CALIFORNIA SPOTTED OWL HABITAT SELECTION IN THE CENTRAL SIERRA NEVADA

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Abstract: We examined habitat selection by California spotted owls (Strix occidentalis occidentalis) at 3 spatial scales: landscape, habitat patch, and microsite. We compared landscape characteristics within 457-ha circles surrounding 25 owl activity centers to randomly selected areas of equal size. Owl activity centers were defined as the geometric center of the minimum convex polygon enclosing roosts and nests located between 1986 and 1992. Baxter-Wolf indices of habitat interspersion were lower in owl sites than in random sites suggesting that owl sites contained fewer habitat patches. Ninety-seven percent of the habitat patches in which owls roosted were characterized by residual (i.e., >100 cm dbh [diameter at breast height]) trees. Owl roost and nest sites also were characterized by residual trees and high structural diversity. Current forest classification procedures generally fail to detect this residual tree component, which has important implications for habitat conservation of the owl.

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Key words: California spotted owl, habitat selection, landscape, nest sites, roost sites, Sierra Nevada, spotted owl, Strix occidentalis occidentalis.

Spotted owls show close association with old-growth or late seral stage forests (Forsman et al. 1984, LaHaye 1988, Call 1990, Carey et al. 1990, Solis and Gutiérrez 1990, Gutiérrez et al. 1992). Because they have large home ranges (Carey et al. 1990, Sisco 1990, Solis and Gutiérrez 1990), the forests within an owl territory may contain millions of dollars in potential lumber products (Simberloff 1987). Efforts to maintain viable spotted owl populations by reducing harvest levels on federal lands have resulted in major sociopolitical conflicts (U.S. Dep. Int. 1992).

A great deal of research has been focused on the northern subspecies (S. o. caurina; rev. in Gutiérrez et al. 1995) because of logging conflicts (Gould 1977, Forsman et al. 1984, 1987; Franklin et al. 1990, Thomas et al. 1990). In contrast, fewer studies of California spotted owls in the Sierra Nevada have occurred, even though timber harvest has been an important activity in that region (Laymon 1988, Bias 1989, Verner et al. 1992). Therefore, managers of Sierra montane forests need additional information about the habitat requirements and current status of the California subspecies to predict the potential effect of logging on the owl (Gutiérrez et al. 1992).

California spotted owls inhabit a broader range of habitat types than northern spotted owls (Gutiérrez et al. 1992) which may complicate understanding of large-scale habitat patterns. Landscape-scale habitat analysis is an important aspect of owl habitat use (Gutiérrez et al. 1992). Therefore, in addition to within-patch habitat characteristics, we estimated current levels of habitat heterogeneity within owl territories in the central Sierra Nevada.

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STUDY AREA

The 355-km² study area was located 16 km northeast of Georgetown, California, in the Eldorado National Forest. Elevations ranged from 366 to 2,257 m, and topography was mountainous. The vegetation was typical of Sierran middle elevation mixed conifer forest and was dominated by red fir (Abies magnifica), ponderosa pine (Pinus ponderosa), incense cedar (Caloced-
Table 1. Key to U.S. Forest Service vegetation classification used on the Eldorado National Forest, Central Sierra Nevada, California, 1991.

<table>
<thead>
<tr>
<th>Dominant overstory species</th>
<th>Size-class of dominant overstory species</th>
<th>Canopy closure of coniferous overstory</th>
</tr>
</thead>
<tbody>
<tr>
<td>M = Mixed conifer species</td>
<td>1 = Seedlings and saplings</td>
<td>S = 10–19%</td>
</tr>
<tr>
<td></td>
<td>2 = Poles</td>
<td>N = 40–69%</td>
</tr>
<tr>
<td></td>
<td>3 = 12-24&quot; (30-60 cm) dbh</td>
<td>P = 20–39%</td>
</tr>
<tr>
<td></td>
<td>4 = 24-40&quot; (60-100 cm) dbh</td>
<td>G = 70–100%</td>
</tr>
</tbody>
</table>

Other habitat categories

- Barren = rock, soil, open
- Plantation = area logged in 1990 or 1991, potentially replanted
- Poles/saplings = trees <12" (<30 cm) dbh
- Brush = ceonothus, manzanita, small oaks
- Oak = large oaks are dominant vegetative species
- Overall classification = dominant species + size class + canopy closure.

For example: M4G = dominated by mixed conifers that are >60 cm dbh and have an overall canopy closure of >70%.

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rus decurrens), white fir (Abies concolor), Douglas-fir (Pseudotsuga menziesii), sugar pine (Pinus lambertiana), and black oak (Quercus kelloggi) (Kichler 1977, Bias and Gutíérrez 1992). The study area was composed of 62.7% public (U.S. For. Serv.) land and 37.3% private land.

METHODS

The study area was censused for spotted owls each year (1986–92) according to the methods described by Forsman (1983) and Franklin et al. (1990). Spotted owls were banded with uniquely colored bands and lacking metal U.S. Fish and Wildlife Service bands, which facilitated identification of each owl and territory each year.

A single activity center for an owl pair was identified by calculating the geometric center of the minimum convex polygon defined by all known roost and nest locations for that pair. For our purposes, this activity center represented the center of an owl territory. Random locations within the study area were generated with a random Universal Transverse Mercator (UTM) number generator. Random locations that fell near the northern edge of the study area were adjusted into the study area to allow the complete analysis area to be incorporated within the habitat map boundaries derived from a 1991 Landsat Thematic Map, 30-m image that was obtained from the U.S. Forest Service in digital format. Analysis areas of activity centers that fell near the northern edge of the study area were supplemented with additional habitat data from U.S. Forest Service timber-type maps.

Habitat vegetation characteristics in the Landsat image were classified according to: (1) dominant species, (2) size class, and (3) canopy closure (Table 1). Digital data were imported into a Geographic Information System (GIS; ARC/INFO; Version 3.4.1D+, Environ. Systems Res. Inst., Inc., Redlands, Calif.), which was used to quantify the area of each habitat type.

We assessed the accuracy of the Landsat digital data by comparing vegetation characteristics within 310 randomly selected vegetation plots that were measured on site (Bias 1989) to the habitat type derived from the Landsat classification for that location. Similarities and differences within each of the 3 classification categories were noted and percentages of agreement were tallied (Table 2).

We selected the size of landscape analysis area by first estimating the nearest-neighbor distance of owl activity centers and then using one-half the average distance. This distance, 1,207 m, was used as the radius of a circular area (457 ha) to minimize overlap and increase the likelihood of independence between circles in spatial analysis. We then estimated the amount of each habitat type within the circle. California spotted owl foraging habitat has been characterized as having ≥40 percent canopy closure, and average tree dbh of ≥60 cm (Gutíérrez et al. 1992). Therefore, for purposes of analysis we combined cover types M4G and...
M4N (Table 1) to represent suitable spotted owl habitat. Owl habitat will hereafter be defined as M4G and M4N combined. All M5 habitat was incorporated into M4 habitat by the satellite image processor, therefore all M4 habitat potentially could include M5 habitat as well.

Habitat heterogeneity was estimated with the Baxter and Wolf (1972) interspersion index, which is a count of habitat changes along 2 transects that lie perpendicular to each other over the analysis area. We used a t-test to evaluate differences in habitat heterogeneity between owl and random areas.

At the spatial scale of the habitat patch, we estimated whether habitat characteristics at roost sites differed from random sites. We overlaid the UTM capture location (roost sites) of 82 different California spotted owls and 82 random points onto the digitally derived habitat polygon maps and compared the vegetation classes at roost and random sites using a Chi-square test (Zar 1984). Some spotted owls have been observed continuously using the same roost site (Barrows 1980), therefore, we chose one roost site (i.e., the capture location) for each of 82 California spotted owls. In addition, if both individuals of a pair were captured on the same occasion we used only that location once for analysis.

Individual tree characteristics were not available from the Landsat data, therefore we used 0.04-ha vegetation plots measured around owl roost locations and random points from 1986 to 1993 to examine microsite characteristics (Bias 1989). Variables measured in the vegetation plot included: aspect, canopy closure, slope, elevation, tree size and density (with a 20 basal area factor prism), and ground-cover characteristics such as herb, litter, and debris. Trees were put into 1 of 5 dbh categories: sapling (10.1–12.3 cm dbh), pole (12.3–27.3 cm dbh), medium (27.3–52.5 cm dbh), mature (52.5–89.9 cm dbh), and old-growth (>90 cm dbh).

Habitat that fits the definition of M3 habitat is not considered suitable for spotted owls (Verner et al. 1992). Because the Landsat imagery classified 42 spotted owl roost locations as M3 habitat, we compared the presence or absence of residual trees (>100 cm dbh) within those 42 M3-classified roosts and 132 randomly selected M3-classified vegetation plots. We also compared the number of residual trees within the 42 M3 roost plots and the 70 random M3 plots that exhibited residuals.

Table 2. Accuracy assessment of vegetation data obtained from U.S. Forest Service of the Eldorado Study Area, Central Sierra Nevada, California, 1993. Three-hundred ten random, on-site vegetation plots were compared to habitat classified from Landsat Thematic Map image.

<table>
<thead>
<tr>
<th>No. of plots compared</th>
<th>Class</th>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Species</td>
<td>Size</td>
</tr>
<tr>
<td>Conifer plots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>M4G</td>
<td>54</td>
<td>45</td>
</tr>
<tr>
<td>11</td>
<td>M4N</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>M4P</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>M4S</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>72</td>
<td>M3G</td>
<td>67</td>
<td>49</td>
</tr>
<tr>
<td>88</td>
<td>M3N</td>
<td>82</td>
<td>56</td>
</tr>
<tr>
<td>17</td>
<td>M3P</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>M3S</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>255</td>
<td>Pooled</td>
<td>94%</td>
<td>70%</td>
</tr>
</tbody>
</table>

Conifer accuracy = 74% 26%

<table>
<thead>
<tr>
<th>No. of plots compared</th>
<th>Class</th>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-coniferous plots</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Barren</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>Plantation</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Poles/Sapling</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Brush</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>28</td>
<td>Oak</td>
<td>26</td>
<td>2</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non-conifer accuracy = 94% 6%

Overall accuracy
310 Plots compared = 76% 24%
Table 3. Area (ha) of M4G/M4N habitat (mixed coniferous forest, mean dbh ≥60 cm, ≥40% canopy closure) within 457 ha spotted owl territories and random areas in the central Sierra Nevada, California.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Territory</th>
<th>Random</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total M4G/M4N habitat</td>
<td>25</td>
<td>68.84 ± 24.92a</td>
<td>50.38 ± 14.92</td>
</tr>
<tr>
<td>Mean M4G/M4N patch size</td>
<td>25</td>
<td>18.29 ± 5.77</td>
<td>16.01 ± 5.17</td>
</tr>
</tbody>
</table>

a 1 ± 95% Confidence interval.

In addition, we compared the structural diversity of 16 nest plots with 16 random vegetation plots within the study area. Each nest plot used for the analysis represented different male owls and no nest was used twice for analysis. We believe that the 16 nest plots were independent because male spotted owls probably initiate nest site selection (Gutiérrez et al. 1995).

The Shannon-Wiener diversity index (Magurran 1988) was used to measure structural diversity within nest and random vegetation plots. Because the girth of a tree is related to its height (Mueller-Dombois and Ellenberg 1974), we used diameter size-class categories to represent a strata of canopy layers. We then tallied the number of trees in each size class for owl nest plots and random plots to calculate a Shannon-Wiener index for each vegetation plot. We used Mann-Whitney tests (Zar 1984) on the Shannon-Wiener index values to compare diversity indices in nest and random locations.

RESULTS

Total amounts and patch size of M4G/M4N habitat did not differ between owl sites and random areas (t = 0.774, P = 0.4424 and t = 0.6067,  P = 0.5469; Table 3). However, habitat heterogeneity (as measured by the interspersion index) was lower in owl territories (t = 18.24, SE = 0.849) than in random locations (t = 23.6, SE = 1.016; t = -4.04,  P = 0.0002).

Distribution of habitat types did not differ between owl territories and random areas (χ² = 3.81, 7 df,  P = 0.8010; Fig. 1). However, amounts of size-class 3 conifer habitat with canopy closure of >70% (M3G) was greater in owl territories than in random areas (t = 1.836,  P = 0.0725).

California spotted owl roosts were located in mixed conifer habitat that contained trees of at least 30 cm dbh, more often than expected by chance (χ² = 59.99, 4 df,  P < 0.001). Thirty-one percent of the 82 owl roosts were in habitat characterized by ≥40% canopy closure and trees >60 cm dbh (M4), and 68% were in habitat characterized by ≥40% canopy closure and trees >30 cm dbh (M3; Fig. 2). Moreover, 97% of owl roosts were characterized by the presence of residual old-growth.

Residual trees were present in roosts classified as M3 more frequently than in random M3 forest sites (χ² = 29.31, 1 df,  P < 0.001;
Fig. 3. Frequency of residual old-growth trees within roosts classified as M3 (mixed conifer forest with dbh height of 30–60 cm) and random M3 forest stands on the Eldorado Study Area in the central Sierra Nevada, California 1986–93.

Fig. 4. Distribution of trees within conifer classes in nest and random sites in the central Sierra Nevada, California 1986–93. M1 = sapling (10.1–12.3 cm dbh), M2 = pole (12.3–27.3 cm dbh), M3 = medium (27.3–52.5 cm dbh), M4 = mature (52.5–89.9 cm dbh), and M5 = residual (>90 cm dbh).

Fig. 3). In addition, residual trees within the roost plots classified as M3 were more abundant ($\bar{x} = 4.26$, SD = 2.58) than in random plots classified as M3 ($\bar{x} = 3.22$, SD = 2.55) that also contained residuals ($z = 2.107, P = 0.0352$).

Comparison of the Shannon-Wiener diversity indices of tree dbh indicated that nest plots had higher structural diversity ($\bar{x} H' = 1.713$, SE = 0.062) than random plots ($\bar{x} H' = 1.339$, SE = 0.133; $z = 2.186$, $P = 0.0288$). Nest plots contained more ($n = 235$ trees) as well as larger (>52 cm dbh; $z = 2.940$, $P = 0.0033$) trees than did random plots ($n = 169$ trees). In addition, nest plots contained more residual trees ($z = 3.128$, $P = 0.0018$; Fig. 4) than random plots.

DISCUSSION

California spotted owls inhabit a broader array of habitat conditions than northern spotted owls (Forsman et al. 1984, Gutiérrez et al. 1992, Verner et al. 1992). Our results are consistent with this generalization. Further, the presence of large trees characterize spotted owl habitat on public land in the Sierra Nevada (Gutiérrez et al. 1992).

Spotted owls on our study area selected roost and nest stands that exhibited higher structural diversity and contained significantly more residual trees than random areas. Apparently spotted owls were behaving as habitat specialists because selected habitats differed significantly from random areas at 3 spatial scales: landscape, territory, and microsite. The method we used for identifying a territory center effectively reduced the difference between owl sites and random sites, because the activity center we chose was not necessarily centered on owl habitat. Thus, we performed a conservative analysis.

Residual trees, an important component of owl habitat in the Sierra Nevada (Gutiérrez et al. 1992), are characteristic of owl roosts and nests but not of random areas. Residual trees could perform several functions in owl habitat. Spotted owls have a low tolerance to heat stress (Ganey et al. 1993). The residual tree component may add to the multi-layered structure of the forest canopy, thereby moderating local temperature (Barrows and Barrows 1978). These trees could provide cover from inclement weather (Gutiérrez et al. 1995). They provide nest sites (Gutiérrez et al. 1992) and they add structure and coarse woody debris to the forest, which may be important to spotted owl prey (Maser 1979, Williams et al. 1992).

Habitat patches on the Olympic Peninsula were larger in spotted owl areas than in random areas, however, a larger analysis area was used
and it was estimated that this larger area more closely reflected actual spotted owl home ranges (Lehmkuhl and Raphael 1993). Our analysis areas were much smaller and often patches were artificially truncated at the edge of the area which may account for the lack of difference between owl and random areas. This artificial truncation may also explain differences in our results from those of Ripple et al. (1991) and J. Meyer (Univ. Wyoming, pers. commun.). If the patches tend to be large relative to other ecological provinces then the method of truncating them with a buffer area will tend to create patches of equal area due to the buffering process. In addition, Ripple et al. (1991) found significant differences between owl and random areas at a scale similar to ours: however, the authors only considered the age of the forest and did not differentiate between different amounts of canopy closure. By designating owl habitat as that greater than 40% canopy closure we have decreased the amount of effective owl nesting and roosting habitat.

MANAGEMENT IMPLICATIONS

The digital Landscape habitat classification had an accuracy of 76% which is consistent with most other studies that use satellite imagery (Fox et al. 1983, Chuvieco and Congalton 1988, Hodgson et al. 1988, Congalton et al. 1993; Table 2). However, one element notably lacking in the digital vegetation information was the “residual tree” component. “Large trees” were coded as M5 by the U.S. Forest Service (1987) and were not used in the satellite-image classification (all coniferous trees ≥60 cm dbh were consolidated into the size-class 4 classification). In conducting the accuracy assessment we found that 36% of the coniferous vegetation plots established by Bias (1989) exhibited this large-tree “residual tree” component. This category was not used in our initial accuracy assessment because the Forest Service classification combined all tree diameters >60 cm dbh. Bias and Gutiérrez (1992) also found a relatively low degree of accuracy in habitat maps derived by the land management agency.

The use of satellite imagery is used commonly to inventory vegetation and wildlife habitat. Yet the presence of key habitat features such as residual trees may not be detected easily with this technology. These residuals clearly are associated with spotted owls in the central Sierra Nevada.

One of the management recommendations for California spotted owls is the retention and protection of large trees within spotted owl activity centers, because these trees are disappearing rapidly in the Sierra (Verner et al. 1992). Our study supports the hypothesis that residuals are an important habitat component for spotted owls. Selective logging within owl ranges may result in less effect on spotted owls if residual trees and nest sites are protected. However, we recommend that final timber strata classifications, particularly the residual tree component be confirmed, by visual field verification before logging. Visual field verification will be necessary because satellite imagery analysis currently appears unable to detect accurately this important spotted owl habitat component.

LITERATURE CITED

———, C. R. Bruce, M. A. Walter, and E. C.


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