# Dead Branches and Other Wildlife Resources on California Black Oak (*Quercus kelloggii*)[1]

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### Abstract
In 1995, we began counting dead branches, mistletoe, and acorns on individually tagged living California black oak *(Quercus kelloggii).* On the same plots, data on dead branches and mistletoe were recorded from ponderosa pine *(Pinus ponderosa)* in 1999. Number of dead branches per oak varied among the four stands ($P$ = 0.049) and among the 5 years ($P$ < 0.001). Large diameter oaks had more dead branches, acorns, and oak mistletoe *(Phoradendron villosum)* bunches ($P$ < 0.008) than did small diameter oaks, while large diameter pines had more dead branches ($P$ < 0.001) than did small diameter pines. In 1999, oaks averaged 1.33 dead branches per tree while pines averaged 0.45 dead branches per tree ($P$ < 0.001), and 52 percent and 15 percent of oaks and pines, respectively, had dead branches ($P$ < 0.001). Oak mistletoe was more prevalent in oaks (19 percent) than dwarf mistletoe *(Arceuthobium campylopodium)* was in pines (4 percent) ($P$ < 0.001). Basal area of dead branches exceeded basal area of snags in the four stands. To some extent, dead branches can offset deficiencies in other forms of dead wood resources needed by wildlife.

## Introduction

Dead wood in live trees is often overlooked by land managers when assessing dead wood resources of forest habitats. Because dead branches have value to wildlife (Powell and Zielinski 1994, Waters and others 1990), quantifying dead branch abundance should be useful when developing and implementing land management actions. Models for estimating snag densities required by woodpeckers have no

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model components for dead branches that might provide cavities for primary and secondary cavity-nesting birds (Thomas and others 1979). Furthermore, some methods for determining snag densities do not include dead branches (Anonymous 1995, Bull and others 1990, Bull and others 1997, Morrison and others 1986a). Field inventories on National Forest lands include estimates of live crown-ratio and defects or decay of live trees but these are not explicit assessments of dead branch abundance (Anonymous 1995). In contrast, Chojnacky (1994) developed a method for estimating dead wood in live pinyon pines *(Pinus edulis)* and junipers (*Juniperus* spp.) because of decadence in these trees. Dead branches are a "hidden" resource that, if ignored, could bias management actions intended to correct deficits in snag abundance. Management actions taken to rectify perceived deficiencies in snag densities where trees are purposefully killed to create snags (Bull and others 1997, Chambers and others 1997, Lewis 1998) may be unnecessary or minimized in some cases if dead branches were quantified.

In mid-elevation mixed-conifer forests in the central Sierra Nevada where hardwoods and conifers occur, hardwoods provide important dead wood resources, such as dead branches, that may be lacking in conifers. California black oak is the dominant hardwood in these forests (McDonald 1988), and dead branches in living oaks are used by wildlife (Powell and Zielinski 1994, Waters and others 1990). Oaks also produce acorns that are important seasonal food for dozens of species of birds and mammals (Barrett 1980, Verner 1980). Leaves and berries of oak mistletoe, which occurs in California black oak, are eaten by many species of birds and mammals (Martin and others 1951). California black oaks grow differently, become decadent sooner, and have different snag characteristics[6] than do conifers (such as ponderosa pine), so they may provide substantially different dead wood resources in forests.

Initial field observations of the substantial amount of dead branches in living California black oak, lack of dead branches in conifers, and lack of management consideration for dead branch resources prompted us to undertake this study. Our objectives were to quantify dead branch abundance in California black oak; quantify abundance of other attributes in oaks that have wildlife values including acorn production and mistletoe infestation; compare dead branches and mistletoe infestations between California black oak and ponderosa pine to determine if these two species provide similar levels of these resources; and assess the relationship between tree diameter and abundance of dead branches, acorns (oaks only), and mistletoe.

## Study Area

We worked on four 21.2-ha study stands in southern Placer County, California. The stands were similar in elevation and vegetation characteristics and were selected for a study of mule deer *(Odocoileus hemionus)* and other wildlife in oak-dominated habitat in the central Sierra Nevada (Garrison and others 1998a). Each stand consisted of two 10.6-ha subplots that were adjacent to each other. The paired subplots represented treatment and control units for an experimental timber harvest within each of the four stands that was conducted after this investigation. Elevations ranged from 1,240-1,450 m, and the stands were on plateaus and upper portions of

[6] Unpublished data on file at California Department of Fish and Game, Sacramento Valley and Central Sierra Region, 1701 Nimbus Road, Suite A, Rancho Cordova, CA 95670.

steep river canyons. Study stands were located within large homogeneous forest stands with a tree layer dominated by large diameter (>40 cm diameter breast height) California black oak and ponderosa pine. Other less abundant tree species were interior live oak *(Q. wislizenii),* Douglas-fir *(Psuedotsuga menziesii),* white fir *(Abies concolor),* sugar pine *(P. lambertiana),* and incense cedar *(Calocedrus decurrens).* Seedling and sapling California black oak and ponderosa pine dominated the subcanopy at one stand, while the other stands had little subcanopy. The shrub layer was generally sparse, and deerbrush *(Ceanothus integerrimus)* and manzanita (*Arctostaphylos* spp.) were the most common shrubs. The herbaceous layer was dominated by sparse to dense cover of mountain misery *(Chamaebatia foliolosa).* Commercial timber harvesting of live conifers has occurred intermittently over the past several decades, and cutting of downed California black oak logs for fuelwood continuously occurs in all stands.

## Methods

Each subplot occupied a 325-m x 325-m square area (10.6 ha) inside which we established a 250-m x 250-m sampling area (6.3 ha). The sample area was divided into a 25-m x 25-m grid with 11 stations per side (121 points in the grid), and a 37.5 m-wide buffer zone separated the sampling grid from the subplot boundary. All sampling occurred within the sampling grid. A total of 30 0.04-ha circular plots (15 circular plots per subplot) were randomly selected for vegetation measurements in each stand. In each subplot, 1 circular plot each was randomly selected in 1994 from the 11 points on each of the 11 alphabetized transects on the sampling grid, and 4 more circular plots were randomly selected from the same transects for each subplot in 1995. This resulted in a total of 15 circular plots per subplot and 30 circular plots per stand (2 subplots with 15 circular plot each per stand). Data from paired subplots were combined because subplots were adjacent to each other in the same stand. Vegetation sampling methods are described by Garrison and others (1998a), and data on live stems and snags were recorded using stem counts and diameter tapes. California black oaks were aged by counting annual growth rings from sections cut from trees harvested in 1998 and 1999.

A total of 32-36 individual California black oaks per stand were individually tagged in 1994 with numbered aluminum tags to assess acorn production. One tree ≥25 cm dbh was randomly selected from each 0.04-ha circular plot. An additional California black oak 13-25 cm dbh was tagged (2-6 per stand) whenever they occurred in the 0.04-ha plots to quantify acorn production by smaller, presumably younger, trees. In 1999, 30 individual ponderosa pines ≥13 cm dbh per stand were individually tagged from the 0.04-ha plots for comparisons between the two species. The tagged trees were the ones closest to the plot center stake. Diameters of all tagged trees were measured in 1994 (oaks) and 1999 (pines), using a diameter tape placed at a height of 1.37 m (dbh).

Beginning in 1995, we counted on each tagged tree the total number of dead branches that were ≥13 cm basal diameter (diameter at attachment to tree) and ≥0.7-m long from point of basal diameter to end. The 13-cm diameter threshold is the minimum required by some wildlife that use snags and dead branches (Bull and others 1997, Raphael and White 1984, Thomas and others 1979). We felt that 13 cm represented an appropriate size threshold as most branches had considerably greater diameters in oaks and approximately that diameter in pines.

Dead branches were identified by lack of bark, shredded bark, broken ends, and lack of live foliage. Counts included individual branches that fit the size criteria whether they were dead branches off dead branches or off live trunks and branches. Basal diameter did not include large, swollen bark wads growing at the base of the branch. Dead branches on the ground were measured with dbh tapes to calibrate visual measurements. Incidental observations were made of nesting cavities and other wildlife use.

Acorn production by California black oak was determined in late August-early September using visual counts of acorns in trees using methods of Garrison and others (1998b) and Koenig and others (1994a). The observer visually bisected the tree's live crown area into an upper and lower half, and all acorns observed during 15-second counts in each half were counted (total of 30 seconds). We also quantified infestation of California black oak by oak mistletoe and ponderosa pine by dwarf mistletoe by counting the number of mistletoe bunches in the tagged trees using binoculars (oaks) or noting mistletoe presence (pines). Mistletoe and acorns in live portions of the tree were counted during surveys for dead branches.

Total number of dead branches, acorns (oaks only), mistletoe bunches (oaks only) per tree were averaged among tagged oaks and pines within each stand and among years. Frequency of pines with dwarf mistletoe infestation was determined in lieu of counting mistletoe bunches because bunches were infrequently encountered (see below) and were more difficult to enumerate than oak mistletoe. Statistical comparisons for number of dead branches, acorns, and mistletoe bunches for California black oaks were made among stands and among years using a repeated measures analysis of variance (ANOVAs). Linear regression was used to determine linear relationships between California black oak diameter and average number of dead branches, acorns, and mistletoe bunches per tree over the 5-yr study. Linear regression was also used to determine the relationship between pine diameter and number of dead branches. Differences between number of dead branches for oaks and pines in 1999 were determined using t-tests. Differences between oaks and pines in frequency of trees with and without dead branches and mistletoe was determined using $X^2$ tests. Logarithmic ($\log_{10}$) transformations were applied to all variables used in the ANOVAs, t-tests, and regressions because the data had non-normal distributions (Zar 1996). All analyses were done using SYSTAT (Anonymous 1998), and statistical significance was set at $P < 0.05$.

# Results

## *Stand Characteristics*

Trunk diameters at the four stands for all live trees, hardwoods, and conifers $\geq$13 cm dbh averaged (quadratic mean) 39.4-53.9 cm, 37.4-63.5 cm, and 28.2-53.9 cm, respectively. Densities for all live trees, hardwoods, and conifers $\geq$13 cm averaged 190-326 trees/ha, 57-153 trees/ha, and 53-270 trees/ha, respectively. Basal area for all live trees, hardwoods, and conifers $\geq$13 cm averaged 30.5-43.2 $m^2$/ha, 7.3-21.6 $m^2$/ha, and 9.8-21.4 $m^2$/ha, respectively. Overstory canopy cover for all live trees, hardwoods, and conifers averaged 70.0-75.8 percent, 36.3-57.6 percent, and 12.9-33.7 percent, respectively. Height (m) for all live trees, hardwoods, and conifers averaged 15.8-22.4 m, 14.8-19.9 m, and 14.9-26.5 m, respectively. Age of California black oaks (n=10 for each stand) in the stands averaged 120-166 yrs (age range of individual trees 53-347 yrs) (Garrison and others 2002).

## *California Black Oak Attributes*

Number of dead branches per tree in California black oak varied among stands ($F_{3,134}$ = 2.69, $P$ = 0.049) and years ($F_{4,536}$ = 5.13, $P$ < 0.001) *(table 1).* There was significant interaction between stands and years ($F_{12,536}$ = 2.52, $P$ < 0.004) as some stands had consistently more dead branches per tree during all years. Wildlife observed in our stands foraging, nesting, or roosting in dead branches included northern pygmy-owls *(Glaucidium gnoma),* downy woodpeckers *(Picoides pubescens),* mountain chickadees *(Poecile gambeli),* red-breasted *(Sitta canadensis)* and white-breasted *(S. carolinensis)* nuthatches, and brown creepers *(Certhia americana)*.[7] Mistletoe bunches per tree in California black oak varied among stands ($F_{3,134}$ = 5.43, $P$ < 0.002), and there was no variation among years ($F_{4,536}$ = 2.08, $P$ = 0.091) nor any significant stand by year interaction ($F_{12,536}$ = 1.26, $P$ = 0.240) *(table 1)*. Acorn production per tree varied among stands ($F_{3,134}$ = 10.60, $P$ < 0.001) and years ($F_{4,536}$ = 54.96, $P$ < 0.001) *(table 1).* There was significant interaction between stands and years ($F_{12,536}$ = 12.88, $P$ < 0.001) as some years (1995 and 1999) and stands (two and four) produced more acorns than others. Larger diameter oaks had more dead branches per tree than smaller diameter oaks ($R^2_{adj.}$ = 0.586, $n$ = 138, $t_{(2)}$ = 13.87, $P$ < 0.001) *(fig. 1)*. Larger diameter oaks also produced more acorns per tree ($R^2_{adj.}$ = 0.051, $n$ = 138, $t_{(2)}$ = 2.69, $P$ = 0.008) and had more mistletoe bunches per tree ($R^2_{adj.}$ = 0.125, $n$ = 138, $t_{(2)}$ = 4.41, $P$ < 0.001) than smaller diameter oaks, although the relationships were not as strong as with dead branches because many trees did not have mistletoe or produce acorns *(fig. 1)*.

**Table 1**—*Mean ± SD for number of dead branches >13 cm diameter, mistletoe bunches* (Phoradendron villosum), *and number of acorns/30 seconds per tree for California black oaks* (Quercus kelloggii) *from four 21.2-ha stands from 1994-1999, Placer County, California.*[1]

| Attribute | Stands | n | 1995 | 1996 | 1997 | 1998 | 1999 | All years |
|---|---|---|---|---|---|---|---|---|
| Dead branches | 1 | 32 | 2.06±2.45 | 1.69±2.65 | 1.41±1.79 | 1.63±2.09 | 1.91±2.10 | 1.74±0.25 |
| | 2 | 36 | 1.75±2.18 | 0.75±1.13 | 0.94±1.51 | 0.72±1.39 | 1.53±1.89 | 1.14±0.40 |
| | 3 | 36 | 1.31±1.70 | 1.64±2.10 | 1.06±1.79 | 1.00±1.27 | 1.08±1.30 | 1.22±0.26 |
| | 4 | 34 | 0.68±1.04 | 0.65±0.88 | 0.47±0.83 | 0.79±1.37 | 0.62±1.05 | 0.64±0.12 |
| | All | 138 | 1.44±1.96 | 1.17±1.86 | 0.96±1.55 | 1.02±1.57 | 1.28±1.68 | 1.17±0.20 |
| Mistletoe | 1 | 32 | 0.59±1.64 | 1.28±3.90 | 0.72±2.26 | 0.63±1.90 | 1.09±2.56 | 0.86±0.31 |
| | 2 | 36 | 1.58±3.51 | 2.25±5.54 | 2.06±4.76 | 1.89±3.98 | 2.25±4.66 | 2.01±0.28 |
| | 3 | 36 | 0.42±1.23 | 0.89±1.92 | 0.75±2.06 | 0.81±1.79 | 0.50±1.52 | 0.67±0.20 |
| | 4 | 34 | 0.00±0.00 | 0.03±0.17 | 0.03±0.17 | 0.00±0.00 | 0.00±0.00 | 0.01±0.02 |
| | All | 138 | 0.66±2.12 | 1.12±3.59 | 0.91±2.93 | 0.85±2.48 | 0.97±2.89 | 0.90±0.17 |
| Acorns | 1 | 32 | 2.09±3.77 | 0.00±0.00 | 0.03±0.18 | 0.00±0.00 | 0.16±0.72 | 0.46±0.92 |
| | 2 | 36 | 4.39±9.16 | 0.67±2.10 | 0.00±0.00 | 1.11±3.46 | 16.11±20.74 | 4.46±6.73 |
| | 3 | 36 | 5.50±14.53 | 0.08±0.37 | 0.00±0.00 | 0.00±0.00 | 1.33±3.96 | 1.38±2.37 |
| | 4 | 34 | 10.24±16.07 | 0.12±0.41 | 0.18±0.63 | 0.06±0.24 | 1.12±3.42 | 2.34±4.44 |
| | All | 138 | 5.59±12.22 | 0.23±1.13 | 0.05±0.33 | 0.30±1.82 | 4.86±12.73 | 2.21±2.77 |

[1] See text for statistical differences among stands and years; data from 2 10.6-ha subplots within each stand.

[7] Unpublished data on file at California Department of Fish and Game, Sacramento Valley and Central Sierra Region, 1701 Nimbus Road, Suite A, Rancho Cordova, CA 95670.

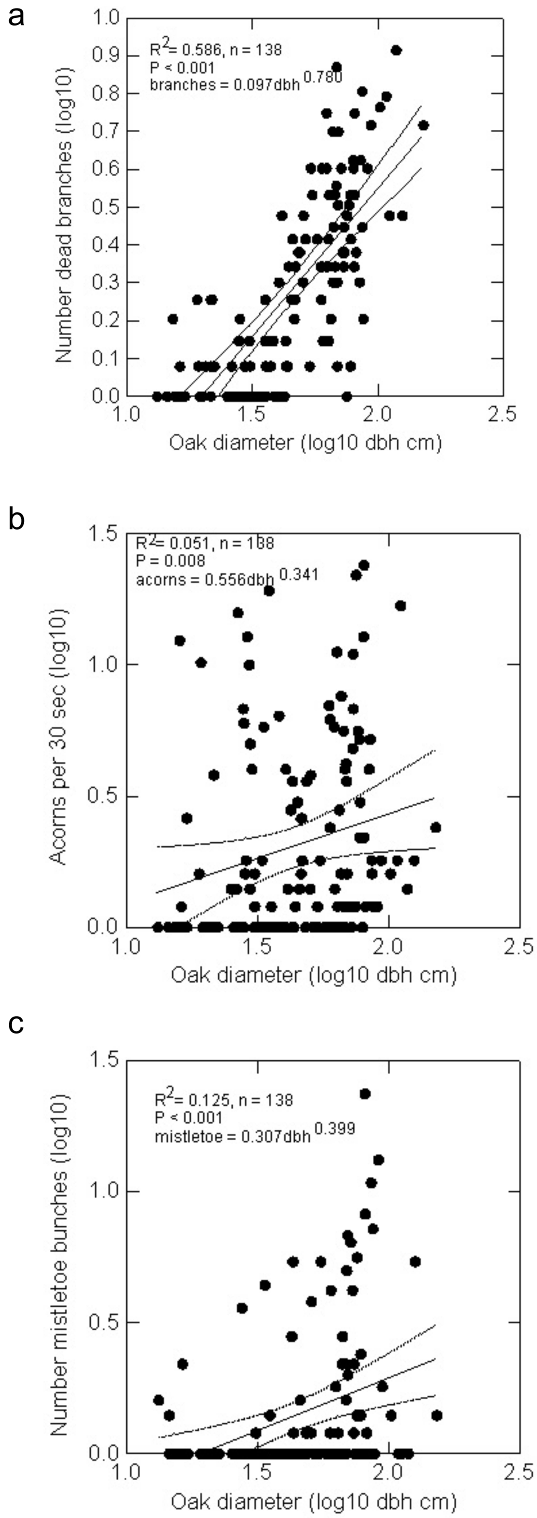


**Figure 1**—Relationships between stem diameter of California black oak *(Quercus kelloggii)* ($log_{10}$ dbh cm) and (a) average number of dead branches ($log_{10}$) per tree, (b) average number of acorns/30 seconds ($log_{10}$) per tree, and (c) average number of mistletoe bunches *(Phoradendron villosum)* ($log_{10}$) per tree.

California black oak and ponderosa pine had equivalent stem diameters ($t_{(2)}$ = -1.72, df = 241.3, $P$ = 0.868), but oaks had almost three times more dead branches than pines ($t_{(1)}$ = 5.92, df = 259.0, $P$ < 0.001) *(table 2).* Dead branches were found in 52 percent of oaks and 15 percent of pines ($X^2$ = 39.45, df = 1, $P$ < 0.001). Mistletoe was found in 19 percent of oaks and 4 percent of pines ($X^2$ = 13.97, df = 1, $P$ = 0.0002). Larger diameter pines had more dead branches than smaller diameter trees ($R^2_{adj.}$ = 0.261, $n$ = 120, $t_{(2)}$ = 6.46, $P$ < 0.001, dead branches = 0.338*dbh$^{0.420}$), but the relationship was not as strong as with oaks.

**Table 2**—*Mean ± SD (min, max) for several characteristics per tree of California black oak* (Quercus kelloggii) *and ponderosa pine* (Pinus ponderosa) *measured in 1999 at four 21.2-ha stands in Placer County, California.*[1]

| Characteristic | California black oak (n=144) | Ponderosa pine (n=120) | P-values from tests[2] |
|---|---|---|---|
| DBH (cm) | 51.15±27.09 (13.2, 152.0) | 60.67±36.89 (15.0, 188.8) | 0.087 |
| Dead branches ≥13 cm diameter | 1.33± 1.72 (0.0, 8.0) | 0.45± 1.30 (0.0, 8.0) | 0.001 |
| Pct trees with dead branches ≥13 cm diameter | 52.1 pct | 15.0 pct | 0.001 |
| Number of mistletoe bunches[3] | 0.98± 2.86 (0.0, 23.0) | — | — |
| Pct trees with mistletoe[2] | 19.4 pct | 4.2 pct | 0.001 |

[1] Data from two 10.6-ha subplots within each of the four stands.
[2] T-tests for dbh and dead branch numbers and $X^2$ for frequency of trees with dead branches and mistletoe.
[3] Oak mistletoe *(Phoradendron villosum)* in California black oak and dwarf mistletoe *(Arceuthobium campylopodium)* in ponderosa pine.

## Discussion

California black oaks had dead branches with diameters ranging from a few cm to large branches >30 cm, while ponderosa pines had dead branches mostly at the 13-cm diameter threshold. Larger diameter (>40 cm) oaks and pines had more dead branches than smaller diameter oaks and pines, but this relationship was stronger with oaks. California black oak acorn production and mistletoe infestation were variously distributed among stem diameters. There were many oaks without dead branches (30 percent) or mistletoe (48 percent) and that did not produce acorns (38 percent), showing that all trees do not provide these resources.

Because amounts of dead branches, acorns, and mistletoe in California black oak varied by stand and individual tree, there were localized differences in abundance of these resources. Stands had some differences in elevation, aspect, slope, age, and vegetative characteristics, so some variation could be explained by stand differences. Individual trees, however, likely accounted for most differences, as tree dbh explained 59 percent of the variance in dead branch number, while stand amounts were barely significantly different ($P$ = 0.049). Oak dbh explained only 13 percent and 5 percent of the variance in mistletoe bunches and acorns, respectively, because many trees of all diameters lacked acorns or mistletoe. Conversely, amounts of mistletoe and acorns varied ($P$ < 0.002) among stands, so individual tree characteristics were less important than stand attributes. Stand-level differences were most pronounced with mistletoe and acorns compared to dead branches.

Numbers of dead branches and acorns from California black oak varied annually, although there were no obvious increasing or decreasing trends. Dead branch abundance varies as branches fall off and trees are damaged due to storms (Matlack and others 1993, Webb 1989). Observer differences (Block and others 1987) also may have caused some variation. Annual variation occurs in acorn production by California black oak due to spring weather conditions (Koenig and others 1994b). Annual variation occurs in ponderosa pine cone production (McDonald 1992), and nuts from cones also are eaten by wildlife (Martin and others 1951). Although we did not measure cone production, we feel the two tree species provide equivalent food resources to wildlife. Oaks, however, had greater numbers of dead branches and more mistletoe than the pines. Dwarf mistletoe in ponderosa pine is also food for wildlife (Martin and others 1951). Therefore, live California black oaks and ponderosa pines provide multiple resources to wildlife in our study stands. Ponderosa pines, however, have less dead branch and mistletoe resources than do California black oaks.

In some areas, management efforts may be necessary to increase snag numbers (Chambers and others 1997, Lewis 1998, Morrison and others 1986b, Thomas and others 1979), but these efforts may be unnecessary in habitats with large numbers of larger diameter California black oak. Managers should quantify dead branch resources in live California black oaks and other trees, and snag abundance should be combined with dead branch abundance to fully quantify the amount of standing dead wood. Basal area of all snags, including hardwoods and conifers, in our study areas averaged 2.34 $m^2$/ha, and that amount was relatively low compared to snag abundances reported from spotted owl *(Strix occidentalis)* habitat in the Sierra Nevada (Gutierrez and others 1992) and other locations in the Sierra Nevada (Morrison and others 1986a).

Increasing snag levels in our stands through directed management might be justified based on snag basal area alone, but might not be necessary when dead branches are considered with other dead wood resources. For example, using grand means from the four stands for the number of dead branches per oak (1.17 dead branches/tree) and the number of living oaks per ha (113 oaks $\geq$13 cm dbh/ha), there were 2,803 dead branches $\geq$13 cm diameter in each 21.2-ha study stand. In the four study stands, there were 11,211 dead branches $\geq$13 cm diameter from California black oak. Oak dead branch basal area averaged 1.72 $m^2$/ha with 13-cm diameters, and dead branch basal area is certainly greater in the stands because many dead branches were >13 cm diameter.

Using similar calculations for ponderosa pine, which averaged 0.45 dead branches/tree in 1999, there were 1,336 dead branches $\geq$13 cm diameter in each 21.2-ha study stand, 5,344 dead branches $\geq$13 cm diameter in the four study stands, and an average of 0.82 $m^2$/ha of dead pine branch basal area. Total snag basal area in our stands was 2.34 $m^2$/ha, while total dead branch basal area for California black oak and ponderosa pine was 2.54 $m^2$/ha. While not all dead branches are useful to wildlife, particularly smaller diameter branches (Bull and others 1997, Thomas and others 1979), we observed many being used by several species of birds for nesting, roosting, and feeding. Our limited field observations indicated that wildlife used some dead branches of oaks but did not use dead branches of pines.

Management of forest and woodland habitats is shifting from traditional methods emphasizing single species and individual resources (e.g., snags, acorns, etc.) to communities and ecosystems (Chapel and others 1992, Hunter 1990). Forest ecosystems are diverse, and ecosystem management efforts require assessments of the presence and/or abundance of many habitat attributes. Dead branches are often overlooked during these assessments, and our study has shown that these resources can be substantial in certain habitats and particular locations. With shorter lengths and mostly smaller diameters, dead branches cannot fully duplicate the total dead wood volume of many snags, particularly conifers, which provide very tall snags. Yet, we observed that dead branches were used by wildlife, and dead branches were more numerous and had greater cross-sectional area than snags.

Variation in dead branches, mistletoe, and acorns among locations and years indicates that assessments should be conducted at multiple locations and over many years to adequately measure amounts of these resources. In some instances, cavities in live and dead trees and branches may not limit populations of cavity-nesting birds (Waters and others 1990), so managers should inventory snags and dead branches prior to initiating management efforts to increase dead wood abundance. Furthermore, where snag abundances are particularly low due to fuel woodcutting efforts, dead branches may replace or offset snag losses. Dead branches were more prevalent in large diameter oaks, so trees must be allowed to grow old enough to provide dead branches of appropriate diameters for wildlife use. Large diameter trees also are the oldest oaks in the stand (Garrison and others 2002), so forest management should retain these trees as well as replace them as they die. Because California black oaks are intolerant to shade and respond favorably to canopy openings, individual tree, small group selection, or thinning harvests that open canopies, reduce competition from conifers, retain older and larger oaks, and recruit young oaks through stump sprouting and acorn germination are appropriate management actions (McDonald 1969, Tappeiner and McDonald 1980).

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