

## Bald Eagle Winter Roost Characteristics in Lava Beds National Monument, California

### Abstract

This study provided a survey of bald eagle (*Haliaeetus leucocephalus*) winter roost habitat (in 4 km<sup>2</sup> of potential roost areas) in southern Lava Beds National Monument, California. A systematic-clustered sampling design ( $n = 381$  plots) was used to compare forest stand characteristics in two primary roost areas (Caldwell Butte and Eagle Nest Butte) and two potential roost areas (Hidden Valley and Island Butte). A 100 percent inventory of roost trees in Caldwell Butte ( $n = 103$  trees) and Eagle Nest Butte ( $n = 44$  trees) showed they were spatially clumped and restricted to 12.7 percent and 2.8 percent, respectively, of the study areas. Roost trees, primarily ponderosa pine (*Pinus ponderosa*), averaged  $81.1 \pm 1.3$  cm dbh (mean  $\pm$  1 S.E.) compared to non-roost trees ( $> 35$  cm dbh) that averaged  $52.2 \pm 1.0$  cm dbh. Roost trees were generally taller and more open-structured than non-roost trees. All four study sites had adequate numbers of mid-sized trees (10 to 50 cm dbh) to replace the current stock of older, larger roost trees. However, seedlings and small trees ( $< 10$  cm dbh) in the roost areas were spatially clumped and few, suggesting that maintaining a continuous population of roost trees may be a problem in the distant future. Long-term studies of changing winter roost habitat and eagle use are essential to protect the bald eagle in the northwestern US.

### Introduction

A critical stage in the population dynamics of the bald eagle (*Haliaeetus leucocephalus*) is the fall migration from areas of harsh to milder climates (Keister and Anthony 1983, USFWS 1986, Keister *et al.* 1987). The Klamath Basin of southern Oregon and northeastern California serves as one of the major winter roost areas in the lower 48 states (Keister 1981).

Wildlife biologists are becoming increasingly aware of the need to manage not only endangered species but also their habitat (Scott *et al.*, 1990, Hobbs and Hanley 1990). Bald eagle winter roost area characteristics in the northwestern US have been described as old-growth, multi-layered, forest stands (roost trees 100 to 535 years old) within 0.25 to 24 km of food resources (fish, carcasses, waterfowl in wetlands habitat, and various rodents in open forests) (Hansen *et al.* 1980, Keister 1981, Anthony *et al.* 1982). Careful monitoring of bald eagle habitat is essential because the habitat can be affected by a variety of land use practices including old-growth logging (Keister and Anthony, 1983) and draining wetlands for agriculture (USFWS 1986), and catastrophes including persistent drought, wildfire, and pathogen outbreaks (Martin and Johnson 1979, Dale and Kliejunas 1987).

The threats listed above are a real and present danger to winter roost sites in or adjacent to Lava Beds National Monument (LBNM) in northeastern

California. Proposed logging of old-growth timber south of LBNM in the Modoc National Forest and on private lands and the threat of wildfire in LBNM prompted this evaluation of the status of bald eagle winter roost habitat and a survey of potential ("or replacement") roost areas.

Specific objectives of this study were to: (1) quantify the characteristics and spatial distribution of roost trees; (2) identify roost trees recently used by bald eagles; and (3) survey the forest for potential roost areas throughout the study area.

### Study Area

The Caldwell/Cougar Roost is between Cougar and Caldwell Buttes near the southeastern boundary of LBNM (Fig. 1). Sogge and Sydorik (1990) provide additional details on the primary and secondary roost areas that represent about 4 km<sup>2</sup> and 7 km<sup>2</sup>, respectively, of LBNM. Forest vegetation in the area has been classified broadly as stands of mixed conifers: ponderosa pine, western juniper (*Juniperus occidentalis*), white fir (*Abies concolor*), Shasta red fir (*Abies magnifica shastensis*), sugar pine (*P. lambertiana*), lodgepole pine (*P. contorta*), incense cedar (*Calocedrus decurrens*), and curl-leaved mountain mahogany (*Cercocarpus ledifolius*) (Erhard 1979). Except for some preliminary information from Keister (1981), little is known about the size or age structure of the stands, or of the spatial distribution of roost trees and potential roost trees within the stands. The understory is composed primarily of bitterbrush (*Purshia*

# LAVA BEDS NATIONAL MONUMENT

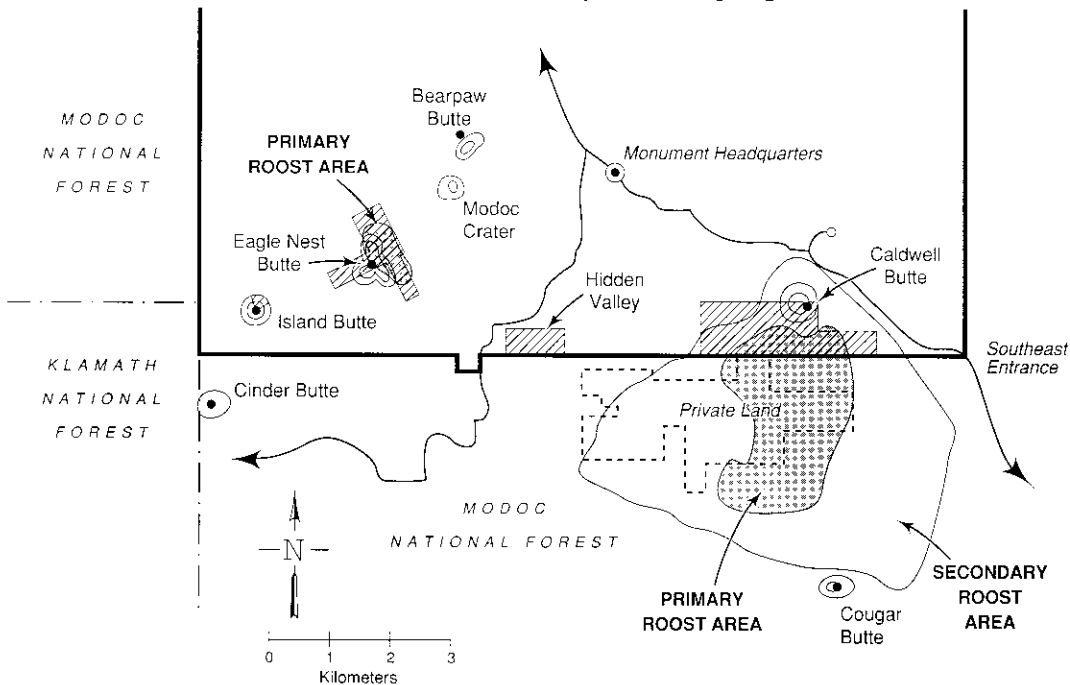


Figure 1. Map of Lava Beds National Monument (and adjacent lands), general locations of primary and secondary bald eagle winter roost areas (from Sogge and Sydoriak 1990), and study area locations (hatched areas).

*tridentata*), rabbitbrush (*Chrysothamnus* sp.), bitter cherry (*Prunus emarginata*), sagebrush (*Artemisia tridentata*), current (*Ribes* sp.), manzanita (*Arctostaphylos* sp.), and elderberry (*Sambucus* sp.) (Erhard 1979, Sogge and Sydoriak 1990).

The geology and physiography of the area are complex but little is known about their influences on forest development. The underlying volcanic substrate was formed within the last 1.25 million years, and some lava flows in the roost area are from the Holocene period (Donnelly-Nolan 1983). Glass mountain, south of the roost, erupted about 1,000 years ago, depositing frothy rhyolite pumice over the entire area (Chesterman 1955, Donnelly-Noland and Champion 1987).

Bald eagle use of the Caldwell/Cougar Roost Area varies annually. Maximum winter counts ranged from 360 eagles in January 1979 (Keister 1981) to 34 eagles in January 1990. Counts have decreased greatly since 1983/84 (278 eagles), with fewer than 60 eagles counted each year since then (Sogge and Sydoriak 1990). The reasons for this decrease are not understood at this time. Typically, bald eagles arrive in the area in November and

depart in February or March, with peak use in January (Sogge and Sydoriak 1990).

Previous studies have provided important baseline information on bald eagle winter roost characteristics in the general area. Krauss (1977) conducted a general survey of the Klamath Basin bald eagle winter use areas in 1976 and 1977. His observation suggested bald eagles in the Caldwell/Cougar roost area preferred tall, open-canopied ponderosa pines for roosting, but that eagles occasionally used tall snags and full canopy trees.

Keister (1981) compared general 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), tree heights (24.6 vs. 27.6 m) and "structure" classes. However, detailed information on the distribution of tree size classes was not reported, thus, it is impossible to fully assess spatial patterns or

potential vulnerability of the forest structure. For example, if all the old, tall trees are in one small area of the roost, one localized wildfire could greatly affect much of the habitat.

DellaSala *et al.* (1987) conducted a systematic survey of forest structure of the Bear Valley roost area in Oregon. A careful study design examined characteristics of individual roost trees and several forest structure attributes surrounding roost trees. A similar approach will be taken in this study.

## Methods

Field surveys were conducted in two primary roost areas (Caldwell Butte and Eagle Nest Butte) previously identified by Sogge and Sydoriak (1990), and two potential roost areas in LBNM (Hidden Valley and Island Butte) known to have old trees. The size and shape of the study units were selected to encompass most of the preferred habitat in the area in the southern areas of the monument (Fig. 1).

Within each study unit, variable-radius circular plots were located in a systematic-cluster design (Legendre and Fortin 1989) with primary plots regularly located 150 m (by pacing) apart along west-east transects with secondary "cluster" plots located 60 m north-east of each primary plot. Because Eagle Nest Butte was a smaller, cliff-confined area, primary plots were located 75 m apart. The systematic-clustering sampling design has proven more efficient and effective in describing landscape features than straight systematic or random sampling designs (Legendre and Fortin 1989, Fortin *et al.* 1989). Vegetation plots had a radius of 12.6 m (0.05 ha) for trees  $< 35$  cm dbh, and a radius of 17.6 m (0.1 ha) for larger trees.

The origin (SW corner) of each grid was permanently marked (steel post) and given a letter, and distance and direction was measured to a bench mark or relocatable permanent feature of the landscape. Each plot was individually numbered (i.e., sampling unit and x,y coordinates in meters from the sampling unit origin). Physical information recorded at each plot included slope (%), aspect (e.g., N, NW, NE, etc.), and elevation (by altimeter to  $\pm 10$  m). An ocular estimate of percent shrub cover, herb cover, and grass cover was assigned to each 0.1-ha plot for general descriptive purposes.

Other vegetation characteristics were measured following methods in DellaSala *et al.* (1987) to allow comparison with other eagle roost areas. Within

a 12.6-m radius of each plot center (0.05 ha) trees  $\leq 35$  cm were tallied by species in four broad size classes ( $> 0-4$ , 5-15, 16-25, 26-35 cm dbh).

Trees  $> 35$  cm dbh within a 17.6 m radius of the plot center (0.1 ha) were individually measured (dbh in cm) and assigned a species code, height class, structure class and castings class. Classes for tree heights, canopy structure and number of castings (i.e., regurgitated remains of eagle prey) followed DellaSala *et al.* (1987). Height classes were  $< 10$ , 11 to 20, 21 to 30, and  $> 30$  m. Casting classes (i.e., number of individual castings) were 0, 1 to 5, 6 to 11, 12 to 20, and  $> 20$  castings. Structure classes (Figure 2) were based on the tree canopy and crown classification system of Kccn (1943) as modified by Keister and Anthony (1983). As in other bald eagle studies, castings found at the base of trees provided an index of habitat use (Keister 1981, DellaSala *et al.* 1987). Obvious roost trees  $\leq 35$  cm dbh (previously tagged trees or trees with castings) were individually recorded throughout each study area. Roost tree data included x,y coordinates and tree characteristics as defined above.

Site descriptions and forest structure were summarized for each study area (Caldwell Butte, Hidden Valley, Eagle Nest Butte and Island Butte). Emphasis was placed on the density, basal area, and spatial distribution of ponderosa pine (the preferred roost tree species).

Ponderosa pine roost trees and non-roost trees ( $> 35$  cm dbh) were compared for differences in mean diameter, percent trees by height class, and percent trees by structure class. The Student's t-test was used to test for significant differences between roost tree and non-roost tree diameter using log-transformed data. For the Caldwell Butte and Eagle Nest Butte roost areas, spatial "contour" maps (SAS 1988) were used to display isolines of ponderosa pine density (by size class) and total basal area. The spatial distribution of known eagle roost trees is also presented.

## Results

The number of plots and size of area sampled ranged from 214 plots in 2.4 km<sup>2</sup> in the Caldwell Butte area to 8 plots and 0.04 km<sup>2</sup> in the Island Butte area (Table 1). Current eagle roost areas (Caldwell and Eagle Nest Buttes) tended to be lower in elevation and have moderate slope values

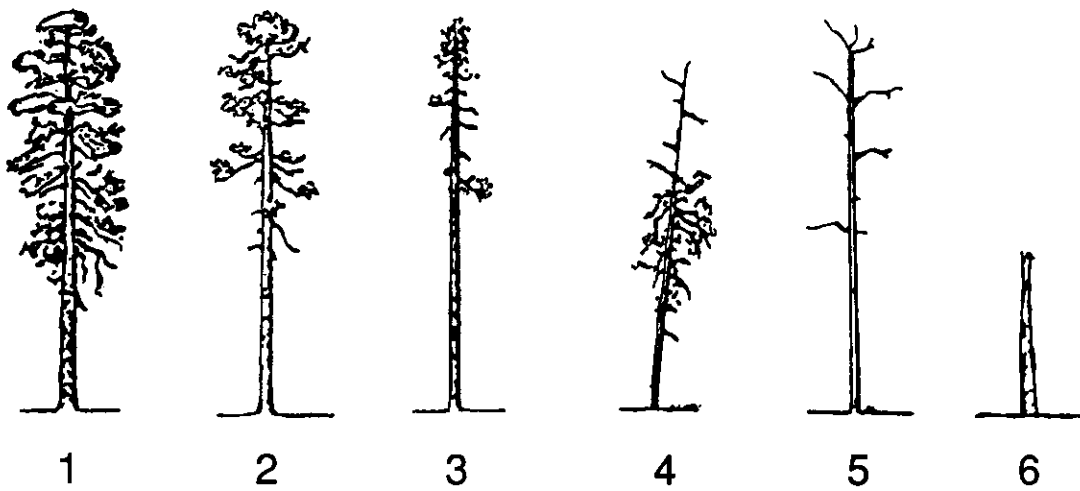


Figure 2. Characteristics used to classify tree structure within Lava Beds National Monument (adapted from Keen 1943, and Keister and Anthony 1983).

TABLE 1. Site characteristics of sampled bald eagle roost areas in Lava Beds National Monument.

Site Characteristics	Caldwell Butte	Eagle Nest Butte	Hidden Valley	Island Butte
Number of plots	214	108	51	8
Area Sampled (km <sup>2</sup> )	2.4	1.2	0.4	0.04
Mean Elevation (m)	1440	1570	1580	1640
Aspect Range	1365-1634	1524-1667	1554-1597	1615-1670
Mean Slope (%)	14	16	7	26
(S.E.)	(1)	(2)	(2)	(2)
range	0-50	1-45	1-80	15-35
Mean Shrub Cover (%)	17	25	17	21
(S.E.)	(1)	(2)	(2)	(6)
Mean Herb Cover (%)	12	8	9	4
(S.E.)	(1)	(1)	(2)	(1)
Mean Grass Cover (%)	21	7	9	3
(S.E.)	(2)	(1)	(2)	(1)
Aspect of Plots %				
W	3.3	14.8	0	0
SW	3.3	0.0	2.0	0
SE	10.3	3.7	5.9	0
S	10.3	1.8	9.8	0
NW	13.8	13.9	17.6	0
NE	11.7	14.8	5.9	75
N	21.0	22.2	43.1	25
E	23.4	29.6	17.6	0

compared to non-roost areas (Hidden Valley and Island Butte). The four study areas were dominated by generally northern exposed plots and did not greatly differ in mean shrub, herb, or grass cover (Table 1).

Stand characteristics varied among the four study areas (Table 2). However, for ponderosa

pinus, and for the other species combined, the density of trees in the small to middle size classes (<4, 5-15, 16-25 cm dbh) greatly exceeded the density of seedlings and the density of large size class trees (16-25, 26-35, >35 cm dbh). Ponderosa pine total density was not as great as the total density of the other tree species combined (i.e.,

TABLE 2. Stand characteristics of roost areas (Caldwell Butte, Eagle Nest Butte) and potential roost areas (Hidden Valley, Island Butte) in Lava Beds N.M. Mean values per ha shown with standard error in parentheses.

Stand Characteristics	Caldwell Butte	Eagle Nest Butte	Hidden Valley	Island Butte
Mean Density (No./ha)				
Ponderosa Pine				
Seedlings	3.4 (1.7)	5.0 (1.5)	3.1 (1.0)	0.0
< 4 cm dbh	15.4 (6.0)	16.9 (3.9)	9.4 (3.0)	5.0 (0.0)
5-15 cm dbh	23.4 (5.8)	30.0 (5.8)	19.2 (3.9)	0.0
16-25 cm dbh	15.6 (2.6)	22.6 (4.3)	16.1 (4.3)	0.0
26-35 cm dbh	11.7 (10.9)	10.6 (2.8)	8.2 (2.0)	7.5 (3.8)
> 35 cm dbh	7.8 (1.0)	8.5 (1.8)	7.8 (1.9)	33.8 (6.0)
Total	77.3 (11.0)	93.6 (12.7)	63.8 (9.8)	46.3 (8.2)
Other trees <sup>1</sup> (No./ha)				
Seedlings	2.1 (0.6)	19.4 (3.4)	12.5 (3.4)	27.5 (14.6)
< 4 cm dbh	40.2 (4.2)	122.0 (8.4)	96.1 (10.9)	40.0 (18.1)
5-15 cm dbh	34.9 (3.7)	73.5 (5.8)	64.7 (9.0)	67.5 (21.4)
16-25 cm dbh	6.4 (1.3)	10.2 (1.6)	7.8 (2.9)	22.5 (7.0)
26-35 cm dbh	1.1 (0.4)	3.3 (1.0)	2.0 (0.8)	15.0 (6.3)
> 35 cm dbh	7.3 (1.1)	21.5 (1.7)	0.0	28.8 (5.1)
Total	92.0 (8.1)	149.9 (14.6)	183.1 (21.5)	201.3 (54.8)
Mean Basal Area (m <sup>2</sup> /ha) of trees >35 cm dbh				
Ponderosa Pine	16.4 (0.2)	31.8 (0.8)	19.8 (0.5)	143.0 (26.2)
Western Juniper	0.7 (0.3)	0.9 (0.6)	0.0	1.4 (0.1)
White Fir	0.2 (0.2)	0.4 (0.4)	0.0	42.0 (22.7)
Mountain Mahogany	0.0	0.0	0.0	0.0
Incense Cedar	0.1 (0.1)	0.0	0.0	0.0
Total	17.4 (0.2)	33.1 (0.8)	19.8 (0.5)	186.4 (29.0)

<sup>1</sup>Includes species listed under basal area except ponderosa pine.

Western juniper, white fir, mountain mahogany and incense cedar). However, ponderosa pine accounted for between 76.7 percent and 100 percent of the basal area in the four areas. Thus, the dominant tree species and largest trees in the areas are ponderosa pines.

The absence of small ponderosa pine trees in the four areas is apparent in the size class distributions of the four areas (Figure 3). But, large trees (> 50 cm) are also rare in the sub-populations of ponderosa pine (except for the clump of large trees sampled in the 200 m x 200 m Island Butte area).

The 2.4 km<sup>2</sup> Caldwell Butte study area contained 103 eagle roost trees compared to 44 eagle trees in the 1.2 km<sup>2</sup> Eagle Nest Butte area (Table 3). Only two of the 147 roost trees were not ponderosa pines: one white fir, one incense cedar. In both roost areas, roost trees were significantly larger in diameter than non-roost trees ( $P < 0.05$ , Student's t-test on log-transformed data).

Most (89%) of the eagle roost trees were 21 to 30 m tall, while 77 percent of non-roost trees

were < 20 m tall. The majority (77.6%) of roost trees were open-structured, live trees. Snags were rarely used by bald eagles. Only 58 of 103 roost trees in the Caldwell Butte area had castings present, while 42 of 44 roost trees at Eagle Nest Butte were recently used (Table 3).

An analysis of the spatial distribution of ponderosa pine from the seedling stage to the eagle roost tree stage was conducted for Caldwell Butte (Figure 4) and Eagle Nest Butte (Figure 5). High density contour lines for seedling areas (i.e., > 20 seedlings/ha) in the Caldwell Butte areas, for example, did not extensively overlap the current distribution of eagle trees (Figure 4). About half the 214 plots did not have pine seedlings. The low density contour lines for seedling areas (0 to 20 seedlings/ha) generally overlapped the high density isobars of the larger size class ponderosa pines. Thus, density information generated from the systematic clustering design used showed there are large portions of the study area without seedlings.

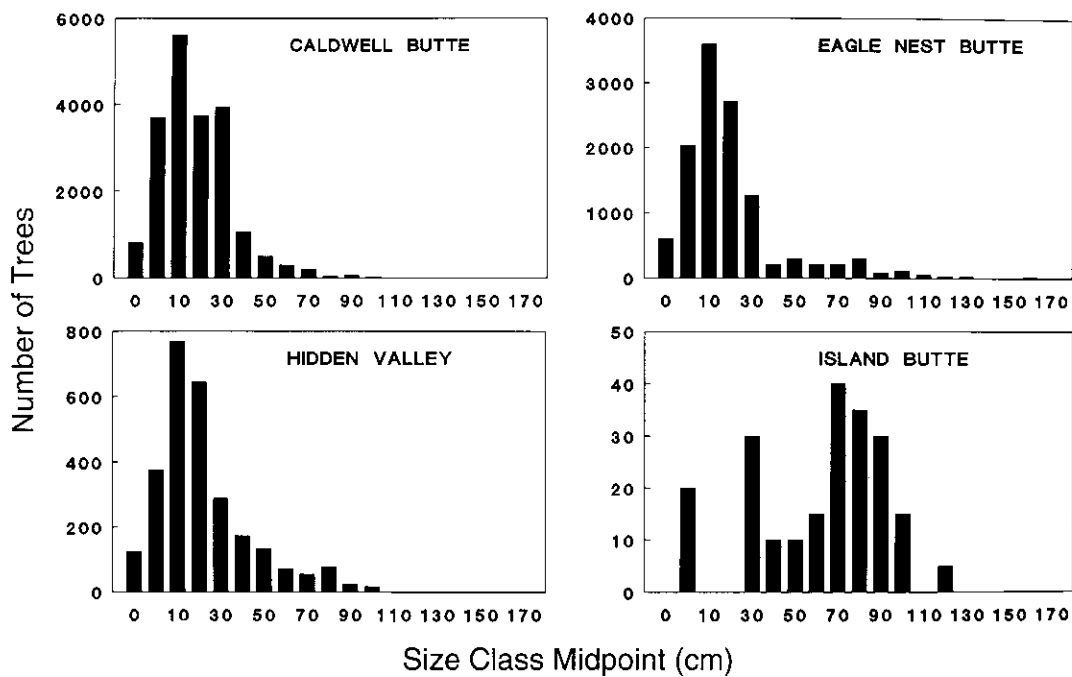


Figure 3. Size class distributions of ponderosa pines in roost areas (Caldwell Butte, Eagle Nest Butte) and potential roost areas (Hidden Valley, Island Butte).

TABLE 3. Characteristics of *Pinus ponderosa* (>35 cm dbh) by bald eagle roost area, Lava Beds National Monument, California.

Roost Area/ Tree Type	Number of Trees	Mean dbh cm (±S.E.)	% trees by height (m)				% trees by structure class <sup>1</sup>						% trees by number castings			
			1-10	11-20	21-30	>30	1	2	3	4	5	6	0	1-5	6-11	12-20
Caldwell Butte																
Non-Roost	273	46.7 <sup>2</sup> (1.0)	19.4	65.6	14.3	0.7	76.9	9.9	0.0	0.0	0.7	12.4				
Roost	103	80.3	1.0	8.7	90.3	0.0	21.4	73.8	1.0	0.0	2.9	1.0	43.7	42.7	8.7	4.9
Eagle Nest Butte																
Non-Roost	90	72.1 (1.8)	14.4	62.2	23.3	0.0	53.3	34.4	1.1	3.3	1.1	6.7				
Roost	44	83.0 (2.1)	0.0	11.4	88.6	0.0	2.3	93.2	0.0	2.3	2.3	0.0	4.6	77.3	9.1	9.1
Hidden Valley																
Non-Roost	70	51.3 <sup>2</sup> (1.0)	10.0	61.4	28.6	0.0	80.0	12.9	0.0	2.9	1.4	2.9				
Island Butte																
Non-Roost	47	61.6 <sup>2</sup> (1.0)	6.4	40.4	53.2	0.0	2.1	89.4	0.0	0.0	0.0	8.5				
All Roosts <sup>3</sup>																
Non-Roost	480	52.2 <sup>2</sup> (1.0)	15.8	61.9	21.9	0.4	65.6	22.7	0.2	1.0	0.8	9.6				
Roost	147	81.1 (1.3)	0.7	9.5	89.8	0.0	15.6	77.6	0.7	0.7	2.7	0.7	32.0	53.1	12.9	6.1

<sup>1</sup>Structure class as adapted by Keister 1981 from Keen 1943. New structure class 6 contains broken snags.

<sup>2</sup>Averages based on log-transformed data.

<sup>3</sup>Averages weighted by numbers of trees.

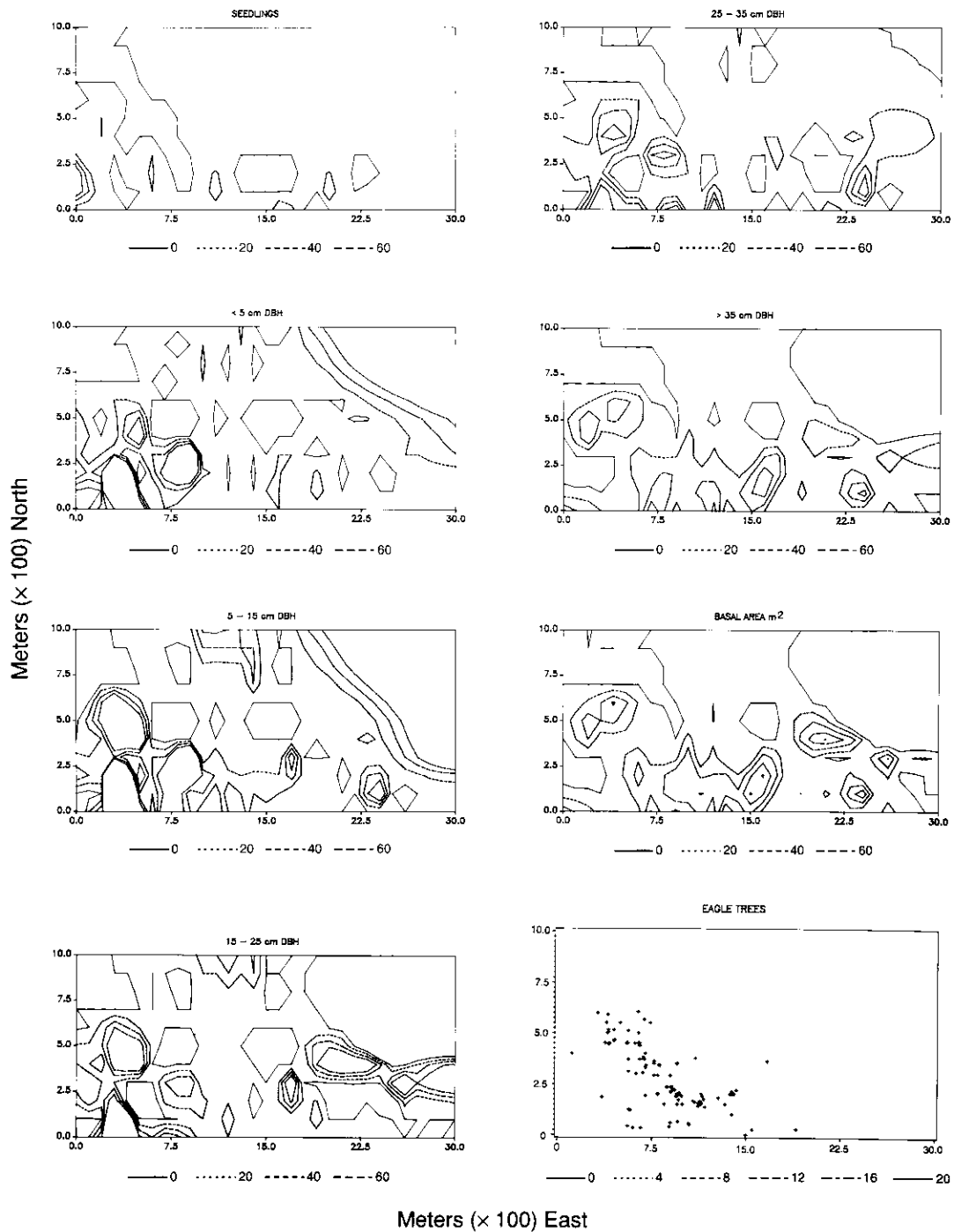


Figure 4. Density isobars (number of trees per ha) for different size classes of ponderosa pines, ponderosa pine basal area ( $m^2/ha$ ), and spatial distribution of bald eagle roost trees in the Caldwell Butte study area.

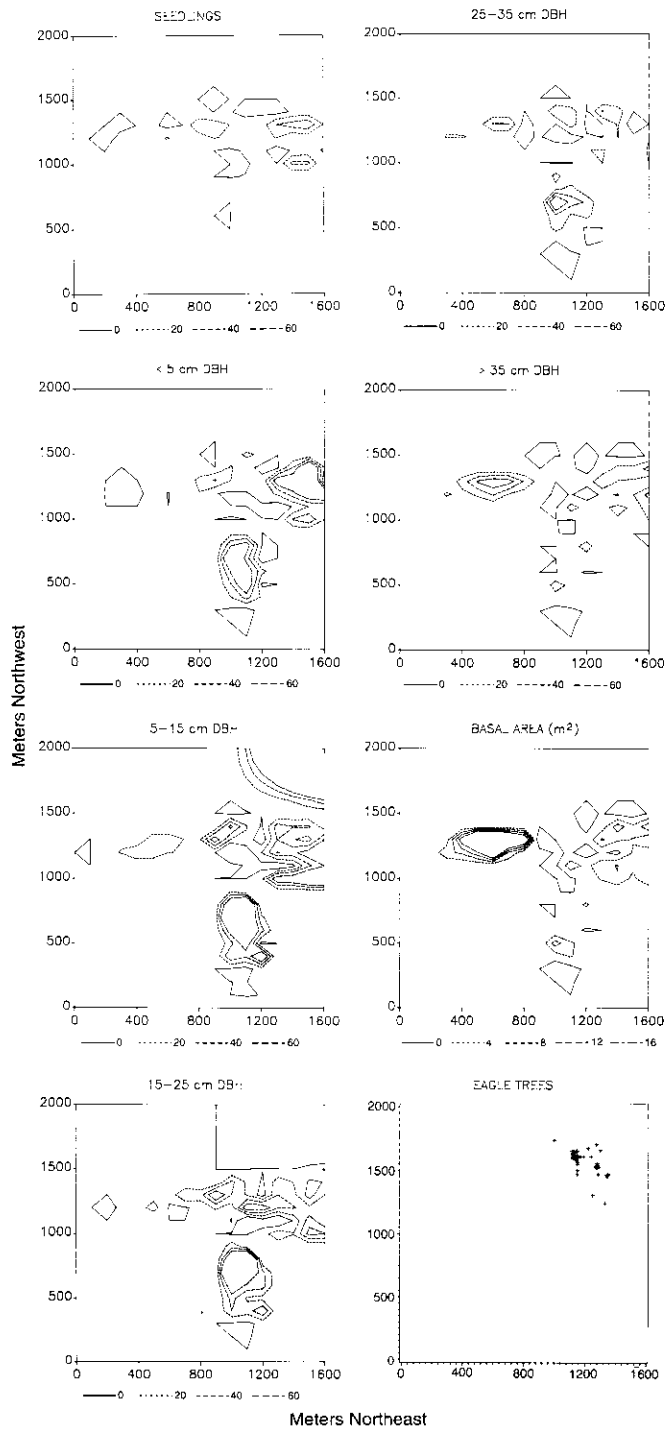


Figure 5. Density isobars (number of trees per ha) for different size classes of ponderosa pines, ponderosa pine basal area ( $m^2/ha$ ), and spatial distribution of bald eagle roost trees in the Eagle Nest Butte study area.

Likewise, high density contour lines of ponderosa pines >35 cm dbh and high contour lines of ponderosa pine basal area (m<sup>2</sup>/ha), did not extensively overlap the current distribution of eagle trees (Figure 4). Areas of high pine basal area and large (>35 cm dbh) trees in the southwest corner of the Caldwell Butte area were not used by eagles.

Ponderosa pine seedlings and eagle roost trees were clumped in distribution in the Eagle Nest Butte area (Figure 5). The highest seedling density areas were adjacent to the eagle roost trees. Areas in the southeast portion of the roost area contain high densities of 0 to 35 cm dbh trees but no eagle roost trees. The areas of highest densities of >35 cm dbh ponderosa pines (and thus, areas of high basal area) in the southwestern portion of the study area also did not contain current eagle roost trees.

Calculations based on digitally recorded polygons of roost tree locations showed that 12.7 percent of the 2.4 km<sup>2</sup> Caldwell Butte study area and only 2.8 percent of the 1.2 km<sup>2</sup> Eagle Butte study area contained eagle roost trees. In each case, 3 outlying roost trees were excluded in the calculations of primary habitat.

## Discussion

As shown in other studies in the Klamath Basin (Krauss 1977, Keister and Anthony 1983, DellaSala *et al.* 1987), bald eagle winter roost trees in LBNM tended to be more open-structured, larger (in diameter) and taller than non-roost trees (Table 3). However, it may be more important to examine differences, rather than similarities among winter roost areas to: (1) quantify relationships between habitat quality and eagle use; (2) identify the role of Caldwell Butte and Eagle Nest Butte in the local population dynamics of bald eagles; and (3) to evaluate better the management challenges that lie ahead.

Keister and Anthony (1983) showed the five major winter roost areas in the Klamath Basin greatly differed in area, number of roost trees, and number of castings found in 1979. Based on their census, less than 8 percent of the eagle use occurred in the Caldwell roost area. The concentration of eagle use I calculated at Caldwell was the lowest of the five areas with 8 castings/ha. Because eagle use in the five Klamath Basin roost areas was generally proportional to the number of available roost trees (Keister and Anthony 1983), the Caldwell Butte and Eagle Nest Butte areas may have

been (and may continue to be) low eagle use areas compared to the other roost areas in the Klamath Basin.

Because stand characteristics (i.e., species composition, size structure, age structure), distance to feeding grounds, and annual eagle use vary considerably among the roost areas in the Klamath Basin, it is not easy to assess or compare habitat quality of eagle roost areas. Within the Caldwell Butte and Eagle Nest Butte areas in LBNM, habitat quality was highly variable and spatially concentrated. For uncertain reasons, not all areas with large trees were used by eagles (Figures 4 and 5). Areas currently unused by the eagles may be more exposed to wind, have no traditional use, or have other resource limitations not yet identified in field studies. Alternatively, eagle populations may not be high enough to disperse into the currently unused areas.

For the same reasons, it is difficult to identify "potential" roost areas. The stand characteristics of Hidden Valley were generally intermediate between those of Caldwell Butte and Eagle Nest Butte (Tables 1 to 3, Figure 3). There are many large trees in the area with no sign of past eagle use. Furthermore, the gregarious nature of bald eagles during the winter roost period may discourage the "colonization" of potential roost areas by one or two adventurous individuals. Such dispersal/colonization events may occur only infrequently during peak population periods.

Continued bald eagle use in the Caldwell Butte and Eagle Nest Butte areas may be, in part, largely dependent on the population dynamics of ponderosa pines (i.e., the continued availability of large trees). There are many medium-sized trees in both study areas (Figure 3). And, many of these trees are located in specific areas currently used by bald eagles (Figures 4 and 5). Thus, barring major catastrophes (extreme fire or pathogen outbreaks, etc.) over the next 50 to 100 years, there should be an adequate number of replacement roost trees in the tree population. All four study areas, however, had very few small trees (Figure 3). Thus, there may be a discontinuous supply of large trees to the population in the long-term.

The population dynamics of ponderosa pine in LBNM appear temporally and spatially complex. Compared to similar-sized bald eagle roost trees elsewhere in the Klamath Basin (Keister 1981, DellaSala *et al.* 1987), roost trees in the Caldwell Butte roost area grow much more slowly and live

longer (mean age = 289 years) than trees in the Three Sisters, Mt. Dome, and Bear Valley roosts. Thus, the cycling of trees from the seedling stage to the roost tree stage may be much slower in the drier and more sparsely vegetated pine stands in LBNM. Very little information is available on the age structure of ponderosa pine stands in the area; no systematic survey has been undertaken. Thus, stage-class or age-class projections are problematic at this time.

The population dynamics of ponderosa pine in Caldwell Butte and Eagle Nest Butte also were spatially complex. Seedling distribution and eagle roost trees were spatially clumped and not necessarily overlapping other size class trees on the landscape (Figures 4 and 5). Two important factors influencing the size distribution and spatial patterns of ponderosa pines are insect outbreaks and fires. Western pine beetle (*Dendroctonus brevicomis*) infestations in the 1920's reportedly killed large numbers of large trees (Dale and Kliejunas 1987). However, lack of fires due to a full fire suppression policy from 1910 to 1974 (Sogge and Sydoriak 1990) may have severely limited pine reproduction.

Historically, lightning-caused fires in the Caldwell Butte area occurred on average 11 years apart (range 2 to 18 years; Olsen and Martin 1982). Most of these fires were small (<0.1 ha) and other than three small fires in 1970 and 1972, the natural role of fire has greatly diminished in these ecosystems (Martin and Johnson 1979, Olsen and Martin 1982, Sogge and Sydoriak 1990). An active prescribed burning program may be necessary to reduce heavy fuels and the possibility of catastrophic fires in currently used roost areas. This also will promote the establishment of pine seedlings that are scarce (Figure 3) and noticeably absent in many areas (Figures 4 and 5).

These findings confirm the many management challenges previously identified for the continued protection of bald eagle roost habitat in the Klamath Basin (Keister and Anthony 1983, DellaSala *et al.* 1987). The decrease in eagle use since 1983/84 probably warrants an intensive annual monitoring of eagle use.

A lack of ponderosa pine seedlings perhaps due to drought or to decades of fire suppression indi-

cates a need to enhance pine regeneration by prescribed burning selected areas. However, barring unforeseen catastrophes, the large number of medium-sized trees in the Caldwell Butte and Eagle Nest Butte areas should ensure that short-term habitat requirements are met.

Eagles have not expanded into similar nearby habitat (e.g., Hidden Valley, Island Butte) despite the presence of large open-structured trees. Thus, the current understanding of roost area characteristics and eagle behavior make it difficult to identify or assess potential or alternate roost sites. Logging in currently used bald eagle roost areas should be curtailed until we can accurately identify alternate roost sites that may be used annually by bald eagles.

Additional studies of bald eagle habitat characteristics, population dynamics of ponderosa pines, and bald eagle roost behavior are needed. These studies should be carried out on a state-wide or Klamath Basin-wide scale and over several years. They should be conducted in a hierarchical fashion (as suggested by DellaSala *et al.* 1987) at three spatial scales: tree level, plot level, and sub-roost or roost level. Winter roost activity should be carefully monitored at all roosts and sub-roosts. The systematic-clustering sampling design used in this study could easily be expanded to the other roost areas and areas of potential habitat. Because of the patchy nature of eagle trees on the landscape, a 100 percent inventory of roost trees is essential and should be repeated periodically in the future.

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- Anthony, R. G., R. L. Knight, G. T. Allen, B. R. McClelland, and J. I. Hodges. 1982. Habitat use by nesting and roosting bald eagles in the Pacific Northwest. *Trans. North. Amer. Wildl. Nat. Resour. Conf.* 47:332-342.
- Chesterman, C. W. 1955. Age of obsidian flow at Glass Mountain, Siskiyou County, California. *Amer. J. Science* 253:418-424.
- Dale, J. and J. K. Kliejunas. 1987. A biological evaluation of forest pest conditions at the Caldwell Butte eagle roost area, Lava Beds National Monument. U.S. Forest Service, Pacific Southwest Region. Forest Pest Management Report No. 87-9.
- DellaSala, D. A., R. G. Anthony and T. A. Spies. 1987. A habitat management plan for bald eagles (*Haliaeetus leucocephalus*) communal roost sites at the Bear Valley National Wildlife Refuge, Oregon. Report to U.S. Fish and Wildlife Service, Klamath Basin National Wildlife Refuge, Contract No. 14-16-0009-1533. RWO #7.
- Donnelly-Nolan, J. M. 1983. Structural trends and geothermal potential at Medicine Lake Volcano, Northern California. *EOS Transactions, Amer. Geophys. Union* 64:898.
- Donnelly-Nolan, J. M. and P. E. Champion. 1987. Geologic map of Lava Beds National Monument, Northern California. U.S.G.S. Map 1-1804.
- Erhard, D. H. 1979. Plant communities and habitat types in the Lava Beds National Monument, California. M.S. Thesis. Oregon State University, Corvallis, Oregon.
- Fortin, M. J., P. Drapeau and P. Legendre. 1989. Spatial autocorrelation and sampling design in plant ecology. *Vegetatio* 83:209-222.
- Hansen, A. J., M. V. Stalmaster, and J. R. Newman. 1980. Habitat characteristics, function, and destruction of bald eagle communal roosts in western Washington. *In* R. L. Knight, G. T. Allen, M. V. Stalmaster, and C. W. Servheen, eds. *Proceedings Washington Bald Eagle Symposium*, Seattle. Pp. 221-230.
- Hobbs, N. T. and T. A. Hanley. 1990. Habitat evaluation: do use/availability data reflect carrying capacity? *J. Wildl. Manage.* 54:515-522.
- Keen, F. P. 1943. Ponderosa pine tree classes redefined. *J. For.* 41:249-253.
- Keister, G. P., Jr. 1981. Characteristics of winter roosts and population of bald eagles in the Klamath Basin. M.S. thesis. Oregon State University, Corvallis, OR. 82 pp.
- Keister, G. P., Jr. and R. G. Anthony. 1983. Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California. *J. Wildl. Manage.* 47:1072-1079.
- Keister, G. P., Jr., R. G. Anthony and E. J. O'Neill. 1987. Use of communal roosts and foraging areas by bald eagles wintering in the Klamath Basin. *J. Wildl. Manage.* 51:415-420.
- Krauss, G. D. 1977. A report on the 1976-1977 Klamath Basin bald eagle winter use area investigation. USDA Forest Service, Klamath National Forest. 68 pp.
- Legendre, P. and M. J. Fortin. 1989. Spatial pattern and ecological analysis. *Vegetation* 80:107-138.
- Lehman, R. N. 1988. Mount Dome habitat management plan. USDI Bureau of Land Management, Susanville District, CA. 81 pp.
- Martin, R. E., and A. H. Johnson. 1979. Fire management of Lava Beds National Monument. *In* Linn. R. M. (ed.) *Proceedings of the First Conference on Scientific Research in the National Parks*. Vol. II. National Park Service and American Institute of Biological Sciences, Washington, D.C. Pp. 1209-1218.
- Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and methods of vegetation ecology*. John Wiley and Sons, New York, NY. 547 pp.
- Olsen, C. and R. E. Martin. 1982. Recommended program for fire management at Lava Beds National Monument, California. N.P.S. Western Region Final Report, Contract CX-8000-9-0015.
- SAS. 1988. SAS for Personal Computer. Release 6.03 edition. SAS Institute, Inc. Cary, NC.
- Scott, M. J., B. Csuti, K. Smith, J. E. Estes and S. Caicco. 1990. Beyond endangered species: an integrated conservation strategy for the preservation of biological diversity. *Endangered Species UPDATE* 5(10):43-48.
- Sogge, M. and C. Sydorak. 1990. Caldwell/Cougar bald eagle winter roost management plan. Lava Beds National Monument and Modoc National Forest, CA. 32 pp.
- U.S. Fish and Wildlife Service. 1986. Pacific bald eagle recovery plan. USDI. Portland, OR. 163 pp.

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