# Use of Hardwoods by Birds Nesting in Ponderosa Pine Forests[1]

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### Abstract

We examined the use of hardwood tree species for nesting by bird species breeding in ponderosa pine (*Pinus ponderosa*) forests in the Sierra National Forest, California. From 1995 through 2002, we located 668 nests of 36 bird species nesting in trees and snags on four 60-ha study sites. Two-thirds of all species nesting in trees or snags used hardwoods for nesting, with 19 species using California black oaks (*Quercus kelloggii*) and 11 using canyon live oaks (*Quercus chrysolepsis*). Although hardwoods comprised only 17 percent of available trees, 51 percent of nests in trees were in hardwoods. The two oak species comprised more than 90 percent of the hardwoods used. Oaks used for nesting were larger than those available. Hardwood snags were seldom used. Cavity nesters used mostly conifers, especially conifer snags, but when nesting in hardwoods they nested mostly in dead portions of live trees. Of 10 species with adequate sample sizes to examine individually, six species used hardwoods more than expected [Anna's Hummingbird (*Calypte anna*), Western Wood-Pewee (*Contopus sordidulus*), Cassin's Vireo (*Vireo cassinii*), Hutton's Vireo (*Vireo huttoni*), American Robin (*Turdus migratorius*) and Black-headed Grosbeak (*Pheucticus melanocephalus*)]. Two species used conifers more than expected [Western Tanager (*Piranga ludoviciana*) and Purple Finch (*Carpodacus purpureus*)], and two species showed no overall preference compared to available trees [Hammond's flycatcher (*Empidonax hammondii*) and Steller's Jay (*Cyanocitta stelleri*)]. Western Wood-Pewees and Cassin's Vireos nested primarily in California black oaks. Hutton's Vireos, American Robins, and Black-headed Grosbeaks showed a preference for nesting in canyon live oaks. Anna's Hummingbirds used both oak species. Our results underscore the importance of hardwood trees species, particularly oaks, to birds breeding in ponderosa pine forests. For recruitment to mature trees, these shade-intolerant species need openings in the understory that were probably created primarily by fire in the past. We recommend retention of mature oaks in ponderosa pine stands, creation of openings to encourage growth of existing oaks, and management activities that encourage recruitment of oaks to replace those that die, such as carefully-applied prescribed fire.

*Keywords: Breeding birds, California black oak, canyon live oak, hardwoods, nesting habitat, ponderosa pine,* Quercus chrysolepsis, Quercus kelloggii.

## Introduction

Hardwood forests cover more than 4.5 million hectares of land in California and are important in providing fuelwood, grazing, forest products, watershed protection, recreation opportunities, and wildlife diversity (Waddell and Barrett 2005). Hardwood forests rank among the most important for wildlife (Verner 1987). For example, more than 355 vertebrate species in the western Sierra Nevada are associated with oaks (Verner and Boss 1980). In addition to their value as a

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component of habitat, the propensity of hardwoods to produce large amounts of acorns at critical times of the year is a beneficial trait of these trees for wildlife (McDonald 1990, McDonald and Huber 1995).

California's hardwood resources fall into two basic groups: those that grow in the foothills and woodlands at lower elevations and those that grow in the forest zones at higher elevations (McDonald and Huber 1995). In this paper, we focus on hardwoods of forest zones of the Sierra Nevada. Hardwoods in Sierra Nevada forests are generally found as single trees or in clumps, and seldom grow in pure stands (McDonald and Huber 1995, McDonald and Tappeiner 1996). Hardwood tree species are generally shade intolerant, and require openings in the conifer canopy to sprout and grow (McDonald 1969). They are adapted to a broad range of conditions, including harsh conditions, and are able to withstand severe moisture stress (McDonald 1969, McDonald and Huber 1995, McDonald and Tappeiner 1996). Hardwoods require periodic disturbance for establishment and, with prolonged absence of disturbance, the shade-intolerant hardwoods are crowded out by conifers. (McDonald and Huber 1995, McDonald and Tappeiner 1996).

Almost 20 years ago, Verner (1987) listed critical wildlife research needs for hardwood habitats that included studying habitat preferences of wildlife associated with hardwoods, developing more accurate models of wildlife habitat relationships, and developing better models to predict successional changes in plant species composition. However, few studies to date have examined the importance of forest hardwoods to wildlife in California. Garrison and others (2005) studied the effects of group-selection harvest done to enhance stand conditions for black oak and found no adverse effects. Given the importance of hardwoods for wildlife, it is surprising that the needs of wildlife species using hardwoods have been little studied. Here we examine the use of hardwoods for nesting by birds breeding in ponderosa pine (*Pinus ponderosa*) forests in the Sierra Nevada. We examine selection for tree and snag species across all bird species and for individual species in which sample sizes allow. We also compare attributes of trees and snags used to those available for selection.

## Methods

### *Study Areas*

Four research sites were selected in ponderosa pine forests within the Sierra National Forest in the Southern Sierra Nevada, California, ranging in elevation from 1,024 to 1,372 m. Each site consisted of at least 60 ha of mature forest with relatively high canopy cover. Within the larger 60-ha plot, a 40-ha grid was established with 50 m spacing to aid in the mapping and relocation of nests. Ponderosa pine was the dominant tree species with incense cedar (*Calocedrus decurrens*) co-dominant. Other conifer species included white fir (*Abies concolor*) and sugar pine (*Pinus lambertiana*). Several hardwood species occurred in the area, the most common of which were California black oak (*Quercus kelloggii*) and canyon live oak (*Q. chrysolepsis*), but white alder (*Alnus rhombifolia*) and Oregon ash (*Fraxinus latifolia*) occurred in moist areas. Sites also included riparian elements, granitic outcrops, and shrub fields dominated by white-leaf manzanita (*Ceanothus viscida*). Portions of the study area had been impacted by past silvicultural treatments such as selective tree harvesting, however, these areas were protected from major disturbance such as timber harvest, road construction, and major fuel breaks for the duration of the study.

## Fieldwork

Fieldwork began in 1995 and continued through 2002, and was part of a larger study on the productivity of forest birds across an elevational gradient (Purcell 2002). Field crews searched each 40-ha grid for nests of all bird species. Over the eight years of the study, we spent approximately 3,224 hours searching for nests on the four study sites. We recorded the substrate type (for example, tree, snag, shrub, and so forth) and plant species for each nest. We recorded height and diameter at breast height (dbh) for trees and snags. For trees, we recorded whether the portion of the tree where the nest was located was live or dead. Dbh was calculated as the sum of the diameters of all stems for multi-stemmed species rather than the geometric mean as we were interested in the overall size of the tree rather than basal area. Trees were defined as > 2 m tall. A snag was defined as having no living foliage.

To describe available trees, a total of 140 randomly-located plots were established on the four study grids. Data were recorded at 15 plots on each of the four grids in 1996, and 10 each in 1997 and 1999. Plot centers were located a random distance and direction from randomly selected points on the grid, with the stipulations that selected grid points were at least 100 m apart to avoid overlap and within 50 m of the study grid boundary. In 1996 and 1999, we recorded tree species, height, and dbh of the tree and snag closest to the plot center. In 1997, plots were divided into four quadrants and data were recorded for the nearest tree and snag in each quadrant.

## Statistical Analysis

In seven cases, nests in consecutive years were built in the same location by the same species; data from only the first nest was used in analyses. We compared tree species used for nesting with available trees. We used Chi-square tests, with a continuity correction for a 2 x 2 table, to examine tree species preferences for hardwood versus conifer tree species for all nests combined, and for individual species with sample sizes of ≥ 19 nests. As is typical for this type of analysis, we examined relations between used and available trees rather than non-used trees. Although we do not know whether the trees in our available sample contained a nest, we believe the probability that available trees were used for nesting was low, as most trees were unused for nesting in any year.

Differences in tree height and dbh between nest trees and available trees were examined using *t*-tests (Proc TTEST, SAS Institute, Inc. 2004). Satterthwaite's adjustment for unequal variances was used when appropriate (Satterthwaite 1946).

## Results

Over the eight years of the study, we found a total of 668 nests of 36 bird species in trees or snags in ponderosa pine forests; seven nests used in consecutive years were excluded for a total of 661 nests examined here (*tables 1 and 2*). A total of 24 of the 36 species nested in hardwood trees or snags.

Of nests in trees, 51 percent were located in hardwood tree species and hardwoods were used more than expected compared to available trees ($\chi c2 = 79.2$, $P < 0.0001$; fig. 1a). The two oak species comprised more than 90 percent of the hardwood species used. Nineteen species nested in California black oak trees and 11 in canyon live oak trees (*table 1*).

Hardwood snags were seldom used, although used snags did not differ from available snags ($\chi c2 = 0.5$, $P = 0.47$; fig. 1b). Of 151 nests found in snags, 11 percent were in hardwoods, most of which were in white alder. Species nesting in alder snags included four species of cavity nesters (Downy and Hairy woodpeckers, White-headed Woodpecker, and Red-breasted Nuthatch; see *tables 1 and 2* for scientific names) and one open nester (Pacific-slope Flycatcher). Only three nests were found in oak snags and included White-headed Woodpecker (one nest) and American Robin (two nests).

***Table 1**—The number of nests found by tree species and available tree species in ponderosa pine forests in the southern Sierra Nevada, 1995 to 2002. Vertical line divides hardwood and conifer tree species.*

| Bird species | California black oak | Canyon live oak | Oregon ash | White alder | Ponderosa pine | Incense cedar | Sugar pine | White fir | Total |
|---|---|---|---|---|---|---|---|---|---|
| Cooper's Hawk (*Accipiter cooperii*) | 1 | | | 2 | 1 | | | | 4 |
| Red-tailed Hawk (*Buteo jamaicensis*) | | | | | 1 | | | | 1 |
| Band-tailed Pigeon (*Patagioenas fasciata*) | | 1 | | | | 1 | | | 2 |
| Mourning Dove (*Zenaida macroura*) | | | | | 3 | | | | 3 |
| Vaux's Swift (*Chaetura vauxi*) | 1 | | | | | | | | 1 |
| Anna's Hummingbird (*Calypte anna*) | 13 | 20 | | 4 | 7 | 3 | | 2 | 49 |
| Acorn Woodpecker (*Melanerpes formicivorus*) | | | | | 1 | 1 | | | 2 |
| Downy Woodpecker (*Picoides pubescens*) | 4 | | | 5 | | | | | 9 |
| Hairy Woodpecker (*Picoides villosus*) | 1 | | | | | 1 | | | 2 |
| Northern Flicker (*Colaptes auratus*) | | | | | 1 | | | | 1 |
| White-headed Woodpecker (*Picoides albolarvatus*) | 1 | | | | | | | | 1 |
| Olive-sided Flycatcher (*Contopus cooperi*) | | | | | 2 | | | | 2 |
| Western Wood-Pewee (*Contopus sordidulus*) | 29 | | | | 9 | 2 | | | 40 |
| Hammond's Flycatcher[1] (*Empidonax hammondii*) | 2 | | | 4 | 13 | 14 | | | 33 |
| Pacific-slope Flycatcher (*Empidonax difficilis*) | 3 | | | 4 | 1 | 2 | | | 10 |
| Cassin's Vireo (*Vireo cassinii*) | 27 | 12 | | | 1 | 19 | 1 | 2 | 62 |

| Bird species | California black oak | Canyon live oak | Oregon ash | White alder | Ponderosa pine | Incense cedar | Sugar pine | White fir | Total |
|---|---|---|---|---|---|---|---|---|---|
| Hutton’s Vireo (*Vireo huttoni*) | 2 | 43 | | | | 4 | 2 | 1 | 52 |
| Warbling Vireo (*Vireo gilvus*) | 10 | 2 | | 1 | | 2 | | | 15 |
| Steller’s Jay (*Cyanocitta stelleri*) | | 8 | | | 7 | 10 | | 1 | 26 |
| Mountain Chickadee (*Poecile gambeli*) | 1 | | | | 1 | | | | 2 |
| Bushtit (*Psaltriparus minimus*) | 1 | 6 | | | | | | | 7 |
| Red-breasted Nuthatch (*Sitta canadensis*) | 1 | | | 2 | 1 | | | | 4 |
| Brown Creeper (*Certhia americana*) | | | | | 1 | 3 | | | 4 |
| Golden-crowned Kinglet (*Regulus satrapa*) | | | | | | 2 | | | 2 |
| Blue-gray Gnatcatcher (*Polioptila caerulea*) | 1 | 1 | | | 5 | | | | 7 |
| American Robin (*Turdus migratorius*) | 6 | 21 | 1 | | 11 | 16 | 1 | 1 | 57 |
| Yellow-rumped Warbler (*Dendroica coronata*) | | | | | 1 | 3 | | | 4 |
| Black-throated Gray Warbler (*Dendroica nigrescens*) | 3 | 6 | | | 5 | 1 | | | 15 |
| Hermit Warbler (*Dendroica occidentalis*) | | | | | 4 | 1 | | 1 | 6 |
| Western Tanager (*Piranga ludoviciana*) | | | | | 15 | 4 | | | 19 |
| Chipping Sparrow (*Spizella passerina*) | | | | | 7 | 6 | | 1 | 14 |
| Black-headed Grosbeak (*Pheucticus melanocephalus*) | 2 | 7 | | 1 | 1 | 7 | | 1 | 19 |
| Purple Finch (*Carpodacus purpureus*) | | | | | 25 | 4 | | 2 | 31 |

| Bird species | California black oak | Canyon live oak | Oregon ash | White alder | Ponderosa pine | Incense cedar | Sugar pine | White fir | Total |
|---|---|---|---|---|---|---|---|---|---|
| Lesser Goldfinch (*Carduelis psaltria*) | | | | | 2 | 2 | | | 4 |
| Total | 109 | 127 | 1 | 23 | 126 | 108 | 4 | 12 | 510 |
| Available[2] | 25 | 15 | | | 108 | 84 | 7 | 2 | 241 |
| Available (Summit only)[2] | 8 | 2 | | | 25 | 24 | 2 | | 61 |

[1] Hammond's Flycatchers were found on the Summit study site only.
[2] Available trees were based on plot-level vegetation measurements from all four study sites for all species, except for Hammond's Flycatcher. For Hammond's Flycatcher, tree species used for nesting were compared with available trees for the Summit study site only.

***Table 2**—The number of nests found by snag species and available snag species in ponderosa pine forests in the southern Sierra Nevada, 1995 to 2002. Vertical line divides hardwood and conifer snag species.*

| Bird species | California black oak | Canyon live oak | Oregon ash | White alder | Ponderosa pine | Incense cedar | Sugar pine | Unknown species | Total |
|---|---|---|---|---|---|---|---|---|---|
| Northern Pygmy-owl (*Glaucidium gnoma*) | | | | | 2 | | | | 2 |
| Northern Saw-whet Owl (*Aegolius acadicus*) | | | | | 1 | | | | 1 |
| Acorn Woodpecker (*Melanerpes formicivorus*) | | | | | 17 | | | | 17 |
| Downy Woodpecker (*Picoides pubescens*) | | | | 1 | | | | | 1 |
| Hairy Woodpecker (*Picoides villosus*) | | | | 3 | 2 | 1 | | | 6 |
| Northern Flicker (*Colaptes auratus*) | | | | | 21 | | | | 21 |
| White-headed Woodpecker (*Picoides albolarvatus*) | 1 | | | 1 | 19 | 1 | | | 22 |
| Western Wood-Pewee (*Contopus sordidulus*) | | | | | 1 | | | | 1 |
| Pacific-slope Flycatcher (*Empidonax difficilis*) | | | 1 | 6 | | 2 | | 1 | 10 |
| Mountain Chickadee (*Poecile gambeli*) | | | | | 1 | | | | 1 |
| Red-breasted Nuthatch (*Sitta canadensis*) | | | | 1 | 35 | | 2 | | 38 |
| Brown Creeper (*Certhia americana*) | | | | | 22 | 1 | 2 | | 25 |
| American Robin (*Turdus migratorius*) | 1 | 1 | | | | 4 | | | 6 |
| Total | 2 | 1 | 1 | 12 | 121 | 9 | 4 | 1 | 151 |
| Available[1] | 11 | 2 | 0 | 2 | 94 | 59 | 17 | 8 | 193 |

[1] Available trees were based on plot-level vegetation measurements from all four study sites for all species, except for Hammond's Flycatcher. For Hammond's Flycatcher, tree species used for nesting were compared with available trees for the Summit study site only.

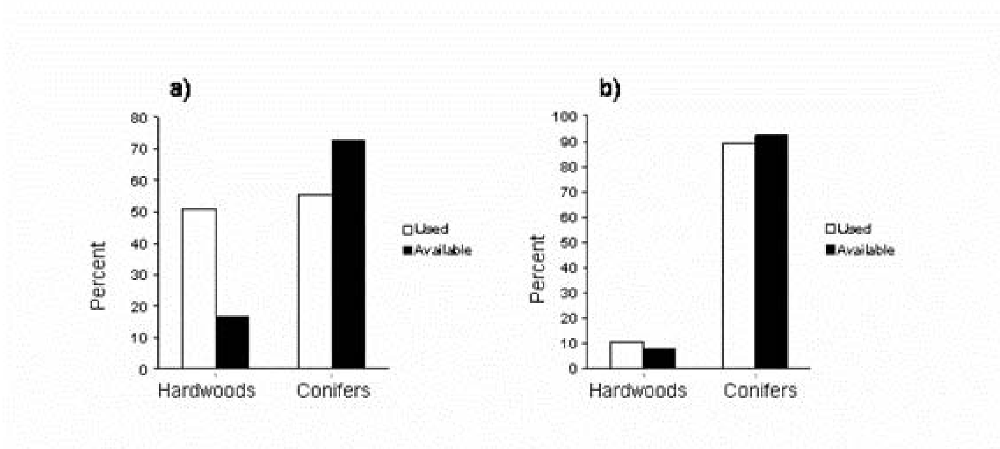


**Figure 1**—Proportion of hardwood and conifer trees (a) and snags (b) used as nest substrates by birds and available

More than 90 percent of nests in hardwoods were built in live portions of live trees (*table 3*). Of nests found in dead portions of live hardwood trees, the majority were cavity nests of three species: Downy Woodpecker, Red-breasted Nuthatch, and Mountain Chickadee.

***Table 3****—Numbers of nests in live hardwood trees that were found in live and dead portions of the tree in ponderosa pine forests in the southern Sierra Nevada.*

| | Nests in live portion | Nests in dead portion |
|---|---|---|
| California black oak | 96 | 13[1] |
| Canyon live oak | 124 | 3[2] |
| Oregon ash | 1 | 0 |
| White alder | 16 | 7[3] |
| Total | 237 | 23 |

[1]Species included Downy Woodpecker (4 nests), Mountain Chickadee (1), Pacific-slope Flycatcher (3), Red-breasted Nuthatch (1), Western Wood-Pewee (2), Bushtit (1), and Cassin's Vireo (1).
[2]Species included American Robin (1) and Cassin's Vireo (2).
[3]Species included Downy Woodpecker (5), Pacific-slope Flycatcher (1), and Red-breasted Nuthatch (1).

Cavity nesters nested more often in conifers than in hardwoods (85 percent of nests in cavities) and 92 percent of nests in conifers were in snags. When nesting in hardwoods, however, most nests were in live trees (71 percent) and, of nests in live trees, 76 percent were in dead portions of live trees.

Oaks used for nesting were larger than those available (*table 4*). California black oak trees used for nesting averaged nearly 21 m tall, with an average total dbh of 64 cm. Canyon live oak trees used for nesting were shorter, averaging slightly more than 9 m high, but were likewise larger than available trees.

***Table 4** — Mean height and diameter at breast height (dbh) for California black oak and canyon live oak nest trees and available trees.*

| | Nests Mean ± SE (*n*) | Available Mean ± SE (*n*) | *t* | df | *P* |
|---|---|---|---|---|---|
| | **California black oak** | | | | |
| **Tree height (m)** | 20.6 ± 0.7 (109) | 16.7 ± 1.5 (26) | 2.4 | 133 | 0.017 |
| **Tree dbh (cm)** | 64.0 ± 2.4 (109) | 47.5 ± 4.4 (26) | 3.1 | 133 | 0.02 |
| | **Canyon live oak** | | | | |
| **Tree height (m)** | 9.3 ± 0.4 (127) | 6.9 ± 0.6 (17) | 3.5 | 37.2 | 0.001 |
| **Tree dbh (cm)** | 58.2 ± 12.0 (127) | 14.5 ± 2.1 (17) | 3.6 | 133 | 0.001 |

Of the 10 bird species for which we found ≥ 19 nests, six species used hardwoods more than expected compared to available trees and snags, two species used conifers more than expected, and two species showed no preference.

Anna’s Hummingbirds showed a preference for nesting in hardwoods ($\chi_c^2$ = 69.5, *P* < 0.0001), with 76 percent of nests in hardwoods, including 27 percent in California black oak and 41 percent in canyon live oak (*table* 1).

Western Wood-Pewees nested more often than expected in hardwood species ($\chi_c^2$ = 52.79, *P* < 0.0001), with the overwhelming majority of nests in trees (79 percent) in California black oak (*table 1*).

Hammond’s Flycatchers nested at only one site that had a greater component of mixed conifer species in a distinct riparian zone. Hammond’s Flycatchers showed no preference for hardwoods vs. conifers for nesting substrates ($\chi_c^2$ = 0.0, *P* < 1.00) compared to available trees at this site. This species, however, is a conifer specialist, with 82 percent of nests in conifers (*table 1*).

Both vireo species showed a preference for nesting in hardwoods ($\chi_c^2$ = 52.5, *P* < 0.0001 for Cassin’s Vireo, and $\chi_c^2$ = 98.2, *P* < 0.0001 for Hutton’s Vireo). Cassin’s Vireos used California black oak disproportionately, with 43 percent of nests in black oak, and appeared to avoid nesting in pines (*table 1*). Hutton’s Vireos nested roughly equally in trees and shrubs. Of a total of 95 Hutton’s Vireo nests, 45 percent were in shrubs, all of which were whiteleaf manzanita. When nesting in trees, Hutton’s Vireos showed a strong preference for canyon live oaks, with 83 percent of all tree nests in this species (*table 1*).

Steller’s Jays showed no clear preference for hardwoods vs. conifers ($\chi_c^2$ = 2.3, *P* = 0.13). Thirty-eight percent of the 26 nests were in incense cedar; 31 percent were in canyon live oak (*table 1*).

Although American Robins nested slightly more in conifers in terms of number of nests found, they preferred hardwoods as nesting substrates compared to available trees ($\chi_c^2$ = 25.4, *P* < 0.0001). Although they were found nesting in all species of trees except white alder, 35 percent of robin nests were found in canyon live oak (*table 1*).

Western Tanagers and Purple Finches both nested only in conifers and showed a preference for conifers over hardwoods compared to available trees ($\chi_c^2$ = 3.7, *P* < 0.05 for Western Tanager, $\chi_c^2$ = 4.8, *P* = 0.03 for Purple Finch; *table* 1). All of the 19 Western Tanager nests were built in two conifer species, with 79 percent in ponderosa pine. Purple Finches used ponderosa pine, incense cedar, and white fir, with 81percent in ponderosa pine.

Seventy-eight percent of Black-headed Grosbeak nests were in shrubs. When nesting in trees, they nested in hardwoods more often than expected ($\chi_c^2 = 12.5$, $P = 0.0004$), with 37 percent of nests found in both canyon live oak and incense cedar (*table 1*).

## Discussion

We found that hardwoods were important as nest substrates for birds breeding in ponderosa pine forests in the southern Sierra Nevada. Hardwoods were used by 24 species—two-thirds of all species nesting in trees and snags used hardwoods to some extent. Although hardwood trees comprised only 17 percent of available trees, 51 percent of nests in trees were in hardwoods. Fifty-six percent of the 34 tree-nesting species used California black oaks; 32 percent used canyon live oaks. Six of the ten species examined individually used hardwoods more than expected, with the two oak species responsible for the observed differences.

The two oak species were used by a wide variety of bird species. Two species, Western Wood-Pewee and Cassin's Vireo, showed clear preferences for California black oak compared to available trees. Anna's Hummingbirds, Western Wood-Pewees, Cassin's Vireos, and Black-headed Grosbeaks used California black oaks for at least 25 percent of their nesting attempts. Black oaks were also preferred by Warbling Vireos nesting in ponderosa pine habitat (Purcell 2007). Studying foraging preferences of birds in mixed conifer forests, Airola and Barrett (1985) found that the insect-gleaning guild as a whole showed a preference for foraging in California black oaks compared to other tree species, with Warbling Vireos and Nashville Warblers (*Vermivora ruficapilla*) foraging more often in black oaks.

In the Sierra Nevada, California black oak grows abundantly along the west slope (McDonald 1969, 1990). Its most common associate is ponderosa pine, but white fir, incense cedar, sugar pine, and Jeffrey pine are less common associates (McDonald and Huber 1995). It will also grow on sites too poor to support ponderosa pine (McDonald 1969). In ponderosa pine forests, it is found as scattered individual trees and in small groups (Tappeiner and McDonald 1980). Due to its ability to withstand high moisture stress, black oak also grows in harsh sites too poor to support pines (McDonald 1969, 1990).

Canyon live oaks were important nest substrates for Anna's Hummingbirds, Hutton's Vireos, American Robins, and Black-headed Grosbeaks, which all used live oaks for at least 25 percent of nesting attempts. Hutton's Vireos showed a particularly clear preference for canyon live oaks (83 percent of nests in trees). They nested in both trees and shrubs, however, with 45 percent of all nests in canyon live oak, which often has a shrub-like growth form, and 45 percent in a common shrub species (whiteleaf manzanita). Live oaks are closely associated with this species, especially in California where 67 percent of reported nests were in coast live oak (*Quercus agrifolia*; Davis 1995).

Canyon live oak is widespread and is the most numerous hardwood tree species in California forest lands (Waddell and Barrett 2005). On better sites, it is shorter than its associates, and is a persistent member of the stand (McDonald and Huber 1995). On steep, rocky sites, it grows better than its associates (McDonald and Huber

1995). The shrub form grows on poor sites (McDonald and Tappeiner 1996).

While the importance of snags of coniferous tree species to wildlife is widely recognized, hardwood snags, especially oaks, were used only rarely for nesting by birds in the Sierra Nevada, including cavity-nesting species. In this study, only three nests were found in oak snags. White alder snags were the only hardwood snag species used to any degree.

Dead portions of live trees were not used by most bird species. Cavity nesters were the exception, where most nests in live trees were located in dead portions of trees where decay contributed to conditions favorable for cavity formation. Garrison and others (2002*a*) found that California black oaks had nearly three times more dead branches than ponderosa pines. They concluded that dead branches represent a significant contribution to the deadwood resource in Sierra Nevada pine-oak forests; however, they did not present any data on wildlife use. Half of the cavities used by Acorn Woodpeckers (*Melanerpes formicivorus*) were in dead limbs of live valley oaks (*Quercus lobata*; Hooge and others 1999). We found that, while dead branches were not an important nesting substrate for species that build in open cup nests, they were used by those cavity-nesting birds that used hardwoods.

## Management Recommendations

The hardwood component of Sierra Nevada forests has been largely overlooked, not only in terms of commercial timber production and wood products, but for its value for wildlife, aesthetics, and water. No guidelines existed for retention of hardwoods in terms of tree size or age, basal area, canopy cover, or dispersion (Verner 1987) until the late 1980s when interim guidelines for hardwood management were developed by California Department of Fish and Game (1989) that recognized the importance of hardwood habitats to wildlife species. The 2000 Sierra Nevada Forest Plan Amendment EIS brought hardwood ecosystems to the forefront as a significant conservation issue when lower westside hardwoods were a major emphasis area (USDA Forest Service 2001).

Developing guidelines and recommendations for managing hardwood ecosystems is difficult because the plant communities of which they are a part are complex and diverse, their physical environments are variable, and the adaptations and evolutionary strategies of hardwoods are complex (McDonald and Huber 1995). Periodic disturbance of forest zone hardwoods is necessary but must be carefully considered. Without disturbance, they are out-competed by the faster-growing conifers and eventually eliminated from all but the poorest sites. In addition, managers must expand planning beyond the individual tree and stand to the landscape level, and must also acknowledge the need to consider a long timeframe for hardwood management to succeed (McDonald and Huber 1995).

Some daunting problems need to be addressed, however. Based on a multi-ownership assessment of California hardwoods and oak woodlands, the California black oak forest type had the greatest percentage decrease from 1984 to 1994 compared to other forest types (Waddell and Barrett 2005). Conifers are shading out oak seedlings and saplings, and regeneration and recruitment of young trees is insufficient to replace mortality of older trees (Garrison and others 2002*b*, McDonald and Tappeiner 1996). And, while the disease has not yet been verified in the Sierra

Nevada, California black oak and canyon live oak are susceptible to the pathogen that causes sudden oak death.

High fuel loads and fuel ladders have accumulated from decades of fire suppression. Once a hardwood stand is established, fire is undesirable because oaks are often damaged or killed by fire due to their thin bark (McDonald and Tappeiner 1996), but hardwoods require disturbance such as fire for establishment. They have the capability to sprout and grow rapidly following disturbance, and fire kills competing conifers (Tappeiner and McDonald 1980). Although fire must be used with caution in managing hardwoods, prescribed fire appears to be a viable management tool to promote seedlings and sprouts, eliminate leaf litter and destructive insects in the duff and soil, kill competing vegetation, and reduce the risk of severe stand-replacing fire (Garrison and others 2002*b*, McDonald 1990).

Large oaks were used preferentially by nesting birds. The average height of black oaks used for nesting was 21 m and was significantly larger than available black oak trees. As stated by McDonald and Huber (1995:19): "It cannot be emphasized enough that the total worth of carefully grown forest hardwoods is maximized with large trees." Although a balance of all size and age classes is necessary, we recommend retaining large-diameter trees and creating openings around existing oaks to provide conditions for attaining large size quickly (Garrison and others 2002*b*, McDonald and Huber 1995).

There are many uncertainties surrounding the management of California forest zone hardwood ecosystems. Ecological risks will have to be taken because the high fuel loads from decades of fire suppression must be addressed. Fuels treatments can provide the periodic disturbance needed by hardwoods, but we have little information regarding how much disturbance wildlife species can tolerate without negative affects. We see reason for optimism, however, due to the growing awareness among managers of the importance of hardwood ecosystems and the need to consider hardwood resources as a priority when planning management activities.

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