AN ABSTRACT OF THE THESIS OF

Steven M. Desimone for the degree of Master of Science in Wildlife Science presented on 20 June 1997. Title: Occupancy Rates and Habitat Relationships of Northern Goshawks in Historic Nesting Areas in Oregon.

Abstract approval: Redacted for Privacy

Stephen DeStefano

The ability of northern goshawks (*Accipiter gentilis*) to persist in intensively managed and selectively harvested forest habitats is largely unknown. To address the concern that populations of northern goshawks in eastern Oregon may be declining in response to habitat alteration, I studied occupancy rates and habitat relationships of nesting goshawks on the Fremont National Forest and adjacent private lands during 1992-1994. My objectives were to determine if historic territories (i.e., those occupied ≥1 season during 1973-1991) were still occupied, document current site conditions and quantify changes in forest cover on those territories between 1973-1994, and compare present conditions of forest vegetation between nest sites that were currently occupied and those where I did not detect the presence of territorial goshawks (no-response sites). In 1994, I surveyed a forest-wide random sample of 51 historic nest sites, stratified by forest cover type. Occupancy of historic sites by goshawks was 29% (15 of 51), compared to 79% (30 of 38) mean annual occupancy rate of current territories (found initially during 1992-1994). Across all strata, 86% of current nest sites (n = 38) were in Mid-aged or Late structural stage forest (trees >23 cm DBH) with >50% canopy closure. Among the historic territories used for analysis (n = 46), those found occupied

(n = 15) in 1994 had significantly more Mid-aged Closed forest (average stand DBH 23-53 cm, <15 trees per ha >53 cm DBH; >50% canopy closure) and Late Closed forest (≥15 trees per ha >53 cm DBH; >50% canopy closure) than no-response sites (n = 31). This relationship was significant ($P < 0.05$) for circular scales of 12, 24, 52, 120, and 170 ha surrounding goshawk territory centers. Within the 52 ha scale around historic nest sites surveyed in 1994, occupied sites had 49% (SE = 6.6) total Late Closed and Mid-aged Closed forest, while sites with no response had 19% (SE = 3.0) total Late and Mid-aged Closed forest. Historic sites had 51% (SE = 3.8) total Late and Mid-aged Closed forest when last known occupied before 1992. Among historic territories, mean percent area of habitat in Late Closed forest at the 12 ha nest stand scale was 4 times greater in occupied (27%) than in no-response sites (6%) ($P < 0.05$). A logistic regression model for occupied sites confirmed the importance of Late Closed and Mid-aged Closed forests as indicators of quality habitat within the 52 ha scale on historic sites where goshawks were still present in 1994. Goshawk pairs were more likely to persist in historic territories having a high percentage of mature and older forest (about 50%) in closed-canopied conditions within the 52 ha scale, suggesting that little or no habitat alteration within aggregate nest stands is important to ensure the persistence of nesting pairs. I recommend preserving multiple nest stands within the 52 ha scale and discourage further cutting of large, late and old structure trees (>53 cm DBH) within the PFA to preserve stand integrity, maintain closed canopies, maintain connectivity to alternate nest stands, and optimize conditions for breeding goshawk pairs to persist.

Occupancy Rates and Habitat Relationships of Northern Goshawks in Historic Nesting Areas in Oregon

by

Steven M. Desimone

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Major Professor, representing Wildlife Science

Redacted for Privacy

Head of Department of Fisheries and Wildlife

Redacted for Privacy

Dean of Graduate School

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INTRODUCTION

The northern goshawk (*Accipiter gentilis*) is most closely associated with late-successional coniferous forests for nesting habitat in western North America (Reynolds et al. 1982, 1983; Moore and Henny 1983; Hall 1984; Crocker-Bedford and Chaney 1988; Kennedy 1988; Hayward and Escano 1989; Austin 1993; Siders and Kennedy 1996; Daw 1997). Avian predators such as forest-dwelling raptors are increasingly viewed as indicators of forest health or habitat quality (Forsman et al. 1984, Reynolds 1989, Howell et al. 1995), and the loss of nesting habitat due to timber harvest may pose a significant threat to their populations (Reynolds 1989, McCarthy et al. 1989, Crocker-Bedford 1990).

Northern goshawk, Cooper's hawk (*Accipiter cooperii*), and sharp-shinned hawk (*A. striatus*) ecology and nesting habitat were first studied by Reynolds (1975, 1978) in intensively managed National Forests and private timberlands of eastern Oregon in the 1970s, where the breeding ranges of the 3 species overlap. There has been no formal monitoring of accipiter densities in his study area since the mid-1970s. Surveys and incidental sightings of accipiters and other raptors by U. S. Forest Service and private timber inventory crews have been irregular and incidental in the last 2 decades (1973-1994). As a result, the ability of goshawk pairs to persist in these intensively managed and selectively harvested forest habitats is largely unknown. Although the effects of timber harvesting on goshawk ecology are not clearly understood, there is evidence to suggest that harvest impacts nest site selection (Reynolds 1989, Crocker-Bedford 1990, Ward et al. 1992, Woodbridge and Detrich 1994). Closed canopy (>50%), mature forest is thought to be the most consistent structural characteristic of preferred goshawk nest stands (Reynolds et al. 1982, 1992; Moore and Henny 1983; Crocker-Bedford and Chaney 1988; Hayward and Escano 1989; Ward et al. 1992; Bull and Hohmann 1994; Siders and Kennedy 1996; Squires and Ruggiero 1996). In Arizona, Ward et al. (1992) suggested that the loss of forest acreage in the ≥40% canopy closure classes was correlated with goshawk territories becoming inactive. In California, Austin (1993) found that goshawks used closed canopy forest (>40% canopy closure) more than open forest (<40% canopy closure) or meadows.

To address the concern that populations of northern goshawks in eastern Oregon may be declining in response to habitat alteration, I studied occupancy rates and habitat relationships of northern goshawk nesting territories on the Fremont National Forest and adjacent private lands during 1992-1994. I wanted to determine how breeding goshawks responded to changes in forest structure over time and assess whether these disturbances were natural (e.g., forest succession, wildfire) or human-caused (e.g., timber harvest, regeneration forest management). I used the aerial photographic record to examine of the impacts of forestry management operations in harvested areas (Reutebuch and Gall 1990). I also wanted to determine how variable occupancy of territories by goshawks might affect an observer's ability to detect presence or absence of goshawks in historic nesting areas. My objectives were to: (1) compare densities of nesting accipiters documented in 1974 (Reynolds 1975) to densities in 1993; (2) determine if goshawks were still present or nesting in 1994 from a random sample of historic nest sites (i.e., nests first found in 1973-1991); (3) document current forest conditions and quantify changes in forest cover on historic nesting territories; and (4) compare present conditions of forest cover between currently occupied sites and historic sites that I termed no-response sites (i.e., where I did not detect presence of goshawks in 1994).

METHODS

Study Areas

Research took place on the Silver Lake, Paisley, Bly, and Lakeview Ranger Districts of the Fremont National Forest and the Klamath Province of the Weyerhaeuser Corporation in eastern Oregon, encompassing >5,000 km^2 (Figure 1). Elevations on the study area ranged from 1,200 - 2,200 m. Ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor)*, and lodgepole pine (*P. contorta*) were the dominant commercial timber species. Generally, large expanses of lodgepole pine interspersed with small stands of pure ponderosa pine on higher ground dominated the northern half of the study area; large blocks of Weyerhaeuser Corporation pine plantations were common. Dry mixed-conifer stands dominated the southern half of the study area. Douglas-fir (*Pseudotsuga menziesii*) was absent or rarely encountered in pine or dry mixed-conifer stands. Natural openings consisted of xeric rocky flats with sagebrush (*Artemisia* spp.) and bitterbrush (*Purshia tridentata*) near ponderosa pine and mixed-conifer stands. Wet meadows were typically associated with lodgepole pine and had a vegetative cover of sedges (*Carex* spp.) and sagebrush next to perennial streams or springs. The landscape was a mosaic of forest cover types, 2 large burned areas from the 1950s and 1992, natural openings, partially harvested stands, and early regeneration or clearcut harvest units. Dominant silvicultural practices were partial cut, selection cut, and shelterwood treatments in dry mixed-conifer and ponderosa pine, and clearcut patches in lodgepole. Forest Service management, regulated timber harvest, and aggressive fire suppression date back >50 years, and selective railroad logging took place circa 1920 (Hopkins 1979, Laudenslayer et al. 1989). Historical accounts described by

Munger (1917) state that eastside pine stands typically were structurally composed of large trees with a mean diameter at breast height (DBH) of 16 - 27 in. (40.6 - 68.6 cm) and basal area ranging from 56 to 100 ft^2/acre (12.9 - 23.0 m^2/ ha).

Within the Fremont National Forest, 2 density study areas (DSA) were established. The Bly DSA is where Reynolds (1975) searched for accipiters in 1974. I surveyed this same area in the breeding seasons of 1993 and 1994. The Bly DSA consisted of montane and upper montane landscapes comprised of pure ponderosa pine stands at lower elevations (1,200-1,500 m), with western juniper (*Juniperus occidentalis*) at xeric forest edges. At mid-elevations (1,500-2,100 m), a dry mixed-conifer community existed that contained white fir, incense cedar (*Libocedrus decurrens*), ponderosa pine, and sugar pine (*P. lambertiana*). Streams were few and mostly ephemeral. Terrain varied from flat to steep slopes with a predominantly south aspect. The Bly DSA is comprised of mixed ownership of about 49% National Forest and 51% percent Weyerhaeuser Corporation, of which there has been extensive overstory removal on the private lands.

The Paisley DSA was searched in the breeding seasons of 1992-1994 to document current forest conditions for a sample of active nests in lodgepole pine forest. The Paisley DSA was comprised largely of expansive pure (<20% other tree species) stands of lodgepole pine. The terrain is relatively flat and typically associated with an abundance of perennial streams and productive wet meadow systems with small pockets of trembling aspen (*Populus tremuloides*) at elevations of 1,500 to 2,100 m. Clearcut, partial harvest management, and road building were the most visible disturbances, along with some natural tree mortality. Lodgepole regeneration occurs relatively soon after burns or clearcuts.

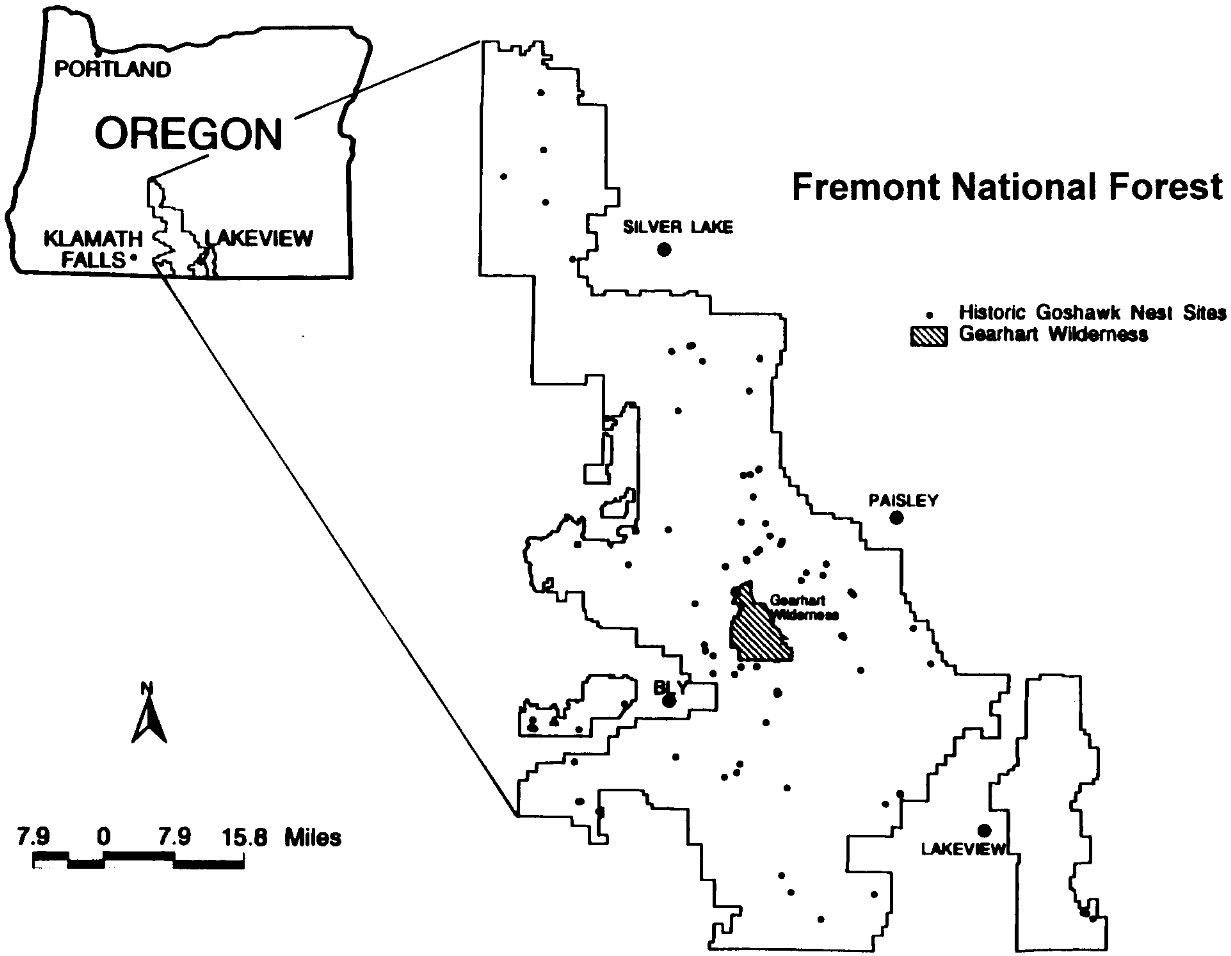

Figure 1. Study area showing the distribution of current and historic northern goshawk nest sites, Fremont National Forest, Oregon, 1994. Some nests occurring on private lands outside the National Forest boundaries are not shown.

Terminology

I classified goshawk nest locations based on occupancy (modified after Postupalsky 1974). An *occupied* territory was any territory where goshawks attempted to breed, independent of success (i.e., having fledged successfully ≥1 young), for which there was confirmed evidence such as an incubating or brooding female, nestlings or fledglings, or eggshell fragments. The term *current* territory specifies those territories first found in 1992-1994.

The term *historic* refers to any territory occupied before 1992 (i.e., first found during 1973-1991). After conducting surveys for goshawks at historic sites, I divided the territories into 3 categories: occupied, presumed occupied, and no-response. *Presumed occupied* denotes occupancy of a historic territory in 1994 (i.e., no nest found but definitive evidence of territory use, such as visual or auditory confirmation of ≥1 goshawk, molted adult feathers, droppings, and/or prey remains present). *No-response* sites were those historic territories where I did not detect presence of goshawks during ≥2 protocol surveys, and where no evidence of nesting was found during in 1994. I defined a goshawk reproductive effort as successful if ≥1 fledgling was produced (Steenhoff and Kochert 1982).

Surveys

I used a survey protocol similar to that reported by Kennedy and Stahlecker (1992) and Joy et al. (1994), which involved the broadcast of conspecific calls to elicit responses from nesting goshawks or fledglings. The adult alarm call was used during the nestling period (mid-May-June) and a juvenile begging call during the fledgling-dependency period (July-August). Taped calls were played on a portable Sony

Walkman cassette player and broadcast through a modified Realistic powerhorn (model 32-2030a). There were 35-45 calling stations located at each historic nest site, spaced 320 m apart and staggered on adjacent transect belts. At each station, goshawk vocalizations were played in a 120° arc for 10 sec, followed by a pause of 20 sec to listen for a response. This was repeated in all directions 5 more times at each station, totaling 3 min/station. If a response was detected, an immediate search for the nest began. For those territories where no response was detected during the nestling period, I resurveyed the site 1-2 additional times in July during the fledgling period, so that each historic "no response" site was visited at least twice in the season and surveyed to the above protocol.

In 1994, a list of 102 historic goshawk territories was compiled from original data collected by Reynolds (1975, 1978, 1980), U. S. Forest Service, and Weyerhaeuser Corporation. To determine credible historical nest locations, emphasis was placed on the amount of documentation (written reports, legal description, mapped locations, and area descriptions) associated with the site, reliability of the observers (biologist or experienced observer), and number of years the site was known to be active. Historic nest records were used only if there was an actual report of young or an incubating goshawk noted on the field form. Records not meeting suitable criteria were dropped as possible historic sites.

From the original list, I compiled 72 territory locations I considered credible. These locations were then stratified into 1 of 3 principal forest cover types: 47% of the territories were in dry mixed-conifer, 27% were in ponderosa pine (<20% other tree species); and 25% in lodgepole pine (<20% other tree species). Of these, a stratified random sample of 51 sites was chosen for field survey. Distribution of nest years and cumulative number per year are shown in Figure 2. Forest cover at survey sites was validated by aerial photograph examination or on-ground visits before surveys commenced.

Broadcast surveys to determine presence or absence (more accurately, no-response) of goshawks at each historic territory took place from the last week of May to early August, and were centered on the last known historic nest location. To establish a search radius, I used mean distance moved by breeding goshawks between alternative nests in successive years (273 m, SE = 68) as reported by Woodbridge and Detrich (1994) for the nearby Klamath National Forest in north-central California. Vegetative cover and climate on the Klamath is very similar to the Fremont, as they are both within the Modoc Plateau physio-geographic province (Franklin and Dyrness 1973).

To ensure that complete coverage of all potential nest stands occurred (an area of about 52 ha [Woodbridge and Detrich 1994]), I doubled the mean distance (273 m) and added 2 standard deviations, which defined a radius of approximately 800 m. (Ward et al. [1992] defined alternate nests as being within 800 meters of a common center, with no more than one nest active per year.) To further maximize the likelihood of finding goshawks in historic territories, I searched a radius of approximately 900 m (~260 ha), well overlapping the area of the post-fledging family area (PFA) of 170 ha, as described by Kennedy et al. (1994). Furthermore, the effective auditory range of the megaphone caller was $\geq$100 m (Joy et al. 1994; S. Desimone, pers. obs.), increasing coverage to about 1,000 m on all sides of the historic nest location. The effective search area per territory (>300 ha) was much larger than the PFA (170 ha).

I searched for additional current goshawk nests (i.e., not historic territories) during May-August in 1992, 1993, 1994. Surveys were conducted in timber sale units, in areas of confirmed incidental sightings, and in the Bly and Paisley DSA, where I conducted complete-coverage protocol surveys in an attempt to find all nests.

For current nest sites known from 1992 and 1993, I did not use protocol surveys in most cases to avoid unnecessary disturbance to possibly nesting known pairs and maximize time to search the remaining number of territories. A silent search of the last known nest stand by multiple observers was done to determine if goshawks were present. If not present, we extended the search pattern to radiate out from the nest tree.

Vegetation Sampling

I used aerial photographs available from the U. S. Forest Service and Weyerhaeuser Corporation (1:12,000 and 1:15,800 scales) to compare historical forest vegetation conditions (1973-1991) to current (1994) conditions. I first used a 3x Dietzgen stereoscope to delineate 25 reference stand polygons representing the range of forest conditions and habitats on the most recent (1994) set of photographs. These reference polygons were then ground verified by the variable-plot vegetation sampling method (Bell and Dilworth 1988). I sampled 8-12 plots, 160 m apart on a transect along the longest axis through the polygon, or parallel transects if the polygon was >200 m wide. Each plot was ground measured for basal area (BA) using a 20-factor (ft^2/acre) wedge prism at plot center to determine the number of trees to be measured. Diameter at breast height (DBH, 1.4 m from ground) was recorded for all count trees to determine trees per hectare (TPH) and BA for each forest structure class; tree species and condition (live or dead) was noted. For each variable plot, canopy closure (CC) was measured using a Lemmon spherical densiometer 5 meters from plot center in 4 cardinal directions. The 4 readings were averaged for each plot, and mean percent CC was calculated across all plots for a stand.

The number of live trees were tallied into diameter classes by combining plots for each stand. Trees per ha for a diameter class were tallied and the BA calculated by multiplying the number of count trees for a diameter class by the basal area factor (Avery and Burkhart 1983, Bell and Dilworth 1988). Stem count per sample point multiplied by the BA factor gives the total BA occupied by tree stems on a per acre basis (Bell and Dilworth 1988). Stands were then classed into forest vegetative cover classes based on total BA of trees per diameter class.

Vegetation Structure Variables

Forest vegetation structure variables were based on the USFS Region 6 Vegetation Structural Stage (USDA 1994) guidelines for general forest cover types in eastern Oregon. Two non-forest categories (Open Wet, Open Dry), Very Early category, and a combination of 3 forest structure categories (Late, Mid, Early) with 2 canopy closure classes (< or >50%) were designated as vegetative cover variables for the reference plots and all photograph habitat delineation (Table 1). Very Early seral stage contained early regeneration or clearcuts, with trees <12 cm DBH. Late-successional forest was defined as mature and old forest with ≥15 TPH having a DBH >53 cm. Mid-aged forest contained trees 23-52 cm DBH with <15 TPH having >53 cm DBH, and Early structural stage forest had trees in the 12-22 cm DBH class. I was not able to compare the ingrowth of shade tolerant species such as white fir (*Abies concolor*) to historic levels, but it did not appear to be a significant factor in vegetation sampling.

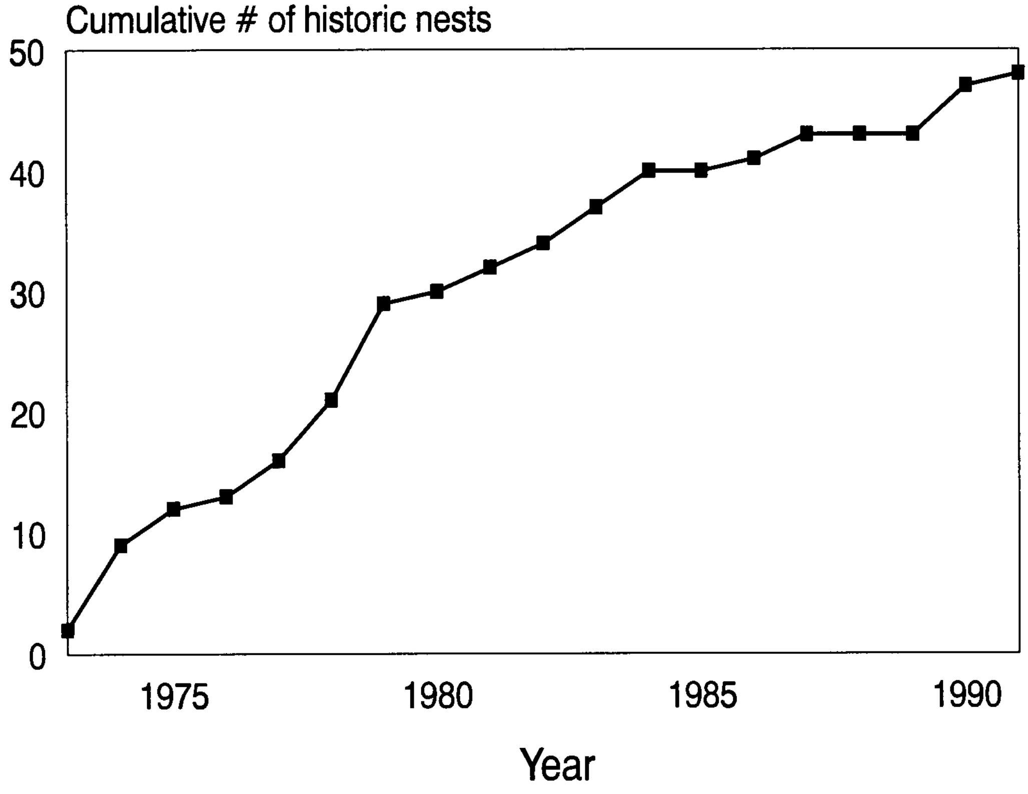

Figure 2. Cumulative distribution of historic goshawk nests (n = 51) by historic year, surveyed in Fremont National Forest and adjacent private lands, Oregon, 1994. Historic nests were stratified by general forest cover and randomly selected for analysis.

Table 1. Habitat classification scheme for aerial photograph interpretation on the Fremont National Forest and adjacent private lands, Oregon, 1994. Forest vegetation structure categories were modified from designations used by USDA Forest Service (1994) Region 6 eastside forests in Oregon and Washington. Very Early stage is forest regeneration or clearcut. Other habitat types were Open Wet (wet meadows) and Open Dry (rocky sage flats). Trees per ha for a diameter class were tallied and the basal area (BA) calculated by multiplying the number of count trees for a diameter class by the basal area factor. Stem count per sample point multiplied by the BA factor gives the total BA occupied by tree stems on a per acre basis. Stands were then classed into forest vegetative cover classes based on total BA of trees per diameter class.

Forest Vegetation Structure	DBH(cm)	Crown closure (%)	Trees/ha (TPH) ≥53 cm
Late Closed	>53	>50	≥15
Late Open	>53	<50	≥15
Mid-aged Closed	>23-53	>50	<15
Mid-aged Open	>23-53	<50	<15
Early Closed	>12-23	>50	--
Early Open	>12-23	<50	--
Very Early	≤12	<50	--

Canopy or crown closure was defined as the amount of sky obscured by tree foliage and branches (Vales and Bunnell 1985) as measured by a Lemmon spherical densiometer. Once the validated reference set was established, I used USDA Forest Service and Weyerhaeuser Corporation aerial photographs (1:12,000, and 1:15,800 scales) from 1992-1994 to assign habitat categories to all polygons at historic sites. If 1994 photographs were not available, the 1994 Fremont National Forest Harvest Inventory (a GIS database) was used to manually update the most recent photographs. Based on the validated reference plots, habitat polygons were delineated within a 170 ha circle defined around all historic and current nest locations (Figure 3). Circles were used because there was lack of telemetry data showing the true territory shape. All delineated polygons (N = 546) from current photographs were segregated by vegetative cover categories. A 18.7% stratified random sample (n = 102) was ground-verified using the same variable-plot sampling method outlined for the reference stands. Stand typing accuracy was assessed by constructing an error matrix to determine credibility of photograph interpretation.

To delineate habitat of historic forest conditions, I used USDA Forest Service and Weyerhaeuser Corporation aerial photographs (1:12,000, 1:15,800, and 1:24,000 scales) representing stand conditions present in the year of the last known historic nest for each site. I extrapolated the results of the reference set and validated 1994 photographs to type stands into vegetative cover classes on the remaining historic photograph sets. All completed photos were transferred to 1:24,000 scale USGS quadrangle maps using a Bausch and Lomb Zoom Transfer Scope and then digitized into ArcInfo for data manipulation. Areas (ha) were calculated for each habitat polygon.

Annual Variation in Territory Occupancy

Mean annual occupancy rates of goshawk territories from 5 study areas in the western U. S. for which there is at least 4 years of occupancy data were compared to the occupancy rate of current (nest first found during 1992-1994) and historic territories on the Fremont in 1994. A table of annual variation in occupancy of territories was constructed to compare all studies and as a pretense for establishing occupancy as the response variable for the habitat model analysis. The annual variation in occupancy is defined as the mean annual percent of occupied territories with standard error of variance. The assumptions were: (1) territory occupancy was determined by all researchers using the same or similar survey techniques with equal effort (Woodbridge and Detrich 1994, Joy et al. 1994, Kennedy 1997, R. Reynolds, pers. comm.); and (2) little or no major stand disturbance or habitat alteration occurred within territories since discovery. An occupied territory was defined by all researchers as goshawks present in or near the alternate nest cluster (52 ha) (Woodbridge and Detrich 1994) on at least 2 separate occasions during the breeding season, and includes pairs attempting nesting (Reynolds et al. 1994, Woodbridge and Detrich 1994, Kennedy 1997). I hypothesized that, if the assumptions were not violated, the occupancy rate of the historic sites surveyed in 1994 would be similar to both the occupancy rates of the current (1992-1994) Fremont territories and the western U. S. studies.

Habitat Change Analysis

Using each nest as the territory center, I established buffers of 5 different radii to encompass 12, 24, 52, 120, and 170 ha around the nest (Table 2, Figure 3). These landscape scales have biological and/or managerial significance: 12 ha was recommended as a minimum core nest area for goshawks (Reynolds 1983, Reynolds et al. 1992); 24 ha was the goshawk habitat areas designated on the Fremont NF (USDA Forest Service 1989); 52 ha is the alternate nest-cluster scale (modified after Woodbridge and Detrich 1994) found to include most alternate nests associated with the primary nest site (I calculated this using the mean distance between same-territory alternate nests plus 2 standard deviations), and it is roughly equivalent to the minimum size for goshawk management areas in California recommended by Bloom et al. (1986); 120 ha is the area of old-growth habitat allocated for management of pileated woodpeckers (*Dryocopus pileatus)* (USDA Forest Service 1989); and 170 ha is the size of the goshawk post-fledging family area (PFA) (Reynolds et al. 1992, Kennedy et al. 1994). For all analyses, occupied and presumed-occupied categories were combined into one category as occupied to increase sample size for comparison to no-response sites.

Comparisons were conducted at both the "disk" (12, 24, 52, 120, and 170 ha) and "ring" (24 - 12 ha, 52 - 24 ha, 120 - 52 ha, and 170 - 120 ha) scales (Figure 3). Disks represent cumulative effects as the scale increases because smaller disks are included within the larger disks. Rings were tested individually, so that influence of inner disks were removed. For example, the 24 - 12 ha ring is defined as the area of 24 ha minus the area inside of the 12 ha disk; this leaves a "ring" of area between the 24 ha and 12 ha outer boundaries. As distance increased from the nest, only the effect of the ring being analyzed was examined (after Ramsey et al. 1994).

To determine how vegetation structure around historic nest sites may have changed over time, I determined the percent change for each vegetative cover variable by the equation :

(1) $$\%Change = [(Area_{1994} - Area_{HISTORIC}) / Area_{HISTORIC}] * 100$$

where $Area_{1994}$ is the area of a habitat category for 1994, and $Area_{HISTORIC}$ is the area of the same habitat category in the year the site was last known active (goshawks present and nesting). This calculation was made for each of the paired sites for all scales of disks and rings. I calculated percent change for each vegetative cover category based on occupancy status (occupied, presumed occupied, and no-response).

Paired comparisons were made of each vegetative cover category, for all disk and ring scales, between the historic nest site in the year last known to be active and the same site in 1994. I used the Wilcoxon signed-ranks paired comparison (2-tailed) on non-transformed data to test for differences in mean area for each vegetative cover type. Wilcoxon was used to incorporate outliers in the data because the non-normality of the data diminished the power of the *t* test considerably (Conover 1980:290). Outliers represent significant loss or gain of a particular vegetative cover, so they were included in this analysis. I hypothesized the mean amount of change was significantly different from zero. I used Kruskal-Wallis test of means and multiple comparison test of least significant difference to test between pairs of means.

I used linear regression to test the rate of vegetative cover loss for each class over the number of historic years, using the difference in amount of area between the historic nest and 1994 conditions as the response variable, and difference of the historic nest year and 1994 as the explanatory variable. Mean area of each vegetative cover over time within each disk and ring was plotted, residual points examined, transformed if necessary, and fitted. The individual cover types of ponderosa, lodgepole, and dry mixed-conifer forest were combined for all analyses.

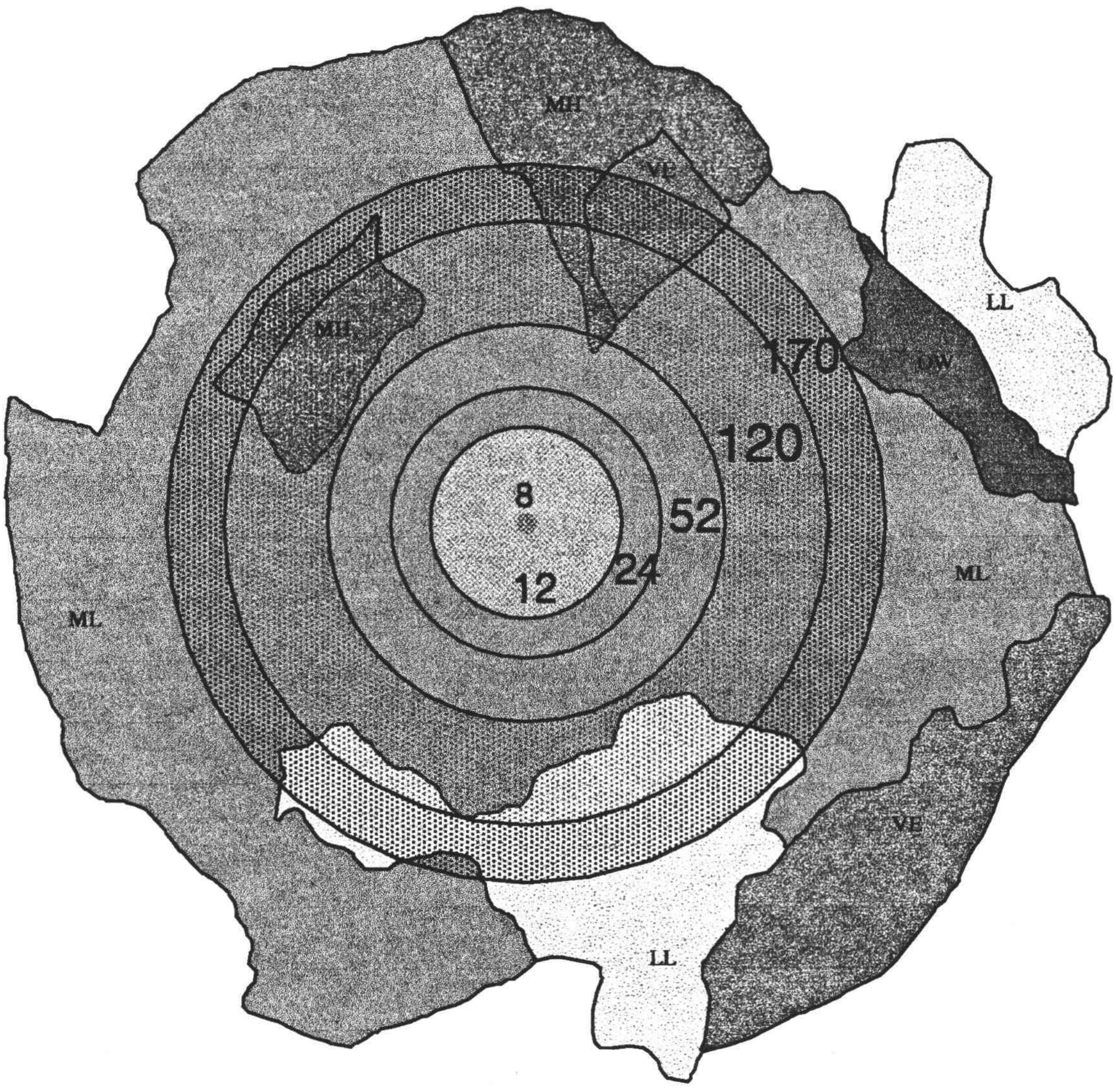

Figure 3. Concentric scales of 5 different areas (ha) for levels of territory analysis around historic, occupied and no-response northern goshawk nest sites, Fremont National Forest and adjacent private lands, Oregon, 1994. Labeled circles indicate outer boundaries of the associated scale, and the center point represents an active nest or last known nest if a territory was historic or presumed-occupied (birds on territory but no nest found). Delineated polygons depict coded vegetative cover types.

Table 2. Scales (ha) defined for use in analysis of northern goshawk habitat on the Fremont National Forest and adjacent private lands, Oregon, 1973-1994. Territory center was defined as last known active nest.

Designation	Source	Disk Area (acres)	Radius from center (m)	Ring size[a] between disks (ha)	Ring Radius boundaries from nest (m)
Nest stand	Reynolds et al. (1992)	12 (30)	195.4	--	--
Fremont NF reserve	USDA (1989)	24 (60)	276.4	24 - 12	195.5 - 276.4
Alternate nest cluster	Woodbridge and Detrich (1994)	52 (130)	406.8	52 - 24	276.5 - 406.8
Old Growth reserve	USDA (1989)	120 (300)	618	120 - 52	406.9 - 618.0
Post-fledging family area	Reynolds et al. (1992)	170 (470)	735.6	170 - 120	618.1 - 735.6

[a] Ring size is defined as the area of the larger disk with the area of the next smaller disk removed; e.g., 24-12 ha ring is the residual ring of area left from a 24 ha disk minus the 12 ha disk, using the same center.

Logistic Regression Model

I constructed a logistic regression model using the binary response variable of occupied (Y = 1) or no-response (Y = 0) by goshawks on a historic territory in 1994. I wanted to know the likelihood of predicting the suitability of historic territories by considering the amount of area of each vegetation structure variable (forest and non-forest) around occupied and no-response sites in 1994. The importance of a particular habitat variable was determined by a stepwise analysis (PROC LOGISTIC, SAS Institute Inc., 1992). Logistic regression analysis lends itself well to comparative studies with a binary response (Hosmer and Lemeshow 1989, Ramsey and Schaffer 1994, Ramsey et al. 1994). The explanatory variables were represented by the continuous data (ha) of vegetation structure classes.

Models were run for each of 5 disks (12, 24, 52, 120, and 170 ha) and 4 rings (24 -12 ha, 52 - 24 ha, 120 - 52 ha, and 170 - 120 ha). The alpha for entry level (p_E) of the variable to be considered for the model was $p_E = 0.15$, because I wanted to detect possible trends in the event of an insignificant P-value. The full model includes all explanatory habitat variables biologically significant:

(2) $$logit\ P(Y) = B_0 + B_1{*}VeryEarly + B_2{*}EarlyClosed + B_3{*}EarlyOpen + B_4{*}MidClosed + B_5{*}MidOpen + B_6{*}LateClosed + B_7{*}LateOpen + B_8{*}OpenWet + B_9{*}OpenDry$$

where B_0 is constant and B_1 through B_9 are the coefficients. The model was run in *logit P(1)* mode (stepwise descending) to calculate odds ratios for significant variable(s) associated with a territory being occupied (Y = 1). The final model was tested for interaction terms.

In logistic regression, residual values (termed deviance) are measures of discrepancy between the observed response and the estimated probability of that response based on likelihood theory. The drop-in-deviance test in logistic regression equates to an extra-sum-of-squares F-test used for linear regression analysis for model validation (Hosmer and Lemeshow 1989, Ramesy and Schaffer 1994). For this analysis, the drop-in-deviance test was accomplished by the stepwise procedure model selection process.

RESULTS

Surveys

Historic Density Study Area

Reynolds (1975) first examined nesting and habitat relationships of accipiter hawks on the Fremont National Forest in 1974. This historical data set was the impetus for studying and documenting changes on the Bly DSA in 1993-1994 on Reynolds' (1975) original study area. He found 4 goshawk territories, 5 Cooper's hawk territories, and 4 sharp-shinned hawk territories during the 1974 breeding season in an area of about 116.5 km^2 (45 mi^2). Resurveying within the same area boundary in 1993, I found 3 active goshawk nests and 1 suspected territory; 1 active Cooper's hawk nest; and 2 active sharp-shinned hawk nests. In 1994, I found 3 active goshawk nests and 1 occupied territory, 1 active Cooper's hawk nest, and 1 active sharp-shinned nest. Sample sizes were too small to make statistical comparisons. Two of the 4 original goshawk nest sites on the Bly DSA (Reynolds 1975) were active (breeding female present). In 1992, the Boyd Spring nest was active and found to be within 50 m of the same mapped location as the 1974 nest. In 1993 and 1994, the territory was occupied but no active nest found. Another nest site first found by Reynolds (1975), the Cottonwood Spring nest, was within 200 meters and 100 meters of the 1974 location in 1993 and 1994, respectively. These two sites were subsequently given nest protection in the early 1980s as old growth management areas after discovery by Reynolds.

Current Territories (1992 -1994)

Results of protocol and non-protocol surveys for 1994 are summarized in Table 3. For current territories (first discovered 1992-1994) in ponderosa pine, lodgepole pine, or dry mixed-conifer, 25 of 42 (60%) nest trees were in Late Closed vegetative structure, and 11 of 42 (26%) nests were in Mid-age Closed structure. Combined, this was 86% of total nests (Figure 4). For current sites, mean inter-nest distance between alternate nests on the Fremont was 245 m (SE = 48) and was comparable with 2 other western U. S. studies (Table 4). Current nests were located in forest cover types that was relatively proportional to the distribution of historic nests in forest cover over the study area. In dry-mixed conifer, about 56% were current nests compared to 47% historic nests; in lodgepole pine, 24% were current and 28% historic; and in ponderosa pine, 20% were current and 25% historic.

Random Historic Territories

Of the 51 historic goshawk territories surveyed to protocol in 1994, 16 (29.4%) were determined occupied by goshawks. A total of 46 historical sites were available for analysis of habitat change; 5 sites (including 1 occupied territory) were removed from analysis because of inadequate photographic records for comparisons. For those used in the analysis, 10 territories were found to be nesting (active) and 5 were determined to have goshawks present (presumed occupied, but no evidence of nesting found) on territories, for a total of 15 occupied sites; 31 territories were determined to be no-response sites. Nest success for the Fremont historic and current territories for 1994 was calculated as defined by Steenhoff and Kochert (1982) and found to be similar (Table 5).

Table 3. Northern goshawk 1994 survey results, Fremont National Forest and adjacent private lands, Oregon. For historic sites, occupied status is defined as a territory with a breeding record first found before 1992 and having an active nest (breeding) in 1994, and presumed status is a territory with a breeding record first documented before 1992, with goshawks present in 1994, but no evidence of nesting. For current sites, occupied status is a breeding territory first found in 1992, 93, or 94 (but not historic); presumed means that goshawks were present but no evidence of breeding attempt was found in 1994. For analysis, presumed sites were considered occupied. Undetermined sites had no detections in one visit.

	Historic		Current				
Survey method	Occupied	Presumed	Occupied	Presumed	No-response	Undetermined	Total
Protocol[a]	10	5	0	0	36	0	51
Non-protocol[b]	0	0	13	6	4	4	27
Total	10	5	13	6	40	4	78

[a]Established U. S. Forest Service Region 6 survey methods using regularly spaced calling stations along transect lines.
[b]Surveys not using regular stations or transect lines.

Table 4. Mean inter-nest distances (meters) between alternate within-territory northern goshawk nests on National Forests (NF) in the western U. S.

Source	Study Area	$\bar{x}$	SE	n[a]
Detrich and Woodbridge 1994[b]	Klamath NF, California	273	68	30
Reynolds et al.1994[b]	Kaibab NF, Arizona	266	38	17
This study, current nests[c]	Fremont NF, Oregon	245	48	23

[a]Number of inter-nest distances measured.
[b]Marked goshawk pairs.
[c]Non-marked goshawks nesting on current territories which were discovered in 1992 and monitored through 1994.

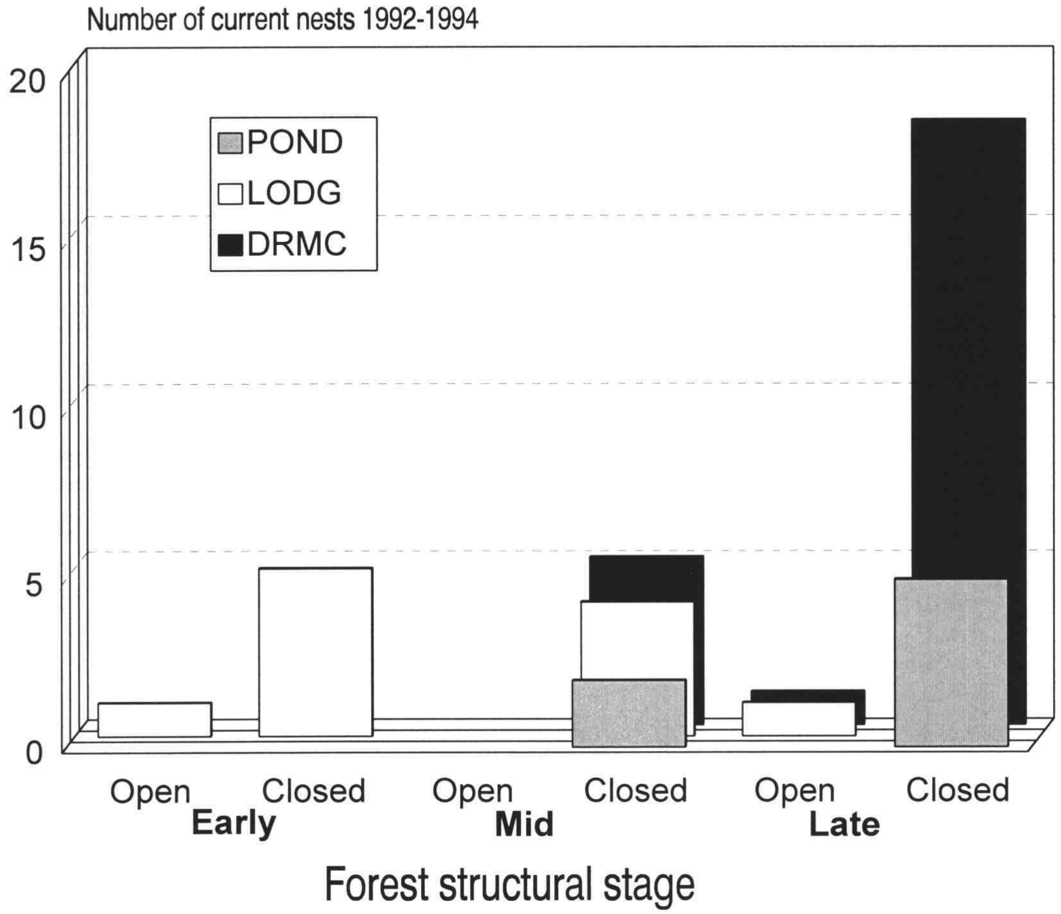

Figure 4. Number of current (first found 1992-1994) northern goshawk nests, distributed by vegetation structure categories (Early, Mid , Late) and general forest type on the Fremont National Forest and adjacent private lands, Oregon, 1994. Forest types were ponderosa pine (POND), lodgepole pine (LODG), and dry mixed-conifer (DRMC). Vegetation structure categories were Early forest (tree DBH between 12-22 cm), Mid-aged forest (tree DBH between 23-52 cm and <15 TPH [trees per hectare] having >53 cm DBH), and Late structure forest ($\geq$15 TPH having a DBH >53 cm). Canopy closure categories were Open (>50%) and Closed (<50%).

Table 5. Northern goshawk nest (n) success rates, Fremont National Forest and adjacent private lands, Oregon, 1994. A successful nest is defined as fledging ≥1 young.

	n	Failed nest	Young fledged	Young per nest	Nest success
Historic[a]	10	3	15	1.50 ±1.18	0.700
Current[b]	13	3	18	1.39 ±0.96	0.769
Total	23	6	33	1.44 ±1.04	0.739

[a]Historic territory with an active nest (breeding) first found prior to 1992-94.
[b]Nest first found in 1992, 93, or 94 as active breeding site.

Land ownership of the historic nest locations (Table 6) showed a fairly even age distribution between occupied (mean age = 14.4 years; SD = 4.6; range 3 - 20) and no-response (mean age = 14.0 years; SD = 5.3; range 4 - 21) sites in 1994. Thirty-five of 51 (68.6%) historic locations were on Forest Service land and 13 of 51 (25.5%) were on Weyerhaeuser ownership. Three of 51 (5.9%) were on mixed ownership, i.e., the nest location was within 100 m of property boundary lines. Forest Service locations had 34% of historic territories occupied in 1994 compared to 18% occupied on private land.

Accuracy Assessment of Vegetation Sampling

An error matrix constructed for 18.7% (102 / 546) of habitat polygons randomly sampled for ground verification from typed photographs rendered an overall accuracy assessment of 80.4% (Table 7), allowing me to proceed with the analysis (Lillesand and Kiefer 1994). Late Open canopy and Late Closed canopy forest was most accurately detected from photographs (90%), followed by Mid-aged Open (84%), and Mid-aged Closed forest (80%). The Early structural stages were least accurately detected; Early Closed was sometimes difficult to discern from Mid-aged Closed forest.

Annual Variation in Territory Occupancy

Mean annual occupancy rates of goshawk territories from 5 study areas in the western U. S. were compared with the occupancy rates of the Fremont current (1992 - 1994) and historic territories surveyed in 1994. Occupancy rates among all study areas, with the exception of the Fremont historic territories, were strikingly similar (Table 8).

Table 6. Land ownership of historic goshawk territories surveyed by occupancy status, Fremont National Forest and adjacent private lands, Oregon, 1994.

Ownership	Occupied + Presumed occupied	No-response	Total
Forest Service	12	23	35
Weyerhaeuser	2	11	13
Mixed[a]	2	1	3
Total	16	35	51

[a] Historic nest within 100 meters of ownership boundary lines.

Table 7. Error matrix for assessing accuracy of photo interpretation of vegetative categories for northern goshawk nesting territories on the Fremont National Forest and adjacent private lands, Oregon, September 1994. The major diagonal indicates polygons classified into the proper categories, and non-diagonal elements are classification errors. User's accuracy indicates the probability that a polygon classified into a given category actually represents that category on the ground, and is computed by dividing the number of correctly classified polygons in each category by the row total. Producer's accuracy is defined as how well the training set of polygons was classified, and is computed dividing the number of correctly classified polygons in each category (on the major diagonal, bold type) by the number of training set polygons used (column total). Overall accuracy is computed by dividing the total number of correctly classified polygons (along the diagonal) by the total number of reference polygons (Lillesand and Kieffer 1994).

	Very Early	Early Open	Early Closed	Mid- Open	Mid- Closed	Late Open	Late Closed	Dry Open	Wet Open	Row Total
Very Early	**10**									10
Early Open	4	**9**								13
Early Closed			**4**							4
Mid- Open		4		**16**	2					22
Mid- Closed			2		**16**		1			19
Late Open				2		**9**				11
Late Closed				1	2	1	**9**			13
Dry Open	1							**5**		6
Wet Open									**4**	4
Column Total	15	13	6	19	20	10	10	5	4	**102**

% ACCURACY

User's	10/10=100	9/13=69.2	4/4=100	16/22=72.7	16/19=84.2	9/11=81.8	9/13=69.2	5/6=83.3	4/4=100
Producer's	10/15=66.7	9/13=69.2	4/6=66.7	16/19=84.2	16/20=80	9/10=90	9/10=90	5/5=100	4/4=100

OVERALL ACCURACY: (10 + 9 + 4 + 16 + 16 + 9 + 9 + 5 + 4) / 102 = 80.4%

I averaged the occupancy rates for the Arizona, California, New Mexico, Utah, and Malheur NF studies (72.2%, SE = 0.019, N = 5). I hypothesized that the mean occupancy of 72% for the 5 studies in any given year would not be significantly different than the percent of Fremont occupied sites expected in 1994. This was not the case, as occupancy of random historic territories surveyed in 1994 was 29.4% (in this case, 70.6% is equal to the no-response rate), while the current (1992-1994) Fremont nests had an occupancy rate of 79.3% (Table 8). I did not include Fremont current territories in the average of studies because of the low number of seasons of data.

Habitat Change Analysis

Paired Comparisons of Historic and Current Territories

Results of Wilcoxon signed-rank paired comparisons for differences in mean area of vegetation structure types between the historic and current photographs were significant (rejecting the null hypothesis of mean area difference = 0) in all types except Early Closed, Open Dry, and Open Wet. This trend was fairly consistent among scales (2-tailed P-values) (Tables 9, 10). Corresponding 95% confidence intervals did not include zero for $P < 0.05$.

Table 8. Occupancy rates ($\bar{x}$) of northern goshawk territories among 6 western U. S. studies, calculated not using first year discovered. Occupancy rates for the Fremont National Forest (NF) were calculated separately for current (1992-1994) territories and historic (first found 1973 -1991) territories surveyed in 1994. An occupied territory is defined as a territory regularly used by ≥ 1 adult goshawk during the breeding season.

Study area	Source	N[a]	$\bar{x}$	SE	Duration (years)[b]	Disturbance[c]
Kaibab NF, Arizona	Reynolds (1996 unpubl. data)	32	0.720	0.046	4-5	Low
New Mexico	Kennedy (1997)	22	0.744	0.067	4-11	Low
Klamath NF, CA	Woodbridge and Detrich (1994)	26	0.740	0.011	5-9	Low
Utah	Kennedy (1997)	26	0.747	0.057	4-7	Low
Malheur NF, OR	Rickabaugh et al. (1996 unpubl. rep.)	33	0.657	0.016	2-4	Low
Fremont NF, OR	This study (1992-1994)[d]	20	0.793	0.044	2	Low

[a] Cumulative number of nests over study.

[b] Years of occupancy data per territory.

[c] Disturbance among all sites within 52 ha nest stand cluster since discovery of territory. Disturbance event is defined as natural or human caused alteration of the forest, including fire, road building, or timber harvest over the duration of study. Low is defined as 0 - 25% habitat alteration within 52 ha circle around nest.

[d] Current territories found since 1992 and monitored through 1994; does not include historic territories surveyed in 1994.

Table 9. Mean difference ($\bar{x}$) in area (ha) for 9 vegetative covers at 5 scales (disks), between historic and 1994 conditions for 46 northern goshawk territories, Fremont National Forest and adjacent private lands, Oregon. ***ns*** = not significant for Wilcoxon 2-tailed paired test at α = 0.10 level. Asterisk (*) indicates not significant at α = 0.05 level, performed on untransformed data. Minus sign (-) denotes mean loss of area. H_o: Mean Area (Historic) - Mean Area (in 1994) = 0

12 ha DISK	Very Early	Early Open	Early Closed *ns*	Mid-aged Open*	Mid-aged Closed*	Late Open	Late Closed	Open Wet *ns*	Open Dry *ns*
$\bar{x}$	1.611	3.092	-0.303	1.096	-0.880	-1.856	-2.076	-0.530	1.174
SD	1.687	3.960	2.947	3.758	2.886	3.226	3.495	1.149	2.858
SE	0.533	0.762	0.851	0.664	0.502	0.610	0.638	0.363	0.740
Wilcoxon 2-tailed *t*	0.02	<0.001	0.206	0.058	0.055	0.004	0.001	0.461	0.168
95% CI for the mean	0.404 to 2.817	1.525 to 4.658	-2.175 to 1.569	-0.206 to 2.451	-1.903 to 0.143	-3.107 to - 0.605	-3.381 to -0.771	-1.352 to 0.2917	-0.409 to 2.756

24 Ha DISK	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry ***ns***
$\bar{x}$	2.682	5.413	-0.140	2.257	-2.029	-3.366	-4.586	-0.512	2.135
SD	2.864	6.639	4.933	6.234	4.538	5.387	5.939	1.413	5.570
SE	0.735	1.192	1.319	1.069	0.746	0.952	1.034	0.365	1.351
Wilcoxon 2-tailed *t*	0.002	<0.001	0.305	0.048	0.004	<0.001	<0.001	0.182	0.229
95% CI for the mean	1.096 to 4.268	2.976 to 7.847	-2.984 to 2.708	0.082 to 4.432	-3.542 to -0.526	-5.308 to -1.424	-6.692 to -2.480	-1.295 to 0.270	-0.729 to 4.999

Table 9 (continued).

52 HA DISK	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open	Mid-aged Closed	Late Open	Late Closed	Open Wet *	Open Dry *ns*
$\bar{x}$	4.560	10.587	1.016	3.343	-5.119	-5.683	-8.610	-0.702	3.872
SD	4.746	12.555	9.300	1.649	7.254	9.353	10.855	1.429	10.944
SE	0.990	2.153	2.192	1.649	1.133	1.538	1.809	0.328	2.282
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.329	0.049	<0.001	<0.001	<0.001	0.098	0.334
95% CI for the mean	2.508 to 6.612	6.218 to 14.979	-3.609 to 5.641	0.002 to 6.683	-7.401 to -2.829	-8.802 to -2.565	-12.283 to -4.937	-1.391 to -0.014	-0.861 to 8.604

120 HA DISK	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open*	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry ***ns***
$\bar{x}$	10.160	19.4223	1.358	3.671	-11.647	-9125	-17.364	-0.583	6.824
SD	10.667	20.719	13.484	16.489	14.148	16.620	23.562	2.467	--
SE	1.1916	3.958	2.509	2.544	2.183	2.535	3.773	0.458	3.847
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.146	0.092	<0.001	<0.001	<0.001	0.218	0.245
95% CI for the mean	6.247 to 14.072	11.418 to 27.428	-3.772 to 6.487	-1.467 to 8.809	-16.056 to -7.249	-14.240 to -4.011	-25.002 to -9.726	-1.522 to 0.355	-1.057 to 14.705

Table 9 (continued).

170 HA DISK	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open*	Mid-aged Closed	Late Open	Late Closed	Open Wet	Open Dry ***ns***
x̄	14.495	26.612	1.429	4.882	-16.141	-12.008	-22.756	-0.866	8.773
SD	14.452	32.765	16.254	20.437	18.585	21.586	31.976	3.403	26.959
SE	2.516	5.117	2.968	3.046	2.802	3.254	4.934	0.611	4.922
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.160	0.074	<0.001	<0.001	<0.001	0.032	0.175
95% CI for the mean	9.37 to 19.632	16.270 to 36.954	-4.640 to 7.499	-1.258 to 11.021	-21.790 to -10.490	-18.571 to -5.445	-32.720 to -12.791	-2.114 to 0.382	-1.293 to 18.840

Table 10. Mean difference ($\bar{x}$) in area (ha) for 9 vegetative covers at 4 scales (rings), between historic and 1994 conditions for 46 northern goshawk territories, Fremont National Forest and adjacent private lands, Oregon. ***ns*** = not significant for Wilcoxon 2- tailed paired test at $\alpha = 0.10$. Asterisk (*) denotes not significant at $\alpha = 0.05$, performed on untransformed data. Minus sign denotes net mean loss of area. H_o: Mean Area (Historic) - Mean Area (in 1994) = 0.

24 - 12 HA RING	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry ***ns***
$\bar{x}$	1.608	2.718	0.119	1.225	-1.244	-1.713	-2.335	-0.170	1.000
SD	1.581	2.953	2.344	2.89	2.176	2.445	2.653	0.505	2.906
SE	0.408	0.53	0.626	0.496	0.357	0.432	0.46	0.135	0.705
Wilcoxon 2-tailed *t*	0.001	<0.001	0.414	0.031	0.001	<0.001	<0.001	0.230	0.169
95% CI for the mean	0.733 to 2.484	1.636 to 3.802	-1.234 to 1.473	0.217 to 2.234	-1.969 to -0.519	-2.624 to -0.861	-3.276 to -1.395	-0.462 to 0.121	-0.395 to 2.594

52 - 24 HA RING	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open ***ns***	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry ***ns***
$\bar{x}$	2.811	5.654	1.125	1.323	-3.288	-2.930	-4.406	-2.975	2.293
SD	2.810	6.443	5.299	5.163	4.015	4.638	5.893	0.821	6.207
SE	0.586	1.105	1.249	0.838	0.627	0.784	0.982	1.884	1.302
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.678	0.116	<0.001	<0.001	<0.001	0.174	0.134
95% CI for the mean	1.596 to 4.026	3.406 to 7.902	-1.510 to 3.760	-0.374 to 3.020	-2.021 to -4.555	-4.523 to -1.337	-6.400 to -2.412	-6.933 to 0.099	-.0.390 to 4.977

Table 10 (continued).

120 - 52 HA RING	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open ***ns***	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry *
x̄	6.777	10.433	0.781	0.647	-6.656	-4.336	-9.416	- 0.123	3.753
SD	7.325	13.729	6.867	9.366	8.281	9.475	13.861	1.707	10.974
SE	1.315	2.171	1.322	1.445	1.278	1.462	2.220	0.363	2.038
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.405	0.492	<0.001	<0.001	<0.001	0.338	0.068
95% CI for the mean	4.090 to 9.463	6.033 to 14.814	-1.936 to 3.497	-2.227 to 3.565	-9.231 to -4.069	-7.288 to -1.383	-13.910 to -4.923	--	- 0.421 to 7.927

170 - 120 HA RING	Very Early	Early Open	Early Closed ***ns***	Mid-aged Open ***ns***	Mid-aged Closed	Late Open	Late Closed	Open Wet ***ns***	Open Dry *
x̄	5.106	7.662	0.135	1.456	-5.022	-3.236	-6.633	-0.320	2.25
SD	4.834	8.731	3.471	6.403	5.559	6.309	10.046	1.425	6.792
SE	0.855	1.364	0.681	0.955	0.838	0.973	1.550	0.256	1.261
Wilcoxon 2-tailed *t*	<0.001	<0.001	0.342	0.199	<0.001	0.002	<0.001	0.267	0.086
95% CI for the mean	3.363 to 6.849	4.907 to 10.418	-1.267 to 1.537	-0.468 to 3.380	-6.712 to -3.332	-5.203 to -1.271	-9.763 to -3.502	-0.843 to 0.202	-0.331 to 4.835

Percent Change of Vegetative Cover in Historic Territories

For those historic sites where change was detected from photographs, I pooled occupied and no-response sites (n = 46). Among all analysis rings (24 - 12 ha, 52 - 24 ha, 120 - 52 ha, and 170 - 120 ha), there was >50 % decrease of Late Closed forest, and significant decreases in Late Open (range 40 - 60%) and Mid-aged Closed forest (range 20 - 40%) (Table 11) (Figure 5). These decreases were associated with a mean increase of >600% of the Very Early seral stage (range 400 - 1150%) and Early Open forest (range 190 - 290%) (Figure 5). At the 12 ha scale, a 50% decrease in both Late Open and Late Closed forests coincided with a nearly 300% increase in Early Open forest habitat and >700% increase in Very Early seral stage. The proportions were relatively consistent between 12, 24, 52, 120 ha disk scales (Table 12).

Change of Historic Territories Through Time

Linear regression correlation coefficients of vegetative cover area ($DIFF_{Area} = Y$) on years since last known active nest per territory ($DIFF_{Year} = X$) for combined forest types (ponderosa pine, lodgepole pine, and dry mixed conifer) were very weak for most comparisons ($r^2 < 0.20$). Transformation of the data did not improve the fit or correlation coefficients.

Table 11. Mean percent change ($\bar{x}$) and standard error (SE) of historic area within vegetative cover types at 4 circular scales (rings) centered around historic goshawk nests on the Fremont National Forest and adjacent private lands, Oregon, 1994. Ring size is defined as the area of the larger disk with the area of the next smaller disk removed; e.g., the 24 - 12 ring is the 24 ha disk minus the area of the concentric 12 ha disk. Vegetative cover codes combined 3 forest structure categories of Early, Mid, Late and 2 canopy closure classes, Open or Closed (< or >50%). Very Early seral stage is early regeneration or clearcut, with trees <12 cm DBH, and Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 TPH over 53 cm DBH. Late forest was defined as mature and old forest with ≥15 trees per hectare (TPH) having a DBH >53 cm. Non-forest categories are Open Wet meadows and Open Dry sage flats. Negative values indicate a decrease of vegetative cover.

	Ring size (ha)					
Vegetative cover	24 - 12	52 - 24	120 - 52	170 - 120	$\bar{x}$	SE
Very Early	1,131	534	403	396	616	202
Early Open	244	220	177	210	213	16
Early Closed	8	59	21	4	23	14
Mid Open	51	24	5	15	24	12
Mid Closed	-32	-40	-36	-40	-37	2
Late Open	-60	-54	-40	-44	-50	5
Late Closed	-48	-47	-50	-54	-50	2
Open Dry	80	83	63	46	68	10
Open Wet	-15	-11	-3	-10	-10	3

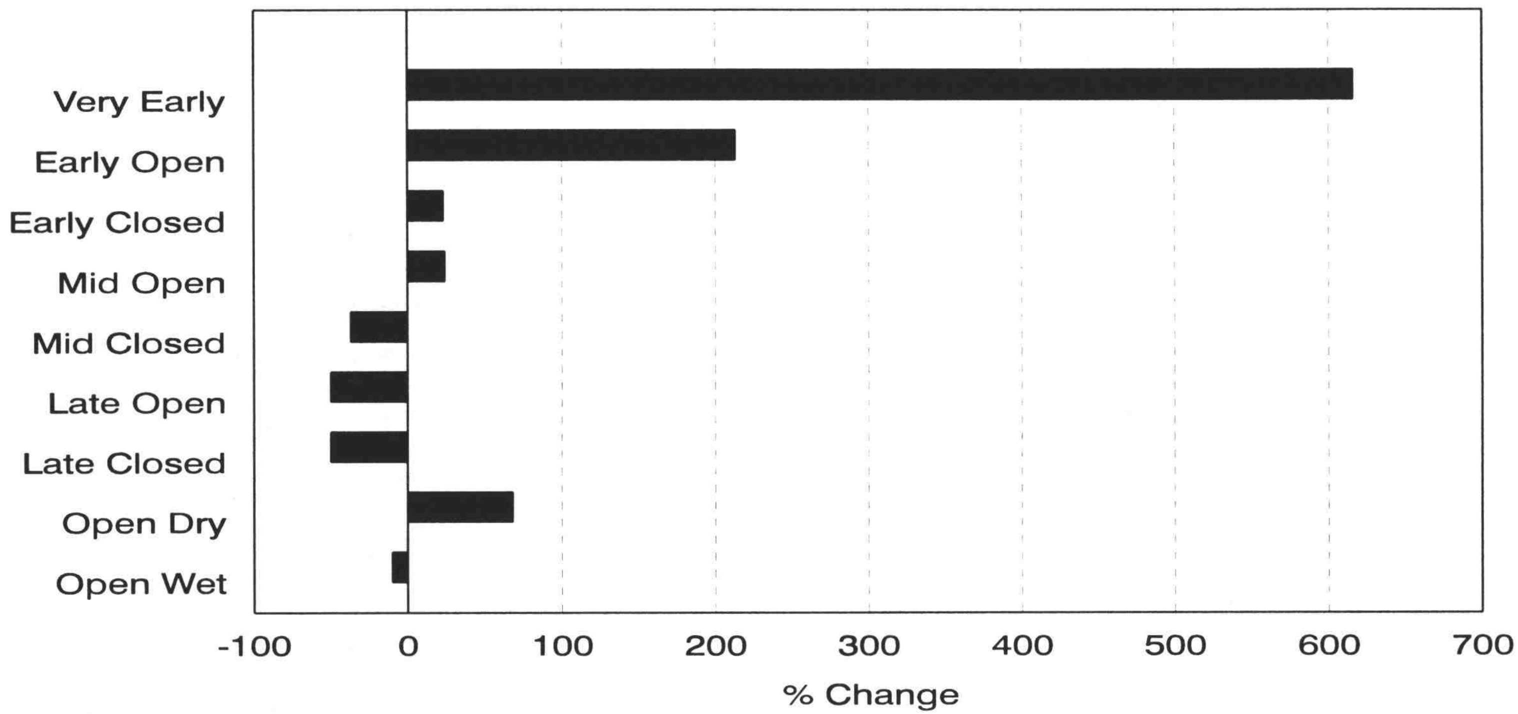

Figure 5. Mean percent change of vegetative cover types among 4 ring scales around historic northern goshawk territories, Fremont National Forest and adjacent private lands, 1994. Historic photographs were compared to the most recent updated image for 1994 conditions. Black bars represent the average % change between 24 - 12 ha, 52 - 24 ha, 120 - 52 ha, and 170 - 120 ha rings. Vegetative cover codes combined 3 forest structure categories of Early, Mid, Late and 2 canopy closure classes, Open or Closed (< or >50%). Very Early seral stage is early regeneration or clearcut, with trees <12 cm DBH, and Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 TPH over 53 cm DBH. Late forest was defined as mature and old forest with $\geq$15 trees per hectare (TPH) having a DBH >53 cm. Non-forest categories are Open Wet meadows and Open Dry sage flats. Negative values indicate a mean decrease of vegetative cover.

Table 12. Mean percent change ($\bar{x}$) of historic area within 7 habitat types at 5 disk scales centered around historic goshawk nests on the Fremont National Forest and adjacent private lands, Oregon, 1994. Disks denote increasing area emanating from the nest (territory center). Vegetative cover codes combined 3 forest structure categories of Early, Mid, Late and 2 canopy closure classes, Open or Closed (< or >50%). Very Early (VE) seral stage is early regeneration or clearcut, with trees <12 cm DBH, and Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 TPH over 53 cm DBH. Late forest was defined as mature and old forest with ≥15 trees per hectare (TPH) having a DBH >53 cm. Non-forest categories are Open Wet (OW) meadows and Open Dry (OD) sage flats. Negative values indicate a decrease of vegetative cover.

	Disk size (ha)						
Vegetative cover	12	24	52	120	170	$\bar{x}$	SE
Very Early	742	935	640	460	435	642	93
Early Open	285	263	239	200	203	238	17
Early Closed	-13	-4	22	22	16	9	7
Mid Open	43	47	34	16	16	31	7
Mid Closed	-20	-26	-33	-35	-36	-30	3
Late Open	-58	-59	-56	-48	-47	-54	3
Late Closed	-42	-45	-45	-48	-49	-46	1
Open Dry	136	100	90	73	64	93	13
Open Wet	-45	-28	-17	-9	-9	-21	7

Distribution of Vegetative Categories Within the PFA

For occupied (n = 15) territories in 1994, the most abundant vegetation cover type at the 52 ha scale was Mid-aged Closed forest (28.9%, SE = 8.4), and Late Closed forest was the second most abundant (19.9 %, SE = 5.4) (Table 12); total mean percent area of Late Closed and Mid-aged Closed forests was 48.8% (SE = 6.6). Late Open forest and Mid-aged Open forest combined accounted for a substantial amount (32.3%). Combined Early forest was 10.3%; Wet and Dry openings (non-forest) accounted for 9.0% of the total. At the 170 ha PFA, relative proportions of Mid and Late Closed reduced slightly, and the Open categories increased slightly (Table 13; Figures 6-8)

For those vegetation cover types that had changed, I compared mean proportion of area between historic, occupied, and no-response territories. The Kruskal-Wallis test for difference in means between the 3 compared groups was used. The null hypothesis of equal means for historic, occupied, and no-response was rejected ($\alpha = 0.05$) (Table 13) for Late Closed forest, Mid-aged Closed forest, Early Open forest, and Very Early vegetative covers, and a variable created by combining Late Closed and Mid-aged Closed types. Fisher's test of Least Significant Difference (LSD) for multiple comparisons (Table 13) compared differences among individual pairs of means found significant by the Kruskal-Wallis test for grouped means (Conover 1980:231, 236).

No-response territories (n = 31) in 1994 showed significant changes in the general distribution of vegetative cover compared to all historic territories and differed significantly from occupied sites for all disk scales (Table 13) (Figures 6-8). The greatest change in proportions was between Late Closed forest in historic territories (range 27.2 - 21.8% among disks) compared to no-response sites (range 6.1- 7.6% among disks).

Table 13. Mean proportion area of vegetation cover at 12, 24, 52, and 170 ha around historic, occupied, and no-response goshawk nests, Fremont National Forest and adjacent private lands, Oregon, 1994. Categories compared had significant changes of vegetation cover. Difference among grouped means assessed by Kruskal-Wallis test (α = 0.05) and least significant difference (LSD) multiple comparison test for all pairs of means. Those pairs not significantly different at $P < 0.05$ share superscript letters.

12 Ha DISK	Mean proportion (SE)			Kruskal-Wallis
Vegetation cover	Historic (46)	Occupied (15)	No-response(31)	Prob>X^2
Very Early	0.39^a (0.28)	0.00	4.95^b (1.8)	0.0009
Early Open	5.30^a (1.79)	10.41^b (4.80)	25.31^c (5.4)	0.0022
Mid-aged Closed	26.18^a (4.56)	34.79^a (9.34)	14.23^b (4.5)	0.0241
Late Open	16.34^a (3.58)	2.82^b (1.60)	8.97^c (2.9)	0.0454
Late Closed	27.18^a (4.52)	27.05^a (8.19)	6.11^b (3.2)	0.0002
Mid Closed + Late Closed	53.36^a (4.73)	61.84^a (8.35)	20.35^b (4.40)	0.0001

24 Ha DISK	Mean proportion (SE)			Kruskal-Wallis
Vegetation cover	Historic	Occupied	No-response	Prob>X^2
Very Early	0.39^a (0.27)	0.05^a (0.04)	5.96^b (1.74)	0.0001
Early Open	5.74^a (1.81)	10.75^a (4.05)	25.86^b (5.00)	0.0011
Mid-aged Closed	26.25^a (4.01)	32.14^a (8.99)	13.31^b (4.00)	0.0104
Late Open	16.50^a (3.33)	3.47^b (1.46)	8.33^c (2.72)	0.02
Late Closed	25.90^a (3.96)	23.64^a (6.92)	6.22^b (2.89)	0.0002
Mid Closed + Late Closed	52.15^a (5.11)	55.78^a (7.47)	19.53^b (3.97)	0.0001

Table 13 (continued).

52 Ha DISK	Mean proportion (SE)			Kruskal-Wallis
Vegetation cover	Historic(46)	Occupied(15)	No-response(31)	Prob>X^2
Very Early	0.69^{a} (0.36)	1.38^{a} (0.74)	6.86^{b} (1.62)	0.0001
Early Open	6.21^{a} (1.74)	12.06^{b} (3.41)	25.72^{c} (4.57)	0.0011
Mid-aged Closed	26.34^{a} (3.53)	28.96^{a} (8.40)	12.05^{b} (3.29)	0.0039
Late Open	15.51^{a} (3.04)	5.65^{b} (2.00)	7.23^{b} (2.39)	0.0169
Late Closed	24.14^{a} (3.48)	19.86^{a} (5.36)	6.98^{b} (2.87)	0.0001
Mid Closed + Late Closed	50.48^{a} (3.81)	48.82^{a} (6.56)	19.03^{b} (3.00)	0.0001

170 Ha DISK	Mean proportion (SE)			Kruskal-Wallis
Vegetation cover	Historic	Occupied	No-response	Prob>X^2
Very Early	1.40^{a} (0.57)	4.20^{b} (1.73)	9.13^{c} (1.63)	>0.0001
Early Open	6.84^{a} (1.55)	15.32^{b} (2.89)	23.45^{c} (3.78)	>0.0001
Mid-aged Closed	24.34^{a} (2.91)	22.80^{a} (6.34)	11.97^{b} (2.59)	0.0083
Late Open	14.65^{a} (2.32)	8.28^{b} (2.62)	7.36^{b} (2.18)	0.01
Late Closed	21.83^{a} (3.26)	13.74^{b} (3.48)	7.61^{c} (2.80)	0.0003
Mid Closed + Late Closed	46.17^{a} (3.77)	36.54^{b} (4.91)	19.58^{c} (2.51)	0.0001

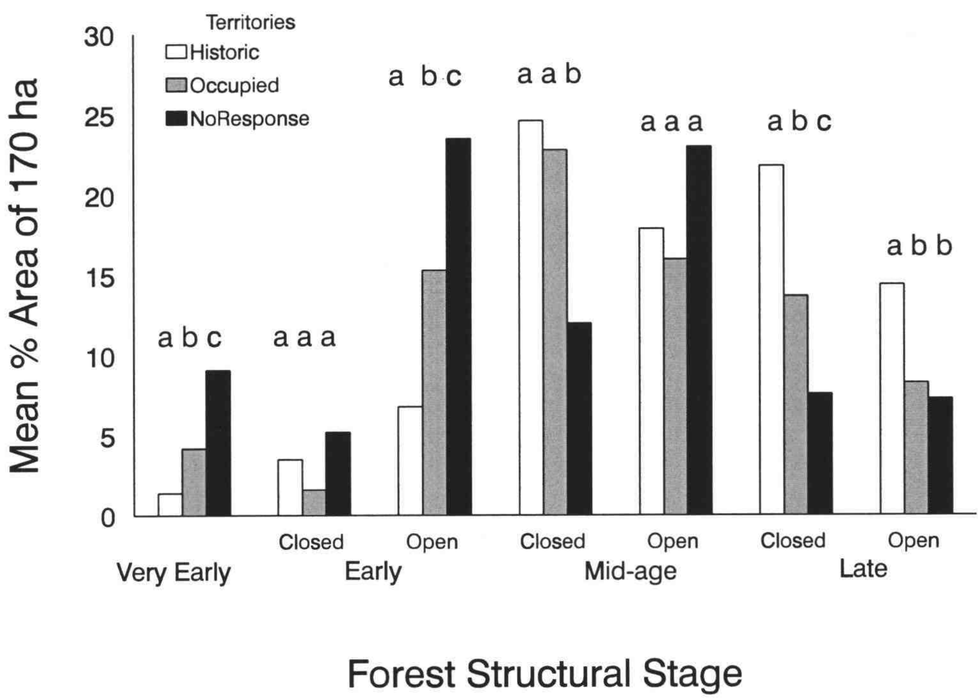

Figure 6. Distribution of vegetative cover among historic (n = 46), occupied (n = 15), and no-response (n = 31) northern goshawk sites at the 170 ha post fledging family area scale, Fremont National Forest and adjacent private lands, Oregon, 1994. Difference among grouped means assessed by Kruskal-Wallis test ($\alpha = 0.05$) and least significant difference (LSD) multiple comparison test for all pairs of means. Within each group, those pairs not significantly different at $P < 0.05$ share letters. Vegetative cover relected a combination of forest structure categories Early, Mid, Late and 2 canopy closure classes, Closed or Open (< or >50%). Very Early seral stage was early regeneration or clearcut, with trees <12 cm DBH. Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 trees per hectare (TPH) over 53 cm DBH. Late forest was defined as mature and old forest with ≥15 TPH having a DBH >53 cm.

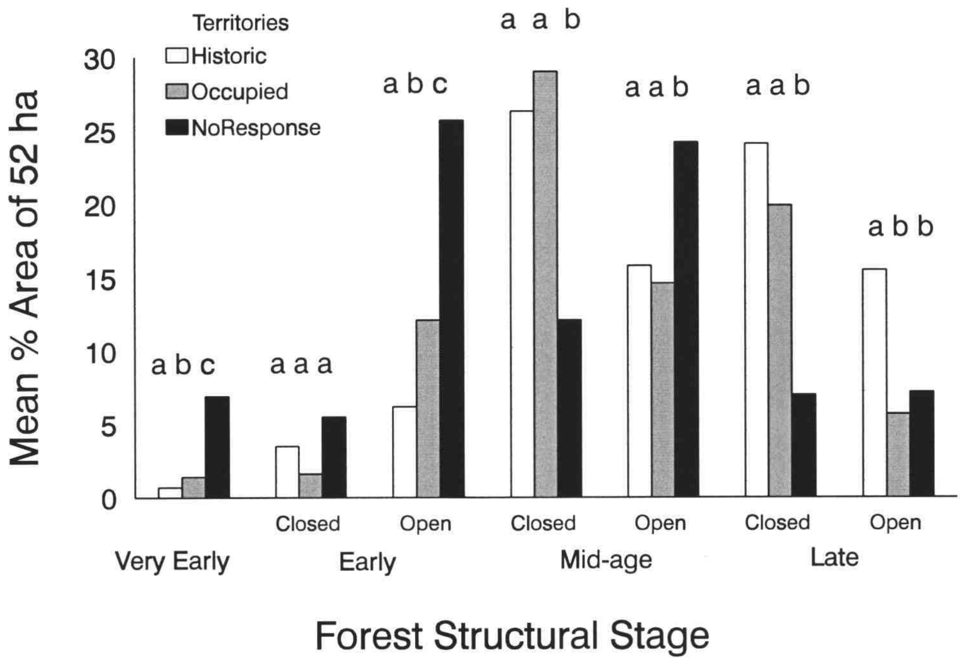

Figure 7. Distribution of vegetative cover among historic (n = 46), occupied (n = 15), and no-response (n = 31) northern goshawk sites at the 52 ha alternate nest cluster scale, Fremont National Forest and adjacent private lands, Oregon, 1994. Differences among grouped means assessed by Kruskal-Wallis test ($\alpha = 0.05$) and least significant difference (LSD) multiple comparison test for all pairs of means. Within each group, those pairs not significantly different at $P < 0.05$ share letters. Vegetative cover reflected a combination of forest structure categories Early, Mid, and Late, and 2 canopy closure classes, Closed or Open(< or >50%). Very Early seral stage was early regeneration or clearcut, with trees <12 cm DBH. Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 trees per hectare (TPH) over 53 cm DBH. Late forest was defined as mature and old forest with ≥15 TPH having a DBH >53 cm.

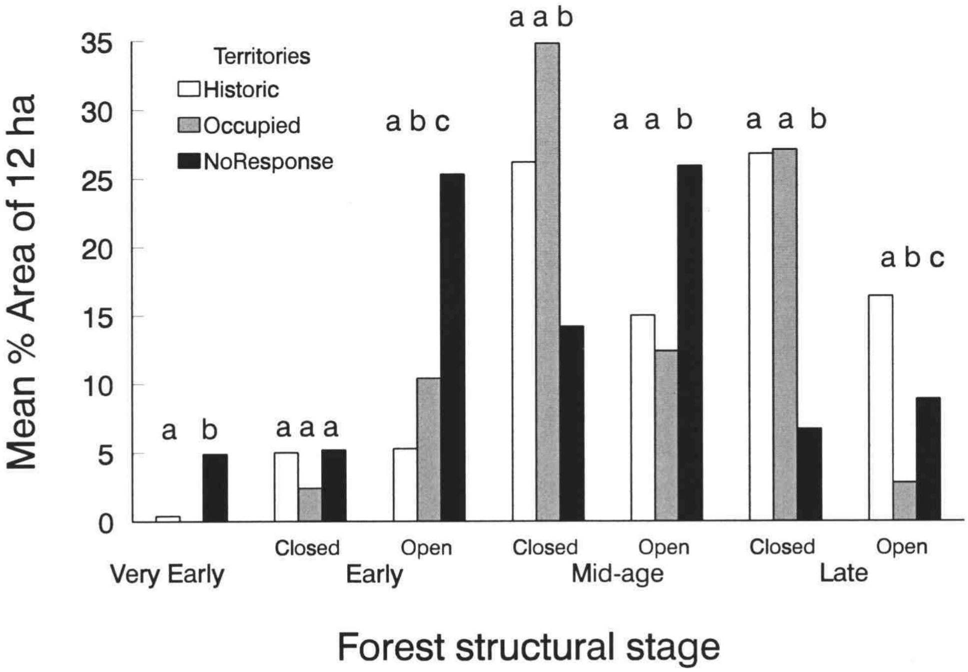

Figure 8. Distribution of vegetative cover among historic (n = 46), occupied (n = 15), and no-response (n = 31) northern goshawk sites at the 12 ha nest stand scale, Fremont National Forest and adjacent private lands, Oregon, 1994. Differences among grouped means assessed by Kruskal-Wallis test (α = 0.05) and least significant difference (LSD) multiple comparison test for all pairs of means. Within each group, those pairs not significantly different at $P < 0.05$ share letters. Vegetative cover codes combined 3 forest structure categories of Early, Mid, Late and 2 canopy closure classes, Open or Closed (< or >50%). Very Early (VE) seral stage is early regeneration or clearcut, with trees <12 cm DBH, and Early forest was trees in the 12 - 22 cm DBH class. Mid-aged forest was trees 23 - 52 cm DBH with <15 trees per hectare (TPH) over 53 cm DBH. Late forest was defined as mature and old forest with $\geq$15 TPH having a DBH >53 cm.

For occupied sites at the 52 ha alternate nest cluster scale, mean percent area of Late Closed forest (19.9%) remained nearly the same as historic sites (24.1%) in 1994. Less than half of the mean area of Mid-aged Closed forest that once existed in historic territories (25%) was available in no-response sites (12%). This was associated with a significant increase of mean percent Mid-aged Open forest in no-response sites (24.2% of 52 ha nest cluster) compared to occupied territories (14.6%) (Table 13).

In no-response sites, mean percent area of Early-aged Open canopy forest (sub-marginal quality habitat) was >4 times the historic amount, and more than twice that of occupied territories (LSD test of means, 1-tailed $P < 0.05$). Mid-aged Open forest was significantly greater in no-response sites than occupied sites (LSD test of means, 1-tailed $P < 0.05$), and Very Early habitat was significantly greater in no-response than occupied sites (LSD test of means, 1-tailed $P < 0.05$) (Table 13; Figures 6-8).

Logistic Regression Model of Vegetative Association

For occupied territories (Y = 1), both the Late Closed and Mid-aged Closed variables were significantly associated with the 52 ha disk model (Drop in Deviance $X^2 = 9.5$; 1 *df*; $P < 0.01$) and the 52 - 24 ha ring model (Drop in Deviance $X^2 = 20.7$; 1 *df*; $P < 0.01$) (Equation 3).

(3) $$logit\ (1) = B_0 + B_1\ (Late\ Closed) + B_2\ (Mid\text{-}aged\ Closed)$$

For occupied territories, there was a strong association between territory occupancy and both Late Closed forest and Mid-aged Closed forest at the 12, 24, 52 ha scales (Table 14). At the 12 ha nest stand scale, the odds that a site is occupied increase by 61% (odds ratio 1.61) for each unit (1 ha) increase of Late Closed forest habitat, holding the Mid-aged Closed forest variable constant. For each unit increase of Mid-aged Closed forest habitat, the odds that a site is occupied increase by 37% (odds ratio 1.37), holding the Late Closed forest variable constant. The odds ratio for each parameter estimate is interpreted similarly for each scale.

The reduced model was also significant for the 24 - 12 ha ring and the 52 - 24 ha ring (Table 14). The stepwise descending model procedure did not yield a significant model for any variables associated with occupied sites for 120 ha and 170 ha disk, or for 120 - 52 ha and 170 - 120 rings. The interaction term of the reduced model for disks was not significant (X^2 = 43.1; 1 *df*, P = 0.23).

Table 14. Parameter estimates, statistics, and odds ratios from stepwise logistic regression analysis for occupied (Y=1) goshawk territories (n =15), Fremont National Forest and adjacent private lands, Oregon, 1994. Stepwise entry level was at 0.15, and model build terminated after analysis of the 52 ha scale disk and 52-24 ha ring. Scales emanate from territory centers; ring size is the area between two concentric disk areas. Parameter estimates are natural log (ln) of odds ratios. The interaction term (Late Closed * Mid-aged Closed) was not significant (*P* = 0.23).

Disk size (ha)	Variable	Parameter estimate	SE	Wald χ^2	*P*-value	Odds ratio[a] estimate	95% confidence interval (95% CI of odds ratio)
12	Intercept	-83.9333	24.4576	11.7771	0.0006	--	--
	Late Closed	0.4771	0.1650	8.3594	0.0038	1.611	0.1537 to 0.8005. (1.166, 2.227)
	Mid-aged Closed	0.3344	0.1157	8.3554	0.0038	1.397	0.1076 to 0.5612 (1.114, 1.753)
24	Intercept	-46.5816	13.664	11.6205	0.0007	--	--
	Late Closed	0.2660	0.0947	7.8850	0.005	1.305	0.0804 to 0.4516 (1.084, 1.571)
	Mid-aged Closed	0.1729	0.0616	7.8829	0.005	1.189	0.0522 to 0.2936 (1.054 , 1.341)
52	Intercept	-21.9700	6.3879	11.8290	0.0006	--	--
	Late Closed	0.1131	0.0401	7.9426	0.0048	1.120	0.0345 to 0.1917 (1.035, 1.211)
	Mid-aged Closed	0.0818	0.0307	7.1046	0.0077	1.085	0.0216 - 0.1420 (1.022, 1.155)

Table 14 (continued).

Ring size (ha)	Variable	Parameter estimate	SE	Wald χ^2	*P*-value	Odds ratio estimate	95% confidence interval (95% CI of odds ratio)
24 - 12	Intercept	-85.3932	25.1893	11.4925	0.0007	--	--
	Late Closed	0.5126	0.1798	8.1303	0.0044	1.670	0.2109 to 0.9366 (1.235, 2.551)
	Mid-aged Closed	0.3175	0.1215	6.8264	0.009	1.374	0.0984 to 0.5913 (1.103, 1.806)
52 - 24	Intercept	-33.9116	10.7673	9.9193	0.0016	--	--
	Late Closed	0.1754	0.0691	6.4489	0.0111	1.192	0.0533 to 0.3301 (1.055, 1.391)
	Mid-aged Closed	0.1423	0.0579	6.0437	0.0140	1.153	0.0376 - 0.2719 (1.038, 1.313)

DISCUSSION

Variation in Occupancy

An occupancy rate of 29.4% of randomly surveyed historic territories on the Fremont in 1994 is significantly lower than expected compared with other studies in the western U. S. Habitat alteration by management activities most likely influenced the low occupancy rate. Management practices for nesting habitat protection among the historic goshawk territories on the Fremont National Forest and private timber lands have been inconsistent during the last 2 decades. This has resulted in varying amounts of harvest in and around historic nesting territories as there was no imposed formal management strategy implemented by USFS Region 6 or private landowners before 1992.

Management for goshawk nesting areas in historic territories on the Fremont NF and private lands from 1973-1991 has ranged from no protection (unrestricted harvest) of nest areas to a no-harvest buffer of 30 acres (12 ha) imposed during the breeding season (Reynolds 1983, USDA 1993). In 1983, the Fremont forest plan established 60-acre (24 ha) goshawk habitat management areas. However, conditions on most of these management areas ranged from early successional forests (non-suitable nesting habitat) to mid-aged or some late-successional patches. Moreover, some goshawk management areas have been "reassigned" and moved to different locations periodically to meet timber management objectives (Fremont NF, unpublished data). Before 1992, if an active goshawk nest was discovered in a sale unit during an active timber harvest, protection and mitigation was at the discretion of the sale owner.

Most (40 of 51) of the historic Fremont nest sites in this study have not been monitored nor buffered from management activities over the long-term. There was no proactive goshawk monitoring program for the Fremont and virtually no records of monitoring historic nests from about 1983 until 1992 when this study began. It is apparent from the photographic record that little or no long-term historic site protection was implemented for the 36 no-response sites, as all of these historic sites that were no-response in 1994 had some portions within the 52 ha nest stand harvested during or after the historic nesting season. In contrast, most of the goshawk territories on the Arizona, California, New Mexico, and Utah study areas have had a minimum amount or low disturbance from timber harvest practices since discovery by the researchers (Table 8) and have had yearly ongoing monitoring programs.

The assumption of no major stand disturbance or habitat alteration within the historic territory since first discovered was violated on most of the Fremont no-response territories analyzed. This strongly suggests that the low detection (hence, occupancy) rate of 29.4% in 1994 was largely the result of habitat alteration; i.e., the conversion of Late Closed and Mid-aged Closed forest conditions to mainly Very Early seral stage or Early Open canopy forest conditions within the 52 ha alternate nest cluster.

Like many raptors, northern goshawks do not breed every year, and determining if a territory is occupied using less than 2 years survey data is tentative (Forsman et al. 1984, DeStefano et al. 1994a). The limitations of comparing occupancy rates between data sets with less than two years survey data for the historic Fremont territories are apparent. Estimates of density and productivity can be variable between areas and years. Goshawks may not have been detected because (1) the pair had moved from the previous season's breeding location to an alternate nest, (2) it was a bad reproductive year due to low prey availability or inclement weather (e.g., early nest failure), (3) it was a non-reproductive year for the pair, or (4) there was a lack of suitable nesting cover.

I purposely searched about 4 times the mean distance recorded to alternate nests (about 1,000 m radius) around historic nest locations to maximize the likelihood of finding goshawks using alternate nests within a territory; this constituted a similar search effort with other researchers (Table 8). This effective search area was >300 ha in size and 1.7 times the area of the PFA, in which all alternate nests for a territory are theoretically located.

Kostrewza and Kostrewza (1990) reported that weather did not affect the density of territorial goshawk pairs over an 8 year period in Europe, but was an influential limiting factor to breeding success. In eastern Oregon, poor goshawk reproduction in the 1993 breeding season was suspected as being related to an unusually moist, cool season with inclement weather conditions, and early nesting failures may have influenced goshawk response rates. In 1994, however, weather patterns were notably dryer (more typical for the region), and territory occupancy of current (not the historic random sample) territories was 78.3% in mixed-conifer, ponderosa pine, and lodgepole pine. For all Fremont nests in 1994, 17 of 23 (73.9%) successfully fledged young. On the Malheur National Forest in eastern Oregon in 1994, Rickabaugh et al. (1994) reported 22 of 30 (73.3%) territories occupied in pondersosa pine and mixed-conifer forest, with 20 of 22 (90.9%) nests successfully fledging young. The 1994 nesting productivity rate reported on the Fremont (Table 5) and Malheur NFs in eastern Oregon implies adequate prey densities for that season. Other studies in eastern Oregon and eastern Washington reported similar occupancy and nest success levels for 1994 (Finn 1995; Wallowa-Whitman NF, pers. comm.). The 1994 occupancy rate of the Fremont historic territories, when compared to similar studies in Oregon during 1994, greatly diminishes the possibility of an "off" year of breeding attempts or substantial nest failure being weather-related as the basis for such a low detection rate or low occupancy rate. Occupancy of Fremont current territories in 1994 was very similar to the Arizona, Utah, New Mexico, California, and Malheur studies, although this may be somewhat biased, as there are only 2 estimates of occupancy between years for current Fremont nests compared to a minimum of 4 for the other studies. However, chi-squared analysis of proportions showed Fremont current territory (n = 20) occupancy rate for 1994 (known territories in 1993) to be significantly different from the historic (n = 51) 1994 rate ($X^2 = 12.4$, 1 *df*, $P = 0.0004$). The Fremont historic territory occupancy rate in 1994 was also significantly different from the 1994 Malheur territories (n = 21) known occupied in 1993 ($X^2 = 6.5$, 1 *df*, $P = 0.011$). I compared the 3 samples using only 1994 data.

To infer that goshawk populations have declined on the Fremont NF is beyond the scope of this study, and it is possible that pairs not found in no-response territories had relocated to more suitable areas elsewhere. However, in those historic sites examined and determined to be no-response sites in 1994, present forest structural conditions due to significant alteration from past timber harvests suggest that nesting habitat quality has been substantially reduced, preventing goshawks from occupying a territory on that historical site through time (Woodbridge et al. 1988, Hargis et al. 1994). Post-hoc studies have implicated forest management practices such as timber harvest as the main reason for nesting pairs vacating sites (Bloom et al. 1986, Crocker-Bedford and Chaney 1988, Crocker-Bedford 1990). Crocker-Bedford (1990) observed that goshawks responded to timber harvest in nest stands by vacating partially harvested nesting sites, and purported that goshawk populations largely declined from historical levels. It is apparent that harvesting has negatively impacted suitability of nesting sites; however, the conclusions of a population decline may not have been warranted. My results indicate that late-successional habitat (i.e., Late Closed vegetative cover) is more predominant in nesting and occupied areas among all forest cover types, concurring with studies in Oregon (Bull and Hohmann 1994, Daw 1997), similar forest types in northern California (Austin 1993, Woodbridge and Detrich 1994), and other western U. S. studies (Reynolds 1978, 1983, 1989; Reynolds et al. 1982, 1994; Moore and Henny 1983; Crocker-Bedford and Chaney 1988; Hayward and Escano 1989; Ward et al. 1992; Siders and Kennedy 1996; Squires and Ruggiero 1996). As of 1994, only 2% - 8% of the forested area in the Fremont NF is ponderosa pine or pine associated late-successional climax-old growth forest (Henjum et al. 1994:5). Noss et al. (1995) stated that, because of the decline of contiguous, old growth (≥53.3 cm [21 inches] DBH *or* 150 years of age [Henjum et al. 1994:28]), ponderosa pine forest has become one of the most endangered forest ecosystem in western North America.

The random nest locations of my study could serve as a surrogate for random points for forest cover evaluation, providing a snapshot view of general forest conditions. The percent change (i.e., conversion of habitat) in no-response territories compared to occupied sites showed very large increases in Very Early (range 400 to >1000% change) and Early Open vegetative cover (Table 11, Figure 5). This corresponded with about a 50% decrease of Late Closed, and a 20% - 40% decrease of Mid-aged Closed cover types. The large-scale harvesting of Late and Mid-aged forest and subsequent conversion to mostly regenerating stands (Very Early or Early Open vegetative cover) on the Fremont over time suggest that the serious decline of preferred nesting habit in the no-response sites has contributed to the low occupany rate of goshawks in historic sites in 1994.

High site fidelity to good quality breeding territories may be advantageous for hawks of the genus *Accipiter* (Newton 1979, Newton and Wyllie 1992, Rosenfield and Bielefeldt 1996), possibly because there is an increased likelihood of success in familiar areas (Newton 1979). Studies in the U. S. have reported 70% - 75% of banded goshawks occupying the same territory in successive years (Detrich and Woodbridge 1994, Reynolds et al.1994), which is similar to congeneric Cooper's hawks (*A. cooperii*) (Rosenfield and Bielefeldt 1996) and European sparrowhawks (*A. nisus*) (Newton 1993). However, there is evidence that species with strong site fidelity might behave differently in extreme conditions such as food stress (Newton 1979) or disturbed habitats (Woodbridge et al. 1988, Bosakowski et al. 1993, Woodbridge and Detrich 1994). Bosakowski et al. (1993) reported 5 of 6 traditional Cooper's hawk nest sites were abandoned and not reused in the year following clearing of forests and encroachment within a range of 40 - 500 m of the active nests.

Hargis et al. (1994) postulated that monitoring the site fidelity of breeding goshawks provides a valuable indicator of the quality of the surrounding home range. If the specific habitats needed for foraging and development of fledglings are subjected to habitat alteration outside the nest areas (e.g., timber harvest and road building), hawk pairs could vacate even though the nest sites are being protected (Woodbridge et al. 1988, Bosakowski et al. 1993, Hargis et al. 1994, Woodbridge and Detrich 1994).

Forest Structure Change

Closed canopy, mature forest is thought to be the most consistent structural characteristic of goshawk nest stands (Reynolds et al. 1982, 1992, 1994; Moore and Henny 1983, Hall 1984; Crocker-Bedford and Chaney 1988, Hayward and Escano 1989, Ward et al. 1992, Siders and Kennedy 1996, Squires and Ruggiero 1996). Comparing the distribution of Late Closed and Mid-aged Closed forest between occupied and no-response sites showed a marked decrease in the amount of preferred nesting habitat. Territories occupied in 1994 had >50% of the mean area of the 12 ha nest stand scale in Late Closed and Mid-aged Closed vegetation types, and most resembled the historic photograph conditions.

Woodbridge and Detrich (1994) found that occupancy of territories was positively correlated with alternate nest cluster size (i.e., the area containing all alternate nests for a pair of goshawks). They found that nest cluster size was correlated with amount of suitable nesting habitat present within the nest cluster, and 82% of territories were associated with larger patches of mature forest. Reduced occupancy in smaller stands (<20 ha) suggests that patch size of a habitat type (forest structural stage) maybe an important factor in determining the quality of nest habitat (Woodbridge and Detrich 1994).

I documented significant reductions of Late Closed forest and Mid-aged Closed forest from the historic sites compared to the 1994 no-response sites across all scales. Early Open forest was approximately 2.5 times more abundant in no-response sites than in occupied territories. Occupied sites within the alternate nest cluster (52 ha) had mean amounts of Mid-aged Closed and Late Closed forest >2 times that in territories having no-response. Moreover, Late Closed canopy forest was nearly 5 times more abundant in occupied nest stands (12 ha) than in no-response territories. Average proportions of Late-successional stage forests were significantly smaller at all scales in no-response stands than both historic and occupied. Again, these results support the hypothesis of habitat alteration and loss of nesting habitat as the most likely reason for no goshawk detections at no-response sites.

Natural dry and wet openings (Open Dry and Open Wet) are prevalent on the Fremont, although the logistic regression analysis did not show a statistical association between these vegetation types and occupied territories within the 52 ha nest cluster scale. At all 1992-1994 nest sites, >50% of the prey biomass (27% of total items) found were small mammals (Cutler and DeStefano 1993), typically Douglas squirrel (*Tamiasciuris douglasii*), which are abundant in mature forest conditions, and golden-mantled ground squirrels *(Spermophilus lateralis*), which are abundant at forest edges (Ingles 1965, Boal and Mannan 1994). This may indicate that foraging cover is a mix of dense to moderately dense forests and open vegetative cover types, such as dry or wet openings, which have significant forest edges. Telemetry studies in New Mexico (Kennedy 1991) and California (Austin 1993, Hargis et al. 1994) of adult northern goshawks and patterns of juvenile dispersal (Kennedy et al. 1994) have shown that large areas of a mix of forested types and openings are used for breeding and raising young (Kennedy 1991, Reynolds et al. 1992, Kennedy et al. 1994). Perhaps this suggests that goshawks use closed canopy nesting areas for hiding cover, protection of young, and some foraging, while utilizing some open areas for foraging on certain prey species. Kenward (1982) found that radioed adult male goshawks spent >50% of the time foraging in forest, and although only 12% of their range was forested, 70% of prey of was taken in forest. Beier and Drennan (1997) found that breeding male goshawks foraged in mature forest having higher basal area and higher stem density more than was available in the landscape despite equal or less than equal prey abundance at those sites. Telemetry studies in Oregon are needed to answer questions regarding which forest structural characteristics and habitats are used most often by goshawks.

Logistic Regression Model

Those sites where goshawks had persisted through time showed a strong association with Late Closed and Mid-aged Closed forest habitats within the 52 ha alternate nest cluster, as evidenced by the logistic regression model. This supports the findings of Woodbridge and Detrich (1994) which found that occupancy rates of goshawk nest stand clusters remained high (75% - 80%) for nest cluster sizes >40 ha, and between 80% and 100% occupancy for nest cluster size between 40 and 61 ha. The logistic regression model also showed the strongest association occurred within the 12 ha nest stand. It is important to note that the model predicts presence of goshawks and where habitat was most suitable given the available parameters of Late Closed and Mid-aged Closed vegetation. The associations drawn and conclusions reached using the logistic regression model are based on the position of nests in the forested landscape and not the amount of habitat required for successful occupancy of a territory. The model can predict how odds of presence can change relative to the amount of Mid-age and Late Closed habitat available. There may be other factors affecting the odds of goshawk presence that were not measured; e.g., amount of roads, or forest fragmentation indices. However, the model was designed primarily to further validate the findings of the statistical comparisons used in this study, and provide additional insight. Although sample size of occupied sites was not large, logistic regression analysis is fairly robust in predicting effects based on odds ratios for binary responses for low sample sizes (Hosmer and Lemeshow 1989). However, the chosen model (equation 3) has only limited use as a predictor of the odds of goshawk presence or occupancy over the available habitat in the observed data set, based on the amount of Late Closed and Mid Closed vegetative cover types.

Implications of Vegetative Cover Loss

Habitat mosaic may best describe goshawk PFAs on the Fremont (Figures 6-8). For a theoretical goshawk population to maintain existence in a habitat mosaic, potential breeding habitat must exist that promotes positive net reproduction (Rosenzweig 1985, Urban and Shugart 1990). A major assumption is that habitat dynamics are “slow” to change in one direction (i.e., the habitat mosaic remains somewhat constant) in relation to avian demography dynamics, which may fluctuate over relatively brief time periods (Rosenzweig 1985). “Slow” habitat dynamics would imply that a major disturbance, altering the forest mosaic on a large scale, would occur infrequently over a long time interval, allowing succession to progress and maintain the habitat mosaic within its historical range of proportions. Recent analysis of goshawk demography in the U. S. showed no evidence of trends (DeStefano et al. 1994b, Kennedy 1997), and the high fidelity to breeding territories (Detrich and Woodbridge 1994, Reynolds et al. 1994, Kennedy 1997) suggests that the demography dynamics may be somewhat stable. Goshawks are increasing in Great Britain (Kenward 1996), although they were recently reintroduced after being exterminated a few decades ago. From an ecological perspective, intensive harvest, road building, grazing, fire suppression, and other disturbance factors in the last 50 years on the Fremont have occurred at a rate faster and in greater proportion than natural disturbance regimes, as older forest was harvested at a much more rapid rate than replaced (Henjum et al. 1994; Eastside Forest Ecosystem Panel, USDA Forest Service 1993). The habitat dynamic has changed from "slow" and is "accelerating," thereby increasing the proportion of successional forest stands in more early stages, resulting in a skewed distribution of age classes compared to the historical range. This would violate the slow habitat dynamic assumption, reduce availability of suitable nesting and foraging habitat, and potentially threaten positive net reproduction of goshawks and other species that use older forests.

"Ephemeral" goshawk nesting sites, as described by Woodbridge and Detrich (1994), are those sites not used >2 times and the banded pair not relocated again. These locations could represent possible resource sinks for goshawks. Options for pairs in these conditions are to nest in sub-optimum habitat conditions, or to not attempt to breed. If pairs are forced to nest in sub-optimal habitat, their ability to produce viable young that would contribute to the population over the long term may be in question (e.g., a continued low or inconsistent success rate). It would follow that the loss of adequate nesting habitat, if finite, could prevent adults from reproducing. It is possible goshawks nest in marginal habitats only in times of abundant prey. Still, dispersing young goshawks are potentially threatened in open areas and may be out-competed by raptors adapted to open areas such as great horned owls and red-tailed hawks (Moore and Henny 1983, Rohner and Doyle 1992, Kenward 1996).

In an analysis of 4 populations of marked goshawks in the U. S., Kennedy (1997) found no evidence of population decline. Marked individuals on territories within the populations examined ranged from 4 - 11 years of data per territory. However, 3 of the marked populations have had little or no habitat modifications within about 90% of individual goshawk territories (at least the PFA scale) since the individual demographic studies began (S. Dewey, pers. comm.; P. Kennedy, pers. comm.; B. Woodbridge, pers. comm.; R. Reynolds pers. comm.). The amount of suitable nesting habitat available was not addressed by Kennedy (1997), as it was beyond the means of the study, but would be an important component of monitoring the fidelity of hawks to a site over time. DeStefano et al. (1994b) analyzed a limited data set of one population of marked individuals, but were not able to reach a significant conclusion about survivorship and population change of adults.

Clearly, the long-term occupancy of nest clusters is correlated with larger proportions of mature forest (Woodbridge and Detrich 1994). My results indicate substantial amounts of Late and Mid-aged Closed forest (60% within the 12 ha nest scale and 48% within the 52 ha scale) are important to the persistence of northern goshawks in historic nest stands. Differences in the amounts of late-successional closed forest between historic and occupied sites in 1994 were not apparent in this study, suggesting that the relatively intact structure resembling the historic condition contributed to persistence of goshawks. This supports the findings of Woodbridge and Detrich (1994) which found that occupancy rates ($n = 8$ years) of goshawk nest stand clusters remained highest ($\geq 75\%$) for nest cluster sizes >40 ha. Analysis of the Fremont vegetative cover types suggests that any habitat manipulation resulting in substantial reduction of mature, closed-canopy forests, which is subsequently replaced with early successional or more open young forest, would reduce the suitability of an area as a potential nest site (McCarthy et al. 1989). It is difficult to predict the response of goshawks to limited alterations of habitat (e.g., thinning, light selection harvest). My analysis suggests that more severe alterations (regeneration clearcuts, partial removal of stands resulting in <50% canopy closure, and moderately high to severe alteration) may be better predictors of goshawks not nesting in areas where nest site potential has significantly deteriorated and become non-suitable for nesting.

MANAGEMENT IMPLICATIONS

The northern goshawk is on the Oregon state list of sensitive species and the U. S. Fish and Wildlife Service (USFWS) has indicated that there is concern about the status of a species, but there is not enough information to warrant listing under the Endangered Species Act. The goshawk is not being considered for special status by the U. S. Forest Service (USFS) in Region 6 (Oregon and Washington), but is listed as an indicator species for mature and old-growth forests on the Deschutes, Fremont, Wallowa-Whitman, and Winema National Forests of Oregon (Henjum et al. 1994). Further reduction in late-successional habitats is likely to jeopardize many biological components of eastside forests and increase the numbers of sensitive species such as the northern goshawk (Henjum et al. 1994)

Conflicting policies of state and federal agencies are in need of a consistent management strategy. The Fremont National Forest was the first forest in Region 6 to set aside 24 ha (60 acres) of potential nesting sites for goshawks, as suggested by Forsman (1980) and Reynolds (1983), although many of these sites have not been monitored for activity or suitable forest structure for nesting conditions. Forsman (1980) suggested deferral of management activity within 400 m of active nests from the start of nest building until incubation is complete, usually from March to mid-July on the Fremont (Reynolds 1978; S. Desimone, unpubl. data). It is apparent from this investigation that the intended proactive management strategies of the Fremont have not been fully realized since first implemented in the early 1980s.

Reynolds et al. (1992) suggested that forest conditions for nesting goshawks in the Southwest Region of the Forest Service within the 170 ha post-fledging family area

(PFA) be maintained somewhere between the dense foliage and high canopy closure of the nest stand (12 ha) and the more open foraging habitat. These management recommendations were not based entirely on conclusive evidence of an optimum balance of habitat types from scientific studies, but rather a suggested ideal model of desired overall forest conditions conducive to maintaining an adequate goshawk prey base, while allowing regulated timber harvest (Arizona Game and Fish 1993). The U. S. Forest Service Pacific Northwest Region 6 followed suit by proposing an interim standard for active nest stands to include 30 acres (12 ha) of the most suitable habitat with no harvest, and a 390 acre (160 ha) PFA with 60% in mature/overmature forest or intermediate stages at all times, with no dead stands to be included (USDA Forest Service 1994). At the time this project was initiated, goshawk inventory procedures and nest site protection standards were inconsistent among National Forests and not based on the best scientific information.

The current direction for management of goshawks in the U. S. Forest Service Southwest Region (i.e., Southwest Management Guidelines [Reynolds et al. 1992]) is to provide 40% of the total forest land base in late-successional and old-growth forest (>52 cm dbh); the remainder (60%) is to be equally divided among small sawtimber (26-51 cm dbh), pole stands (<26 cm dbh), and sapling-seedling/grass-forb seral stages (Reynolds et al. 1992). The results of my study indicate that the SW management guidelines are not inconsistent with the percentages of comparable successional stages (see Appendix) present in occupied nest sites. However, because of the small sample size of occupied sites used for habitat analysis, caution should be taken when comparing the SW management guidelines for use in Oregon. Also, detailed vegetation analyses should be implemented statewide to draw significant comparisons and contrast variations in vegetation patterns between the two regions.

Tree harvest prescriptions that create large areas with sparse cover (e.g., Very Early, Early Open, Mid Open, Late Open) are potentially detrimental to goshawk occupancy, especially if the percent of open canopy (<50% CC) forests is >33.7% (mean) at the 52 ha scale or >43.8% (mean) of the total area of the 170 PFA (Table 12). Forest structure conditions used by the goshawk, when more clearly identified by habitat use and prey studies, will better evaluate how existing forest allocations or prescriptions in the landscape will affect goshawk use of habitat. Beier and Drennan (1997) indexed prey abundance and measured forest structure at foraging sites used by radioed goshawks and found that they selected sites with higher canopy closure and greater density of trees >40.6 cm DBH, regardless of sites where prey abundance was equal or greater. This supports the hypothesis that moderately dense, mature forests provide preferred structure for the morphological and behavioral adaptations of the goshawk.

This study underscores what many researchers have found; the presence of a high percentage of Late and Mid-aged structural stage forest with well-canopied conditions within the 12 ha nest stand scale is important to ensure suitability of these areas for nesting goshawks. Moreover, I recommend nest management be expanded to the alternate nest cluster scale. I suggest a 52 ha (130 acres) no-harvest zone within the alternate nest cluster and discourage further cutting of large, late and old structure trees (>53 cm DBH) within the PFA to preserve stand integrity, maintain closed canopies, maintain connectivity to alternate nest stands, and optimize conditions for breeding goshawk pairs to persist. The delineated 52 ha should include at least 2 alternate nest stands in addition to the existing nest stand and should have similar suitable structural conditions as the known nest area. Nest stands should be delineated to include the most late-successional, closed-canopy forest structure surrounding the nest tree possible (a minimum of 30% of the 12 ha nest stand [this study]). Outside of the 52 ha nest cluster, the remainder of the 170 ha PFA should retain all existing Mid-age and Late vegetation structure possible. I recommend that <20% of the PFA should be in Very Early and Early Open vegetative cover types. Management activities within the PFA should be limited to light thinnings and/or carefully controlled prescribed burning of overstocked stands to promote uneven-aged stand development, reduce the fuel loading hazard, and possibly improve foraging opportunities for goshawks by removing some of the dense understory of shade tolerant conifers. Application of these management suggestions would help to maintain occupancy of PFAs by goshawks, as well as keep important biodiversity components essential to maintaining health of mature and late-successional forests (DellaSalla et al. 1995).

Adaptive management techniques should be part of an overall monitoring scheme to ensure goals of goshawk habitat management are being met (Dewhurst et al. 1995) because of the limited information on habitat use in Oregon. More prey studies coupled with telemetry studies will best determine how goshawks utilize habitat (e.g., Beier and Drennan 1997). Determining foraging habitat by telemetry on dynamic managed landscapes would provide the basis for determining the size and number of stands present to maintain a territory. If larger proportions of eastside forests become intensively managed, stand size and reoccupancy by goshawks is at risk.

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APPENDIX

Appendix. Silvicultural and ecological classification of vegetation structural stages (vss), increasing in time from left to right. The column boundaries are rough estimates intended for general comparison. (Structural stage is not necessarily associated with stand age or to seral development; definitions are based on existing structure or developmental process.)

SUCCESSION and TIME						
Source	**Structure oriented definition**					
Brown (1985) [1]	Seedling/sapling < 13 cm (mean DBH <5 in.)		Closed sapling-pole 13-23 cm (5-9 in. DBH)	Sawtimber 23- 53 cm (9 -21 in. DBH)	Large sawtimber 53-81 cm (>21 in. mean DBH) 80-200 yrs	Old-growth >81 cm (>32 in. DBH) dead + down and 2+ canopy layers >200 yrs
USDA, Forest Service (1994) [2] and this study	Very Early <12 cm		Early structural stage 12 -23 cm	Mid-aged structural stage 23 - 53 cm	Late succession and Old growth [3] structural stage ≥15 trees per ha > 53 cm	
Reynolds et al. (1992) [4]	VSS 1 1-2 5cm (0-1in)	VSS 2 2.5-13 cm (1-5 in)	VSS 3 Young 13-31 cm (5-12 in)	VSS 4 Mid-aged 31-46 cm (12-18 in)	VSS 5 Mature 46 - 61 cm (18-24 in)	VSS 6 Old >61cm (>24 in.)

Appendix (Continued).

Process oriented definition						
Oliver and Larson (1996)	Stand initiation	Stem exclusion	Understory reinitiation and overstory breakup		Diverse	Old-growth
Eastside National Forests EIS Screens, USDA, Forest Service (1994) [2]	Stand initiation typically by ser[illegible] species	Stem exclusion, Closed Canopy: 1 layer; light or moisture limited	Understory reinitiation: 2nd cohort [5] appears	Multi stratum, without large trees: several cohorts established, large overstory trees uncommon	Multi-stratum, with large trees: several cohorts and strata present; large trees common	Multi stratum, with large trees: single stratum of large trees present; large trees common, young trees few or absent; park-like conditions
		Stem exclusion, Open Canopy: moisture limited; crowns open grown				

[1] Conifer forests west of the Cascade crest in Oregon and Washington.
[2] National Forests east of the Cascade crest in Oregon and Washington.
[3] Ponderosa pine and pine associate forests in the US Forest Service Southwest region.
[4] The Eastside Forests Scientific Society Panel (Henjum et al. 1994) defines old-growth as >21in. DBH *or* >150 years.
[5] A cohort is a class of trees arising after a common natural or artificial disturbance (Oliver and Larson 1996).