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Introduction

The American bald eagle (*Haliaeetus leucocephalus*) was designated our national symbol in 1782. Since that time, populations of the species have declined due to a combination of factors including habitat loss, shooting, and environmental pollutants. As a result, in 1978 the U.S. Department of Interior officially listed the species as endangered in 43 of the 48 contiguous states and threatened in Oregon, Washington, Michigan, Wisconsin, and Minnesota. The bald eagle is protected under the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. These pieces of legislation protect the species from direct persecution, harassment, and destruction of nests, and the Endangered Species Act provides for the identification of "critical habitat" for preservation and enhancement of populations. Five regional recovery teams appointed by the U.S. Fish and Wildlife Service are presently developing management plans to increase populations and secure habitat. The goal of these efforts is the removal of the species from the threatened and endangered list.

Meslow et al. (1981) list the bald eagle as a species that "finds optimum habitat for breeding . . . in old-growth Douglas-fir forests in western Oregon and Washington." They further state that old-growth forests are rapidly being liquidated on lands managed by USDA Forest Service and USDI Bureau of Land Management, and little old-growth timber remains on private lands in the Pacific Northwest. In view of the threatened and endangered status of the bald eagle and its apparent dependency on old-growth forests, a better understanding of its habitat require-

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ments is of paramount importance. In this paper we describe habitat use by nesting and roosting bald eagles in six forest types in the Pacific Northwest and provide recommendations for habitat management for the species. Hopefully, this information will aid state and federal agencies, private companies, and recovery teams in preparing management plans for the species.

Nesting Habitat

In the Pacific Northwest, bald eagles nest primarily in the ponderosa pine (*Pinus ponderosa*), mixed-conifer, Douglas-fir (*Pseudotsuga menziesii*), and sitka spruce (*Picea sitchensis*)/western hemlock (*Tsuga heterophylla*) forest types.[1] In addition, some nesting occurs along the large river systems in riparian communities where nests are often found in black cottonwood (*Populus trichocarpa*). Most nests are located within 1 mile (1.6 km) of large bodies of water, usually lakes, reservoirs, large rivers, or coastal estuaries.

Nest Tree Species

Species of trees used for nesting change on a north-south gradient depending on the forest types (Table 1). In California, ponderosa pine (71%) and sugar pine (16%) are the most frequently used species for nesting (Lehmann 1979). In Oregon, east of the crest of the Cascade Mountains, ponderosa pine (81%) is most often used, with Douglas-fir (13%) replacing sugar pine. In both of these areas the ponderosa pine and mixed-conifer forest types are used for nesting, and ponderosa pine is the most highly preferred nest tree species even when forest stands are dominated by Douglas-fir or other species. In Oregon and Washington, west of the crest of the Cascades, Douglas-fir (74 and 70%, respectively) is most frequently used for nesting with sitka spruce (23 and 17%, respectively) also being used. In

Table 1. Species of tree used for nesting by bald eagles in four states in the Pacific Northwest.

	State				
		Oregon (N = 155)			
Tree species	California (N = 87)[a] (%)	East of the Cascades (%)	West of the Cascades (%)	Washington (N = 218)[b] (%)	Alaska (N = 4455) (%)
Ponderosa pine	71	81			
Sugar pine	16	4			
Douglas-fir	2	13	74	70	
Sitka spruce			23	17	75
Western hemlock			3	4	19
Other species	11	3	0	9	6

[a]From Lehmann (1979)
[b]From Grubb (1976)

[1]Classification of forest types follows Franklin and Dyrness (1973).

Alaska (southeast, Prince William Sound, and Afognak Island), sitka spruce (75%) and western hemlock (19%) are the most important nest tree species in the sitka spruce/western hemlock forest types (Hodges and Robards 1981).

The important nest tree species are also important timber producing species. Consequently, there is a conflict between timber management and habitat management for nesting bald eagles. The severity of this conflict depends on the size of nest trees used by bald eagles and the size of trees available at maximum timber rotation age under current intensive forest management practices.

Nest Tree Characteristics

Height and diameter at breast height (DBH) of nest trees vary from northern California to southeast Alaska (Table 2) due to the use of different tree species in different forest types over a broad geographic area. Considering this variability and the different species of trees used for nesting in other parts of North America,

Table 2. Characteristics of bald eagle nest trees and specifications for old-growth management for four forest types in the Pacific Northwest.

Forest type/ Geographic area	Height[c] (ft.)	DBH[c] (in.)	Minimum DBH[b] specifications for old-growth management (in.)	Percentage of nest trees > minimum specifications
Ponderosa pine				
California[a]	131	43	21	100
	75–205	25–82		
Oregon	134	46	21	100
	95–176	33–76		
Mixed conifer				
Oregon	124	41	32	81
	68–176	21–64		
Douglas-fir				
Oregon	191	69	32	97
	90–285	29–107		
Washington	116	50	32	94
	82–197	24–90		
Sitka spruce/western hemlock				
Washington	145	75	32	100
	82–197	41–109		
Alaska, Southeast	97	43		
	25–200	12–110		
Alaska, Prince William Sound	77	36		
	25–200	12–75		

[a]From Lehmann (1979).
[b]From Pacific Northwest Regional Plan (U.S. Forest Service 1981).
[c]Values are mean and range.

some degree of plasticity in tree size and species for nesting is apparent. Structure of the platform on which to build a nest is what is most highly selected for.

In the Pacific Northwest, bald eagles select large old-growth trees for nesting (Table 2). In the ponderosa pine forest type there is a high degree of similarity in the range and mean values for height and DBH of nest trees in California and Oregon. Nest trees average approximately 44 inches (112 cm) DBH and some are larger than 72 inches (183 cm) DBH and attain heights of 200 feet (61 m). Nest tree characteristics in the mixed conifer forest type of Oregon are similar in size to those in the ponderosa pine type with average DBHs of 41 inches (104 cm) and heights up to 175 feet (53.3 m). In the Douglas-fir forest type, there are considerable differences in the range and means for height and DBH of nest trees in Oregon and Washington. Nest trees are larger in western Oregon than in the Puget Sound area in Washington, where there are shallower soils and more xeric conditions. These differences stress the importance of recognizing geographic areas as well as forest types in managing for nesting bald eagles. Nest trees in this forest type average 50 inches (127 cm) (Washington) and 69 inches (175 cm) (Oregon) DBH and some are as large as 107 inches (272 cm) DBH. Heights of nest trees may be greater than 275 feet (83.8 m).

In the sitka spruce/western hemlock forest type, there are also considerable differences in the range and means for height and DBH of nest trees in Washington, southeast Alaska, and Prince William Sound, Alaska. Nest trees are smaller at the more northern latitudes. These geographic differences in nest tree characteristics in the sitka spruce/western hemlock forest type are similar to geographic differences in other forest types. Nest trees in this forest type in western Washington are some of the largest on record with average DBHs of 75 inches (190 cm) and some as large as 109 inches (277 cm) DBH.

The U.S. Forest Service has established "minimum specifications" for old-growth timber management (Table 2) in the Pacific Northwest Regional Plan (U.S. Forest Service 1981:62), which establish criteria for old-growth inventory. All nest trees in the ponderosa pine type and the sitka spruce/western hemlock type (Washington) are larger than these minimum specifications. For the Douglas-fir type, 97 and 94 percent of the nest trees in Oregon and Washington, respectively, are larger than these specifications. In fact, most nest trees are considerably larger than the specifications. Minimum DBH specifications for the mixed-conifer type are well below the mean and at the lower end of the range in size of nest trees in that type. Eighty-one percent of the nest trees in the mixed-conifer type are larger than the minimum specifications. Average DBH of old-growth trees in southeast Alaska is 24 inches (61 cm) and 91 percent of the nest trees are larger than this value. The above comparisons indicate that most of the forest stands classified as old-growth on National Forests are not adequate for bald eagle nesting habitat.

In summary, bald eagles build their nests in old-growth coniferous trees regardless of forest type or geographic area. Sizes of nest trees depend on the tree species, forest type, and geographic area. Data from California (Lehmann 1979), Washington (Grubb 1976), and Oregon indicate that nest trees are usually (>95% of the time) the dominant or co-dominant member of the forest canopy. Nest trees are generally larger (81 to 100%) than the minimum DBH specifications for inventory of old-growth forests as suggested by the Pacific Northwest Regional Plan (U.S. Forest Service 1981:62).

Forest Stand Characteristics

Nest trees tend to be larger than surrounding trees (Tables 2 and 3). Data in Table 3 are means of mean forest stand characteristics around individual nest trees for a geographic area, so extremes in height and DBH are masked. The range and means in height and DBH are variable due to the occurrence of nesting in different forest types and geographic areas and variation in individual stand structure. Forest stands around eagle nest trees are generally multi-layered with considerable variation in height and DBH. Most forest stands surrounding eagle nests include old-growth trees with mean DBHs close to and maximum DBHs usually above the minimum DBH specifications for old-growth management (Table 2). Consistent with differences in nest tree characteristics, forest stands in the Douglas-fir type for Oregon have larger trees than stands in the Puget Sound area of Washington. However, mean stand characteristics for the Douglas-fir type in western Oregon are similar to those for the sitka spruce/western hemlock type on the Olympic Peninsula of western Washington.

Density of forest stands around eagle nest trees also varies (Table 3), because of alteration of forest stands by logging activities. Mean densities range from 36 to 67 stems/acre (89 to 165 stems/ha). We suggest a range of 45 to 70 trees/acre (111 to 173 stems/ha) for management of nest sites. Densities in the ponderosa pine and mixed-conifer types could be at the lower (45 to 60 trees/acre [111 to 148

Table 3. Characteristics of forest stands surrounding bald eagle nests in four forest types in the Pacific Northwest.

Forest type/ geographic area	Height (ft)	DBH (in)	Density[c] (stems/acre)
Ponderosa pine			
California[a]	101	29	44
	26–220	9–46	6–129
Oregon	75	20	49[b]
	38–176	14–28	5–136
Mixed conifer			
Oregon	65	19	36[b]
	38–176	14–29	4–123
Douglas-fir			
Oregon	98	28	59[b]
	38–285	17–45	4–125
Washington	74	21	64[b]
	56–105	15–31	4–126
Sitka spruce/western hemlock			
Washington	86	27	67[b]
	56–118	19–33	31–146

[a]From Lehmann (1979).
[b]Density of trees larger than 10.5 in DBH.
[c]Values are mean and range.

trees/ha]) end of this range, while densities for the Douglas-fir and sitka spruce/western hemlock types should be at the upper (60 to 70 trees/acre [148 to 173 trees/ha]) part of the range. Human disturbance around nest sites during the nesting season can negatively influence nesting success (Broley 1947, Murphy 1965, Gerrard et al. 1975, Grubb 1976). A dense forest stand around nests will provide a visual barrier to human intrusion into the nest site and mitigate disturbance. Stand integrity and susceptibility to windthrow, disease, and other causes of tree mortality should also be considered in establishing density requirements.

Communal Roosting Habitat

In the Pacific Northwest, bald eagles roost communally in the ponderosa pine, mixed-conifer, Douglas-fir, black cottonwood, and western larch (*Larix occidentalis*) forest types. Roosts receive low to high levels of use, with as many as 400 individuals observed in a roost on a given night. The adaptive significance of communal roosting is not well understood; however, a number of hypotheses have been proposed: (1) aids in food finding, (2) enhances thermoregulation, by the selection of favorable microclimates, and (3) aids in the establishment of a social hierarchy or other social functions. Stalmaster (1981) and Keister (1981) have demonstrated that communal roosts have more favorable microclimates than surrounding areas and thereby require lower energy expenditures.

Forest Stand Characteristics

Mean DBHs (20–24 inches [51–61 cm]) and heights (81–91 feet [24.7–27.7 m]) of trees are similar in forest stands of communal roosts in the ponderosa pine, Douglas-fir (eastern Washington), and mixed-conifer forest types (Table 4). The Eagle Island roost in eastern Washington in the black cottonwood type has a mean DBH and height that are also comparable to these values. In addition, the black cottonwood roost sites in western Washington (Barnaby) and Montana are similar in characteristics. This similarity in stand characteristics within and between forest types suggests that bald eagles are selective for communal roost sites. The large ranges in height and DBH of individual trees within roosts indicate a high degree of variability in size, suggesting a high degree of stratification (multilayering) in the forest stands. Mean values of DBH for roosts in the ponderosa pine, mixed conifer, and Douglas-fir types are similar to the minimum DBH specifications (U.S. Forest Service 1981:62); however, all of the roosts in these types possess old-growth trees that are considerably larger than these specifications. Minimum specifications are not available for the black cottonwood or western larch types.

Roost Tree Characteristics

Roost trees in the ponderosa pine type are larger than the surrounding trees in the forest stands (Tables 4 and 5). Mean DBH and height for roost trees in the Mt. Dome, Three Sisters, and Caldwell roosts of northern California are only slightly larger than mean DBH and height of forest stands in the respective areas. Mean values for roost trees in the Cougar roost are considerably larger than those for the forest stand. Average age of roost trees varies from 131 to 311 years in the ponderosa pine type and is indicative of old-growth forests. The communal roosts

Table 4. Characteristics of forest stands used for communal roosting by bald eagles in 11 communal roosts in the Pacific Northwest.

Forest type/ geographic area	Height[c] (ft.)	DBH[c] (in.)
Ponderosa pine		
California (Mt. Dome)[b]	88	24
	50–125	13–46
California (Three Sisters)[b]	84	21
	50–125	13–34
California (Caldwell)[b]	81	20
	50–125	13–37
California (Cougar)[b]	91	22
	50–150	13–38
Mixed conifer[a]		
Oregon (Bear Valley)[b]	91	20
	50–125	13–40
Eastern Washington (Azwell)	89	23
	50–132	12–34
Douglas-fir		
Eastern Washington (Brewster)	79	24
	50–116	11–48
Black cottonwood		
Washington (Barnaby)	93	21
	66–132	12–52
Washington (Eagle Island)	91	23
	66–149	12–64
Montana (Glacier National Park)	125	38
	108–135	32–41
Western larch		
Montana (Glacier National Park)	82	15
	10–138	3–28

[a]Weighted means of measurements on ponderosa pine and Douglas-fir.
[b]From Keister (1981).
[c]Values are mean and range.

in the mixed-conifer type have similar roost tree characteristics, and roost trees are significantly larger than forest stands, indicating a selection for larger trees and/or associated factors (i.e. openness, visibility, canopy cover) for roosting. Average age of roost trees in the Bear Valley roost (Oregon) is 199 years. Roost trees in the Douglas-fir type are larger than the general forest stand characteristics. Hansen et al. (1980) indicate that roost trees in two communal roosts (Table 5) in western Washington averaged 63 and 60 feet (19.2 and 18.3 m) taller than surrounding trees. Roost trees in the Douglas-fir type of western Washington (Van Zandt, Slide Mt.) are the tallest thus far measured.

Table 5. Characteristics of roost trees used by bald eagles in 13 communal roosts in the Pacific Northwest.

Forest type/ geographic area	Height[e] (ft.)	DBH[e] (ft.)	Average Age (yrs.)
Ponderosa pine			
California (Mt. Dome)[b]	89 51–110	25 20–32	250
California (Three Sisters)[b]	82 69–100	22 17–26	131
California (Caldwell)[b]	81 70–88	30 24–41	289
California (Cougar)[b]	101 86–121	31 24–40	311
Mixed conifer[a]			
Oregon (Bear Valley)[b]	111 69–138	29 17–42	199
Eastern Washington (Azwell)	104 67–160	29 20–44	ND[d]
Douglas-fir			
Eastern Washington (Brewster)	83 72–93	43 38–52	ND[d]
Western Washington (Van Zandt)[c]	190	33	ND[d]
Western Washington (Slide Mt.)[c]	174	32	ND[d]
Black cottonwood			
Washington (Barnaby)	123 59–191	36 19–79	ND[d]
Washington (Eagle Island)	140 73–182	43 30–74	
Montana (Glacier National Park)	124 108–135	38 32–42	ND[d]
Western larch			
Montana (Glacier National Park)	112 85–138	22 16–28	300+

[a]Weighted means of measurements on ponderosa pine and Douglas-fir.
[b]From Keister (1981).
[c]From Hansen et al. (1980).
[d]ND = Age not determined for roost trees in these roosts.
[e]Values are mean and range.

Roost trees in the black cottonwood type are significantly larger than forest stands for the Washington (Barnaby) site, but this is not the case for the Montana site. Mean characteristics of roost trees are similar for the two sites. Both sites are old-growth stands of black cottonwood. Roost trees in the western larch type are larger than forest stands, and individual old-growth trees are present in the stand. Most roost trees are probably at least 300 years old.

Means and ranges of DBH of roost trees in 3 of the 4 ponderosa pine types and all of the Douglas-fir types are larger than the minimum DBH specifications (Table 2) for old-growth forest management (U.S. Forest Service 1981). Many roost trees in the mixed-conifer type are old-growth (200 years old) and are larger than the minimum specifications of 32 inches (81.3 cm) DBH for this type. No specifications (definitions) are available for the black cottonwood or western larch types. Again, these comparisons show the inadequacy of the minimum specifications for old-growth inventory for bald eagle roosting habitat.

In summary, the communal roosts analyzed have old-growth trees (averaging 131 to 311 years) that are larger than the minimum DBH specifications for the ponderosa pine, mixed conifer, and Douglas-fir types. Many of the forest stands have similar mean DBH and heights, suggesting some degree of selectivity of roosting sites. The large range in height and DBH within each roost indicates a high degree of stratification in communal roosts. Bald eagles select roost trees that are larger than the average size of trees in the stand, and these trees are usually old-growth. In addition, Keister (1981) documented use of snags (9%) and spike-topped (7%) trees for roosting by bald eagles in the Klamath Basin; this use was greater than expected based on availability.

Discussion and Management Implications

The nesting ecology of bald eagles has been studied throughout the range of the species in North America. Bald eagles use a wide variety of tree species for nesting, which indicates they select for structure of the tree rather than species (Gerrard et al. 1975:173). In the Pacific Northwest, old-growth ponderosa pine, Douglas-fir, sitka spruce, and western hemlock provide the desirable structure for nesting, and small trees (<30 inches [76 cm] DBH) are rarely used. Nest trees are usually dominant or co-dominant individuals in the forest stand. Forest stands surrounding nest trees vary from open areas (generally clearcuts) to pristine old-growth. Where forest stands are undisturbed, a component of old-growth is invariably present. Crucial questions in habitat management for nesting bald eagles include: (1) at what level does habitat alteration change a site from being optimal (preferred) to sub-optimal habitat that a pair of eagles continues to use because of nest site tenacity and/or pair bonding, (2) will an altered site be used once one or both members of a nesting pair die, and (3) is there a difference in productivity of eagles nesting in optimal versus sub-optimal habitat? The amount of habitat alteration a pair of nesting bald eagles will tolerate on a short time frame is probably more than what the species can tolerate in general. Until we know how much habitat alteration the species will tolerate we should manage for preferred (optimal) nesting habitat.

The Pacific Northwest appears to differ slightly from other parts of the contiguous 48 states with respect to roosting behavior of bald eagles in that larger numbers (200–400+) of these birds use night communal roosts during fall and winter. These communal roosts are invariably located near a rich food resource (i.e., runs of anadromous fish, high concentrations of waterfowl) and in forest stands that have at least a remnant of the old-growth component. These stands are variable in species composition, size, and tree size (i.e., not entirely old-growth), but the old-growth component provides the roost trees. Keister (1981) found that bald eagles roosted in the old-growth forest stands closest to a rich food resource in the

Klamath Basin even though closer stands of juniper and young-aged ponderosa pine were available.

Special management considerations are needed for communal roosts that have been shaped by natural disturbances such as floods (cottonwood roosts) and fire (larch roosts). Water impoundment projects often eliminate habitat or natural processes that maintain roosting habitat or destroy anadromous fish runs; such projects must be carefully scrutinized. Natural or prescribed fires should be accommodated in any management scheme designed to perpetuate the characteristics of forest communities shaped by fire.

The immediate problem is that old-growth forests are rapidly being removed on lands administered by the U.S. Forest Service and Bureau of Land Management (Meslow et al. 1981). At the current rate of timber harvest, old-growth stands will be eliminated on Bureau of Land Management districts in Oregon within the next 10 to 30 years (Luman and Neitro 1980). In addition, little old-growth timber exists on private and state forest lands in the Pacific Northwest, and there is little incentive or willingness to manage for older forests. Most forest lands in the Pacific Northwest are programmed for a 40- to 80-year stand rotation, which will eliminate nesting and roosting habitat for bald eagles in the Pacific Northwest.

The current strategy of short rotation and even-aged management of forest stands clearly will not provide the necessary requirements (large sized trees and multi-layered forests) for nesting and communal roosting by bald eagles. In addition, the U.S. Forest Service's definitions (minimum specifications) of old-growth (U.S. Forest Service 1981:62) are inadequate for preservation of nesting and roosting habitat for bald eagles in the Pacific Northwest. The solution to this problem is the preservation and management of existing and potential nesting and roosting areas as old growth (200 to 400+ years). We recommend the following steps to insure the continued existence of nesting and roosting habitat for bald eagles:

1. Identify all existing and potential nest and communal roost sites (not all of these areas are currently known and areas used by bald eagles may change annually),
2. Remove all existing and potential nest sites and communal roosts from forest rotation systems and establish special management areas (or zones in the case of dense nesting concentrations), and
3. Develop management plans for individual nest sites and communal roosts, if necessary, to identify and accommodate special management problems.

In addition, modified silvicultural systems that avoid clearcutting should be designed to create the desired habitat, and these systems should be tested.

Some of the above steps have already been initiated in local areas of the Pacific Northwest. Management plans for nesting bald eagles on national forests have been developed (Goold 1981, Isaacs and Silovsky 1981) and represent positive steps. We emphasize the need for similar steps to be accomplished throughout the region. The designation and preservation of *potential* nesting and roosting areas are important to (1) insure adequate habitat in the future when some existing sites are no longer viable and (2) encourage increase in bald eagle populations. This is important for population recovery.

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