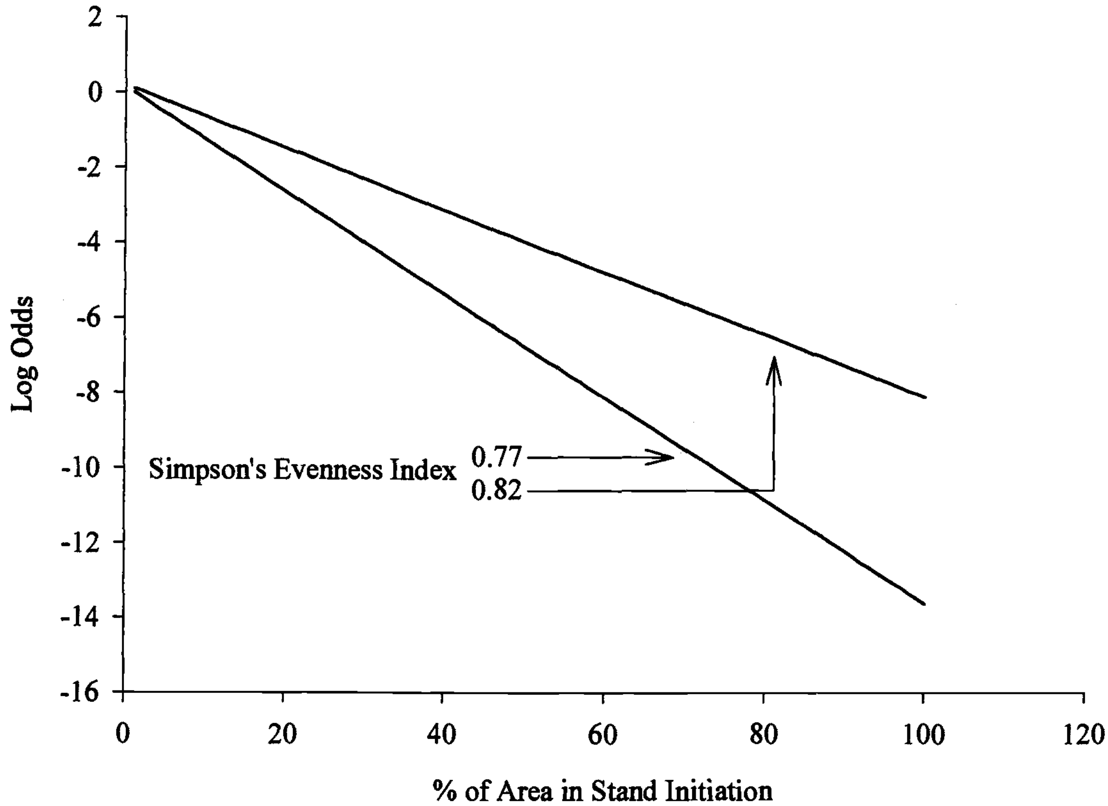

Figure 16. Interaction between stand initiation and Simpson's evenness index in the logistic regression model for the 170 ha post-fledging area circle. The interaction indicates that the rate of decreasing odds due to stand initiation's negative effects is lower in landscapes with relatively high evenness.

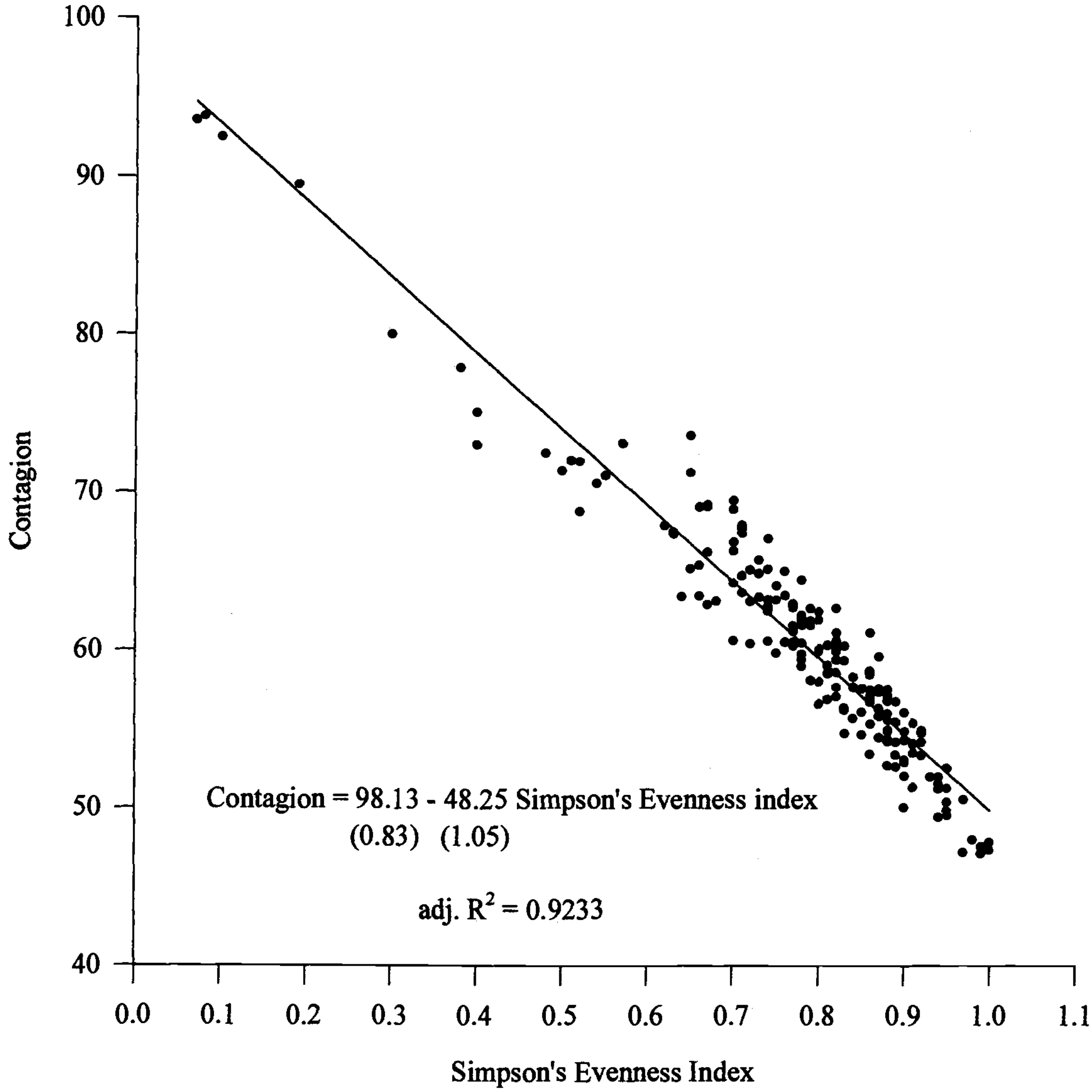

Figure 17. Simple linear regression relationship between Simpson's evenness index and contagion in the 73 ha theoretical post-fledging area ring surrounding goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients are in parentheses. The regression equation explained a significant portion of the variation ($F_{1,175}$, $P = 0.0001$).

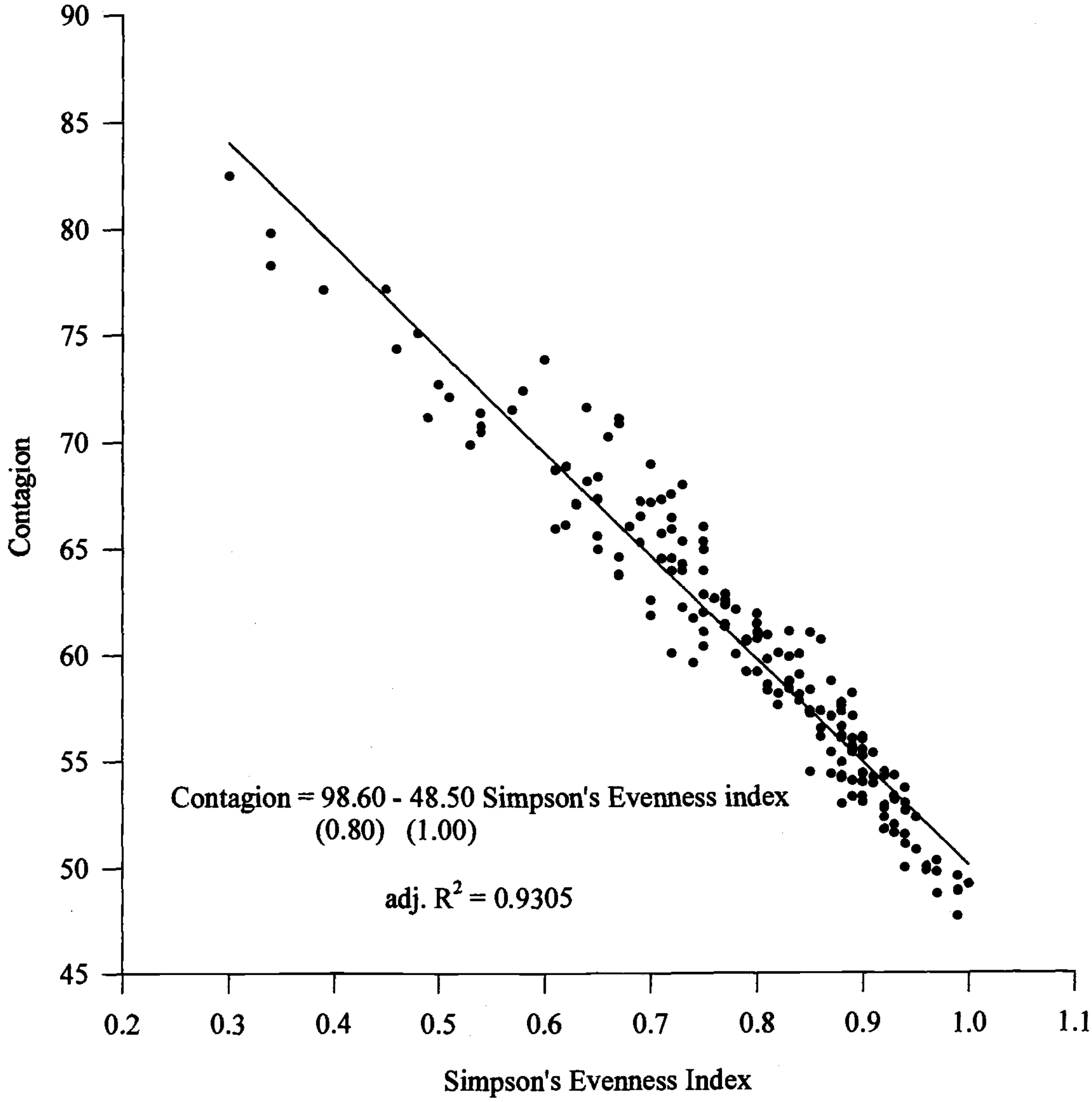

Figure 18. Simple linear regression relationship between Simpson's evenness index and contagion in the 87 ha post-fledging area ring surrounding goshawk and random sites in eastern Oregon and Washington, 1994-1995. Standard errors for the regression coefficients are in parentheses. The regression equation explained a significant portion of the variation ($F_{1,175}$, $P = 0.0001$).

Results of the manual forward selection procedure, where the 10-ha level model was constructed, followed by variables from the TPFA ring, and finally variables from the PFA ring, indicated that significant main effects included the percent of the 10-ha level in high stem exclusion and in high understory reinitiation, percent of the TPFA ring in stand initiation, and the Simpson's evenness index value for the TPFA ring (Table 26). There was no study area effect with all significant main effects in the model (drop-in-deviance = 4.05, 3 df, $P = 0.2561$). Model expansion to include significant first-order interactions detected an interaction between the percent of the 10-ha level in high understory reinitiation and percent of the TPFA ring in stand initiation (drop-in-deviance = 4.7520, 1 df, $P = 0.0293$).

For the ring model, the effects of increasing the amount of either high stem exclusion or high understory reinitiation in the 10-ha level by 1%, with all other variables remaining constant, increases the odds of a site being a goshawk site 1.03 times (Table 27). Similarly, increasing Simpson's evenness index by 1 unit in the TPFA ring, with all other variables remaining constant, increases the odds of a site being a goshawk site 1.03 times. Increasing stand initiation in the TPFA ring by 1%, with all other variables remaining constant, increases the odds of a site being a goshawk site by a factor of 0.90.

The interaction between high understory reinitiation in the 10-ha level and stand initiation in the TPFA ring indicates that in landscapes with larger quantities of stand initiation (e.g., 10.4%) in the TPFA ring, goshawks placed their nests in greater quantities of high understory reinitiation at the 10-ha level to offset stand initiation's negative effects (Fig. 19). Therefore, for high levels of stand initiation in the TPFA ring, every 1% increase in high understory reinitiation in the 10-ha level significantly increases the odds of the site being a goshawk site.

Table 26. Five-variable logistic regression model, with interactions, that best discriminates between goshawk nests and random sites across landscape levels in eastern Oregon and Washington, from the 10-ha level to post-fledging areas, using a habitat analysis of the rings. Level in parenthesis.

Variable	Parameter estimate[a]	SE[a]	χ^{2b}	*P*-value[b]
Intercept	-4.0431	1.2256	10.8832	0.0010
High stem exclusion[c] (NSc)[d]	0.0319	0.00760	17.6776	0.0001
High understory reinitiation[c] (NSc)[d]	0.0282	0.00715	15.5112	0.0001
Stand initiation[c] (TPFAr)[d]	-0.1045	0.0421	6.1571	0.0131
Simpson's evenness index (TPFAr)[d]	0.0308	0.0136	5.1601	0.0231
High understory reinitiation (NSc) x Stand initiation (TPFAr)	0.00146	0.000743	3.8422	0.0500

[a]Parameter estimates and standard errors based on the model with all 5 variables included.
[b] χ^2 and *P*-values based on Wald test.
[c]Percent of the landscape in the respective categories.
[d]"NSc" represents the 10-ha level circle and "TPFAr" represents the 73 ha theoretical post-fledging area ring.

Table 27. Odds ratios for the 5-variable logistic regression model for the ring model that includes habitat variables from the 10-ha level, 73 ha theoretical post-fledging area ring, and 87 ha post-fledging area ring collected in eastern Oregon and Washington, 1994-1995. Odds ratios reflect the change in odds for a 1 unit increase in each variable. Level for each variable is in parenthesis. Continuous variables are measured as the percent of the landscape, for that landscape level, occupied by that stand type.

Condition	Odds Ratio
High[a] stem exclusion (NSc)[b]	1.0324
High understory reinitiation (NSc)[b]	1.0301
Stand initiation (TPFAr)[b]	0.9021
Simpson's evenness index (TPFAr)[b]	1.0313

[a]"High" denotes total canopy closure within a stand ≥50%.
[b]"NSc" represents the 10-ha level circle and "TPFAr" represents the 73 ha theoretical post-fledging area ring.

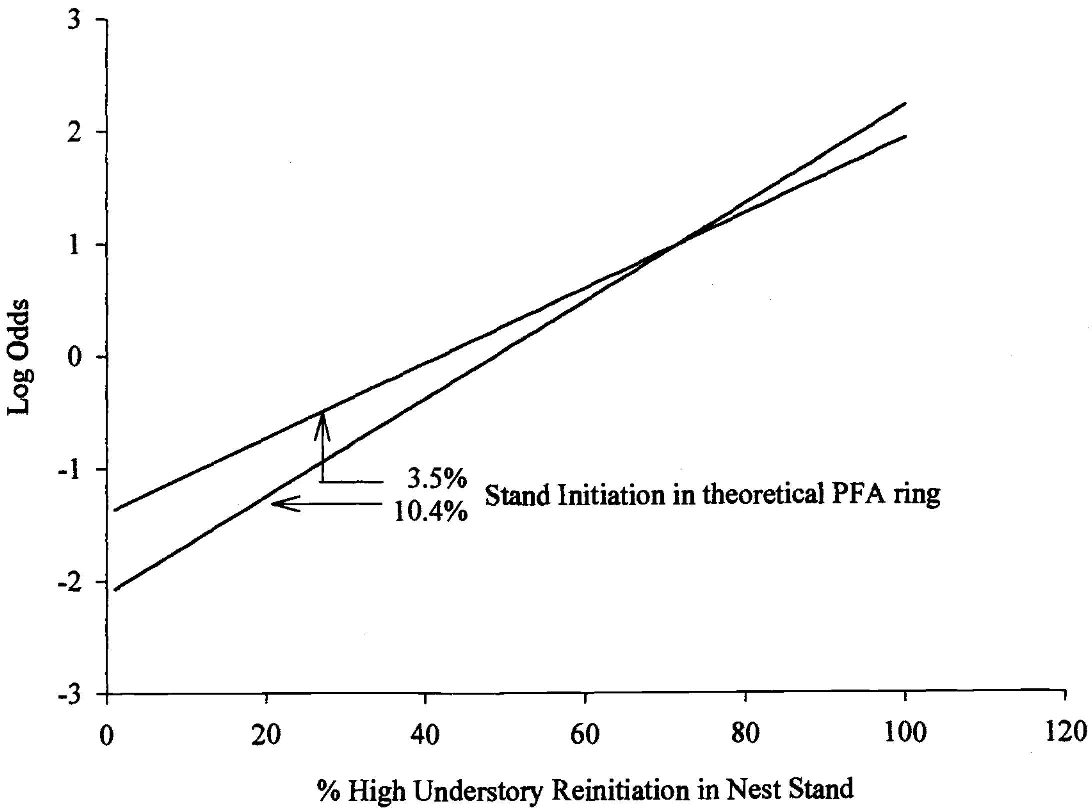

Figure 19. Interaction between the proportions of high understory reinitiation at the 10-ha level and stand initiation in the theoretical post-fledging area (TPFA) ring. The interaction indicates that with every 1% increase in high understory reinitiation at the 10-ha level, and high levels of stand initiation in the TPFA ring, the odds of a site being a goshawk site significantly increase.

Importance of each variable to the ring model (i.e., each variable's drop-in-deviance), relative to the ring model's deviance residual, indicated that variables at the 10-ha level are most important to discriminating between goshawk nests and random sites, explaining 74.5% of model deviance (Table 28).

Validation Model

The coefficients for the validation model were determined from what remained in the original data set after a 10% random sample of the goshawk nests and random sites had been removed. The two data sets are referred to as the "learning" and "test" data sets, respectively (Verbyla and Litvaitis 1989). Results of the classification of the test data set indicated that the 5-variable logistic regression model (Table 29) had a classification accuracy of 67% for goshawk nests and random sites, at a classification cutoff of 50% probability (Table 30). Type I errors (i.e., when the model predicts presence when actually absent) were assessed at 17% in the test data set. Type II errors (i.e., when the model predicts absence when actually present) occurred in 17% of the test data set (Table 30).

Table 28. Relative importance of parameters to the logistic regression ring model. Ring model includes high canopy closure stem exclusion and understory reinitiation variables from the 10-ha level, stand initiation and Simpson's evenness index for the 73 ha habitat ring for the theoretical post-fledging area (TPFA) level, and an interaction between high understory reinitiation in the 10-ha level and stand initiation in the TPFA ring. The ring model has a deviance of 56.04 with 5 degrees of freedom.

Parameters Removed from the Ring model	Deviance Explained	% of Ring model
High[a] stem exclusion	20.77	37.1
Interaction	4.75	8.5
High understory reinitiation + interaction	37.23	66.4
High stem exclusion + high understory reinitiation + interaction	41.76	74.5
Stand initiation + interaction	9.61	17.1
Simpson's evenness index	5.61	10.0
Simpson's evenness index + stand initiation + interaction	15.72	28.1

[a]The term "high" denotes stands with total canopy closure $\geq 50\%$.

Table 29. Validation model for the ring model, constructed from a random sample of 90% of the goshawk nests (n = 73) and random sites (n = 86) in eastern Oregon and Washington, 1994-1995. Model is a 5-variable logistic regression model, including interactions, that discriminates between goshawk nests and random sites across landscape levels, from the 10-ha level to post-fledging areas, using a habitat analysis of the rings. Level in parenthesis.

Variable	Parameter estimate[a]	SE[a]	χ^2[b]	*P*-value[b]
Intercept	-4.9943	1.4067	12.6059	0.0004
High stem exclusion[c] (NSc)[d]	0.0349	0.00832	17.5998	0.0001
High understory reinitiation[c] (NSc)[d]	0.0269	0.00766	12.2934	0.0005
Stand initiation[c] (TPFAr)[d]	-0.1086	0.0435	6.2495	0.0124
Simpson's evenness index (TPFAr)[d]	0.0431	0.0157	7.5068	0.0061
High understory reinitiation (NSc) x Stand initiation (TPFAr)	0.00134	0.000833	2.6027	0.1067

[a]Parameter estimates and standard errors based on the model with all 5 variables included.
[b] χ^2 and *P*-values based on Wald test.
[c]Percent of the landscape in the respective categories.
[d]"NSc" represents the 10-ha level circle and "TPFAr" represents the 73 ha theoretical post-fledging area ring.

Table 30. Classification accuracy of the validation model on a test data set consisting of a 10% random sample of goshawk and random sites found in eastern Oregon and Washington, 1994-1995. Probability cutoff for classification was 50%.

		# Predicted	
		Random Site	Goshawk Site
# Known	Random Site (n = 9)	6	3
	Goshawk Site (n = 9)	3	6

	Classification Accuracy	66.67%
	Type I error[a]	16.67%
	Type II error[b]	16.67%

[a]Model predicts presence when actually absent.
[b]Model predicts absence when actually present.

DISCUSSION

Past research on northern goshawk habitat in North America focused on habitat within 1 or 2 ha of the nest (Hennessy 1978, Reynolds 1978, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski 1987, Hayward and Escano 1989, Lilieholm et al. 1993, Speiser 1993, Bull and Hohmann 1994, Lang 1994, Squires and Ruggiero 1996). Additionally, with the exception of Reynolds (1978), these studies sampled less than 30 nests and concentrated their efforts on individual study areas. This study's analyses are built on a much larger data set (n = 82 nests, n = 95 random sites), and incorporate substantial geographic variation.

Results of this study indicated that at the 1-ha level, goshawk nests typically occurred on the lower 1/3 or bottom of north facing slopes in stands characterized by relatively high basal area, quadratic mean diameter, canopy closure, and live stem density, compared to random sites. Results of the landscape analysis indicated that goshawks were associated with mid- to late-forest structure with canopy closure ≥50% (i.e., high stem exclusion and high understory reinitiation) within the 10-ha level. They were negatively associated with early forest conditions (i.e., stand initiation) occurring between the 10-ha level and the 83 ha theoretical post-fledging area. Results of this study are more robust than those of earlier studies because I measured stand characteristics in detail, ground-truthed 10% of photo-interpreted data, and cross-validated the accuracy of my predictive model.

Habitat Category Structural Characteristics

Table 8 summarizes structural characteristics that are associated with the forest habitat categories. Due to the overlap among structural stages for each variable (Tables 4 - 6), I caution the use of these characteristics for the delineation of stands into forest structural stages. The structural characteristics used to characterize the forest habitat categories (Table 8) are intended solely to provide a structural reference for each category. Creation of a dichotomous key, *per se*, for the forest habitat categories is beyond the scope of this study.

Stand initiation stands are associated with the stand's quadratic mean diameter, total basal area, basal area for dominant/codominant trees, and the number of trees/ha in the 0-12.7 cm and ≥25.41 cm diameter classes (Table 8). Examination of these variables (Tables 4 - 6) indicate that stand initiation has a low DBH_Q (mean = 16.53 cm, SE = 4.25), low total basal area (mean 2.26 m^2/ha, SE = 0.97), and is more strongly associated with trees in the 0 - 12.7 cm diameter class than the other diameter classes (Table 6).

High canopy closure stem exclusion stands are associated with the stand's quadratic mean diameter, basal area for dominant/codominant trees, and the number of trees/ha in the 38.11 - 63.5 cm diameter classes (Table 8). These results are indicative of stands that have high stocking levels and are undergoing competitive exclusion (Oliver and Larson 1990), as evidenced by this category's correlation with two diameter classes and basal area for dominant/codominant trees.

High canopy closure understory reinitiation stands are associated with the stand's quadratic mean diameter, total basal area, basal area for dominant/codominant trees, and the number of trees/ha in the diameter classes ≥38.11 cm (Table 8). Association with the three largest diameter classes may be indicative of the results of competitive exclusion and/or past management activities. Competitive exclusion and certain thinning strategies permit surviving trees to expand their root systems and canopies into space previously occupied by excluded or harvested trees (Smith 1986, Oliver and Larson 1990). This allows for greater diameter growth among opportunistic trees, as depicted by this category's correlation with the three largest diameter classes.

Low canopy closure stem exclusion and understory reinitiation categories may be as much an artifact of management practices as site potential (McGrath, unpubl. data). Characteristics that are associated with these two categories (Table 8) appear to be interrelated, particularly from a management perspective. Silvicultural practices on the Oregon study areas are predominantly uneven-aged harvesting, due to the gentle terrain in each area. A low canopy closure (i.e., canopy closure < 50%) stem exclusion stand might result from a selective harvest in a high density stand (e.g., high canopy closure stem exclusion). Resulting increases in growing space and sunlight on the forest floor permit natural regeneration to occur and increased canopy and diameter growth in the remnant population (Smith 1986). This creates a low canopy closure understory reinitiation stand characterized by diameter classes ≤25.4 cm, and represented by dominant/codominant (i.e, remnants), intermediate, and suppressed (i.e., regeneration) crown classes.

Old growth stands are associated with the stand's total basal area, basal area for dominant/codominant and suppressed trees, and the number of trees/ha in the 25.41 - 63.50 cm diameter classes (Table 8). It is apparent from a comparison of old growth's characteristics with those for high canopy closure stem exclusion and understory reinitiation (Table 8) that these three categories are associated with essentially the same diameter classes (i.e., 38.11 - 63.5 cm diameter classes). However, it could be inferred that old growth differs from these two categories by its multi-storied canopy, as evidenced by its representation by the dominant/codominant and suppressed crown classes (Table 8).

Limitations

As previously mentioned, goshawk nests in this study were originally located through a variety of methods, from standardized searches of all habitat conditions located within a large land tract to biased searches in areas thought to be "optimal" habitat for nesting goshawks. Consequently, the 82 goshawk nests included in this study are not a random sample of all goshawk nests in the study areas. Furthermore, inferences based on this data are correlative and descriptive in nature (Zar 1984). However, Daw (1997) and Daw and DeStefano (in revision) compared nest site habitat (within 0.4 ha of the nest) surrounding goshawk nests (n = 21) found in large survey blocks with nests (n = 20) found in a "non-systematic" fashion on the Bear Valley Ranger District of the Malheur National Forest. They found no significant difference in the total canopy closure or the number of large trees per hectare (trees >53 cm dbh) surrounding these sites. Applying these results to my study, conditions within the 1-ha level may be considered to be representative of the habitat within 1 ha of nests for the greater goshawk population from which my nests were sampled. However, their results may not apply to my larger, landscape analysis. The results presented in this study may provide a foundation for interpreting why goshawks select nesting habitat at higher levels of organization (Johnson 1980) and serve to increase the predictive ability of models for conservation planning (Keane and Morrison 1994).

Results of the landscape analysis and habitat models may not apply to regions outside of my study areas and may only be applicable to climatic and prey conditions present during the course of this study. Mosher et al. (1986) developed habitat models for woodland hawks in Maryland and Wisconsin and found that predicting habitat use in one region on the basis of data from another produced mixed results due to differences in available habitat conditions between regions. Climatically, Kostrzewa and Kostrzewa (1990) found the percentage of egg-laying goshawk pairs in Germany to be negatively correlated with precipitation in March and April and that unusually cold and wet weather conditions prevented adults from feeding efficiently. They found that weather typically affected goshawk reproduction through the food supply, either by suppressing hunting or by reducing the availability of prey. As a result of depressed prey populations, particularly in bad prey years, goshawks may nest only in the best habitats, often at reduced densities with enlarged home ranges, and vacate the poorer habitats completely (Newton 1979). Newton (1979) identified the goshawk as a raptor that is linked with the 4- and 10-year cycles of prey populations, depending on the region. Goshawk breeding populations may be more stable in regions where the goshawk preys on both birds and mammals because the food supply is more stable, typically due to the diversity of available prey species.

Due to logistical constraints, I could not measure habitat quality, either through reproductive output or prey availability. Measures of habitat quality, such as reproductive output, would serve as a measure as to the habitat's ability to provide necessary resources (e.g., cover and food) for goshawks to hatch and fledge young at a particular site. Thus, across the range of habitat conditions in which goshawks nested in this study, a measure of habitat quality could help differentiate "high quality" habitat from "low quality" habitat. Additionally, climatic conditions during the year that nest sites were located were more typical (e.g., temperature, precipitation) for this region than in recent years.

Other considerations when interpreting my results include: (1) this is a nest-centered study and may not account for habitat required by goshawks at other times of the year (e.g., Squires and Ruggiero 1995), and (2) habitat was analyzed using concentric circles rather than actual telemetry locations. Lehmkuhl and Raphael (1993) addressed the latter issue in a study of northern spotted owl (*Strix occidentalis caurina*) habitat. They compared habitat pattern in actual home ranges with circles around owl nests and found the conditions in each to be comparable to one another. Although an analysis of actual home ranges could prove to be more enlightening, it was not possible in this project.

The controversy surrounding the goshawk as an indicator species for old growth forests demands that this study's relevance to this issue be addressed. Results of the 1-ha level analysis and the landscape analysis for the 10-ha level, TPFA, and PFA (Tables 9, 13, 14, and 16, respectively), all indicated that old growth forest was either used in proportion to its availability or there was no significant difference between the amount of old growth forest surrounding goshawk and random sites. Similarities in forest structural characteristics for low understory reinitiation, high understory reinitiation, and old growth (Tables 4 - 6) are indicative of the difficulty in discerning among old growth and the two former categories through aerial photo interpretation. Hence, old growth was correctly classified 50% of the time, while 17% of the old growth misclassifications were actually high understory reinitiation, and another 33% were actually low understory reinitiation (Table 3). Therefore, due to aerial photo interpretation difficulties for landscape data and decreased levels of old growth forest available in the landscape (Everett et al. 1993), the number of samples of nests and random sites may have been insufficient at detecting statistically significant differences, possibly resulting in a Type II error (Zar 1984). Given this, the biological importance of old growth structure to nesting goshawks needs to be evaluated with more accurate forest structure maps or radio-telemetry data. The functional importance of old growth forest structure for foraging and nesting goshawks is a complex question and requires that actual "use" data from a rigorous study design be used to answer questions regarding preferred microclimatic nesting conditions, productivity and nesting success, escape cover for young, prey abundance for foraging goshawks, and the prey's subsequent availability.

One-hectare Level

Univariate Data

Most studies have examined habitat conditions within a few hectares of goshawk nests (Hennessy 1978, Reynolds 1978, Moore and Henny 1983, Hall 1984, Speiser and Bosakowski

1987, Anonymous 1989, Hayward and Escano 1989, Lilieholm et al. 1993, Speiser 1993, Bull and Hohmann 1994, Lang 1994, Squires and Ruggiero 1996). A common theme pervades throughout this literature: goshawks tend to nest on the lower portions of north to east facing slopes and in stands that typically have higher canopy closure, more large diameter trees, greater basal area, and occasionally greater tree densities than what is available in the greater landscape (Hennessy 1978, Reynolds 1978, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984, Hayward and Escano 1989, Lang 1994, Squires and Ruggiero 1996). My results generally agree with previous works at this landscape level. Although the actual numbers for each variable may vary among studies throughout the range of the goshawk in western North America, due to available habitat conditions, it is more important to recognize that these patterns exist and determine their functional importance for nesting goshawks.

Two hypotheses could explain the function of these conditions for nesting goshawks, namely microclimatic conditions or predator avoidance. Reynolds (1978) suggested that these conditions provide for reduced amounts of solar radiation and evapotranspiration, greater soil moisture, cooler temperatures, and higher humidity beneath the canopy, all conditions considered to be important for goshawk nesting. Another plausible theory is that these conditions facilitate concealment of young from predators. Following Janes' (1985:176) simple model for prey detection and capture, in which there are certain distances at which prey is no longer detectable due to height of vegetation and its diameter and density, the tendency for goshawks to place their nests at the base of the live canopy in dense, larger diameter stands on the lower portions of the slope may afford them protection from aerial predators, such as golden eagles (*Aquila chrysaetos*) and great horned owls (*Bubo virginianus*).

These concepts can also be applied to forest management at the stand level. Based on the correlations of basal area, live stem density, and mean canopy closure for the 1-ha level with stand density index (SDI) (r = 0.75, 0.62, and 0.76, respectively) in this study, it may be possible to manage for desirable nest site conditions to maintain microclimatic and predator avoidance conditions using SDI to guide habitat management. Lilieholm et al. (1993) and Long (1985) provide excellent discussions on habitat management using SDI. Stand density index is one of several expressions of relative stand density that integrates mean size and density (West 1982). As such, SDI can be used to guide manipulations of mean stand diameter and stand density to conditions within a stand that are deemed suitable for nesting northern goshawks. Theoretically, stands could be manipulated to provide and maintain the desired tree densities, diameters, and canopy closure that would afford goshawks with the microclimatic conditions and habitat required to avoid avian predators. However, this has not been attempted to the best of my knowledge, and it should be attempted with caution.

Univariate analyses indicated that mean stand age and proximity to human disturbance were statistically significant at this landscape level (Table 11). Although these two variables were statistically significant ($P = 0.0349$ and 0.0538, respectively), biological significance may not be readily apparent. Mean stand age at the 1-ha level was greater ($\bar{x} = 126$ years, SE = 4.9) at goshawk nests than at random sites ($\bar{x} = 115$ years, SE = 5.2), with a difference of only 11 years that might not be detectable by goshawks. Similarly, goshawk nest trees ($\bar{x} = 144$ m, SE = 19.8) were statistically closer to human disturbances than random UTM coordinates ($\bar{x} = 152$ m, SE = 21.7), although the distance between the two means was only 8 m. Therefore, although mean stand age and proximity to human disturbance may be statistically significant at the 1-ha level, biological significance for the goshawk may be lacking for these two variables.

Multivariate Data

Results of the logistic model for 1-ha level sites indicated that stage of stand development, topographic position, and basal area best discriminated between goshawk and random sites (Table 18). Due to the absence of goshawk nests in stand initiation stands, the stand initiation and stem exclusion stages of stand development were combined and used as the reference for the stage of stand development indicator variables in the logistic regression analysis (Hosmer and Lemeshow 1989). As a result, the new "early-to-mid-forest structural" stage, with 36 goshawk and 35 random sites, may have negated the potential beneficial effects of the understory reinitiation and old growth stages of stand development in the model.

Analysis of the coefficients of the rest of the model indicate that a stand's occurrence in a given stage of stand development and its topographic position are not sufficient information alone to differentiate a random site from a goshawk nest site. With the exception of basal area and the interaction term (i.e., low topographic position x basal area), the coefficients for other variables in the model are all negatively related with goshawk nest sites. Basal area, in conjunction with these other factors, appears to be the major factor in discriminating between random and goshawk 1-ha level sites. Of the total deviance explained by the model (deviance = 121.5, 6 df), basal area and its interaction with low topographic position explain 73% of that deviance (deviance = 88.8, 2 df). However, the interaction term does not contribute much to the amount of deviance explained by the model. Rather, basal area appears to be the single most important variable in the model, explaining 67.6% of model deviance by itself (deviance = 84.8, 1 df).

Figures 7 - 9 depict the effects of the basal area-topographic position relationship on the log odds for sites in stem exclusion, understory reinitiation, and old growth stands, respectively. Log odds in each figure represents the odds of a site being a goshawk nest site. For example, a site with a log odds ratio of zero has a 50% probability of being a goshawk nest site. As the log odds increase, the probability of a site being a goshawk nest site also increases. Based on the relationships in the model, the basal area on a given site, coupled with the stage of stand development and topographic position, could potentially be used to evaluate the habitat suitability of 1-ha level sites to support nesting goshawks.

Recognizing that stage of stand development, topographic position, and basal area all interact to produce suitable sites for nesting, a re-examination of nest site management strategies may be necessary. Currently, only goshawk nest trees are protected from harvesting during the nesting season under the Migratory Bird Treaty Act. However, a variety of buffering strategies do exist for the goshawk in the Pacific Northwest, as well as for northern spotted owls and bald eagles (*Haliaeetus leucocephalus*) (e.g., Forsman et al. 1985, Stalmaster et al. 1985, Riggs 1994, Schommer and Silovsky 1994). Buffers have failed to address two contingencies that potentially affect their effectiveness: (1) the influence of external factors on conditions inside the buffer for suitability, and (2) the influence of management on subsequent suitability of the site. Therefore, a management strategy that accounts for interactions among habitat factors and their effect on habitat suitability for the organism may be more appropriate than prohibitive buffers. One alternative to buffers is the use of the 1-ha model coupled with the ring model to evaluate the effects of habitat alterations on site-suitability at multiple landscape levels. Prior to initiation of a harvest in proximity to goshawk nests, current site-suitability should be assessed and the effects of post-harvest projections on site-suitability should be estimated through the models. Harvests should then be planned so that damage to site-suitability is minimized or stand characteristics are enhanced.

Landscape Modeling

Several logistic regression models were constructed corresponding with different landscape levels in order to identify an appropriate multivariate site suitability model. This objective was further refined to select the model that best discriminated between habitat conditions at goshawk and random sites across multiple landscape levels. Each model was evaluated on its predictive power and adherence to the *Principle of Parsimony* (i.e., that a proper model is supported by the data and has enough parameters to avoid bias, but not too many that precision is lost) (Burnham and Anderson 1992).

Of the four landscape models, the ring model (Table 26) is recommended for evaluating site suitability. In comparison with the models for individual landscape levels, the ring model had higher predictive capabilities, fewer parameters, no study area effect, and considered habitat conditions unique to each landscape level. For predictive power, the models for the 10-ha level, TPFA, PFA, and ring model evaluated the observations used to construct each model and had classification rates for goshawk and random sites at the 0.5 probability level of 69.5%, 71.8%, 62.1%, and 71.8%, respectively. Additionally, the 10-ha level, TPFA, PFA, and ring models incorporated 2, 9, 6, and 5 parameters, respectively (Tables 20, 22, 24, and 26, respectively). Although the TPFA and ring models appeared to have equal predictive capabilities, the ring model had fewer parameters and was potentially less biased towards other data sets than the TPFA model due to its lack of a study area effect and lack of study area-specific interactions among main factors. Additionally, the ring model was designed to incorporate parameters unique to each landscape level, after accounting for variables at successively smaller levels, which were associated with nesting northern goshawks (Ramsey et al. 1994). Therefore, the study area effect apparent in the model for the TPFA circle is most likely due to cross-scale correlations that still exist in the model (i.e., the effect of 10-ha level habitat has not been removed from the TPFA level).

Analysis of the ring model shows the importance of habitat conditions within the 10-ha level, how habitat conditions at different landscape levels interact with conditions within another landscape level, and the influence that other "non-significant" habitat categories have on the apparent selection of sites for nesting by goshawks. Ten-hectare level parameters collectively account for 75% of the deviance explained by the ring model, with the percent of the 10-ha level in high stem exclusion accounting for 37% of model deviance, and high understory reinitiation and the interaction term accounting for 66% of model deviance (Table 28). Although the percentages do not sum to 1, they do provide insight into the relative importance of each variable, and the 10-ha level, to the model's discriminatory power between goshawk and random sites. Additionally, the interaction between the percentages of high understory reinitiation and stand initiation in the 10-ha level and TPFA ring levels, respectively, is indicative of how conditions at different landscape levels affect the suitability of a site for goshawks. For example, given a landscape in which 3.5% of the TPFA ring were in stand initiation (Fig. 19), the amount of the 10-ha level in high understory reinitiation required for the odds of that landscape to be 50:50 for goshawk suitability (i.e., log odds = 0 or odds ratio = 1.0) would be approximately 44%. If the amount of stand initiation in the TPFA ring for the same landscape were increased to 10.4%, approximately 52% of the 10-ha level, an 8% increase, should be in high understory reinitiation for the same landscape suitability as a landscape with less stand initiation (Fig. 19). Despite the absence of other landscape composition variables (Table 2) from the model, Simpson's evenness index implies that goshawk nests are associated with landscapes in which the landscape composition variables that are present occur in relatively equal abundances in the TPFA ring.

Although variables from the PFA ring did not enter the model, this does not indicate that the 83 ha level is the biologically appropriate scale at which goshawk habitat management should occur. The question of the appropriate landscape scale to manage goshawk habitat was not addressed in this study. Through an analysis of "dense, late-forest conditions" across 5 landscape levels (three of which were <83 ha) at goshawk sites (n = 22) and sites not used by goshawks (n = 15), Daw (1997) found dense, late forest conditions to be important out to a scale of 24 ha. In order for the "appropriate" scale for goshawk habitat management to be determined, either radio-telemetry data need to be collected, or a study which synthesizes the analytical methods of this and Daw's (1997) research would be necessary. The latter method would incorporate Daw's (1997) multiple landscape levels (n > 5) and this study's multiple variables across multiple levels approach.

Implications for Goshawk Ecology

Goshawk nests appear to be more strongly associated with habitat conditions at smaller landscape levels than at larger levels; the ability to discriminate between goshawk nests and random sites decreased with increasing scale. In the ring model, variables from the 10-ha level account for 75% of model deviance, while variables from the TPFA ring account for 28%, and variables from the PFA ring did not contribute to the model (Table 28). It can thus be inferred that goshawk nest habitat selection appears to be occurring at the smaller landscape levels and that the "best" scale for landscape-level analysis lies between 10 and 83 ha. Landscape-level habitat associations include high canopy closure stem exclusion and understory reinitiation close to the nest, and an avoidance of stand initiation within the larger landscape (i.e., TPFA ring).

Through the 1-ha level and ring models (Tables 19 and 26, respectively), nesting habitat associations for goshawks can be thought of in terms of Johnson's (1980) hierarchical model. Presumably, prey abundance and availability, coupled with available habitat conditions, control home range selection (second-order selection) by raptors (Newton 1979, Johnson 1980). Within the home range, prior to the breeding season, a goshawk searches for an area that has generally low amounts of stand initiation, relatively equal amounts of other stand types, and an area within that region containing a high concentration of high canopy closure understory reinitiation and/or high canopy closure stem exclusion (third-order selection). The goshawk then searches for an area to place the nest within this region that has low topographic position and high basal area (fourth-order selection). As a result of this selection procedure, the goshawk has placed its nest in a location that may provide desirable microclimatic and predator avoidance conditions and is surrounded by a landscape matrix that may be conducive for prey, a deterrent for predation of juvenile goshawks by open-forest avian predators, and may provide divergent conditions in which juveniles can learn.

Management Implications

Some models of wildlife habitat enable biologists to summarize the relationships between a species and its environment, whereas others provide insight into observations and hypotheses about an animal's habitat use. The former equips biologists with tools that may predict the influences that specific habitat management practices may have on a species (i.e., adaptive management) and may allow landscape planners to predict the distribution and abundance of a species throughout a landscape (i.e., landscape assessment). The latter enables biologists to develop conceptual theories for habitat use, such as optimal foraging theory (Morrison et al. 1992, Pyke 1984). Due to the correlative nature of habitat conditions with goshawk nests in this study, the developed models do not lend themselves to the creation of conceptual theories for actual habitat use. More rigorous data, incorporating direct observations of habitat use by goshawks, would be required to develop substantive theories of habitat use and selection. Theories proposed that are based on correlative data are merely speculative in nature. However, models developed in this study have the potential for use in adaptive management situations and could be used to assess landscape suitability for nesting goshawks.

I recommend caution regarding the application of these models beyond the areas included in this study. First, goshawk nests in this study were not a random sample of the greater goshawk population, and any inferences based on these sites are merely correlative and do not represent cause and effect relationships (Zar 1984). Second, this study is based on habitat conditions surrounding goshawk nests and random points, and does not represent actual use. Finally, application of these data to other regions may be inappropriate based on differences in available habitat conditions between regions (Mosher et al. 1986).

Due to the strong fidelity goshawks have for nesting territories (Detrich and Woodbridge 1994), there may be a lag effect in abandonment of the nesting territory if habitat alterations surrounding nests are not mitigated with conditions conducive to nesting within a few years (Desimone 1997). Through adaptive management, the ring model has the potential to evaluate the effects of specific habitat management practices on a site's suitability for nesting northern goshawks. Although untested, the ring model might be used to assess the relative effects of habitat alterations surrounding goshawk nests, as well as offer conditions that would mitigate the effects of those changes. These habitat conditions may be achieved through various silvicultural techniques (e.g., Nyberg et al. 1987, McComb et al. 1993, Oliver et al. 1994). As part of an adaptive management process, the validity of this model for predicting the maintenance of landscape suitability for goshawk nesting should be assessed through rigorously designed manipulative experiments whereby differing silvicultural options are tested and modified as necessary (Irwin and Wigley 1993).

The potential exists for the ring model to be used as a tool to assess the suitability of large landscapes for nesting goshawks. Through assessing habitat conditions surrounding random points in the landscape or through a "moving-window" assessment in a geographical information system (GIS) (Burrough 1986), the likelihood that a landscape contains goshawk nest sites could be estimated. Implicit in the use of the ring model for such habitat assessments are several assumptions including: (1) prey are abundant and available; (2) breeding habitat is the factor that limits goshawk populations; (3) suitable microsites for nest placement are not limiting; and (4) surrounding habitat conditions can support over-wintering goshawks. Prey abundance and availability are important for determining the suitability of a site for breeding because they ultimately control home range selection by raptors, as well as the body condition of females for laying and incubating eggs, and the resources for successfully fledging young (Newton 1979). The assumption that nesting habitat is the limiting factor for goshawk populations discounts the importance of prey to goshawk populations. Younk and Bechard (1994) found goshawks nesting in small, isolated aspen (*Populus tremuloides*) stands in high-elevation, shrubsteppe habitat in northern Nevada. They found that increases in the preferred prey of goshawks may have accounted for the large number of sub-adult female goshawks in their breeding population. Given these assumptions, and the importance of prey to raptor populations, use of the ring model to assess entire landscapes for goshawk nesting habitat probably would overestimate the number of sites actually occupied within the context of the larger landscape. Therefore, although the model could be used for landscape assessment, I do not recommend it unless the practitioner also attempts to explicitly address the veracity of each assumption as part of the process.

CONCLUSIONS

Results of this study have served several purposes. First, at the 1-ha level it has confirmed what is already known about goshawk habitat, mainly, that goshawk nests are typically located in stands which exhibit mid- to late-forest structural conditions on north facing slopes with low topographic position, and have higher basal area, quadratic mean diameter, mean canopy closure, and tree densities relative to available habitat conditions. Second, at the 10-ha level, this study has reconfirmed that goshawk nests are associated with an abundance of mid- to late-forest structural conditions. Finally, the landscape analysis exhibited in the ring model served three functions: (1) to provide insight into habitat factors that may drive goshawk nest selection at higher levels of organization, (2) to depict how conditions at different landscape levels interact to influence habitat suitability, and (3) to increase our ability to develop predictive models for conservation planning for the goshawk.

Insight I have gleaned pertaining to habitat selection at higher levels of organization by goshawks indicate that the strongest habitat associations with goshawk nests occur at relatively small landscape levels. Despite the fact that habitat associations do not equate with individual habitat selection, the relative importance of the 10-ha level variables and unimportance of post-fledging area ring variables in the ring model indicate that selection for goshawk nests appears strongest at the smallest landscape levels.

The landscape analysis also indicates how habitat conditions at different levels interact and influence habitat which surrounds goshawk nests. The ring model indicates that there is an interaction between the percent of the 10-ha level in high canopy closure (i.e., total stand canopy closure $\geq$ 50%) understory reinitiation and the percent of the theoretical post-fledging area ring in stand initiation. Through this interaction it can be inferred that in landscapes which have greater amounts of stand initiation, goshawks place nests in "nest stands" that have greater amounts of high canopy closure understory reinitiation than usual. Perhaps the high understory reinitiation serves to act as a buffer between the nest and the apparent negative effects of stand initiation.

My research serves to increase our ability to further develop predictive models for conservation planning for the goshawk by providing a probabilistic framework in which habitat characteristics and their interactions influence use of a site for nesting by goshawks. Use of these concepts in an adaptive management context, where the effects of various habitat manipulations surrounding goshawk nests are rigorously tested in manipulative experiments, could lead to the development of predictive models to determine the effects various silvicultural options would have on the maintenance and development of favorable forest conditions for goshawk nests. Telemetry studies of fledgling goshawk and nesting adult female habitat use would further elucidate desirable and unfavorable habitat conditions and the scale at which to manage for nesting and fledgling goshawks.

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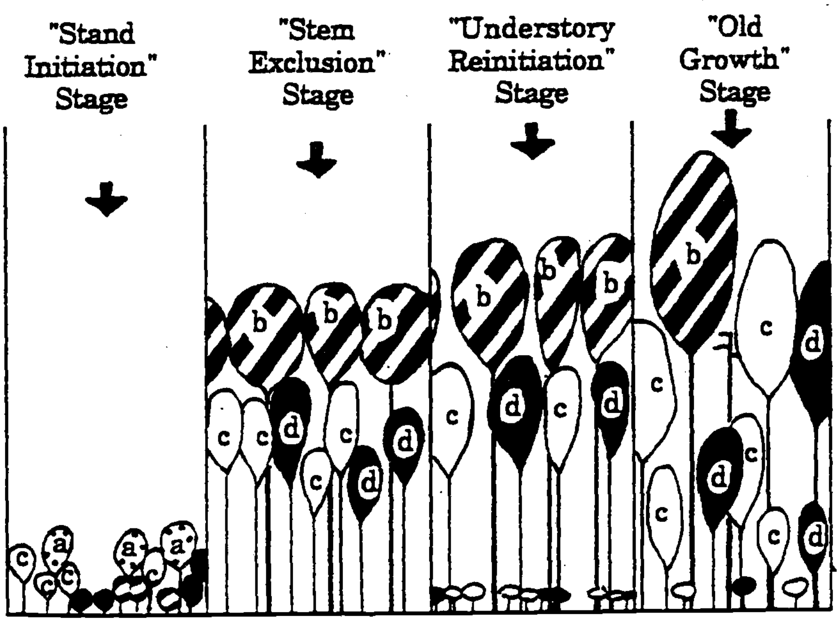
APPENDICES

Appendix 1. Stages of stand development for forested stands. Stand initiation is characterized by young trees of various species following a disturbance. Stem exclusion is characterized by the absence of seedlings and saplings, the onset of self-thinning throughout competition, and the beginning of crown class differentiation into dominant and subordinant species. Understory reinitiation is characterized by the colonization of the forest floor by advanced regeneration and the continuation of competition in the overstory. Old growth is characterized by the senescence of overstory trees in an irregular fashion and the growth of the understory trees to the overstory. Diagram is from Oliver and Larson (1990:143) and letters indicate individual tree species.



Appendix 2. Aerial photo stand typing protocol used to delineate forest structural stands surrounding northern goshawk nests and random sites in eastern Oregon and Washington, 1994-1995.

Objective: To identify, through aerial photo interpretation, stand initiation, stem exclusion, understory reinitiation and old growth stages of stand development, in addition to wet and dry openings, surrounding northern goshawk nests and random sites.

Criteria: Delineating criteria include: 1). crown diameters, 2). canopy layers, 3). diversity of crown diameter classes, 4). canopy closure. Smallest stand area is 2.02 ha, and must be wider than a road.

Stand Initiation

- very small crown diameters.
- individual crowns indiscernible.
- appears as green "peach fuzz". In B/W photos, just peach fuzz.

For individual photo scales, the following are the ranges of crown diameters, in thousandths of an inch, for trees that would fall in this category:

Scale	Range of Crown Diameters
1:12000	0 - 7.5
1:15800	0 - 5.0
1:16000	0 - 2.5

Stem Exclusion

Canopy closure ≥50%

- tight spacing, few gaps in canopy
- uniform crown widths
- single story appearance

Canopy closure <50%

- open spacing between crowns
- uniform crown widths

Appendix 2. (Continued)

- no understory trees can be seen in canopy gaps
- single story appearance

Understory Reinitiation

≥ and <50% canopy closure

- 2 canopy layers are evident
- gaps in canopy are present
- 2 crown diameter classes are present
- abundance of the larger crown diameter class (constitutes >50% of stand)

Old Growth

- 2 or more canopy layers are evident
- 2+ crown diameter classes are visible
- largest crown diameter class constitutes <50% of stand

Openings

Wet

- stream is evident, either through contrasts in vegetation (riparian) or the dendritic pattern is visible.
- area is devoid of trees or trees are sparsely scattered throughout the opening.

Dry

- vegetation appears as a scab flat or is trees are either lacking or sparsely scattered.
- streams are absent.

Appendix 2. (Continued)

Water

- Bodies of water distinguishable on aerial photos (i.e., rivers, ponds, and lakes).

Appendix 3. Contrast weights for the contrast weighted edge density (CWED) variable based on forest structural differences. For example, a stand initiation stand occurring next to a low understory reinitiation stand has a contrast weight of 0.67.

	High stem exclusion	Low stem exclusion	High understory reinitiation	Low understory reinitiation	Old growth	Wet opening	Dry opening	Water
Stand initiation	0.33	0.33	0.67	0.67	1	0.2	0.2	1
High stem exclusion		0	0.33	0.33	0.67	0.53	0.53	1
Low stem exclusion			0.33	0.33	0.67	0.53	0.53	1
High understory reinitiation				0	0.33	0.87	0.87	1
Low understory reinitiation					0.33	0.87	0.87	1
Old growth						1	1	1
Wet opening							0	1
Dry opening								1

Appendix 4. Contrast weights for the contrast weighted edge density (CWED) variable based on canopy closure differences. For example, a high understory reinitiation stand occurring next to a low understory reinitiation stand has a contrast weight of 0.33.

	High stem exclusion	Low stem exclusion	High understory reinitiation	Low understory reinitiation	Old growth	Wet opening	Dry opening	Water
Stand initiation	0.67	0.33	0.67	0.33	0.67	0.33	0.33	1
High stem exclusion		0.33	0	0.33	0	1	1	1
Low stem exclusion			0.33	0	0.33	0.67	0.67	1
High understory reinitiation				0.33	0	1	1	1
Low understory reinitiation					0.33	0.67	0.67	1
Old growth						1	1	1
Wet opening							0	1
Dry opening								1

Appendix 5. Univariate habitat characteristics of goshawk 1-ha level sites compared to those available in the central Washington study area, 1994-1995. Results are for untransformed data.

	Goshawk sites (n = 14)			Random sites (n = 16)			
Variable	Mean	SE	Range	Mean	SE	Range	P-value
Elevation (m)	1101	56.1	728-1649	1131	74.2	695-1780	0.7550
% Slope	41.6	4.3	4.5-63.0	40.3	5.5	6.5-88.0	0.8507
Aspect (°)	0.7	17.4	3-325	107.7	14.4	15-356	0.56[a]
Basal area (m^2/ha)	47.9	2.4	34.8-65.9	26.6	3.4	8.0-50.8	<0.0001
DBH_Q (cm)	26.5	1.5	17.7-36.9	20.5	1.7	12.6-36.5	0.0129
Live stem density (trees/ha)	905.7	74.5	465-1475	944.1	118.8	180-2065	0.7933
SDI	939.1	52.8	643.6-1339.5	641.1	79.6	200.1-1122.8	0.0052
% Canopy closure	72.8	2.2	59.5-86.8	45.9	4.7	14.8-74.1	0.0001
Age	129.4	14.6	71.9-285.5	140.2	18.6	43.6-306.3	0.6600
Proximity (m) to:							
Forest change	70.1	16.4	15.0-259.0	71.4	23.2	4.0-289.0	0.9666
Human disturbance	299.6	92.0	34.0-1358.0	146.8	34.5	7.0-398.0	0.0269[b]
Water	218.2	28.5	24.0-396.0	269.2	61.1	3.0-665.0	0.4582

[a]P-value for two-sample testing of angles.

[b]P-value for log-transformed data.

Appendix 6. Univariate habitat characteristics of goshawk 1-ha level sites compared to those available in the northeast Oregon study area, 1994-1995. Results are for untransformed data.

	Goshawk sites (n = 27)			Random sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Elevation (m)	1242	29.5	905-1576	1422	49.1	792-1932	0.0033
% Slope	26.1	3.5	4.0-75.0	27.7	4.8	4.0-96.5	0.7829
Aspect (°)	2.8	9.8	2-352	139.4	15.3	26-311	0.002[a]
Basal area (m^2/ha)	42.1	1.9	26.2-64.6	19.0	2.2	2.3-51.5	<0.0001
DBH_Q (cm)	27.0	0.9	18.0-36.9	21.4	1.8	6.9-41.5	0.0088
Live stem density (trees/ha)	580.7	59.4	70-1250	602.4	118.2	5-2595	0.8709
SDI	596.8	41.7	84.3-926.7	333.1	41.5	11.2-825.9	<0.0001
% Canopy closure	54.9	3.0	25.4-89.1	27.0	3.0	3.9-55.3	<0.0001
Age	103.3	4.5	59.9-145.2	96.4	8.0	21.8-214.7	0.4525
Proximity (m) to:							
Forest change	53.2	6.6	16.0-155	47.8	8.7	0-168.0	0.6194
Human disturbance	127.1	23.6	10.0-425.0	134.5	42.3	0-800.0	0.0619[b]
Water	335.7	73.1	4.0-1280.0	389.0	59.5	25.0-1110.0	0.5775

[a]*P*-value for two-sample testing of angles.
[b]*P*-value for log-transformed data.

Appendix 7. Univariate habitat characteristics of goshawk 1-ha level sites compared to those available in the Malheur study area, 1994-1995. Results are for untransformed data.

	Goshawk sites (n = 20)			Random sites (n = 24)			
Variable	Mean	SE	Range	Mean	SE	Range	P-value
Elevation (m)	1555	15.5	1402-1743	1566	26.7	1317-1829	0.7283
% Slope	15.1	2.0	6.0-38.5	21.7	3.0	4.0-52.0	0.2297[a]
Aspect (°)	118.8	15.5	16-360	168.0	14.7	30-358	<0.0001[b]
Basal area (m^2/ha)	30.7	1.5	18.7-43.6	23.0	1.7	9.9-44.6	0.0021
DBH_Q (cm)	21.8	1.4	12.9-34.8	23.3	1.3	14.5-35.5	0.4345
Live stem density (trees/ha)	903.5	113.4	310-1925	549	50.2	160-1080	0.0082
SDI	598.5	34.6	391.0-1031.7	451.6	39.3	194.7-1081.9	0.0088
% Canopy closure	44.6	1.8	27.1-57.0	38.2	2.5	16.1-66.0	0.0527
Age	150.3	9.1	89.1-254.3	120.6	7.0	79.2-216.5	0.0116
Proximity (m) to:							
Forest change	75.8	14.0	6.0-216.0	52.7	8.6	15.0-213.0	0.1521
Human disturbance	93.8	14.7	30.0-282.0	174.0	42.8	0-820.0	0.8258[a]
Water	367.0	50.5	24.0-744.0	280.6	39.3	40.0-707.0	0.1785

[a]P-value for log-transformed data.
[b]P-value for two-sample testing of angles.

Appendix 8. Univariate habitat characteristics of goshawk 1-ha level sites compared to those available in the Fremont study area, 1994-1995. Results are for untransformed data.

	Goshawk sites (n = 21)			Random sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Elevation (m)	1730	57.7	1164-2131	1767	37.6	1378-2036	0.5849
% Slope	13.1	2.1	2.0-34.5	14.6	2.7	0.5-52.0	0.6705
Aspect (°)	25.1	15.7	40-358	169.3	13.3	2-332	0.0035[a]
Basal area (m^2/ha)	43.3	2.8	11.2-67.2	22.0	2.0	1.6-41.7	<0.0001
DBH_Q (cm)	20.8	1.0	15.0-33.2	17.9	0.8	7.7-23.0	0.0254
Live stem density (trees/ha)	1156.7	121.8	260-2155	563.4	98.4	140-2375	0.0648
SDI	789.9	68.0	149.1-1429.2	473.4	52.8	77.0-1190.3	0.0005
% Canopy closure	45.7	2.5	14.3-65.8	26.3	2.9	2.7-57.0	<0.0001
Age	131.0	10.7	69.6-236.2	113.6	9.3	61.6-210.3	0.2228
Proximity (m) to:							
Forest change	40.1	8.2	0-144.0	55.7	12.6	60.0-287.0	0.3043
Human disturbance	110.0	19.5	0-291.0	153.2	48.2	0-1200.0	0.4123
Water	410.4	81.8	39.0-1415.0	520.0	149.4	47.0-3622.0	0.5239

[a]*P*-value for two-sample testing of angles.

Appendix 9. Univariate habitat characteristics of goshawk 10-ha level sites compared to those available in the central Washington study area, 1994-1995. Values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 14)			Random Sites (n = 20)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	2.1	1.0	0-10.5	28.5	9.5	0-100	0.0118
High[a] stem exclusion	44.3	9.7	0-100	36.3	7.1	0-100	0.5005
Low[a] stem exclusion	6.6	4.9	0-66.6	15.7	6.0	0-79.3	0.2747
High understory reinitiation	45.0	10.1	0-100	8.4	3.9	0-70.8	0.0037
Low understory reinitiation	NA	NA	NA	NA	NA	NA	NA
Old growth	0	0	0	2.5	1.8	0-27.9	0.1649
Wet openings	0.8	0.8	0-10.9	4.8	2.7	0-38.6	0.1615
Dry openings	1.3	0.9	0-9.5	3.7	2.1	0-34.7	0.2945
Water	NA	NA	NA	NA	NA	NA	NA

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.

Appendix 10. Univariate habitat characteristics of goshawk 10-ha level sites compared to those available in the northeast Oregon study area, 1994-1995. Values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 27)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	3.9	1.8	0-34.9	8.8	4.0	0-73.2	0.2755
High[a] stem exclusion	16.9	5.1	0-87.4	8.3	4.4	0-90.0	0.2107
Low[a] stem exclusion	4.8	2.1	0-44.5	0	0	0	0.0306
High understory reinitiation	46.7	5.5	0-99.0	31.9	6.6	0-95.0	0.0891
Low understory reinitiation	17.1	4.1	0-80.6	40.0	7.0	0-100	0.0076
Old growth	4.1	3.1	0-82.9	0.8	0.8	0-19.9	0.3195
Wet openings	0.2	0.2	0-5.4	1.6	1.1	0-21.3	0.2393
Dry openings	6.2	2.3	0-44.3	8.5	2.8	0-51.1	0.5105
Water	0	0	0	4.7	0.1	0-1.2	0.3033

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.

Appendix 11. Univariate habitat characteristics of goshawk 10-ha level sites compared to those available in the Malheur study area, 1994-1995. Values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 20)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	0.1	0.1	0-0.4	5.5	4.2	0-99.6	0.2054
High[a] stem exclusion	21.3	6.7	0-92.2	8.1	6.5	0-60.6	0.0888
Low[a] stem exclusion	1.3	1.1	0-21.2	7.7	4.5	0-93.5	0.1752
High understory reinitiation	55.9	7.2	0-100	39.4	6.7	0-98.7	0.0756[b]
Low understory reinitiation	20.1	4.8	0-77.8	35.0	5.8	0-96.5	0.1443[b]
Old growth	NA	NA	NA	NA	NA	NA	NA
Wet openings	0.9	0.7	0-12.5	0.2	0.2	0-5.4	0.3252
Dry openings	0.4	0.3	0-6.2	4.1	2.0	0-39.4	0.1143[b]
Water	NA	NA	NA	NA	NA	NA	NA

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value is for arcsine square root transformed data.

Appendix 12. Univariate habitat characteristics of goshawk 10-ha level sites compared to those available in the Fremont study area, 1994-1995. Values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 21)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	0	0	0	4.8	2.6	0-42.8	0.0801
High[a] stem exclusion	24.9	7.1	0-100	11.5	3.8	0-62.9	0.0848[b]
Low[a] stem exclusion	12.5	6.6	0-100	12.0	4.2	0-77.3	0.9495
High understory reinitiation	40.5	7.4	0-100	17.9	5.3	0-89.5	0.0151
Low understory reinitiation	13.1	4.6	0-60.1	47.8	6.5	0-100	0.0001
Old growth	3.5	3.5	0-73.1	1.6	1.6	0-39.8	0.6250
Wet openings	3.8	1.7	0-27.4	3.6	2.2	0-46.5	0.9437
Dry openings	1.8	0.9	0-17.5	0.9	0.6	0-13.0	0.4032
Water	NA	NA	NA	NA	NA	NA	NA

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value is for arcsine square root transformed data.

Appendix 13. Univariate habitat characteristics of goshawk 83 ha theoretical post-fledging areas compared to those available in the central Washington study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 14)			Random Sites (n = 20)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	6.6	2.1	0-23.5	29.6	7.4	0-98.5	0.0067
High[a] stem exclusion	36.9	5.9	8.0-86.7	30.7	5.1	0.8-87.3	0.4286
Low[a] stem exclusion	15.8	3.8	0-50.2	18.1	5.1	0-72.1	0.7406
High understory reinitiation	35.6	4.8	4.6-71.4	9.4	2.4	0-38.2	0.0001
Low understory reinitiation	NA	NA	NA	NA	NA	NA	NA
Old growth	0	0	0	1.5	1.1	0-20.4	0.1906
Wet openings	1.1	0.7	0-8.5	4.9	2.5	0-44.9	0.1559
Dry openings	2.7	1.4	0-17.9	5.8	2.1	0-31.0	0.2232
Water	1.4	1.4	0-19.2	0	0	0	0.3356
CWED[b]: structure (m)	26.0	4.0	4.7-49.8	24.7	3.2	1.3-61.8	0.7988
CWED: canopy closure (m)	27.2	5.0	6.9-61.7	33.8	3.4	2.7-59.2	0.2671
Mean nearest neighbor (m)	172	40.3	38-607	174	15.4	51-296	0.9641
Simpson's evenness index	0.8	0.1	0.4-1.0	0.7	0.1	0.1-1.0	0.0774[c]
Contagion (%)	58.7	1.9	48.2-77.2	65.3	2.3	53.1-94.2	0.0501

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]Contrast weighted edge density.
[c]Results for arcsine square root transformed data.

Appendix 15. Univariate habitat characteristics of goshawk 83 ha theoretical post-fledging areas compared to those available in the Malheur study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n =20)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	1.3	0.8	0-15.4	3.4	2.1	0-47.9	0.3508
High[a] stem exclusion	13.2	3.5	0-53.3	9.5	2.2	0-33.6	0.3604
Low[a] stem exclusion	5.5	2.1	0-30.2	6.6	3.5	0-66.0	0.7773
High understory reinitiation	45.3	3.9	9.0-73.4	36.9	4.2	0-74.9	0.1588
Low understory reinitiation	30.8	3.6	8.9-63.5	36.6	4.0	0-71.4	0.2990
Old growth	0	0	0	0.1	0.1	0-2.2	0.3273
Wet openings	3.1	0.9	0-12.8	1.4	0.5	0-10.4	0.0699[b]
Dry openings	0.9	0.5	0-9.8	5.5	2.4	0-54.3	0.0758
Water	NA	NA	NA	NA	NA	NA	NA
CWED[c]: structure (m)	24.3	2.5	8.0-48.4	25.0	3.9	0-75.5	0.8754
CWED: canopy closure (m)	34.4	3.5	8.6-70.0	39.1	3.9	6.8-91.2	0.3900
Mean nearest neighbor (m)	143	19.3	49-406	91	8.7	27-193	0.0217
Simpson's evenness index	0.8	0.1	0.6-0.9	0.8	0.1	0.6-1.0	0.6351
Contagion (%)	62.7	1.2	52.4-70.3	61.3	1.4	46.9-71.3	0.4573

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]Results for arcsine square root transformed data.
[c]Contrast weighted edge density.

Appendix 16. Univariate habitat characteristics of goshawk 83 ha theoretical post-fledging areas compared to those available in the Fremont study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 21)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	0.3	0.2	0-3.2	4.6	1.7	0-30.7	0.0181
High[a] stem exclusion	23.0	4.4	0-78.5	10.2	1.8	0-29.0	0.0128
Low[a] stem exclusion	10.0	4.3	0-70.8	10.2	3.3	0-70.3	0.9637
High understory reinitiation	38.4	5.3	0-97.0	21.2	4.6	0-89.3	0.0175
Low understory reinitiation	20.2	3.5	0-57.8	45.7	4.2	0-88.6	0.0001
Old growth	1.4	1.4	0-28.8	0.7	0.7	0-18.1	0.6785
Wet openings	3.3	1.3	0-19.8	3.3	1.4	0-30.2	0.9831
Dry openings	3.5	1.3	0-18.2	4.0	1.9	0-37.5	0.8072
Water	0.1	0.1	0-1.4	0	0	0	0.3293
CWED[b]: structure (m)	32.8	4.7	5.5-82.7	33.0	4.4	6.2-105.2	0.9720
CWED: canopy closure (m)	31.3	5.4	0.4-83.5	31.5	4.8	0-103.1	0.9731
Mean nearest neighbor (m)	95	14.2	32-303	117	13.7	30-331	0.2560
Simpson's evenness index	0.8	0.1	0.1-1.0	0.8	0.1	0.3-1.0	0.8888
Contagion (%)	60.0	2.3	47.7-93.2	60.2	1.6	49.6-79.9	0.9289

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]Contrast weighted edge density.

Appendix 17. Univariate habitat characteristics of goshawk 170 ha post-fledging areas compared to those available in the central Washington study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 14)			Random Sites (n = 20)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	9.9	2.9	0-27.7	29.0	6.6	0-88.6	0.0132
High[a] stem exclusion	35.5	4.5	5.8-69.2	32.5	4.2	4.9-78.5	0.6255
Low[a] stem exclusion	18.0	3.2	0-44.3	16.6	4.3	0-67.8	0.8104
High understory reinitiation	30.6	3.0	10.9-47.6	9.3	2.1	0-29.4	<0.0001
Low understory reinitiation	NA	NA	NA	NA	NA	NA	NA
Old growth	0	0	0	1.0	0.7	0-12.3	0.1765
Wet openings	0.7	0.5	0-5.6	5.7	2.6	0-47.7	0.0519[b]
Dry openings	3.2	1.4	0-15.1	6.0	1.9	0-29.9	0.2861
Water	2.02	2.02	0-28.3	0	0	0	0.3356
CWED[c]: structure (m)	21.0	3.4	5.3-41.9	22.3	2.2	4.8-43.0	0.7494
CWED: canopy closure (m)	23.9	4.2	7.6-51.7	32.2	2.6	9.5-57.8	0.0481[d]
Mean nearest neighbor (m)	193	27.8	58-462	171	17.1	35-308	0.4862
Simpson's evenness index	0.9	0.1	0.7-1.0	0.7	0.1	0.3-1.0	0.0044
Contagion (%)	54.6	1.0	49.7-61.2	62.0	1.9	51.4-82.0	0.0014

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value for arcsine square root transformed data.
[c]Contrast weighted edge density.
[d]*P*-value for square root transformed data.

Appendix 18. Univariate habitat characteristics of goshawk 170 ha post-fledging areas compared to those available in the northeast Oregon study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 27)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	4.9	1.8	0-41.4	6.6	1.8	0-29.3	0.5263
High[a] stem exclusion	11.0	2.8	0-50.2	6.3	2.5	0-60.2	0.2097
Low[a] stem exclusion	4.2	1.5	0-33.5	1.0	0.4	0-6.4	0.0546[b]
High understory reinitiation	32.6	3.4	0-63.4	27.7	3.6	73.1	0.3261
Low understory reinitiation	33.4	3.4	2.2-77.9	42.3	4.1	6.0-82.7	0.1053[b]
Old growth	1.7	0.8	0-15.3	1.6	1.6	0-41.0	0.9865
Wet openings	0.3	0.2	0-5.2	0.7	0.5	0-11.5	0.5388
Dry openings	11.9	2.7	0-52.6	13.7	3.2	0-56.2	0.6653
Water	0	0	0	0.2	0.2	0-3.8	0.3273
CWED[c]: structure (m)	38.8	5.1	3.5-105.4	41.0	5.2	1.8-104.6	0.7721
CWED: canopy closure (m)	41.6	5.3	8.3-117.9	46.5	4.8	9.6-96.0	0.5025
Mean nearest neighbor (m)	153	22.0	24-545	170	39.3	21-952	0.7048
Simpson's evenness index	0.8	0.1	0.5-1.0	0.8	0.1	0.4-1.0	0.0780
Contagion (%)	58.2	1.2	49.8-70.5	61.1	1.4	47.0-78.5	0.1140

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value for arcsine square root transformed data.
[c]Contrast weighted edge density.

Appendix 19. Univariate habitat characteristics of goshawk 170 ha post-fledging areas compared to those available in the Malheur study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 20)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	1.6	0.8	0-14.0	2.9	1.4	0-30.2	0.4059
High[a] stem exclusion	11.7	3.1	0-48.5	9.1	2.0	0-34.4	0.4659
Low[a] stem exclusion	6.6	1.7	0-26.0	5.2	2.7	0-57.2	0.6673
High understory reinitiation	43.5	3.7	6.5-64.2	38.1	3.6	0-75.8	0.3120
Low understory reinitiation	31.4	3.9	8.4-66.9	37.4	3.8	0-77.5	0.2907
Old growth	0	0	0	0.1	0.1	0-18.1	0.1766
Wet openings	3.9	0.9	0-13.5	1.9	0.6	0-11.4	0.0477[b]
Dry openings	1.3	0.5	0-9.2	5.3	1.9	0-40.4	0.1272[b]
Water	NA	NA	NA	NA	NA	NA	NA
CWED[c]: structure (m)	23.8	2.3	9.6-45.9	23.0	2.4	0-73.9	0.8562
CWED: canopy closure (m)	33.6	3.0	13.2-58.3	34.6	3.4	6.2-82.7	0.8396
Mean nearest neighbor (m)	169	19.4	17-372	140	18.7	17-372	0.2816
Simpson's evenness index	0.8	0.1	0.6-0.9	0.8	0.1	0.5-1.0	0.4296
Contagion (%)	62.3	1.0	54.0-70.3	60.6	1.4	47.3-72.1	0.3049

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]*P*-value for arcsine square root transformed data.
[c]Contrast weighted edge density.

Appendix 20. Univariate habitat characteristics of goshawk 170 ha post-fledging areas compared to those available in the Fremont study area, 1994-1995. Stand type values are for the mean percent of the landscape occurring in each habitat category. Results are for untransformed data.

	Goshawk Sites (n = 21)			Random Sites (n = 25)			
Variable	Mean	SE	Range	Mean	SE	Range	*P*-value
Stand initiation	0.6	0.4	0-8.4	4.5	1.4	0-25.6	0.0108
High[a] stem exclusion	19.6	3.6	0-63.1	11.3	1.9	0-31.5	0.0481
Low[a] stem exclusion	8.7	3.3	0-51.1	9.7	3.1	0-67.9	0.8234
High understory reinitiation	37.4	4.9	0-87.0	21.1	4.3	0-79.1	0.0159
Low understory reinitiation	25.7	3.9	0-64.2	45.2	4.1	7.1-84.8	0.0014
Old growth	0.8	0.8	0-17.5	0.6	0.6	0-15.2	0.8232
Wet openings	3.5	1.1	0-16.2	3.1	1.3	0-31.1	0.7955
Dry openings	3.6	1.1	0-17.4	4.4	2.1	0-43.6	0.7336
Water	NA	NA	NA	NA	NA	NA	NA
CWED[b]: structure (m)	28.6	3.8	4.8-74.4	27.7	3.3	5.7-78.0	0.8577
CWED: canopy closure (m)	28.6	4.4	4.0-71.7	26.4	3.7	1.8-78.5	0.7099
Mean nearest neighbor (m)	161	22.0	39-415	157	17.0	30-334	0.8736
Simpson's evenness index	0.8	0.1	0.4-1.0	0.8	0.1	0.4-0.9	0.2128
Contagion (%)	58.3	1.5	49.2-78.4	61.2	1.3	53.0-75.2	0.1498

[a]"High" and "low" denote ≥ or <50% canopy closure, respectively.
[b]Contrast weighted edge density.