The History of Oak Woodlands in California, Part II: The Native American and Historic Period

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Abstract

This paper is the second in a two-part review of the history of California oak woodlands. Part I reviewed the paleoecologic record, and here the Native American and Historic periods are documented. The open oak woodlands described in the accounts of Spanish explorers were in large part created by land use practices of the California Indians, particularly burning. Extensive ethnographic evidence documents widespread use of fire by indigenous people to manipulate plants utilized for food, basketry, tools, clothing, and other uses. Fire helped maintain oak woodlands and reduce expansion of conifers where these forest types overlapped. There is no clear evidence that the Spanish or subsequently the Mexican land uses had any significant impact on the distribution or abundance of oak woodlands. The introduction of livestock led to dramatic changes in understory species, which may have had some effect on oak regeneration, but this first wave of European settlement left California's oak woodlands largely intact. During the American period, impacts on oak woodlands intensified. Oaks were cleared for fuel and charcoal, to open land for agriculture, and to improve rangeland. Fire suppression favored conifers where oaks and confers co-occur, leading to loss of oak woodlands. The latest threat is urbanization and expansion of homes into oak rangelands. New measures are being taken to limit continued loss of oak woodlands.

Introduction

In a previous paper (Mensing 2005), the paleoecologic history of California oak woodlands was reviewed. In this paper, I review the history of human interactions with oaks woodlands, beginning with Native Californians and continuing through the Spanish, Mexican, and American periods. From earliest times, people have lived among the oaks, and the woodlands we see today are the complex result of a landscape that has been extensively managed through different land use practices. These land use practices have intensified over

time, directly impacting the abundance and distribution of oak woodlands. Ethnographic evidence, descriptions of early explorers, and historic records are supported by fossil pollen evidence to present the history of land use changes in oak woodlands from the time of earliest human occupation, about 10,000 years ago.

The Influence of Native Californians on Oak Woodlands

The influence of California Indians on oak woodlands must be inferred largely from observations made at the time of initial contact, oral histories of elders, and landscape changes that have been documented since the demise of the native populations. Virtually every tribe in California harvested acorns as a major food source. Acorns are easily collected and stored, and as a food source, their protein and fat content is comparable to wheat (Pavlik et al. 1991). California Indians repeatedly tended and gathered acorns from the same oaks and were given usufruct rights to specific trees and groves (Anderson 2005, p. 133). Among the Pomo, the anthropologist Fred Kniffen noted "Like large manzanitas, all the great oaks of the valley flat were privately owned; those of the hills were owned by villages as a whole" (quoted in Anderson 2005 from Kniffen 1939). Archeological sites dating to between 7,400 and 10,200 yr B.P. (years before present) include charred acorn nutshell. Moreover, acorns are the most abundant plant food found in sites throughout central California (Anderson 2005), indicating that oaks have been important to California Indians since the region was first inhabited.

Fires, set by California Indians, are believed to have been the major factor in determining the type of vegetation found by Europeans when they arrived in California (Stewart 2002). California Indians set fires for the purpose of clearing ground to gather acorns, promoting secondary growth used for basketry materials, clearing brush for hunting, and facilitating collection of seeds (Anderson 2005; Blackburn and Anderson 1993). Early explorers consistently described open, park-like woodlands dominated by majestic oaks throughout coastal California and the Central Valley and suggested that the characteristics of these woodlands were probably the result of intense manipulation through the use of fire.

The renowned California botanist Willis Jepson (1923:39) wrote,

> "The long inhabitation of the country by the Indians and the peculiar local distribution of the Valley oak in the rich valleys

> are in some way connected. These oak orchards, of great food importance to the native tribes, indicate plainly the influence on the trees of Indian occupancy of the country. The extent and nature of the relations of Indian tribal culture and the habitat of the oaks cannot yet, if ever, be completely defined, although it is clear that the singular spacing of the trees is a result of the periodic firing of the country—an aboriginal practice of which there is ample historical evidence."

Griffin (1988) stated that direct evidence for the frequency and extent of Indian burning in oak woodlands is lacking. While it is difficult to find physical evidence for specific fire-return intervals and area burned by California Indians, there is now abundant ethnographic evidence for the regular use of fire by indigenous people of California to manipulate their environment (Anderson 2005). Pollen studies of lake sediments in Yosemite National Park provide some of the clearest physical evidence that anthropogenic influences were important in maintaining oak woodlands in the Sierra Nevada.

Woski Pond, a small oxbow lake in Yosemite Valley (1,212 m elev.) preserves a 1,500-year-long record of vegetation change (Anderson and Carpenter 1991). Between 1,550 and 650 yr B.P., the pollen record has very little oak (~6 percent) and is dominated by pine 60–70 percent and other conifers (Figure 1). After 650 yr B.P., the vegeta-

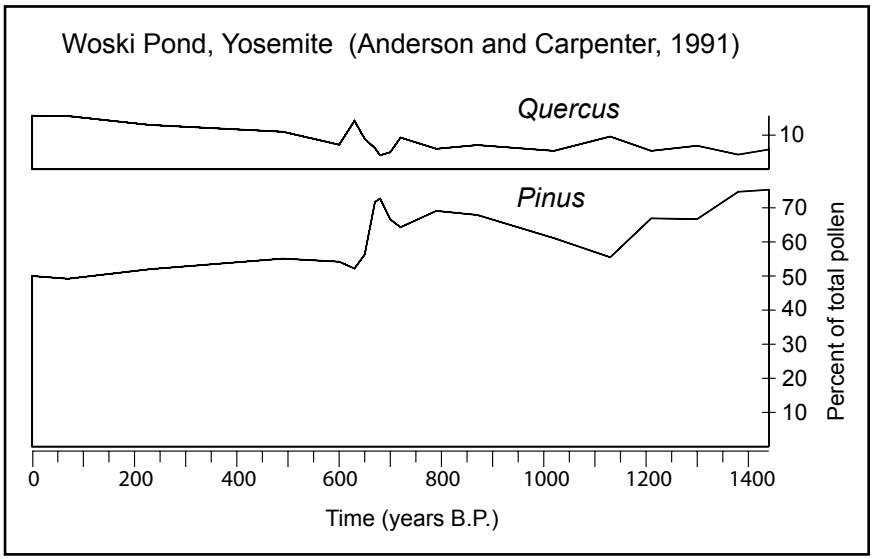

Figure 1.— Pollen percentages of selected taxa from Woski Pond, Yosemite National Park, analyzed by Anderson and Carpenter (1991). Pollen Data obtained from the North American Pollen Database.

tion changed from a closed to an open forest, pine pollen decreased to 45–50 percent, oak increased to 15 percent, and shrubs and fern spores increased. Although Yosemite has been occupied for at least the last 3,000 years, between 750–650 yr B.P. there was a shift from the Tamarak complex to the Mariposa complex, characterized by a larger population and greater reliance on horticulture. Acorns were a major food source for these people, and forest clearance through burning would have favored expansion of oaks and improved conditions for gathering acorns. Anderson and Carpenter's study provides indirect evidence that indigenous people converted closed coniferous forest into open oak woodlands.

Oak woodlands predominated in Yosemite Valley as a result of Indian-set fires rather than climate change (Reynolds 1959). Prior to 1850 A.D., glaciers were advancing in the Sierra Nevada, but since that time, glaciers have receded as the climate became warmer and drier (Harrison 1950, 1951). If climate had been the dominant control of recent vegetation change, one would expect a closed forest canopy dominated by conifers in the 19th century, becoming an open forest or woodland in the 20th century. In fact, the opposite occurred. Photographs taken during the last century show that in the early 1900s Yosemite was an open-oak woodland and since that time has become a closed coniferous forest (Reynolds 1959). California Indians used fire, pruning, and weeding in Yosemite to promote growth of desirable plants and diminish the importance of less-desirable ones (Lewis 1973; Anderson 1993).

In 1855, Galen Clark visited Yosemite Valley and wrote the following account:

> "My first visit to Yosemite was in the summer of 1855. At that time there was no undergrowth of young trees to obstruct clear views in any part of the valley... The Valley then had been exclusively under the care and management of the Indians, probably for many centuries. Their policy of management for their own protection and self-interest, as told by some of the survivors who were boys when the valley was first visited by Whites in 1851, was to annually start fires in the dry season of the year and let them spread over the whole Valley to kill the young trees just sprouted and keep the forest groves open and clear of all underbrush, so as to have no obscure thicket or hiding places or an ambush for any invading hostile foes, and to have clear grounds for hunting and gathering acorns.

> "When fires did not thoroughly burn over the moist meadows, all the young willows and cottonwoods were pulled by hand. Prepared acorns were as much an article of food with the Indians as the cereals are with the more civilized races. In order to get the necessary supply early in the season, before ripe enough to fall, the ends of the branches were pruned off to get the acorns, thus keeping the branches well cut back and not subjected to being broken down by heavy snows in the winter and trees badly disfigured as is the case since that practice has been stopped. Thus, probably for self-protection and utile purposes, the Indians for hundreds of years had cared for and preserved the Yosemite Valley." (Quoted in Reynolds 1959.)

Population estimates for the Miwok Indians of the west slope of the Sierra Nevada range between 9,000 and 10,300 (Kroeber 1925; Cook 1943). Acorns of black oak (*Q. kelloggii*) were one of the most important single items in the vegetable diet of the Miwok Indians and aboriginal inhabitants of the central Sierra Nevada. By many accounts, black oak produced the most-desirable acorns for consumption. In the absence of periodic burning, ponderosa pine (*Pinus ponderosa*) is successional to black oak, and within the lower montane forest, the typical forest structure today is one of young, tall ponderosa pine and incense cedar (*Calocedrus decurrens*) overtopping old black oak. Young black oaks are uncommon. Often at the base of groves of old black oak trees, one can find grinding stones where Indians prepared acorns. Archeologists have catalogued many of the mortar holes used for grinding acorns. One particularly large site with 34 mortar holes indicated the presence of a village, yet is located at 2,100 m elevation (Bennyoff 1956), near the upper treeline of black oak today. At the time of its discovery, the site included only a few scattered oaks in a pine-dominated forest. However, evidence of such a large grinding complex suggests that oaks must have been common in the area, and that stands of oaks were maintained by aboriginal burning, allowing oak woodlands to extend to higher elevations than if their distribution was controlled only by climate (Reynolds 1959).

Frequent burning by California Indians to manipulate the landscape was not confined to the Sierra Nevada, but has been documented throughout the state (Anderson 2005). At least 35 tribes in California used fire to increase the yield of desired seeds, drive game, and stimulate growth of specific plants (Reynolds 1959). Burning was not random over large areas, but was in specific locations for a particular purpose (Lewis 1973).

Anderson (1999) notes that basketry was very important to indigenous people of California, and baskets were the single most common possession of every family. California Indians did not develop pottery, but rather all carrying, cooking, and storage containers were baskets. A diverse assemblage of shrubs was manipulated for use in making baskets, including oaks such as black oak, blue oak (*Q. douglasii*), and interior live oak (*Q. wislizenii*). Epicormic branches from the boles of recently burned black oak were harvested for spoons, winnowing baskets, and fishing baskets, and blue oak were used for cradleboards (Anderson 1993, 2005). Most shrubs produced brittle stems if left on their own, but if burned or pruned, the new shoots were long and straight and ideal for weaving. A recent study of a low-intensity prescribed fire in an oak woodland containing blue oak, black oak, and valley oak found little mortality or change in stand structure after the fire, and many trees had fuller, healthier crowns due to sprouting after the fire (Fry 2002). Other studies have found that even badly burned trees will vigorously sprout from the root crown (Plumb and Gomez 1983). Because plant materials were intensively utilized for specific products, indigenous burning had a functional purpose, not just to produce more sprouting, but also to influence the quality of sprouting, in terms of size, shape, color, length, diameter, and other attributes (Anderson 2002).

Ideally, sprouting branches needed to be only 1 or 2 years in age, requiring annual to semi-annual burning. The quantity of plants needed to supply a village with sufficient material to supply all needs suggests that basketry was an industry-scale operation (Anderson 1999). The implication of this activity is that California Indians were probably very skilled at using fire to control the landscape and maximize the benefits of useful plants. Although the areal extent that was annually burned cannot be calculated, the uses described in ethnographies suggest a scale of small stands, or hillsides.

Oral histories indicate that indigenous people were aware that annual burning under oaks removed old acorns and leaves that harbored insects and larvae that would infest the next year's crops (McCarthy 1993). Entomologists have pointed out that two acorn pests, Tilbert worm (*Mellissopus latiferreanus*) and Filbert weevil (*Cucurlio occidentalis*), reproduce on the ground and emerge to reinfect acorns. Thus, regular burning provided a defense against damage to the following year's crop. Individual trees with large acorns that masted consistently were particularly prized and protected when fires were set (Lewis 1973). The largest oaks (80 to 500 years old)

were favored and the ground was kept clear of shrubs under such trees (Anderson 2005).

By all accounts, the greatest impact frequent burning had on oak woodlands was to reduce the invasion of brush and trees and maintain a more open, savanna-type landscape. A description of a valley north of San Francisco inhabited by the Pomo Indians reads:

> "The vegetation covering has experienced great changes. Certainly the chaparral thickets of manzanita, madrone, scrub oak, and buckbrush which now characterize many sections of the Valley were formerly restricted to the higher slopes and ridges of the mountains. A beautiful park landscape, largely of oaks, was maintained by annual burning, done 'when the straw was dry.' In this manner the brush was held down and larger trees were uninjured." (Quoted in Kniffen 1939.)

In describing the Santa Clara Valley (better known today as Silicon Valley) south of San Francisco, George Vancouver wrote in 1796:

> "For about twenty miles it could only be compared to a park which had originally been closely planted with the true old English oak; the under wood that had probably attended its early growth, had the appearance of having been cleared away and left the stately lords of the forest in complete possession of the soil which was covered with luxuriant foliage." (Quoted in Pavlik et al. 1991.)

The Spanish described a similar situation along the coast of Santa Barbara, where an estimated population of 15,000 Chumash inhabited the region when the first explorers visited in 1769. Fray Juan Crespí wrote:

> "We went over land that was all of it level, dark and friable, well covered with fine grasses and very large clumps of very tall, broad grass, burnt in some spots and not in others; the unburned grass was so tall that it topped us on horseback by a yard. All about are large tablelands with big tall live-oaks (I have never seen larger), and many sycamores as well." (Quoted in Timbrook et al. 1982.)

Although there is ample evidence that California Indians directly modified oak woodlands by frequently burning, there is no evidence that they affected distribution patterns by purposely planting trees (McCarthy 1993). Oaks are slow growing, taking 30 years to produce acorns, 80 years before yielding a good crop, and up to 175 years

to reach full maturity. In addition, there was no guarantee that the planted tree would be a good acorn producer. Accidental planting is also improbable because the common practice was to dry acorns at the collection site, and germination potential diminishes rapidly with desiccation. Oral accounts indicate that indigenous people left the planting to scrub jays. Jays have been noted to remove as many as 400 acorns from a tree within an hour (Griffin 1980). Caching of acorns by jays and squirrels probably led to most successful germination.

The Impact of European Settlement on Oak Woodlands

The Spanish and Mexican Periods 1769–1848 A.D.

Franciscan Missionaries constructed a chain of 21 missions and 9 settlements in Alta California between 1769 and 1821 A.D. (Gerhard 1982) (Figure 2). The distribution of missions closely followed the distribution of coast live oak (*Q. agrifolia*) (Jepson 1910), termed *encina* by the Spanish (Pavlik et al. 1991), and Spanish land grants included many of the coastal valleys dominated by valley oak (*Q. lobata*) termed *robles* (Rossi 1980). Although the Spanish introduced many herbaceous weedy species that completely transformed the understory layer in oak woodlands, there is no clear evidence that the mission period, or the subsequent period of Mexican control, had any significant impact on the distribution or abundance of California oak woodlands.

A 560-year record of vegetation history reconstructed using pollen recovered from annually laminated sediments in the Santa Barbara Basin shows that during the pre-European period, oak woodlands along the Santa Barbara coast show no evidence of change (Mensing 1998). For more than three centuries (1435–1780 A.D.), percent oak pollen averaged between 20 and 25 percent, with very little variability (Figure 3). With the arrival of the Spanish, the pollen record suggests that oak populations increased slightly. Beginning in 1780, A.D. oak pollen increases to 30 percent but then averages only 20–25 percent between 1820 and 1865 A.D. After 1865 A.D., percent oak pollen increases to 40 percent, suggesting that oak woodlands either expanded their range or increased in density during the American period.

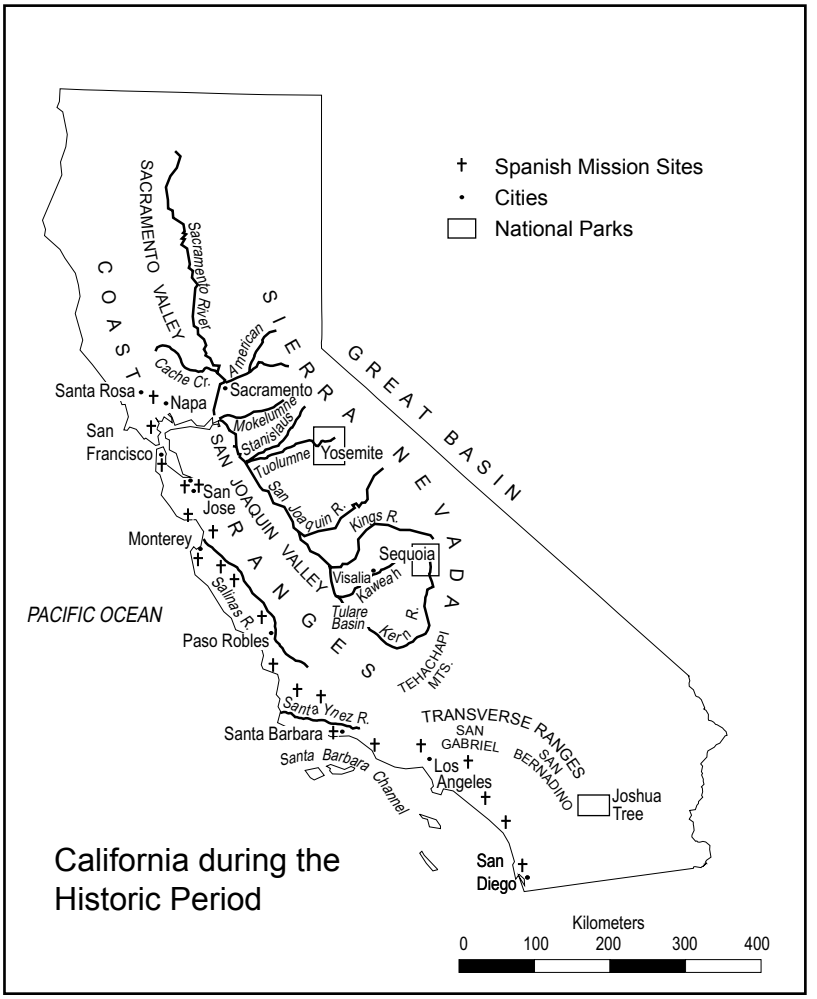

Figure 2.—Location map of Spanish Mission sites, cities, and national parks from the historic period referred to in the text following Gerhard (1982).

Efforts at fire suppression by the Spanish may have benefited coastal oaks. The Spanish had a very different attitude than Native Californians toward fire. Explorers relied on forage for their horses, and missionaries needed pasture for their livestock. The native population had no use for these grasses once the seed had been collected, and typically burned the fields in late summer or early fall, thereby preparing them for next year's harvest, and at the same time depriv-

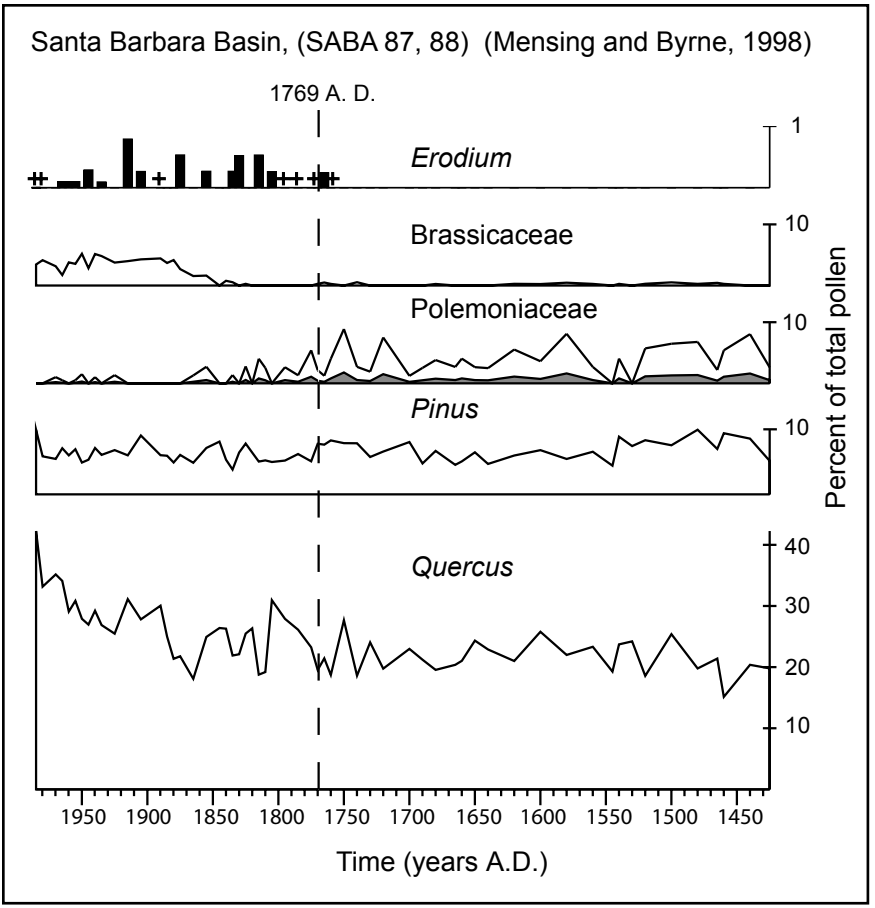

Figure 3.—Selected pollen types from core SABA 87 and 88 from the Santa Barbara Basin. The unshaded area under Polemoniaceae represents five times exaggeration. Note the scale change for Erodium (+) represents a level where Erodium pollen was identified by scanning (Mensing and Byrne 1998).

ing the Spanish of a source of pasture. Several early accounts describe this scenario. In October, 1771 an account from Monterey notes:

> "The heathens are want to cause these fires because they have the bad habit, once having harvested their seeds, and not having any other animals to look after except their stomachs, they set fire to the brush so that new weeds may grow to produce more seeds, also to catch the rabbits that get confused and overcome by the smoke." (Quoted in Lewis 1973.)

Another account from the interior of California, near the San Joaquin Valley in 1806, made the following log entry:

> "There are at this spot about sixty oak trees and a few willows in the bed of the stream. The forage was extremely scanty, and that the country appeared to have been burned over by Indians did not conceal the fact that the land is very poor. Consequently there is little pasturage." (Quoted in Lewis 1973.)

Portola's expedition to San Francisco Bay in 1769 found that many of the hills were grass-covered and "without firewood." Inland rolling hills supported oak woodlands (dominated by coast live oak) and oak savannas (with valley oak and coast live oak) often covered the valley floors. The expedition members noted that the prairies under the oaks had been burned by the native population. Although fires were typically considered harmful, one enlightened priest, Father Duran of Mission San Jose, observed in 1812 that the non-Christian Indians did not need agriculture because they subsisted on wild seeds that did not require any labor but the use of fire (Mayfield 1981).

In an attempt to control Indian-set fires, the acting Governor, Jose Joaquin de Arrillaga (Cutter 1990), issued a proclamation in 1793 prohibiting burning, not just in towns but "even at the most remote distances, which might cause some detriment" and to try to extinguish all fires that might be started (Timbrook et al. 1982). It is impossible to know how effective the ban was, but the pollen record suggests that it was not significant enough to result in a long-term change for oak woodlands (Mensing 1998). Such a change did not occur until a much-larger American population dramatically changed the fire regime.

The introduction of livestock and alien annual plants by the Spanish probably produced the largest impact on oak woodlands. The historic record indicates that initially, the distribution of livestock through California was extremely limited. Even after the initial establishment in San Diego in 1769, it took nearly a decade to develop a permanent livestock base in California (Mensing and Byrne 1998, 1999). Records from the five earliest missions list only 205 head of cattle total by 1773 A.D. and fewer than 330 breeding animals in the state as late as 1778 (Burcham 1957).

As herds expanded, population estimates became less precise. By 1800, livestock were increasing in abundance at Mission sites, and feral horses and cattle are reported to have been present in the San

Joaquin Valley by 1807 (Preston 1981). By 1830, estimates for cattle in California ranged from 180,000 to 423,000 head (Burcham 1957). Livestock affect oaks largely through herbivory, or trampling of seedlings. Most studies have found that browsing by deer and livestock impairs the growth of individuals and may be responsible for reducing regeneration in oak woodlands (Griffin 1971; Borchert et al. 1989; Harvey 1989). Two studies in blue oak (*Q. douglasii*) woodlands found that intensive grazing pressure limited regeneration of oaks (Harvey 1989; Mensing 1992), but another study of blue oak on grazed and ungrazed sites found that the presence or absence of livestock does not guarantee successful regeneration or lack of regeneration among oaks (McClaran 1986; McClaran and Bartolome 1989). The introduction of livestock into California probably had a minimal affect on oak regeneration during the Spanish period.

Several authors have suggested that the introduction of pigs have affected oak regeneration (Rossi 1980; Sweitzer and Van Vuren 2002). The Spanish drove pigs into oak woodlands to feed on the acorn mast (Rossi 1980). More recently, the impact of feral pigs on promoting or discouraging oak regeneration has been debated (Sweitzer and Van Vuren 2002).

Competition for soil moisture and nutrients between introduced Mediterranean annuals and oak seedlings may have negatively affected oak woodlands. Introduced annuals such as red-stem filaree (*Erodium cicutarium*), curly dock (*Rumex crispus*), slender wild oat (*Avena barbata*), wild oat (*Avena fatua*), and ripgut brome (*Bromus diandrus*) successfully invaded California grasslands with the spread of Spanish livestock, and there is good evidence that red-stem filaree successfully invaded Alta California from Baja California prior to the arrival of livestock in 1769 A.D. (Figure 3) (Mensing and Byrne 1998). Mediterranean species were pre-adapted to California's climate, and evidence of their rapid spread throughout the state suggests that they transformed the understory of oak woodlands at a very early date. Wild mustard (*Brassica nigra*) was so thick by the mid 1800s that *vaqueros* would make an annual two to three day "run through the mustard" to knock down these weeds that were tall enough to harbor runaway cattle (Cleland 1941). When the American John Fremont explored the Central Valley in 1844, he wrote, "Instead of grass, the whole face of the country is closely covered with *Erodium cicutarium*" (Fremont 1845). Laboratory studies comparing shoot and root growth of blue oak grown with two Mediterranean annuals (long-beaked storksbill, *Erodium botrys*, and ripgut brome, *Bromus*

diandrus) found that competition for soil moisture significantly increased blue oak mortality (Gordon et al. 1989). Field experiments with blue oak support the conclusion that water availability significantly affects oak seedling survival (Gordon et al. 1991).

The impact of Spanish settlement on oak woodlands was limited to coastal California. Before 1800, several expeditions peered into the Central Valley from the San Francisco Delta region (Crespi in 1772, de Anza in 1776, Moraga in 1776, and Eliza in 1793) noting that "…the plain through which the river runs is as level as the palm of the hand without any trees except in the bed of the river" (Cutter 1950; McGowan 1961). After 1800, several expeditions were sent to explore potential mission sites in the Central Valley, but none were ever built (McGowan 1961). Forays inland were generally for the purpose of pursuing deserters and runaways, capturing neophytes, or in later years searching for livestock (Johnson and Dawson 1993).

Mexico declared independence from Spain in 1821 and soon turned its attention to California (Hutchinson 1969). Beginning in 1824, land grants were issued to encourage development of the territory. Only a few grants were given each year until 1833, after which the numbers increased (McGowan 1961). In the San Joaquin Valley, only one rancho was ever inhabited, and it was not developed (Preston 1981). John Sutter was granted the first land grant in the Sacramento Valley in 1841, 19,500 ha of land east of the Sacramento River. John Bidwell, an employee on Sutter's ranch wrote in 1843,

> "…the plains are covered with scattered groves of spreading oaks; there were wild grasses and clover, two and three and four feet high, and most luxuriant. The fertility of the soil was beyond question, and the waters of Chico Creek were clear, cold and sparkling; the mountains were lovely."

Only 707 land grants were made in California before fighting broke out between the United States and Mexico in July of 1846 (McGowan 1961). Land use was dominated by ranching for hides and tallow that could be easily stored and exported to the Eastern United States (Dana 1937). Agriculture was a minor part of the California economy. An informal census taken by Bidwell prior to the Gold rush of 1849 found that only about 82 Caucasians lived in the Sacramento Valley and another 120 in the San Joaquin Valley, for a total of only about 200 whites living in the Central Valley.

It is clear that through the Spanish and Mexican occupations, California remained a remote, sparsely populated region. The missions and ranchos served to deplete the native populations, with no replacements through immigration. In the 1830s it is believed that cholera and malaria epidemics killed as many as 75 percent of the Native Californians in the San Joaquin Valley (Preston 1981). Although the Spanish had a significant impact on the understory layer of oaks through the introduction of exotic annual plants and grazing livestock, their direct impact on oak woodlands was probably minimal. If anything, disruption of the practice of frequently set fires may have slightly increased oak woodland densities in some areas. Mensing (1998) and Vankat and Major (1978) both note a small increase in oaks during the period of Spanish and Mexican occupation. Remarkably, though, the first wave of European settlement left California's oak woodlands largely intact, and the trees seen by American settlers probably would have been familiar to the previous generations of Native Californians.

The American Period (1848 to Present)

Descriptions written by the earliest Americans confirm that 80 years of Spanish and Mexican occupation had done little to change oak woodlands. A quote describing valley oaks near Cache Creek taken from the 1854 railroad survey states,

> "This timber belt is composed of the most magnificent oaks I have ever seen. They are not crowded as in our forests, but grow scattered about in groups or singly, with open grass-covered glades between them; the trunks often seven feet in diameter, soon divide into branches, which spread over an area of which the diameter is considerably greater than the height of the tree. There is no undergrowth beneath them, and as far as the eye can reach, when standing among them, an unending series of great trunks is seen rising from the lawn-like surface." (Quoted in Thompson 1961 and Griffin 1988.)

With the Gold Rush in 1849, impacts on oak woodlands intensified. Changes to oak woodlands during the American period are complex. Although there has been a decline in the abundance of oak woodlands as a result of extensive clearing for agriculture, range improvement, and urban development, in some wildland areas changes in fire frequency have led to an actual increase in woodland densities and more abundant oaks. Changes in land use practices have led to poor oak regeneration in many but not all woodlands,

but the factors that result in low regeneration rates are not clearly understood.

Four broadly defined changes took place. First, along all major river corridors in the Central Valley where valley oaks dominated riparian woodlands, oaks were nearly completely removed for use as fuel and clearing for agricultural land. Second, in rich agricultural lands of the Coast Ranges, southern California, the Sacramento Valley, and the San Joaquin Valley, oak woodlands including coast live oak, valley oak, blue oak, and Engelman oak (*Q. engelmannii*) were cleared for charcoal production, agriculture, and range improvement. Third, in wildland settings, forests and woodlands increased in density as policies of fire suppression replaced the annual burning practiced by Native Californians as well as sheepherders and early American Settlers (Griffin 1988). In some communities, oaks increased in abundance with the absence of fires, whereas in others oaks have been out-competed by conifers. Finally, urbanization has expanded into oak woodlands, fragmenting wildland habitat.

Loss of Riparian Woodlands

The earliest and most complete devastation of California oaks was along the rivers that provided transportation corridors during the Gold Rush. These rivers were lined with a growth of trees and vines so thick that they were difficult to penetrate. Trees included valley oaks, alders (*Alnus*), willows (*Salix*), sycamore (*Populus*), and ash (*Fraxinus*). Gallery forest width appears to have ranged from about 1 kilometer along the smaller tributaries to up to 4 or 5 kilometers on each side of the banks for the Sacramento River. A description of riparian forests made in the 1840s indicates the massive size of these oaks.

> "Within and at the very verge of the banks, oaks of immense size were plentiful. These appeared to form a band on each side, about three hundred yards in depth, and within (on the immense park-like extent, which we generally explored when landing for positions) they were seen to be disposed in clumps, which served to relieve the eye, wandering over what might otherwise be described as one level plain or sea of grass. Several of these oaks were examined and some of the small felled. The two most remarkable measured respectively twenty-seven feet and nineteen feet in circumference at three feet above the ground. The latter rose perpendicular at a height of sixty feet before expanding its branches, and was truly a noble sight." (Quoted in Thompson 1961.)

Early maps and accounts indicate that beyond the riparian systems, much of the Central Valley was treeless, or groves were so small that they did not warrant mapping (Thompson 1961). The pattern was one of dense woodland along streams, few or no trees on much of the valley, and oak savanna along the valley margins and in the foothills, as described in the 1855 Railroad Survey:

> "On the banks of the Sacramento, in a few instances, I saw this oak when considerably crowded… but, generally, both on the hills and on the plain, it inclines to form groups, or open groves in which the trees assume the spreading form."

Few estimates of density exist; however, one account made in 1841 by William Brackenridge calculated a density of "20 good trees to the acre" (49 per hectare) for oak woodlands near Willows (Griffin 1988). Eastwood (1945) interpreted the species to be valley and interior live oak (*Q. wislizenii*).

Unfortunately, none of the riparian species had value as timber trees and were rapidly cut for fuel, fence material, and cordwood for passenger ships. Wood-burning steamships first embarked on the Sacramento River in 1847, with regularly scheduled paddlewheel service by 1849 (Garvey 1995). By 1850, 28 steamboats were in regular operation on the Sacramento and Feather rivers, with boats also serving the San Joaquin, American, Tuolumne, Mokelumne, and Stanislaus rivers (Garvey 1995). The riparian woodlands disappeared quickly. Not only were the woodlands easily accessible and the only ready source for fuel, but also the natural levees that bordered the Sacramento River were the most fertile and manageable agricultural land in the valley (Thompson 1961). The extensive groves of oaks on the natural levees indicated the productive nature of the soils; these lands were commonly converted into fruit orchards. Much of the Central Valley provided limited opportunities to farming because it was either waterlogged or required extensive irrigation. Native Californian population densities reflect the productivity of these groves, since the highest concentrations of people in northern and Central California (>10 persons per square mile) existed along the Sacramento River corridor (Lewis 1973). By 1870 A.D., a period of only 20 years, the extensive riparian oak woodlands along the river systems had virtually disappeared. Today only a few remnants remain.

Charcoal Production

Harvesting of oaks for both fuel and charcoal production also removed many hectares of woodlands. One account describes fuelwood cutting near Monterey in 1881:

> "On the uplands and low hills east of town there is an almost inexhaustible supply of good oak cordwood, and large trade in which with San Jose and other points is carried on by medium of the Southern Pacific Railroad." (Quoted in Griffin and Muick 1990.)

Another example of firewood cutting was documented from the Salinas River in San Luis Obispo County where valley oak, blue oak, and coast live oak were cleared from 4,800 ha and shipped to San Francisco and Los Angeles for fuel (Rossi 1980).

Charcoal made from oak was an important fuel source during the Gold Rush era. In 1855, San Francisco consumed 110 tons of charcoal produced from local oaks, and industries in the area also relied on charcoal. Charcoal was used in the refining of metals, and in the late 1800s, one iron company used 10,000 to 15,000 tons of charcoal per year, the equivalent of about 30,000 cords of oak (1 cord = 3.5 cubic meters) (May 1956). Consumption slowed in the 1900s; however, production continued until about 1960. Between 1905 and 1910, about 2,000 tons were produced, with the majority coming from oaks cut north of San Francisco. Charcoal declined in importance between 1920 and 1940 but then surged again after World War II with the increased popularity of barbecuing. In 1955, production had increased to 4,650 tons (May 1957), with the vast majority of trees cut for charcoal being oaks. By 1961, production increased to 5,400 tons; however, after this date inexpensive charcoal from Mexico cut into the market and slowed woodland clearing (Rossi 1980).

Agricultural Expansion

Agricultural expansion cleared much oak woodland throughout the state. In the Sacramento Valley, orange groves were planted as early as 1886. By 1900, 1,250,000 trees were in production, covering approximately 2,200 ha (Green 1902). By 1853, settlers were establishing farms and ranches in the Tulare Basin of the San Joaquin Valley. In 1857, the local remaining Native Californians were put onto a reservation, removing their influence on the woodlands forever. Between 1857 and 1871, clearing of oak woodlands for cropland and settlements accelerated. Jepson (1910) reported 104,000 ha of valley oaks on the Kaweah River plain in the San Joaquin Valley. Alarmed by

the rapid removal of these trees, residents persuaded Tulare County officials to purchase 100 acres as an ecological preserve (Rossi 1980) that remains intact today (Pavlik et al. 1991). A 324-acre preserve was also saved in Kaweah (Pavlik et al. 1991), but this is a mere bauble in comparison with the original woodland. Falling water tables in the eastern San Joaquin Valley also may have caused loss of valley oaks and constitute an ongoing threat in the region.

A common pattern that emerged was that oaks were initially cleared for orchards, to be cleared again later for farming or urban development. Between 1910 and 1925, 3,200 ha of dense coast live oak and 2,400 ha of valley oak and blue oak savanna were converted to almond orchards in the Coast Ranges around Paso Robles (Rossi 1980). The orchards turned out to be unprofitable and were converted to dryland farming. The entire Santa Clara Valley, south of San Francisco, was cleared of valley oak and coast live oak savanna for fruit orchards in the first half of the 20th century (Broek 1932). This landscape change caused one observer to note,

> "Once a grassland dotted with evergreen oaks, a large portion of the valley is now covered by a veritable forest of deciduous trees." (Broek 1932, quoted in Rossi 1980.)

Later, these orchards were cleared for homes and manufacturing plants as the computer industry created what is now known as Silicon Valley. Oak woodlands were removed in portions of the Napa and Sonoma valleys of northern California to plant vineyards for the California wine industry. In some cases, large valley oaks were destroyed using explosives (Pavlik et al. 1991). In an article documenting the encroachment of agriculture into valley oak savannas, Griffin (1973) wrote, "… the scene is now one of tired relics towering over an intensively cultivated system." Those relics in fields today are reminiscent of what the ecologist Dan Jansen termed the "living dead"—living individuals that are part of the existing population but are not contributing to the future population. Most regeneration is found in protected waste places such as along fence lines and along roadway borders, protected from repeated plowing. In the Santa Ynez Valley of Santa Barbara County, high mortality and lack of recruitment suggest that the scattered valley oaks that persist in these valleys will eventually revert to grassland (Brown and Davis 1991).

Rangeland Improvement

In the period from about 1940 until 1970, rangeland clearing was the major cause for removal of oak woodlands in California (Bolsinger 1988). Agricultural land clearing was encouraged through federally funded programs after 1940, including the War Food Program started in 1941, and the Agricultural Adjustment Administration range improvement program intended for the Eradication and Control of Destructive and Competitive Plants (Griffin and Muick 1990). All oak savannas may form hardwood rangelands, as they are often referred to (Standiford 1991), but the most widespread are blue oak savannas. It was assumed that removal of blue oak would improve forage production, so inexpensive methods were devised for killing and removing oaks (Rossi 1980). These methods included poisoning with herbicides such as 2,4-D and 2,4,5-T (Leonard 1956; Leonard and Harvey 1956; Johnson et al. 1959), and burning and bulldozing (Brown 1973).

Woodland clearing was concentrated in agricultural counties (Figure 4). Between 1948 and 1952, six counties (Amador, Calaveras, El Dorado, Placer, Tuolumne, and Mariposa) along the central Sierra Nevada foothills accounted for more than half of the 44,000 ha cleared (Rossi 1980). In Tehama County, in the 1950s and 1960s, 36,000 ha of blue oak were cleared. But in 1973, a study found that in fact livestock forage was better under oaks rather than on the cleared land (Holland 1973). This work prompted a number of studies related to forage quality in the oak understory, as well as a reassessment of the policy on woodland clearing. But by then a great deal of damage had already been done. Between 1945 and 1973, about 356,000 ha of oak woodland were cleared for range improvements, averaging about 12,800 ha per year (Bolsinger 1988).

Reduced Fire Frequency

Changes in fire frequency, associated with the demise of the native population and a policy of fire suppression supported during the American period, has led to an increase in the density of oak woodlands in many wildland settings. In the foothills of Sequoia National Park, Vankat and Major (1978) documented a period of successful blue oak regeneration between 1860 and 1880. They suggested that the increase in woodland density occurred at a time when the native population was diminishing and livestock grazing was increasing. They hypothesized that the increase in numbers of oaks was initiated by livestock grazing, that both removed competing herbaceous species and reduced fuel loads and fire frequency. In

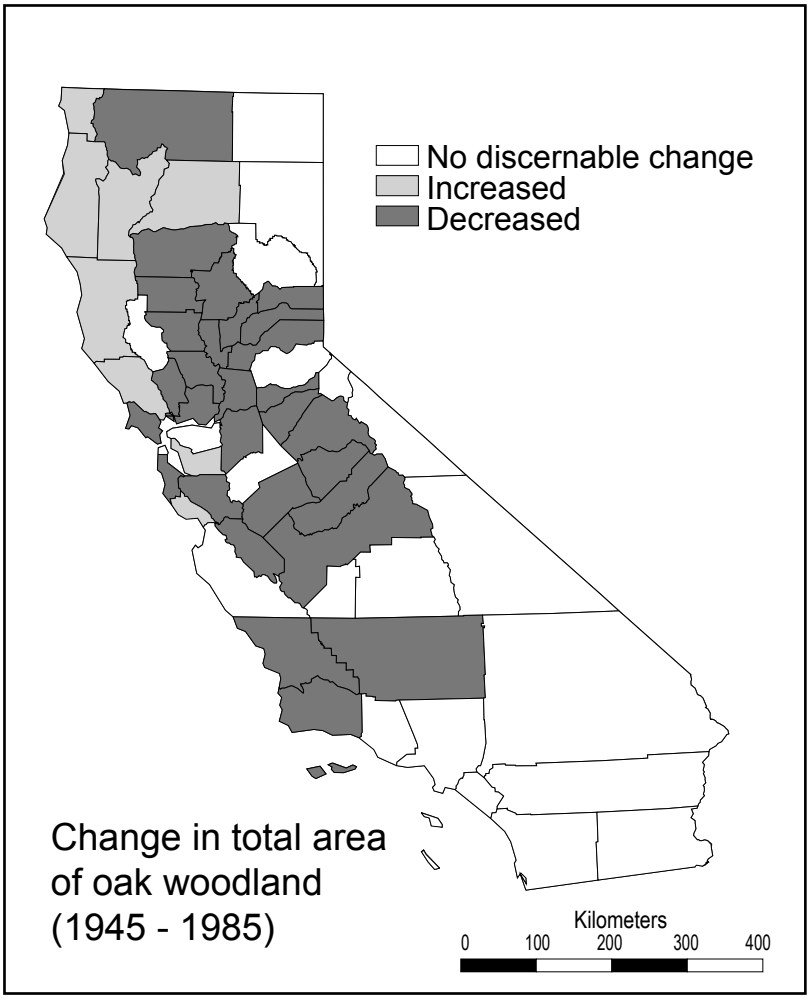

Figure 4.—Map by county identifying changes in area of oak woodlands in California between 1945 and 1985 A.D. (adapted from Bolsinger 1988).

contrast, in nearby Yosemite National Park, cessation of Indian-set fires led to an increase in growth of coniferous forests rather than oaks (Reynolds 1959).

Between 1850 and 1860, there was a major pulse of blue oak recruitment in the Tehachapi Mountains (Mensing 1992). More than half of the trees at the site date to this decade, suggesting that the woodland has increased in density. This timing coincides with the removal of Native Californians to reservations and the beginning of intensive

livestock grazing in the area. Prior to 1850, fire scars record fires at least once every 10 years, with many scars during the 1850–1860 decade. After 1860, fires are nearly absent from the region for 50 years. Similar to what Vankat and Major (1978) described, after 1860, Native Californians were not carrying out traditional burning practices and the introduction of intensive livestock grazing reduced fuel loads. Fires kill small shrubby blue oaks, whereas keeping an area free of fire for a period encourages successful recruitment of saplings and an increase in woodland density (Bartolome et al. 2002). Under a regime of frequent fires during the pre-European period in the Tehachapi Mountains, young trees would have burned, keeping the woodland open. However, in the absence of fire after 1860, more trees survived, increasing woodland density. The modern woodland with dense stands of blue oaks is an artifact of European impacts (Mensing 1992).

Blue oak woodlands in the central Coast Ranges also show a pulse of regeneration during the early American period when livestock numbers were high (White 1966). Age-structure analysis of blue oak sampled in 49 stands of foothill woodland in Monterey County found that over half of the trees sampled dated to the decades from 1875 to 1895. By 1880, livestock grazing within the woodland range declined sharply. White suggests that fires were probably not effectively controlled, but fuel loads were probably not sufficient to kill trees anyway. He did not propose a cause of the regeneration; however, it is worth noting that the timing matches other studies around the state.

There is some evidence that Engelman oak stands increased in density in association with settlement activity during the American period. Age structure studies show that the highest density of Engelman oak occurs among trees dating to the period 1830–1880 (Lathrop and Arct 1987). The authors do not suggest what caused this pattern, but again, the timing matches other studies.

Similar increases in oak woodland density in the late 1800s have been reported for coast live oak woodlands in the Santa Barbara region (Mensing 1998). Without periodic fires, coast live oak increase in density (Davis et al. 1988; McBride 1974; Callaway and Davis 1993). Mensing suggested that the increase in woodland density after 1880, inferred from increases in percent oak pollen described above, coincides with increased population along the coast and improved fire suppression for protection of property. The change from

periodic fires set by the Chumash (Timbrook et al. 1982) to a policy of fire suppression during the American period has favored coast live oak. Small coast live oaks (<7.6 cm diameter at breast height) are commonly killed by fire, but trees with trunks >15 cm will typically survive (Plumb and Gomez 1983). A cessation of frequent native Californian-set fires likely allowed saplings to increase in size sufficiently to persist and increase woodland density.

At higher elevations where oaks co-occur with pines, the absence of fire has favored succession to coniferous forest. At Zaca Lake (730 m elevation), at the transition zone between coast live oak and ponderosa pine, repeat photography and pollen analysis both show that pines have increased at the expense of oaks during the past century. No fires larger than a few hectares have burned in the Zaca Lake watershed since records began being kept in 1911 (Mensing 1998). Today, pines are invading oak woodlands, similar to the successional pattern found in Yosemite National Park (Reynolds 1959; Gibbens and Heady 1964). Thus where conifers and oaks are associated, fire suppression favors conifers, whereas in stands of pure coast live oak, the absence of fire favors increased density of oak woodlands.

In the northern Coast Ranges, conifers such as Douglas-fir (*Pseudotsuga menziesii*) are invading oak woodlands dominated by Oregon white oak (*Q. garryana*) on north-facing slopes and oak savannas dominated by blue oak, black oak, and coast live oak on south-facing slopes (Barnhart et al. 1996). Fire histories indicate that prior to 1900, fires were widespread and frequent (Finney and Martin 1992). The Pomo Indians of this region set fires annually, and these fires were probably responsible for maintaining open oak woodlands (Kniffen 1939). Reduction of fires over the past century allowed oak woodlands to increase in density, favoring the eventual establishment of the more shade-tolerant Douglas-fir. Douglas-fir shade oaks, limiting oak regeneration in the understory. Barnhart et al. (1996) conclude that as long as fire is excluded, unusually dense oak woodlands will continue to support establishment of Douglas-fir in the region, leading to eventual loss of oak woodlands.

Urbanization

In the decades since 1960, most of the loss of oak woodlands has been to urbanization as the state's population has soared. Between 1970 and 1984, oak woodland converted for residential uses included 42,800 ha of blue oak, 15,600 ha of valley oak, 12,000 ha of interior live oak, and 9,200 ha of canyon live oak (*Q. chrysolepis*).

The majority of this clearing has taken place in the foothills of the Sierra Nevada on the eastern edge of the Central Valley (Bolsinger 1988). A tongue-in-cheek assessment refers to the new "climax" for oak woodlands as ranchettes and housing developments (Barry and Huntsinger 2002). Often when land is cleared for residential uses, only 20 percent of the trees are removed from the land; however, the woodland is essentially removed from wildland status. In many cases, trees in residential property are more susceptible to early death due to rot associated with irrigation. Thus, although the actual loss of trees is slow in this process, it can be significant over time. Ongoing residential development threatens at least another 112,000 ha of oak woodlands (Bolsinger 1988).

No historical accounts provide a good description of the original range of Engelman oak in southern California, the most restricted of the California oaks. Urban sprawl in the Los Angeles and San Diego basins has eliminated the species from its northern and western range, leaving concentrations on the Santa Rosa Plateau in Riverside County and the mountains of San Diego County from Palomar Mountain to Cuyamaca Peak (Scott 1991). Nearly two-thirds of all Engelman oak woodlands are on private land, and much of this occurs on small parcels, making preservation of this woodland species precarious.

The state government and many municipalities have begun to create ordinances to slow the loss of oak woodlands in the state. Cities that were named for the woodlands they replaced, such as Thousand Oaks and Paso Robles, now work to preserve oaks (Elmendorf 1991; Oberauer 1991). Public forums between the ranching community, land managers, and land protection groups are seeking ways to protect woodlands by maintaining land in farms and ranches in what are referred to as "working landscapes" (Barry and Huntsinger 2002). After a 150-year history that has treated oaks at best as a natural resource to exploit and at worst as an obstruction to be removed, Californians are finally recognizing oak woodlands as a valuable heritage to protect and use through sustainable means.

New threats—"Sudden oak death"

During 1994–95, a new threat to California oaks was recognized, a forest disease now referred to as "sudden oak death." The disease was found to be caused by the pathogen *Phytophthora ramorum* and is known to infect coast live oak, black oak, and canyon live oak, as well as a number of other species, but tanoak (*Lithocarpus densiflora*)

appears to be the most susceptible species (Rizzo and Garbelotto 2003). The pathogen thrives in cool, wet climates, and sites of infestation have been restricted to within 30 km of the Pacific coastline or San Francisco Bay. To date, 14 counties in California have been affected, ranging from Monterey County north to Humboldt County, and one county (Curry) in Oregon. In several counties the disease has reached epidemic proportions, killing tens of thousands of trees. Although a significant research effort is being conducted, many questions remain unanswered. The broad range of potential hosts of *P. ramorum* suggests that over time, the disease may cause significant ecologic change, including changes in woodland composition, reduced forage for wildlife, changing patterns of plant succession, and possibly a shift in genetic structure among oaks (Rizzo and Garbelotto 2003).

Conclusion

The first humans arrived in California about 11,000 years ago, and soon thereafter there is evidence that indigenous people were using acorns as a food source. By the time of European contact, acorns were a major part of the diet for virtually every tribe. Native Californians were not cultivators; however, they manipulated the environment by frequently burning the landscape to improve the gathering of acorns, facilitate collection of grass seeds, stimulate growth of shoots used for basketry, and clear brush for hunting. These frequent fires helped maintain open oak savannas in environments where succession would have led to coniferous forest. Indian-set fires were probably responsible for creating many of the open oak parks that the earliest European explorers marveled at.

The Spanish built a string of 21 missions along coastal California throughout the range of coast live oaks, but appear to have had remarkably little impact on changing the abundance or distribution of oak woodlands. Exotic annual grasses and forbs introduced with the Spanish completely altered the understory vegetation, which may have impacted oak seedling regeneration, but there is little evidence that they caused major changes among mature oaks. The same is true for the brief Mexican period.

Major changes began during the American period, with the huge population influx that accompanied the Gold Rush. Within 2 decades, riparian oak woodlands were nearly completely destroyed. Clearing of oaks for agriculture, fuel wood, charcoal, rangeland improvements, and urbanization destroyed over 400,000 ha of

woodlands. In the Sierra Nevada and northern Coast Ranges where fire suppression stopped the practice of periodic burning, conifers now out-compete oaks. In the Santa Barbara coastal region, below the elevation of coniferous forests, fire suppression has actually increased oak woodland density. These woodlands are not simply the result of ongoing processes of natural regeneration and recruitment, but of changes in land use practices associated with Spanish and American settlement. The appearance of "sudden oak death" represents a new threat to oak woodlands.

The long-term history of oak woodlands in California illustrates that they have persisted through millions of years of climate change and thousands of years of human impacts. Oaks remain the characteristic tree of the California landscape.

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