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# REEVALUATING DELINEATED BALD EAGLE WINTER ROOST HABITAT IN LAVA BEDS NATIONAL MONUMENT, CALIFORNIA

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ABSTRACT.—We reevaluated bald eagle (*Haliaeetus leucocephalus*) winter roost habitat in the Caldwell Butte area in southern Lava Beds National Monument, California. A gradient of five forest habitat strata was evaluated in previously delineated "primary" and "secondary" roost habitat to quantify the size and age structure of ponderosa pine (*Pinus ponderosa*) along the habitat gradient, and to reevaluate current and potential eagle roost habitat. Results indicated that primary roost habitat was considerably smaller in area and more concentrated in the Caldwell Butte roost area than previously reported. Forest plots centered on randomly selected, known eagle roost trees in the high basal area forest (>18 $m^2$/ha of ponderosa pine) had significantly greater past eagle use (136.4 ± 39.7 castings/ha; mean ± 1 SE) than adjacent high basal area forest plots (1.8 ± 1.2 castings/ha) whose locations were randomly selected. Previously identified primary roost areas of moderate and low Ponderosa pine basal area (<18 $m^2$/ha) and previously identified secondary roost areas lacked signs of past eagle use. On average, the trees with the greatest diameters in these strata were >200 yr younger than known roost trees. Stratum A plots had 47 trees >150-yr-old (7.4% of the trees) compared to just 6 trees >150-yr-old (0.7% of the trees) in Stratum B plots. Strata C, D and E had very few trees >150-yr-old. We found that future bald eagle habitat in the area may be severely limited by current forest stand structures, forest dynamics, and the probability of producing old-growth trees.

KEY WORDS: *bald eagle habitat; forest age structure; forest demography;* Haliaeetus leucocephalus.

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Reevaluación de los hábitat de descanso invernal de *Haliaeetus leucocephalus* en el Monumento Nacional de Lava Beds, California.

RESUMEN.—Reevaluamos el hábitat de descanso invernal de *Haliaeetus leucocephalus* en el área de Caldwell Butte, al sur del Monumento Nacional de Lava Beds, California. Un gradiente de cinco estratos de hábitat de bosque fue evaluado previamente, como hábitat de descanso "primario" y "secundario," cuantificando el tamaño y la estructura de edad de *Pinus ponderosa* a lo largo del gradiente. Los resultados indicaron que el hábitat de descanso primario fue considerablemente más pequeño en área y más concentrado en el área de descanso de Caldwell Butte que lo previamente informado. Parcelas centradas en el bosque y seleccionadas azarosamente, con árboles de descanso conocidos en el área basal alta del bosque (>18 $m^2$/ha de *P. ponderosa*) tenían un uso pasado significativamente mayor (136.4 ± 39.7 observaciones/ha; media ± 1 E.S.) que en las parcelas adyacentes del área basal alta del bosque (1.8 ± 1.2 observaciones/ha) y cuya localización fue seleccionada azarosamente. Areas de descanso primarias, previamente identificadas, de moderadas y bajas áreas basales de *P. ponderosa* (<18 $m^2$/ha) y áreas de descanso secundaria, previamente identificadas, perdieron las señales del uso pasado por esta águila. En promedio, los árboles con el mayor diámetro en estos estratos eran 200 años mayores que los más jóvenes. El Estrato A tenía 47 árboles sobre 150 años de edad (7.4%), comparado

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con los seis árboles mayores a 150 años (0.7%) del Estrato B de la parcela. Los Estratos C, D y E tenían muy pocos árboles mayores de 150 años de edad. Encontramos que futuros hábitat de *H. leucocephalus* en el área pueden ser severamente limitados por la estructura de los bosques actuales, dinámica de bosques y la probabilidad de crecimiento de los árboles viejos.

[Traducción de Ivan Lazo]

The exact boundaries of wildlife habitats, forest types, and ecosystems are often difficult to delineate (Kerr 1986). Yet, biologists are often asked to map primary, secondary, or potential habitat for rare and threatened, politically sensitive, or locally important species. This was the case for bald eagle (*Haliaeetus leucocephalus*) winter roost habitat in the Klamath Basin of northeastern California. In the 1990s, an interagency agreement between the Modoc National Forest (USDA Forest Service) and Lava Beds National Monument (USDI National Park Service) required both parties to assess current and potential bald eagle winter roost habitat on their respective lands in the Caldwell/Cougar roost area.

Some information on the roost area was available. Krauss (1977) reported that the Caldwell Butte portion of the roost area covered about 12 ha in old-growth ponderosa pine (*Pinus ponderosa*) forests "but the exact boundaries were not yet determined." However, Krauss (1977) and others (Keister 1981, Sogge and Sydoriak 1990) delineated large areas in the roost site as either infrequently used secondary roost area or "heavy use daytime perching area" ("primary roost area" [Fig. 1]). Keister (1981) compared general forest stand characteristics of five roost areas in the Klamath Basin with the point-quarter method (Mueller-Dombois and Ellenberg 1974). He found considerable differences between the Caldwell and Cougar roost stands in density (25.6 vs. 44.3 trees/ha) and number of stumps (0.3 vs. 12.2 stumps/ha), but similar mean tree diameters (50.4 vs. 56.0 cm dbh) and heights (24.6 vs. 27.6 m). However, the methods used provided only wide-area averages and no information on potential habitat, the forest age structure and dynamics of ponderosa pine, the principle roost tree species.

Keister and Anthony (1983) reported that bald eagles roosted primarily in trees averaging 76.5 cm diameter at breast height (dbh), 24.7 m tall, and 289 yr of age on the Caldwell Butte roost area. Stohlgren (1993) systematically surveyed 4 $km^2$ of forested areas in Lava Beds National Monument to locate and describe the physical characteristics of roost trees. He also described ponderosa pine size distributions and basal area, and the distribution of areas of high (>18 $m^2$/ha) and low (<18 $m^2$/ha) basal area of ponderosa pine. Areas of high basal area did not always contain eagle roost trees. Only about 32 ha of the 250 ha primary and secondary roost areas surveyed in the Caldwell Butte area contained roost trees (Stohlgren 1993). Consequently, a higher resolution analysis of forest structure was needed. The primary objectives of our study were to: (1) evaluate forest characteristics, particularly stand age structure, along a potential bald eagle habitat gradient, and (2) reevaluate previously delineated primary and secondary roost habitat to emphasize the role of forest demography in perpetuating, and managing, bald eagle winter roosts.

## STUDY AREA

The Caldwell/Cougar Roost is between Caldwell and Cougar Buttes near the southeastern boundary of Lava Beds National Monument (Fig. 1). Vegetation in the area has been classified as mixed coniferous dominated by ponderosa pine, western juniper (*Juniperus occidentalis*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*), and some curl-leaved mountain mahogany (*Cercocarpus ledifolius*) (Erhard 1979). The understory is composed primarily of bitterbrush (*Purshia tridentata*), currant (*Ribes* sp.), manzanita (*Arctostaphylos* sp.), and elderberry (*Sambucus* sp.) (Erhard 1979).

Bald eagles typically arrived in the area in November and departed in March with peak use in January (Keister 1981). Stohlgren (1993) found castings under 58 of 103 previously used bald eagle roost trees (see Keister 1981). The annual maximum winter daily count of bald eagles in Caldwell/Cougar Roost declined from 278 eagles in 1983/84 to fewer than 60 eagles in 1991 (P. Toops pers. comm.). The reasons for this decline are unknown.

The recent land use history of the area is complicated because the study site straddles national park and national forest land. Lava Beds became a National Forest Reserve in 1925, and incidental livestock grazing occurred until 1933 when the area was placed under National Park Service jurisdiction. No logging has occurred in Lava Beds National Monument, but typical of ponderosa pine forests, there have been several fires: a 73-ha wildfire in 1911, a 480-ha wildfire in 1924 in the northern half of the primary roost habitat (in-

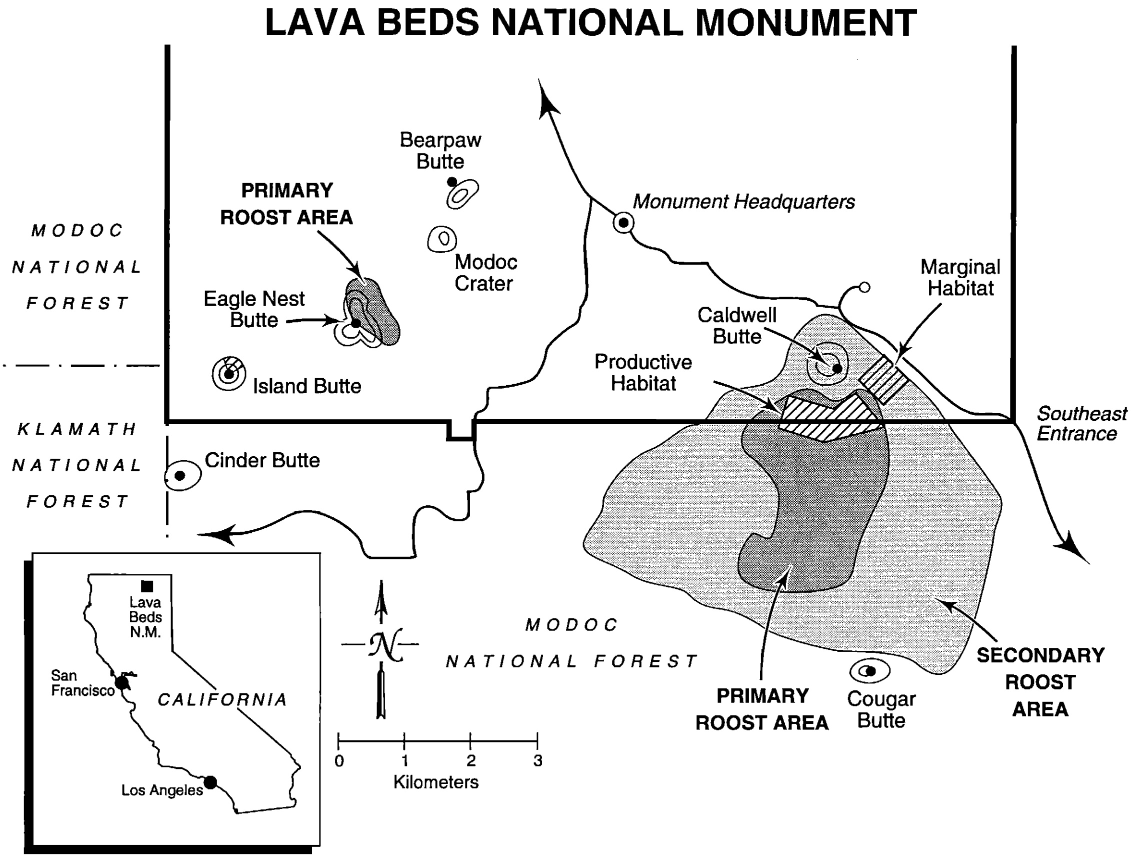


Figure 1. Map of Lava Beds National Monument and adjacent lands showing previously delineated areas of primary and secondary bald eagle winter roost habitat (Keister 1981, Sogge and Sydoriak 1990), and areas of productive (>18 $m^2$/ha ponderosa pine basal area) and marginal habitat (<18 $m^2$/ha ponderosa pine basal area; Stohlgren 1993).

cluding some of Strata A, B and C described below), and two prescribed fires in 1976 (26 ha) and 1977 (64 ha) in the secondary roost habitat (including some of Strata C, D, and E described below). Twelve lightning-caused fires of <0.1 ha have occurred throughout the study area between 1934 and 1990 (Martin and Johnson 1979, Olsen and Martin 1982).

## METHODS

A stratified-random study design was used with five habitat strata based on previous information on bald eagle roost tree locations (Keister 1981), and known areas of high (>18 $m^2$/ha), moderate (12–18 $m^2$/ha), and low basal area (<12 $m^2$/ha) of ponderosa pine (Stohlgren 1993). All five study strata were selected within areas previously delineated as primary or secondary roost habitat (Krauss 1977, Sogge and Sydoriak 1990, Stohlgren 1993). Eleven variable-radius forest structure plots (described below) were established in each stratum. The forest structure plots in Stratum A were centered on randomly selected roost trees in a 0.5 $km^2$ site of high basal area forest southwest of Caldwell Butte (Fig. 1). Another set of 11 plots were randomly selected throughout the same high basal area forest (Stratum B) irrespective of the locations of known bald eagle roost trees. Eleven forest structure plots were randomly located in a 0.5 $km^2$ area due south of Caldwell Butte (Fig. 1) presumed to have moderate basal area (12–18 $m^2$/ha) of ponderosa pine within the previously delineated primary roost habitat (Stratum C).

The previously delineated secondary roost habitat in a 0.5 $km^2$ southeast of Caldwell Butte (Fig. 1) was lower in basal area (<12 $m^2$/ha ponderosa pine) than the primary roost habitat (Stohlgren 1993). Eleven forest structure plots also were randomly placed in each of these two strata. The strata were selected to differentiate between areas that contained at least one large (>25 cm dbh) tree (Stratum D) and areas that contained no large trees (Stratum E). Thus, the strata represented a continuum of potential roost sites, all about equidistant from the primary bald eagle feeding area (Tule Lake) 18 km north (Keister et al. 1987).

Variable radius circular plots were randomly located in

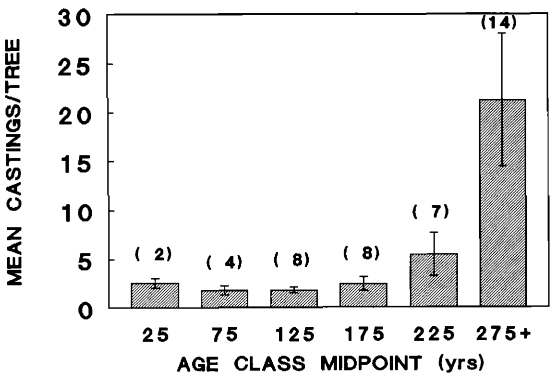


Figure 2. Relationship of mean number of castings per tree and tree age class for 43 trees with castings. Number of trees by age class in parentheses. Vertical bars are standard errors of mean castings per tree.

each stratum to determine the size and age structure of ponderosa pine. Within a radius of 12.6 m of each plot center (0.05 ha), small ponderosa pines (<1.4 m tall) were measured in height (to the nearest centimeter) and diameter at ground level (to the nearest mm), and the number of branch whorls counted. Other tree species <1.4 m tall in the 0.05-ha plot were tallied. Within a 17.6-m radius of each plot center (0.1 ha), all trees >1.4 m tall were measured (dbh in centimeters); assigned a code for species, height class, and canopy structure; and the number of castings were tallied. Height classes were <10 m, 11–20 m, 21–30 m, and >30 m. Structure classes were based on the tree canopy and crown classification system of Keen (1943) as modified by Keister and Anthony (1983) and Stohlgren (1993). To provide more information on local eagle use (i.e., castings), all eagle roost trees within a 28.2 m radius of the plot center (0.25 ha) were recorded similarly. Also, a 100% survey of previously used or currently used roost trees was conducted throughout the Caldwell Butte roost area.

The age of each tree with the greatest dbh on each 0.1-ha plot was determined by coring (two perpendicular cores per tree) near ground level and carefully counting the annual rings. Tree ages were estimated only to the nearest 20-yr interval and no attempt was made to cross-date rings or estimate missing or multiple rings. Age/diameter relationships were determined within each stratum (except for Stratum E) for a minimum of 30 randomly selected ponderosa pines.

Standard linear regression (SAS 1988, Neter et al. 1990) was used to relate diameter to age for ponderosa pine in each stratum. Log transformations were used on all data to normalize the highly skewed distributions. The residuals of each regression were graphed and analyzed to ensure that the error terms conformed to the assumption of normality and that the linear model chosen was indeed the best fit. If the resulting regression equations were highly significant ($P < 0.0001$), the regression equations for each stratum were applied to the other uncored trees to estimate their ages. To reduce the error associated with estimating ages of individual trees, broad 50-yr age classes were used to display the age distribution of ponderosa pine in each stratum. Trees with estimated ages >275-yr-old were lumped into a single class. Estimating the ages of ponderosa pine seedlings (trees <1.4 m tall) was the focus of another study in the same area and all seedlings were found to be <50-yr-old (C. Farmer unpubl.).

The number of trees (and basal area) of each species was summed to assess the species composition of the strata. Two methods were used to compare forest structure characteristics (i.e., tree densities by size class, basal area per plot, largest tree dbh, largest tree age, and number of castings/ha) among strata. Standard analysis of variance was performed on log-transformed data. Since castings were found only on two strata and the data were not normally distributed, the nonparametric Wilcoxon rank-sum test was used (SAS 1988) Where the ANOVA revealed a significant difference (at $\alpha = 0.05$) among groups (i.e., strata), Ryan-Einot-Gabriel-Welsch (SAS 1988) multiple range tests were used to detect significance differences ($\alpha = 0.05$) among means.

## RESULTS

Ponderosa pine was the dominant tree species in Strata A, B, C and D (>92% of the basal area; Table 1). Western juniper was the dominant tree in Stratum E (69% of the basal area) and total basal area was far less than in the other strata. Total basal area of Stratum C, the presumed moderate basal area site (Fig. 1), was greater than the 12–18 $m^2$/ha anticipated. Thus, ponderosa pine basal area in Stratum C was similar to Strata A and B (high basal area stands, and somewhat similar to Stratum D that included clumps of trees in the low basal area stand in the secondary roost habitat (Fig. 2).

All variables tested were significantly different among strata (i.e., at least one stratum was different from the others; Table 2). However, means of many stand structure variables were not significantly different among strata due to the variability within strata. For example, the mean density of trees was not significantly different among Strata A, B, C and D for trees in the <25 cm dbh and 25–50 cm dbh classes. Stratum A had a significantly greater density of >50 cm dbh trees than Strata B, C, D and E but the mean basal area of trees was not significantly different among Strata A, B, C and D (Table 2).

Several significant differences among strata were found when the largest diameter trees in each plot were compared in size and age. Largest tree diameters in Stratum A were significantly larger than the diameters in all other strata (Table 2). The mean diameter of the largest trees in Stratum B was significantly greater than that for the largest trees in Strata D and E.

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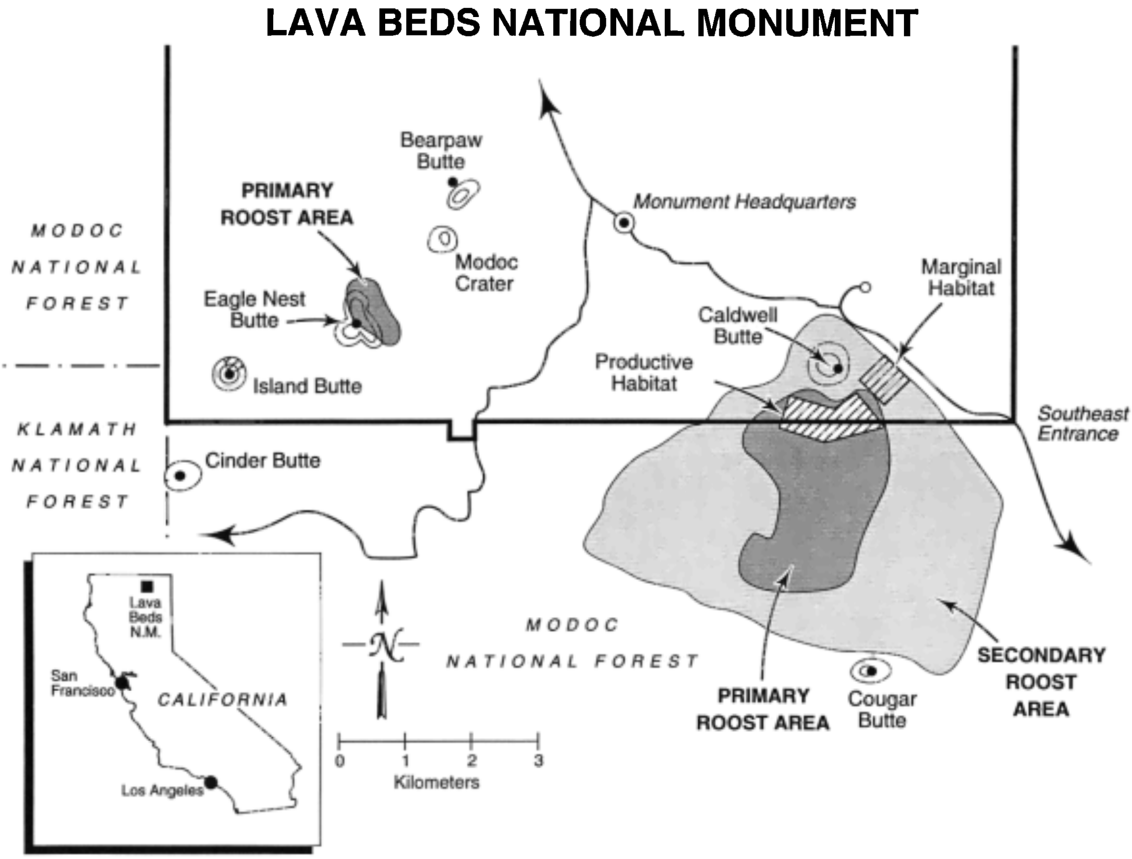


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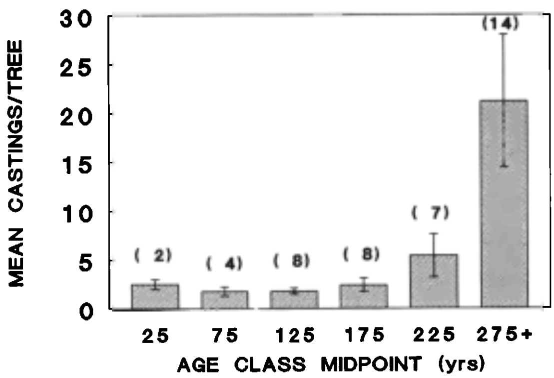


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The mean age of the largest diameter trees on each plot also varied among strata (Table 2). The largest

Table 4. Number of trees sampled by age class in each habitat stratum. Percent trees by strata in age class.

| | AGE CLASS (YR) | | | | | | |
|---|---|---|---|---|---|---|---|
| STRATA | <50 | 50–99 | 100–149 | 150–199 | 200–249 | 250+ | TOTAL |
| A | 453 (72.2%) | 90 (14.4%) | 37 (5.9%) | 18 (2.8%) | 11 (1.8%) | 18 (2.8%) | 627 |
| B | 692 (82.5%) | 124 (14.8%) | 17 (2.0%) | 5 (0.6%) | 1 (0.1%) | 0 | 839 |
| C | 349 (68.3%) | 139 (27.2%) | 21 (4.1%) | 1 (0.2%) | 1 (0.2%) | 0 | 511 |
| D | 197 (46.7%) | 208 (49.3%) | 17 (4.0%) | 0 | 0 | 0 | 422 |
| E | 15 (40.5%) | 13 (35.1%) | 8 (21.6%) | 1 (2.7%) | 0 | 0 | 37 |

ever become roost trees (i.e., >275-yr-old and attain the necessary structure). The small percentages of the trees in the 150–199 and 200–249-yr-old-age classes in Strata B, C, and D suggests that ponderosa pine survivorship may be lower in those strata than in Stratum A. That is, recruitment might be high (i.e., high percentages of <50-yr-old trees) but survivorship to old age may be limited, and dependent on local soil development, resistance to fire (e.g., due to size, bark thickness, or location in rocky outcrops), or other reasons. Except as a buffer-area to protect roost trees from unwanted disturbance from humans, it is difficult to classify the types of forests in Strata C, D, or E as primary or secondary roost habitat. Furthermore, the size and age structure of ponderosa pine in those stands suggests they should not be considered as potential roost area in a 100-yr period.

Bald eagles will roost in younger trees (Fig. 2). However, they may do so only when large, old trees are in the immediate vicinity (Stratum A). We found no evidence of eagle use in younger stands in Strata C, D, and E. Anthony et al. (1982) and Keister and Anthony (1983) also stressed the need for large (old) trees in multi-layered (uneven-aged) stands for communal roosting by bald eagles in the Klamath Basin.

Managing bald eagle winter roost habitat requires detailed, quantitative information of forest age structure and stand dynamics. Bald eagle winter roost habitat can be defined quantitatively at the tree level and defined qualitatively at the stand level (DellaSala et al. 1987). Bald eagles in the Caldwell Butte area preferred roosting in large ponderosa pines averaging >80 cm dbh (Keister and Anthony 1983, Stohlgren 1993) many of which are >200-yr-old (Fig. 2). A strict definition of primary roost habitat might include only these trees that dot the landscape. At the stand level, a multi-tiered canopy (uneven-aged stand) containing some >200-yr-old ponderosa pines (Table 4; Stratum A) best defines primary roost habitat. Because these primary resources may be clumped or scattered in distribution or concentrated in space when viewed at the landscape level, it may be misleading to delineate primary roost habitat as a large, continuous area. This study showed that much of the area previously delineated as primary roost habitat (Krauss 1977, Keister 1981, and Sogge and Sydoriak 1990) contained no sign of recent eagle use and no large, old trees preferred by eagles for roosting (Tables 2 and 4; Fig. 2).

However, there may be other reasons for delineating and protecting larger areas around scattered primary resources (i.e., any previously used roost trees). Buffer zones might be established to protect the eagles from human disturbance, particularly while the birds are roosting. Alternatively, buffer areas may include secondary or potential habitat. Secondary habitat might include areas adjacent to roost trees having moderately large, old trees that could serve as overflow areas when eagle numbers are high. Using this definition, the areas we identified in Strata D and E should probably not be considered as secondary roost habitat.

Defining areas as potential roost habitat should incorporate aspects of eagle use (behavior and population size), forest development (tree population dynamics), and time. The communal nature of winter roosting in bald eagles influences eagle use at the tree level while eagle population numbers influence eagle use at the stand, landscape and regional levels (DellaSala et al. 1987, Keister et al., 1987). The differences in age structure of ponderosa pine among habitat strata (Table 4) suggest strongly that future bald eagle habitat in the area may be severely limited by current forest stand structures, forest dynamics, and the probability of producing old-growth trees. That is, we are not confident that Strata B, C, D and E areas can produce significant numbers of large, old ponderosa pines in the next 100 yr. Meanwhile, existing roost trees may be threatened by wildfire, drought, and pathogens.

Maintaining, perpetuating, and protecting primary bald eagle roost habitat requires an understanding of forest development and tree population dynamics as well as changing bald eagle use patterns, population sizes, and behavior. The gradient approach used here to assess bald eagle winter roost habitat could be used to delineate habitat gradients for other species.

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