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Restoring California Black Oak Ecosystems to Promote Tribal Values and Wildlife

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Cover photograph: Tribal acorn gatherers and scientists gather underneath an actively tended black oak tree near North Fork, California. Photo by Jonathan Long.

Abstract

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This report synthesizes information to help promote the distinctive ecological and cultural benefits provided by California black oak. Production of abundant, high-quality acorns desired by Native Americans in California, as well as other valued services, requires the presence of mature, broad-crowned trees with low fuel levels and low pest levels. Although black oaks are vulnerable to intense fires, they depend on low-intensity, more frequent fires to reduce competition from conifers, pest loads, and build-up of fuels that promote intense fires. Traditional burning by Native Americans helped to promote these conditions historically; however, in many areas that have become overly dense, thinning, out-of-season burns, or relatively severe fires may be needed to reopen the forest and reduce fuel levels before a more customary use of fire can maintain desired outcomes. Applying a landscape-scale approach to black oak restoration can help sustain tribal values and wildlife habitat, as well as promote greater ecological resilience to drought and wildfire during this time of a warming climate.

Keywords: Forest management, cultural burn, ecosystem services, landscape restoration, prescribed burning, resilience, traditional ecological knowledge, woodlands, acorns.

Preface

To better understand how to restore California black oak ecosystems and the reasons for doing so, we convened a forum at which people with indigenous, local, and Western scientific perspectives were brought together in one room and across various field sites to enable us to learn together. We held a 2½ day meeting in July 2013, coincident with the nearby Aspen Fire. In attendance were members of several tribes from in and around the community of North Fork, California; scientists from the U.S. Forest Service Pacific Southwest Research Station (PSW) and the USDA Natural Resources Conservation Service; managers from the Sierra National Forest, particularly its Bass Lake Ranger District; and academic researchers (see "Acknowledgments"). At the start of that meeting, Bass Lake District Ranger Dave Martin (now retired) noted that he and many of his fellow forest managers had come to recognize that California black oak was an important indicator of forest health, and that they were eager to work with tribes in collaborative forest restoration. Participants at the workshop offered insights into the dynamics of forest ecosystems with black oak, including both ecological and social elements. From those discussions emerged key topics and ideas, many of which are reviewed in this report. At a subsequent meeting of the Northern California Prescribed Fire Council, Danny Manning from the Greenville Rancheria delivered a presentation on the importance of black oaks to Maidu people, which has been condensed into a short section in this report. Also included are references that reinforce, expand upon, or contextualize many of the observations and understandings that were shared at these meetings. This report focuses on the Sierra Nevada, where black oak's role is particularly distinctive and important. Because many of the specific relationships between tending practices and ecological outcomes have not been validated or quantified in experimental settings, they represent hypotheses that may warrant further exploration, particularly through field experiments where feasible. Further monitoring and research partnerships among scientists, land managers, and tribal peoples will improve understanding of roles, values, and prospective restoration strategies across the full range of black oak, and ultimately help to secure the benefits of black oak for future generations.

Summary

California black oak provides distinctive benefits to wildlife and people throughout its wide range in California and southern Oregon, making it both an ecological keystone and a cultural keystone for many California tribes. Production of abundant, high-quality acorns as well as other valued services requires the presence of mature, broad-crowning trees with low fuel levels and low pest levels. Although black oaks are vulnerable to intense fires, they depend on low-intensity, more frequent fires to reduce competition from conifers, pest loads, and build-up of fuels that promote intense fires. Native American tending of black oak trees not only facilitated such conditions, but it also exerted effects on the broader ecosystem through an array of food webs and fire-related interactions. Restoring the desired condition of mature, broad-crowning, productive oaks will depend upon reestablishing a more frequent fire regime. However, in many areas that have become overly dense, thinning, out-of-season burns, or relatively severe fires may be needed to reopen the forest and reduce fuel levels before a more customary use of fire can maintain desired outcomes. In addition, in some stands, treatments intended to enhance acorn production may conflict with policies that require maintaining high forest canopy cover and decadent structures to support some sensitive wildlife species. Despite this apparent conflict, a landscape-scale approach may support both acorn gathering and old forest-associated wildlife species as management objectives. Developing strategies to reconcile multiple objectives for black oak ecosystems would likely benefit from an adaptive management approach that engages tribes and other land managers. Restoration of California black oak would not only sustain tribal values and wildlife habitat, but it would also promote greater ecological resilience to drought and wildfire during this time of a warming climate.

Contents

Introduction

California black oak (*Quercus kelloggii*) is one of the most widespread and important oaks of California forests. This report synthesizes information needed to develop strategies for restoring black oak to support tribal values while considering other benefits such as habitat for diverse wildlife species. Much scientific information has been generated about black oak ecology and the species' importance to California native peoples (Anderson 1993, 2005; McDonald 1969, 1990). This report[1] builds upon that foundation by laying out a strategy to restore desired conditions for black oaks within the range where native peoples have traditionally used fire to tend this important species. Most research on this species has been conducted in the Sierra Nevada and southern Cascade Range, although much of the information should generally apply across its distribution (fig. 1).

The report has four main areas of emphasis:

- Explaining why black oak can be considered both an ecological and cultural keystone species.
- Describing its historical relationship with fire, current trends, and a desired condition for black oaks and their forest habitat to support tribal values and wildlife.
- Highlighting the effects of fire and traditional Native American management practices on forest ecosystems with black oak.
- Outlining strategies for achieving desired conditions for black oaks and their habitat given current forest conditions.

Black Oak Characteristics

Description

In 1857, California black oak was given the scientific name *Quercus kelloggii* by John Strong Newberry in honor of Albert Kellogg, who prepared botanical illustrations of this and other oaks of western North America (fig. 2). California black oak is a "red" or "black" oak belonging to the section Lobatae, whose members are characterized by bitter acorns owing to their high tannic acid levels; relatively dark bark, jagged leaves; and reddish-brown wood (Messner 2011). Black oak is noted for its deeply lobed, alternate leaves that turn from green to yellow and then brown in

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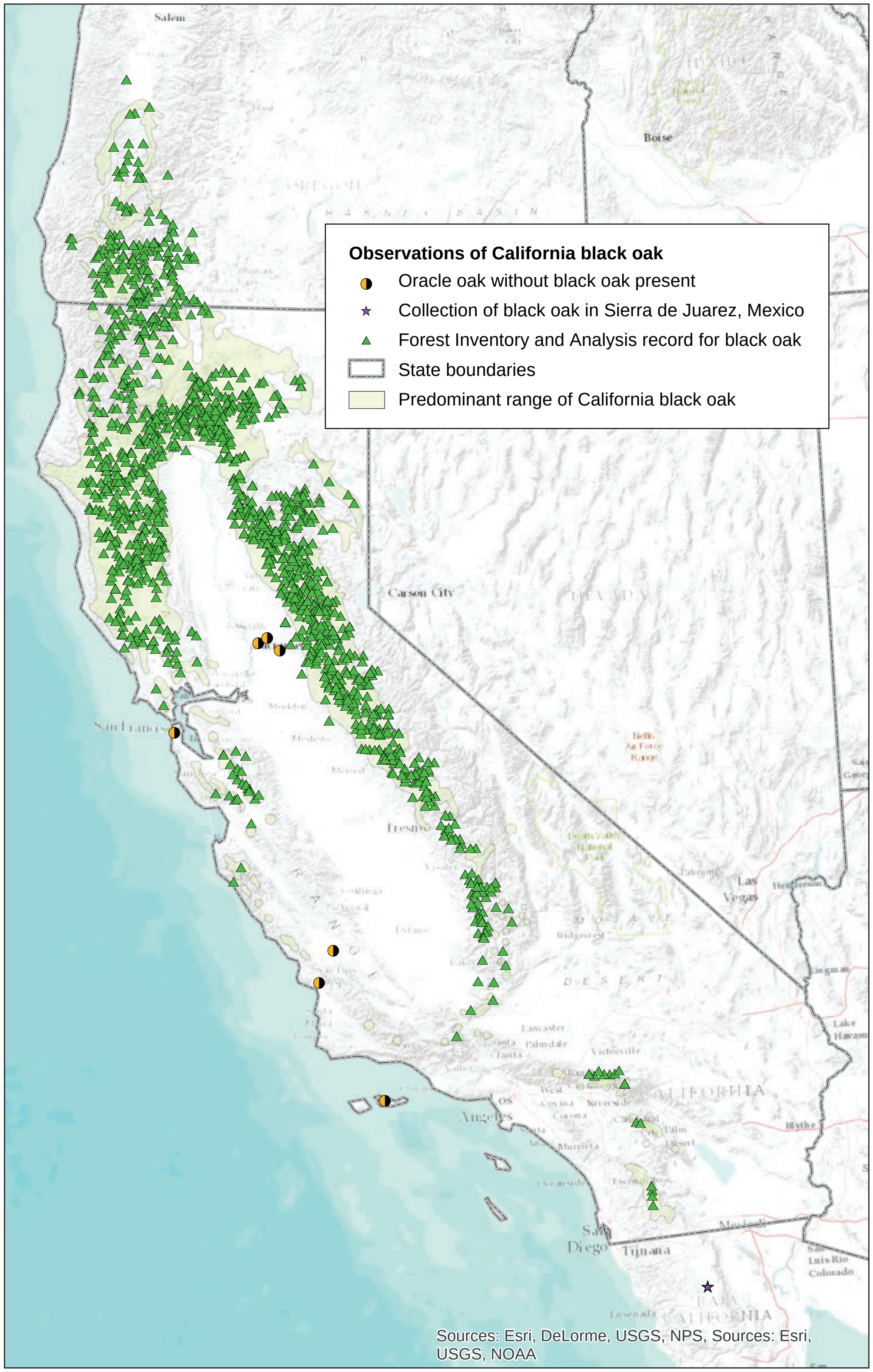
[1] A much abbreviated version of this report was presented at the 7th California Oak Symposium: Managing Oak Woodlands in a Dynamic World, Nov. 3–6, 2014, Visalia, California, and published in the conference proceedings as **Long, J.W.**; **Quinn-Davidson, L.N.; Goode, R.W.**; **Lake, F.K.; Skinner**, **C.N. (2015)**. Restoring California black oak to support tribal values and wildlife. In: Standiford, R.B., ed. Proceedings of the 7th California Oak Symposium. Gen. Tech. Rep. PSW-GTR-251 Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 113–122



Map compiled by Jonathan Long from sources in the text

Figure 1—Range of California black oak, including populations of oracle oak that were observed without black oaks.

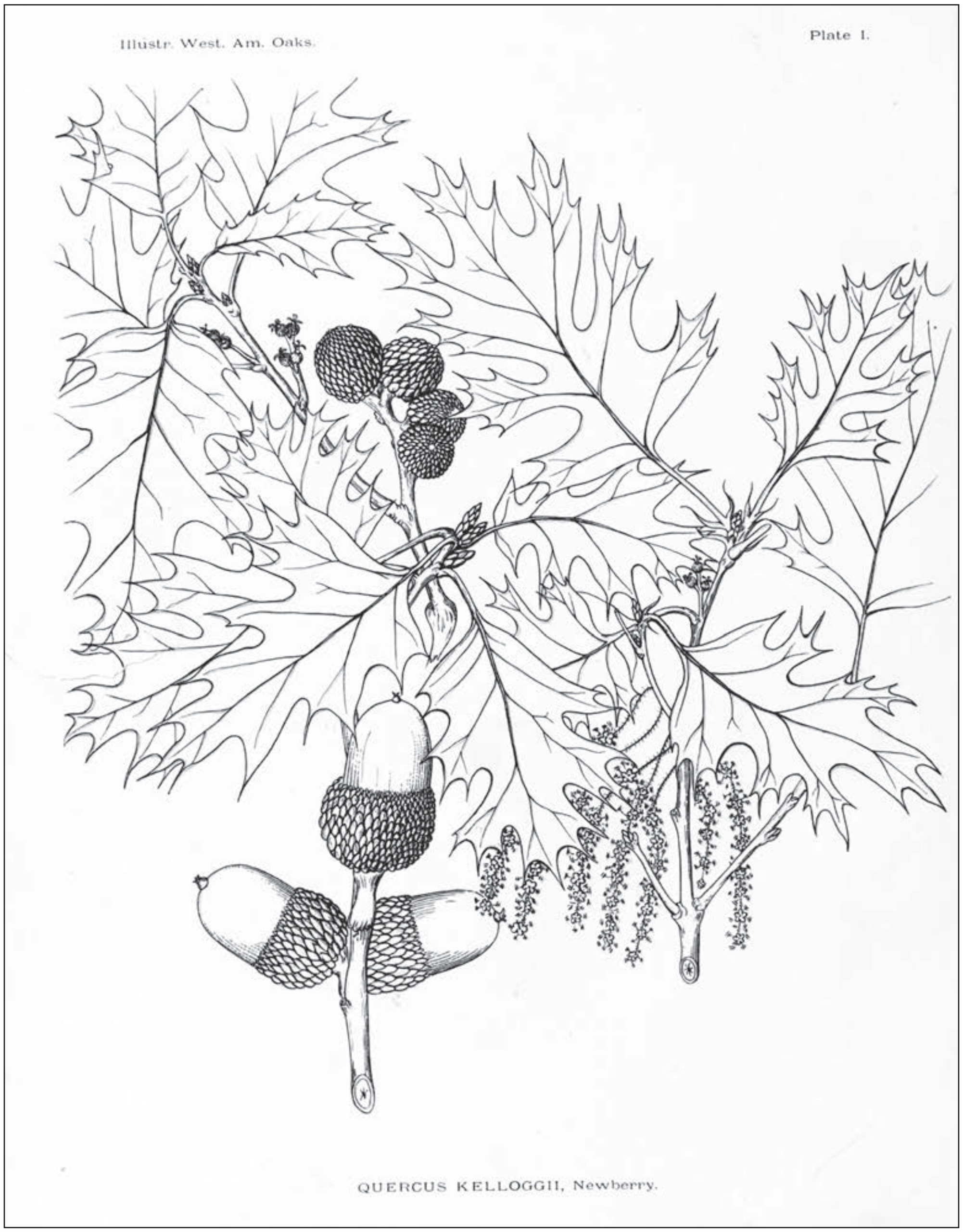


Figure 2—Illustration of California black oak by Albert Kellogg, from Greene (1889).

fall. The bark on young trees is thin and smooth, but it becomes moderately thick, deeply fissured, and platy as the tree grows old (Fryer 2007). Mature trees produce large acorns (up to 4.4 cm long) that typically take 2 years to develop (McDonald 1969). The acorns are held within deeply cupped caps that have fine, light-brown scales (McDonald 1969).

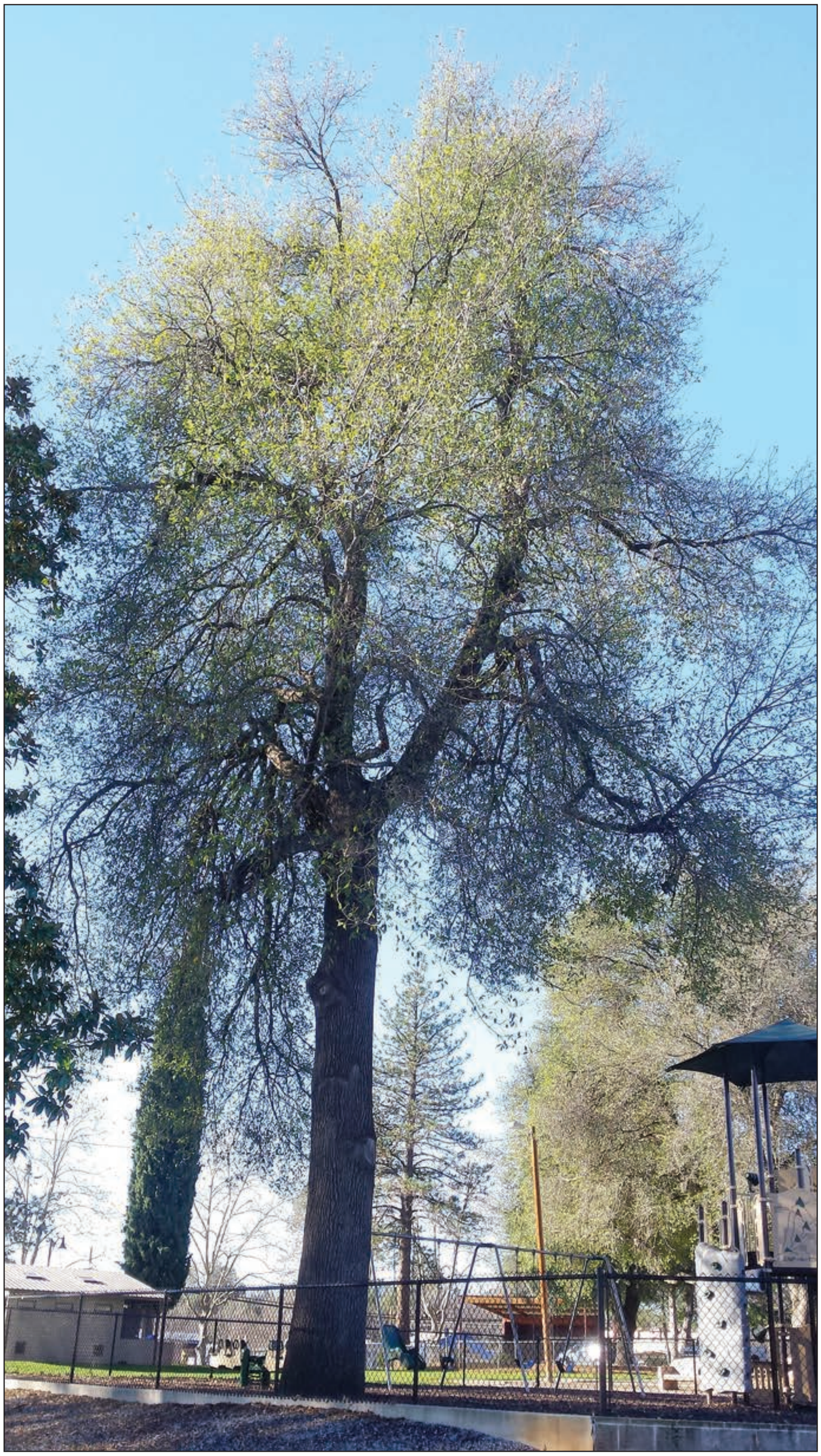
Black oaks are the tallest true oaks in the mountains of California and Oregon, with individual trees typically growing about 23 m tall (McDonald 1990). The current "national champion" black oak, in Groveland, California, in the heart of the Sierra Nevada, is 28 m tall with a girth of 726 cm (UFEI 2015). The current record tree in Oregon is reported as 32 m tall but only 602 cm in girth (Ascending the Giants 2015). A previous national champion from the Siskiyou National Forest of Oregon was 38 m tall and 859 cm in circumference (Fryer 2007) before it died, so black oaks larger than the current record trees may well occur elsewhere.[2]

Hybrids

Black oak, which is completely deciduous, hybridizes with several evergreen oaks in the section Lobatae that overlap with it in the lower elevation of its range. The resulting crosses retain sparse foliage in the winter. For example, a cross with interior live oak (*Quercus wislizeni*) creates oracle oak (*Quercus* × *morehus*). Oracle oaks are typically smaller than black oaks, as the largest oracle oak listed in the big tree registry is only 18 m tall (UFEI 2015); however, Phil McDonald and Carl Skinner have identified an oracle oak over 27 m tall in a city park at Shasta Lake city (fig. 3). A cross with coast live oak (*Quercus agrifolia*) forms Chase oak (*Quercus* × *chasei*), as reported in Santa Clara County from a tree that was much larger than an oracle oak (McMinn et al. 1949). A cross with the interior form of coast live oak (*Quercus agrifolia* var. *oxyadenia*) results in Gander oak (*Quercus* × *ganderi*), reported from San Diego County (Wolf 1944). A hybrid black oak reported from Santa Cruz island has an unknown parent, which could possibly be coast live oak, or even Santa Cruz island oak (*Quercus parvula* var. *parvula*), which, as a variety of Shreve's oak (*Quercus parvula*), is closely related to interior live oak (Dodd et al. 2002).

Although these hybrid black oaks are generally considered oddities of minor significance, they have special qualities owing to their semi-evergreen nature, and the wood of oracle oak has been described as superior to that of either parent (Jepson 1910). Furthermore, in parts of California, the oracle oak has been reported

[2] **Ritter, M.** 2015. Personal communication. Professor, California Polytechnic State University, San Luis Obispo, CA 93407.



John Duckett

Figure 3—This tall oracle oak in Claire Engle Park in the city of Shasta Lake could be nominated the state champion. Note the persistent leaves in the middle of winter.

from locations without well-established observations of the pure parent black oak (fig. 1). This unusual distribution warrants attention when considering restoration in outlying locations such as Santa Cruz Island, where the local population of either black oak or oracle oak may have been extirpated. Therefore, restoration strategies for black oak should consider the importance of these hybrids.

Distribution

Black oak has a wide range across California and into south-central Oregon, with an isolated population reported from Baja California, Mexico. The map in figure 1 incorporates range data from the U.S. Geological Survey (1999), isolated occurrences of oracle oak from Griffin and Critchfield (1976), a collection of California black oak in 1987 at La Matanza Ranch in the Sierra de Juarez of Baja California (Carrillo N.d.), and forest inventory plots containing California black oak (USDA FS 2014). The hybrid oracle oak is widespread in California and south-central Oregon. A black oak hybrid was collected on Santa Cruz Island in the 1930s, although the identity of the other parent species needs to be confirmed, and that particular specimen is reported to have died.

The distribution of black oak reflects interacting influences of precipitation, elevation, aspect, and soil qualities. Specifically, McDonald (1990) reported that the tree occurs at elevations ranging from 61 m to over 2438 m; in north-central California, black oak occurs primarily in draws or on north slopes at elevations below 305 m, on all aspects between 762 to 915 m elevation, and not on north- and east-facing slopes above 1067 m. He also reported that black oak is found on west-facing slopes with sufficient moisture in the southernmost mountains. Since the Neogene period (23 to 2.6 million years ago), the range of black oak has apparently contracted as the climate has become drier in areas formerly occupied by its presumed ancestor, *Quercus pseudolyrata*, which is well represented in high-elevation fossil floras of California, Oregon, Nevada, and Idaho (Chaney 1918, McElwain 2004, Smith 1941).

In recent decades, black oaks were estimated to occur on 2.9 million ha of forest land, which is approximately 7 percent of all lands in California (Waddell and Barrett 2005). That area was evenly divided between private lands and national forest land (Waddell and Barrett 2005). The species is most abundant in woodlands, ponderosa pine (*Pinus ponderosa*) forests, and mixed-conifer forests along the west side of the Sierra Nevada Mountains and along lower slopes in fairly dry sections of the Klamath and Cascade Mountains (McDonald 1990).

Associated Tree Species

Throughout that range, black oak commonly grows in stands that are dominated by other species. As a result, only 506 000 ha in California were classified as the black oak forest type in a 1990 inventory (Waddell and Barrett 2005), indicating that the species was the predominant tree in less than one-fifth of the areas where it occurred.

Black oak grows with a wide variety of conifer trees, hardwood trees, and shrubs, although its most common associates are ponderosa pine, Pacific madrone (*Arbutus menziesii*), and tanoak (*Notholithocarpus densiflorus*) (McDonald 1990). Particularly in the northern and coastal part of its range, black oak often grows with Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and with Oregon white oak (*Quercus garryana*). Within lower elevation woodlands, black oak occurs with other oaks, leading to several of the previously mentioned hybrids. Canyon live oak (*Quercus chrysolepis*) also grows within much of the range of black oak, although it tolerates drier and harsher sites.

Tanoak is a distantly related hardwood species that also produces acorns and supports diverse wildlife species and tribal cultural uses, but tanoak is more concentrated along the coast than black oak. Although there are more tanoak trees than black oaks in California, their stem volumes are similar (Christensen et al. 2008), and the two species are tied for third in area of hardwood forest types in California behind blue oak (*Quercus douglasii*) and canyon live oak. However, black oak had the most large trees (≥28 cm diameter at breast height [dbh]) of any hardwood species in 1990 inventories (Waddell and Barrett 2005).

This report devotes particular attention to the role of black oak as a component within forests dominated by conifers. Many of the management strategies discussed in the report apply to woodland areas, but the challenges are more complex within the mixed-conifer forests where black oaks, and especially mature trees, appear vulnerable to long-term declines. Within the typical range of mixed-conifer forests, black oaks occur as isolated trees, in clumps, or in small groves, but very rarely in large open-grown stands (McDonald 1969). However, historical data on size, crown attributes, and spatial pattern of black oak are more limited than for conifers. The section on “trends” considers the extent and condition of black oak in historical and recent periods, as well as concerns regarding future climate.

Distinctive Qualities

Black oak has several unusual adaptations and other qualities that afford it a distinctive role among the many conifer species with which it grows. Many of these qualities are also important for understanding how and why Native Americans tended this important tree, as will be discussed further.

Hard mast—

Acorns are an important hard-shelled food in landscapes that are dominated by conifers that produce soft seeds in cones. The hard shell allows the nut meat to be available longer to foraging people or wildlife, although acorns may quickly germinate or become too moldy for people to eat if left in moist conditions (Anderson 2005, McDonald 1969). Other than tanoak, sources of hard mast that are commonly found within the range of black oak are less productive smaller trees and shrubs, including chinquapins (*Chrysolepis chrysophylla* and *Chrysolepis sempervirens*), California hazelnut (*Corlyus cornuta* ssp. *californica*), California nutmeg (*Torreya californica),* and California buckeye (*Aesculus californica).* Within the lower elevations of the range of black oak are many other important masting species, including other oaks as well as native walnut (*Juglans hindsii*), which has a very limited distribution.

Maturation time—

Black oak trees produce acorns starting as soon as age 30, with sporadic production until they enter prime production between 80 and 100 years; prime production can continue until at least 200 years (McDonald 1969). According to the USDA woody plant seed manual (Bonner and Karrfalt 2008), the minimum age of 30 years needed for black oaks to produce seeds is generally much longer than competing conifers, including Douglas-fir (10 years), Jeffrey pine (*Pinus jeffreyi*) (8 years), and ponderosa pine (16 to 20 years), although it is faster than the time for white fir to produce "commercial" quantities of seed (40 years) or for sugar pine (*Pinus lambertiana*) to produce seeds (40 to 80 years). Note that the time needed for fire-killed resprouts of mature trees to produce acorns may be much shorter given that such trees have well-developed root systems; however, research is needed to study the relationship between age of resprouts and acorn production, and how management practices can influence production.

Black oaks form large, often well-insulated cavities within their trunks and dead or broken branches, and these cavities support many animals, including Pacific fisher.

Cavities—

Black oaks form large, often well-insulated cavities within their trunks and dead or broken branches, and these cavities support many animals, including Pacific fisher (*Pekania pennanti* spp. *pacifica*), as discussed further below. Black oaks become decadent sooner and provide more cavities than do conifers of similar sizes (Garrison et al. 2002b), and they reportedly have a higher incidence of decay and breakage than other oaks with which they occur (Bolsinger 1980).

Flammable litter—
Black oaks produce large, curling leaves that form the most flammable litter of the California oaks, which helps them to carry frequent, low-intensity fire (Engber and Varner 2012). In a comparison with seven common conifer trees, black oak litter was the fastest to ignite and the quickest to spread, producing tall flames that were not sustained as long as most of the conifers; these qualities could facilitate frequent fires that cause less injury to mature trees (de Magalhães and Schwilk 2012).

Variable fire resistance—
Whereas young stems are highly susceptible to fire, stems of mature trees are somewhat resistant to fire, although fires may cause open scars that can make trees more vulnerable to future fires. Because of their relatively thin bark, black oaks are more sensitive to fire than the mature forms of associated conifers, such as Douglas-fir, ponderosa pine, sugar pine, and white fir (*Abies concolor)* (Skinner et al. 2006); however, black oaks do have thicker bark and are more resistant to fire than many other hardwood trees (Plumb 1980).

Resprouting of mature trees and seedlings—
When the aboveground parts of black oaks have been killed or even merely injured or exposed to increased sunlight, the trees can resprout, often rapidly, from the base of their trunks, forming "root-crown sprouts." Black oaks also have the ability to resprout from seedlings that have been top-killed, forming "seedling-sprouts." McDonald and Tappeiner (2002) noted that black oak seedlings may take more than 7 years before they begin to grow tall stems, during which time they develop a long tap root. The black oak seedlings may be repeatedly top-killed and then resprout, and they may remain only a few inches tall for decades, especially in shaded environments. The ability of seedlings to resprout following dieback demonstrates an adaptation that can maintain the species until better conditions for growth arise (McDonald and Tappeiner 2002). Because of the capacity to resprout vigorously following intense stand-replacing fires or other major disturbances that remove the overstory, black oaks can outgrow coniferous trees and shrubs (McDonald 1969). For example, at a productive site on the Challenge Experimental Forest, black oak resprouts reached 6 m tall in 10 years following a clearcutting treatment that increased sunlight (McDonald and Tappeiner 2002). This rapid growth helps to reduce soil erosion in the short-term, because quickly established shoots and leaves break the impact of rainwater (McDonald 1969). Over longer periods, black oaks can provide a nursery environment for reestablishing conifers (Barr 1946, McDonald and Tappeiner 2002).

Drought tolerant—

Black oaks, like many other oaks, have numerous physiological adaptations to harsh conditions, especially drought, including an ability to tap deep water supplies in fractured bedrock and to tolerate moisture stress at levels that are lethal to competing species (McDonald 1969, McDonald and Huber 1995b). Studies have shown that large trees, including coast live oak, can lift deep water into shallower soil mycorrhizal networks, which in turn can help seedlings withstand droughts (Bingham and Simard 2012, Egerton-Warburton et al. 2007). Royer et al. (2008) reported that leaf shapes on black oak vary with elevation, possibly because of wind speed or water availability, but not with mean annual temperature. This adaptation suggests that black oak as a species can vary its leaves over time to take advantage of differing evapotranspiration conditions. Related studies (Royer 2012, Royer et al. 2009) found that red maples (*Acer rubrum*) had the ability to alter their leaf shapes over short periods (not only through long-term genetic selection); however, that researcher has not studied whether black oak's ability to change was also so fast.[3]

When black oaks are retained in fuelbreaks and other fuels treatment areas, they maintain canopy cover while reducing fire hazard.

Open crown and canopy—

Black oaks have an open, low-density crown structure, which allows more light in the understory compared with conifers (Fralish 2004). This quality also makes them less likely to promote or carry crown fires than evergreen and densely leaved forest types (Skinner et al. 2006). Thus, when black oaks are retained in fuelbreaks and other fuels treatment areas, they maintain canopy cover while reducing fire hazard.

Deciduous—

In contrast to evergreen oaks and most conifers in California, black oaks are dormant in winter, which reduces both transpiration and interception of precipitation in winter months. This trait also allows sunlight to dry fuels in the fall and winter, which facilitates fires when more shaded areas are too wet to burn (Knapp et al. 2009). Furthermore, the absence of leaves on oaks during those seasons allows heat from fires to dissipate easily and alleviates the potential for crown scorch (Skinner 1995).

Shade intolerance—

Mature black oaks are one of the least tolerant trees to shading within the mixed-conifer forest, although very young trees may be more tolerant than pines (Bigelow et al. 2011, McDonald 1990).

[3] **Royer, D.** 2015. Personal communication. Professor, Wesleyan University, Department of Earth and Environmental Sciences, Exley Science Center 445 (265 Church St.), Middletown, CT 06459-0139.

Values for Biological Diversity and Food Webs

Ecological Keystone

Scientists who study the ecology of California black oak, and Native Americans who depend on its products, both regard it as a critically important species. Some ecologists use the term "ecological keystone" to describe species whose removal would cause dramatic changes in the structure and function of its biological community (De Leo and Levin 1997). Despite some historical efforts to curtail black oak to favor conifers in some forests, the species has proved highly resilient, and there do not appear to have been studies that tested effects of its removal.[4]

Other scientists have proposed somewhat narrower criteria for a keystone species, including having disproportionately large ecosystem impacts relative to their abundance (Paine 1995, Power et al. 1996) and performing unique roles within the ecosystem (Kotliar 2000). Although the abundance of oaks makes it difficult to qualify them as keystones in many ecosystems (McShea and Healy 2002), Fralish (2004) asserted that various kinds of black oaks and hickory in hardwood forests of the central United States qualified as keystones because they performed disproportionate and unique roles in producing mast and high-light environments that facilitated persistence of other species in the community. California black oak similarly meets these criteria within landscapes such as the Sierra Nevada that are dominated by conifer trees because of hard mast, open crowns, flammable litter, rapid resprouting, and other distinctive qualities described in the previous section. Although some scientists have suggested that the concept of keystone species is problematic to apply to plants, there is general agreement that it is important to understand the complex interactions within food webs or communities (Menge and Freidenburg 2001, Mills et al. 1993).

Plant Diversity

In areas dominated by deciduous oaks, understory plant diversity can be very high relative to other vegetation types (Jimerson and Carothers 2002, Thysell and Carey 2001). Both fire and thinning treatments can promote structural and biological diversity and counteract the effects of conifer encroachment by maintaining a patchy array of open and closed areas (Engber et al. 2011, Wayman and North 2007, Webster and Halpern 2010). The high-light environment afforded by the relatively open crown and leaf structure of California black oaks are likely to favor

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[4] However, the spread of sudden oak death (caused by the pathogen *Phytophthora ramorum*) may provide a test of the importance of black oak and tanoak in parts of California where the disease is rampant (see Waring and O'Hara 2008).

understory plants in ways similar to oaks in other parts of the United States (Fralish 2004). Although burning in these ecosystems can volatize nitrogen, an important nutrient, it can also promote understory plants that can fix nitrogen, including big deervetch (*Hosackia crassifolia*), deerbrush (*Ceanothus integerrimus*), whitethorn, lupines, and others (Kilgore 1973, St. John and Rundel 1976).

Fungal Diversity

Fungi are an important component of the biodiversity in forests with black oak, especially as food sources for wildlife (North et al. 1997), and because many fungi form mycorrhizal associations that help trees to exchange carbon, nitrogen, and water (Southworth et al. 2011). Although it is apparently not known whether black oaks support unique fungi, the frequent fires that maintain mature black oaks may encourage various kinds of fungi to fruit. More studies are needed to understand the responses to season of burn and burn severity for various species (Pilz et al. 2007, 2004). Morels (*Morchella* sp.) and the charcoal-loving elf cup (*Geopyxis carbonaria*) are two examples of fungi from a group known as "Pezizales," which often flourish between 6 weeks and 2 years following fires; insect disturbances that damage trees can also increase production of fruiting bodies (Greene et al. 2010, Kuo et al. 2012, Pilz et al. 2004). A study in a moist forest from British Columbia that experienced high-severity fire suggested that both consumption of duff (with remaining depths less than 4 to 5 cm) and damage to nearby trees may be necessary to trigger an unusually large abundance of mushrooms (Greene et al. 2010, Kuo et al. 2012). Some of the known fire-following fungi such as morels may form mycorrhizal associations in the absence of fire (Fujimura et al. 2005).

Acorns provide a unique food resource that can either be consumed directly by wildlife to build fat reserves, or stored for use during leaner times.

Animal Diversity

Black oaks provide a food source and habitat for a variety of wildlife species. Acorns provide a unique food resource that can either be consumed directly by wildlife to build fat reserves, or stored for use during leaner times (McShea and Healy 2002). Black oaks support black bear (*Ursus americanus*), mule/black-tail deer (*Odocoileus hemionus*), and many small mammals and their associated predators in the fall, winter, and other times when other food sources are not available (Mazur et al. 2013, McShea and Healy 2002). In a burned area on the Plumas National Forest, where the current crop of acorn and other tree nuts had failed and fungi were rare, Tevis (1952) reported long-eared chipmunks (*Tamias quadrimaculatus)* surviving on year-old black oak acorns. Dusky-footed woodrats (*Neotoma fuscipes*), an important prey species for California spotted owl (*Strix occidentalis* ssp. *occidentalis*), appeared in higher densities in areas with large (>33 cm dbh) black oaks in a mixed-conifer forest with few other sources of hard mast (Innes et al. 2007). Black oak acorns are also important for mountain quail (*Oreortyx pictus*) and valley quail (*Callipepla californica*) (Potter and Johnston 1980). The acorn woodpecker (*Melanerpes formicivorus*) depends on black oak acorns, and good crops have demonstrated potential to expand the bird's breeding season (Koenig and Knops 1995). These woodpeckers also use mature black oaks, along with other large trees (fig. 4), as granaries to store acorns within productive stands (Johnson and Rosenberg 2006, MacRoberts and MacRoberts 1976). Abundance of band-tailed pigeons (*Columba fasciata*) may be an important indicator of the condition of black oaks because of their strong association with those trees for roosting and acorns (Bottorff 2007, McDonald 1969). The western gray squirrel (*Sciurus griseus*), western scrub jay (*Aphelocoma californica*), and Steller's jay (*Cyanocitta stelleri*) are important consumers of acorns, but they also disperse acorns into new areas (Kauffman and Martin 1987, McDonald 1990). Consequently, these wildlife species demonstrate a strong mutualism by both eating black oak acorns and benefitting the trees.

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Figure 4—Acorn woodpeckers consume black oak acorns they store in granary trees, including these dead ponderosa pines on the Power Fire, Eldorado National Forest.

An 8-year study of ponderosa pine forests on the Sierra National Forest identified 19 bird species that nest in California black oak, with a greater use of live trees than snags (Purcell and Drynan 2008). It found that black oaks were used for 21 percent of the nests even though they represented only 10 percent of all trees >2 m tall. Black oaks used for nesting were larger than other available trees in terms of both height (mean was 21 m) and dbh (mean was 64 cm), which points to the importance of mature trees as a resource for wildlife. Black oak provides important den sites for fisher (Yaeger 2005, Zielinski 2014), which also uses black oaks as resting sites (fig. 5) out of proportion to their availability in the southern Sierra Nevada (Purcell et al. 2009). Many bird species, including northern pygmy-owl (*Glaucidum gnoma*), downy woodpecker (*Picoides pubescens*), mountain chickadee (*Poecile gambeli*), red-breasted nuthatch (*Sitta canadensis)*, white-breasted nuthatch (*Sitta carolinensis)*, and brown creeper (*Certhia americana*), use dead black oak branches for foraging, nesting, or roosting (Garrison et al. 2002b).

Values for Humans

Many cultures have identified oaks as "trees of life" (Cristancho and Vining 2004). Acorns have been central to indigenous cultures in California for millennia (Baumhoff 1963, Stevens 2002), serving as both a direct food source and an indirect food source by sustaining game animals. Black oaks also have served as important sources of raw materials, primarily various wood products, for a wide variety of household goods, and for cultural inspiration (figs. 6 and 7; box 1). In addition to their material significance, mature oak trees have intangible sociocultural values as large and old denizens of forests (Blicharska and Mikusiński 2014). These values include the scenic appeal of fall color and the diverse form that oaks, especially large trees, add to conifer-dominated forests (McDonald and Huber 1995b). Favorable water flows are another benefit of restoring black oak, as the leafless crowns of deciduous trees reduce evapotranspiration and allow winter rain and snow to enter the litter and soil; consequently, conversion of stands from deciduous hardwoods to conifers can reduce water yields (McDonald and Huber 1995b).

Wood Products and Other Material Goods

California black oak has long been a source of a wide variety of household goods used by Native Americans (fig. 6). Black oak has also provided considerable economic values for more recent settlers of California, who use the wood as fuel and building materials, although forests have not typically been managed to produce oak lumber (Rossi 1980). McDonald and Huber (1995a) reported that there was potential to develop a value-added hardwood industry within the central Sierra

Figure 5—Fisher resting in a black oak cavity formed from a dead and broken branch.

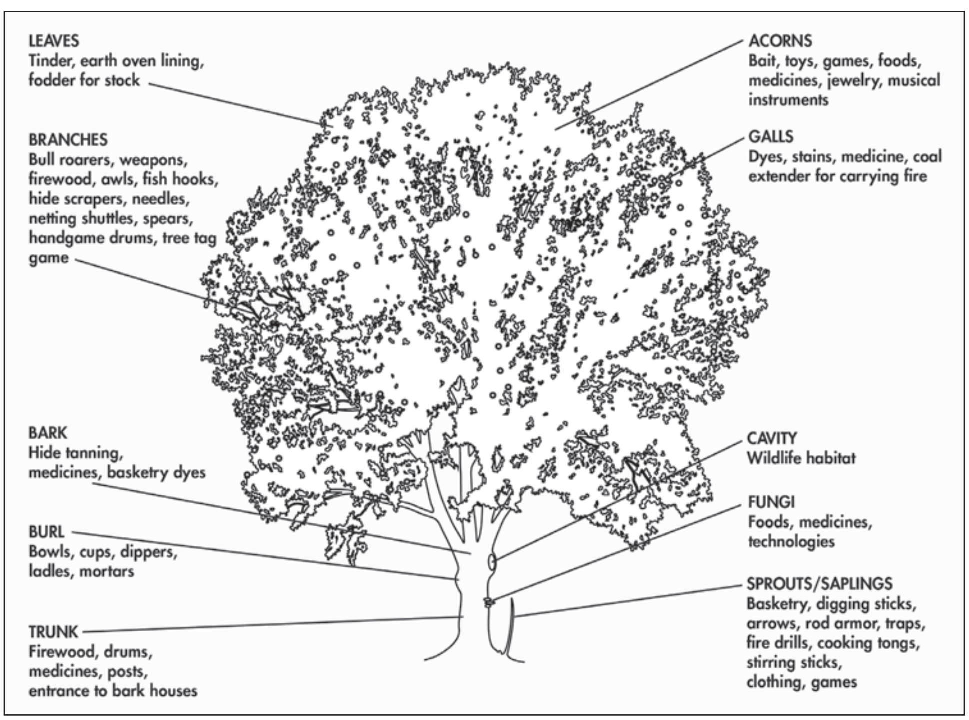


Figure 6—Native American uses of California black oak (modified from Anderson 2007).

Figure 7—(A) Danny Manning cutting a black oak sapling, (B) bending the sapling into a frame, and then (C) the finished cradleboard; (D) a basket of black oak acorns with beaded necklace by Mike Savala, and (E) a drawing by Paul Cason further illustrate the importance of black oak to Maidu people. (Photos courtesy of Danny Manning)

Box 1

Significance of California Black Oak to Maidu

Contributed by Danny Manning, Greenville Rancheria

Black oaks are significant to Maidu because they were/are one of our primary food sources. We make baskets for storing acorns, for winnowing and processing acorns, and for cooking acorns. Different families or clan groups have responsibility for and rights to certain trees. When babies are first born, they are placed in a cradleboard with a frame made from an oak branch. In Mountain Maidu country, traditionally the split rock or *o'witchono* at the top of the Feather River Canyon must be filled in each year to stop the wind from blowing in and knocking off the acorns too early. In addition, the ponderosa pine tree, *bu'bum ch'am* or wind-lessening tree, is named for its role in catching the wind so that it does not reach the shorter oak tree and blow the acorns down. Although we no longer depend on acorns the way we did in the past, Maidu elders warn of a future time in which we will need to know how to steward oaks and process acorns because "we will be happy to have acorns to eat."

Nevada, with black oak and canyon live oak contributing a "moderate" volume for potential utilization. Maximizing the economic value of hardwood lumber requires changes in typical methods used to process conifer lumber, in order to accommodate shorter and more variable logs, the need for slower drying (seasoning), and different milling requirements (Huber and McDonald 1992).

Game

Black oak acorns support a variety of game species, including deer, black bear, band-tailed pigeons, wild hogs (*Sus scrofa*), and wild turkeys (*Meleagris gallopavo*). The economic value of deer hunting associated with black oak has resulted in state and federal efforts to promote black oak (Skinner 1995). One study found that black oak contributed substantial economic values by enhancing the quality of deer hunting experiences (Loomis et al. 1995). Indeed, within an area that overlaps the Shasta-Trinity National Forest, that study found that proposed efforts to reduce oak basal area from an average of 3.9 m^2/ha to only 2.3 or 1.1 m^2/ha would reduce annual hunting values by $3.4 million and $5.5 million, respectively, whereas increasing basal area of oaks to 6.9 m^2/ha would increase hunting benefits by $8 million. Within the San Jacinto Ranger District on the San Bernardino National

Many Native Americans and others are "oak enthusiasts" who continue to cultivate, process, and consume acorns today, and some share their skills with the general public.

Forest, economists estimated that burning in habitats that include California black oak would generate approximately $8.65 to $17.80 per hectare of increased deer hunting benefits for the first 445 ha burned, or about 3.4 percent of the total costs of such a burn, with diminishing returns for larger burns (González-Cabán et al. 2003).

Food

Acorns have long been an important part of the Native American diet in most places where oaks grow. In addition to eating wild game that consumed acorns, Native American families would gather and store thousands of pounds of acorns. Acorns were sometimes used right away, but they could be stored for at least 4 years and possibly over a decade (Anderson 1993). Many Native Americans and others are "oak enthusiasts" who continue to cultivate, process, and consume acorns today, and some share their skills with the general public (fig. 8) (Ortiz 1991, Stevenot 2008). Processing acorns involves several time-consuming steps: removing the shell (fig. 9), winnowing to remove the skins on the shelled acorns, pounding (fig. 10) and sifting (fig. 11) the nuts into a fine meal, leaching the meal to remove tannins, and then cooking it to create an excellent acorn porridge, mush, or soup (fig. 12).

Frank Lake

Figure 8—Lois Conner Bohna with acorns on a tree tended by her grandmother, Lilly Harris, at a ranch near North Fork.

Kat Anderson

Figure 9—Lois Conner Bohna cracking an acorn with a hammer stone to remove the shell.

Kat Anderson

Figure 10—Lois Conner Bohna pounding the shelled acorns into flour in a traditional mortar hole.

Kat Anderson

Figure 11—Lois Conner Bohna sifting the acorn flour to separate the coarse grains from the fine flour.

Kat Anderson

Figure 12—Black oak acorn mush or porridge, a traditional food prepared by Lois Conner Bohna, North Fork Mono, in a basket made by her grandmother, Lilly Harris, circa 1920.

Interviews with tribal elders indicate that black oak was the most favored acorn among many of the tribes in California, and second only to tanoak for many others.

Interviews with tribal elders indicate that black oak was the most favored acorn among many of the tribes in California, and second only to tanoak for many others (Appendix J in Anderson 1993) (fig. 13). A comparison with the range map (fig. 1) indicates that this preference even extends beyond the range of black oak in southern California. However, tribes in northern California often have preferred tanoak over black oak where they had access to both species, either within their territory or through trade (Baumhoff 1978, Holt 1946, Kroeber 1925, Schenck and Gifford 1952). However, even in these instances, black oak may have a distinctive value, such as serving as a ceremonial food among the Karuk (Heffner 1984). In southern Oregon, black oak acorn paste was reportedly traded from California to the Rogue River Valley (Dixon 1907), and Sapir (1907) specifically described black oak acorns as the chief of the staple foods for the Takelma Native Americans. Among coastal tribes in southern Oregon, Barnett (1937) reported that acorns (species unspecified) were commonly used, but that they were especially important for the Tolowa (along the California border) and became less important farther north.

Food preferences depend on a variety of influences, including individual tastes, accessibility, ease of processing, and traditions. California natives used acorns from a variety of oak species that occur within the range of black oak, including blue oak, interior live oak, canyon live oak, and Oregon white oak (Anderson 2009). Oregon white oak is widely found in southern Oregon and northern California, and scattered in the Sierra Nevada, but it was generally not a preferred food because of its sticky consistency (Dixon 1907). Desirable properties of black oak acorns include a large nut that is easier to deshell, pound, and grind than other nuts; a distinctive taste and texture; high oil content; and storability (Anderson 1993, Lee 1998). That tribes would prefer such a tannic-rich food, which requires more time to process (Bettinger et al. 1997), may seem counterintuitive; however, the same preference for acorns from red or black oaks (section Lobatae) appears to hold for Native Americans from eastern North America (Messner 2011). The higher tannin and oil content of black oak may account for enhanced texture and flavor, better storage, and dietary benefits. In addition to being an important source of energy, acorns have been shown to have desirable qualities for controlling blood sugar levels (Brand et al. 1990).

Cultural Keystone

The opportunity to gather traditional foods and maintain associated lifeways are important in maintaining the biological, economic, and cultural well-being of tribal communities (Lynn et al. 2013). Garibaldi and Turner (2004: 4) described cultural keystone species as "culturally salient species that shape in a major way the cultural

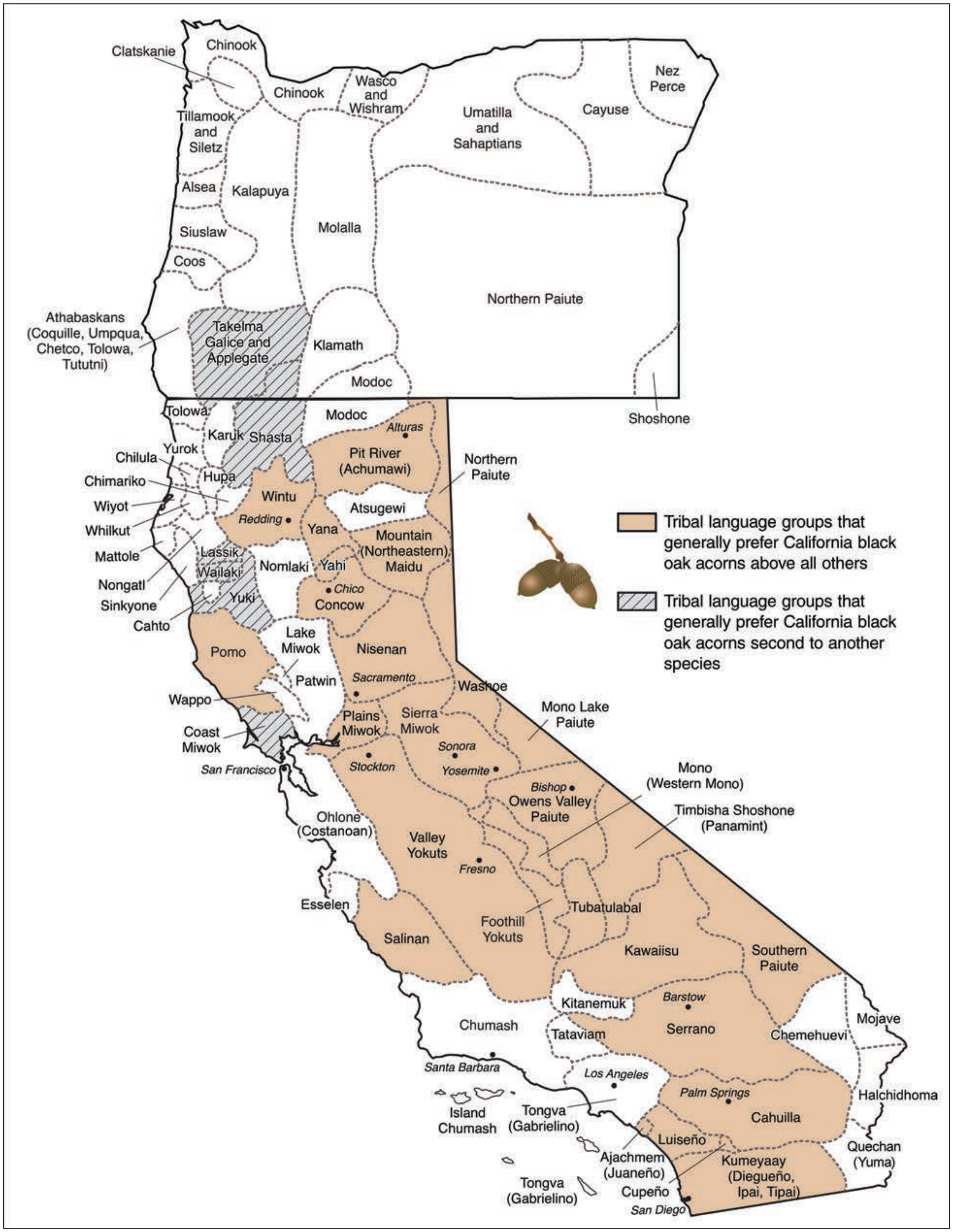


Figure 13—Preferences for black oak acorns among tribal language groups.

identity of a people, as reflected in the fundamental roles these species have in diet, materials, medicine, and/or spiritual practice." Garibaldi and Turner (2004) proposed a list of criteria to determine the relative value of different species according to this definition (table 1). California black oak clearly meets the criteria for this distinction based upon its multiplicity of uses; significance in names, stories, and ceremonies; value for trade; and lack of substitutability for Native Americans who live in the heart of its range, such as the different Mono cultural groups (Aginsky 1943, Anderson 2007).

Cristancho and Vining (2004: 155) proposed the term "culturally defined keystone species" as "plant and animal species whose existence and symbolic value are essential to the stability of a culture over time" (table 2). The questions they proposed to identify these species focus on spiritual values that are harder to objectively evaluate, and it is worth noting that Garibaldi (2009) later suggested dropping the question about ceremonial uses owing to the sensitivity of such information. However, Ortiz (2008) shared several quotes from Native American acorn gatherers and other examples that illustrate the spiritual significance of oaks.

Acorns have had an important role in cultural transmission and rituals, including dances, festivals, and ceremonies. At the July 2013 workshop, Ron Goode recounted a story explaining how acorns were used as a currency. Tribal members also noted that social activities often centered on acorn gathering and processing, with women gathering and processing while children would play games of tag in the trees. The trees provided shade under which women worked long hours. The relationships that were established to facilitate acorn harvest often governed broader social interactions among families and across the landscape. For example, people would consult one another to determine the optimum gathering sites in a given year, and they would often work together to complete gathering and processing activities (Anderson 1993, Bettinger et al. 1997).

If trees are not producing abundant acorns, then squirrels, chipmunks, and deer aren't doing as well. Predators aren't going to do as well either.

During the 2013 workshop, Ron Goode presented a representation of a food web associated with black oak (fig. 14). He noted a particularly strong relationship between oaks and squirrels, chipmunks, deer, and their predators, and he stressed the cascading effects associated with compromised oak health: "If trees are not producing abundant acorns, then squirrels, chipmunks, and deer aren't doing as well. Predators aren't going to do as well either." This position is consistent with the claim by a wildlife biologist that acorn production "reigns supreme as the greatest contribution to the welfare of forest wildlife" (Kerns 1980: 359); evidence that deer populations are strongly correlated with acorn production (Leach and Hiehle 1957); and an assertion by a prominent wildlife researcher (Barrett 1980) that several mammals, especially bears, deer, pigs, and squirrels, depend on regular supplies

Table 1—Criteria suggested by Garibaldi (2009) for indexing cultural keystone species, with responses and citations for California black oak

Category	Question	Response and citation
Intensity, type, and multiplicity of use	Is the species used intensively (routinely and/or in large quantities)?	Black oak acorns have been intensively used in very large quantities (Anderson 1993).
	Does the species have multiple uses?	Black oak has been an important source of a wide array of material items (Anderson 1993).
Naming and terminology in a language, including use as seasonal or phenological indicators, names of months or seasons, place names	Does the language incorporate names and specialized vocabulary relating to the species?	The species name is commonly used in place names and names of months and seasons (Anderson 1993, Pavlik et al. 1995).
Role in narratives, ceremonies, or symbolism	Is it prominently featured in narratives or ceremonies, dances, songs, or as a major crest, totem, or symbol?	Black oaks are prominent in stories, personal names, songs, festivals, and ceremonies of native Californians, including first acorn feast ceremonies (Anderson 1993, Kroeber 1925, Ortiz 2008, Pavlik et al. 1995).
Persistence and memory of use in relationship to cultural change	Is the species ubiquitous in the collective cultural consciousness and frequently discussed?	Black oak is one of the most important species utilized by tribes in the area (Anderson 1993).
Level of unique position in culture	Would it be hard to replace this species with another available native species?	Gatherers noted that black oak has a large nut, it is easier to grind, and it has more oil; it was highly valued and grows at elevations above other oaks in the Sierra Nevada. Therefore, substitution with other species is not desirable, although it may be possible through trade and gathering at different locations (Anderson 1993, Ortiz 2008).
Extent to which it provides opportunities for resource acquisition from beyond the territory	Is this species used as a trade item for other groups?	Trade networks involving black oak were extensive in California and beyond; for example, Miwok traded black oak acorns for piñon nuts from the Great Basin (Anderson 1993).

Table 2—Criteria proposed for "culturally-defined" keystone species by Cristancho and Vining (2004), with responses and citations for California black oak

Question	Black oak example
The story of the species' origin is tied to the myths, the ancestors, or the origin of the culture.	Myths among Mono (Gifford 1923:366) and Karuk (Harrington 1932) personify black oaks as young women.
The species is central to the transmission of cultural knowledge.	Harvest and tending practices are a central, intergenerational cultural activity (Ortiz 2008).
The species is indispensable in the major rituals on which the community's stability depends.	Fall festival, bear dance, and other rituals (Ortiz 2008).
The species is either related to or used in activities intended to supply the basic needs of the community, such as getting food, constructing shelters, curing illnesses, etc.	As depicted in figure 6 and supporting references (Anderson 1993, Goode 1992).
The species has significant spiritual or religious value for the culture in which it is embedded.	Provides habitat for spiritually important animals, such as owls and bears.
The species exists physically within the territory that the cultural group inhabits or to which it has access.	The range of black oak (fig. 1) overlaps with cultural groups who prefer it as a food (fig. 13).
The cultural group refers to the species as one of the most important species.	Although groups might have concerns about ranking species in terms of importance, they regard black oak as a notably important species.

Ron Goode

Figure 14—Elements of black oak food web. The quote at the bottom by Rebecca Bliege Bird reads, “People affect all other species, to manage is a religious philosophy of dominion. An alternative is the Aborigine way of thinking—everything has an inter-relationship, a web of positive and negative species.”

of acorns to maintain their normal densities. Many carnivores, including bears, are particularly important symbolic animals for tribes.

Relationships Between Fire and Black Oak

Goldilocks Principle

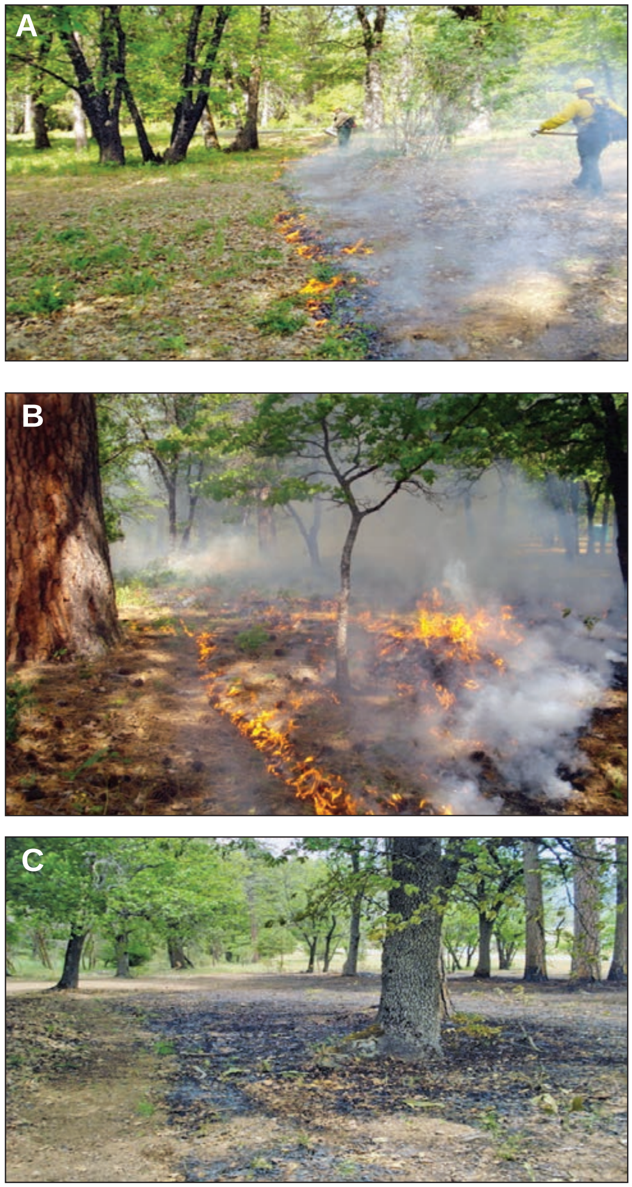
McDonald (1969: 15) described fire as “black oak’s worst enemy,” reflecting a concern that individual black oak stems are highly vulnerable to fire damage, even from low-intensity prescribed fires. However, he and other researchers later acknowledged that in the long-term, fire can also be a “blessing” for black oak by providing favorable conditions against competitors (McDonald and Tappeiner 2002). Furthermore, traditional practitioners and researchers both have shared the perspective that large oaks frequently tolerated fire well and that frequent, low-intensity fires maintained the more open structures and low fuel levels that helped avoid top-kill of oaks (Jack 1916, Skinner et al. 2006). For example, in reviewing effects of winter prescribed burning around Shasta Lake, Skinner (1995) observed complete top-kill of black oaks less than 5 cm dbh, mixed impacts to trees between 5 and 20 cm dbh, and no cambial damage to black oaks larger than 20 cm dbh that did not have any existing open fire scars. Similarly, Kauffman and Martin (1990) found high rates of top-kill from prescribed burning of small black oaks (<3 m tall), with no top-kill to taller trees. Furthermore, Douglas-fir, ponderosa pine, white fir, and incense cedar (*Calocedrus decurrens*) tend to establish underneath black oaks and eventually overtop them, which reduces the amount of light and other resources available to the oaks and which, over time, may reduce their resilience to fire and other disturbances (Cocking et al. 2012b, McDonald 1969). Frequent fires provide shade-intolerant black oak with openings and resources needed to thrive within forest landscapes dominated by conifers. That black oak both needs fire and is threatened by it suggests a "Goldilocks" effect in which fuels and structural conditions need to fall within particular margins for fire to favor development and persistence of large oak trees. This complex relationship with fire helps explain why the pros and cons of fire in forests with black oak have been debated for at least a century. Klamath River Jack wrote, "Indian burn every year just same, so keep all ground clean, no bark, no dead leaf, no old wood on ground, no old wood on brush, so no bug can stay to eat leaf and no worm can stay to eat berry and acorn. Not much on ground to make hot fire so never hurt big trees, where fire burn" (Jack 1916). In response, forest ranger Jim Casey said, "If that place had been left alone there would be big timber all over it and you could ride anywhere and there would be lots of grass on the ground for deer and cattle….And I have seen the best kind of acorn crops in places that never felt a fire" (Jack 1916).

That black oak both needs fire and is threatened by it suggests a "Goldilocks" effect in which fuels and structural conditions need to fall within particular margins for fire to favor development and persistence of large oak trees.

Cultural Burns

Cultural burning is the traditional use of fire to stimulate desired conditions for specific cultural purposes (Goode 2014, Lake 2013). Intended outcomes of cultural burning may differ according to their diverse objectives, which also include making lands more favorable for particular activities (fig. 15). Accordingly, the historical effects of cultural burning would have been most pronounced surrounding frequently used areas such as villages, acorn processing camps, and trade or travel routes (Bettinger et al. 1997, Morgan 2008). The early appeal for cultural burning in oak forests by Klamath River Jack, cited above, explained that regular fires had been used to reduce pests in acorns and to sustain deer and berry production.

Goode (2014) explained how burning practices have been taught among the Mono through a system of lifelong learning. His description emphasizes that frequent understory burning was not practiced everywhere on the landscape; instead, it would have been concentrated along trails, around camp sites, and at meadows. Some areas that had been overgrown would be targeted with three burns in a decade. Subsequent burns were not necessarily so frequent, with two to three maintenance burns spread across the following two decades. However, actively



Danny Manning

Danny Manning

Danny Manning

Figure 15—(A and B) During and (C) after a cultural burn under black oaks to prepare the grounds at a Native American-Mission site for the traditional bear dance.

harvested oak groves have been burned more regularly to consume litter and remnant acorns under the trees. Consistent with these descriptions, Anderson (1993) noted that indigenous fires were set every year in the Sierra Nevada wherever the land “needed it,” as indicated by abundant growth of brush, with the result that tended areas were customarily burned every 2 to 10 years. To curtail pests, tribal burning in black oak forests managed for acorn production may have been conducted as frequently as surface fuels and weather conditions allowed for a contiguous understory burn.

Studies of Past Fire Frequency in Forests with Black Oak

Research to infer historical fire patterns based upon fire scars confirms that forests with black oak experienced frequent fires, and such studies have concluded that native peoples likely increased that frequency in many areas. According to a review by Van de Water and Safford (2011), median fire return intervals for dry mixed-conifer and yellow pine (ponderosa pine and/or Jeffrey pine) forests that commonly have a California black oak component were 9 and 7 years, respectively. Historical fire return intervals can vary considerably, with a reported range of 2 to 23 years in the yellow pine/black oak forest type (Skinner and Chang 1996). Fires were more frequent in the southern and central Sierra Nevada and throughout the black oak range in drier sites associated with south aspects, ridges, and lower elevations (van Wagtendonk and Fites-Kaufman 2006). At a more northerly site in the Klamath Mountains, black oak appeared more common on mesic, north-facing slopes at lower elevations with a median fire return interval of about 11 years (Taylor and Skinner 2003).

Researchers generally agree that Native Americans used fire and other practices to promote desired forest conditions, although there has been considerable debate over the extent of such modifications (Lake 2013). In many parts of North America, oaks and other trees producing fruits were most accessible in landscapes maintained by Native Americans using fire and other tools to cultivate these resources (Abrams and Nowacki 2008). Within California, Anderson and Moratto (1996) reviewed information about the population densities and likely ecological impacts of Native Americans in the proto-historical period, noting that frequent burning was an insurance policy against loss of important resources by promoting the black oak–ponderosa pine forest type and other highly valued habitats. Anderson and Carpenter (1991) reviewed pollen and other evidence in suggesting that Yosemite Valley was a specific example of a landscape modified by Native Americans to favor black oaks and other food resources.

Researchers have identified burning by Native Americans as a probable contributor to the high frequency of fires in many areas prior to settlement or active fire suppression by Euro-Americans. For example, at a mixed-conifer forest at Black Mountain in the San Jacinto Mountains where black oak was a co-dominant tree, Everett (2008) reported a median fire return interval of 2 years between 1700 and 1900, and 5 years in the 20th century; he suggested that burning by Native American groups, including the Cahuilla, Serrano, and Kamia, likely contributed to the frequent fires recorded in the pre-settlement period. Most indigenous landscape burning ended by the early 20th century, coinciding with the beginning of the fire suppression era, although in some cases it was curtailed or ended even earlier because of settlement impacts on Native American populations (Fry and Stephens 2006, Swetnam and Baisan 2003). Alterations to traditional burning practices associated with Native American population declines as early as the late 18th century may have contributed to a reported shift from frequent small fires to larger fires, owing to increased continuity of heavier fuels across landscapes (Taylor and Beaty 2005). Stephens (1997) reported a median fire return interval of 7 to 8 years for a site in the Sierra Nevada foothills in El Dorado County from 1850 to 1952; he speculated that early range managers accounted for the frequent fires, as Native Americans had already been displaced by the start of that record. At a more northerly site with black oak near Whiskeytown Lake, Fry and Stephens (2006) suggested that Native American ignitions likely contributed to the frequent fire regime prior to 1850; however, fire frequency after 1850 declined dramatically with Euro-American settlements that greatly affected the local Wintu population. However, at a nearby site west of Hayfork, California, Taylor and Skinner (2003) found that active fire suppression and declines in fire frequency did not become evident until after 1920, and they concluded that the longer active fire regime likely reflected continued fire use by Native Americans to promote acorns and other desired values.

Trends

Declines of Black Oak

Competing ecological trends over the past century have caused black oak to increase in some areas while decreasing in others, as reported in comparisons to historical vegetation surveys from the 1930s (Thorne et al. 2007, 2008). Those researchers reported that, between 1936 and 1996, the area where black oak was present as a subdominant under conifers declined by 25 percent, but that it expanded by a similar amount in areas classified as dominated by montane hardwoods. They attributed the increase in oak-dominated area to removal of overstory conifers by logging and wildfires. Historical logging often selectively removed conifer species, especially large pines and Douglas-fir. For example, Stephens (2000) reported that 25 percent of black oaks were cut in four “average” mixed conifer stands, which was a lower percentage than white fir (33 percent), sugar pine (88 percent), ponderosa pine (58 percent), and Douglas-fir (100 percent), and a higher cut rate than incense cedar (13 percent), which had low value. This selective timber cutting may have caused black oak to become more dominant; however, oaks were also cut to fuel logging engines in the late 19th and early 20th centuries (Merriam 2013). Furthermore, in the mid-20th century black oaks were systematically killed to reduce competition and improve growth of conifers (Pavlik et al. 1995, Rossi 1980). Fire exclusion has helped shade-tolerant conifers invade and outcompete black oak, reducing the vigor of remnant mature oaks (Cocking et al. 2012b, Skinner et al. 2006) and making old-growth, open ponderosa pine-California black oak woodlands rare (Taylor 2010). Figure 16 depicts a historical example of a logged ponderosa pine site that had large black oak with a full crown. Increasing the density of shade-tolerant conifers promotes more severe fires that top-kill mature oaks. Though oaks usually survive as young sprouts, the large, mature trees are lost at least for decades (Cocking et al. 2012, 2014). Therefore, a common trend is a decline in the abundance of large, productive black oak trees, especially those embedded in a forest of conifers (fig. 17). Within Yosemite National Park, black oaks larger than 31 cm dbh were twice as dense in plots from the 1990s than they had been in Wieslander plots from the 1930s, although that difference was not statistically significant, and there were few very large trees (>61 cm dbh) in either period (Lutz et al. 2009).

A common trend is a decline in the abundance of large, productive black oak trees, especially those embedded in a forest of conifers.

Quantitative data on historical black oak composition in mixed-conifer forests are limited and often problematic, as hardwoods were typically ignored in early 20th century timber inventories (Collins et al. 2011). The General Land Office (GLO) surveys in the Sierra Nevada showed that black oaks represented between 23 and 28 percent of total stems per acre at that time of those surveys in the later 19th century (Fites-Kaufman et al. 2007). However, researchers have cautioned that certain tree species might be overrepresented in those surveys if they were perceived to better

Figure 16—Black oak within second-growth ponderosa pine forest in Antelope Creek, one-half mile east of Mount Grossman in Amador County, California. Photo taken June 1, 1934 by Albert Wieslander, courtesy of the Marian Koshland Bioscience and Natural Resources Library, University of California–Berkeley, http://www.lib.berkeley.edu/BIOS/vtm/.

Figure 17—Shade-tolerant conifers encroaching upon a mature black oak at Blodgett Forest near Georgetown, California.

Alteration of fire regimes has been associated with shifts to closed canopy forests that have less deciduous oak. Beyond the impacts to oaks themselves, these shifts have resulted in landscapes that are more sensitive to fire, have less diverse and abundant plant understories, and contribute less to diets of humans and wildlife.

serve as long-term monuments. An 1899 survey recorded black oak as having a basal area of 2.4 m^2/ha and tree density of 13.3 trees/ha within "average" mixed conifer stands, but it did not report any black oak in "large" mixed conifer stands that had much higher densities of shade-tolerant trees (Stephens 2000). Another source of historical stand data and photographs are the "methods of cutting" plots available on various national forests; unfortunately, these reports offer only partial information regarding oaks (see box 2).

In many areas, alteration of fire regimes has been associated with shifts to closed canopy forests that have less deciduous oak (Agee 1993; Cocking et al. 2014, 2012b; Taylor 2010; Vankat and Major 1978). Beyond the impacts to oaks themselves, these shifts have resulted in landscapes that are more sensitive to fire, have less diverse and abundant plant understories, and contribute less to diets of humans and wildlife (Abrams and Nowacki 2008). Increased stand density and reductions in understory vegetation have reduced the fine fuels that carried lighter, more frequent surface fires (Engber et al. 2011). Research from the western part of Yosemite National Park has found that cessation of fire within the past century has resulted in much higher overall tree density and canopy cover, and shifted species dominance from pine to fir (Collins et al. 2011). In particular, that study remeasured historical belt transects and determined that mean canopy cover (only conifer trees were

Box 2

A 1911 Plot with Large Black Oaks on the Sierra National Forest

One historical "methods-of-cutting" plot on the Sierra National Forest, located on a gently sloping ridge at 1370 m in elevation in the Chowchilla Mountains, was mapped and described in a report by Dunning (1925). The report did not provide size or species information for individual oaks, but the author noted the "large size attained by the conifers and black oak," and black oaks are evident in photo points (fig. 18). All conifers greater than 4 cm were recorded; it is not clear if the same threshold or a larger one was applied to oaks. Twenty-five oaks were mapped in the 2.4 ha plot (10.4 trees/ha), compared with 112 conifer trees/ha with dbh greater than 10 cm. The map shows that 48 percent of the oaks were widely separated (by more than 9 m), 24 percent were pairs spaced between 2 m and 6 m apart, and the remaining five oaks were in a semi-circular clump with a 4 m radius. The stand had nearly 16-percent cover of shrubs, dominated by mountain misery (also known as bearclover, *Chamaebatia foliolosa*) and dense pinemat (*Ceanothus diversifolius*), along with Mariposa manzanita (*Arctostaphylos viscida* ssp. *mariposa*) and whitethorn (*Ceanothus cordulatus*). The report also mentioned presence of grasses and herbs, including strawberry (*Fragaria* spp.), lupines (*Lupinus* spp.), and mariposa lily (*Calochortus* spp.). The plot was about 800 m from the Hogan Ranch, where a famous Maidu woman, Lucy Hite, passed away in the care of her niece in 1927; this proximity suggests that native tending and burning practices might have been practiced through the time when the plot was first sampled. Meyer et al. (2013) were not able to relocate and resample the plot, but they reported that recent Forest Inventory and Analysis plots in yellow pine forest in the area had nearly five times more trees, similar amounts of conifer basal area, and twice the cover of shrubs.

Figure 18—Photo point 1976A in a "methods-of-cutting" plot established on the Bass Lake Ranger District, Sierra National Forest, taken in 1911, 5 years after an initial timber harvest as reported by Dunning (1925). The plot was dominated by ponderosa pine, but it included large black oaks such as the one in the upper right corner.

Reducing canopy cover below a threshold value of 40 percent appears to be important to favor shade-intolerant yellow pines and California black oak over more shade-tolerant conifers.

measured) in 1911 was typically below 30 percent, compared with modern stands with no fire that have mean canopy covers of more than 50 percent. Researchers have found similar results for the Stanislaus National Forest (Collins et al. 2015) and the Sequoia National Forest (Stephens et al. 2015). The authors also emphasized that historical stands were heterogeneous and that such variability should be promoted in restoration treatments. Reducing canopy cover below a threshold value of 40 percent appears to be important to favor shade-intolerant yellow pines and California black oak over more shade-tolerant conifers (Bigelow et al. 2011).

Acorn Production on Public Lands

Gatherers attending the July 2013 workshop indicated that there used to be many more acorns, and because they find relatively few productive black oaks on public lands today, they mostly gather on private lands. The belief that acorn production has declined and is less reliable than it was in the early 20th century has been documented in interviews with elders from many different tribes (Anderson 2009). This perception of inadequate supply likely leads acorn gatherers to be reticent about sharing the locations of their preferred harvesting sites. National forests and other public lands are particularly important in providing gathering opportunities for Native Americans in California because most tribes do not control their traditional territories, and access to private lands is often limited.

National forests and other public lands are particularly important in providing gathering opportunities for Native Americans in California because most tribes do not control their traditional territories, and access to private lands is often limited.

Regeneration Concerns

Regeneration of black oak may be an important issue in some areas; however, McDonald and Tappeiner (2002) noted that environmental conditions typically pose more challenges to growing large trees rather than establishing young trees. Managers on the Sierra National Forest and tribal members participating in the July 2013 workshop noted that young oaks remain abundant in the southern Sierra Nevada, especially following burns. Wildfires like the Rim Fire have stimulated extensive resprouting of oak trees (fig. 19). The extent to which young oaks are growing from acorns, seedling-sprouts, or root-crown sprouts is not consistently reported in studies, although it has important ramifications for growth rates because stems growing from larger root systems develop more quickly (McDonald and Tappeiner 2002). Reproduction from acorns might be particularly important for colonizing areas where oaks were completely killed by unusually severe fire, and for facilitating

Angela White

Figure 19—Black oak resprouting shortly after the Rim Fire in summer 2013 on the Stanislaus National Forest.

species movement with changes in climate. Kauffman and Martin (1990) suggested that reproduction from acorns was important for colonizing areas after fires, and they reported observing seedlings that were 50 m away from the nearest potential parent tree following prescribed burns.

Although deer browse young black oaks (fig. 20), in many areas browsing may thin the oaks and promote the surviving stems to replace the large trees. However, studies in some areas have reported a scarcity of recruitment and a population skewed toward older trees, including Cuyamaca Rancho State Park in San Diego County (Bowyer and Bleich 1980), parts of Sequoia-Kings Canyon National Park (Parsons and DeBenedetti 1979), and Yosemite National Park (Kuhn and Johnson 2008). Researchers have posited several hypotheses for the lack of regeneration, including reduced fire, reduced tending by Native Americans, changes in hydrology (particularly in the Yosemite Valley black oak grove), and increased deer browsing. Many of these possible causes are interrelated, because Native American practices would have promoted acorns through fire while keeping deer populations in check


Jonathan Long

Figure 20—Example of browsing by deer on young oaks at the Crane Valley site on the Sierra National Forest, July 2013.

through hunting. In a recent report on California hardwoods, Merriam (2013) noted that in fire-excluded stands, there were mostly mature black oaks with few very young trees and almost no saplings. Ripple and Beschta (2008) found support for the deer browse hypothesis in reporting greater recruitment in stands that were not accessible by deer since the early 1900s because of physical barriers. They attributed this to the reduction in mountain lions in the early 20th century, which stimulated a trophic cascade of increased deer populations and, in turn, reduced numbers of black oak seedlings. They cautioned that prescribed burning in areas where ungulate herbivory is high could accelerate decline of black oaks. In discussing the competing explanations for declining recruitment, Kuhn and Johnson (2008) agreed that deer browsing seemed the best explanation for trends in the Yosemite Valley, although they noted that other factors might also be involved. They also pointed out numerous ways in which ecological dynamics in the Yosemite Valley may be distinctive as the result of historical management first by Native Americans, then by Euro-American settlers, and most recently by the National Park Service. On the other hand, concerns over oak regeneration have also been widespread in the southeastern United States and have spurred both prescribed burning and attention to burgeoning deer populations (Arthur et al. 2012).

Concerns Regarding Future Climate

Drought, wildfire, and other stressors—

Effects of a changing climate, including increased episodes of drought and severe wildfire, are expected to favor black oak at the expense of less drought-tolerant, non-resprouting conifers (Kershner 2014). However, drought, damage from fire, and browsing of resprouts following fire may also impair black oak recruitment (Merriam 2013). Furthermore, an increase in severe fires will jeopardize large, mature oaks in favor of young sprouts. Large and old black oaks at the limits of the range for the species may also die owing to projected increases in moisture stress (Lutz et al. 2010). Mature black oaks may be particularly vulnerable to drought because they tend to be dominant primarily in sites that are already too harsh for competing conifers (Holmes et al. 2008, Vankat and Major 1978).

These stressors are also expected to interact with diseases, pests, pollutants, and other stressors that are affecting black oak in various regions. Sudden oak death pathogen (*Phytophthora ramorum*), which is affecting black oak in coastal regions (Sturrock et al. 2011); the gold-spotted oak borer (*Agrilus auroguttatus*), a pest from southern Arizona and Mexico that has killed black oaks in San Diego County and could spread widely across the range of black oak (Venette et al., in press); and nitrogen deposition and ozone pollution, especially in southern California (Handley

Black oaks may continue the recent trend of increasing in some areas, particularly in woodland types and severely burned areas, while declining as a mature tree within mixed-conifer forests. The synergistic effects of these stressors are likely to cause declines in acorn production to the detriment of Native American harvesters as well as wildlife.

and Grulke 2008). As a consequence of these stressors, black oaks may continue the recent trend of increasing in some areas, particularly in woodland types and severely burned areas, while declining as a mature tree within mixed-conifer forests. The synergistic effects of these stressors are likely to cause declines in acorn production to the detriment of Native American harvesters (Ortiz 2008, Voggesser et al. 2013), as well as wildlife.

For many California plant species, including valley oak and blue oak, future climates may cause range contractions as well as pressure to move upslope or northward, especially within the California-Oregon border region (Kueppers et al. 2005, Loarie et al. 2008). Declines in black oak are expected at more drought-prone, low-elevation, and low-latitude sites, including the Tehachapi Mountains of the southern Sierra Nevada (Dingman et al. 2013). Monleon and Lintz (2015) demonstrated that black oak seedlings are found at colder temperatures and higher elevations, but not higher latitudes, than older, larger black oak trees, which also suggests that its distribution may shift upslope with time. Black oaks may be more restricted in their ability to move long distances in response to climate change than many other species because they depend on animals to disperse their seeds (Devine et al. 2012).

Changes in phenology—

Increasing temperatures and other changes to seasonal weather patterns could influence black oak acorn production, gathering, and tending. McDonald (1990) reported that "sound acorns begin dropping from late September to early November and cease by November 15 at lower elevation. At higher elevations almost all acorns have fallen by early December" (McDonald (1990: 665). However, at the North Fork meeting, Ron Goode noted that rains have become less predictable during the fall season and that the prime window for gathering in the southern Sierra Nevada has shifted toward the two weeks at the end of November. Less predictable and reduced precipitation may constrain windows to apply fire.

Desired Conditions

Desired conditions are descriptions of goals to be achieved at some time in the future. They are most helpful for forest planning when they can be considered across scales from individual trees out to the forest landscape (fig. 21). Because restoration of black oak ultimately depends on understanding larger social, cultural, and ecological forces that affect forests (McShea and Healy 2002), restoration strategies ultimately need to consider the full socioecological system (Lake and Long 2014). Many Native Americans consider it necessary to restore fire as an ecological and cultural process (Norgaard 2014). Many ecologists also emphasize

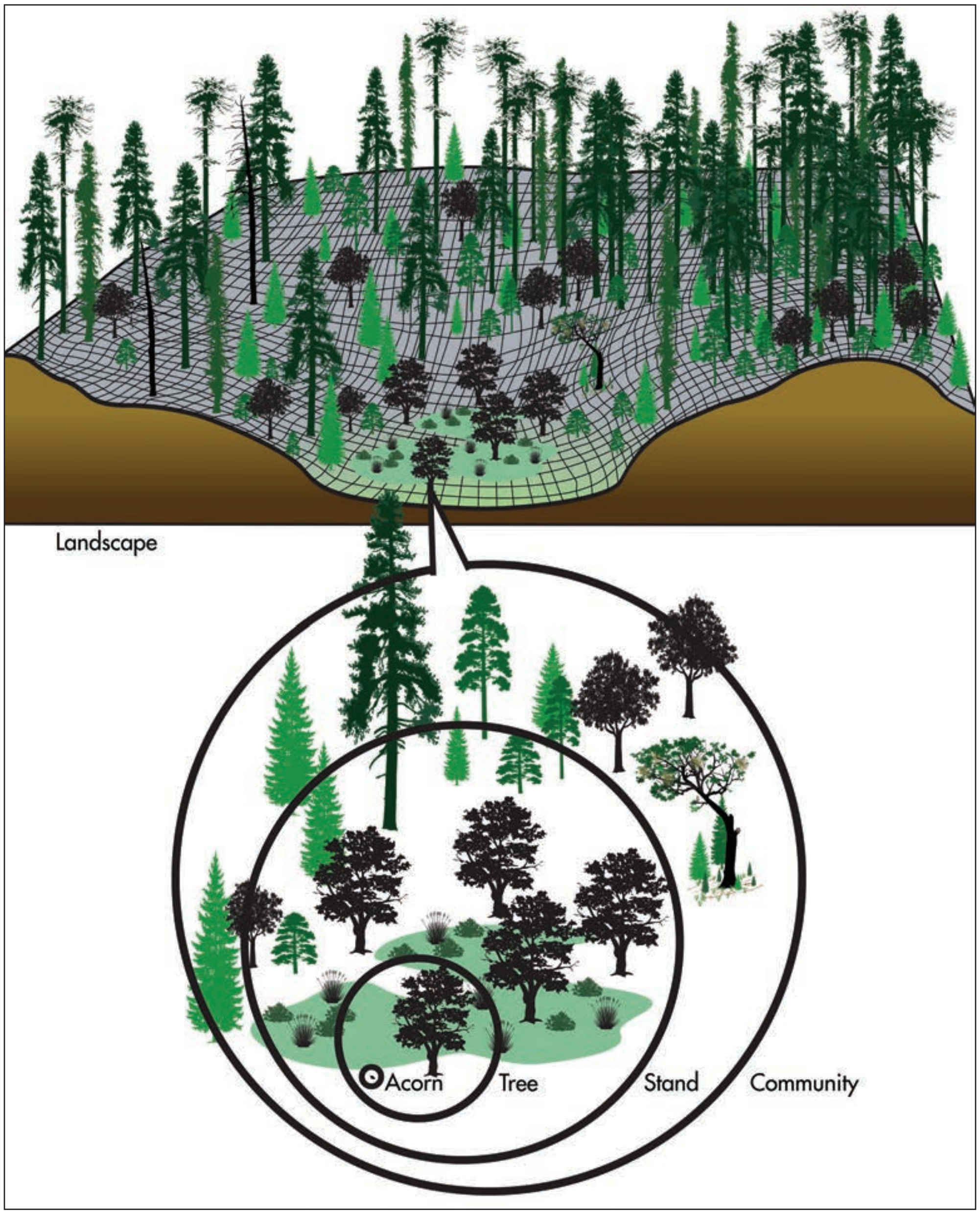


Figure 21—A conceptual model of indigenous management of California black oak at different scales of biological organization, modified from Anderson (2002).

Many Native Americans consider it necessary to restore fire as an ecological and cultural process. Many ecologists also emphasize the importance of forest restoration based upon reestablishing fire as a fundamental process and restoring heterogeneity according to topography, and black oak plays an important role in that vision.

the importance of forest restoration based upon reestablishing fire as a fundamental process and restoring heterogeneity according to topography, and black oak plays an important role in that vision (North et al. 2014).

Desired conditions will vary with the values and goals that people have for forests, and they change over time. For example, in the 20th century, many land managers focused on forests in the United States as a source of wood products, and therefore desired conditions reflected a concern for producing high-quality lumber primarily from conifer trees, although some scientists have proposed strategies to promote black oak and other hardwoods as commercial species (Tappeiner and McDonald 1980). This report focuses on desired conditions expressed by many Native Americans who gather black oak acorns, but it also considers what conditions might be desirable from a perspective of fire resilience, production of lumber, and conservation of sensitive wildlife species. By considering how these different perspectives might inform forest practices, people may envision how to design an overall strategy that would sustain this range of values. McDonald and Huber (1995b) have previously laid the foundation for this type of integrated approach, although they did not focus on production for tribal use and conservation of old-forest associated species.

Native Americans emphasize the need for black oaks to produce large quantities of high-quality acorns to support abundant harvest on a reliable basis.

Conditions Associated with Tribal Values

Native Americans emphasize the need for black oaks to produce large quantities of high-quality acorns to support abundant harvest on a reliable basis. Consistent production is unrealistic because many factors besides tree condition influence masting (Koenig and Knops 2002). However, gatherers can spread risk by gathering from various stands at different elevations, and by storing black oak acorns and adding acorns from other oaks. Consequently, desired conditions may be described at the scale of the tree and even in terms of individual acorn quality. An idealized depiction of desired condition at the tree scale (fig. 22) integrates many qualities described in further detail below.

Mature trees—

The mere presence of oaks is not sufficient to meet tribal needs because black oaks take 80 to 100 years before they become mature enough to consistently produce large quantities of acorns (McDonald 1969). However, the time to maturity may be greatly accelerated for resprouts of top-killed trees, as the well-developed root systems facilitate regrowth above competing plants and the reach of browsing animals. Large oak trees are also particularly important for wildlife species including fisher and California spotted owl, and they can be an important source of wood. Anderson (2005) noted that the Native American practice of tending and frequent burning favored older oaks and may have enhanced their longevity. It would be difficult to ensure the survival of large trees under a fire regime that includes large amounts of high-intensity fire, which could happen to some extent under a managed fire regime. However, extensive loss of mature trees in mixed-conifer forests should be expected under fire-suppression-based management without intensive reduction of fuels and competing conifers that reduce oak vigor and eventually cause oak mortality, and increase potential for severe fire (Cocking et al. 2012b).

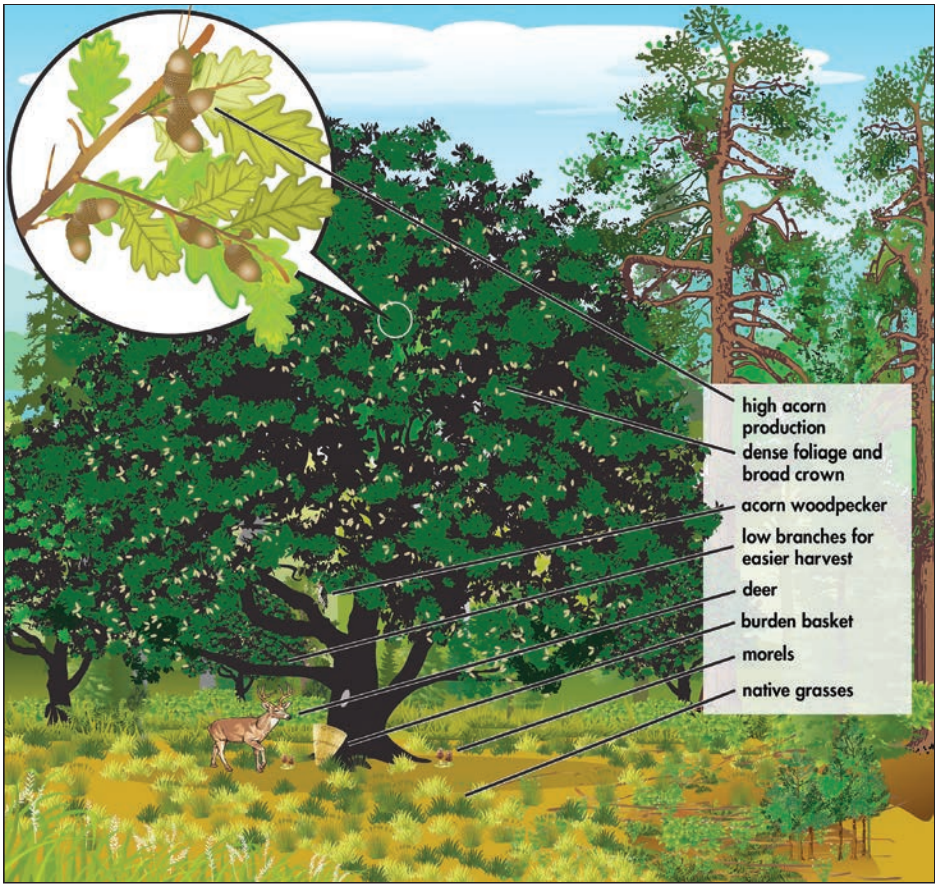


Figure 22—Idealized tree condition desired by tribal acorn gatherers. Illustration by Steve Oerding with guidance from the authors.

High acorn production—

A black oak tree may remain an abundant producer until it is at least 200 years old and may live for half a millennium (McDonald 1969). However, the oldest trees may not necessarily be as productive as the middle-aged ones (Anderson 1993; Garrison et al. 2002a, 2002b). McDonald (1969) suggested that a large 150- to 200-year-old tree would produce approximately 6,500 acorns annually. In 1989, he communicated to Anderson (1993) that a mature black oak will yield 140 pounds (64 kg) of acorns in a good year. A study in southern Placer County of four black oak stands with trees between 58 and 356 years of age found that larger diameter trees produced more acorns but the relationship was not strong, in part because 38 percent of the sampled trees did not produce acorns, even though they were in the prime age to be good producers (Garrison et al. 1998). Moreover, they observed the highest acorn production in the youngest stand and the lowest production in the oldest stand (Garrison et al. 2002a, 2002b), which does suggest that middle-aged trees might be more productive.

Upper values for acorn production and relationships to size might be different in tended and burned stands. Tribal practitioners at the 2013 North Fork meeting estimated production at approximately 90 kg (198 lbs) of acorns from typical trees they use for gathering, while noting that particularly high-quality trees could produce up to twice that amount in a good masting year. Heizer and Elsasser (1980) reported yields ranging from 41 to 62 kg (90 to 136 lbs) per tree. These estimates demonstrate that even production is highly variable. To provide a sense of scale, a typical traditional Native family would use from 82 to more than 618 kg (180 to more than 1,360 lbs) of acorns in a year, according to reports summarized by Anderson (1993).

Gatherers also emphasize the importance of the productivity of black oaks for supporting the larger ecosystem, including the multitude of wildlife species that utilize acorns.

Gatherers also emphasize the importance of the productivity of black oaks for supporting the larger ecosystem, including the multitude of wildlife species that use acorns—which are also culturally significant. They note that acorn production is a good indicator of tree health, and a mature tree that is not producing a good crop may be compromised by the effects of pathogens or fire. However, gatherers do recognize the many benefits that oaks provide to humans even when they are not producing acorns, including as habitat for wildlife, fuelwood, or lumber.

High acorn quality—

An important metric of management practices is whether the desired resources are usable (Lake and Long 2014). Useful indicators of acorn quality include the quantity of good acorns per tree or unit area and the ratio of good to bad acorns; these metrics are good measures of suitability for gathering. Good quality acorns are not infested with weevils or worms (Anderson 2005). A useful visual indicator of acorn condition is the color of the "eye," or the spot on the acorn where it was attached to the cap; the eye will usually appear brown or blotchy where an insect has injured the acorn, as Frank Lake observed at the North Fork meeting in 2013. Members of the North Fork Mono and other tribes comment that exit holes on acorns and the weight of acorns in the hand are some of the best indicators of insect damage (Anderson 2009).

It is important to note that scientists have measured acorn production using timed, relatively short visual counts of acorns on individual trees (Koenig et al. 1994), which does not directly evaluate acorn **quality**. However, measuring sound acorns typically involves the arduous task of constructing traps that catch acorns while excluding animals. Koenig and Knops (1995) noted that trapping is very labor intensive and that birds remove many acorns on the tree before they even fall. Research by Garrison et al. (1998) suggested that timed counts of acorns are significantly related to acorns counted in traps, with a strong relationship between the visual counts and the total number of sound acorns and an even stronger relationship between visual counts and the weight of sound acorns. Those relationships appear strong enough to provide meaningful indicators of black oak condition, although they may or may not be sufficient to rigorously evaluate potential effects of fire and other tending practices on acorn quality. Where acorn gatherers are actively harvesting stands, it may be possible to relate yields of sound acorns to the more routine visual counts on the trees.

Trees with broad crowns and low branches—

Trees that are desired for acorn harvest have full crowns (high crown volume). Close proximity of conifer trees tends to degrade the acorn production, crown structure, and vigor of oaks (Harrington and Devine 2006, Holmes et al. 2008). However, as noted by Danny Manning in box 1, tall pine trees in the vicinity of oaks may benefit acorn production by providing protection from winds. Gatherers desire low branches (fig. 23) that can be reached with knocking sticks to facilitate gathering. At the 2013 North Fork workshop, Ron Goode pointed out that many trees today have limbs too high off the ground to be reachable with a 2.5- to 3.0-m pole. Where the branches are too high, the knocking stick may be used on the trunk, taking care to avoid

Jonathan Long

Figure 23—Black oak tree with desirable architecture for acorn gatherers, including full crown and low branches on Tom Harris ranch, North Fork.

Neither conifer encroachment nor relatively intense wildfires promote this broad-canopied, low-branched architecture, but instead promote taller and narrower growth forms.

damaging the bark. Ron Goode and other participants explained that trees with low branches were used by children in games of tree tag. Children and young men also climbed those low branches to help gather acorns (Anderson 2007, Siegel et al. 2008).

Neither conifer encroachment nor relatively intense wildfires promote this broad-crowned, low-branched architecture, but instead promote taller and narrower growth forms (Cocking et al. 2012b; Crotteau et al. 2015; Harrington and Devine 2006). This tall tree shape has been common in the Beaver Creek Pinery (fig. 24), which has maintained a lightning-dominated frequent fire regime (Taylor 2010). The absence of low branches may render the trees less susceptible to tall flames from wildfires. This difference in tree architecture might serve as a clue to differences in management history, and it also demonstrates how natural wildfire alone would not create conditions found in tended stands.

Connie Harrington has explained the difference in architecture between full-crowned trees and tall trees as having a whole "hand" of tree crown rather than just "fingernails"—the tops of closely spaced trees.[5] She noted that research has shown that acorn production is greater when you have the "whole hand" in production rather than just the "fingernails," citing Peter and Harrington (2002).

Cavities and heart rot fungi—
Cavities in boles and large limbs are common in both wild and tended oak trees. Although cavities are clearly detrimental to producing high-quality wood (Tappeiner and McDonald 1980), they are not considered by gatherers to be detrimental to acorn production. Furthermore, they are particularly important for some wildlife species, and they may have broader effects on wildlife, including invertebrates, by maintaining pools of water. Although a variety of cavities are used by wildlife at different times, trees scorched by fires may produce cavities that are not as well insulated—and generally not as useful for wildlife—as those formed from heart rot. The principal fungi that cause heart rot in black oak are oak canker rot fungi (*Inonotus andersoni* and *Inonotus dryophilus*) and sulfur fungus or chicken-of-the-woods (*Laetiporus gilbertsonii*) (McDonald 1969, Swiecki and Bernhardt 2006). The latter species is a yellow-orange fungus used by various tribes as food and medicine (Anderson and Lake 2013). The fruiting bodies (fig. 25) are edible when young and after being thoroughly cooked, although caution is warranted

[5] **Harrington, C. 2015**. Personal communication. Research forester, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Ave. SW, Olympia, WA 98512.

Carl Skinner

Figure 24—Black oak in the wildfire-maintained Beaver Creek Pinery in the Ishi Wilderness, Tehama County, exhibits full crowns but few low branches.

Ted Swiecki

Figure 25—Fresh fruiting bodies of the sulfur fungus, also known as chicken-of-the-woods, on California black oak.

because some people have allergic reactions after eating these mushrooms (Swiecki and Bernhardt 2006). Fruiting bodies on a tree indicate infection, which can hollow out the trunk and large branches. Heart-rot-inducing fungi can enter the tree at broken branches and wounds created by fire, especially at the base of the tree (Loarie et al. 2008, Plumb 1980). Following a fire, the point of fungal entry may become obscured as the tree heals over (Long 1913); this process can result in a tree that has well-insulated cavities yet is still productive and resistant to fire. In other cases, the scars may continue to enlarge with fires, hollowing out the bole of the tree and leaving it vulnerable to toppling (McDonald 1969).

Few broken and dead limbs—
Tribal acorn gatherers noted that trees that are healthy and productive have few broken and dead limbs, which contribute to fuel loads, shade out productive branches, and pose hazards to people under oaks. The practice of knocking the trees with poles was used along with pruning dead branches with hooked sticks or saws to yield firewood and enhance acorn production (Anderson 2009). Conifer encroachment causes dieback that increases the abundance of dead limbs (Harrington and Devine 2006).

Low mistletoe infection—
Tribal acorn gatherers suggested that heavy infection by oak mistletoe (*Phoradendron villosum*) (fig. 26) is a sign of a declining tree. McDonald (1969) reported that mistletoe is often seen in both open-growing black oaks or in the crowns of trees growing close together, but that the overall effect on tree growth was probably minor. Garrison et al. (2002b) reported that 28 of the 144 trees they studied had mistletoe, but they did not report on any relationship between mistletoe infestation and acorn production.

Open ground with low fuel levels—
To facilitate gathering underneath productive trees, Native Americans prefer to have open ground with few logs or branches and low levels of litter. Kauffman and Martin (1987) suggested that reducing the duff and litter to less than 18 to 36 Mg/ha through a high-consumption burn or several burns of low to moderate consumption would help black oak acorns to germinate.

We should look at whether you can survive on the land—where is there food for survival?

Stand, Community, and Landscape Scales

Native Americans may view the health of the landscape in terms of its capacity to support people according to their traditional lifeways; as Ron Goode remarked at the North Fork meeting, “we should look at whether you can survive on the land—where is there food for survival?” However, Native Americans also emphasize the


Jonathan Long

Figure 26—Oak tree with heavy oak mistletoe infection at Tom Harris Ranch, North Fork.

importance of tending to promote the productivity and health of black oaks for the non-human elements of the forest ecosystem, including understory grasses, shrubs, mushrooms, and the multitude of animals that inhabit oaks and consume acorns directly or indirectly. Native Americans prefer sites that offer good access to productive black oak trees on gentle topography to facilitate gathering. The areas within these desirable gathering groves, and the communities surrounding them, should support diverse and abundant understory plants, especially ones with cultural uses (Lake and Long 2014), including:

- Foods from understory plants such as woodland strawberry, wild sunflowers (*Wyethia* spp.), onions (*Allium* spp.), cluster-lilies (*Brodiaea* spp.), snake lilies (*Dichelostemma* spp.), mariposa lilies, camas (*Camassia* spp.), wild-rye (*Elymus* spp.) and other edible native grasses, elderberries (*Sambucus* spp.), gooseberry (*Ribes* spp.), sourberry (*Rhus trilobata*), and manzanita (*Arctostaphylos* spp.).
- Fiber and basketry materials, including milkweeds, (*Asclepias* spp.), soaproot (*Chlorogalum* spp.), California hazel (*Corylus cornuta* ssp. *californica*), deergrass (*Muhlenbergia rigens*), beargrass (*Xerophyllum tenax*), willows (*Salix* spp.), basket sedge (*Carex barbarae*), western redbud (*Cercis occidentalis*), deerbrush, and Pacific dogwood (*Cornus nuttallii*).

- Medicinal or ceremonial uses such as wild tobacco (*Nicotiana* spp.).
- Various fungi, including sulfur fungus (fig. 25) and morels, that yield foods and medicines (Anderson and Lake 2013).

Many of these desirable plants will not necessarily grow well directly underneath oaks, but desired conditions for gathering will intersperse oaks among openings that support shrubs and meadows that support plants requiring wetter environments. One plant that gatherers do not desire underneath black oaks is mountain misery (bearclover), because its intertwined stems make acorn collection more difficult (Anderson 2005). However, this plant has important cultural values, provides a valued resource for bees and wildlife, has nodules that fix nitrogen (Heisey et al. 1980), and provides highly flammable fuels to carry surface fires, so it has important roles within the wider landscape (Lake and Long 2014). The fact that the desirability of this specific plant varies at a fine scale illustrates the importance of a multiscale view of desired conditions.

Maintaining a variety of productive stands at different elevations across a landscape would help to expand opportunities for gathering across space and time.

Maintaining a variety of productive stands at different elevations across a landscape would help to expand opportunities for gathering across space and time. Because Native Americans value the biodiversity of forests with black oak as a whole, they do not expect nor desire open forest conditions throughout the landscape. Nevertheless, promoting desired conditions for tribal values has potential to affect other desired conditions, including habitat for species of special concern, wildfire resilience, and wood production, which all need to be considered as part of a holistic restoration strategy.

Conditions Associated with California Spotted Owls and Fisher

Promoting large, mature black oaks that produce large quantities of acorns would provide habitat and prey to support carnivores of special concern, including the California spotted owl and the Pacific fisher (the subspecies of fisher present within the range of black oak). For example, the majority of fisher dens in the southern Sierra Nevada are located in large black oaks (mean dbh 70.5 cm).[6] However, fishers and spotted owls have been associated with relatively high levels of conifer canopy cover, multi-layered understories, and decadent tree conditions (figs. 27 and 28). For example, California spotted owls commonly use large black oak trees with features such as cavities, broken tops, and greater than 70 percent total canopy for nesting and roosting (Keane 2014). Fishers appear to prefer areas with canopy

[6] **Purcell, K.L. 2014.** Unpublished data for fisher study. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 24075 Highway 41, Coarsegold, CA 93614.

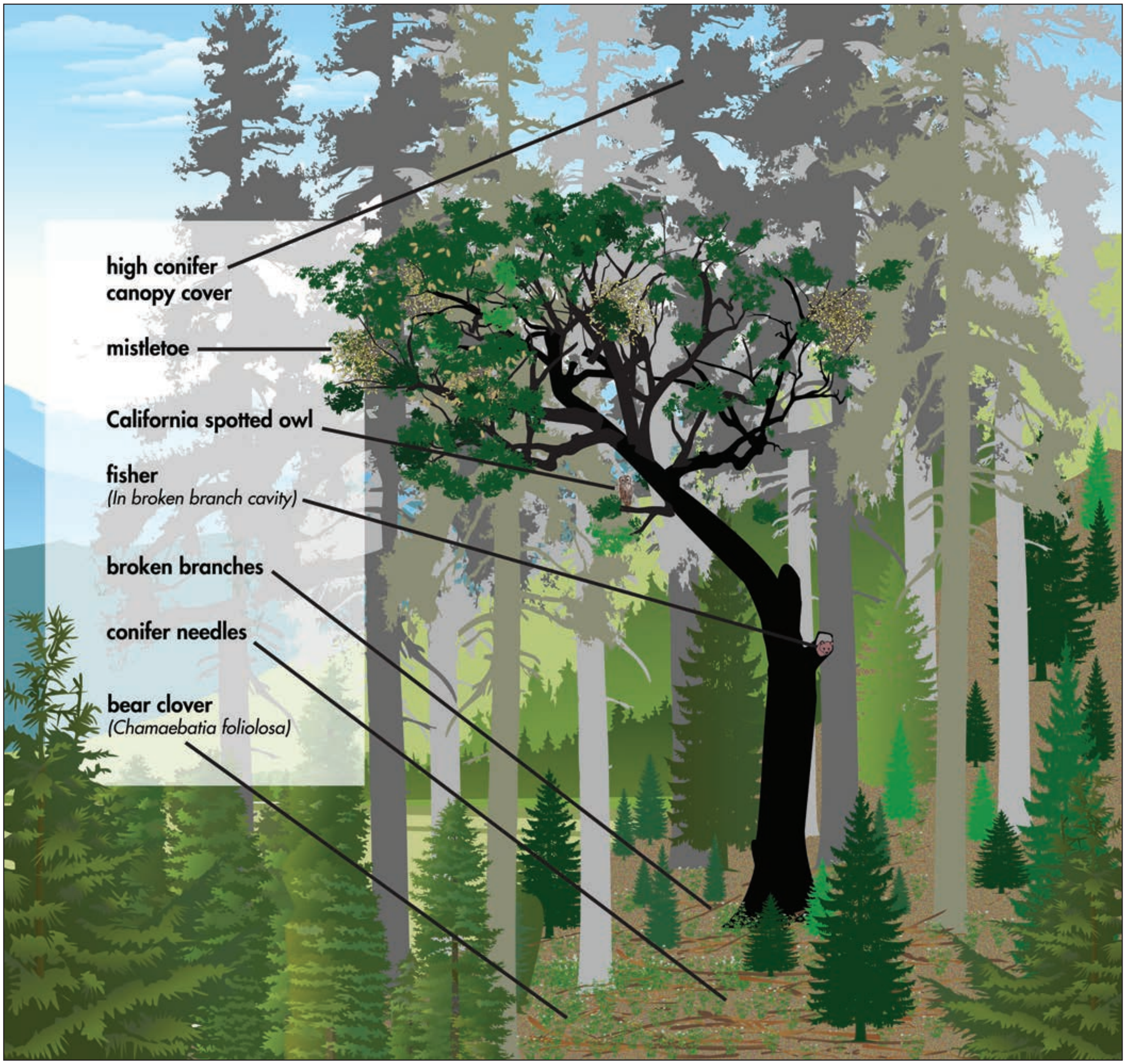


Figure 27—Idealized tree condition for sensitive wildlife species such as fisher and owl. Illustration by Steve Oerding with guidance from the authors.

Figure 28—California black oak being overtopped by conifer trees, Yosemite National Park.

cover of at least 50 to 55 percent for resting (Purcell et al. 2012). They also appear to prefer riparian areas, canyons, and steep slopes more than ridges (Zielinski 2014). Although fishers generally use live trees rather than dead snags, dead limbs with access to cavities are also important (Zielinski 2014). Dead branches are also a particularly valuable and overlooked resource for cavity-nesting birds, and those features are more commonly found in large black oaks (Garrison et al. 2002b). Older black oaks are particularly important, not only because large trees are preferred, but also because the heart rot that forms cavities becomes more prevalent in older trees (Tappeiner and McDonald 1980). Indeed, Bolsinger (1980) reported a sharp increase in decay indicators (visible rot, hollows, breaks, and fungus) with tree diameter, with all trees >73 cm dbh having visible indicators. Consequently, it is important not only to preserve decadent trees, but also to recruit and develop large black oaks to provide for the distinctive habitat needs of the fisher in the future (Zielinski 2014).

Habitat associations among fishers, oaks, and landscape attributes may differ in strength across California. For example, Zielinski et al. (2006) found that average hardwood dbh and slope were both important variables in a predictive model of suitability for fisher rest sites based upon Forest Inventory and Analysis plot data for the southern Sierra Nevada. However, Zielinski et al. (2012) reported that both slope and basal area of black oak were not important in a preferred model of fisher habitat choice based upon forest inventory plot data from northwestern California. These findings suggest possible differences in habitat needs across geographic regions, and they may reflect the greater diversity and availability of hardwoods in the Klamath Mountains. However, the associations between aspect and other attributes to species' occurrence may have changed as forests have become denser and more homogeneous, so relationships in restored forests could be different. Restoration of conditions closer to historical levels of canopy cover, while promoting heterogeneity, would provide for many small gaps needed to favor shade-intolerant trees such as black oak (Gersonde et al. 2004).

Impacts of Fires and Tending Practices

Wildfires

Severe fires may kill the above ground stems of black oaks (top-kill) or the entire tree. Unfortunately, many studies of fire effects simply report mortality in terms of whether the stem lives instead of distinguishing between an undamaged tree, a damaged stem with resprouting from the crown, a dead stem with basal resprouting, and a completely dead, non-sprouting tree. These distinctions have important implications for how quickly the tree can provide important services, such as acorn production and a full crown. Regelbrugge and Conard (1993) studied outcomes of the August 1987 Stanislaus Complex Fire in the central Sierra Nevada in terms of black oak survival. Across a range of burn severities, they found that out of 38 trees, 11 percent were live at the top with no basal sprouts, 16 percent were live with basal sprouts, 66 percent were top-killed but resprouted, and 8 percent were fully killed. More recent studies of wildfires (Cocking et al. 2012b, 2014; Safford et al. 2012) provide some estimates of both top-kill and complete kill for a number of fires with mixed vegetation burn severity (table 3). In an early study from Southern California, Plumb (1980) studied 72 trees nearly 5 years after the Vista Fire on the San Bernardino National Forest and found that 13 percent were dead (all less than 46 cm), 24 percent had been top-killed, and 64 percent still had live crown, although he noted that "a few large, old, hollowed-out trees fell over" (Plumb 1980: 211).

McCreary and Nader (2011) provide guidance on determining the likelihood that the trunks of oaks will survive fires, although they do not provide thresholds

Table 3—Data on black oak mortality (both top-kill and complete kill) from several fires with variable burn severity in California

Fire	Siskiyou Complex (2008)	Storrie Fire (2000)	Grass Valley Fire (2007)		Peterson Fire (2008)	
Study reference	Cocking et al. 2012	Cocking et al. 2014	Safford et al. 2012			
National forest	Klamath	Lassen	San Bernardino		Lassen	
Year of measurements	2010	2010	2010		2010	
Recently treated area? (if yes, then year of treatment)	No	No	No	Yes (2006)	No	Yes (2006)
Number of black oaks	191	227	29	21	12	6
Percentage of oaks completely dead	13	7.5	14	5	42	50
Percentage of oaks top-killed but resprouted	58	71	62	10	59	33
Percentage of oaks not top-killed	28	21	24.1	86	0	17
Plot size	314 m^2	314 m^2	Variable		Variable	
Number of plots with >1 black oak	25	25	7	6	3	2
Percentage of plots with all oaks completely dead	0	0	0	0	0	0
Percentage of plots with all top-killed	12	48	57	0	100	50
Percentage of plots with no kill	88	52	43	0	0	50
Percentage reduction in oak basal area	65	70	NA	NA	NA	NA

of burn severity that consistently result in complete kill. According to them, if the bark is flattened, then the underlying cambium is likely dead. If this extends around the tree, the tree is likely to die. If the bark remains fissured, albeit blackened, there will likely be living, greenish-white tissue under the bark. If the stem is alive, then the tree can actively shed its leaves in the fall. However, if fire kills the stems, then the leaves will remain until they are knocked down by weather.

Recovery Following Wildfires

Although black oaks that are top-killed by fire do not disappear from a site, the ecological services that they provide may be lost for many decades, or even longer if conditions do not facilitate regrowth of mature trees. Researchers working in the area of the Storrie Fire in 2000 have observed acorn production on resprouts, as well as prolific resprouting in areas that burned a second time in the Chips Fire

Although black oaks that are top-killed by fire do not disappear from a site, the ecological services that they provide may be lost for many decades, or even longer.

of 2012 (fig. 29).[7] McDonald (1969), who documented that oaks need many decades to mature, noted that nearly all trees he had seen were resprouts, which can grow much faster than oak seedlings (McCreary and Nader 2011) and competing conifers (Skinner et al. 2006). Cocking et al. (2014) reported that resprouted trees reached 8.5 m tall in 10 years following a wildfire, which is faster than the regrowth observed on sprouts in an unburned, productive forest by McDonald and Tappeiner (2002). Evidently, where mature oaks are merely top-killed they will reestablish mature stems much more rapidly than in areas where acorns must germinate, seedlings are planted, or small trees resprout following severe fires. However, Kauffman and Martin (1990) reported that reproduction from acorns is common following burns.

[7] **Varner, M. 2015.** Personal communication. Assistant professor, Virginia Polytechnic Institute and State University, 310 West Campus Drive, Blacksburg, VA 24061.

Matt Cocking

Figure 29—A black oak top-killed by the Storrie Fire in August 2000 had resprouted and was producing acorns nearly 12 years later when it was top-killed again by the Chips Fire in July, 2012. An abundance of acorn cups are visible on the dead branches in this photo.

Prescribed Burns

Prescribed fires (fig. 30) typically have much less severe effects than wildfires, but conditions and fire behavior can be highly variable. Consequently, outcomes are not necessarily generalizable outside of the specific conditions and fuel and vegetation types included in a particular study.

Studies at the University of California's Blodgett Experimental Forest in El Dorado County have shown variable responses of black oak to prescribed fire. Research in the mid-1980s showed that tree-sized (>3 m tall) black oaks survived fall and spring prescribed burns without top-kill (Kauffman and Martin 1990). However, some large black oak stems that initially survived the fires had toppled by the second year (Kauffman 1986). Subsequent studies confirmed that burning had not only killed small stems, but also induced mortality of larger stems after several years (Kobziar et al. 2006, Krasnow and Stephens 2012). Another study at Blodgett found 100 percent top-survival rates for black oak in a unit burned under moderate conditions in October following a recent rain, and more variable results from a higher severity burn, also in October, but under drier conditions (Schmidt et al. 2006).

James Turner

Figure 30—Members of the Yurok Tribe's fire crew participated in a training exchange (TREX) prescribed fire in a black oak stand near Weitchpec, California. The intent of this burn was to promote access to quality shoots of California hazel for basket weaving, reduce hazardous fuels, and restore wildlife habitat.

Fire Susceptibility of Encroached Oaks

Oaks underneath overtopping conifers may exhibit greater sensitivity to fire than would otherwise be expected because of compromised vigor. Increased fuel loading also increases the likelihood that oaks will be top-killed in fires, as shown in a study in which mechanical fuel reductions preceding prescribed fire lowered black oak mortality as well as risk of damage under modeled wildfires (Stephens and Moghaddas 2005). Although both black oak and pine litter support frequent fire regimes, in the absence of fire, accumulating fuels will increase the severity of fires when they eventually recur. For many large pine trees, heavy accumulation of litter and duff at their base (fig. 31) can induce long-term smoldering that effectively girdles and kills the trees (Hood 2010). Oak litter decomposes more rapidly than pine litter, so litter accumulations may be more of an issue in stands with higher densities of conifers. Sackett et al. (1992) compared litter and soil heating from prescribed fires under two black oaks, one that was a large (102 cm dbh) and full-crowned black oak, and another that had a small (23 cm dbh), leaning bole and was overtopped by large ponderosa pines. The soil under the full-crowned oak was dominated by oak leaf litter and experienced less heating during the burn than the ground underneath the suppressed oak, which was dominated by ponderosa pine litter.

Effects of Season of Prescribed Burning

Because black oaks are deciduous, stands located below snow lines are well suited to burning in the winter, when leaves are available as flashy fuels and leafless crowns allow sufficient sunlight to dry the forest floor (Knapp et al. 2009). Burning in the dormant season when trees do not have their leaves also results in less scorch (Knapp et al. 2009). Following budburst, oaks may be more sensitive to heat and the reserves needed to sprout may be more depleted at that time of year (Knapp et al. 2009). Kauffman and Martin (1990) reported greater top-kill of small black oaks (<3 m tall) in late spring and early fall burns, with the highest survival in late fall burns and intermediate survival in the early spring when conditions were moist. Burning during the spring may also pose some hazards for wildlife, including nesting birds and denning mammals. The primary denning time for fisher is mid-March to mid-April, which can coincide with budburst in oaks. Pups in dens may be vulnerable to carbon monoxide poisoning, leading to concerns over prescribed burning during those weeks in the spring (Long et al. 2014). These natural cycles suggest the need to consider potential negative effects when burning during early spring.


Jonathan Long

Figure 31—The bases of pine trees may get charred during fires because of the accumulation of duff and litter; such heavy accumulations of conifer litter also pose threats to encroached black oaks.

Effects of Cultural Burns

Cultural burning of black oak (figs. 32 through 34) may generate a variety of cultural and ecological benefits at the scale of individual trees as well as the larger plant community (table 4).

Biological diversity—

Burning encourages understory growth of many grasses and forbs (Anderson 2003, Wayman and North 2007), and it can stimulate fruiting of edible fungi, including fire-following sac fungi such as morel and cup mushroom (*Peziza* sp.), as well as mushrooms that are found in burned areas and may benefit from reduced duff, such as coccora (*Amanita calyptroderma*) (Anderson 1993, Anderson and Lake 2013). Cultural burning is an important means of enhancing pyrodiversity, or a range of ecological effects that promote biodiversity (Anderson and Barbour 2003).

Under indigenous regimes, burns were so frequent and fuel levels so low that they did not pose a hazard to the forest, according to elders' accounts (Anderson 1993, 2005). For example, burning from the bottom of a slope was reported as a common practice (Anderson 1993), although that practice tends to be hazardous in forests with extensive areas of high fuel loads and therefore is often disfavored

Ron Goode

Figure 32—Cultural burn of a sourberry patch under a valley oak near Mariposa, California.

Ron Goode

Figure 33—Sourberry with desirable shoots, along with lupine and grasses, grew back following the cultural burn under a valley oak near Mariposa, California.

Figure 34—Prescribed burn in a young stand of black oak on Horse Mountain at Shasta Lake.

Table 4—Potential cultural and ecological benefits of oak cultural burning practices

Effects of burning practices	Cultural benefits	Ecological benefits
Reduce incidence of diseases and pests (especially filbert weevils and filbert worms)	Enhanced quality of acorns (Anderson 2005: 288)	Presumably, enhanced quality would also benefit wildlife species that consume acorns
Possibly reduce incidence of mistletoe	May increase acorn production (Anderson (1993: 45)	May promote oak health and survival (Anderson 1993: 45)
Stimulate production of epicormic branches	Straight, long, flexible branches used for cultural items, including baskets Anderson (2005: 288)	Epicormic branches create platforms for wildlife in some tree species (Ishii et al. 2004)
Reduce undergrowth and fuels	Facilitate acorn collection (Anderson 2005: 288) and improve hunting (Anderson 1993, Jack 1916)	Decrease likelihood of more severe fires that reach tree crowns and promote establishment of oak seedlings and saplings
Formation of charcoal	Charcoal used for making fires	Charcoal consumed by wildlife, sequesters carbon in soils
Encourage understory plant growth (grasses and forbs) and mushrooms	Sources of greens, bulbs, edible seeds, mushrooms, medicines, and basketry materials (Anderson 1993, Anderson and Barbour 2003, Anderson and Lake 2013, Norgaard 2014)	Enhance biological diversity; encourage nitrogen-fixing species
Encourage nitrogen fixing legumes	Sources of food, thatching and other technologies (Anderson 2009)	Compensates for loss of nitrogen during burns

under contemporary practices. Kauffman and Martin (1987) also contended that frequent surface fires and low fuels were typical of presettlement fires in black oak forests.

The typical season of burning reported by tribal practitioners from the central and southern Sierra Nevada was autumn or early winter (October through December), typically after or soon before rains (Anderson 1993). Burning during the fall prior to gathering of the new acorn crop was beneficial for clearing the forest floor and controlling pest incidence, as well as limiting the density of competing conifers. However, Anderson (1993: 39) noted an account of late winter burning by Hazel Hutchins, Mono, who said that, "The Mono women set the fires in January, February, or March before the leaves sprouted and the mushrooms grew." These seasonal relationships may vary from place to place and with time; at the North Fork meeting, Ron Goode and Lois Conner Bohna indicated that some oaks in the vicinity of North Fork were burned in the early winter (December and January), and that mushrooms were out by March.

Acorn production—
Reducing insect pests to improve acorn production was one of the most important reasons for regular burning under oaks. Two important insect predators on acorns are the filbert worm (*Cydia latiferreana*) and the filbert weevil (*Curculio occidentis*) (Swiecki and Bernhardt 2006). These two insects can destroy most of a crop of black oak acorns; however, acorns that are only partially damaged may still be able to grow (Otvos et al. 2012). Anderson (2005) explained that burning treatments can provide a very effective biological control on filbert worms and weevils (fig. 35), supporting claims written nearly a century ago by Klamath River Jack (1916). The combination of knocking to remove acorns from the trees and burning following the harvest is likely to be an effective means of controlling a range of pests and diseases, as research in many nut orchard systems has shown that retention of "mummy" nuts in the trees and on the ground contributes to such problems (Eilers and Klein 2009, Siegel et al. 2008). Because black oaks will drop or abort unhealthy acorns earlier than healthy acorns to reduce losses from insect predators (Otvos et al. 2012), burns conducted prior to gathering can both reduce insect pests and facilitate collection of acorns in the burned area.

Burns conducted prior to gathering can both reduce insect pests and facilitate collection of acorns in the burned area.

Beginning in the 1970s, Forest Service managers at Shasta Lake sought to mimic the historical burning by local Wintu and Pit River people to improve acorn production, with a goal of enhancing deer and elk populations (Skinner 1995). They found that by burning the stands in January, there would be a large increase in that year's fall acorn crop; that was in contrast to surrounding unburned areas, which experienced a poor crop (Skinner 1995).

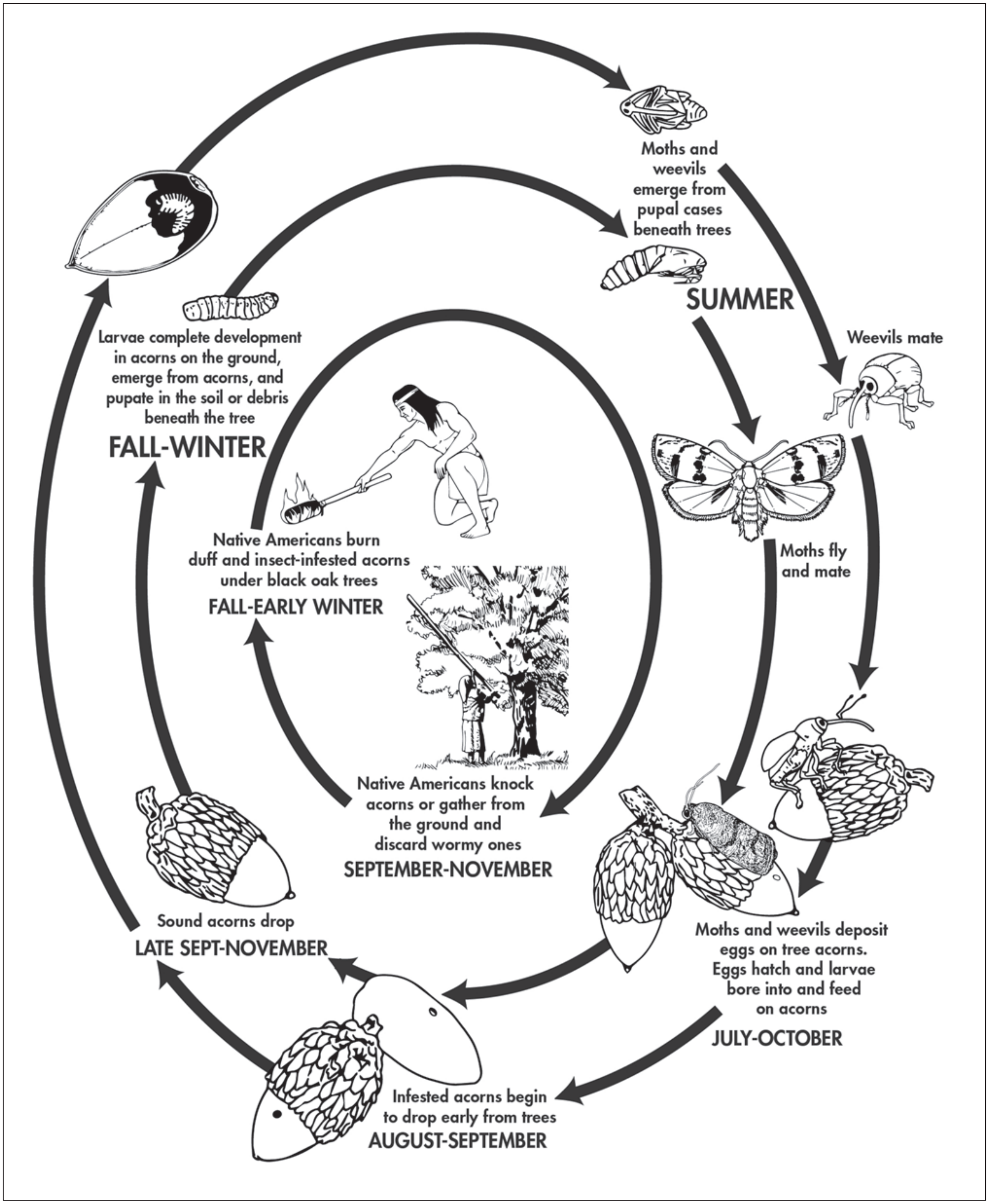


Figure 35—Cycles of filbert worms, filbert weevils, and Native American tending practices to manage these two pests of black oak acorns. Modified from Anderson (2007).

Research is currently underway to evaluate effects of cultural burning on acorn production (Codding et al., in press). There are several mechanisms by which tending practices can enhance production of high-quality acorns for consumption or germination:

- Reducing stress on large, acorn-producing trees, which increases production of acorns in terms of total quantity, period within the year, and production across years.
- Reducing the incidence of pests, leading to higher quality acorns.
- Reducing the incidence of tree- or stand-replacing fires, which in turn stabilizes acorn production.
- Facilitating persistence of black oak across a wider elevation range, potentially expanding seasonal availability (Hunt 2004).
- Extending the life and productivity of individual oaks by reducing competition from other trees and shrubs for water, nutrients, and light and shifting those resources into fewer, larger, and more productive trees.

Masting, or years of exceptionally great production, is believed to have developed as a means of contending with species that prey on acorns, by depleting the food for predators in mast failure years and satiating them in good crop years (Koenig and Knops 2002). To the extent that treatments increase production and provide for more continuous food supplies, there is also potential to increase the abundance of insects and rodents that prey on acorns, particularly if acorns are not being harvested or burned in a manner that controls such pests. This idea suggests that it may be important to gather and burn in conjunction with treatments that enhance production to avoid creating pest problems, and also that it is important to maintain those elements of food webs that keep acorn predators in check.

Promoting oak tree health—
Traditional practitioners have suggested many other benefits of tending and burning in addition to increasing production of high-quality acorns and reducing insect pests, such as enhancing the diversity of desirable plant communities and the health and growth of the oak trees. A preliminary experiment found that several fungi, including species causing root disease and heart rot, might be inhibited through smoke from forest fires (Parmeter and Uhrenholdt 1974). Moritz and Odion (2005) suggested that frequent fires may curb spread of fungal pathogens such as sudden oak death. Several mechanisms for this type of effect have been proposed, including releasing calcium that could enhance the tree's defenses, promoting drier microclimates, and producing smoke with fungicidal properties (Calder et al. 2010). However, researchers of sudden oak death have shown that its relationship to fire is complex (Rizzo et al. 2005).

Participants at the 2013 North Fork meeting noted that burning could reduce incidence of mistletoe, which is a claim that had been supported by the pioneering fire ecologist Harold Biswell (Anderson 1993). A study in a foothill community of blue oak and interior live oak also reported that fire reduced oak mistletoe infestation from "abundant" to "completely absent," although the incidence was not quantified nor evaluated over a longer period (Haggerty 1994). In addition, Zimmerman and Laven (1987) found that smoke from burning forest fuels for at least an hour may inhibit the viability of seeds of dwarf mistletoe (*Arceuthobium* spp.), which infects ponderosa pine. Harrington and Hawksworth (1990) suggested that pine stands with light to moderate dwarf mistletoe infection could be sanitized using prescribed understory burning. Mathiasen et al. (2008) explained that this effect was induced through scorch that kills infected trees, lower infected branches, and brooms, as well as smoke and heat that caused "dehiscence" of mistletoe plants. At the 2013 North Fork meeting, Carl Skinner noted that following burning treatments at Shasta Lake, a lot of the oak mistletoe fell to ground, still green, where it was eaten by deer. His observations suggested that smoke or heat, rather than scorch, was responsible.

Practitioners also contend that ash from the burning can help the trees grow better (Anderson 2005). Lois Conner Bohna suggested at the 2013 North Fork meeting that tannic acid from the oak leaves might be harmful to the oak trees, according to her grandmother, who recommended regularly burning that litter. Researchers in France reported a relationship between accumulations of oak leaves in litter near the trunk base and increases in soil acidity in the same area, and they noted that the trend was stronger in soils that were poorer in clay (Beniamino et al. 1991). The acidifying potential of oaks is expected to be less than conifers, but more than grasses (Chandler and Chappell 2008), and therefore, isolated acidification under oaks may be more evident in oak woodlands than in mixed-conifer forests, where acidification is presumably more widespread.

These new growths serve various cultural uses, may also form platforms that are desirable for wildlife, and may help to fill gaps in the tree crown, in particular by reforming branches closer to the ground.

Production of Epicormic Branches or Root Sprouts

Practices that induce stress to the tree or increase exposure to light, including thinning and burning, can stimulate sprouting of new branches (epicormic branches) from the bole or old stems, or sprouts from the roots (Meier et al. 2012). These new growths serve various cultural uses, may also form platforms that are desirable for wildlife, and may help to fill gaps in the tree crown, in particular by reforming branches closer to the ground (fig. 36). Although opening the canopy through treatments can stimulate acorn production, McDonald and Ritchie (1994) cautioned that epicormic branches may not produce acorns. However, Devine and Harrington


Lenya Quinn-Davidson

Figure 36—Epicormic sprouts on a black oak five years after a release treatment on private land in Laytonville, California, May 8, 2015.

(2006) observed acorn production on 5-year-old epicormic branches on Oregon white oak, so production may just require time for the branches to grow. Treatment design should consider this potential response, especially when reclaiming overly dense stands. Because these physiological responses are complex, they warrant further investigation (Meier et al. 2012).

Effects of Other Native American Tending Practices

Pruning and knocking can remove dead and dying branches, mummy nuts, galls, and mistletoe; stimulate emergence of new sprouts and branches; open the crown; and enhance productivity (Anderson 2005). These effects in turn increase crown surface area and production of acorns, while reducing incidence of broken branches. Weeding around individual oaks and seeding of desired grasses and forbs may help promote desired conditions and community composition (Anderson 2005).

Approaches for Reclaiming Degraded Stands

Black oak groves that have been overgrown with conifers because of fire exclusion may have changed so dramatically in terms of fuels and structure that restoring their condition may not be feasible simply by reintroducing fire. Researchers in the southeastern United States have cautioned that because departures from historical conditions in their region have increased constraints on burning and made mature trees more vulnerable, use of fire needs heightened scrutiny to avoid damaging effects (Arthur et al. 2012). One consequence of these changes is that the strategies to reclaim degraded forests may initially require practices that differ from those typically employed in actively maintained forests. For example, a nontraditional practice may involve burning concentrations of fuels ("jackpot burning") when the fire will not spread easily between concentrations. In terms of burns designed to spread through the understory, it may be helpful to conceive of various stages of burning:

- Initial entry or preparatory burns are intended to reduce continuity and amount of surface fuels, but are not likely to modify forest structure. Such burns are likely to be conducted well outside the natural wildfire season when moisture or other conditions limit intensity.
- Restorative burns reduce fuels and may kill trees of various sizes to realign forest structure and composition closer to a reference condition.
- Maintenance burns kill smaller trees and reduce fuels but are not likely to kill mature, healthy trees.

Spring Burns and Multiple Burns

Reclamation of degraded stands may require multiple burns before the stand is prepared for intensive use and frequent dormant-season burning; that principle is consistent with the tradition of cultural burning described above. Furthermore, burning outside of the historical fall-winter seasons may help to realign the system to the point where in-season burning can occur more safely (Knapp et al. 2009). For example, burning in the early spring, when moisture levels are higher, may help to reduce heavy accumulations of brush and duff and reduce the potential for large tree mortality that might occur in the fall (Kauffman and Martin 1987). However, out-of-season burning has been a topic of controversy in some areas, because of concerns about impacts to wildlife and plant growth in particular (Knapp et al. 2009). By the time a second or third burn is planned, fuel conditions may be better suited for more traditional fall burning. Fall burns may be appropriate for creating conditions on the landscape that help to restore resources, although it is important to engage tribal practitioners in designing, monitoring, and evaluating these treatments to determine whether desired outcomes come to fruition.

Corrective Fires

The potential use of managed wildfire or more intense prescribed fire as a forest restoration strategy becomes very complex when considering black oaks, not only because of their inherent susceptibility to fire but also because compromised oaks tend to be more sensitive than overtopping conifers to fire. Cocking et al. (2014) suggested that to allow black oaks to regain dominance in stands where conifers are well established and mechanical thinning is not practical, severe fires would be needed to kill the competing conifers, but would also top-kill the oaks. This idea recalls the "corrective burning" used by aborigines in Australia and described by Lewis (1994) as a way to reclaim forests that had gone too far from their desired condition; those more severe burns would effectively reset the system, and then be followed up with maintenance burning at intervals that promote desired conditions. However, if severe burns were to occur over a wide area, they would reduce for decades the flow of ecological services provided by mature black oaks. Corrective fires also have potential to generate considerable smoke, which may make them challenging to implement. However, once a frequent understory burning regime has been reestablished in black oak-dominated forests, maintenance burns should generate much less smoke. Therefore, strategies may need to be tailored to reduce the potential for unusually large and severe wildfires and to safeguard particularly sensitive, high-value trees through multi-staged interventions (Cocking et al. 2012b). Wildfires, whether managed or not, offer opportunities to reestablish tending practices with a goal of reestablishing mature oak groves (fig. 37).

Strategies may need to be tailored to reduce the potential for unusually large and severe wildfires and to safeguard particularly sensitive, high-value trees through multi-staged interventions.

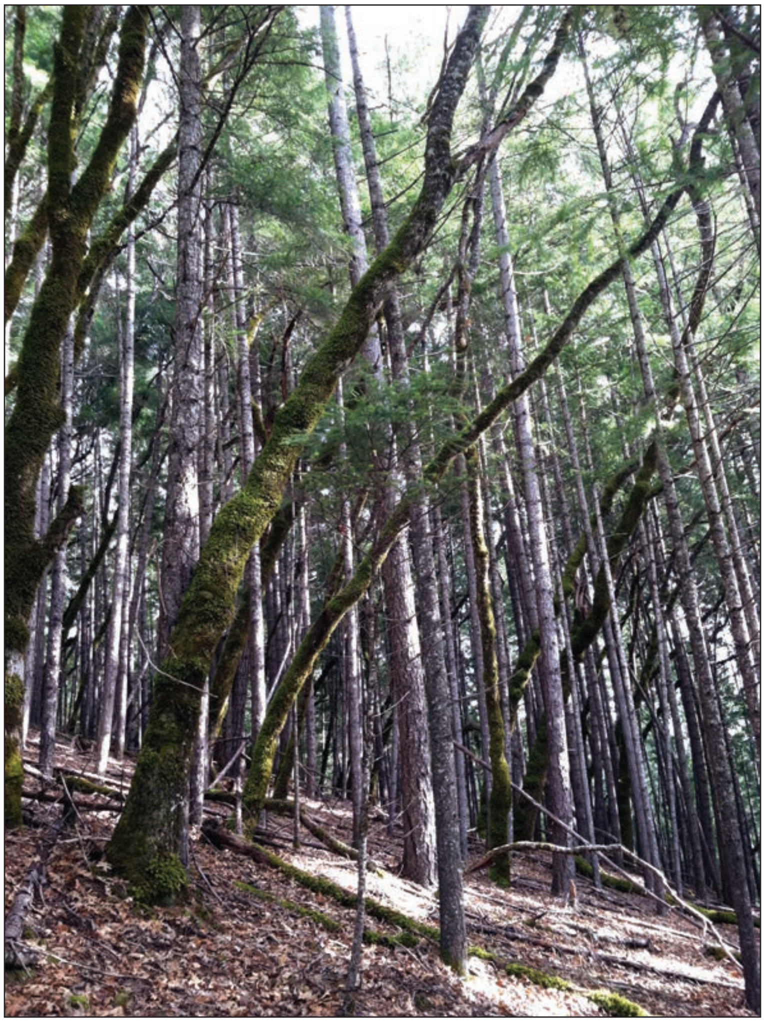
Thinning Conifers to Release Oaks

Forest managers facing atypically dense stands around black oaks commonly prescribe thinning treatments to favor oaks. In a 10-year study of Oregon white oak, Devine and Harrington (2013) found that removing all conifers around oaks within one tree height ("full-release" treatments) significantly increased oak growth and acorn production compared with nontargeted thinning in encroached stands. If black oak responds similarly, these relatively aggressive treatments may be important in restoring desired conditions, including acorn production and crown survival. However, McDonald and Ritchie (1994) suggested thinning lightly around black oaks at first and retaining shading by conifers to minimize adverse impacts

Figure 37—The Eldorado National Forest has proposed an area on the Power Fire (2005) for special management to promote the oak resource. This stand of mature black oaks survived with stems intact.

on acorn production that might result from stimulating sprouting. They also suggested that integrating thinning with burning to consume some of the lower branch sprouts might help ensure that resources are invested more in acorn production than branching, as well as to inhibit build-up of insect pests. Yet, epicormic sprouting is a means of restoring low branches and filling in the tree crown that has been lost. Consequently, experimenting with a variety of treatments may be valuable in evaluating potential tradeoffs.

Current practices include treatments that increase sunlight around oak trees and remove conifers under and near the tree's crown, as well as thinning oaks to promote development of fewer, larger trees. Opening up large patches of sun as part of variable density thinning (Knapp et al. 2012) would facilitate reproduction of both oaks and pines. Some practitioners have considered treatments that focus on the south side of oak trees; however, this approach might increase the propensity of trees to lean toward the south, which can decrease their structural integrity. These growth patterns are already a common occurrence for heavily encroached oaks (fig. 38). Harrington (2015) observed that a full release treatment benefits oaks by reducing belowground competition and increasing availability of indirect light. Although tree form is not generally as important for oaks as conifers that are being grown



Lenya Quinn-Davidson

Figure 38—Black oaks in a dense Douglas-fir stand in the Klamath Mountains. Oaks are leaning toward the south to capitalize on limited sunlight availability. Treatments that focus on the south side of trees can exacerbate this problem.

Having a well-formed tree rather than a leaning tree will facilitate faster growth and better acorn production, and should reduce the tendency for toppling, all of which would encourage larger, long-lived, and more productive oaks with larger cavities.

for lumber, having a well-formed tree rather than a leaning tree will facilitate faster growth and better acorn production, and should reduce the tendency for toppling, all of which would encourage larger, long-lived, and more productive oaks with larger cavities.

Harrington and Devine (2006) outlined strategies for prioritizing oak stands for release treatment based upon tree condition, but additional research on black oak would help to evaluate which trees might be too decadent to respond. Devine and Harrington (2006) found that Oregon white oak trees with less crown dieback (measured as pretreatment live-crown ratio) responded better to release treatments, and trees rated as healthy yielded more acorns following treatment. However, more recent work by the same authors demonstrates the capacity of long-suppressed white oaks to recover and produce acorns after release treatments, so it is important that even heavily compromised trees be considered for restoration treatments, especially if they are valued for their size, location, cultural significance, or other attributes (Devine and Harrington 2013). Because it may take 5 to 7 years to evaluate outcomes, studies need to be moderately long; Devine and Harrington (2013) offer a good example of a long-term study, as they evaluated restoration outcomes 10 years after treatment.

Thinning Resprouts

To encourage faster growth of tall and large-stemmed oaks, researchers and managers have proposed thinning resprouts from root crowns (McCreary and Nader 2011, McDonald and Vaughn 2007). Even-aged stands of black oak are common, owing to resprouts following severe disturbances, including fires as well as pollution from mining (Byers et al. 2001, Skinner 1995). Natural mortality of resprouts in unmanaged areas appears to reduce the number of stems growing in clumps below 10, but clumps of stems often consist of relatively skinny trees, some of which curve upward to reach gaps in the canopy (McDonald and Vaughn 2007). In large, severely burned areas, the need to accelerate development of large trees may be deemed particularly important. McDonald and Vaughn (2007) studied effects of thinning resprouts and found that trees in small clumps of two to four trees grew at about the same rate as a single tree of the same diameter within relatively open stands that had been thinned; however, within denser, unthinned areas, stems in such small clumps grew slower than single stems. Tappeiner and McDonald (1980) noted that thinning before 4 years promotes more sprouting, and that thinning between 4 and 8 years may promote forked trees. Combined, these findings suggest there may be opportunity to accelerate recovery of mature oaks through thinning clumps with more than four stems. However, treatments should be studied over the long term to evaluate whether they are efficient in promoting desired outcomes and whether they have any undesirable effects.

Promoting Black Oak When Replanting Conifers After Wildfires

As large and severe fires have become a more common occurrence in the Sierra Nevada and southern Cascade region, managers have proposed replanting conifers to promote desired conditions. Because of their capacity to vigorously resprout, black oaks are well adapted to become dominant following wildfires. To conserve oaks in areas proposed for planting, the Sierra Nevada Forest Plan Amendment (USDA FS 2004) imposed a guideline of buffering 6.1 m from the crown edge, which was consistent with recommendations by Tappeiner and McDonald (1980).

Because that distance is less than half the height of mature oaks, it is less than the amount recommended for release treatments of mature oaks proposed by Devine and Harrington (2013). Consequently, at least in theory, applying such a relatively narrow buffer (compared to the height of mature oaks) might limit the opportunity for black oaks to be dominant in the future. On the other hand, using a planting buffer also potentially constrains the opportunity to use black oaks as nurse trees for planted conifers. Strategies that might promote forest heterogeneity could include explicitly reserving stands or groups where conifers were not interplanted among black oaks, as well as planting conifers using a more variable buffer. Using wide buffers could promote diversity and oak values in places where mature oaks are scarce, especially at higher elevations, whereas a smaller buffer could help to diversify lower-elevation areas where oaks are more dominant. Wide planting buffers may be more important for California black oak than other oaks such as canyon live oak, given black oak's reduced tolerance of shading.

Protecting Legacy Black Oaks

Land managers might consider special actions to conserve especially large and productive black oaks during prescribed burns or wildfires because of their importance. The term "legacy tree" has been used to distinguish trees that are larger and older than the average trees in a landscape (Mazurek and Zielinski 2004). These considerations may heighten the need to develop maps or data layers that locate important trees or groves, which could be identified in a wildfire decision support system. It is important to promote conditions that will allow fire to enter the stands while lowering the risk of top-kill, because many black oaks and other large trees do not survive present-day fires. One particular strategy may be to remove down branches or boles that may be close to the tree, to avoid causing damage to the trees. In addition, many researchers and managers have suggested raking litter, especially pine needles, away from the boles of large pines and large oaks to promote their survival during burns (Abella and Fule 2008, Truex and Zielinski 2013). Hood suggested removing both litter and duff using rakes or leaf blowers in areas with low summer moisture (Hood 2010). Researchers have found value in these types of raking treatments on yellow pines (Hood 2010, Laudenslayer 2008) and sugar pines (Nesmith et al. 2010).

However, caution is warranted, particularly where organic soil layers harbor valuable mycorrhizal fungi; this is recommended to avoid damaging the mycelial mats, also called shiro (Anderson and Lake 2013, Pilz and Molina 1996). A study from the Pacific Northwest showed that shallow raking (i.e., not raking into the mineral soil surface) and/or litter and duff replacement can mitigate impacts to mushroom production, although those findings might not necessarily extend to black oaks and associated fungi (Luoma et al. 2006). Furthermore, reducing litter may also favor mushroom production (Luoma et al. 2006, Weigand 1998). Consequently, although raking heavy accumulations of pine litter may be important for reducing fire severity under encroached black oaks, studies are needed to test the effectiveness and possible risks of that treatment. In addition to studies based upon monitoring and experiments, local knowledge of mushroom harvesters may be particularly helpful in suggesting appropriate practices (Anderson and Lake 2013).

Other Treatments

Although the saw and the flame are likely to be key tools for restoring black oak ecosystems, other treatments may have important roles in specific contexts. For example, an option for reclaiming large black oaks that are being overtopped is to girdle the competing conifers (Engber et al. 2011). In areas of heavy browsing, treatments to protect sprouts until they exceed the browse height may be necessary. Planting of acorns or seedlings may be necessary where populations have been extirpated, as may have occurred on Santa Cruz Island, although any such plantings would have to consider a range of issues, including appropriate source materials, resilience to future climate, and safeguards to avoid spread of pests and pathogens. Furthermore, planting of black oak stock with desirable genetic properties, such as resistance to sudden oak death, may be an important treatment option for some areas in the future (Rizzo et al. 2005).

Black oak has a particularly important role in the evolving approach toward restoration forestry in the Sierra Nevada, which emphasizes the importance of considering multiple scales, retaining hardwoods, restoring heterogeneity, and designing treatments according to productivity and topography.

A Landscape Strategy for Intensive Black Oak Restoration

Black oak has a particularly important role in the evolving approach toward restoration forestry in the Sierra Nevada, which emphasizes the importance of considering multiple scales, retaining hardwoods, restoring heterogeneity, and designing treatments according to productivity and topography (North et al. 2009). A landscape approach considers the condition of individual trees and groups of trees, as well as the wider landscape in which they are situated. Furthermore, these strategies need to consider interactions with the sociocultural systems that value and depend on the organisms in the forest (Long et al. 2014). When brought together, these elements suggest a three-part approach for managing landscapes with black oak (table 5).

Considering the Landscape Context for Acorn Gathering

A landscape strategy to promote tribal use of black oak needs to consider how, when, and where to get the system to a point at which desired levels of gathering

Table 5—Multiscale restoration strategy

Context	Orchard areas	General forest	Priority resting/denning areas
Topography	Flatter areas, near meadows		Canyons, riparian area, steep, north-facing slopes
Access	Good access via roads, which also serve as fire barriers		Poor access via roads
Current oak condition	Remnant large oaks, often suppressed and crowded	Oaks often thin, snake-like owing to overtopping and crowding by conifers	Dying, decadent trees often shaded by high conifer canopy
General treatment approach	Intensive release treatments around productive groves, followed by frequent burning and tending	Highly variable, and often less intensive, treatments intended to promote oak longevity, productivity, and recruitment	Areas not to be intensively treated, except perhaps in select patches to retain their long-term value and promote diversity
Expected fire frequency	Frequent	Moderate	Less frequent
Expected fire severity	Low	Moderate	High
Resource benefits	Acorn production and supporting wildlife values	Fire resilience	Maintain habitat for old-forest associated species in near term

can reliably occur. Maintaining a more reliable supply of the desired services may depend on having a number of areas that have experienced fires in recent years and can be managed for acorn production. Treatments need to be rotated through various stands across a broad elevation range to maintain availability of the resource over time. The distance that gatherers would need to go to gather acorns and other key food resources is an important consideration at the landscape scale (table 5). The resources have to be plentiful enough to encourage gatherers to seek them out, and desirable gathering areas will feature a diverse mix of resources. Both Tappeiner and McDonald (1980) and Potter and Johnston (1980) suggested guidelines for oak basal area and canopy cover to support high quantities of oak production within relatively pure groups ranging from 0.2 to 4 ha to facilitate treatments to favor oak within conifer areas.

Gathering areas that are close to areas of flat or gently rolling topography and roads will be preferred over steeper, less accessible areas. Sites near meadows (fig. 39) may not only afford easier access, but also yield a diversity of resources for gatherers; in particular, desirable locations would be near meadows with sandy soils for basket sedge and near stands of shrubs. Locations of historically tended “orchards” identified by gatherers or in historical records would provide a useful starting point. However, long-term treatments should not be limited to these traditional areas, as other locations may be important to support those values in the future. Moreover, many of the sites where oaks have better withstood encroachment are likely to be

Jonathan Long

Figure 39—Mature black oak with spreading branches surrounded by conifers near a meadow at Grey's Mountain treatment area, Sierra National Forest.

poorer, drier sites; to promote production it may be worth targeting more productive sites. Prioritizing sites on more level ground and close to meadows, consistent with criteria supported by tribal gatherers, could help to restore oak in more productive areas.

In the general forest (i.e., not specific gathering sites, box 2), treatments designed to enhance oak growth and acorn production may be undertaken without necessarily employing the more intensive tending practices used in gathering areas. In addition to considering the landscape-scale context for gathering, the age, condition, and growth form of the oaks will inform which individual trees are best suited for intensive treatment, and which are best left alone (fig. 40). To restore the values provided by black oaks, release thinning or restoration of fire are needed throughout the general forest to redirect conditions away from the trajectory of conifer dominance that has been set by the change in fire regime.

Targeting restoration treatments to promote acorn gathering groves in areas with gentle topography, good access by roads, and in historically more open stands would avoid conflicts with wildlife that depend on steeper, more remote, and historically more closed-canopy forests.

Avoiding Conflicts with Sensitive Species

When viewed at a tree- or stand-scale, treatments to increase sunlight to black oak trees appear to conflict with tactics to conserve California spotted owls and fisher that appear to depend on decadent, dense, and complex cover. Furthermore, treatments that remove dead branches, inhibit decadence, and clear the understory beneath individual oaks could reduce desirable habitat features for those species. However, applying a broader, multiscale perspective can help to address these concerns in several ways. First, targeting restoration treatments to promote acorn gathering groves in areas with gentle topography, good access by roads, and in historically more open stands would avoid conflicts with wildlife that depend on steeper, more remote, and historically more closed-canopy forests. At a finer scale, creating gaps around mature oaks may encourage both acorn production and recruitment of young trees that can take off when mature trees fall (Purcell et al. 2012). Meanwhile, treatment strategies could retain tree clusters with high canopy cover and features favored by wildlife, including broken branches and other resting platforms (fig. 41), for their high present habitat value (North et al. 2009). Researchers have suggested that maintaining large oak trees along with areas of dense canopy cover is a key element of a larger landscape resilience strategy that can sustain both spotted owls and fishers (Keane 2014, Zielinski 2014). Promoting high variability at multiple scales could retain decadent conditions to support those wildlife species in the near term while also maintaining healthy oaks that can provide food resources and habitat for the long term. Because of the chronic pressure of forest densification combined with the risk of severe wildfires, active restoration treatments will be important for sustaining and reestablishing large oaks.

Jonathan Long

Figure 40—A black oak in a small riparian area at Crane Valley, Sierra National Forest, lies on a steep slope that is probably unsuitable for acorn gathering.

Rebecca Green

Figure 41—A large legacy black oak used by a fisher as a resting site.

A project at the Sagehen Experimental Forest offers a relevant example of this conceptual approach. That project, which was refined through a collaborative process (Stine and Conway 2012), was proposed for a high-elevation forest type where marten, rather than fisher, was a chief wildlife concern. The plan proposed to create variable amounts of Dense Cover Areas (DCAs) and Early Seral Openings (ESOs) within areas that prioritized different resources, and to remove smaller trees around large "legacy trees" to increase their resiliency to fire, drought, pathogens, and disease, **except** in the DCAs. In lower elevation Sierra Nevada landscapes, that treatment strategy may be adapted to favor black oaks as a focal legacy tree.

Conclusions: Opportunities to Increase Socioecological Resilience

Restoration of California black oak lies at the heart of broader discussions of how to promote socioecological resilience in the Sierra Nevada (Long et al. 2014). The species has suffered long-standing declines because of fire suppression and other historical activities, including widespread efforts to systematically replace it with conifers favored for timber production. But today, the many values provided by black oak have made it a centerpiece for demonstrating the benefits of fire-centric restoration of forests in California (Byers et al. 2001, North et al. 2014).

Promoting Ecological Diversity

Conditions desired by Native Americans would be likely to support a wide variety of wildlife species through increased frequency of fire, enhanced acorn production, and retention of large oaks. These conditions do not necessarily conflict with sensitive species when considering the system at larger spatial scales and longer temporal scales. Indeed, there are wide-ranging benefits to promoting more heterogeneous and more open stands with fewer conifers, especially shade-tolerant ones. At least in the near future, thinning and perhaps girdling to release oaks from conifer competition are important tools for conserving legacy oaks (Engber et al. 2011). Fire also can maintain a diversity of vegetation conditions and edges between those areas, and managed fire has been recommended as a way to restore and sustain features that were abundant in the pre-fire suppression forest (Taylor 2010). Moreover, fire and smoke (fig. 42) promote pyrodiversity, or a range of ecological effects that promote biodiversity (Anderson and Barbour 2003) and are not replicated through thinning, including inhibition of pests and pathogens, formation of cavities, and stimulation of fire-following fungi and plants.

Enhancing forests with black oaks to support tribal values offers a win-win opportunity to increase social and ecological resilience in the face of stressors such as drought, disease, and uncharacteristically severe wildfires.

Promoting Resilience to Climate-Related Stressors

Enhancing forests with black oaks to support tribal values offers a win-win opportunity to increase social and ecological resilience in the face of stressors such as drought, disease, and uncharacteristically severe wildfires, which may become more common as the climate changes in the future (Long et al. 2014). Reestablishing a more frequent fire regime would promote structural changes that might render forests more resilient to sudden oak death (Moritz and Odion 2005). Targeted reductions in tree densities, creation of openings around black oaks, and greater reliance on low-intensity fires may increase resilience to stressors, as well as provide dividends in terms of increased water yield and reductions in the extent of severe wildfires (Long et al. 2014). Extreme fires such as the Rim and King Fires (fig. 43) kill overtopping conifers and may allow resprouting oaks to reclaim dominance and extend into higher elevation areas, but not without losing mature oaks and the valuable benefits they provide for many decades. Moreover, repeated high-severity fires, which have become increasingly common, are likely to inhibit development of mature oaks, and drying conditions are likely to inhibit reestablishment at lower elevations and latitudes. Intentional caretaking through judicious use of fire and removal of conifers can safeguard and promote legacy trees and their associated values in ways that reduce vulnerability of Native Americans, other people living in rural areas, and wildlife (Charnley et al. 2007, Devine et al. 2012).

Lenya Quinn-Davidson

Figure 42—Prescribed burning implemented through a low-cost training program (TREX) on 45 ha of private lands with black oak, white oak, and ponderosa pine near Hayfork, California, October 29, 2013.

Jonathan Long

Figure 43—The Rim Fire of 2013 featured many extensive high-severity patches that were marked by bare soils, white ash, holes around tree boles, charred organic matter, dead conifer trees, and loss of mature black oaks.

Promoting Adaptive Management

Useful indicators for evaluating trends in black oak conditions include the abundance of trees with large, full canopies, and the availability of high-quality acorns for gathering.

To promote an integrated approach to managing forests with hardwood, McDonald and Huber (1995b) had previously emphasized the need for teamwork involving agency researchers, planners, workers, and various landowners. Their framework can be expanded to recognize the importance of tribal governments, Native Americans, oak enthusiasts, and other stakeholders who value these important resources and have a vision for restoring this important component of our forests. In particular, continuing research partnerships among scientists, land managers, and tribal gatherers (fig. 44) can guide adaptive management efforts in forests with black oak. Useful indicators for evaluating trends in black oak conditions include the abundance of trees with large, full crowns, and the availability of high-quality acorns for gathering. Research has suggested that trees need to be 80 years old to be significant producers of acorns, which translates to a dbh of at least 33 to 50 cm and crown diameters of at least 8 m, depending upon site productivity (McDonald and Tappeiner 2002, Potter and Johnston 1980). Forest management plans can use these indicators to track progress in retaining and restoring legacy black oaks and their benefits. Research at the scale of large landscape demonstration areas and extensive monitoring, as well as smaller experimental plot studies, will help to understand the benefits of more intensive caretaking of mature black oaks.

Jonathan Long

Figure 44—A group of tribal members, scientists, and managers at the North Fork meeting considered how the context of black oak sites should influence treatments.

Supporting Community Engagement in Restoration

Reintroducing fire using their own traditional knowledge allows Native peoples to reengage as caretakers of their ancestral lands (Eriksen and Hankins 2014). Tribal participation in efforts to promote resilience, especially by enhancing the quality of black oaks, can strengthen the adaptive capacity of both tribal communities and government resource managers (Lynn et al. 2013). Specifically, tribal practitioners note that actively tending gathering areas cultivates an important sense of place and teaches respect for those places and organisms within the community, especially among tribal youth. Various models exist for cultivating tribal engagement, including the use of tribal fire crews with traditional knowledge and training in the use of fire for cultural resources, as well as co-management agreements (Eriksen and Hankins 2014, Lake and Long 2014). Fire-use training could be developed to emphasize how to use fire from both cultural and ecological perspectives. Having cultural expertise available would help institutions manage both prescribed fires and wildfires to sustain black oaks and other forest values.

Efforts to engage communities in restoration can extend broadly beyond Native American tribes. Examples of black oak restoration projects include the Forest Service program of prescribed burning at Shasta Lake inspired by traditional knowledge of local tribes (Skinner 1995), several demonstration sites on the Sierra National Forest pictured in this report and designed with guidance from Mono tribal members, and partnership-based efforts led by the Lomakatsi Restoration project, U.S. Fish and Wildlife Service, Natural Resources Conservation Service, Klamath Bird Observatory, and several other organizations in southern Oregon (Cocking et al. 2012a). The Eldorado National Forest has also proposed special management for oaks in parts of the Power Fire (fig. 37).

The majestic, widely distributed black oak trees serve as an appropriate centerpiece for illustrating the benefits of active, fire-centric restoration in the forests of California and southern Oregon.

The majestic, widely distributed black oak trees serve as an appropriate centerpiece for illustrating the benefits of active, fire-centric restoration in the forests of California and southern Oregon. Promoting forest conditions that increase Native American access to high-quality acorns are likely to enhance habitat for a broad array of wildlife species, as well as yield other societal benefits. Rather than designing strategies to promote these values individually, an integrated approach would seize the opportunity to link conservation of cultural diversity, biological diversity, and other ecological services (Charnley et al. 2007). Researchers studying forest ecosystems recognized for having high biocultural diversity have concluded that strategies that reinforce traditional cultural values, including use of wild resources, are likely to be more effective in conserving forests because they foster supportive attitudes and behaviors (Byers et al. 2001). As more people understand the complex web of relationships that bind a variety of species through acorns and oak dwellings, they can better appreciate the value of caretaking to sustain the many benefits provided by these trees of life.

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List of organisms with common, scientific, and western Mono (*Nium*) names and uses[a]

	Common name	Scientific name	Mono/*Nium* name	Mono/*Nium* cultural use
Birds:				
	Acorn woodpecker	*Melanerpes formicivorus*	Pa-na-ta-da	Regalia
	Band-tailed pigeon	*Patagioenas fasciata*	Soo-we	Food
	Brown creeper	*Certhia americana*	Ceet-ne-saht	
	California spotted owl	*Strix occidentalis* ssp. *lucida*	Muhu	Spirituality
	Downy woodpecker	*Picoides pubescens*		
	Mountain chickadee	*Poecile gambeli*		
	Mountain quail	*Oreortyx pictus*		
	Northern pygmy-owl	*Glaucidum gnoma*	Muhu-cee	Spirituality
	Red-breasted nuthatch	*Sitta canadensis*		
	Steller's jay	*Cyanocitta stelleri*	Chsg-o-noh	Spirituality
	Valley quail	*Callipepla californica*		
	Western scrub jay	*Aphelocoma californica*	Chot-nu-key-neh	
	White-breasted nuthatch	*Sitta carolinensis*	Ka-be-ka-be-nah	
	Wild turkey	*Meleagris gallopavo*		
Mammals:				
	Black bear	*Ursus americanus*	Pahubich	Resource
	Douglas' squirrel	*Tamiasciurus douglasii*		Meat
	Dusky-footed woodrat	*Neotoma fuscipes*	Kah-wah	
	Fisher (Pacific fisher)	*Pekania pennanti* (ssp. *pacifica*)		Fur/hide for pouches
	Hog, wild	*Sus scrofa*		
	Mule deer	*Odocoileus hemionus*	Tah-huit	Food, resource
	Western gray squirrel	*Sciurus griseus*	Mau-we	Food, resource
	Filbert weevil	*Curculio occidentis*		
Insects:				
	Filbert worm	*Cydia latiferreana*		
	Gold-spotted oak borer	*Agrilus auroguttatus*		
	Canker rot fungi	*Inonotus andersoni* and *Inonotus dryophilus*		

	Common name	Scientific name	Mono/*Nium* name	Mono/*Nium* cultural use
Fungi:				
	Charcoal-loving elf cup	*Geopyxis carbonaria*		
	Chicken-of-the-woods (also known as sulfur fungus)	*Laetiporus gilbertsonii*		Food
	Coccora	*Amanita calyptroderma*	Toap'	Food
	Cup mushroom	*Peziza* spp.	Nuc-ca	Food
	Morel	*Morchella* sp.	Chu-yu/Tsu-yu	Food
	Sudden oak death pathogen	*Phytophthora ramorum*		
	Ancestral black oak (fossil species)	*Quercus pseudolyrata*		
Trees:				
	Blue oak	*Quercus douglasii*	Pa-wi-yap'	Acorns, dyes
	California black oak	*Quercus kelloggii*	Wi-yap'	Acorns, wood, walking/ digging sticks, dyes, others in text
	California buckeye	*Aesculus californica*	Wo-yo-nobi	Nuts
	California hazelnut	*Corylus cornuta ssp. californica*		
	California nutmeg	*Torreya californica*		
	Canyon live oak	*Quercus chrysolepis*		
	Chase oak	*Quercus* × chasei		
	Giant chinquapin	*Chrysolepis chrysophylla*		
	Coast live oak	*Quercus agrifolia*		
	Coast live oak, interior variety	*Quercus agrifolia* var. *oxyadenia*		
	Douglas-fir	*Pseudotsuga menziesii* var. *menziesii*	Sa-qwa'abee	Wood
	Gander oak	*Quercus* × *ganderi*		
	Incense cedar	*Calocedrus decurrens*	Wau-up	Wood, food, nuts, pitch, medicine, food, drink
	Interior live oak	*Quercus wislizeni*	Tsigi-nobe	Acorns
	Jeffrey pine	*Pinus jeffreyi*	Kusi-wo-qobi	Nuts
	Oracle oak	*Quercus* × *morehus*		
	Oregon white oak	*Quercus garryana*		
	Pacific madrone	*Arbutus menziesii*		
	Ponderosa pine	*Pinus ponderosa*	Woh-koob'	Wood, basketry, nuts
	Red maple	*Acer rubrum*		

	Common name	Scientific name	Mono/*Nium* name	Mono/*Nium* cultural use
	Santa Cruz island oak	*Quercus parvula* var. *parvula*		
	Shreve oak	*Quercus parvula* var. *shrevei*		
	Sugar pine	*Pinus lambertiana*	Pa-ne-wi-nip’	Wood, basketry, nuts, medicine
	Tanoak	*Notholithocarpus densiflorus*		
	Walnut	*Juglans hindsii*		
	Western redbud	*Cercis occidentalis*	Ta-qwa-qwa-abee	Basketry
	White fir	*Abies concolor*	Sa-qwa-abee	
	Yellow pine	*Pinus jeffreyi* or *Pinus ponderosa*	Woh-koob’	Wood, food, nuts, pitch, medicine
	Dwarf mistletoe	*Arceuthobium* spp.		
Mistletoes:				
	Oak mistletoe	*Phoradendron villosum*	Pa-zo-o-bi	Medicine, poison
	Basket sedge	*Carex barbarae*	Te-de-nap’	binding
Shrubs and herbs:				
	Beargrass	*Xerophyllum tenax*		
	Big deervetch	*Hosackia crassifolia*		
	Bush chinquapin	*Chrysolepis sempervirens*	Tsi-ni-pin	Nuts
	Camas	*Camassia* spp.		
	Cluster-lilies	*Brodiaea* spp.	Po-no-o-wi/ Qo-no-o-wi	Food
	Deerbrush	*Ceanothus integerrimus*	Tsi-ni-pab’	Basketry
	Deergrass	*Muhlenbergia rigens*	Mo-nop”	Basketry, cordage
	Elderberry (blue)	*Sambucus nigra ssp. cerulea*	Hu-bu-he-yab’	Food, musical instruments
	Elderberry (Mexican)	*Sambucus mexicana*	Hu-bu-he-ya/ Ku-nu-geb’	Food, musical instruments
	Gooseberries	*Ribes* spp.	Ta-bap’/Ta-ba’ya	Food
	Lupines	*Lupinus* spp.		
	Manzanita (green-leaf)	*Arctostaphylos patula*	Pa-na-qo-zabi	Food, medicine, walking/ digging sticks

Common name	Scientific name	Mono/*Nium* name	Mono/*Nium* cultural use
Manzanita (Mariposa)	*Arctostaphylos viscida* ssp. *mariposa*	Aposo-wabi	Food, medicine, walking/ digging sticks
Mariposa lilies	*Calochortus* spp.		Food
Milkweeds	*Asclepias* spp.	Wi-si-bi/We-tsib’	Cordage, medicine
Mountain misery or bearclover	*Chamaebatia foliosa*	Sa-a-tu-wib/ Sat-tu-wib	Medicine
Onions	*Allium* spp.	Ped-is	Food
Pacific dogwood	*Cornus nuttallii*		Medicine
Pinemat	*Ceanothus diversifolius*		
Snake lilies	*Dichelostemma* spp.		Food
Soaproots	*Chlorogalum* spp.	So-o-sibe/So-sib’	Brush, medicine
Sourberry	*Rhus trilobata*	Ta-ka-te/ Kwa-nu-nup’	Food, medicine
Whitethorn	*Ceanothus cordulatus*		
Wild sunflowers	*Wyethia* spp.	Aki-bi	Food, medicine
Wild tobacco	*Nicotiana* spp.	Pa-mo	Medicine
Wildrye	*Elymus* spp.		Food
Willows	*Salix* spp.	Se-he-be/See-hibe?	Arrows and bows, basketry, medicine, musical instru- ments
Woodland strawberry	*Fragaria vesca*		Food

[a] Scientific names are based upon records in the Integrated Taxonomic Information System (http://www.ITIS.gov).

English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	.394	Inches
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres
Square meters (m^2)	10.76	Square feet
Kilograms (kg)	2.205	Pounds
Square meters per hectare (m^2/ha)	4.37	Square feet per acre
Trees per hectare	.405	Trees per acre

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Glossary

Corrective fire—Fires set in relatively dense stands of vegetation to reduce accumulated litter and understory growth in areas that have missed expected recurrence of fires (Lewis 1994).

Cultural burn—Use of fire to stimulate desired conditions for traditional cultural purposes.

Cultural keystone—Species that significantly shape the cultural identity of a people, as reflected in diet, materials, medicine, and/or spiritual practice.

Deciduous—The propensity of a tree to shed its leaves (in winter in the case of black oak).

Desired condition—Descriptions of goals to be achieved at some time in the future, from the landscape-scale down to fine-scales.

Diameter at breast height (dbh)—A measure of the diameter of a tree trunk at 1.37 m (4.5 ft) above the ground.

Duff—A component of the forest floor, below the litter and above the mineral soil, consisting of partly decomposed organic material.

Ecological keystone—Species that have disproportionately large ecosystem impacts relative to their abundance.

Ecosystem services—Goods and services provided by natural ecosystems that are important for human well-being. These may be tangible goods like acorns, intangible benefits such as spiritual renewal and sense of place, and ecological functions that regulate processes such as fire and water flows.

Epicormic branches—Shoots that arise from adventitious or dormant buds on the stem or branch of a woody plant, often after fire or increases in sunlight.

Interception—Precipitation that does not reach the soil, but is instead retained on leaves and branches of plants and the forest floor.

Food web—A system of interconnected and interdependent food chains.

Goldilocks principle—Conditions need to fall within certain margins ("not too hot, not too cold") to support a desired condition ("just right").

Granary tree—A tree, often dead, in which woodpeckers drill holes to store acorns.

Heart rot—Rotting of the bole and large limbs of living trees by fungal pathogens.

Hybrid—An offspring of two animals or plants of different breeds, varieties, species, or genera.

Initial entry burn—A preparatory burn set to reduce continuity and amount of surface fuels, but not likely to modify forest structure. Such burns are likely to be conducted well outside the natural wildfire season when moisture limits intensity.

Jackpot burning—A prescribed burn that consumes "jackpots" or concentrations of fuels that are discontinuous, so the fire will not spread easily between concentrations.

Knocking—A traditional practice for gathering acorns by hitting the trees with long poles.

Legacy tree—A tree that is especially large and old.

Live-crown ratio—The vertical distance from the top of the tree to the base of the lowest live branch (excluding epicormic branches) divided by the tree's total height.

Maintenance burn—A fire that kills smaller trees and reduces fuels but is not likely to kill mature, healthy trees due to already low fuel levels.

Mast—Fruit produced by trees or shrubs that is eaten by animals. Hard mast refers to nuts in a hard shell, in contrast to soft mast such as berries.

Mummy nut—An unharvested nut left in the tree or on the ground, which can be a reservoir for pests and diseases.

Mutualism—A relationship in which two organisms of different species benefit from the activity of each other.

Mycelial mats (also called shiro)—The vegetative part of a fungus, consisting of a mass of branching, thread-like structures called hyphae.

Mycorrhizal association or fungi—Colonization of a plant's roots by a fungus, often in a way that benefits the host plant.

Out-of-season burn—Use of fire outside of the historical fire season in order to reduce fuels and alter stand structure sufficiently to prepare the site to more safely accept fire during the historical fire season.

Phenology—The timing of life cycle events (such as acorn ripening) and how these are influenced by climate, elevation, and other factors.

Release—Removing competing overstory trees to increase light, water, and nutrients to benefit trees that are currently suppressed.

Restorative burn—A fire that reduces fuels and may kill trees of various sizes to realign forest structure and composition closer to a reference condition. Some wildfires could meet this description.

Socioecological resilience—The capacity of systems to cope with, adapt to, and influence change; to persist and develop in the face of change; and to innovate and transform into new, more desirable configurations in response to disturbance.

Top-kill—Aboveground portion of plant is killed while the belowground portion survives and is able to sprout. Alternative postfire outcomes for black oaks include no damage, resprouting from their crowns, or being entirely killed.

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