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Abstract approved: ______________________

Dr. E. Charles Meslow

Nocturnal surveys were conducted in February - May 1989 and January - May 1990 to locate great horned owls (*Bubo virginianus*) and northern spotted owls (*Strix occidentalis caurina*) throughout the range of forest fragmentation levels in the Central Cascades of Oregon. Forest fragmentation levels ranged from landscapes ($\geq$ 500 ha in size) containing intact stands of mature/old-growth forest (0% fragmentation) to landscapes containing younger stands with no mature/old-growth forest (100% fragmentation). Six survey visits were made to each of 469 calling stations located along 28 roadside survey routes. Total length of survey routes was 535.8 road km; relative abundance for great horned owls and spotted owls was 0.069 and 0.139 owls/road km, respectively. Owl response rates were examined for differences 1) during the night, 2) by moon phase, and 3) by month during the survey period. Great horned owls responded less than expected before midnight and more than expected after midnight, less than expected during full moon and more than expected during new moon phases, and less than expected during January and April of the survey period. Spotted owls responded more than expected from 1800-1959 hr, more than expected during full moon phases, and generally more than expected during May of the survey period.

Thirteen habitat/landscape variables within 500-ha circular landscape plots surrounding 77 great horned owl, 103 spotted owl, 70 no-owl, and 70 random points were assessed. Significant differences existed between great horned and spotted owl landscapes for 6 variables: great horned owl landscapes contained more shrub/forb and shelterwood, less mature/old-growth and interior habitat, had a higher linear edge-to-mature/old-growth area ratio, and were higher in elevation than spotted owl landscapes. The amount ($\bar{x} \pm SE$) of mature/old-growth forest was 48% ± 2% around great horned owls, 60% ± 2% around spotted owls, 53% ± 3% around no-owl points, and 53% ± 2% around random points. The greatest number of great horned owl responses were associated with landscapes containing 10-20% old forest. Great horned owl responses generally declined with increasing amounts of old forest, and few (11%) great horned owls were detected in landscapes containing ≥ 70% old forest. The majority (62%) of spotted owls were detected within landscapes containing ≥ 60% old forest. Spotted owl responses generally declined with declining amounts of old forest, and few (7%) spotted owls were detected within landscapes containing ≤ 20% old forest.

The spatial distribution of old forest stands was compared to dispersed (checkerboard) and clumped landscapes: 95% of great horned owl, 88% of spotted owl, 89% of no-owl, and 86% of random landscapes were classified as dispersed. Clearly, the forests of the Central Cascades are very highly fragmented. A method for linking owl biology and landscape level plot size is described.

SPOTTED OWLS, GREAT HORNED OWLS, AND FOREST FRAGMENTATION IN THE CENTRAL OREGON CASCADES

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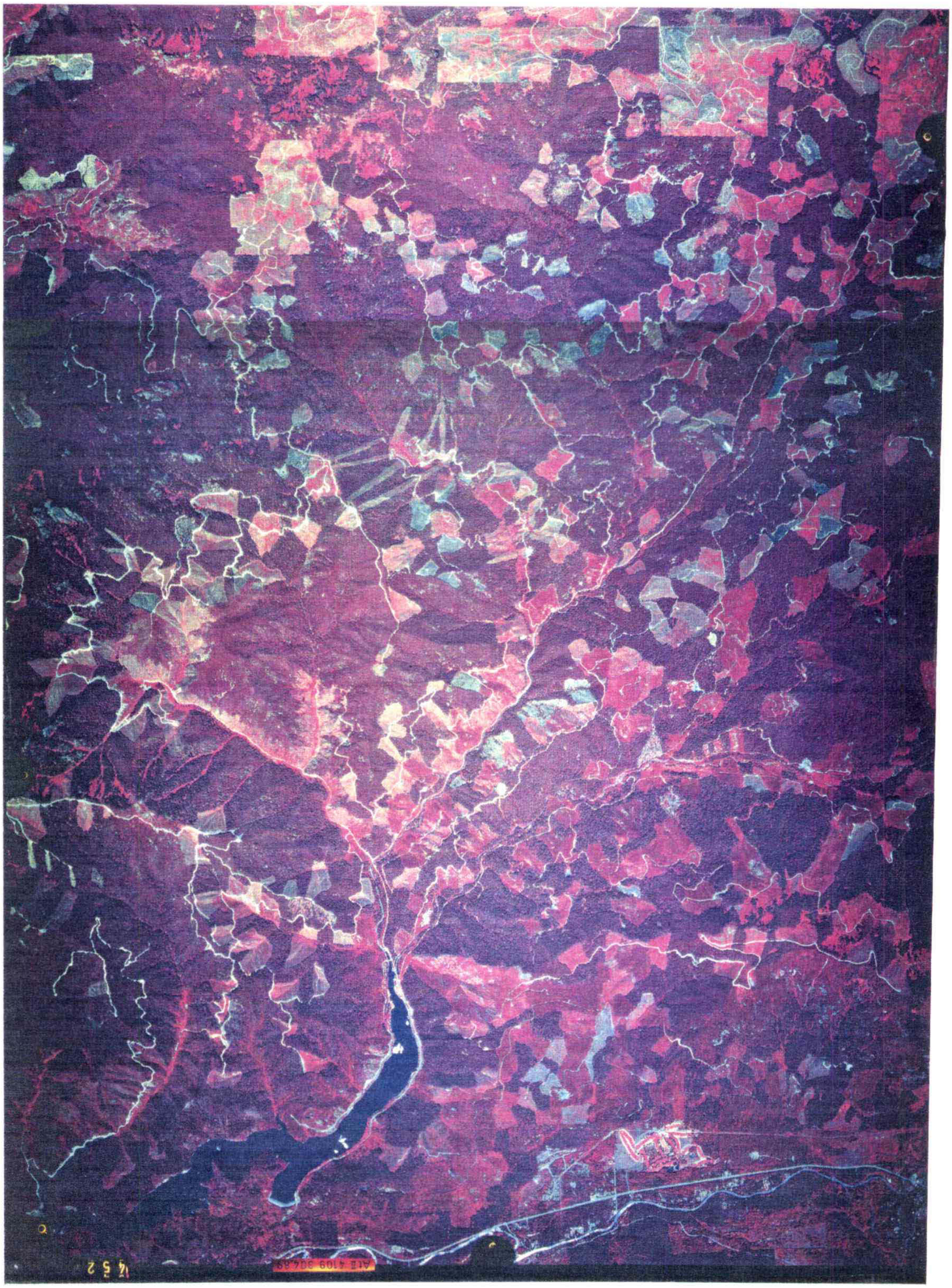


SPOTTED OWLS, GREAT HORNED OWLS, AND FOREST FRAGMENTATION IN THE CENTRAL OREGON CASCADES

INTRODUCTION

Forest fragmentation is a process that results in a landscape consisting of remnant areas (patches) of native vegetation surrounded by a matrix of tree plantations, agricultural, or other developed land. Remaining patches are situated in different positions in the landscape and on different soil types, possess different vegetation types, and vary in their size, shape, isolation, and type of ownership. As a result of fragmentation, fluxes of radiation, wind patterns, water, nutrients, and the movement of species across the landscape are altered significantly. For plant and animal species, the consequences of fragmentation vary with the size of remnant, time since isolation, distance from other remnants, and degree of connectivity with other remnants (Saunders et al. 1991, Lehmkuhl and Ruggiero 1991, Lehmkuhl et al. 1991).

In the Pacific Northwest, forest fragmentation typically is the result of staggered clearcutting of late-successional forest. Forty years of staggered clearcutting on National Forests (Harris 1984, Spies and Franklin 1988) and BLM lands (Luman and Neitro 1980, Monthey 1984) have resulted in various stages of fragmentation of the remaining forest. Two issues are associated with current harvest patterns of old-forest: quantitative loss of old-forest habitat for associated species, and qualitative loss of old-forest habitat resulting from the reduced capacity of remaining patches to support wildlife communities and the functions of old-forest conditions (Raphael 1984, Rosenberg and Raphael 1986, Lehmkuhl and Ruggiero 1991, Lehmkuhl et al. 1991).

The northern spotted owl (*Strix occidentalis caurina*) is closely associated with old-growth Douglas-fir forests from southwestern British Columbia through northwestern California (Anderson et al. 1990, Thomas et al. 1990). It is declining in numbers as old-growth forests are harvested and converted to managed younger forest stands (Gould 1977, Marcot and Gardetto 1980, USFWS 1982, Forsman et al. 1984, Anderson et al. 1990, Booth 1991). The majority of remaining spotted owls are found on federal lands (Thomas et al. 1990).

Distinct sets of "edge" and "interior" species have been recognized in landscapes that have been fragmented for long periods of time, for instance in the eastern United States (Ranney et al. 1981). Great horned owls (*Bubo virginianus*) are considered forest edge species, while spotted owls are associated with the closed-canopy forest interior. As old-growth forests are logged, the proportion of edge between old-growth forests and plantations increases; this habitat manipulation favors great horned owls and the likelihood of overlap between the home ranges of the two owl species. Great horned owls are found throughout the range of the spotted owl, and with the present extent of forest fragmentation, it seems likely that home ranges of the two species overlap regularly.

As old-growth forests become fragmented through logging, it is hypothesized that great horned owls become established and increase in numbers as this new niche is created. Although fairly well studied elsewhere in North America, little is known about great horned owl ecology in the Pacific Northwest. The larger and more aggressive great horned owls negatively impact spotted owls through (1) territorial overlap, resulting in spotted owl displacement (at least short-term) (Gutierrez 1985), (2) food competition (Anderson et al. 1990), and (3) predation (Anderson et al. 1990). Great horned owl predation upon adult and juvenile spotted owls has been documented (Forsman 1976, Forsman et al. 1984, Miller and Meslow 1985a, Carey et al. 1990). A query of researchers engaged in radio-telemetry studies indicated that from 1975-1991, 40% of 91 adult/subadult and 25% of 60 juvenile spotted owl deaths were the result of avian predation; great horned owls were the primary predator.

Current spotted owl management is directed toward maintaining a viable population of owls in a network of old-forest reserves or Habitat Conservation Areas (HCAs) spaced ≤ 19.2 km (12 mi) apart (Thomas et al. 1990). Under this network system, demographic replacement and genetic transfer relies primarily on dispersing juveniles. Also, this network system allows a significant reduction (around 60%) in spotted owl habitat from current levels, as timber harvest continues between HCAs and HCAs become increasingly isolated. One can envision these HCAs as old-forest "islands" surrounded by a "sea" of younger managed forests (and theoretically at least, great horned owls). The above scenario has caused concern over the spotted owls' vulnerability as they move in and through fragmented forests (Gutierrez 1985, Gutierrez et al. 1985, Miller and Meslow 1985b, Carey 1985, Dawson et al. 1987, Anderson et al. 1990).

This study had three primary objectives: 1) determine great horned owl and spotted owl population indices across a gradient of forest habitats -- least to most fragmented, 2) evaluate habitat surrounding located owls and determine how owl locations relate to forest fragmentation, and 3) evaluate elevational or other landscape patterns with regards to the distribution of owls. A secondary objective was to evaluate owl response rates with regards to season, time of night, and moon phase.

Because spotted owls are closely linked with old (mature/old-growth) forests (Forsman et al. 1984, Thomas et al. 1990, Anderson et al. 1990), and because of concerns over management of spotted owl habitat, much of the attention during the landscape assessment portion of this project was focused on old forest stands. In particular, my efforts were directed towards describing the amount, shape, and spatial distribution of old forest stands. Linking owl biology with landscape-level patterns is a complex task. It requires knowledge of owl habits, habitats, and prey base; it requires the selection of pertinent habitat variables and measurement of these variables at a scale that reflects "landscape" patterns; and finally it requires the analysis of differences between landscapes and between species (if any exist), and challenges us to produce a product that is amenable to management.

All references to the spotted owl in this report refer to the northern spotted owl (*S. o. caurina*) unless otherwise noted.

STUDY AREA

The study area (Figure 1) lies on the western slope of the Cascade Range in Linn and Lane Counties in central Oregon (43°43′- 44°37′ N, 121°55′- 122°50′ W). Specifically, the study area includes the Sweet Home, Blue River, McKenzie, and Lowell ranger districts on the USDA Forest Service (USFS) Willamette National Forest and a portion of private and Bureau of Land Management (BLM) lands directly west of the Sweet Home and Blue River districts. The study area was bounded on the east by the Three Sisters and Mt. Washington Wilderness Areas. The 100-km (north-south) by 71-km (east-west) study area falls within portions of the western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), and mountain hemlock (*Tsuga mertensiana*) zones with the major tree species consisting of Douglas-fir (*Pseudotsuga menziesii*), western hemlock, Pacific silver fir, noble fir (*Abies procera*), and western redcedar (*Thuja plicata*) (Franklin and Dyrness 1973). Elevation ranges from 205 to 1,600 m. The topography is strongly dissected with an abundance of steep slopes. The climate is maritime. Annual precipitation averages 230 cm at low and 330 cm at high elevations. Winter snowpack ranges from 1 to 4 m above 500 m elevation.

Approximately 40% of the study area has been logged during the last 60 years, with staggered clearcutting of 7-38 ha patches (Ripple et al. 1991a) the prevalent harvest practice. Roughly 8% of the study area is comprised of scattered, privately-owned lands which are managed for timber production.

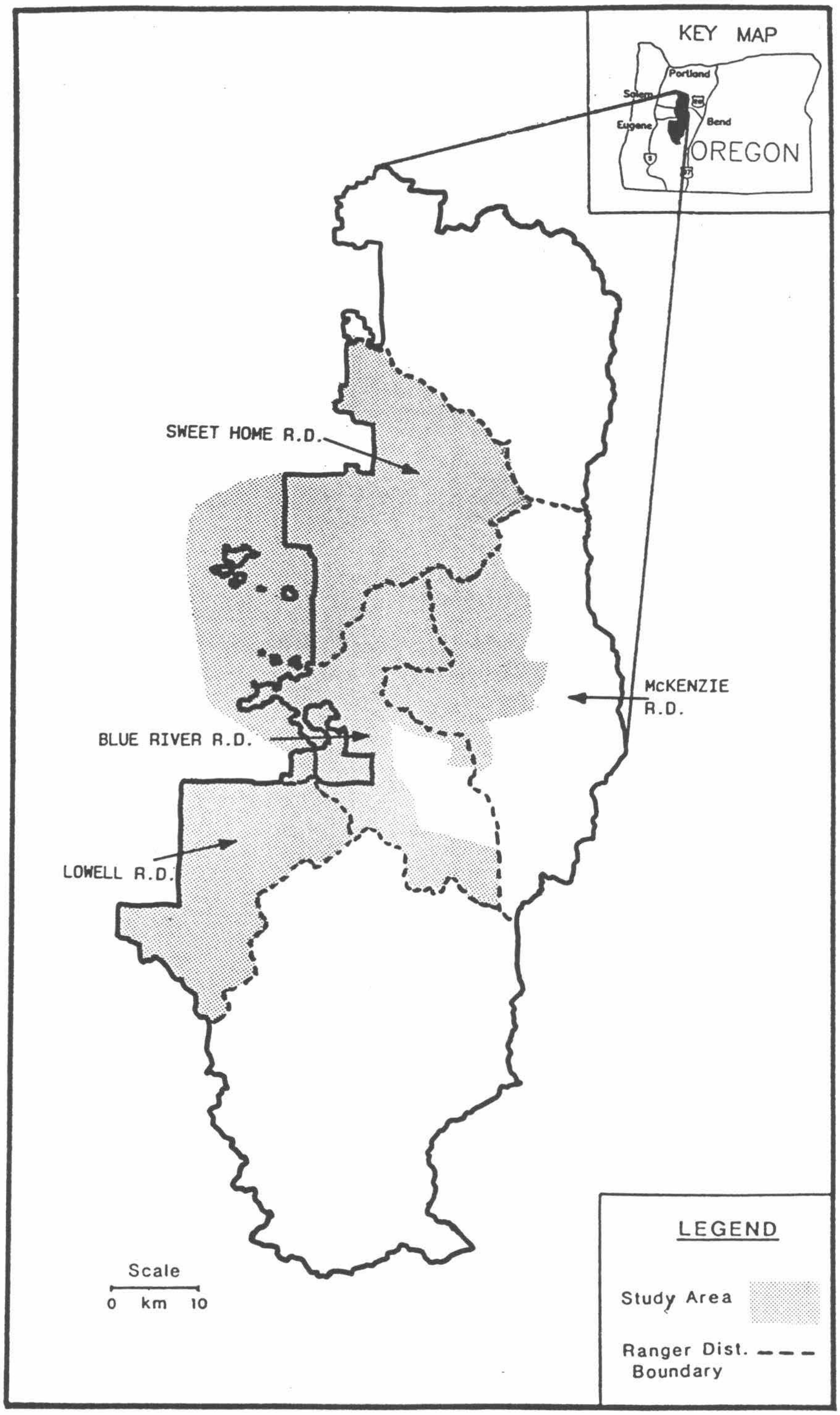


Figure 1. Location of study area on the western slope of the Cascade Range in Linn and Lane Counties, Oregon.

METHODS

Nocturnal Survey

Survey efforts were conducted between 30 min after sunset until 30 min before sunrise on 124 nights during 2 field seasons (58 nights between 19 February and 17 May 1989, and 66 nights between 19 January and 13 May 1990). Four-hundred sixty-nine (469) calling stations were located along 28 survey routes, with each route having 6-26 calling stations (see Appendix A for summary list and maps of survey routes). Measured as straight-line distances, stations were at 0.8-km (0.5-mi) intervals. A few stations were moved slightly (<0.2 km) to take advantage of topographic features or to avoid excessive stream noise.

Routes were selected to reflect the range of elevations and stand conditions (e.g., shrub/forb, sapling, closed-pole, shelterwood, mature/old-growth). In particular, routes were established through the range of fragmentation levels (i.e., through landscapes containing 0-100% mature/old-growth forest) present in the Central Cascades. However, for about the last 40 years, the study area has been logged by the staggered-setting system, in which 10- to 40-ha clearcuts were dispersed across large areas of old forest. The overall pattern of harvest has resulted in a fairly evenly distributed mosaic of younger and old (mature/old-growth) stands across the study area, and most of the drainages in the Central Cascades now contain between 30-60% old forest. As a result of past harvest patterns, it is difficult to obtain a sample representing the full gradient of fragmentation levels. In particular, very few areas of contiguous old (mature/old-growth) forest

>1,000 ha currently exist outside of wilderness areas. Routes also were selected where stream and vehicle noise, and human activity (i.e. houses) would be minimal. Stands dominated by deciduous trees were minimized as they represented a very small proportion of the Western Cascade Douglas-fir forest. Although 3 routes were adjacent to wilderness areas, no routes extended into wilderness areas. Because of snow avalanche problems, 2 routes with stations above 1372 m (4500') elevation were abandoned and replaced with routes at lower elevations. Each route was surveyed a total of 6 times and no routes surveyed in 1989 were repeated in 1990. A minimum of 7 days elapsed between visits to the same survey route.

The calls of only one species were broadcast during each of the 6 visits to each survey route: in 1989 great horned owl calls were broadcast during the first, second, and fifth visits; spotted owl calls were broadcast during the third, fourth, and sixth visits. In 1990 great horned owl calls were broadcast during the first, second, and third visits; spotted owl calls were broadcast during the fourth, fifth, and sixth visits. Specifically, survey efforts targeted at great horned owls were conducted between 19 February and 7 April 1989, and between 19 January and 12 April 1990. Survey efforts targeted at spotted owls were conducted between 16 March and 17 May 1989, and between 23 March and 13 May 1990. I compared the number of responses from each species with the number of calling stations visited with no owls responding during targeted survey efforts to see if differences in owl response rates occurred during any given month.

At each station, I first listened for unsolicited owl calls (a "hooting" owl) for 1 minute. Taped owl calls (reflecting the species being surveyed) were then broadcast during the following 5- or 6-minute period. Taped owl calls were broadcast using a portable cassette player and amplified through an 8-watt hand-held megaphone. A broadcast for great horned owls consisted of individual great horned owl calls (each ≈ 3 seconds in duration) separated by 20 seconds of silence. Great horned owl calls were broadcast during a 5-minute period in 1989 and during a 6-minute period in 1990. The extra minute was added in 1990 due to the delayed response pattern observed in great horned owls in 1989. Broadcasts for spotted owls consisted of individual spotted owl calls (each ≈ 3-5 seconds in duration) separated by 15 seconds of silence. Spotted owl calls were broadcast during a 6-minute period in both 1989 and 1990. The 20- and 15-second intervals between calls reflected the unsolicited call frequency observed in the field for great horned and spotted owls, respectively.

Calls from male and female great horned owls and spotted owls were used. The call of a female great horned owl was broadcast in 1989 and the call of a male great horned owl was used in 1990. In both cases the call was believed to be the contact call. Both male and female spotted owl calls were broadcast in 1989 and 1990. Spotted owl calls included: male four-note contact calls, male agitated calls, and female agitated calls (Forsman et al. 1984). Spotted owl calls were broadcast in a sequence of 4 male four-note calls, 2 male agitated calls, and 2 female agitated calls (as noted above, each call was separated by 15 seconds of silence). This sequence would typically be broadcast twice at each calling station.

During each visit to a station, I recorded the date, route number, visit number, station number, temperature, moon phase, and time at start of survey (at each station). When an owl responded, I also noted time from start of broadcast to owl response, species, sex, type of response (see below), whether it was the first, second, third, etc. observation on the owl, the direction and distance from observer, the owl's location (Universal Transverse Mercator coordinates), and any distinguishing characteristics in the owls' vocalization (e.g., pattern or tone). I categorized owl responses into 7 types: 1) visual only, 2) owl called within 100 m, 3) owl called from > 100 m and moved in, 4) owl called > 100 m away and did not move in, 5) owl called from an unknown location, 6) unsolicited response, and 7) owl was recorded at a previous station during the same night. An example of the data codes and field form is in Appendix B. Responding owls were located by triangulating on their calls using a hand-held compass and 3-4 observer locations. Because of very brief responses, long distances, or obstructing topography, triangulations of owl locations were acquired for only 65% of the owl responses. Survey efforts were discontinued when precipitation was greater than a drizzle, when winds exceeded 16 kph (10 mph), or during fog.

Great horned owls are considered edge species; logging takes place near roads and creates edge; therefore, one would hypothesize that there is more edge habitat (and great horned owls) along roads. The converse would also apply: there is more interior habitat away from roads. If the above scenario is accurate the census effort would be biased because surveys take place along roads. To address this concern I measured the distance from 200 points to the nearest edge. One hundred points were along survey routes (roads); 100 were located at random in general forest land within the study area. Distances were measured to the nearest 10 m; measurements from points that fell within old forest areas had positive values, measurements from points that fell within logged areas or other habitat types had minus values. Mean distance-to-edge was 81 m (SD = 376 m) along survey routes and 128 m (SD = 328 m) from random points. These distances were not different ($P = 0.35$) and the survey was not significantly biased in this regards.

To remain consistent with published survey formats (e.g., Forsman et al. 1977), I have addressed the survey data as follows: each visit to a route was considered a separate route and only responses from owl species targeted on that visit were used in the analysis. During the survey, if an owl moved > 0.4 km (i.e. followed the observer from one station to the next) an additional response location was recorded for that owl on that visit; however, only the first response was used in the analysis. Thus, an individual owl could be counted only once on each of the survey visits, even if it responded at multiple locations during each of its respective three targeted survey visits.

All survey stations, random points, and owl locations were plotted on USGS orthophoto quadrangles (scale 1:24,000). I used 1988 aerial photographs and a zoom transfer scope to update the orthophotos to show recent roads and timber cutting. Field inspections and timber sale maps were used to update maps for cutting that took place after 1988. Stands ≥ 2 ha were classified.

All survey efforts were conducted between 1800 and 0700 hr. The night was partitioned into 6 periods (1800-1959, 2000-2159, 2200-2359, 0000-0159, 0200-0359, and 0400-0659 hr). I compared the number of responses from each species with the number of calling stations visited with no owls responding to see if differences in owl response rates occurred among periods.

Moon phase was divided into four 7-day periods, centered around the calendar dates for new moon, first quarter, full moon, and last quarter. I compared the number of responses from each species with the number of calling stations visited with no owls responding during the 4 moon phases to see if differences in owl response rates occurred among moon phases.

I conducted a "proximity assessment" to examine how frequently owl response locations from the two species were within 500 m of one another either during the same night, or on different nights during the survey period.

The survey effort required the use of snowmobiles (4,000 km), All Terrain Vehicles (ATVs) (1,600 km), and 4-wheel drive trucks (28,000 km). Fallen trees and branches were a significant problem on all but 1 route; chainsaws were used to minimally open survey routes to allow access. Snow depths (1-4 m) existed on all routes for the majority of the survey period; routes with snow intermixed with gravel stretches proved the most troublesome. Temperatures averaged 3° C during the survey effort, with nightly lows of -9° C being common.

Determination of the 500-ha Landscape Plot Size

Biological Considerations

My objective was to select a plot size that was large enough to adequately assess landscape features but small enough to allow detection of those features actively selected by the owls. What landscape features are important to owls? My best estimate of important landscape features was derived through a review of habitat use and owl prey studies (Table 1).

Spotted owls have shown a selection for old-forest habitats and prey found within them (Thomas et al. 1990). The scale at which spotted owls select old-forest habitat was examined by Ripple et al. (1991b), Meyer et al. (1992), and Carey et al. (1990). By comparing the proportion of mature and old-growth forest around 30 spotted owl nest sites with that found around 30 random sites and using 7 different plot sizes, Ripple et al. (1991b) found significantly greater amounts of old forest around nest sites for all plot sizes (260-3588 ha). Further, the relative amount (%) of old forest decreased almost linearly as plot size increased from 260 ha to 3588 ha, suggesting that spotted owls selected nest sites which were surrounded by the maximum amount of available old forest habitat.

Meyer et al. (1992) compared habitat data from landscapes surrounding 50 spotted owl nest sites with landscape data surrounding 50 random points in the Klamath, Western Cascades, and Coast Range provinces in Oregon. They found spotted owl nest landscapes to contain considerably more old-growth forest, larger average size of old-growth patches, and larger maximum size of old-growth patches for all plot

Table 1. Comparison of northern spotted owl and great horned owl life history attributes in the Pacific Northwest.

	Northern Spotted Owl	Great Horned Owl
Distribution	Northwestern California, western Oregon, western Washington, southwestern British Columbia (Thomas et al. 1990).	Throughout the Pacific Northwest (Johnsgard 1988).
Population Status	Declining, primarily due to logging of habitat; federally listed as threatened throughout its range in U.S. (Anderson et al. 1990).	Status unknown, but considered stable except in areas undergoing agricultural or urban development (Forsman and Bull 1989).
Habitat	Older, multilayered, multispecies coniferous forests containing large live and dead trees, heavy accumulations of logs on forest floor, considerable open space within and beneath the canopy; these attributes are usually found in old-growth forests (Thomas et al. 1990).	Extremely varied; deciduous and coniferous forest, riparian zones along valley-floor river systems, dry forested uplands, isolated groves and wooded coulees in prairie regions, open grasslands with rocky canyons, steep gullies and shade-giving trees (Voous 1988); up to at least 2290 m in Oregon.
Home Range Size	Median for 11 pairs in Oregon Cascades = 1193 ha (Thomas et al. 1990).	Home range for 1 female in N. WA Cascades = 1273 ha (based on 147 locations during 7.5 months of radio-tracking; T. Hamer pers. comm.).
Use of Edge Habitat[a]	Will forage up to non-old forest edge at night, but avoids a 100-m buffer from an edge during the day (Johnson et al. unpubl. data; see Appendix C).	No data; generally thought to forage and nest along edges.
Nest Sites	Tree cavities, platforms (e.g. mistletoe clumps), hawk nests (Forsman et al. 1984).	Old red-tailed hawk (<u>Buteo jamaicensis</u>), other hawk, corvid nests; platforms, tree cavities, rock crevices, occasionally on ground (Keebe 1958); see also Austing et al. 1966, Smith 1968, Gilmer et al. 1983.
Nesting	Average of 2 eggs laid 9 March - 19 April ($\bar{x}$ = 2 April); incubation 30 ± 2 days; young leave nest at 34-36 days old (Forsman et al. 1984).	Average of 2.7 eggs present from 26 January - 18 May ($\bar{x}$ = 10 March); incubation 34 ± 2 days; young leave nest at 35-50 days old. Egg dates are from museum egg set data for nests throughout Oregon (this study); a similar nesting timeframe was found by Hudson and Yocom (1954) and Foster (1973) for SE Washington.

Table 1. (continued)

Dispersal	Mean dispersal distance for 48 radio-marked juveniles in Oregon was 28 km during the first year (Miller 1989). Median dispersal distance for owls banded in Oregon as juveniles and later reobserved as members of pairs was 23.7 km for 41 females and 9.9 km for 40 males (D.H. Johnson unpubl. data).	No data for Pacific Northwest; for 128 recoveries of Saskatchewan-banded owls during their first year: 69 were recovered within 10 km of their nest site, 29 were recovered 11-250 km away, and 24 were recovered > 250 km away (Houston 1978).
Migration/Movements	Non-migratory; young owls often "float" for first 2 years; adults reside in defended territories.	Non-migratory; adults considered residents of defended territories (Miller 1930, Baumgartner 1939), movements may occur during times of prey scarcity (Adamcik and Keith 1978); see also Soper 1918, Munro 1928, Stewart 1969.
Diet	Analysis for Western Cascades (data represent % of 2243 samples): flying squirrel (Glaucomys sabrinus) 39.1%, woodrats 7.5%, red tree vole (Phenacomys longicaudus) and other voles 23.2%, deer mouse (Peromyscus maniculatus) 6.8%, lagomorphs and other mammals 17.4%, birds 3.6%, insects, reptiles, and unknown 2.5% (Forsman et al. 1984, Miller 1989, Meslow et al. 1990).	Analysis from a small amount of pellet material from Cascade forest habitats contained 5 snowshoe hare (Lepus americanus), 1 brush rabbit (Sylvilagus bachmani), 1 bushy-tailed woodrat (Neotoma cinerea), and 1 red tree vole (this study). The following analysis is based on prey remains from arid or low elevation (<300 m) zones excluding Cascade forest habitats (data represent % of 8702 samples): 14 sp. of small mammals (e.g. voles, mice) 85.85%, pocket gophers 4.62%, lagomorphs 1.72%, chipmunks, squirrels and rats 1.75%. 20 sp. of birds 2.74%, insects, reptiles and unknown 3.34% (Maser and Brodie 1966, Maser 1966, Brodie and Maser 1967, Maser et al. 1970, Foster 1973, Knight and Erickson 1977, Rudolph 1978, Knight and Jackman 1984).
Weight	577 gms ($\bar{x}$ for 12 males); 667 gms ($\bar{x}$ for 11 females) (D.H. Johnson unpubl. data).	1154 gms ($\bar{x}$ for 18 males); 1555 gms ($\bar{x}$ for 18 females) (data for B. v. occidentalis from Earhart and Johnson 1970).
Wing Loading[b]	0.307 ($\bar{x}$ for 12 males); 0.342 ($\bar{x}$ for 11 females) (D.H. Johnson unpubl. data).	0.500 ($\bar{x}$ for 2 females) (D.H. Johnson unpubl. data).
Longevity record for owl in wild:	14 yrs 6 mo (D.H. Johnson pers. obs.).	23 yrs 4 mo (US Fish and Wildlife Service Bird Banding Lab, pers. comm.).

[a] Edge habitat refers to a 100-m buffer along the periphery but within mature/old-growth forest stands.
[b] Wing loading is calculated using bird mass (gms) divided by area (cm^2) of both wings.

sizes examined (0.8, 1.6, 2.4, and 3.4 km radius circular plots) ($P < 0.01$).

Carey et al. (1990) compared the amount of old-growth within 9 spotted owl home ranges to that within 6 1,000-ha and 5 2,000-ha circular plots systematically located along 2 km transects in their Oregon Coast Range study areas. In all cases the amount of old growth in the individual home ranges was significantly greater than that observed in the circular plots ($P < 0.05$).

Spotted owls have also demonstrated an avoidance of edges. Johnson et al. (Appendix C) measured distance to edge at 1,159 telemetry and 650 random locations within 13 spotted owl territories, 51 spotted owl nest sites, and at 100 random points in the Central Oregon Cascades. Edge was defined as the junction of old stands (mature/old-growth) with young stands, or with non-habitat (reservoirs, lakes). The examination indicated that although spotted owls may forage adjacent to an edge during the night, they select areas ≥ 100 m into old forest stands from an edge for roosting and nesting.

Great horned owls are considered generalists with regards to habitat and prey selection, with the exception that they are not generally found (or have reduced productivity) in extensive closed-canopy forests (Voous 1988, Frounfelker 1977, Bosakowski 1989) and that lagomorphs are important prey in more northerly zones (Rusch et al. 1972, Adamcik et al. 1978, Houston 1987).

It has been demonstrated repeatedly that great horned owls and spotted owls show preferential use of various locations or habitat features within their home ranges (Errington 1938, Baumgartner 1939, Orians and Kuhlman 1956, Baker 1962, Maser and Brodie 1966, Frounfelker 1977, Petersen 1979, Thomas et al. 1990). I hypothesized that the owls actively select locations/habitats in the following (decreasing) order: (1) nest sites, (2) core areas (areas within 400 m of the nest site), (3) day roost sites, and (4) night foraging locations. Telemetry data from spotted owls in the Central Oregon Cascades suggested that the overall strength of habitat selection matches this order (Forsman et al. 1984, pers. obs.). It is important to note, however, that there is overlap among these features (e.g., owls located at night may be at their nest, day roosting can occur at core areas).

Home ranges for both owl species are large but not circular, and centering a large radius plot over owl locations can result in 1) a significant portion of the plot falling outside of the owls' actual home range, and importantly 2) use of large plots would likely mask any selection effects shown by the owls (i.e., one could not detect differences between owl and random sites if they did exist). This reasoning raises cautions about the use of large plots for the assessment of owl habitat selection.

Technical Considerations

Three technical considerations involved in landscape assessment are resolution, plot size, and sample size. Resolution reflects the fineness or coarseness (i.e., "grain size") of the landscape features being assessed; in this study stands were delineated down to 2 ha (5 ac). Depending on the variability of the habitat/landscape features involved, plot sizes and sample sizes can be small or large. Larger plots inherently capture more of the variability due to the area involved, as do larger sample sizes. To address these issues I felt it preferable to first examine the general landscape using different sized circular plots around random points, and thereafter evaluate owl and other landscapes. I first examined the amount of old forest within 6 plot sizes (51, 150, 260, 440, 620, and 800 ha) centered on 60 random points (Figure 2). Because of within-plot variability, the 51 and 150 ha plots did not accurately reflect the stabilized mean of old forest until a large (120+) sample size was employed. Plot sizes of 260 ha and larger consistently reflected the area of old forest with a sample size of 60 (Figure 2). Thus, with a reasonable sample size (60), a plot size between 260-800 ha adequately assessed the area of old forest within the general landscape.

I determined a range of plot sizes based solely on the amount of old forest (the landscape feature most strongly selected by spotted owls (see review by Thomas et al. 1990)); other habitats such as closed-pole, open-pole, shrub/forb, etc. need to be considered in some fashion. A plot size that adequately describes the old forest variable may or may not adequately assess other landscape variables of interest. The variability in other habitat measures (shelterwood, closed-pole, open-pole, sapling, shrub/forb, nonhabitat, edge, perimeter, interior, elevation, and edge-to-area of old forest ratio (EA); see Table 2) was examined using data from 500-ha landscape plots surrounding 70 random points. Shelterwood, open-pole, and nonhabitat require either very large sample sizes (n >200) or larger plot sizes (>500-ha), or both, to capture the inherent variability of these features in the landscape.

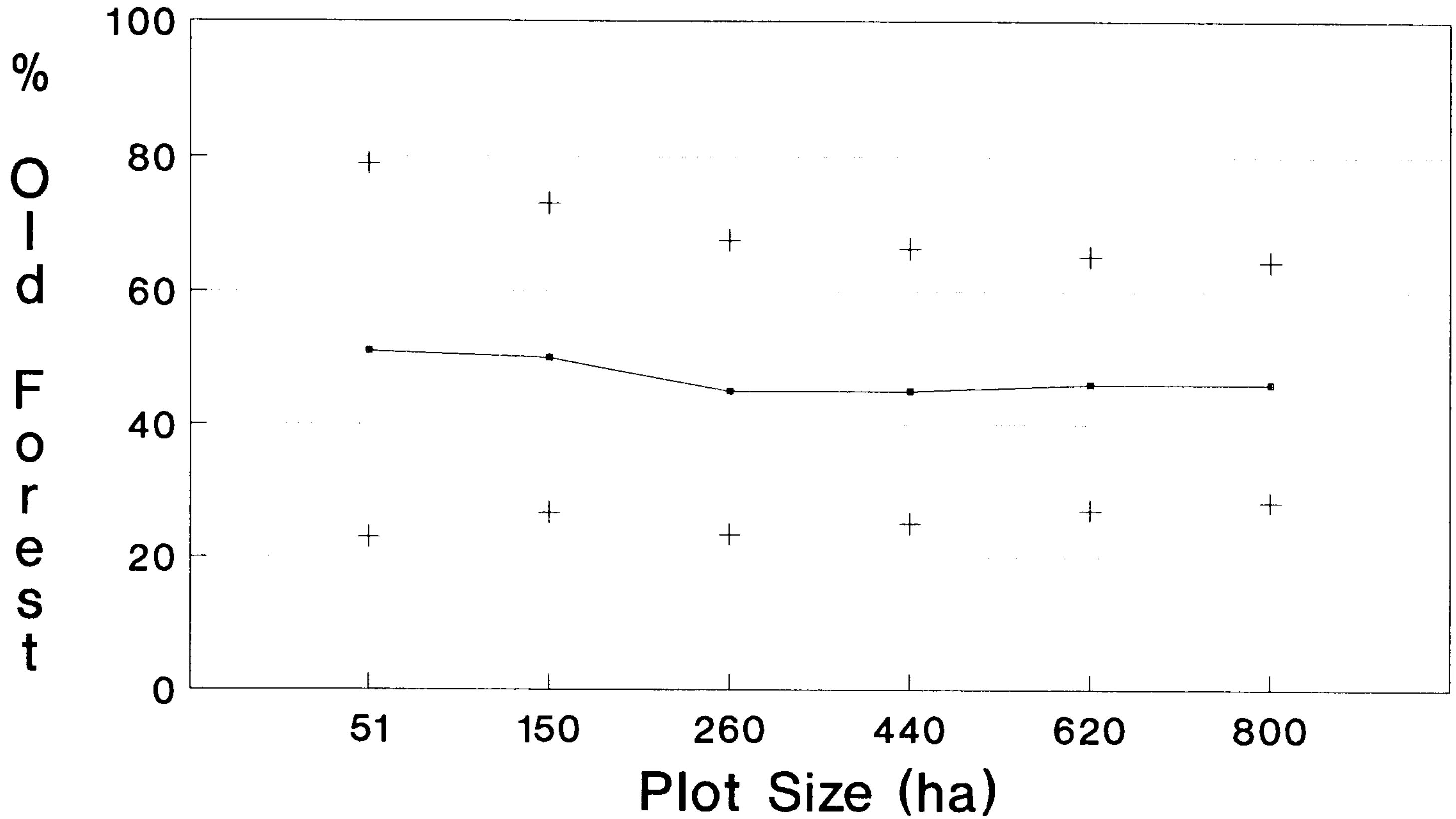


Figure 2. Mean percent (line) and standard deviation (+) of old forest within 6 plot sizes surrounding 60 random points in the Central Oregon Cascades; assessment using 1990 habitat conditions.

Table 2. Landscape variables measured within 500-ha circular plots centered on great horned owl, spotted owl, no-owl, and random locations.

Variable	Description
OLD	ha of mature/old-growth forest: composed of trees > 53 cm (21") DBH, > 30.5 m (100′) tall. Old-growth characterized by dominant overstory > 200 yrs old, with a multi-layered, multi-species canopy, moderate to high canopy closure, and large numbers of snags and downed logs (Kuiper 1988, Thomas et al. 1990). Mature stands characterized by smaller average diameter, less age class variation, and less structural complexity than old-growth.
SHELTERWOOD	ha of stands reflecting previous partial harvest, typically designed under a shelterwood regeneration system. Overstory trees: 25-50 trees/ha (10-20 trees/ac), > 53 cm DBH, 25-40% canopy cover, generally > 80 yrs old. Understory trees (if present) generally < 9.1 m tall.
OPEN-POLE	ha of open-pole stands: 10-51 cm (4-20") DBH, > 9.1 m (30′) tall, < 60% canopy cover.
CLOSED-POLE	ha of closed-pole stands: 10-51 cm (4-20") DBH, > 9.1 m (30′) tall, > 60% canopy cover.
SAPLING	ha of sapling stands: 2.5-10 cm (1-4") DBH, 1.5-9.1 m (5-30′) tall, < 60% canopy cover.
SHRUB/FORB	ha of shrub/forb stands: areas dominated by forbs, grass, or shrubs < 3 m (10′) tall, trees < 40% canopy cover; typically are stands 1-10 years after logging.
NONHABITAT	ha of non-habitat areas including water, lava flows, rock outcrops, gravel pits, and residential areas.
PERIMETER	perimeter of mature/old-growth stands measured in linear kilometers.
EDGE	ha of old forest within 100-m of the perimeter interior to a mature/old-growth stand.
INTERIOR	ha of interior mature/old-growth; INT = OLD - EDGE.
EA	edge-to-area ratio for OLD forest; EA = PERIMETER ÷ OLD.
DISCORE	the dispersion score, a relative measure of how "clumped" or "dispersed" old forest stands are distributed within plots; scores are compared to those developed from simulated landscapes reflecting minimum and maximum fragmentation (see text).
ELEVATION	elevation above mean sea level.

If one is concerned about revealing selection differences between species, and if night locations are used exclusively (as in this study), less strongly selected features will be more difficult to detect. In light of the above, a 500-ha plot was chosen because it represented a biologically meaningful as well as logistically feasible plot size.

Landscape Assessment

The landscape assessment focused on 3 main characteristics: the ***amount***, ***shape***, and ***spatial distribution*** of features found within 500-ha circular plots. Thirteen habitat/landscape variables were measured (Table 2). Plots were centered on owl response locations (77 great horned owls, 103 spotted owls), 70 random points, and 70 calling stations where no spotted or great horned owls were heard within 0.8 km (no-owl points).

Amount

The ***amount*** of mature/old-growth (old) (Table 2), shelterwood, open-pole, closed-pole, sapling, shrub/forb, and non-habitat within the 500-ha plots was determined using a dot grid (150-m spacing) on the updated orthophoto quadrangles (Avery 1977:76-77). Records of the managing agency, 1:24,000 aerial photos, and field checks were used to resolve questions of forest classifications. Edge refers to the area of old forest within a 100-m strip on the periphery but within a mature/old-growth stand (Table 2). The area of edge was determined using a dot grid with 100-m spacing. The choice of a 100-m edge was based on analysis of 1,159 telemetry locations for 13 spotted owls and distance-to-edge measurements for 51 spotted owl nests (see Appendix C). The area of forest interior was derived by subtracting the area of edge from the area of old forest and reflects forest interior only within mature/old-growth forest habitat.

Shape

The ***shape*** of old forest stands was assessed by determining the perimeter (linear km of edge) surrounding old forest stands and by calculating the edge-to-area of old forest ratio (EA): dividing the perimeter by ha of old forest (Table 2). Perimeter was determined using a map measuring wheel.

Spatial Distribution - Overview

Forest fragmentation is the process of conversion of large blocks of old (mature and old-growth) forest into a mosaic of young plantations and nonforest. Forest fragmentation leaves the remaining old forest in stands of varying size and degrees of isolation (Burgess and Sharpe 1981, Harris 1984, Ripple et al. 1991a, Lehmkuhl and Ruggiero 1991, Lehmkuhl et al. 1991). Measuring forest fragmentation requires that the spatial character of habitats as well as changes in ecological processes within the landscape be quantified. Numerous methods and indices for quantifying the spatial pattern of habitats have been proposed (e.g., Patton 1975, Forman and Godron 1986, Milne 1988, O'Neill et al. 1988, Turner 1989, Ripple 1991a, Turner and Gardner 1991). Current methods and indices have described landscape patterns with varying degrees of success. Some landscape indices (i.e., contagion and dominance) are unable to distinguish variations in synthetic landscapes with distinct patterns (Li 1989). Other measures (e.g., patch size and density, shape, edge/area ratio) can change significantly with increasing plot size (Lord and Norton 1990). Many indices require a geographic information system (GIS) for analysis.

I surveyed owls across the range of forest fragmentation levels (0-100% old forest) present in the Central Cascades landscape. In order to adequately address the spatial distribution of old forest stands, I was interested in a measure that was sensitive to the *amount*, *shape*, and *spatial distribution* of old forest, *that did not suffer constraints caused by plot size*, and indicated if the old forest in a particular landscape was fragmented *as well as indicating the degree to which it was fragmented*. A GIS was not available to assist in the landscape analysis process. This necessitated the creation of a new landscape measure; this measure was the dispersion score (DISCORE). The dispersion score (DISCORE) reflected the degree to which old forest stands within real landscapes were "clumped" (minimum fragmentation) or "dispersed" (maximum fragmentation). Several steps were involved in the derivation of DISCORE: 1) creation of simulated landscapes, 2) acquiring a plot score for each landscape, 3) determining midpoint values for all increments of old forest (0-100%), and 4) from the plot score and midpoint value determine a landscapes' DISCORE.

Spatial Distribution - Simulated Landscapes

I developed simulated landscapes by placing 16-ha square patches (the mean patch size encountered in the study area, Ripple et al.

1991a), or portions of 16-ha patches, in dispersed and clumped patterns, representing 0, 1, 5, 10, 20, 25, 35, 50, 65, 75, 80, 90, 95, 99, and 100% old forest levels. Figures 3, 4, and 5 are examples of simulated landscapes at the 50%, 35%, and 10% old forest levels.

An acetate overlay with 19 evenly spaced dots in a 500-ha circular plot (Figure 6) was oriented randomly over the simulated landscapes and the distance from each dot to the nearest old/non-old forest edge was measured to the nearest 10 m. If a dot fell in an old forest patch, the resulting distance-to-edge measurement was recorded as a positive number, if a dot fell in a non-old forest patch the measurement was recorded as a negative number. If no edge existed in the 500-ha plot, the distance to the farthest location on the perimeter of the plot was recorded for each dot. The mean and the standard deviation (SD) of measurements from the 19 dots were then calculated for each plot. If the amount of old forest in the plot was ≥ 50% the SD was added to the mean; if the amount of old forest was < 50% the SD was subtracted from the mean. The resultant value established the plot score. Dispersed landscapes contained many short dot-to-edge measurements and consequently small SD's; clumped landscapes contained short as well as long dot-to-edge measurements resulting in larger SD's (see examples in Figures 3, 4, and 5). Plot scores from the simulated landscapes thus established the range of maximum and minimum plot scores one could expect from real landscapes across the array of fragmentation levels. The plot scores from the array of simulated landscapes are shown in Appendix D.

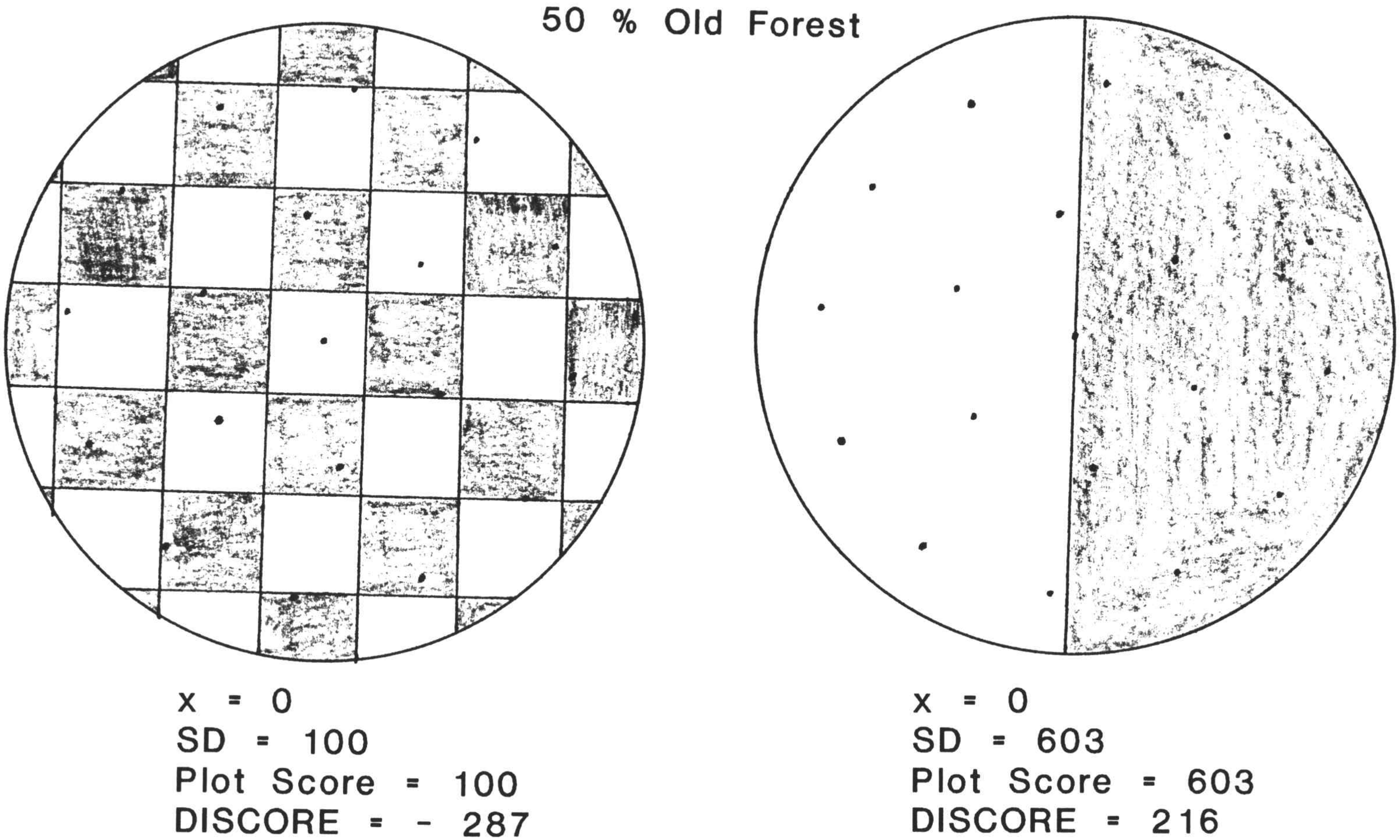
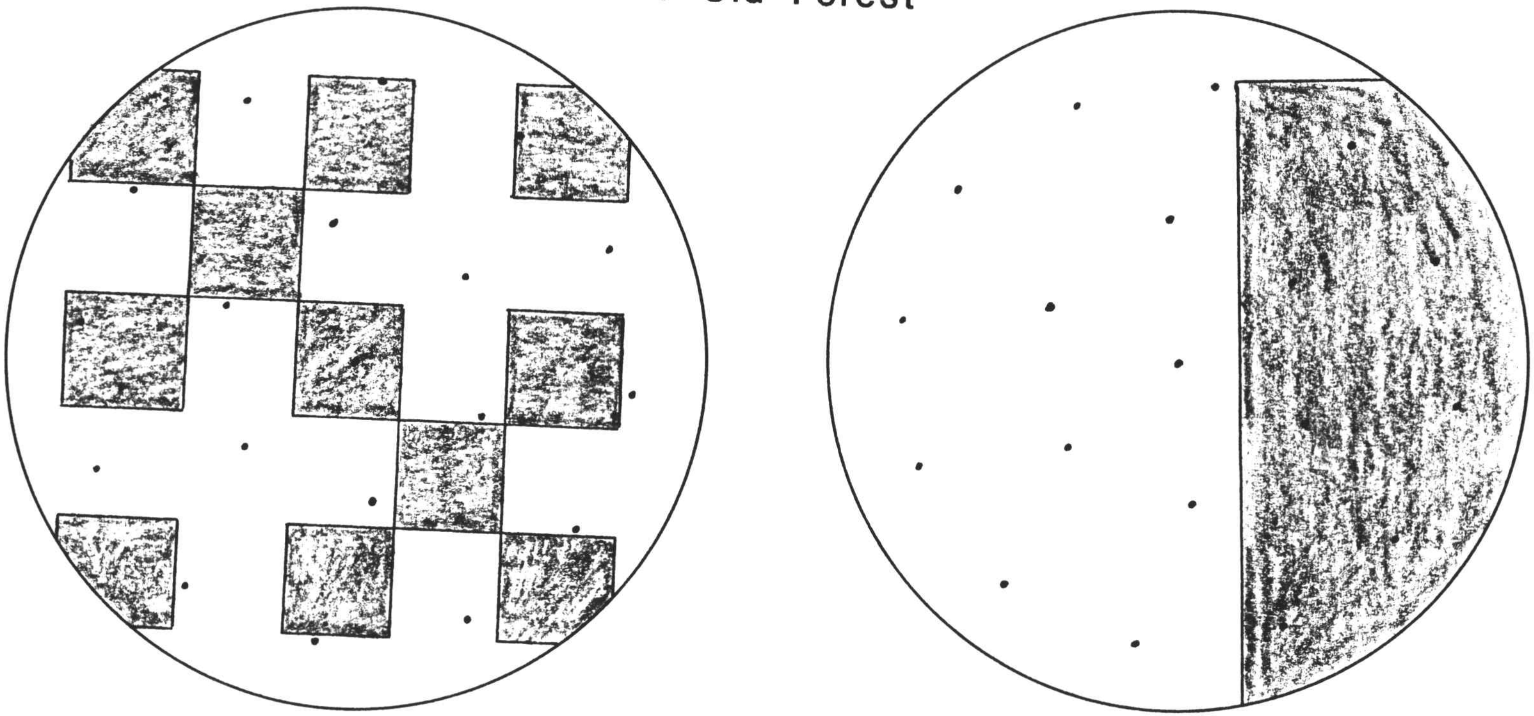


Figure 3. Mean, standard deviation, plot score, and DISCORE for simulated landscapes representing maximum and minimum fragmentation, 50% old forest level.

35 % Old Forest



x = - 59
SD = 109
Plot Score = - 168
DISCORE = - 290

x = - 251
SD = 524
Plot Score = - 775
DISCORE = 317

Figure 4. Mean, standard deviation, plot score, and DISCORE for simulated landscapes representing maximum and minimum fragmentation, 35% old forest level.

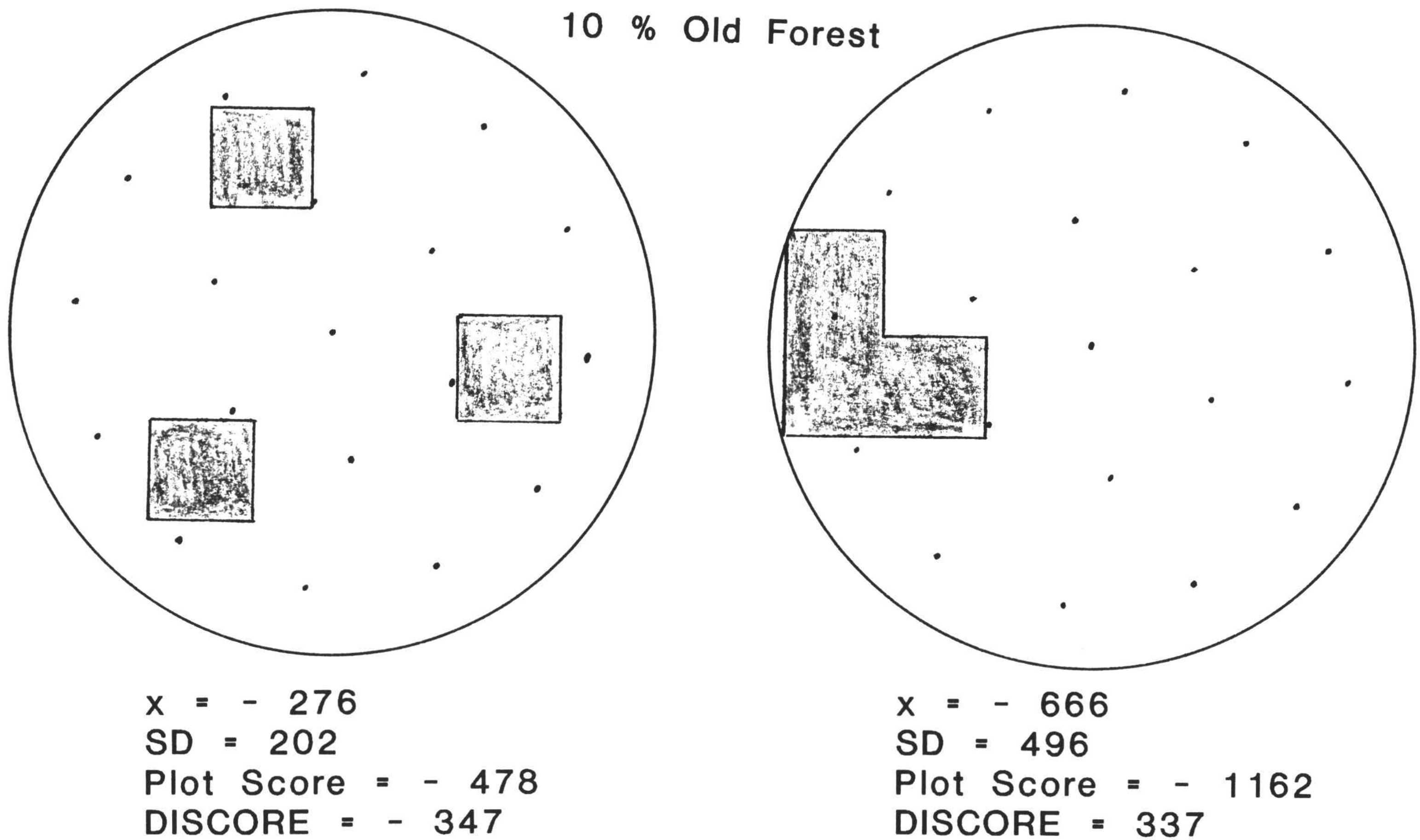


Figure 5. Mean, standard deviation, plot score, and DISCORE for simulated landscapes representing maximum and minimum fragmentation, 10% old forest level.

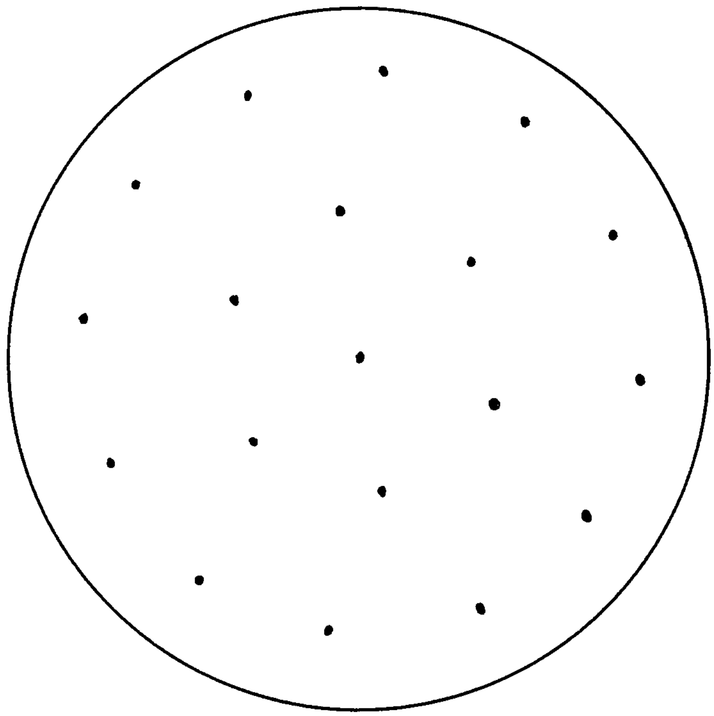


Figure 6. A 500-ha circular plot with 19 evenly spaced dots used in determining the spatial distribution of old forest stands; the distance from each dot to the nearest old/non-old forest edge is measured to the nearest 10 m.

The reason that the SD's were added to plots with ≥ 50% old forest and subtracted from plots with < 50% old forest is because the 50% level represents a fragmentation threshold (Franklin and Forman 1987). In landscapes containing ≥ 50% old forest, the old forest is the matrix and patches of young forest are imbedded in it. In landscapes containing < 50% old forest the young stands are the matrix and the old forest are the patches. The 50% old forest level is the threshold at which one goes from a matrix of old forest to a matrix of young forest (Franklin and Forman 1987). In a sense, simulated landscapes with opposing amounts of old forest (for example landscapes with 20% and 80% old forest), are mirror images of one another; measurements derived from simulated landscapes in the DISCORE analysis reflect this (Appendix D).

Midpoint values between the minimum and maximum scores from the simulated landscapes were then determined (from the dispersed and clumped landscapes respectively) for the 0, 1, 5, 10, 20, 25, 35, 50, 65, 75, 80, 90, 95, 99, and 100% old forest levels. A regression equation was calculated for the midpoint values based on the array of old forest percentages from 50-100%. Midpoint values for intervening old forest levels were interpolated (Appendix D). Midpoint values for old forest levels below 50% reflected those above 50% with the exception that they had minus values (Appendix D).

The DISCORE for each simulated landscape was then determined by subtracting the midpoint value (from the simulated landscapes with corresponding % old forest) from the landscapes' plot score. This established the range of maximum and minimum DISCOREs of real landscapes for all fragmentation levels (Figure 7). Positive DISCOREs from the simulated landscapes establish the upper boundary and indicate maximum "clumping" of old forest; likewise, negative DISCOREs establish the lower boundary and indicate maximum "dispersed" old forest (Figure 7).

Spatial Distribution - Real Landscapes

Prior to beginning the DISCORE analysis the percent of old forest within real landscapes was determined using a dot grid (150-m spacing). As with simulated landscapes, the process of measurements using the acetate overlay was then followed and plot scores were determined for each of the real landscapes. Using the corresponding % old forest, midpoint values (from the simulated landscapes) were then subtracted from the real landscape plot scores; the resultant values were the DISCOREs for each real landscape. The DISCORE indicates the degree to which old forest within owl, no-owl, or random landscapes was dispersed (negative values) or clumped (positive values).

In summary, the following steps were involved in determining the spatial distribution of old forest stands:

1) create simulated landscapes reflecting minimum and maximum fragmentation using 16-ha patches for 0, 1, 5, 10, 20, 25, 35, 50, 65, 75, 80, 90, 95, 99, and 100% old forest levels; only 2 categories are recognized within a landscape: either old forest or non-old forest;

2) record distance to old forest/non-old forest edge measurements from each of the 19 dots within the 500-ha plots; calculate means and SD's;

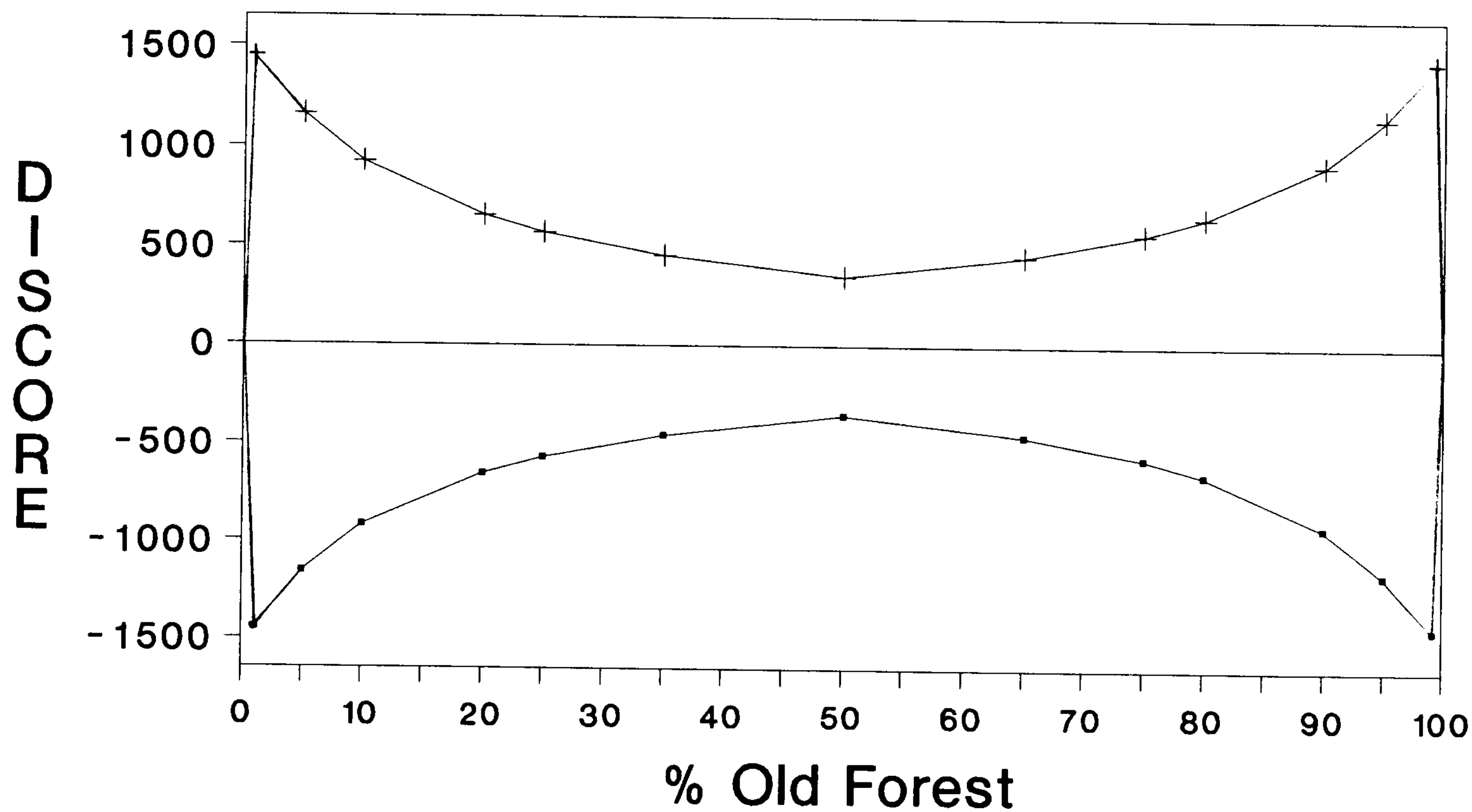


Figure 7. The range of positive and negative DISCOREs one could expect from real landscapes for all levels of old forest. Derived from simulated landscapes, positive DISCOREs (upper region) indicate old forest arranged in a "clumped" fashion; negative DISCOREs (lower region) indicate old forest arranged in a "dispersed" fashion.

3) if plot has $\geq$ 50% old forest add SD to mean; if < 50% old forest subtract SD from mean; retain this plot score;

4) from the simulated landscapes determine midpoint values for the 0, 1, 5, 10, 20, 25, 35, 50, 65, 75, 80, 90, 95, 99, and 100% old forest levels; enter values into regression equation and derive the midpoint values for all fragmentation levels;

5) acquire plot scores for real landscapes (i.e., owl, no-owl, random) landscapes using steps 2 and 3 above;

6) using the % old forest value for each of the real landscapes, locate the respective midpoint value (derived from the simulated landscapes);

7) subtract respective midpoint values from real landscape plot scores and record residual values; these are DISCORE values for the real landscapes;

8) plot DISCOREs; the degree to which landscapes are clumped or dispersed appear above or below the zero (0) line, respectively (see Figure 15 for example).

Selection of Owl, No-Owl, and Random Locations

Owl locations were selected from the dataset using the following criteria (note: all sites are nighttime locations of calling owls; no nest sites or daytime roost locations were used in this study):

1) only 1 location for each owl was used;

2) only owls with identified response locations were considered;

3) owl locations were stratified and further selected with "a" locations preferred over "b" locations, "b" over "c," and so on:

a. site with unsolicited calling by owl

b. site with owl pairs (in this case the habitat data for that site was entered twice)

c. site with repeat owl locations (same owl, same site, on different nights)

d. first site for an owl during the night (some owls were heard more than once during the same night at different locations)

e. only site for that owl during the project

There was concern that by using the broadcast calling technique owls could be drawn into areas they would not otherwise be found and thereby bias the subsequent landscape assessment effort. A test of the calling technique was undertaken by Laymon (1988) using 8 radio-marked spotted owls. After locating a radio-marked owl a 10 min calling period was conducted, after which the owls' location was again acquired. On 217 of 240 (90%) occasions the owls did not move. Owls moved closer 6% of the time and moved farther away 3% of the time. No test of this type has yet been conducted on radio-marked great horned owls.

The 70 "no-owl" locations reflected those calling stations from which no spotted owls or great horned owls were heard within 0.8 km (0.5 mi). No-owl locations were at least 1.6 km from identified owl locations. No-owl locations were at least 1.6 km from one another, and most often were > 4 km apart.

All random points were located on USFS land designated as "general forest," and none were in wilderness areas, roadless areas, research natural areas, lava flows, or water. Importantly, although random points were on USFS lands, the landscape plots centered on these points often included portions of wilderness, roadless, research natural areas, lava flows or water, as well as private or BLM land.

Sample sizes for all landscape analysis were as follows: 77 individual great horned owls (51 male, 26 female), 103 individual spotted owls (65 male, 38 female), 70 no-owl points, and 70 random points.

Elevation was determined from contour lines on USFS district maps (contour lines at 24.4 m (80′) intervals, map scale 1:63,360). To identify if any elevational "thresholds" existed for each of (or between) the owl species, elevations at great horned owl and spotted owl response locations were compared to elevations of the 469 calling stations, and to each other. In a separate evaluation, regression analysis was used to examine if significant changes or general trends in the habitat/landscape variables occurred with increasing elevation. For this evaluation, I regressed the habitat/landscape variables individually against elevation using data from plots surrounding the 70 random points.

Statistical Analysis

Chi-square analysis was used to assess differences in owl response rates during the season, during the night, and during moon phases.

Each of the 13 landscape variables around great horned owls, spotted owls, no-owl, and random points were compared simultaneously using Tukey's Studentized Range (HSD) Test. All tests were 2-tailed and had significance levels set at $\alpha = 0.05$. Data used in analysis for variables old, perimeter, edge, EA, elevation, and nonhabitat (Table 2) were not transformed as the assumption of normality was met. To meet assumptions of normality, square root transformations were made on variables closed-pole, sapling, shrub/forb, interior, and DISCORE. Log transformations were made on shelterwood and open-pole. The variable nonhabitat did not meet the assumption of normality and was not aided by transformations.

RESULTS

Nocturnal Survey

A total of 662 responses was recorded from 8 species of owls during 124 nights of calling during 2 field seasons. There were 193 responses from 95 individual great horned owls and 294 responses from 161 individual spotted owls (Table 3). Responses from the 6 other owl species are shown in Table 4.

A total of 341.3 hr was spent in survey effort (excludes all travel time). Responses per 60 survey minutes were 0.626 and 1.358 for great horned owls and spotted owls, respectively (Table 5). Survey distance was 375.2 linear km (234.5 mi); relative abundance for great horned owls was 0.099 owls/linear km; spotted owl relative abundance was about twice as great: 0.199 birds/linear km (Table 5). Survey distance also was measured in road distance: 535.7 road km (334.8 road mi) with relative abundance for great horned owls and spotted owls at 0.069 and 0.139 birds/road km, respectively. Linear distance and road distance differ in that linear distance is the straight-line map distance between calling stations and road distance is the surface distance between stations and may or may not be linear due to curves and gradient in the road proper.

Great horned owls typically responded with a 5- or 6-note call. This call was given at ≈ 20-second intervals and was considered to be their standard contact call. Variations among individual owls were recognizable. At times both members of a great horned owl pair were involved in courtship vocalizations. In these instances the female

Table 3. Number of calling stations, individual owls, and owl responses by landowner, Central Oregon Cascades, 1989 and 1990.

Landowner	survey stations	Great Horned Owl indiv.	Great Horned Owl resp.	Spotted Owl indiv.	Spotted Owl resp.
USFS, Blue River District	109	15	30	29	45
USFS, Lowell District	130	27	58	64	132
USFS, McKenzie District	95	24	51	22	40
USFS, Sweet Home District	67	15	27	31	59
BLM	8	2	2	4	5
Private	60	12	25	11	13
Total	469	95	193	161	294

Table 4. Number of individuals of other owl species by landowner, Central Oregon Cascades, 1989 and 1990.

Landowner	survey stations	Barred	Saw-whet	Western Screech	Great Gray	Long-eared	Northern Pygmy
USFS, Blue River District	109	3	20	5	0	0	0
USFS, Lowell District	130	6	48	6	0	0	8
USFS, McKenzie District	95	3	14	2	2	2	1
USFS, Sweet Home District	67	1	4	0	0	0	0
BLM	8	2	6	0	0	0	0
Private	60	1	10	4	0	0	0
Total	469	16	102	17	2	2	9

Table 5. Great horned owl and spotted owl responses by station, time, and distance, Central Oregon Cascades, 1989 and 1990.

	Great Horned Owl	Spotted Owl
n[a]	111	223
responses/calling station	0.079	0.158
responses/60 minutes	0.626	1.358
responses/linear km	0.099	0.199
responses/linear mile	0.158	0.317
responses/road km	0.069	0.139
responses/road mile	0.111	0.222

[a] total responses recorded; an individual owl could be counted up to 3 times if it responded during each of the three targeted survey passes.

tended to initiate the vocal calling bouts, with the pattern of calling bouts following that described by Emlen (1973) (see also Baumgartner 1938). Spotted owls responded with the 4-note contact call, agitated calls, and the long-distance contact bark (in the case of females) (Forsman et al. 1984).

Measured as the straight-line distance between observer and the owls' triangulation location, mean distance to located owls was 315 m for great horned owls and 336 m for spotted owls (ranges: 5-1200 and 20-1000 m, respectively).

Of 155 identified great horned owl locations, 147 (94.8%) were < 100 m from an edge (typically the edge between old forest and shrub/forb or sapling stand); 6 (3.9%) owl locations were 100-200 m from an edge, and 2 (1.3%) owl locations were 200-300 m from and edge. When giving unsolicited or solicited calls, great horned owls consistently perched either at or very near the top of the forest canopy in the tallest vegetation available.

On 53 occasions during the survey effort great horned owls were detected moving (100-1000+ m) across the landscape. Movements were quite rapid, and based on visual observations or elapsed time and distance between vocalizations indicated that in all cases the owls were flying over the forest canopy. Cottam et al. (1942) recorded great horned owl flight speed at 64 kph. Movements made by 4 male great horned owls indicated territory sizes similar to that of spotted owls. In these instances, owls followed the observer from station to station (up to 7 stations) across their territories during survey visits.

Owl Response Rates During the Season

Great horned owls responded differentially through time, with significantly fewer responses in January and April than expected (x^2 = 17.4, 3 df, $P < 0.001$). Great horned owl response rates were not different than expected during February or March.

An examination of 96 great horned owl nest record cards for Oregon (statewide) indicated the mean date for clutches was 10 March (SD = 22 days, range 26 January - 18 May). The dates do not necessarily represent nest initiation but rather are simply dates of visits to nests containing clutches. Great horned owls began courtship activities in the Willamette Valley (≈ 75 m above mean sea level) in January (pers. obs.). However, survey efforts indicated that great horned owls began similar activities in the adjacent (but higher in elevation) Cascades study area in early-February, and ended in early-April.

Spotted owl response rates also were different than expected during their March-May survey period (x^2 = 5.76, 3 df, $P = 0.05$), with a generally higher response rate in May. There has been concern as to how early in the year surveys for spotted owls can begin. Results indicated that spotted owl response rates were not different between the periods of 15-31 March and 1-15 April (x^2 = 0.95, 1 df, $P = 0.33$), suggesting that surveys for spotted owls in the Central Oregon Cascades can begin as early as 15 March. Forsman (1983) indicated that spotted owls can effectively be surveyed until September.

Owl Response Rates During the Night

The night was partitioned into 6 periods between 1800 and 0700 hr. Great horned owls responded significantly less than expected between 2200-2359 hr, somewhat more than expected between 0200-0359 hr, and not different than expected for the remaining periods (x^2 = 12.76, 5 df, P = 0.026). In general, great horned owls called less before midnight and more after midnight, a finding that is consistent with that reported by Morrell et al. (1991) for great horned owls in Pennsylvania. Spotted owls responded significantly more than expected between 1800-1959 hr, somewhat less than expected between 2000-2159 hr, and not different than expected for the remaining periods (x^2 = 11.92, 5 df, P = 0.036).

Owl Response Rates by Moon Phase

I compared the number of owl responses from each species with the number of calling stations visited with no owls responding during the 4 moon phases (Table 6). Spotted owl response rates were greater than expected during full moon phases (x^2 = 6.668, 1 df, $P < 0.01$). Great horned owl response rates were less than expected during full moon phases (x^2 = 11.48, 1 df, $P < 0.001$) and greater than expected during new moon phases (x^2 = 9.659, 1 df, P = 0.002).

The finding that response rates varied with moon phase for spotted owls is in contrast to findings of Franklin et al. (1986) and Laymon (1988) in California where spotted owl response rates during the 4 moon phases were not significantly different. As in my study, their results were also based on responses to broadcast owl calls. My results also contrast with those of Ganey (1990) who found that Mexican spotted owls

Table 6. Spotted owl and great horned owl response rates by moon phase during the mid-January through mid-May survey period, 1989 and 1990, Central Oregon Cascades.

Moon Phase	Number of Spotted Owl Responses	No Spotted Owl Responding[a]	Total Spotted	Number of Great Horned Owl Responses	No Great Horned Owl Responding[a]	Total Great Horned
New	55	292	347	54[c]**	263	317
1st Quarter	66	292	358	20[c]	198	218
Full	89[b]**	297	386	35[c]***	416	451
Last Quarter	53	263	316	60[c]	358	418
Totals	263	1144	1407	169	1235	1404

[a] Number of stations from which owl calls were broadcast but no owl responses were recorded; any particular station could recieve from 1-3 visits for each species.

[b] Spotted owls responded significantly more than expected during full moon phases ($x^2 = 7.465$, 1 df, $P = 0.05$).

[c] Great horned owls responded significantly more than expected during new moon phases ($x^2 = 9.659$, 1 df, $P = 0.002$) and significantly less than expected during full moon phases ($x^2 = 11.48$, 1 df, $P < 0.001$).

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

(*S. o. lucida*) in Arizona called significantly more than expected during last quarter and new moon phases. A potential explanation for the contrasting study results may be that Ganey did not solicit owl responses.

Owl Responses to Broadcast Calls of the Other Species

Forty-four (44) spotted owl responses were noted when great horned owls calls were broadcast, representing a response rate of 3.1% (vs a response rate of 15.8% from spotted owls when spotted owl calls were broadcast). These responses came from 35 individual spotted owls. When a spotted owl responded to a great horned owl call it was always strong, brief and distant. Usually, only 2 or 3 calls were given, with male spotted owls giving an aggressive 4-note call and females giving a long-distant contact bark. The estimated average distance to a responding spotted owl was 575 m, with the nearest spotted owl at 300 m from the observer.

Twenty-six (26) great horned owl responses were recorded when spotted owl calls were being broadcast, for a response rate of 1.9% (vs a response rate of 7.9% from great horned owls when great horned owl calls were broadcast). These responses came from 23 individual great horned owls. In this situation, the call given by great horned owls was their standard contact call. There were no discernable differences in the pattern, intensity, or length of this call when compared to the response made when a great horned owl call was being broadcast. The average distance to a responding great horned owl was 450 m, with the nearest owl at 100 m from the observer.

As survey efforts were directed at both owl species using the same calling stations, an assessment of the number of great horned owls present in the landscape, but not responding to spotted owl calls can be made. A word of caution here: this assessment reflects the very wide range of habitat conditions present within the study area and assumes that all the owls were present in the landscapes throughout the survey period. In general, for every great horned owl responding during survey efforts directed at spotted owls, there were 3-4 additional non-responding great horned owls present in the landscape.

Proximity of Great Horned Owl and Spotted Owl Response Locations

How often were great horned owls and spotted owls in close proximity (within 500 m) of one another, either during the same night or during the course of the survey period? The 500 m distance is approximately the owls' mean response distance to tape broadcast of the other species' calls (see "Owl Responses to Broadcast Calls of the Other Species"). Responses from both owl species were recorded on 26 of the 28 survey routes. The remaining 2 survey routes were the shortest (having 6 and 8 calling stations) and had only spotted owls responding along them. From the 26 routes with both owls, there were 475 responses from the 2 species (282 responses from spotted owls and 193 responses from great horned owls). On 5 occasions both owl species were recorded within 500 m of one another *during the same night*. In these situations, 1 or 2 members from both of the owl species (e.g., a pair of spotted owls and a male great horned owl) vocalized, typically within a few minutes of one another. This situation involved 16 owl responses, or

3.4% (16 ÷ 475) of the owl responses. On 14 occasions both owl species were recorded within 500 m of one another *on different nights* (responses were weeks or months apart). In this situation for example, a great horned owl was recorded on 4 February and a spotted owl was recorded within 500 m of the great horned owls' location on 7 April. This situation involved 39 responses, or 8.2% (39 ÷ 475) of the owl responses. Thus, for survey routes having responses from both owl species, 11.6% of the responses from the two species during the course of the study were within 500 m of one another.

Observations of Great Horned Owl and Spotted Owl Interactions

On only 5 occasions (3.4% of the responses) were the two owl species within 500 m of one another during the same night. Details of these observations are given in Appendix E. These few interactions suggest an avoidance behavior by the owls; clearly, as a key predator on spotted owls, it is beneficial for spotted owls to avoid great horned owls. Also, there is a risk of injury to great horned owls in a predation attempt on spotted owls.

Landscape Assessment

Comparison of Owl, No-Owl, and Random Landscapes

The 500-ha landscapes surrounding great horned owl and spotted owl response sites differed significantly for 6 variables (old, shrub/forb, interior, EA, shelterwood, and elevation) ($P < 0.05$) (Figures 8, 9, 10, 11, 12, and 13). Great horned owl landscapes contained more shrub/forb and shelterwood, less old and interior, had a higher edge-to-old forest

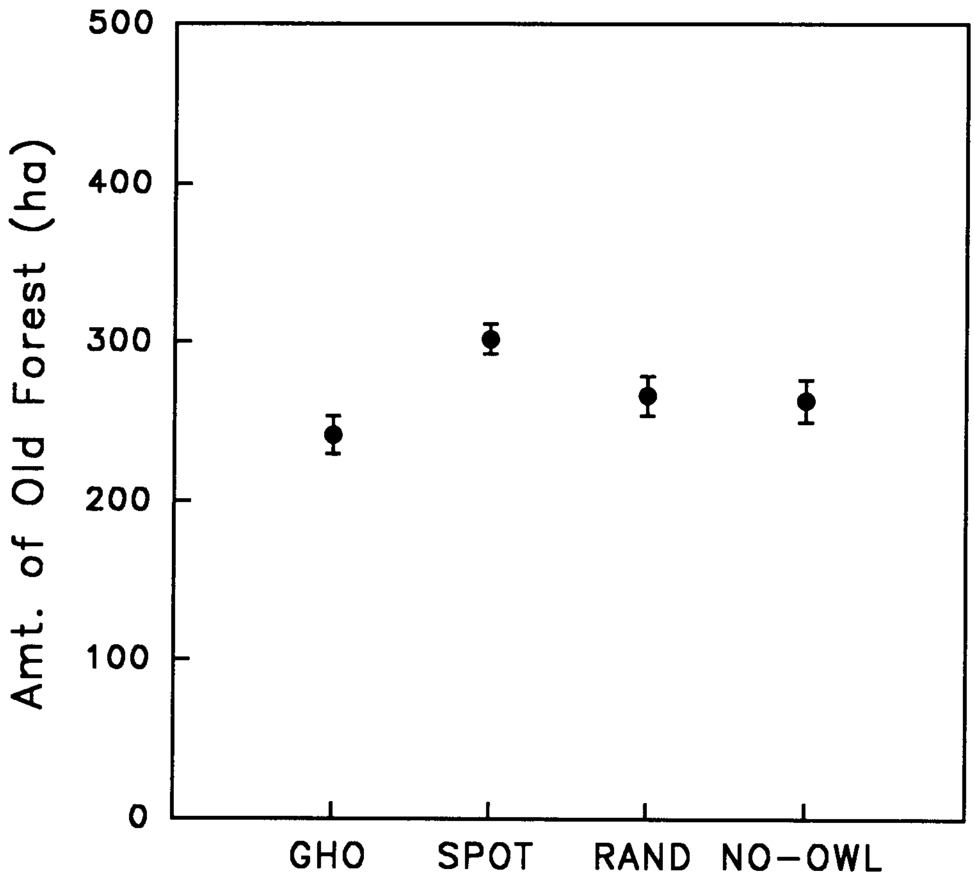


Figure 8. Result of comparisons between great horned owl, spotted owl, random, and no-owl landscapes for the amount of old forest within the 500-ha circular plots. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Shown are mean and standard error.

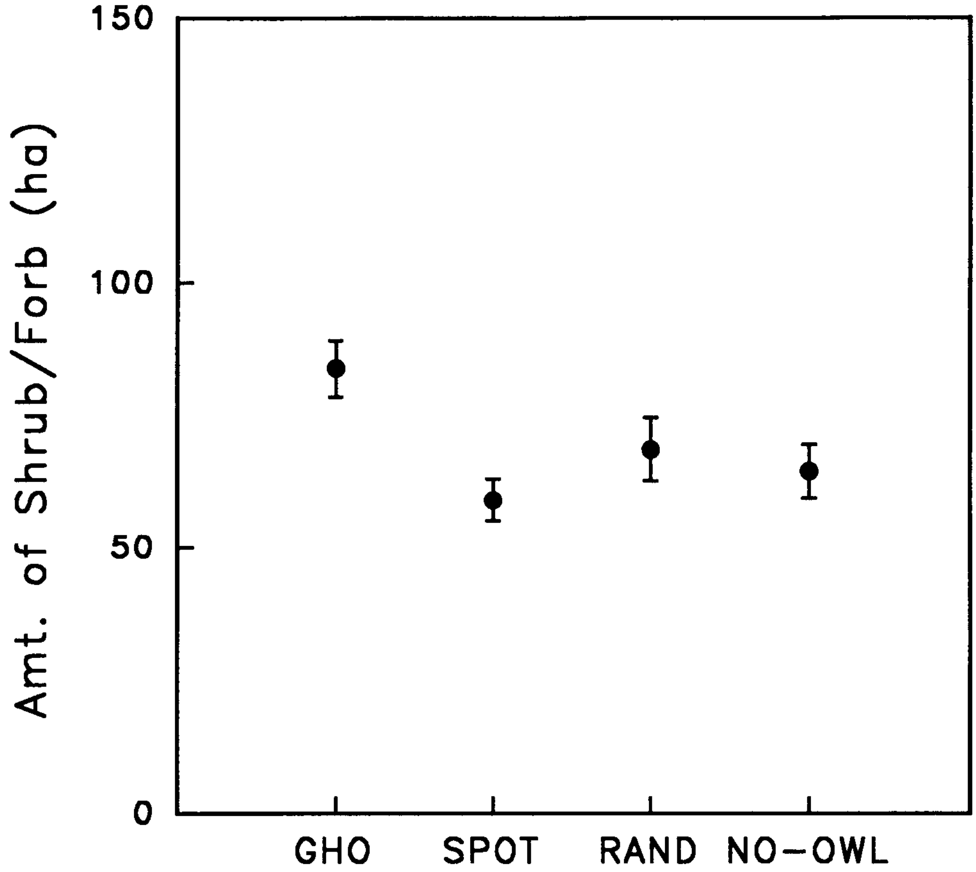


Figure 9. Result of comparisons between great horned owl, spotted owl, random, and no-owl landscapes for the amount of shrub/forb within the 500-ha circular plots. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Shown are mean and standard error.

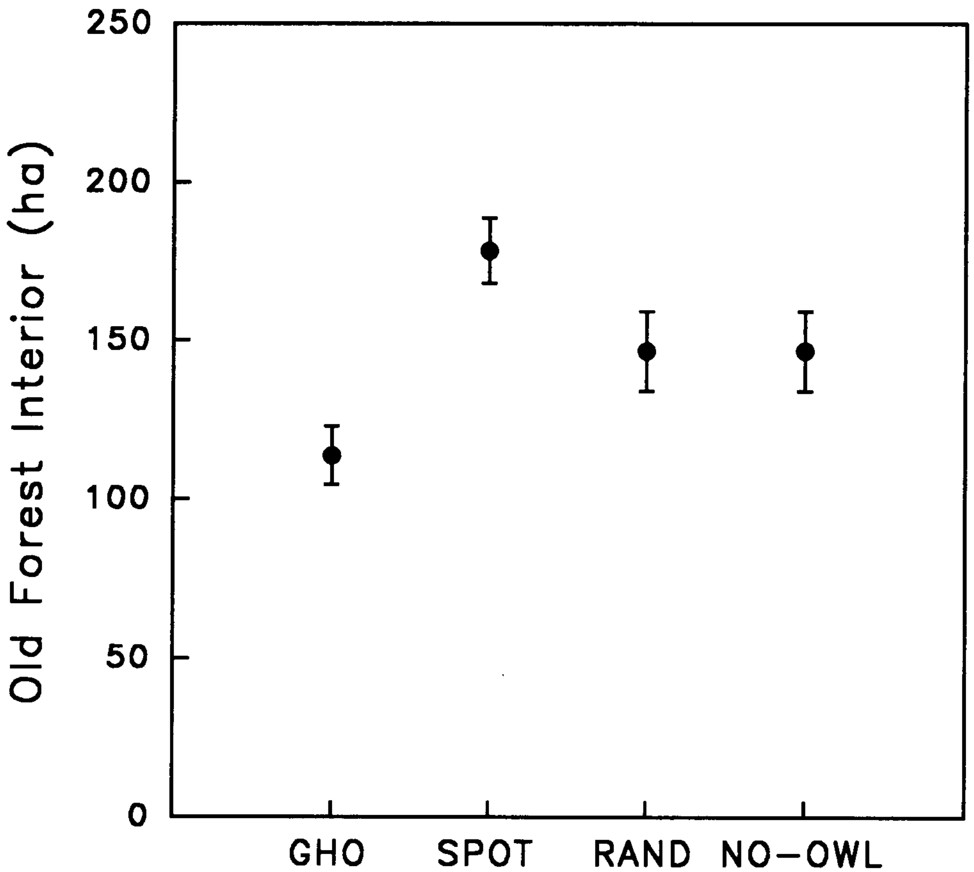


Figure 10. Result of comparisons between great horned owl, spotted owl, random, and no-owl landscapes for the amount of interior old forest habitat within the 500-ha circular plots. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Shown are mean and standard error.

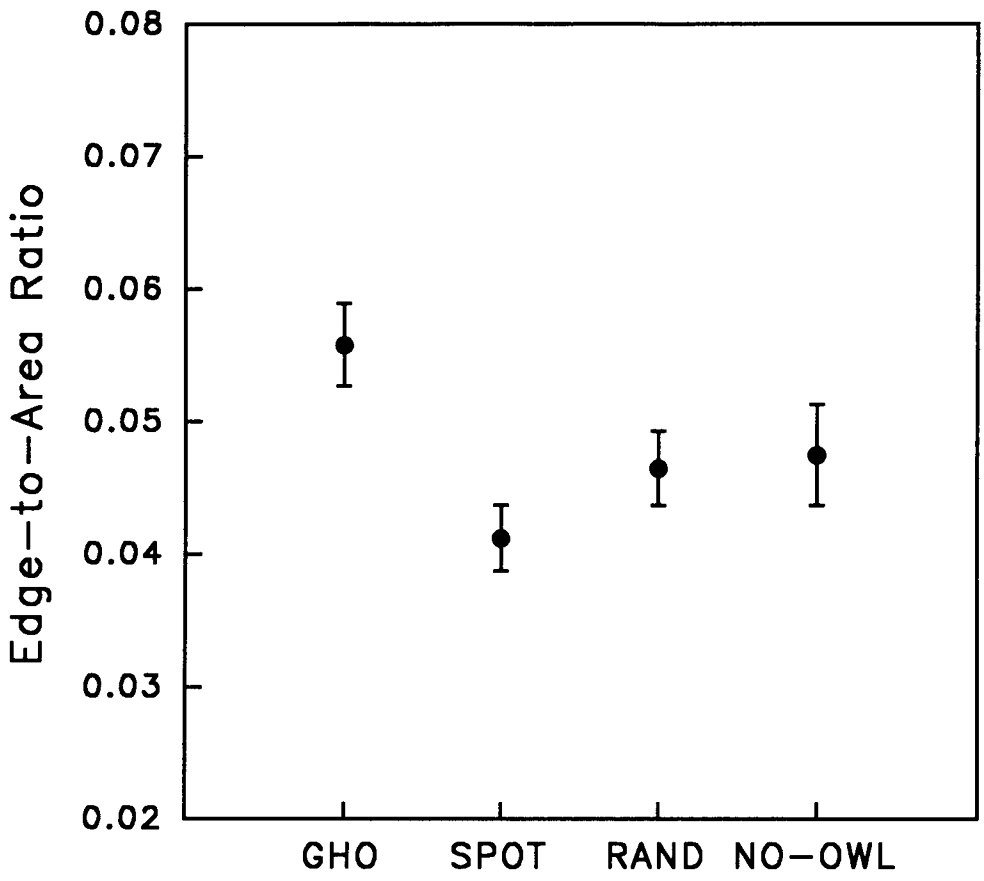


Figure 11. Result of comparisons between great horned owl, spotted owl, random, and no-owl landscapes for the linear edge-to-old forest area ratio within the 500-ha circular plots. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Shown are mean and standard error.

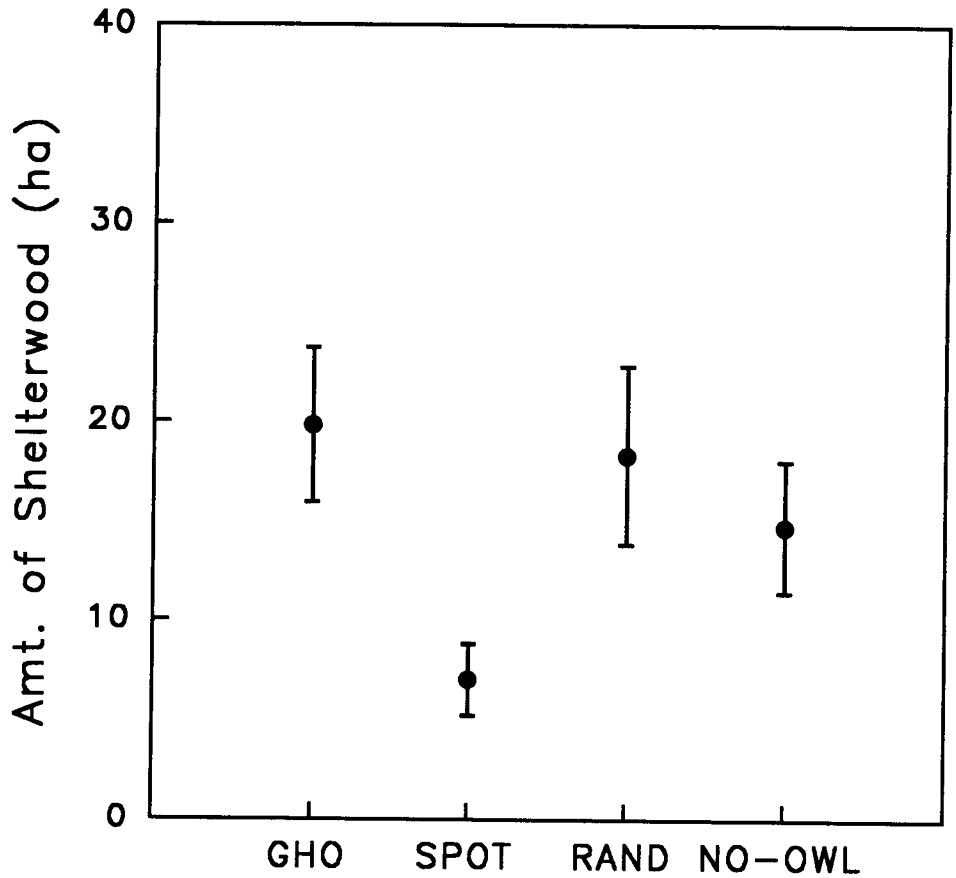
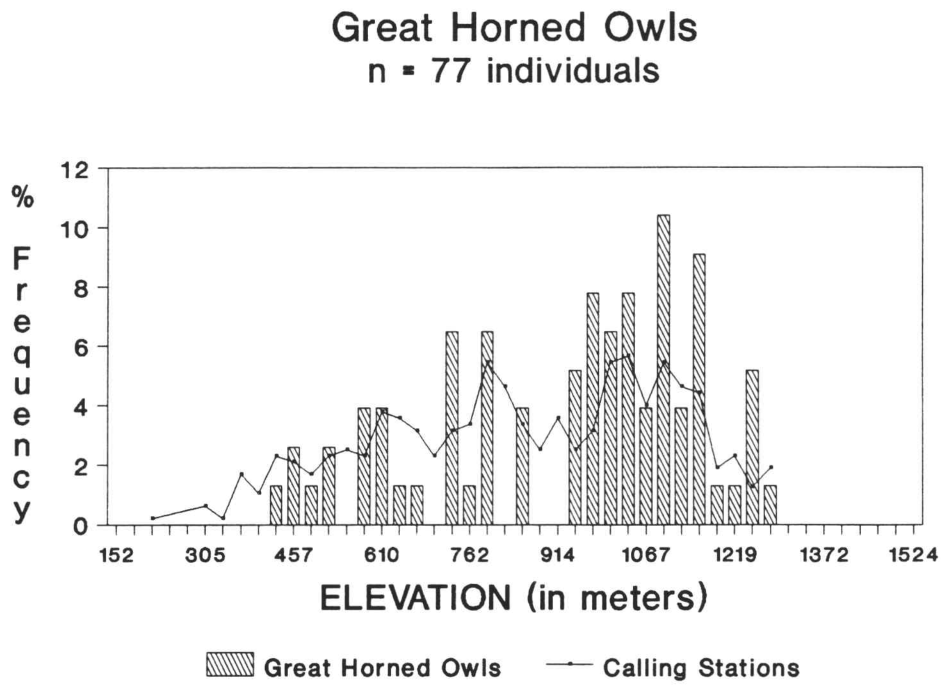


Figure 12. Result of comparisons between great horned owl, spotted owl, random, and no-owl landscapes for the amount of shelterwood within the 500-ha circular plots. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Shown are mean and standard error.



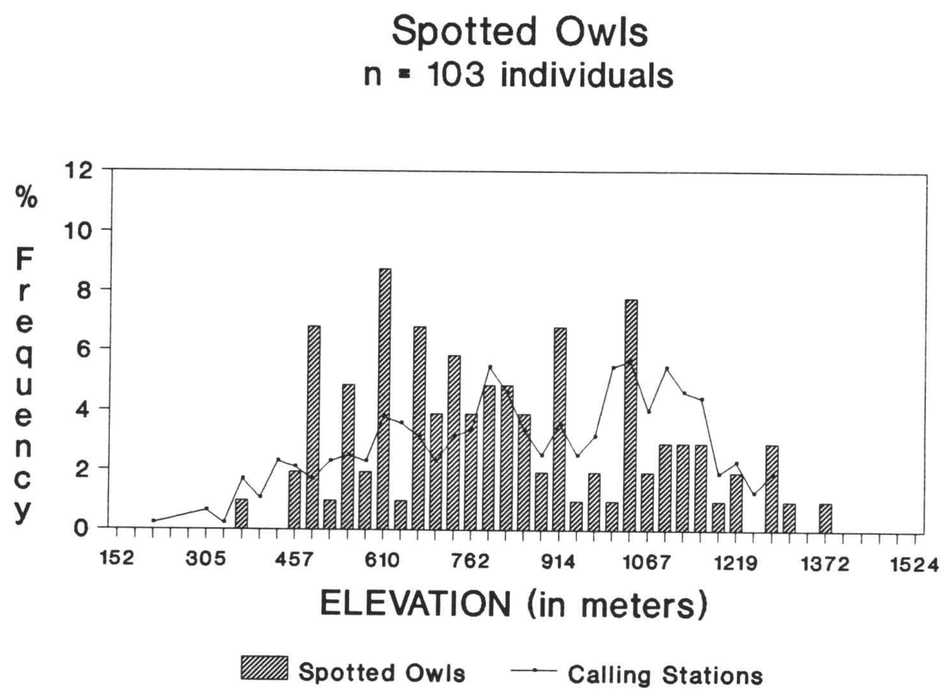


Figure 13. Response locations of great horned owls and spotted owls by elevation. Differences between great horned owl and spotted owl landscapes were significant ($P < 0.05$). Superimposed over the owl frequency bars is a line reflecting the elevation (by % frequency) of the calling stations.

area ratio (EA), and were higher in elevation than spotted owl landscapes. Summary statistics for landscape variables within the 500-ha plots around owl, no-owl, and random locations are shown in Table 7.

Differences between great horned owl and spotted owl landscapes for the remaining variables (closed-pole, open-pole, sapling, nonhabitat, edge, perimeter, and DISCORE), although not significant ($P > 0.05$), were consistent, with great horned owl landscapes having greater amounts of open-pole, sapling, nonhabitat, edge, and perimeter, a lower amount of closed-pole, and lower DISCOREs (indicating more dispersed old forest stands within these landscapes). All of these measures indicate that great horned owl landscapes contained lesser amounts of old forest arranged in a more dispersed manner, greater amounts of younger stands, and stands with more open canopies than did spotted owl landscapes.

Great horned owl landscapes were not different ($P > 0.05$) from random landscapes, and were different from no-owl landscapes only for the variable shrub/forb; great horned owl landscapes had significantly more shrub/forb than no-owl landscapes ($P < 0.05$). Spotted owl landscapes were not different ($P > 0.05$) from random or no-owl landscapes for any of the 13 variables. No-owl landscapes were not different ($P > 0.05$) from random landscapes for any of the 13 variables.

Results of a Pearson correlation analysis (for the 13 variables within random landscapes) indicated the following positive and negative correlations (where $r > 0.60$): old - interior ($r = 0.92$), perimeter - EA ($r = 0.94$), old - EA ($r = -0.85$), interior - EA ($r = -0.89$), edge - DISCORE ($r = -.065$), and perimeter - DISCORE ($r = -0.62$).

Table 7. Summary statistics for landscape variables within 500-ha circular plots for great horned owls, spotted owls, no-owl, and random locations. See Table 1 for descriptions of individual variables.

Great Horned Owl Landscapes (n = 77)

Variable	Unit	$\bar{x}$	SE	range
OLD	ha	241.4	11.9	0 - 429.0
SHELTERWOOD	ha	19.8	3.9	0 - 130.0
CLOSED-POLE	ha	68.9	11.0	0 - 465.0
OPEN-POLE	ha	15.5	3.6	0 - 142.0
SAPLING	ha	62.6	5.6	0 - 210.0
SHRUB/FORB	ha	83.7	5.3	0 - 236.0
NONHABITAT	ha	8.1	2.6	0 - 104.0
EDGE	ha	127.6	5.4	0 - 208.0
INTERIOR	ha	113.8	9.2	0 - 309.0
PERIMETER	km	11.36	0.43	0 - 18.91
EA	km/old	0.0558	0.0031	0 - 0.1386
DISCORE	score	-199	13	-391 - 221
ELEVATION	m	930.5	25.9	439 - 1292

Spotted Owl Landscapes (n = 103)

Variable	Unit	$\bar{x}$	SE	range
OLD	ha	301.9	9.3	12.0 - 467.0
SHELTERWOOD	ha	7.0	1.8	0 - 94.0
CLOSED-POLE	ha	72.6	7.2	0 - 342.0
OPEN-POLE	ha	7.9	1.4	0 - 71.0
SAPLING	ha	45.2	3.5	0 - 149.0
SHRUB/FORB	ha	59.1	4.0	0 - 186.0
NONHABITAT	ha	7.4	2.3	0 - 132.0
EDGE	ha	123.4	4.1	9.0 - 217.0
INTERIOR	ha	178.5	10.4	0 - 420.0
PERIMETER	km	10.38	0.36	1.64 - 18.79
EA	km/old	0.0412	0.0025	0.0062 - 0.1367
DISCORE	score	-168	16	-914 - 361
ELEVATION	m	818.4	23.3	366 - 1366

Table 7. (continued)

No-Owl Landscapes (n = 70)

Variable	Unit	$\bar{x}$	SE	range
OLD	ha	263.1	13.3	0 - 500.0
SHELTERWOOD	ha	14.7	3.3	0 - 142.0
CLOSED-POLE	ha	91.9	12.7	0 - 500.0
OPEN-POLE	ha	11.5	2.2	0 - 83.0
SAPLING	ha	48.6	6.0	0 - 236.0
SHRUB/FORB	ha	64.5	5.1	0 - 208.0
NONHABITAT	ha	5.7	1.9	0 - 92.0
EDGE	ha	116.4	5.4	0 - 200.0
INTERIOR	ha	146.7	12.6	0 - 500.0
PERIMETER	km	10.34	0.49	0 - 21.76
EA	km/old	0.0475	0.0038	0 - 0.2029
DISCORE	score	-169	18	-637 - 318
ELEVATION	m	910.7	33.1	293 - 1585

Random Landscapes (n = 70)

Variable	Unit	$\bar{x}$	SE	range
OLD	ha	266.3	12.4	52.0 - 488.0
SHELTERWOOD	ha	18.3	4.5	0 - 196.0
CLOSED-POLE	ha	65.1	8.1	0 - 288.0
OPEN-POLE	ha	16.9	4.2	0 - 193.0
SAPLING	ha	57.0	7.4	0 - 257.0
SHRUB/FORB	ha	68.6	5.9	0 - 311.0
NONHABITAT	ha	7.6	3.1	0 - 120.0
EDGE	ha	119.6	4.9	14.0 - 200.0
INTERIOR	ha	146.7	12.5	0 - 474.0
PERIMETER	km	10.33	0.43	1.15 - 19.88
EA	km/old	0.0465	0.0028	0.0024 - 0.1196
DISCORE	score	-153	16	-381 - 332
ELEVATION	m	863.0	28.2	463 - 1292

Owl Response by Elevation

Although both owl species were found throughout the elevation range censused, they were not distributed evenly. Great horned owl locations were significantly higher in elevation than either calling stations ($P < 0.01$) or spotted owls ($P < 0.01$). Elevations at spotted owl locations were not significantly different from calling station elevations. Plots of the owls by elevation are shown in Figure 13; a line reflecting the elevation of the calling stations is superimposed over the owl frequency bars (and can be thought of as the expected value if owls responded equally to the elevation of the survey effort).

For great horned owls, and to some extent for spotted owls, an elevation break is apparent at 945 m (3100′) (Figure 13). While 64% of the great horned owls were above 945 m, only 30% of the spotted owls were above 945 m. Potential explanations for this difference in owl distribution are (1) differences in sampling intensity, (2) changes in habitat conditions, (3) changes in prey species composition or availability, and (4) avoidance of great horned owl areas by spotted owls. These potential explanations are discussed below.

The elevation of calling stations ranged from 207 m (680′) to 1292 m (4240′), with 43% of the calling stations above 945 m (3100′) (Figure 13). Individual survey routes generally covered a wide range of elevations due to the design of the road network in the steep topography of the forest landscape. A range of elevations was also covered from individual calling stations when one considers the area within hearing range of the broadcast call (e.g., calling from ridgetops down and across canyons). This suggests that sampling was adequate and that differences shown by the owls were not likely due to calling station location.

Using data from plots surrounding the 70 random points, regression analysis was used to examine significant changes or general trends in the habitat features with increasing elevation. There were significant ($P \leq 0.05$) increases in the amounts of shrub/forb, sapling, and EA, and a general increase ($P \leq 0.08$) in the amount of open-pole with an increase in elevation. Conversely there was a significant decrease ($P < 0.05$) in old, closed-pole, and DISCORE, and a general decrease ($P \leq 0.09$) in interior with increasing elevation. There was no significant change in shelterwood with increasing elevation. The decrease in DISCORE and increase in EA reflect the reduced amount of old forest, the increased distance between old forest stands, and the overall increase in EA with increasing elevation. These elevational changes in vegetation conditions are consistent with that described for the Willamette NF and reflect the western hemlock (*Tsuga heterophylla*) to Pacific silver fir (*Abies amabilis*) zone gradient (Hemstrom et al. 1987, Franklin and Dyrness 1973).

As noted earlier, besides elevation, significant differences exist between great horned owl and spotted owl landscapes for another 5 habitat/landscape variables: old, interior, shrub/forb, shelterwood, and EA. Given the strong differences between the amount of these variables in the owls' landscapes, and that changes in these variables occur with increasing elevation (except for shelterwood), the observed elevational differences between the 2 owl species could in part be explained by the changes in habitat conditions.

Although this study was not directed at evaluation of the prey base, observations of rabbits and hares were recorded. Brush rabbits (*Sylvilagus bachmani*) were observed most frequently below 732 m (2400′) elevation and were not observed at elevations above 975 m (3200′). Snowshoe hares (*Lepus americanus*) were most frequently observed above 914 m (3000′). The majority of the rabbits and hares (or their tracks) were observed in or adjacent to young (10-20 year-old) conifer plantations. Wiens and Nussbaum (1975) and A. McKee (pers. comm. to L. Harris, see Harris 1984:59) have noted that higher elevations in the central part of the study area (H.J. Andrews Experimental Forest) supported the lowest density of birds and small mammals. My observations are generally consistent with the elevational and habitat relationships described by Harris (1984) and Koehler (1990).

Owl Response by Fragmentation Level

The relationship between owl response locations and the level of forest fragmentation was assessed in 2 ways: (1) by examining landscapes surrounding great horned owl and spotted owl locations with regards to increments in the amount of old forest, and (2) by examining landscapes surrounding owl, no-owl, and random locations with regards to the spatial distribution of old forest stands within them (see "Spatial Distribution of Old-Forest Stands").

A key finding of this study was identifying the relationship between the owls and the amount of old forest in the sampled landscapes (Figure 14). The greatest number of great horned owl responses were in landscapes containing 10-20% old forest. Great horned owl responses

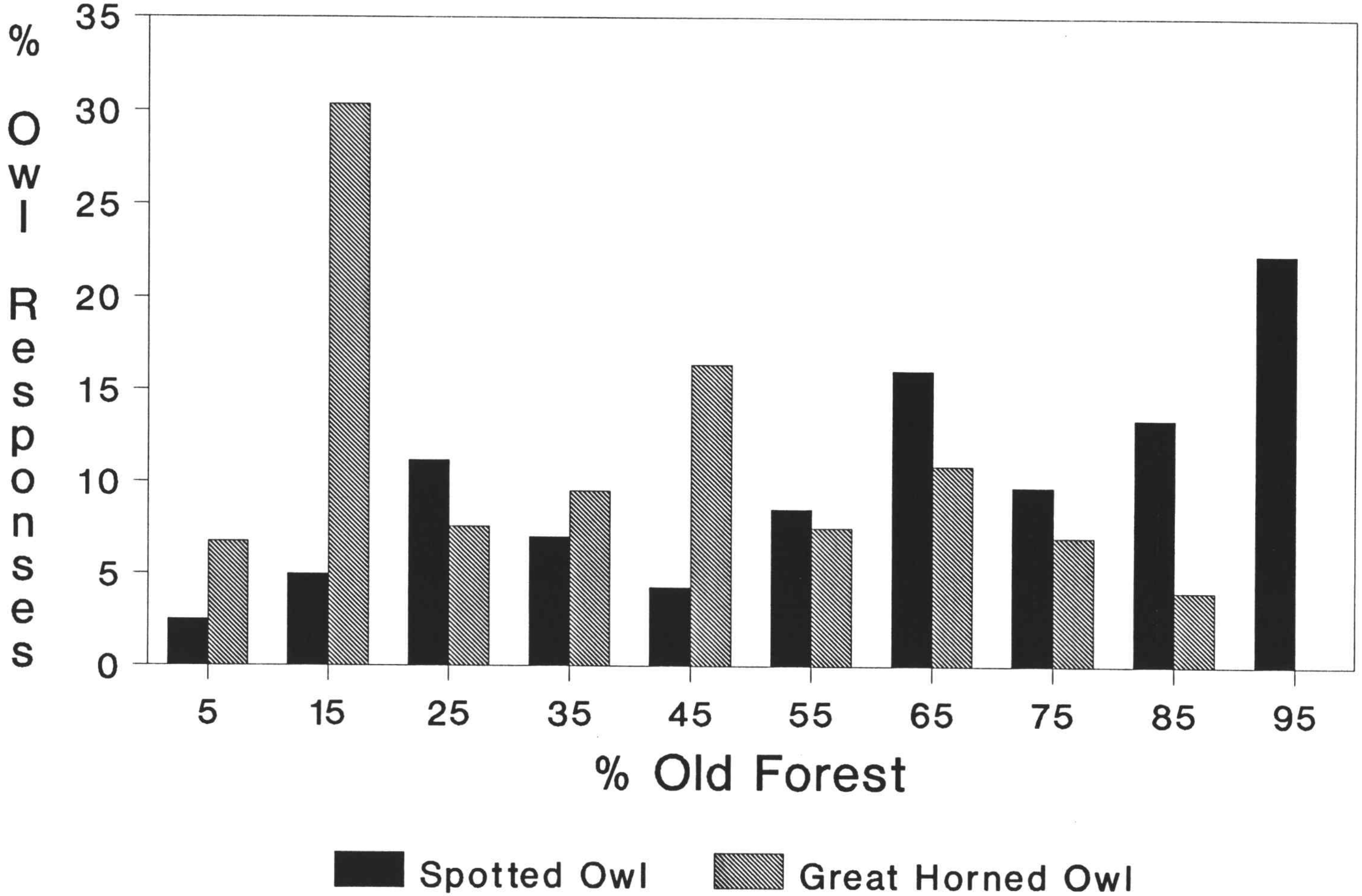


Figure 14. Spotted owl and great horned owl responses by percent of old (mature/old-growth) forest in the Central Oregon Cascades, 1989 and 1990

generally declined with increasing amounts of old forest, and few (11%) great horned owls were detected in landscapes containing ≥ 70% old forest. The majority (62%) of spotted owls were detected within landscapes containing ≥ 60% old forest. Spotted owls responses generally declined with declining amounts of old forest, and few (7%) spotted owls were detected within landscapes containing ≤ 20% old forest (Figure 14).

Two examinations using regression analysis were conducted to compare owl responses against the percent of old forest. In the first examination, all the data was used; in the second examination, the increment of 0-10% old forest (and respective owl responses) was deleted from the data set. Justification for this deletion follows the reasoning that: (a) the impact of old forest on owls in landscapes containing 0-10% old forest is relatively minor compared to the impacts of other habitat types; and (b) few (or no) nesting sites in old forest are likely available for either of the owl species. Results of the first examination indicated that the observed increase in spotted owls with increasing amounts of old forest was significant ($P < 0.01$, $R^2 = 0.63$), whereas the observed decrease in great horned owls with increasing amounts of old forest was not ($P = 0.09$, $R^2 = 0.31$). Results of the second examination, however, reaffirmed the previous pattern for spotted owls ($P = 0.02$, $R^2 = 0.54$), and indicated a significant decrease in great horned owls with increasing amounts of old forest ($P = 0.02$, $R^2 = 0.55$).

There was concern that by using the broadcast calling technique owls could be drawn into areas where they would not ordinarily be found and thereby bias the subsequent landscape assessment effort. To address this concern, owl locations were selected to reflect the strongest biological link to the landscape (see "Selection of Owl, No-Owl, and Random Locations").

Spatial Distribution of Old-Forest Stands

The term fragmentation infers a spatial dimension: is the spatial arrangement of old forest stands different among great horned owl, spotted owl, no-owl, and randomly selected landscapes?

The spatial distribution of old forest stands within owl, no-owl, and random landscapes was compared to simulated landscapes containing the same amount of old forest but distributed in a way to represent the extremes of fragmentation. Based on measurements from the landscapes, a dispersion score (DISCORE) was developed to indicate the degree to which the old forest stands within real landscapes were arranged in a dispersed (checkerboard) or clumped fashion. Negative DISCORE values indicated old forest stands arranged in a dispersed fashion while positive DISCORE values indicated a clumped arrangement. The greater the value (either negatively or positively) the more dispersed or clumped the arrangement of the old forest. Analysis indicated that 95% of great horned owl, 88% of spotted owl, 89% of no-owl, and 86% of random landscapes contained old forest stands classified as dispersed (Figures 15, 16, 17, 18). DISCOREs from great horned owl, spotted owl, no-owl, and random landscapes were not significantly different ($P > 0.05$). Average DISCOREs for great horned owl, spotted owl, no-owl, and random landscapes were -199, -168, -169, and -153, respectively. Great

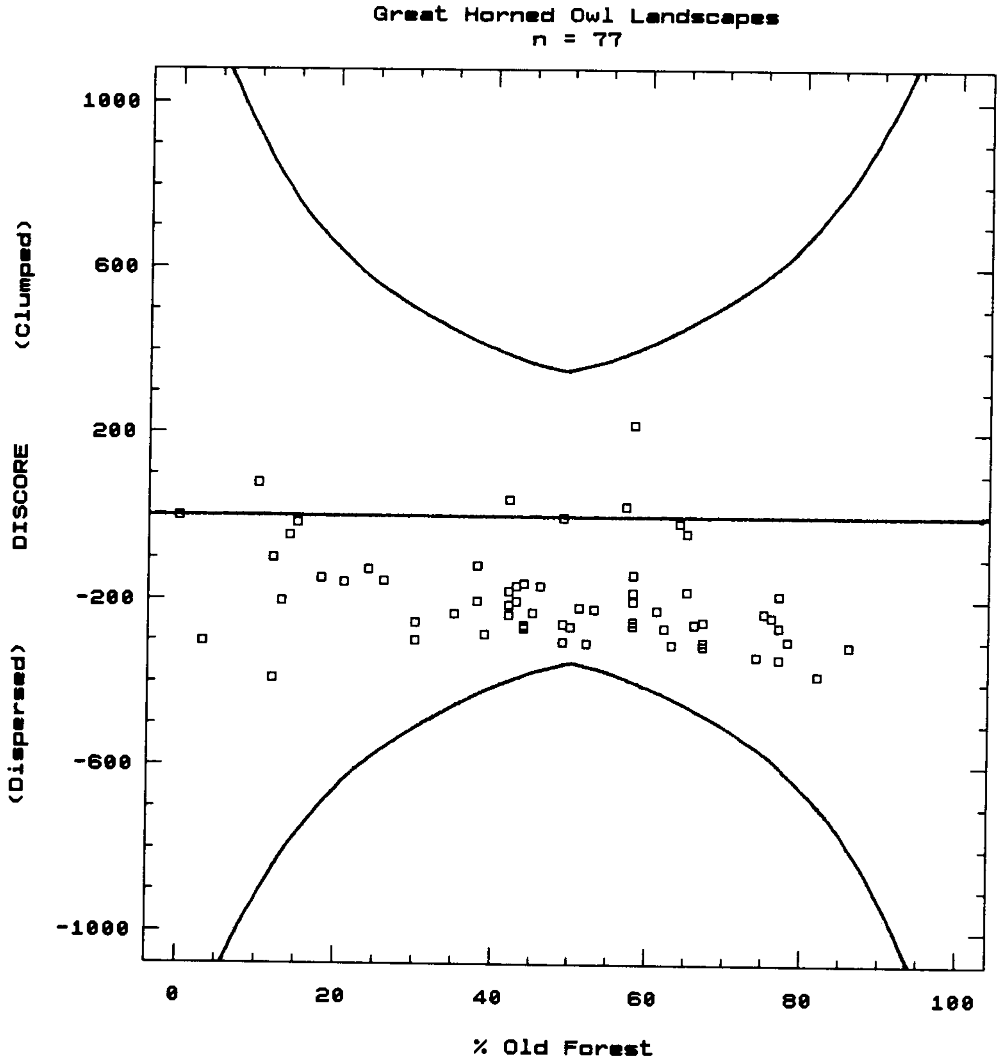


Figure 15. Plot of DISCOREs from great horned owl landscapes by amount of old forest, Central Oregon Cascades, 1989 and 1990. Curves at top and bottom of figure reflect limits of potential DISCOREs (see Figure 7).

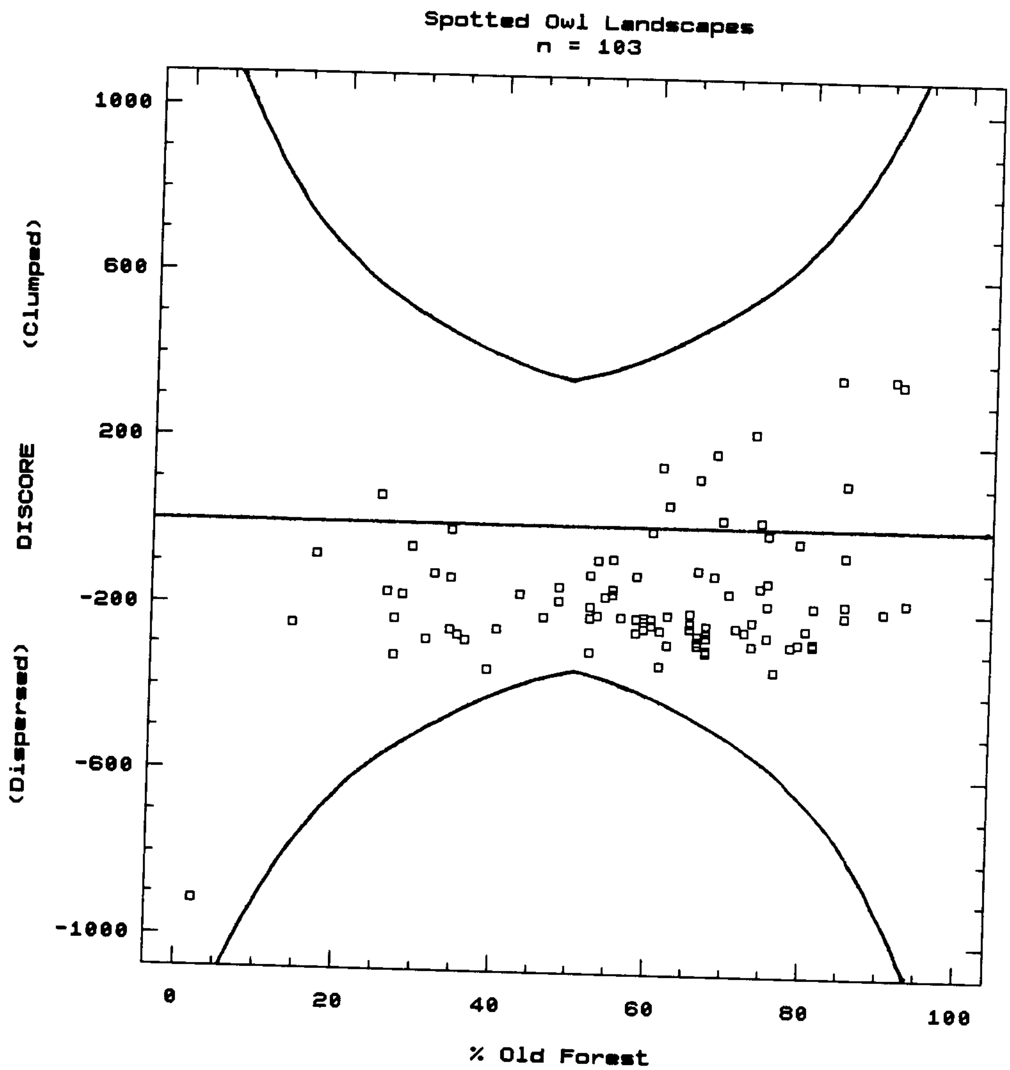


Figure 16. Plot of DISCOREs from spotted owl landscapes by amount of old forest, Central Oregon Cascades, 1989 and 1990. Curves at top and bottom of figure reflect limits of potential DISCOREs (see Figure 7).

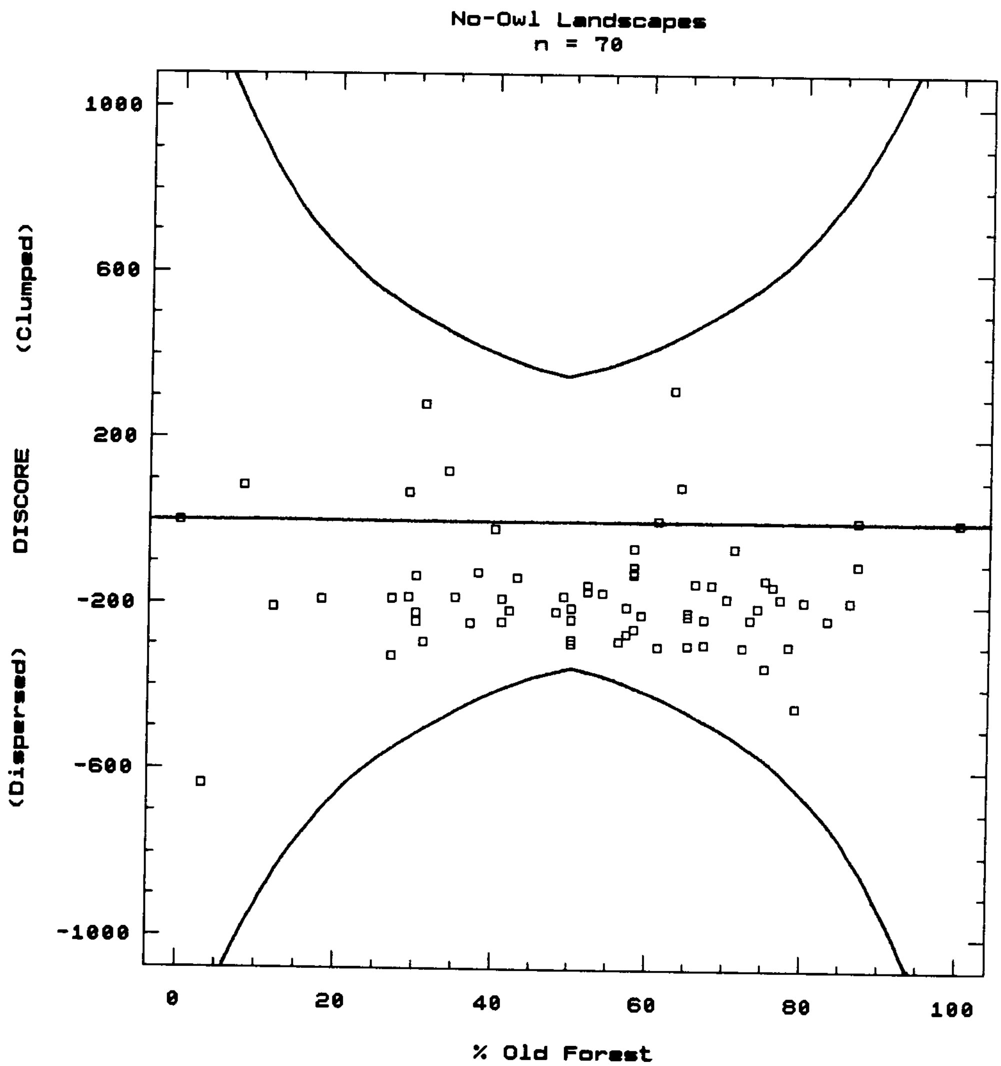


Figure 17. Plot of DISCOREs from no-owl landscapes by amount of old forest, Central Oregon Cascades, 1989 and 1990. Curves at top and bottom of figure reflect limits of potential DISCOREs (see Figure 7).

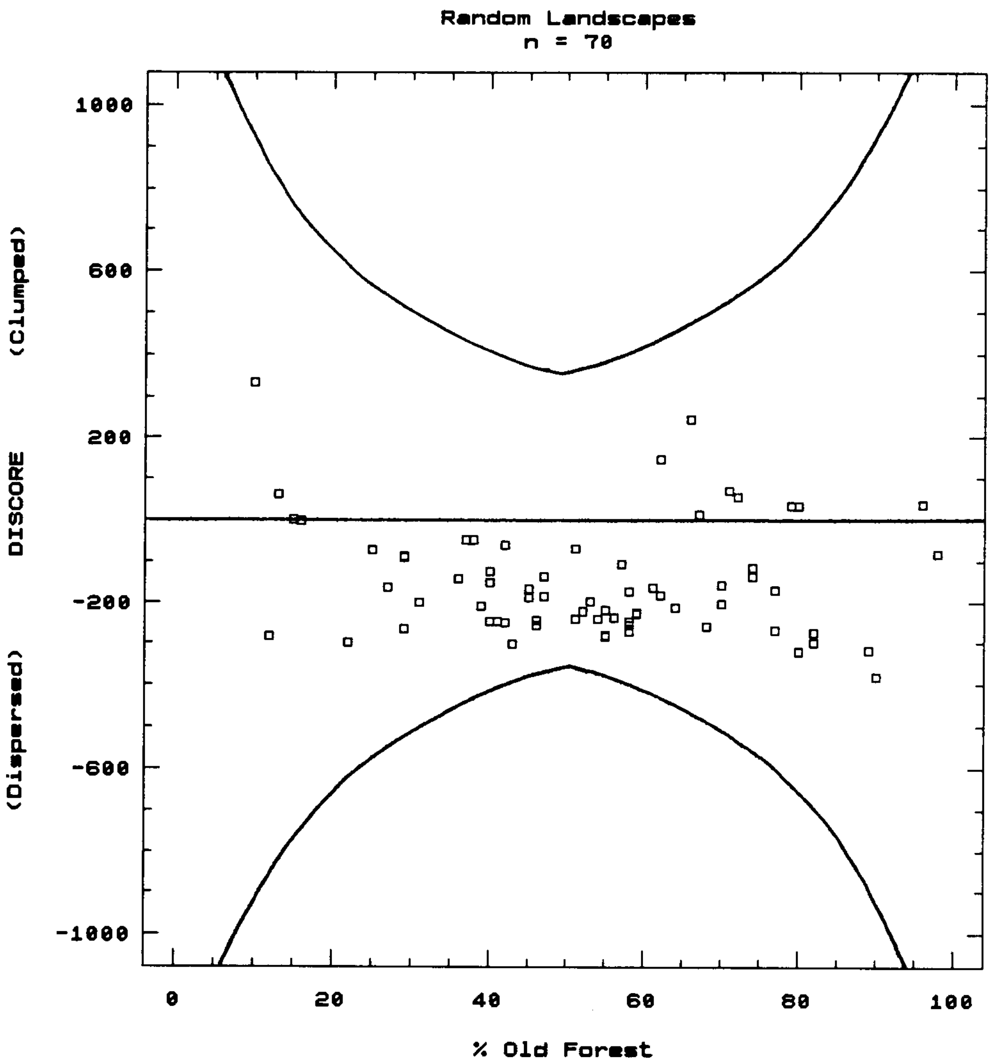


Figure 18. Plot of DISCOREs from random landscapes by amount of old forest, Central Oregon Cascades, 1989 and 1990. Curves at top and bottom of figure reflect limits of potential DISCOREs (see Figure 7).

horned owls had the lowest DISCORE (-199) indicating landscapes wherein the old forest stands were the most dispersed. Clearly, old forest stands in the Central Cascades are highly fragmented (see Frontispiece). Moreover, there are simply very few unfragmented landscapes existing in the Central Cascades study area.

DISCUSSION

Nocturnal Survey Efforts

Nighttime survey efforts employing the broadcast of taped calls were conducted for great horned owls and spotted owls during 124 nights from February through May 1989 and January through May 1990. A total of 469 calling stations were located along 28 survey routes, with each route having 6 to 26 calling stations. Each route was surveyed 6 times, 3 times for each owl species, and no routes surveyed in 1989 were repeated in 1990. Owls responded along all 28 survey routes; 26 routes had both great horned owls and spotted owls responding; the 2 shortest routes had only spotted owls responding. A total of 193 responses was recorded from 95 individual great horned owls; 294 responses were recorded from 161 individual spotted owls. Responses per 60 minutes of survey efforts from spotted owls were roughly double that of great horned owls: 1.358 and 0.626 from spotted owls and great horned owls, respectively. Total survey distance was 535.7 road km, with relative abundance for spotted owls and great horned owls at 0.139 and 0.069 owls/road km, respectively. For comparison, using a similar survey technique Thomas Hamer (pers. comm.) found 0.069 spotted owls/road km and 0.107 great horned owls/road km in northwestern Washington during 1986-1989. Forsman et al. (1977) found 0.72 spotted owls/road km in old-growth and 0.06 spotted owls/road km in second-growth forests in the northern Coast Range of Oregon.

An examination of nest record cards for great horned owls in Oregon (statewide) indicated a mean visit date to nests containing clutches to be 10 March (SD = 22 days, range 26 January - 18 May). Although great horned owls begin courtship activities in the Willamette Valley (≈ 75 m elevation) in January (pers. obs.) survey efforts indicated that great horned owls did not begin similar activities in the adjacent, higher elevation, Cascades study area until early February. Great horned owl response rates were significantly different than expected ($P < 0.001$) throughout the mid-January through mid-April survey period, with response rates less than expected during January and April. The high response period for great horned owls in the Cascades study area was February and March.

Spotted owls begin their courtship activities in March (Forsman et al. 1984). Spotted owl response rates were significantly different than expected ($P = 0.05$) throughout the mid-March through mid-May survey period, with response rates somewhat greater than expected during May.

As survey efforts were conducted throughout the night, owl response rates during 6 periods of the night were determined. Both owl species responded at rates significantly different than expected. Spotted owls responded more than expected in the early evening hours; great horned owls responded less than expected before midnight and more than expected after midnight. Morrell et al. (1991) recorded a similar response pattern for great horned owls in Pennsylvania. Thermals generated during sunny days in the Willamette Valley created updraft winds (typically 6-20 kph) in most of the study area; by 2230 hr these winds had subsided. Soft, low-pitched vocalizations, such as those typically given by great horned owls, would carry greater distances when winds are calm and the air dense (cool). Such conditions were most common in early morning (e.g., 0100-0400 hr).

The moon phase was divided into four 7-day periods centered around the calendar dates for new moon, first quarter, full moon, and last quarter. Moon phase appeared to influence the response rates of both owl species: spotted owls ($P = 0.05$), great horned owls ($P < 0.01$). Spotted owls responded more than expected during full moon phases. Great horned owls responded less than expected during full moon phases and more than expected during new moon phases. This somewhat contrasts the results of Franklin et al. (1986) and Laymon (1988) who reported that spotted owls in their California study areas did not respond differently than expected during moon phases. Results from my study also contrast somewhat with those of Morrell et al. (1991) who contacted more great horned owls on nights between the day following a first quarter moon to and including a full moon. Great horned owls in my study responded in a manner generally consistent with that described by Smith et al. (1987), who reported that eastern screech owl (*Otus asio*) responses were shorter in duration on clear moonlit nights than on dark, cloudy, or foggy nights.

Great horned owls and spotted owls were recorded within 500 m of one another during the same night on 5 occasions during this study (details in Appendix E). The situations may be summarized as follows: (1) a spotted owl pair became silent after a male great horned owl called; (2) a male spotted owl and a great horned owl pair were within 100 m of one another, they displayed awareness but no aggression towards one another; (3) a spotted owl pair was disturbed by a male great horned owl, with the great horned owl indifferent to the spotted owls; (4) there was no apparent interaction between 3 spotted owls (a pair and a single male) and a great horned owl pair; and (5) a male spotted owl was disturbed by a male great horned owl. It is important to recognize that both species are long-lived, territorial, and nocturnal. It seems plausible that particular great horned owls and spotted owls could reside on adjacent and overlapping territories for a number of years. Both would defend territories, court mates, and interact with their young through vocalizations (and by other means as well). It would seem inherently risky for a spotted owl to expose itself (physically or vocally) near a known predator when responding to an intruder (i.e., a broadcast spotted owl call). Similarly, it would be disadvantages for a great horned owl to first advertise its location before making a predation attempt. The situation may be different if the spotted owl was new to its territory.

Landscape Assessment

The landscape analysis focused on 13 habitat/landscape variables measured within 500-ha circular plots. Significant differences between great horned owl and spotted owl landscapes existed for 6 variables: great horned owl landscapes contained more shrub/forb and shelterwood, less old forest and interior habitat, had a higher linear edge-to-old forest area ratio (EA), and were higher in elevation than spotted owl landscapes. Except for differences in elevation, these findings are consistent with the literature and generally recognized aspects of the two species' life histories (see reviews by Thomas et al. 1990, Johnsgard 1988, and Voous 1988).

The amount ($\bar{x}$ ± SE) of old forest within the 500-ha landscapes was 48% ± 2% around great horned owls, 60% ± 2% around spotted owls, 53% ± 3% around no-owl points, and 53% ± 2% around random points. The spatial distribution of old forest stands was compared to simulated landscapes reflecting dispersed (checkerboard) and clumped patterns: 95% of great horned owl, 88% of spotted owl, 89% of no-owl, and 86% of random landscapes were classified as dispersed. While both great horned owls and spotted owls were found in landscapes containing various amounts of old forest, each species keyed on opposite ends of the spectrum. Peak numbers of great horned owl detections occurred in landscapes containing 10-20% old forest, while most spotted owls responded from landscapes with ≥ 60% old forest. Detections of great horned owls decreased with increasing amounts of old forest, and few great horned owls were detected in landscapes containing ≥ 70% old forest. Spotted owl detections generally declined with decreasing amounts of old forest, and few spotted owls were detected in landscapes containing ≤ 20% old forest (Figure 14).

Great horned owl responses were most frequent at mid- to higher elevations; this was an unexpected result. Great horned owls are found throughout Oregon, and at elevations from sea level to 2135 m (7000') (Crater Lake National Park, J. Milestone pers. comm.). Great horned owls are considered common in the Willamette Valley and in lower elevation forested lands at the base of the Cascades. These latter areas are largely privately owned and have less old-growth and mature forest remaining than USFS lands within the study area. Spotted owls in the Cascades tend to be found in a narrower elevation band; generally extending from the base of the Cascades (above the private land) to about 1280 m. Only 13.5% of 1830 spotted owl pair sites in Oregon located from 1988-1990 were between 1220 m (4000′) and 1525 m (5000′) in elevation; 4.8% of the 1830 pairs were above 1525 m (Oregon Dept. of Fish and Wildlife, unpubl. data). That great horned owls were more numerous above 945 m (3100′) has significant implications for programs directed at the maintenance or recovery of a viable spotted owl population.

Review of Forest Fragmentation and Implications to Owls

Forest fragmentation and its effects on biotic diversity have been recognized during the last decade as a pressing problem in conservation biology (Harris 1984, Helle 1985, Thiollay and Meyburg 1988, Newmark 1991, Lehmkuhl and Ruggiero 1991, Cutler 1991). Forest fragmentation is the process whereby a contiguous landscape of older forest (mature and old-growth in the Pacific Northwest) is altered by disturbance (typically timber harvest) creating a complex mosaic of a broad range of successional habitats. Fragmentation of forests on federal and state lands in the Pacific Northwest is the product of about 50 years of logging using the staggered-setting system, where 10- to 40-ha clearcuts are dispersed across large areas of old forest. Three changes in the forest landscape are associated with this harvest pattern of old forest: quantitative loss of old-forest habitat, qualitative loss of old-forest habitat resulting from the reduced capacity of remaining patches to support old forest conditions and wildlife communities, and an increase in the amount of younger successional habitat(s) which may be unsuitable (rather than simply neutral) to interior species. Quantitative and qualitative measures of the impacts of fragmentation on old-forest habitats are derived from inventories of forest habitat types, through the assessment of landscape patterns (e.g., patch size, shape, abundance, and spacing), and by establishing an ecological relationship between landscape features and the animal(s) of interest. This study examined great horned owls and spotted owls, and focused particular attention on the amount, shape, and spatial distribution of old (mature/old-growth) forest.

Estimates of the prelogging and currently remaining old-growth forest in western Oregon and Washington have indicated that between 60-70% of the prelogging forests consisted of old-growth forest, and that at least 82-87% of the original old-growth no longer exists (Booth 1991, Haynes 1986, Morrison 1988, Franklin and Spies 1984, Spies and Franklin 1988).

The Western Cascades province in Oregon runs the length of the state from the Columbia River to the California border and extends from the eastern edge of the Willamette Valley upslope to the crest of the Cascade Mountains. The Western Cascades currently contains the largest number of known spotted owl pairs (n = 925) in Oregon (USFWS 1992). For the period 1950-1990, old forest habitat (suitable for spotted owls) has declined at an annual rate of 1.4% (USFWS 1992). Approximately 30.7% of the 7,371,000 ha forest landbase in the Western Cascade province currently contains old forest, with remaining old forest habitat located primarily on federal lands (USFWS 1992).

Measuring forest fragmentation requires that landscape pattern, that is, the spatial character of habitat within the landscape, be quantified. Numerous methods and indices have been proposed (e.g., Patton 1975, Forman and Godron 1986, Milne 1988, O'Neill et al. 1988, Turner 1989, Ripple 1991a, Turner and Gardner 1991) and tested (Li 1989, Turner 1989, 1990). The size of the landscape under study (i.e., plot size) is of particular importance when attempting to relate owl biology (or other ecological parameters) to landscape patterns. The objective is to select a plot size large enough to adequately assess landscape features but small enough to allow detection of those features actively selected by the owls. While large plot sizes inherently capture more landscape variability because of the area involved, they may include significant portions of the landscape outside of owl home ranges (and suffer "boundary effects"). The use of large plots could also mask any selection effects shown by the owls (i.e., one could not detect differences between owl and random sites if they did exist). The use of small plots could run the risk of not accurately portraying the landscape perspective (as related to the species under review), could potentially draw invalid conclusions about a species' habitat selection, or not accurately reveal the inherent variability in the overall ecological setting. Additional concerns for any choice of plot size reflect landscape resolution (fineness or coarseness of measured features) and the acquisition of statistically adequate sample sizes. As a cautionary note, some landscape variables (e.g., patch size and density, shape, edge/area ratio) can change significantly with increasing plot size (Lord and Norton 1990).

Forest fragmentation has been suggested to influence the quality of wildlife habitat through a variety of processes such as isolation of forest patches and edge effects (Harris et al. 1982, Harris 1984, Wilcove et al. 1986, Franklin and Forman 1987, Lehmkuhl and Ruggiero 1991). A general review of great horned owl and spotted owl life history traits (Table 1), and analysis of data collected during this study, suggest that forest fragmentation patterns are important to both of these owl species. More specifically, the amount of old forest, old forest interior, shelterwood, shrub/forb, edge-to-old forest ratio, and elevation were differentially associated with landscapes surrounding owl response locations. It follows that changes in these variables could significantly impact the 2 owl species.

Studies examining recent changes in landscape patterns have been conducted in the Western Cascades province by Ripple et al. (1991a) and Spies et al. (1991). Both studies reveal significant changes in landscape variables that would appear to favor great horned owls and disfavor spotted owls. Ripple et al. (1991a) assessed changes in forest fragmentation patterns from 1972 to 1987 on approximately 26,250 ha of national forest land in the central portion of the province. In this study, landscapes were classified as either "managed" (< 40-yr-old plantations) or "natural" (uncut) forest; interior habitat was the amount of natural forest remaining after removal of a 100-m edge. A significant increase in forest fragmentation between 1972 and 1987 was indicated, as characterized by: (1) a 98% increase in mean patch abundance, (2) a decrease in mean interpatch distance (928 to 661 m), (3) an 8.7% decrease in the amount of natural forest caused by timber harvest, (4) an 18.0% decrease in the amount of interior natural forest, and (5) the near doubling of total patch edge (1.14 km/km^2 to 2.19 km/km^2). The loss of interior natural forest at nearly double the rate of timber harvest reflected the harvest of timber by staggered clearcutting.

Spies et al. (1991) assessed changes in the amount of closed-canopy conifer forest between 1972 and 1988 on a 258,900-ha study area in the central portion of the province. Changes on 3 land types were assessed: public wilderness, public non-wilderness, and private. The study area was classified into 2 forest types: closed-canopy conifer forest (typically > 40 yr old) and other forest and nonforest types (typically < 40 yr old or deciduous forest). Interior forest was the amount of closed-canopy forest remaining after removal of a 100-m edge zone, and edge length was defined as the total linear distance along the closed-canopy forest boundary. Changes in landscape measures were detected between land types; only overall changes are noted here. During the study period, the proportion of closed-canopy forest was reduced from 71% to 58%, and the amount of closed-canopy interior forest declined from 54% to 37%. The mean interior patch area declined from 160 ha to 62 ha. The amount of linear edge increased from 1.9 to 2.5 km/km^2.

Assessing forest fragmentation is not solely a matter of measuring landscape patterns; it also requires an understanding of the changes it causes to ecological processes within the landscape. Demographic rates for spotted owls are just now being quantified; we know little about demographic parameters for great horned owls. As both of these species are long-lived and have fairly large home range sizes, understanding the relationships between forest fragmentation and demographic rates will take time. We must be patient and resist the temptation to say that if forest fragmentation does not currently appear to be selected for (in the case of great horned owls) or against (in the case of spotted owls) that it is not important. Impacts on owls from forest fragmentation should ultimately be expressed in measures of juvenile and adult survival, reproductive performance, and habitat recolonization rates.

Historical Perspective on Coexistence of the Owls

Great horned owl and spotted owl populations have undoubtedly coexisted in the Western Cascades landscape for centuries, although likely at densities quite different than today. Prior to Euro-american settlement, fire was the main disturbance mechanism altering forest composition. Over the last 5 centuries, a natural fire frequency of 95-145 years has been suggested for the Western Cascades (Means 1982, Stewart 1986, Morrison and Swanson 1990, Teensma 1987, Agee 1991, Booth 1991, Agee and Edmonds 1992). Not all areas have had recurrent fires, as evidenced by stands which are 500+ years old. Those stands which did burn, burned at different intensities (see fire severity maps of Morrison and Swanson 1990). Fires of moderate to high severity topkill 20-80% of the basal area of the stand (Agee and Edmonds 1992). Depending on the size of the area burned, fires of moderate and high severity could alter a landscapes' capability to support great horned owls and spotted owls. Large (> 1,000 ha) stand-replacing fires would eliminate conditions for spotted owls while creating new areas for great horned owls to colonize. As early seral tree recruitment takes place (40-100 years in moist Douglas-fir forests; Franklin and Hemstrom 1981, Huff 1984, Yamaguchi 1986) and the canopy closes, conditions favoring great horned owls would disappear. Later, as forests mature, conditions would again favor spotted owls.

The actual area that contained conditions suitable for great horned owls and spotted owls prior to Euro-american settlement is unknown. However, Franklin and Spies (1984) and Booth (1991) have estimated that 60-79% of the prelogging landscape in Western Oregon was old-growth forest. Assuming that the remaining forest landbase was occupied by a mix of forest conditions of unstocked recently burned areas, shrub/forb, sapling, pole, and mature stands, one would speculate that much of the landscape existed in a closed- or semi-closed-canopy condition and thus only a small percentage (10-20%) of the overall forest landbase would be suited for great horned owls. Support for this speculation in the Western Cascades province comes from Spies et al. (1991) who found that as of 1972, 93.4% of wilderness land (unlogged) contained closed-canopy forest. Fire protection in most areas became effective only after 1910 (Agee and Edmonds 1992). Given that natural fire return intervals are long, the effect of 80 years of fire exclusion has been minimal (Agee and Edmonds 1992).

Since Euro-american settlement and particularly in the last 40 years there has been a significant change in the amount of closed-canopy forest in the Western Cascades province (as elsewhere in the Pacific

Northwest). In the present study, random points were located on federal non-wilderness land. Landscapes around random points contained an average of 53.3% old forest; another 13.0% of the random point landscapes contained closed-pole stands. Combined, old and closed-pole forest stands covered approximately 66.3% of the landscape, a total very similar to Spies et al. (1991) who found that as of 1988, 68.4% of the land classified as public non-wilderness contained closed-canopy forests.

Based on responses recorded in this study, great horned owls were approximately 60% as numerous as spotted owls. Older forest (≥ 80 years) within the Oregon Coast Range province has been reduced to the point where some 15.2% of the forest landbase capable of supporting spotted owl habitat actually contains spotted owl habitat (USFWS 1992). Based on surveys conducted in 1990 and 1991, great horned owls in the central Oregon Coast Range province currently outnumber spotted owls approximately 7:1 (K. McGarigal pers. comm.).

Aspects of Predation

Whether predation by great horned owls on spotted owls actually increases with increasing levels of forest fragmentation is difficult to determine. Evidence gathered during this study reveals differences in numbers of great horned owls and spotted owls with increasing levels of fragmentation (Figure 14). Poor habitat conditions for any wildlife species predisposes them to a number of mortality influences, including starvation, diseases, and predation. At the very least, moderate to high levels of forest fragmentation increase spotted owl exposure to great horned owls as spotted owls must move more frequently and greater distances to use remaining suitable habitat in fragmented landscapes.

Spotted owl mortality caused by avian predation is significant: a query of researchers indicated that 40% of adult/subadult and 25% of juvenile radio-marked spotted owls deaths were attributable to avian predation; an additional 25% of 91 adult/subadult and 37% of 60 juvenile spotted owls died of undetermined causes; it seems likely that avian predation was involved in at least some of these deaths as well. Qualitative assessments of habitat conditions surrounding spotted owl avian predation sites have indicated a high degree of fragmentation (G. Miller pers. comm., J. Reid pers. comm., E. Forsman pers. comm., R.J. Gutierrez pers. comm., pers. obs.); this aspect of spotted owls, their avian predators, and landscape characteristics is deserving of further investigation.

In addition to the absolute loss of habitat and changes in the amount of forest edge habitat induced by timber harvest (Appendix C), spotted owls would likely be affected by a number of other landscape influences. Spotted owl roost locations appear to be influenced by weather conditions (Forsman 1976, 1980, Barrows and Barrows 1978). During warm or hot days, spotted owls roost low to the ground in protected cooler environs. During cold periods, spotted owls roost high in tree canopies located along ridgetops, thereby avoiding lower temperatures near the ground while increasing their exposure to solar radiation. During periods of heavy rain or snowfall, the owls frequently perch immediately adjacent to a tree trunk, under a large water/snow-shedding branch (Forsman 1980, pers. obs.). These strategies serve to reduce the metabolic energy expenditure required for thermoregulation. Timber harvest or other disturbances can secondarily impact remaining owl roost areas (e.g., by elimination of key protective areas used during severe storms or by altering wind patterns in drainages) thereby placing a greater energetic drain on the owls. Owls in a weakened condition could be predisposed to mortality agents.

There is concern by some that the active solicitation of spotted owls by calling could increase the potential for opportunistic predation by great horned owls. During this project, there was no indication at any time that active solicitation of spotted owls resulted in a predation attempt by great horned owls. Additionally, a query of researchers has not identified any such predation attempts during any of the research or monitoring efforts in Washington, Oregon, or California to date.

The density, availability, and demography of prey populations likely impacts great horned owls, spotted owls, and influences great horned owl-spotted owl interactions. Bosakowski et al. (1989) examined the nesting ecology of forest-dwelling great horned owls in the eastern deciduous forest biome. They found great horned owl diets to include at least 33 species of birds, mammals, and fish, with nongame birds higher and lagomorphs lower in proportion compared to great horned owl diets in open-country habitats. Great horned owls in their study area also had lower productivity than did owls in open-country habitats. They suggested that the compensatory shift in diet was the result of the generally poor habitat for favored prey species (rabbits and grouse) and may have explained the poor productivity by great horned owls they observed. Although other studies have identified great horned owls as predators of adult and/or young raptors (Bent 1938, Craighead and Craighead 1956, Orians and Kuhlman 1956, Hagar 1957, Houston 1975, Luttich et al. 1971) few have reported such large numbers of raptors (21 individuals of 9 species) taken by great horned owls. Bosakowski et al. (1989) offered that predation on raptors may have been higher than expected in their study area because of the low availability of large prey (rabbits and grouse).

Initial studies on the ecology of spotted owl prey have begun in recent years (Thomas et al. 1990). We know very little about the prey species taken by great horned owls in forested-dominated environments in the Pacific Northwest. Much more work needs to be done regarding the prey of these 2 owl species.

MANAGEMENT IMPLICATIONS

Great Horned Owl and Spotted Owl Surveys

Results indicated that surveys for great horned owls in the Central Oregon Cascades would be most effective between 1 February and 1 April. Additionally, the logistic difficulty of conducting surveys prior to 1 February in the snow-inundated Cascades is of significance. Spotted owl surveys beginning as early as 15 March and extending into August should be effective. Surveys for spotted owls can be conducted any time of night and during all moon phases, whereas surveys for great horned owls would most be effective after midnight and during other than full moon phases. For both owl species, taped calls of both sexes broadcast through an amplifying device (> 5 watts) such as a megaphone were judged to be effective. Use of standardized taped recordings and amplification systems will allow comparability among areas and studies. Survey stations established at ≈ 0.8 km (0.5 mi) apart, straight-line distance provided effective coverage in the Central Cascades regime of topography and road networks. As spotted owls show some avoidance of great horned owls, surveys for great horned owls and spotted owls should not be conducted along the same route during the same night.

A concern frequently expressed by those conducting spotted owl surveys is that the active solicitation of spotted owls could increase the potential for opportunistic predation by great horned owls. Therefore, spotted owl survey efforts have often been discontinued after great horned owls were heard. Based on the observations made during the course of this project and those from other researchers, the discontinuation of spotted owl survey efforts when a great horned owl is heard is not warranted. Surveyors hearing great horned owls during spotted owl surveys should document the great horned owl(s) presence, but can continue to conduct their spotted owl surveys.

Forest Fragmentation and Owls

Two issues are associated with the fragmentation of old forests: the quantitative loss of old-forest habitat and the associated species, and the qualitative loss of habitat resulting from the reduced capacity of remaining patches to support old-forest conditions and wildlife communities. Great horned owls are a key predator on spotted owls; as old forests are harvested, great horned owls occupy the fragmented landscape, with the result that spotted owls not only lose habitat, they also gain an effective predator.

Thomas et al. (1990) developed the first scientifically credible conservation strategy for the spotted owl. Their program called for two basic elements: 1) a reserve network of habitat conservation areas (HCAs) spaced across the landscape, and 2) management of the intervening forest matrix such that it will allow successful dispersal of spotted owls between HCAs. Because of past harvest, the majority of the identified HCAs are fragmented and often contain < 60% older forest. Great horned owls have regularly been found within and adjacent to HCAs (this study). Additionally, observations made during the present study indicated that the majority of great horned owls were located above 945 m (3100′). A conservation program for spotted owls emphasizing reserves at higher elevations may inadvertently support great horned owl numbers and in so doing maintain or promote a key predator on spotted owls.

Are there any management practices which would lead to greater security for spotted owls within the HCAs? Great horned owls are primarily open-country and semi-forested birds; they are perch-and-pounce hunters, strong but not particularly agile flyers (Cottam et al. 1942, Baker 1962, Caire and Ports 1981, but see Duncan and Lane 1988), have relatively heavy wing loading (this study); within forested and semi-forested landscapes they have shown strong utilization of forest edges for foraging, roosting, and nesting (Frounfelker 1977, Fuller 1979, Bosakowski et al. 1989). Observations during the course of this study indicated few great horned owls in closed-canopy forest situations. Management practices that open the forest canopy (shelterwood, thinnings, clearcuts) would encourage continued (or greater) use by great horned owls. Management practices focused on achieving and/or maintaining canopy closure would disfavor great horned owls. As currently young stands (e.g., 1-10 yr old plantations) within HCAs develop and their canopy closes, the availability of terrestrial prey to great horned owls will decline. As all (or the majority) of the stands within the HCAs acquire canopy closure, great horned owl numbers will likely diminish in the HCA landscape.

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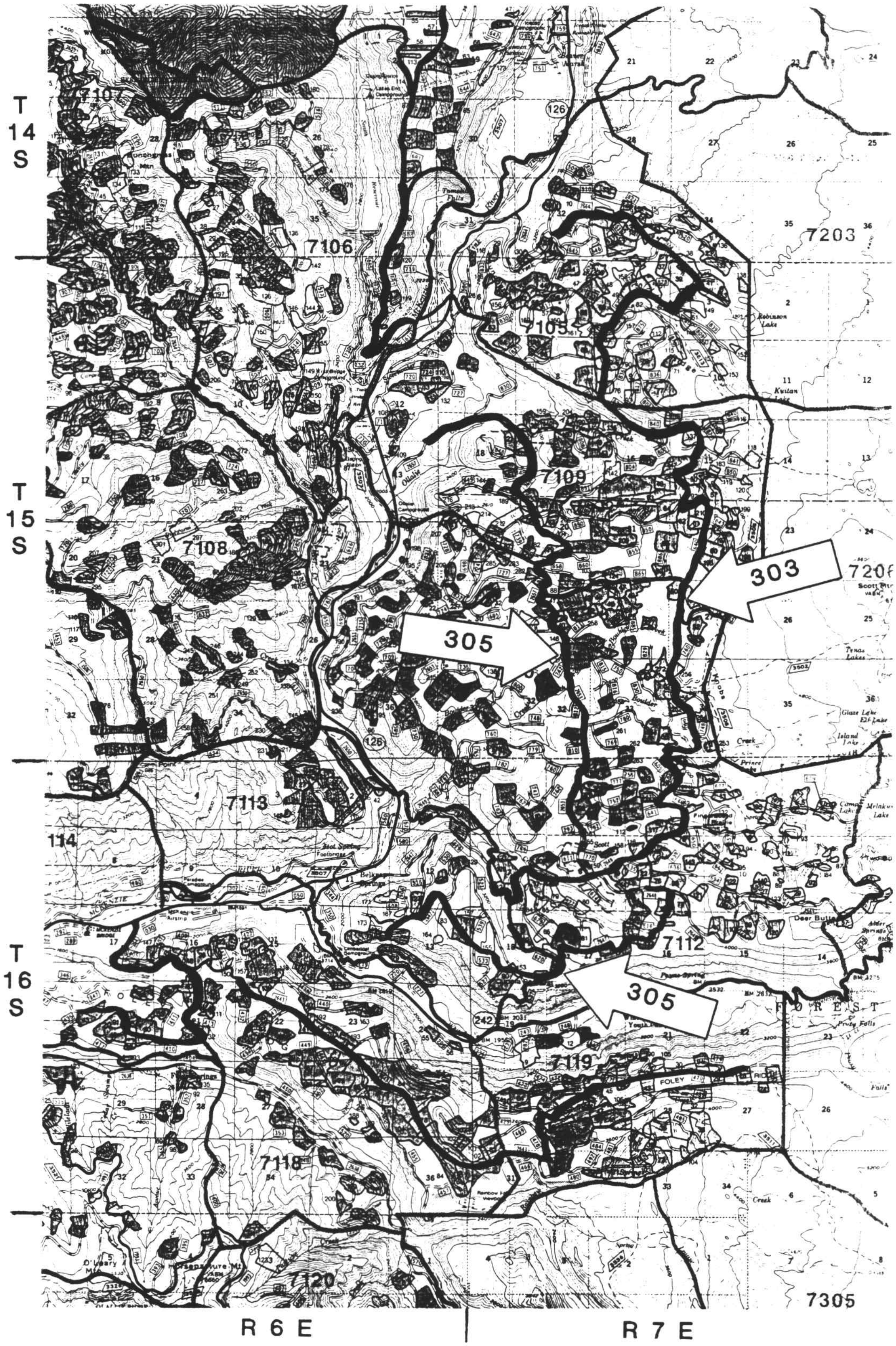
APPENDICES

APPENDIX A. Summary list and maps for the 28 routes in the Central Oregon Cascades, along which survey efforts for great horned owls and spotted owls were conducted during 1989 and 1990.

Route Reference Number	Route Name	Number of Calling Stations	Length (km)	Census Year
101	Ennis Creek	8	9.0	1989
102	Vanilla Leaf	9	10.7	1990
103	Hagan Block	23	25.0	1989
104	Wolf Rock	16	15.5	1989
105	Rush Creek	22	31.2	1989
106	Quentin Creek	23	25.8	1990
107	1501 Road	22	22.4	1990
108	500/502 Road	6	7.2	1990
201	Goodman Creek	22	37.3	1989
202	Winberry Creek	22	22.1	1989
203	Slick Creek	12	13.3	1989
204	Patterson Mtn.	24	29.8	1990
205	Tire Creek	9	11.7	1990
206	Armet Creek	16	18.9	1990
207	Gilbralter Mtn.	10	12.8	1990
208	Delp Creek	15	19.8	1990
301	Horse Creek	14	11.2	1989
302	Foley Ridge	15	15.0	1990
303	Bunchgrass Ridge	26	29.3	1989
304	Smith Reservoir	19	17.4	1990
305	Cupola Rock	21	22.4	1990
401	Highway 20	26	27.2	1989
402	Cascadia	18	18.2	1989
403	Straight Creek	10	11.4	1990
404	Parish Lake	12	13.6	1990
405	N. Fk. Parks Creek	21	25.1	1990
406	Sheep Creek	12	14.1	1990
407	Swamp Mtn.	16	18.4	1990
	Total	469	535.8	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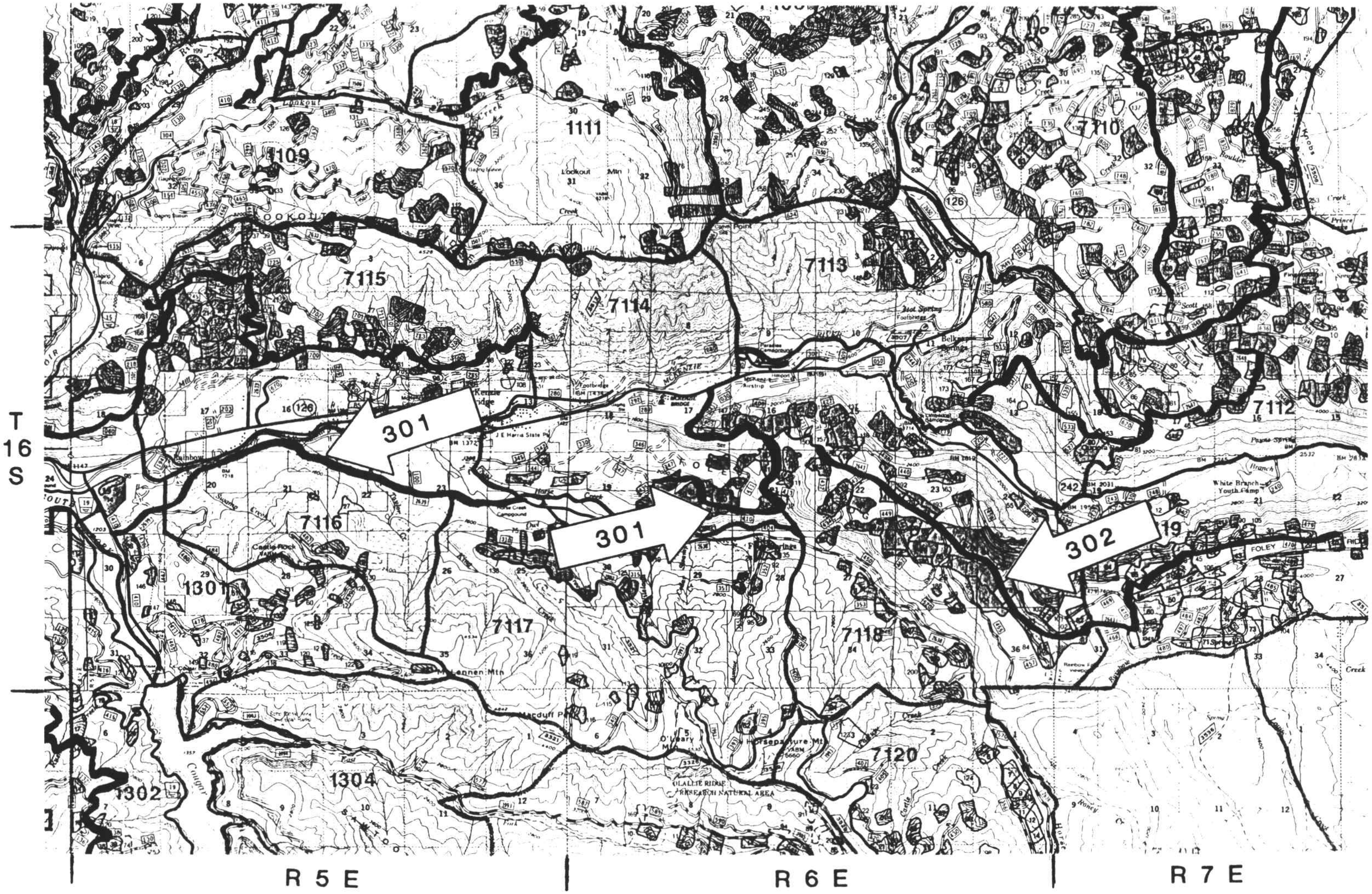
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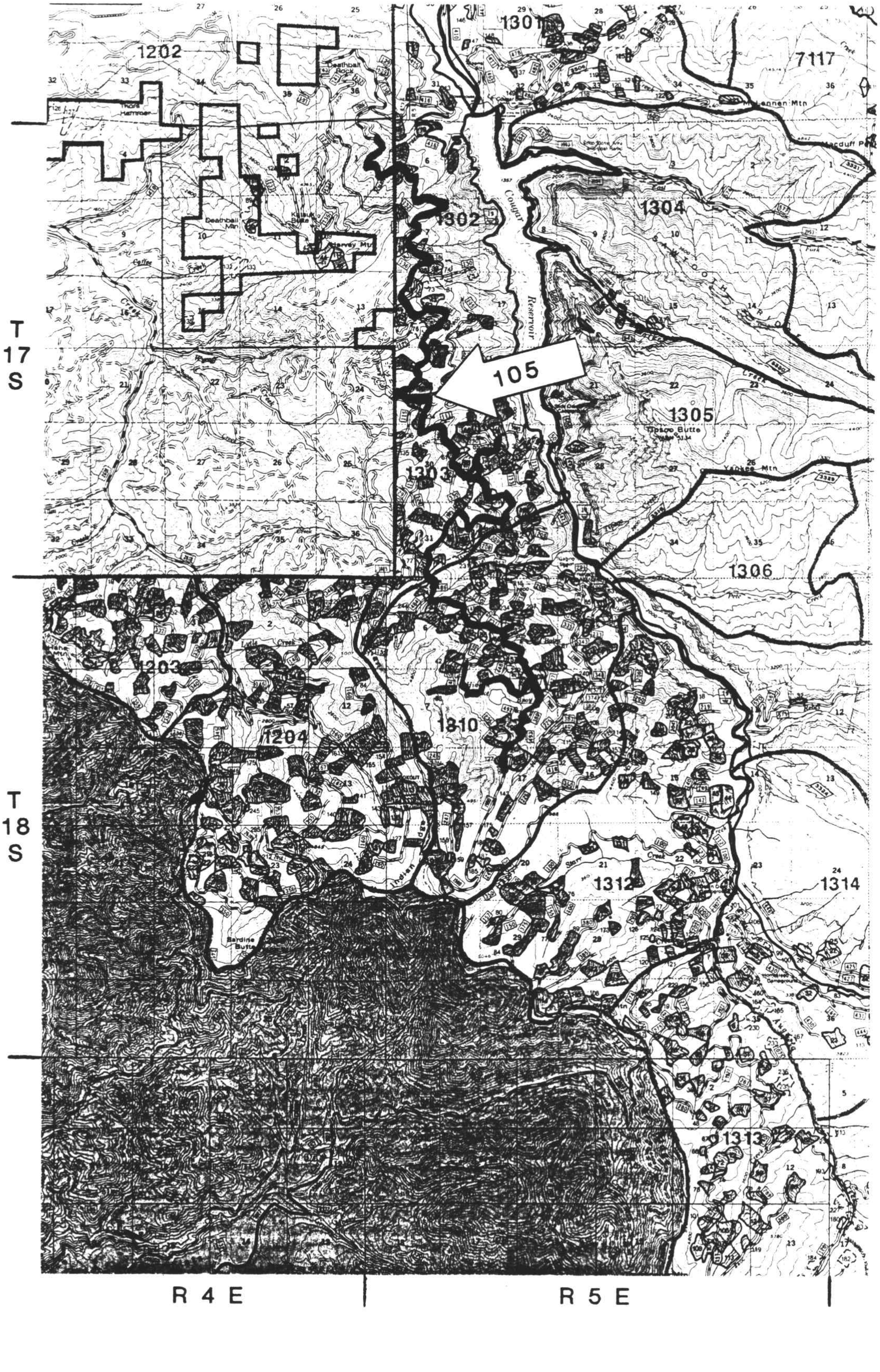
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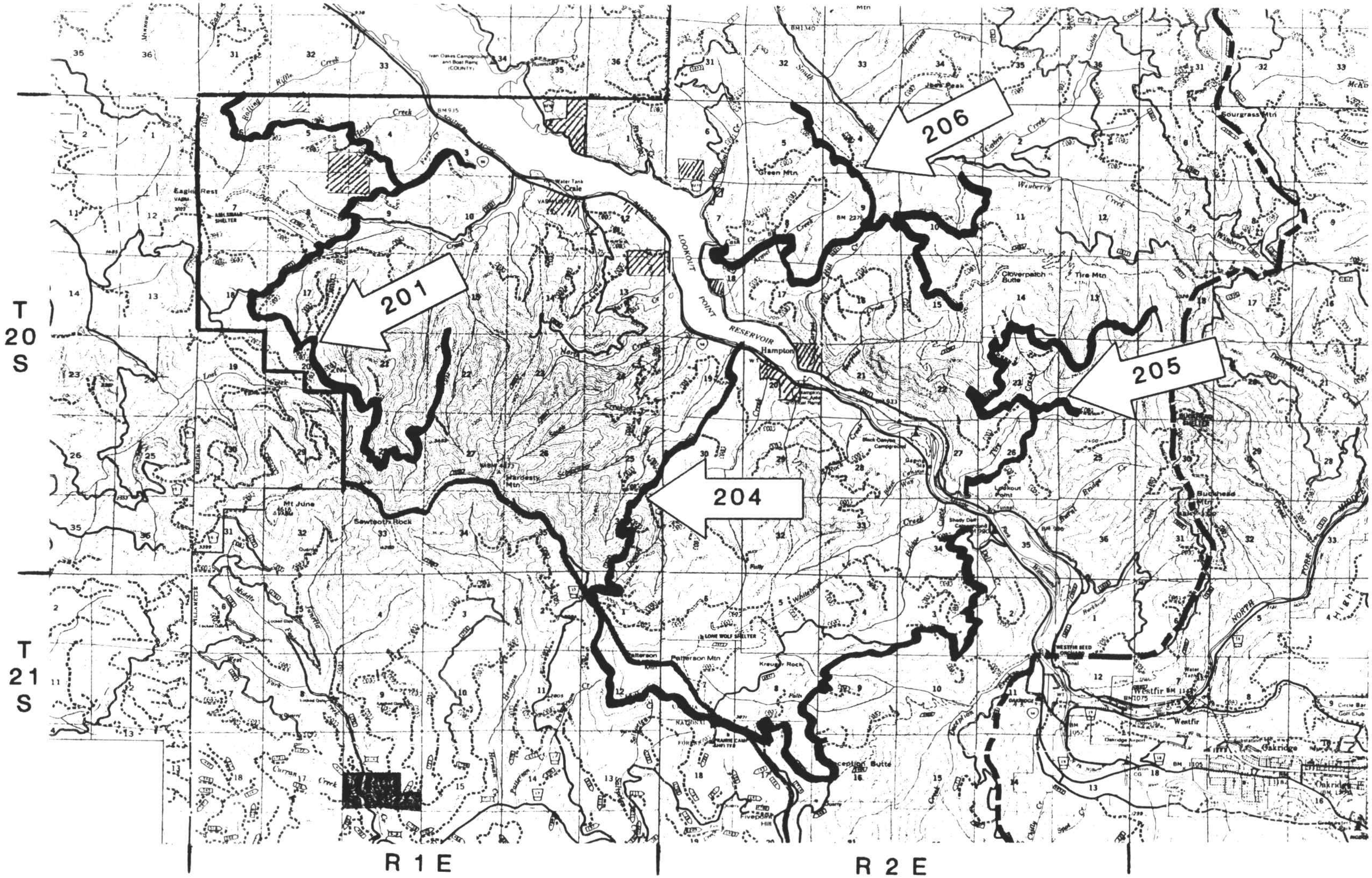
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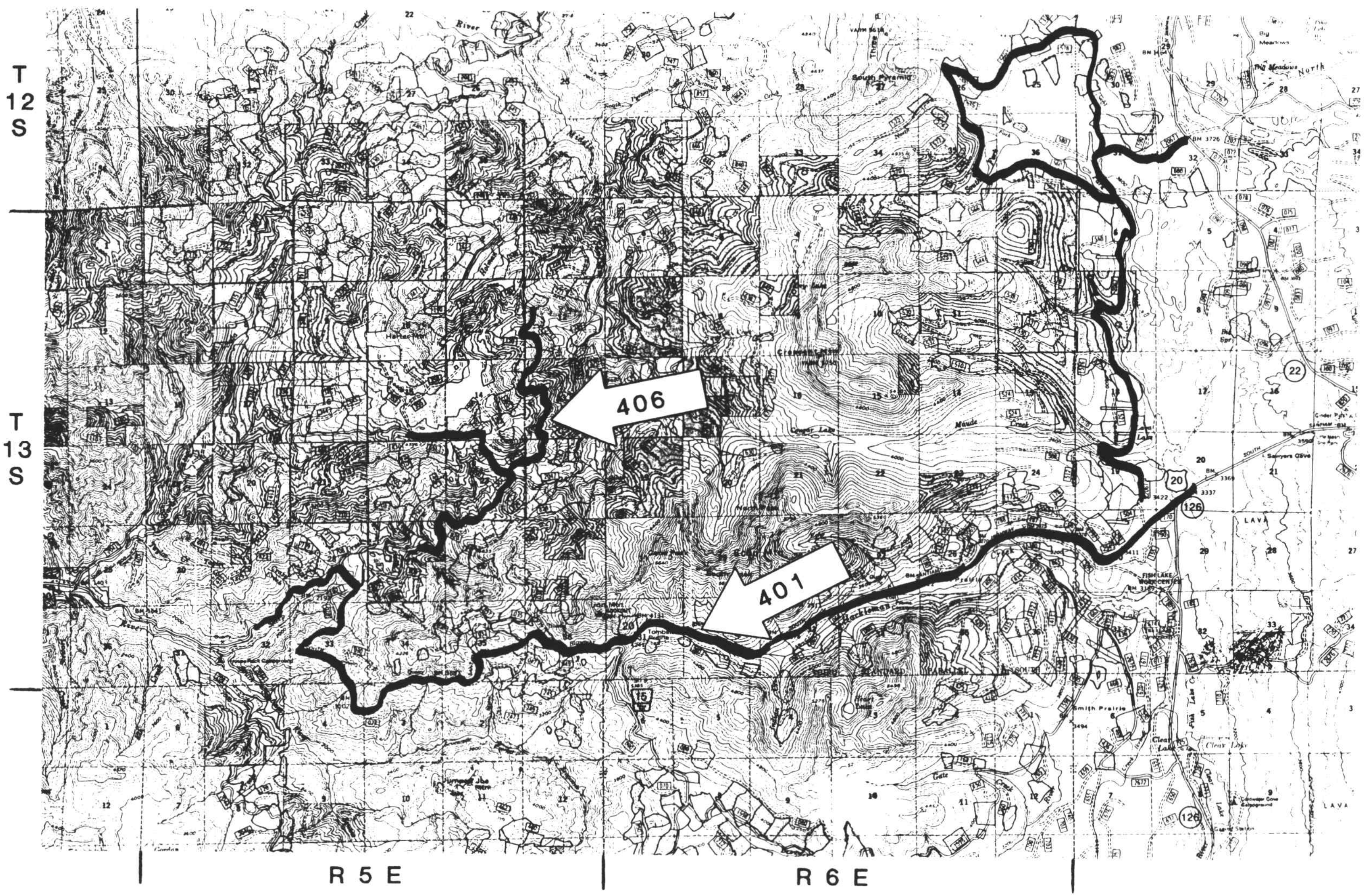
Eagle Rest
Green Mtn
Cloverpatch Butte
Tire Mtn
Sourgrass Mtn
Mt June
Sawtooth Rock
Patterson Mtn
Kreuger Rock
LONE WOLF SHELTER
Buckhead Mtn
Westfir
Oakridge
NORTH FORK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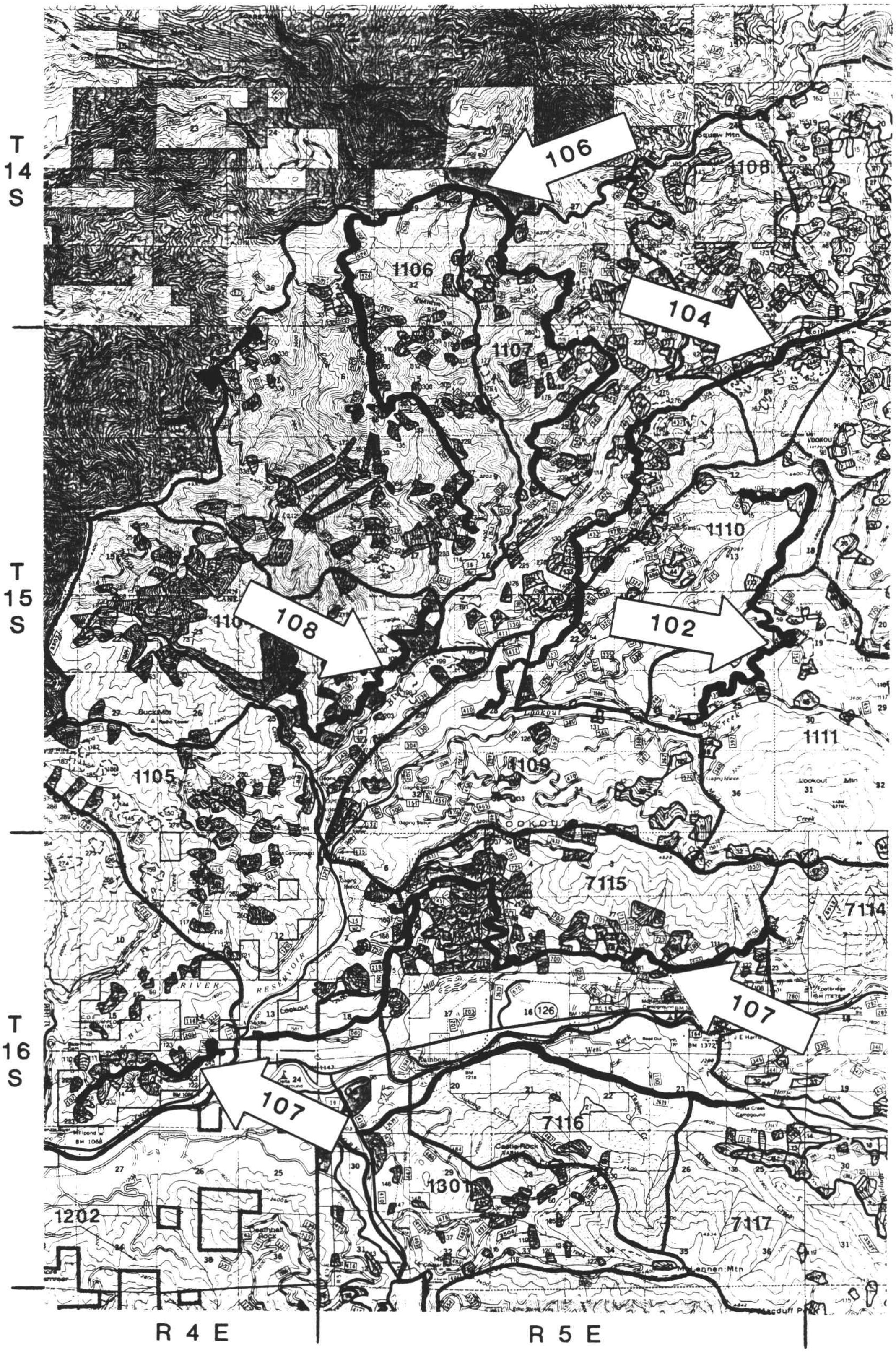
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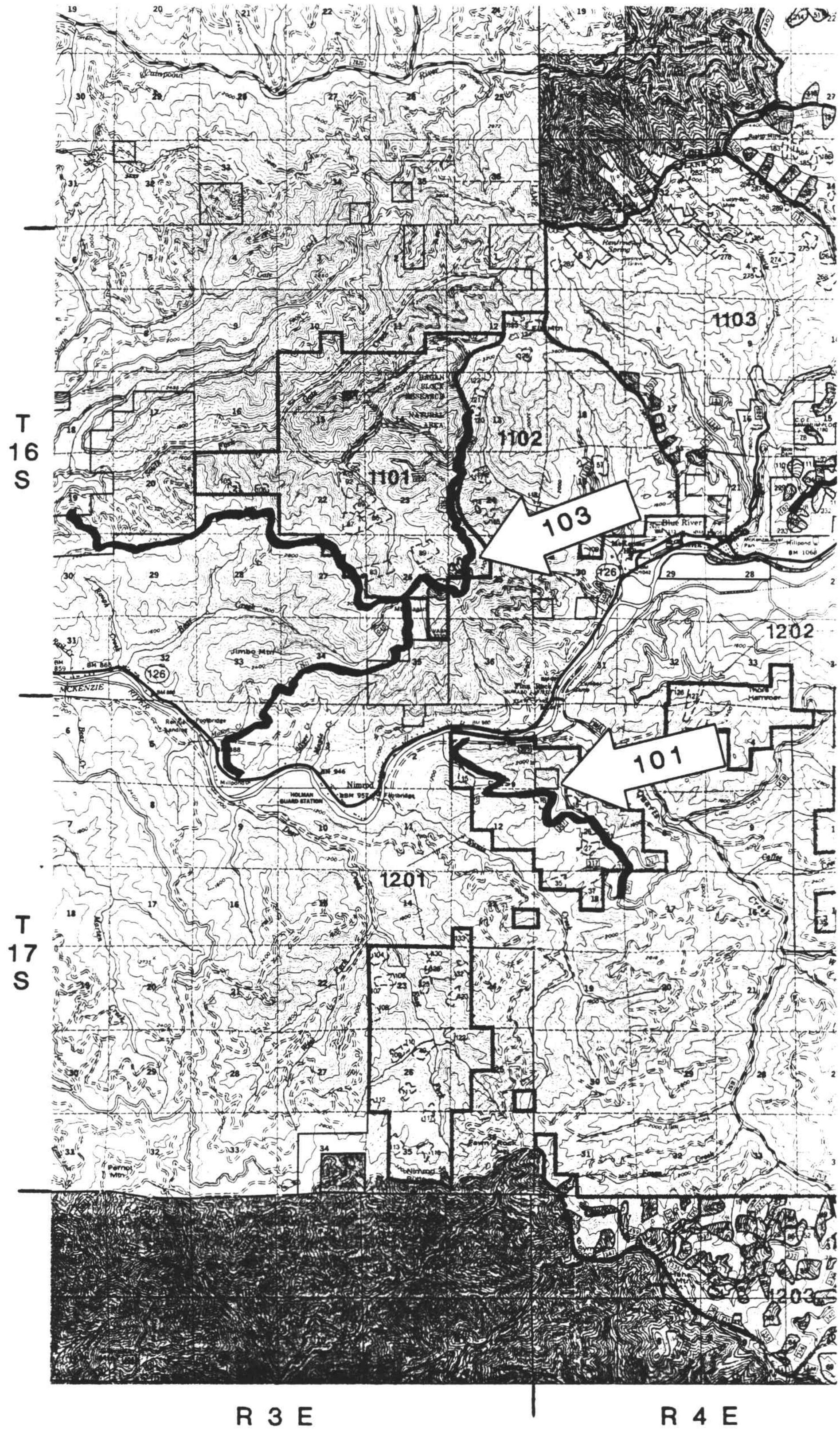
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Jimbo Mtn
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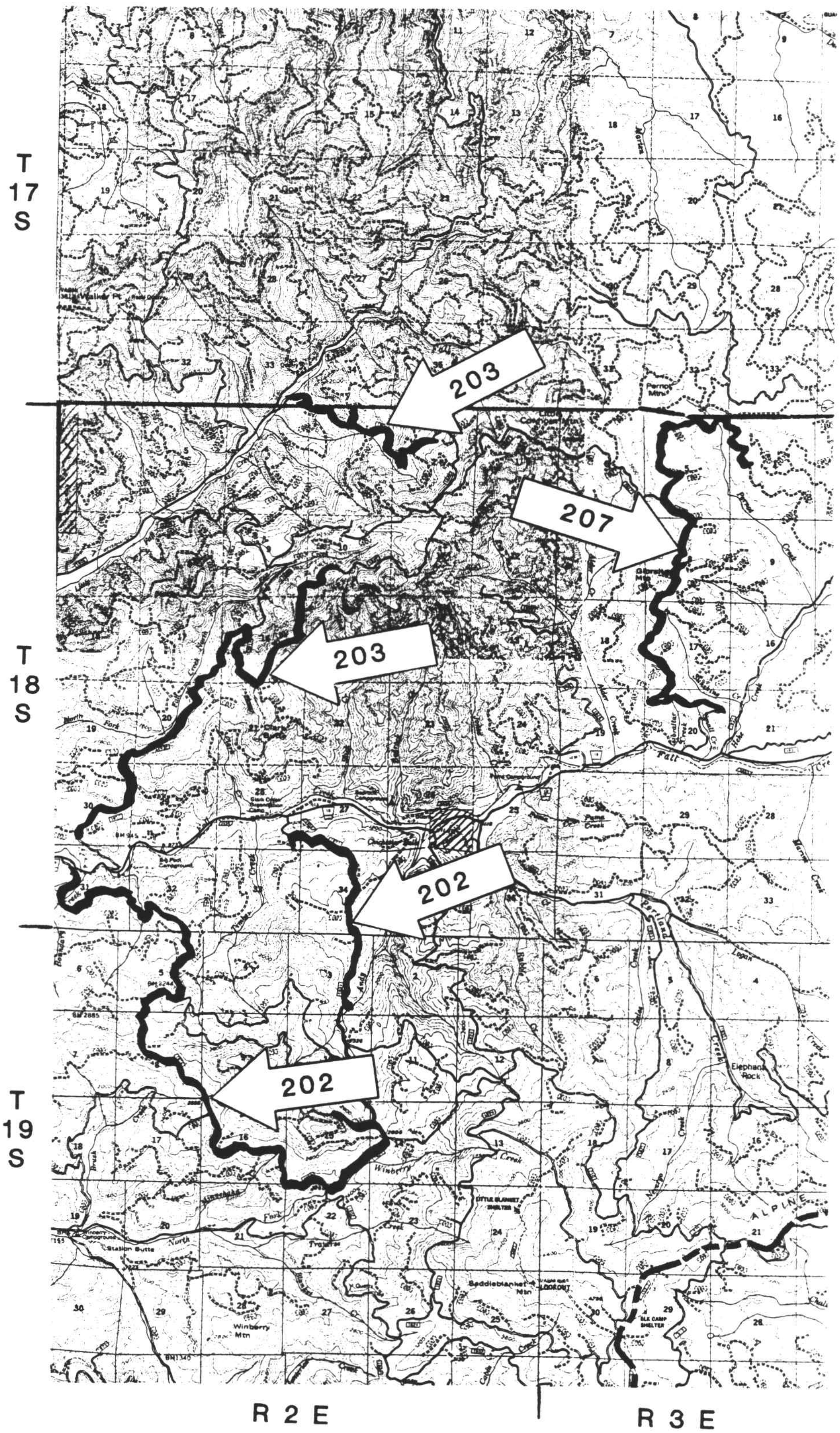
HOLMAN GUARD STATION
McKENZIE
126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203
207
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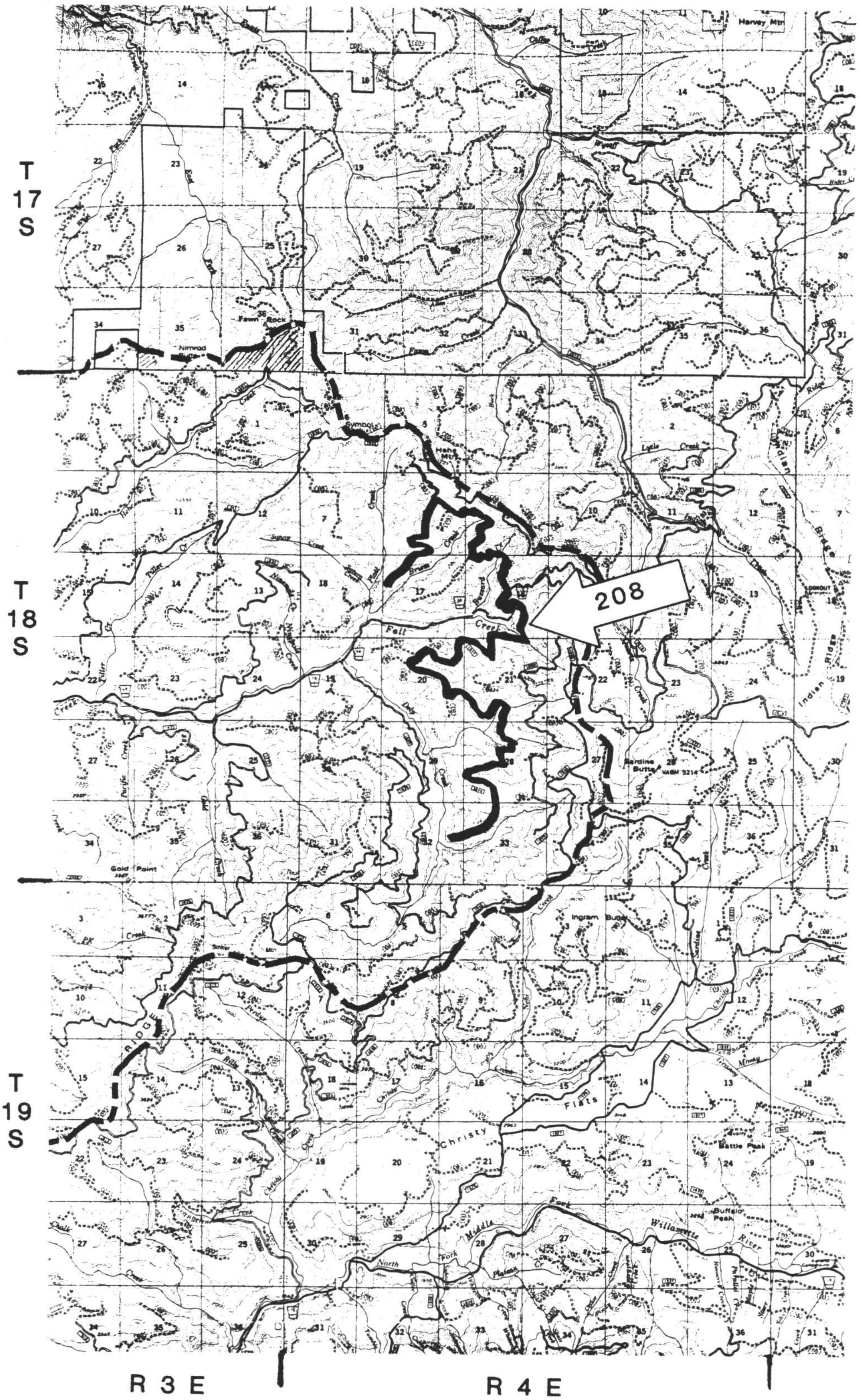
Winberry Mtn
Station Butte
Saddleblanket Mtn
LITTLE BLANKET SHELTER
ELK CAMP SHELTER
Fall Creek
ALPINE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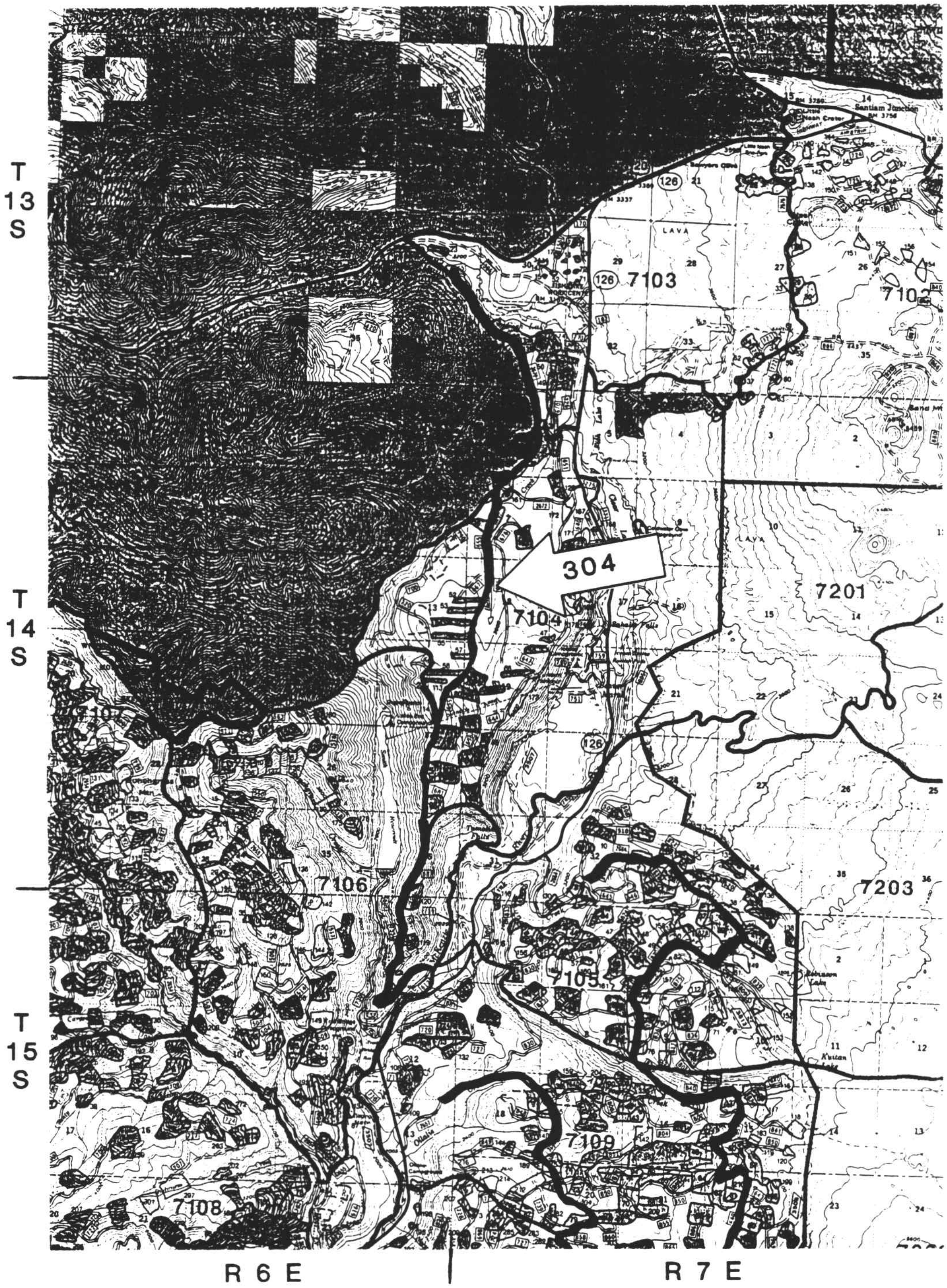
208
Fall Creek
Christy
Flats
Sardine Butte
Ingram Butte
Battle Peak
Buffalo Peak
Harvey Mtn
Gold Point
Nimrod
Fawn Rock
R 3 E
R 4 E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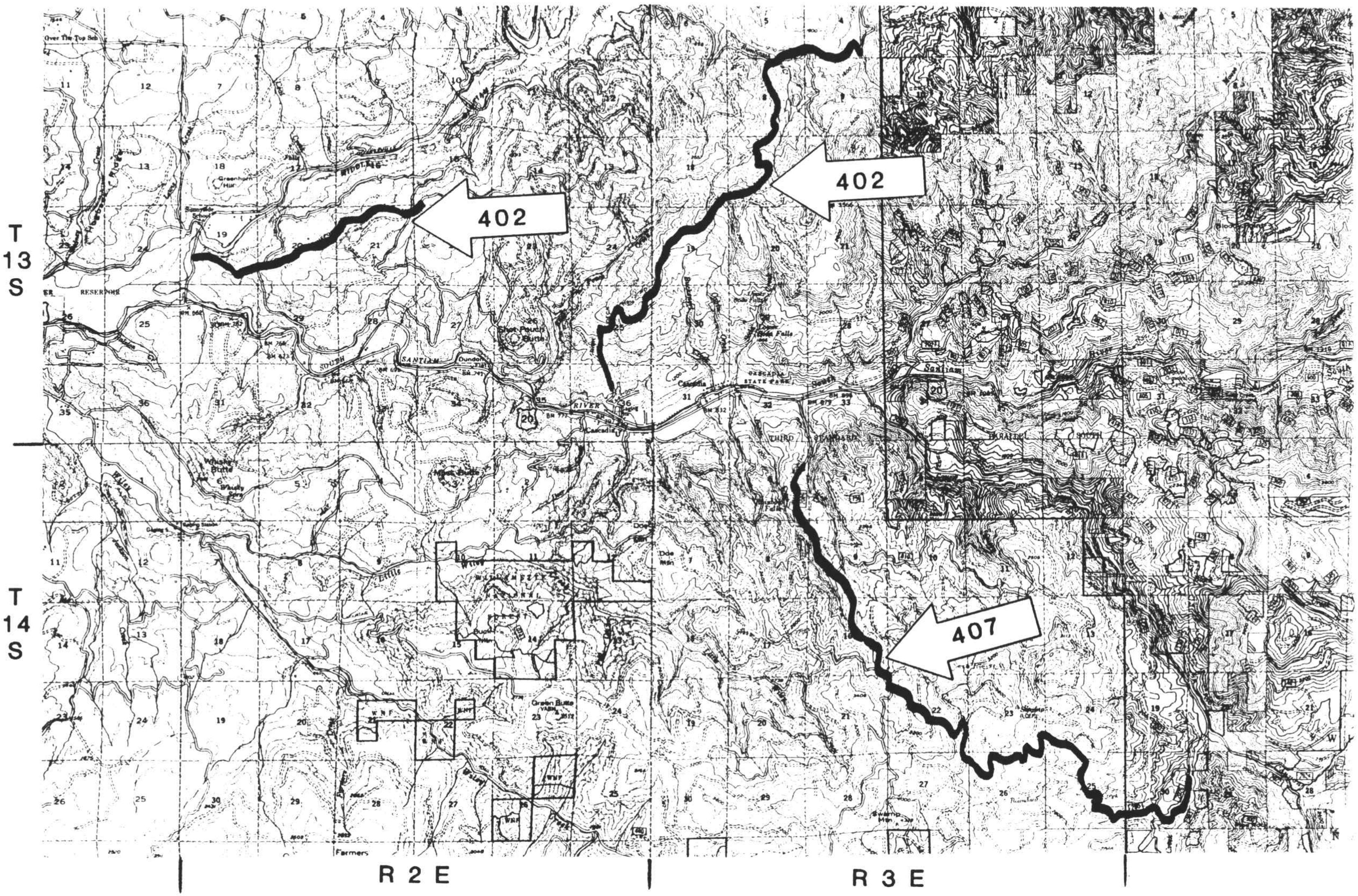
LAVA
Santiam Junction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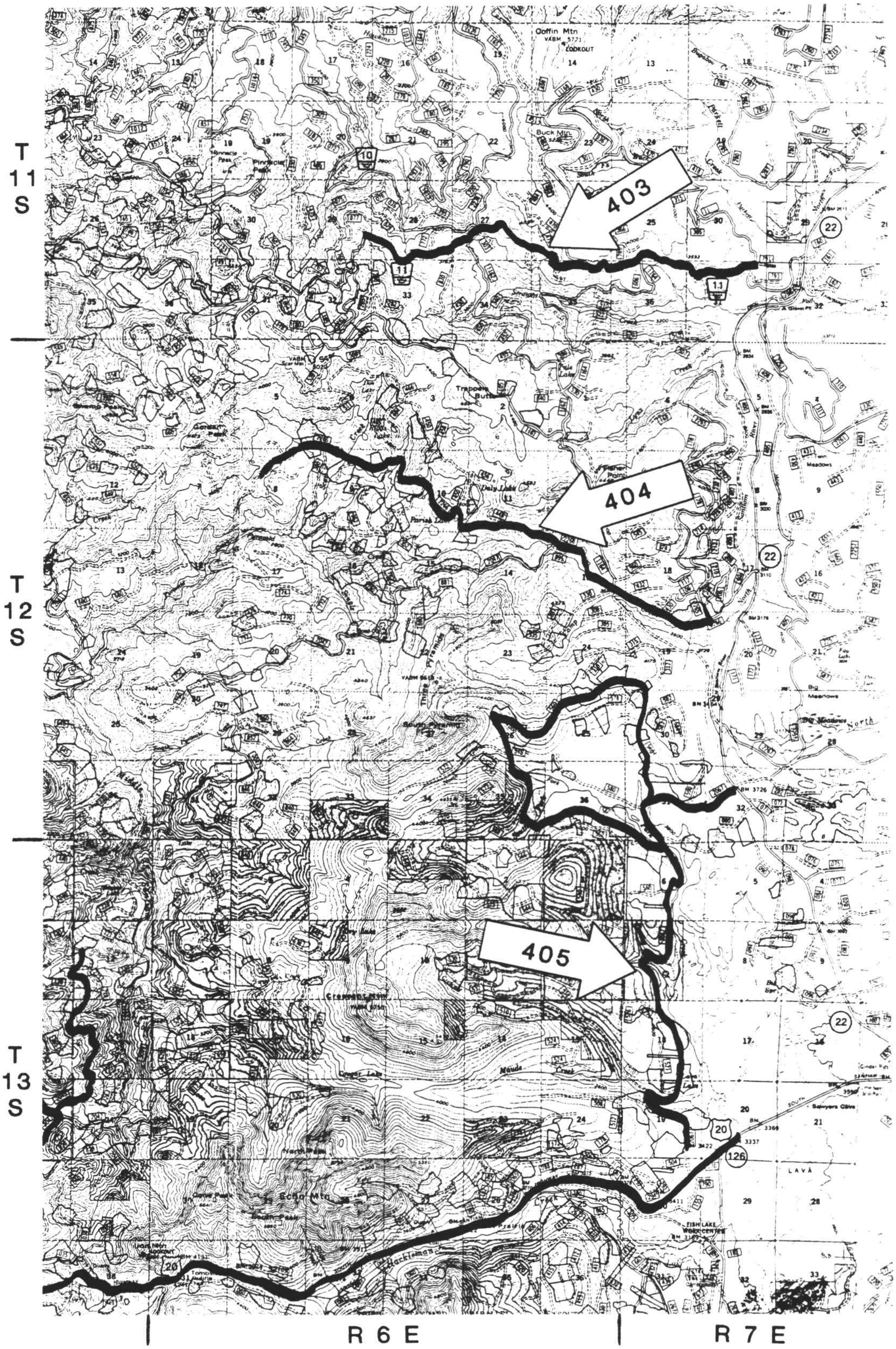
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Coffin Mtn
Buck Mtn

APPENDIX B. Example of the data codes and field form used during great horned owl and spotted owl survey efforts in the Central Oregon Cascades, 1989 and 1990.

OWL CENSUS CODES — DAVID H. JOHNSON

Date	Month, Day, Year
Rt. #	District and route number: Blue River = 1__ Lowell = 2__ Mckenzie = 3__ Sweet Home = 4__
Visit	Number of times route has been visited
Statn #	Station number along route
Temp (F)	Temp taken every 5th station
Precip	1) none 2) light rain 3) moderate rain 4) light snow 5) moderate snow
Clouds	1) 0-10 % cover 2) 11-20 % 3) 21-30 % 4) 31-40 % 5) 41-50 % 6) 51-60 % 7) 61-70 % 8) 71-80 % 9) 81-90 % 10) 91-100 %
Moon	Phases are 3 days either side of published phases: 1) new moon 2) 1st qtr 3) full moon 4) last qtr
Time	Time at start of census at each station
Res Time	Minutes from start of broadcast to owl response
Species	1) Great Horned 2) Spotted 3) Barred 4) W. Screech 5) Pygmy 6) Saw-whet 7) Long-eared 8) Great Gray 9) unknown
Sex	1) male 2) female 3) unknown
Res Type	Type of owl response: 1) no response 2) visual only 3) bird called within 100 m 4) bird called > 100 m, then moved in 5) bird called > 100 m, did not move in 6) bird responded from unknown location 7) unsolicited calling 9)* bird was recorded at a previous station (same night repeat); recorded here for distance only
Repeat	1 = 1st observation on this bird 2 = 2nd observation on this bird 3 = 3rd observation on this bird etc.

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APPENDIX C. Edge Effects and the Northern Spotted Owl.

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INTRODUCTION

The edge ecotone (hereafter referred to as edge) is inferred as being important to northern spotted owls (*Strix occidentalis caurina*); can "edge effect" be described in terms of real distances? Selection for, avoidance, or neutrality of edge can be demonstrated through examination of owl telemetry and nest locations. Appropriate telemetry and nest site databases have been gathered through efforts conducted from 1987-1991 by the Oregon Cooperative Wildlife Research Unit, as part of a larger density and demographic study on the spotted owl in the Central Cascades of Oregon.

If spotted owls are a forest interior species they should demonstrate an avoidance of edges. This avoidance should be exhibited in nighttime and daytime activities, and nest site location. Two evaluations were undertaken to examine the relationship of spotted owls with edges: (1) a comparison of distance-to-edge measurements on night (foraging) and day (roost) locations with random locations within the home ranges of 13 radio-marked owls; and (2) a comparison of distance-to-edge measurements of nest site and random locations.

STUDY AREA

The study area lies on the western slope of the Cascade Range in Linn and Lane Counties in central Oregon (43°50′- 44°30′ N, 121°55′- 122°40′ W). Specifically, the study area includes the Sweet Home, Blue River, Mckenzie, and Lowell ranger districts on the USDA Forest Service (USFS) Willamette National Forest. The 80-km (north-south) by 60-km (east-west) study area falls within portions of the western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), and mountain hemlock (*Tsuga mertensiana*) zones with the major tree species consisting of Douglas-fir (*Pseudotsuga menziesii*), western hemlock, Pacific silver fir, noble fir (*Abies procera*), and western redcedar (*Thuja plicata*) (Franklin and Dyrness 1973). Elevation ranges from 300 to 1,600 m. The topography is well dissected with an abundance of steep slopes. The climate is maritime. Annual precipitation averages 230 cm at low and 330 cm at high elevations. Winter snowpack ranges from 1 to 4 m above 500 m elevation.

Approximately 40% of the study area has been logged during the last 60 years, with staggered-set clearcutting the prevalent harvest practice. Roughly 5% of the study area is comprised of scattered, privately-owned lands which are managed for timber production.

METHODS

Telemetry and Random Points Within Owl Home Ranges

Spotted owls were located using nocturnal and diurnal calling surveys (Forsman 1983) between 1 April and 30 August from 1987 through 1991. We captured owls using a noose pole, and all individuals were banded with a U.S. Fish and Wildlife Service leg band on 1 leg and a colored, plastic leg band on the other leg. Thirteen owls (7 male, 6 female) were fitted with radio-transmitters using the back-pack mount technique (Forsman 1983). During each week, we obtained 3-5 nighttime locations (triangulations) and 1 daytime location from the owls. We obtained only 1 location per night, and avoided locating individual owls at the same time each night. Owl locations were gathered during a 16 month period. Radio-transmitter signal strength and directionality were subjectively evaluated. Poorly directional signals were not used in triangulation. Bearings were taken from different locations until 3 or 4 strong, directional bearings were obtained; these were plotted on 1:24,000 USGS orthophoto quadrangle maps. We retained locations only if the triangulation polygon was < 8 ha. After daytime triangulations, owls were located visually to assess the accuracy of triangulation data and to identify those areas where radio signals were misleading. Daytime locations (n = 154) averaged 76 ± 8 (SE) m from the actual location of the owl. Home range boundaries were determined using the Minimum Convex Polygon (MCP) method (Haynes 1949) and were based on > 200 locations for each owl.

Fifty (50) night and 50 day locations were randomly selected from each owls' home range for analysis. Only those telemetry locations where either visual contact was made or where the triangulation polygon error size was < 1 ha were used. For 11 of the owls, only 27-49 day locations had been acquired and were available for analysis. Fifty (50) random points were selected within each of the 13 owl home ranges.

Distance-to-edge measurements were determined to the nearest 10 m from 1:24,000 USGS orthophoto quadrangle maps, and represent horizontal distances. Given that slopes in the study areas commonly range from 40 to 70%, these distances are conservative measures of actual field distances. Distance-to-edge measurements from owl telemetry locations and random points falling in old forest stands were recorded as positive numbers, those falling in other than old forest were recorded as negative numbers. All distance-to-edge measurements from owl locations and random points within the 13 home ranges were combined for analysis, thus offering pooled sample sizes of distance-to-edge measurements from 650 night locations, 509 day locations, and 650 random points.

Nest Sites and Random Points Within the Larger Study Area

Nest sites were located by feeding 3-4 live mice to individual owls located during diurnal surveys (Forsman 1983). Typically, mice were fed to the male owl, who would deliver the mice to the female at the nest site. During the study period, from 1 to 3 nest sites were located in each of 51 owl territories. All nest sites were located on USFS lands. Only 1 nest site from each territory was used in the analysis; a single nest site was selected at random from those territories having more than 1 nest site. One-hundred (100) random points were selected within the larger study area. All random points were located on USFS land designated as "general forest," and none were in wilderness areas, roadless areas, research natural areas, lava flows, or water.

All owl telemetry locations, nest sites, and random points were plotted on USGS orthophoto quadrangles (scale 1:24,000). We used aerial photographs and a zoom transfer scope to update the orthophotos to show recent roads and timber cutting. Field inspections and timber sale maps were used to update maps for cutting that took place after 1988. We classified stands ≥ 2 ha into 3 categories: those stands containing mature/old-growth forest (hereafter old), those stands containing other than old forest (hereafter young), and areas of non-habitat (reservoirs, lakes). Young stands typically were composed of shrub/forb, sapling, closed-pole, or open-pole stands.

For the purposes of this project edge was defined as the junction of old stands with young stands, or with non-habitat. Within the study area edges were sharply defined, reflecting forest management. Young forest stands or non-habitat areas had to be ≥ 2 ha in size and > 100 m wide at the narrowest point before an edge ecotone was deemed present in the adjacent old stand. Roads were not considered edges as road openings were less than 100 m wide.

Chi-square analysis was used to determine if increments of distance-to-edge measurements from owl locations and nest sites were significantly different than distance-to-edge measurements from random points.

RESULTS and DISCUSSION

Comparison of Owl Locations and Random Points Within Owl Home Ranges

By comparing observed use vs. expected use (night and day locations vs. random points within owl home ranges) strong selection for old forest stands was shown (Figure 1). This is consistent with results from other spotted owl habitat studies (see review by Thomas et al. 1990). These data also reveal preferential selection for locations within these old stands (Figure 1). Mean distances into old stands were 141 m for night locations, 201 m for day locations, and 67 m for random points. Night and day locations were both significantly farther into old forest stands than were random locations ($P < 0.01$). During both day and night the owls very strongly avoided young stands - only 2 of 509 (0.4%) day and 26 of 650 (4.0%) night locations were in young stands. The owls used the old forest differently during the night and day. During the night the owls foraged up to an edge but preferred areas > 90 m from an edge. During the day they avoided areas < 60 m and preferred areas > 90 m from an edge. Eight-eight percent of day and 66% of night locations were ≥ 100 m into old forest stands. Stand size in the telemetry study area is difficult to measure at this point in time, as the uncut natural old forest is still the matrix with logged patches embedded in it, as compared to most private lands where the logged areas are the matrix and the older stands are the patches.

Comparison of Nest Sites and Random Points

Distance-to-edge measurements were assessed for 51 nest and 100 random sites within the larger Central Cascades study area. All 51 nest sites were located in old forest stands, and as with telemetry locations, owls revealed preferential selection for nest site locations within old stands (Figure 2). Mean distances into old forest stands were 260 m for nest sites and 128 m for random points (Table 1). Nest sites were significantly farther into old forest stands than were random points (P = 0.01). Although 5 nests (10%) were located < 90 m from an edge, owls preferred nest sites located > 90 m from an edge. Eight-four percent (84%) of nests were located ≥ 100 m into old forest stands, whereas 43% of random points were ≥ 100 m into old forest stands.

SUMMARY

Distance-to-edge measurements derived from 1,159 telemetry locations and 51 nest sites indicated that owls avoided young stands and preferentially selected locations within old forest stands. Owl telemetry and nest locations were consistently farther into old forest stands than were randomly selected points (P ≤ 0.01). Although owls may forage up to an edge, they prefer areas ≥ 90 from an edge during the night. For daytime roost locations and nest sites, owls have indicated a decided preference for locations ≥ 100 m from an edge into old forest stands. Based on determinations presented here, researchers and managers concerned with edge should use an effective "edge effect" distance of ≥ 100 m for northern spotted owls.

LITERATURE CITED

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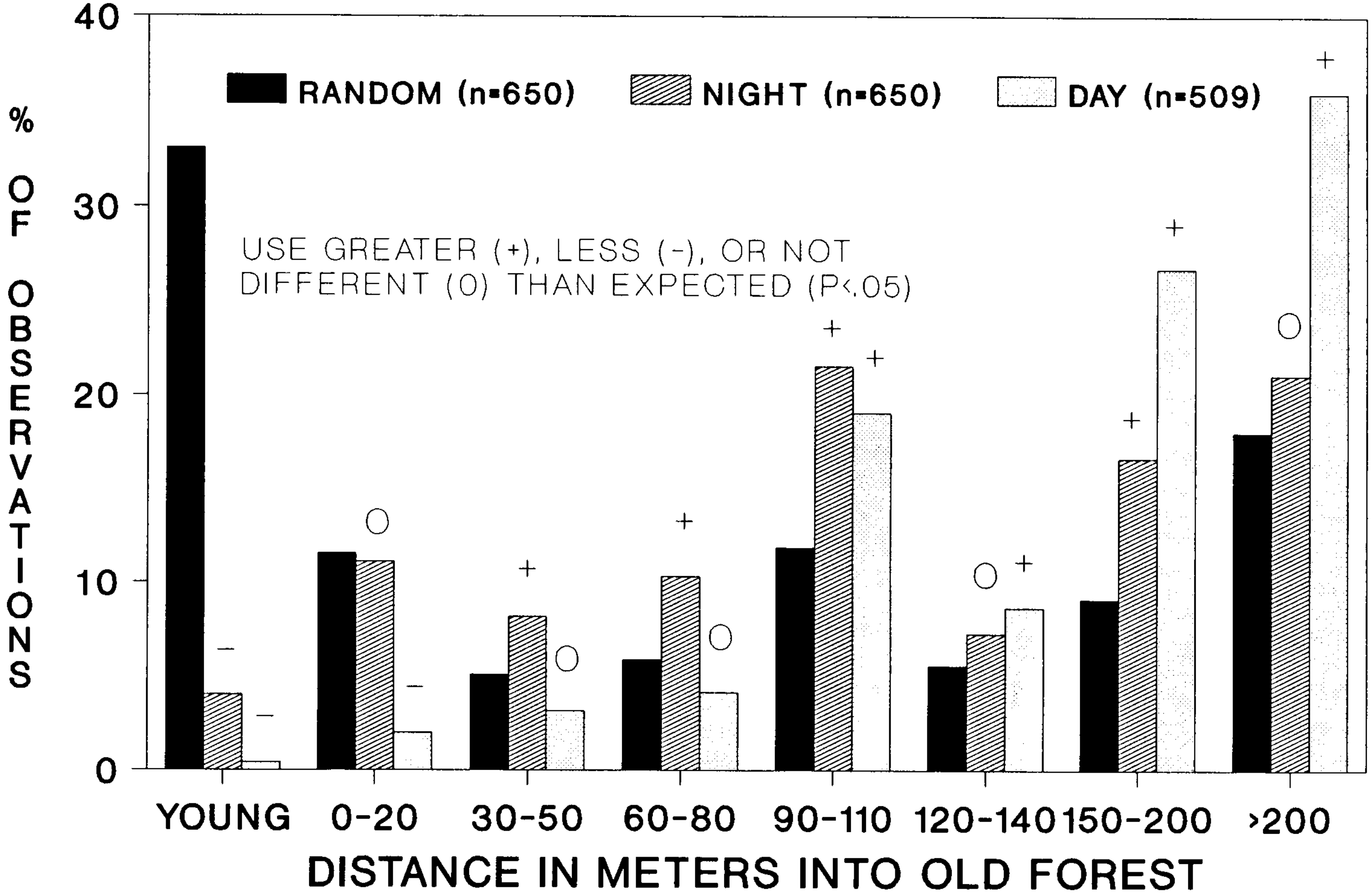

Figure 1. Edge use by 13 spotted owls as compared to random locations within their home ranges.

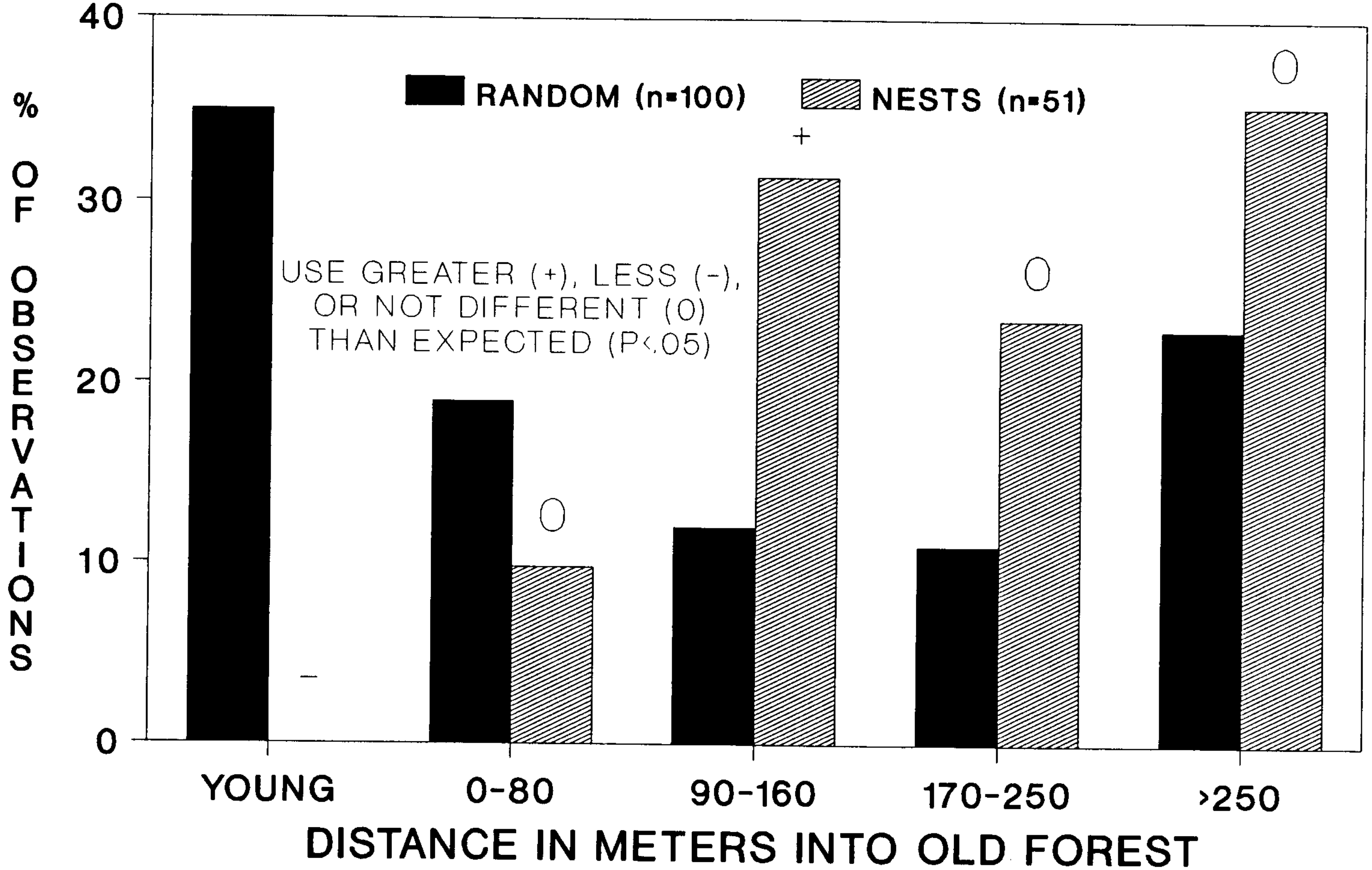

Figure 2. Distance to edge from spotted owl nest sites and random points in the Central Cascades study area.

Table 1. Distance-to-edge measurements (in meters) for night, day, nest, and random locations.

Data Type	n	x	SE	Range
Owl telemetry, night[a]	650	141	6	-400 - 900
Owl telemetry, day[b]	509	201	6	-50 - 800
Random within owl home range[c]	650	68	7	-700 - 800
Owl nest sites[d]	51	260	31	30 - 1150
Random within larger study area	100	127	33	-730 - 1450

[a] 50 nighttime telemetry locations from each of 13 spotted owls' territories; triangulation polygon < 1 ha.

[b] 36-50 day telemetry locations from each of 13 spotted owls' territories.

[c] 50 random locations from within each of 13 spotted owls' territories.

[d] Only one nest per owl territory used in analysis.

APPENDIX D. Plot scores and midpoint values derived from 500-ha simulated landscapes used to establish minimum and maximum fragmentation parameters for real landscapes containing 0-100% old forest.

Percent of old forest within 500-ha circular plot	Plot Score with old forest in "dispersed" arrangement	Plot Score with old forest in "clumped" arrangement	Midpoint value as derived from regression equation
0	-2395	NA[a]	0
1	-968	-1735	-1459
2			-1371
3			-1292
4			-1222
5	-682	-1509	-1159
6			-1103
7			-1051
8			-1004
9			-962
10	-478	-1162	-922
11			-886
12			-853
13			-821
14			-793
15			-766
16			-741
17			-717
18			-695
19			-674
20	-269	-1007	-655
21			-636
22			-619
23			-602
24			-586
25	-184	-941	-571
26			-557
27			-544
28			-531
29			-519
30			-507
31			-496
32			-485
33			-475
34			-465
35	-168	-775	-456
36			-447
37			-438
38			-430
39			-422
40			-414

APPENDIX D. (cont.)

41			-407
42			-399
43			-393
44			-386
45			-379
46			-373
47			-367
48			-361
49			-355
50	100	603	352
51			355
52			361
53			367
54			373
55			379
56			386
57			393
58			399
59			407
60			414
61			422
62			430
63			438
64			447
65	168	775	456
66			465
67			475
68			485
69			496
70			507
71			519
72			531
73			544
74			557
75	184	941	571
76			586
77			602
78			619
79			636
80	269	1007	655
81			674
82			695
83			717
84			741
85			766
86			793
87			821
88			853
89			886
90	478	1162	922

APPENDIX D. (cont.)

91			962
92			1004
93			1051
94			1103
95	682	1509	1159
96			1222
97			1292
98			1371
99	968	1735	1459
100	NA[a]	2395	0

[a] measurements do not apply as 0% old forest indicates a completely "dispersed" landscape; likewise, 100% old forest indicates a completely "clumped" landscape.

APPENDIX E. Observations of great horned owl and spotted owl interactions in the Central Oregon Cascades, 1989 and 1990.

During survey efforts in 1989 and 1990 I recorded 475 responses from the 2 owl species (282 responses from spotted owls and 193 responses from great horned owls). On 5 occasions both owl species were recorded within 500 m of one another during the same night. In these situations, 1 or 2 members from both of the owl species (e.g., a pair of spotted owls and male great horned owl) vocalized, typically within a few minutes of one another. This situation involved 16 owl responses, or 3.4% (16 ÷ 475) of the owl responses. Details on the 5 occasions when great horned owls and spotted owls were within 500 m of one another on the same night are described below.

10 April 1989. Route 103. Stations #9 and 10. Broadcasting spotted owl calls. Female spotted owl responded at 0117 hrs; male spotted owl (mate to female) responded at 0122 hrs, ≈ 800 m from female spotted owl. Male spotted moved to within 400 m of female spotted owl. Male great horned owl responded at 0200 hrs, gave 2 calls. Great horned owl was located approximately between the male and female spotted owls. Spotted owls responded aggressively at initial contact and were calling intermittently when great horned owl responded, but became silent upon first call from the great horned owl. I surmised that the spotted owls became silent due to the nearness of the great horned owl.

30 April 1989. Route 105. Station #6. Female great horned owl giving food-begging "jurreek" call at or very near the top of old-growth trees (≈ 45 m above ground level) at station when I arrived, 0309 hrs. Broadcast spotted owl calls. Male spotted owl responded with two 4-note contact calls at 0319 hrs, approx. 300 m distance. Spotted owl then moved uphill towards station. Male great horned owl arrived at 0404 hrs and transferred food to the female (based on calls). Male spotted owl now at station, ≈ 10 m above ground (visual contact), continued calling until 0416 hrs. It was apparent that the spotted owl was looking for the "intruding" spotted owl. After food transfer male great horned owl called 4-5 more times and drifted NW. Female great horned owl continued food begging call until 0425 hrs. She flew around quite a bit from 0415-0425 hrs., short flights, calling from treetops. Although the 2 species were aware of each other, the species seemed indifferent to one another.

31 March 1989. Route 201. Station #9. Male great horned owl calling at or near top (≈ 45 m above ground) of lone old-growth Douglas-fir tree in clearcut when I arrived at calling station, 2252 hrs. Broadcast spotted owl calls. Male spotted owl responded at 2308 hrs,

600 m north of great horned owl; responded with agitated calls only. Female spotted owl (mate to male) responded at 2330 hrs, 400 m east of great horned owl; responded with long-distance contact bark. Both spotted owls were ≈100 m into old-growth forest stands. Sensed that the spotted owls were disturbed by the great horned owl, who was indifferent to the spotted owls. The great horned owl was heard calling from this same tree on a subsequent visit across census route; appeared to (still) be calling for mate.

8 April 1990. Route 206. Stations #2 and 3. Broadcasting spotted owl calls. Female spotted owl responded at 0030 hrs, and her mate responded at 0034 hrs ≈ 300 m from female. The pair came together (male moved to females' location). A second male spotted owl responded at 0036 hrs. The male spotted owls engaged in a territorial interaction for 20 min, calling at one another from ≈ 100 m apart. At 0159 a male great horned owl began calling 400 m away from the spotted owls locations. The great horned owl was positioned along the opposite edge of a 7 ha closed pole stand (edge of a closed pole/old-growth stand); spotted owls were 150-200 m into an old-growth forest stand. The spotted owls were not calling when the great horned owl called, as their dueling bout was over. There was no apparent interaction between the two owl species.

5 April 1989. Route 402. Station #14 and 15. Male great horned owl gave 2 calls when I arrived at station, 0235 hrs; great horned owl was ≈ 800 m away, near station #15. Broadcast spotted owl calls. Male spotted owl responded aggressively at 0236 hrs, 500 m from me, ≈ 400 m from great horned owl. Spotted owl ≈ 80 m into mature forest stand. Great horned owl was positioned across clearcut from spotted owl, along a clearcut/mature forest edge. Didn't appear that the great horned owl and spotted owl were interacting, although the spotted owl was particularly agitated. On previous (and subsequent) visits to station #15, a pair of great horned owls were consistently heard at the same location where the male great horned owl was heard on this visit; it was apparent that this area was the great horned owls' activity center. This was the sole observation of a spotted owl in this area during the survey effort.