CHAPTER NINETEEN

The Use of Fire by Native Americans in California

M. KAT ANDERSON

> Speech, tools, and fire are the tripod of culture and have been so, we think, from the beginning.
>
> SAUER (1981)

The use of fire is an important dimension of human evolution. Its advent enabled our species to move around the world, occupy higher latitudes and elevations, thrive in cold environments, and, perhaps most importantly, cook food and thereby extract calories from it with much greater efficiency (Wrangham 2009). The use of fire by humans may be more than 400,000 years old (Weiner et al. 1998). It is about this time in the archaeological record that proper hearths consisting of rings of stones, burned bones, and other clear evidence of fire used for cooking become common throughout Europe (McCrone 2000). Fire appears to have been used at this time to drive and hunt wildlife as well (Boyd 1999).

If learning how to use fire figured prominently in human evolution, then gaining the knowledge needed to influence vegetation patterns with fire was surely one of the most important achievements of the human species; it shifted our status from that of foragers to managers of nature (Lewis and Anderson 2002). Because of the power over natural resources and productivity that it gives humans, the use of fire as a land management tool has been virtually universal across human cultures since well before the beginning of settled agriculture. Thus, the first humans to occupy California over 12,000 years ago most likely brought with them knowledge of how to burn the landscape to favor wildlife and increase hunting success (Rosenthal and Fitzgerald 2012). Certainly by the time Europeans first came into contact with them, the indigenous people of California had developed to a high art the practice of burning vegetation to achieve a variety of cultural objectives. When Spanish explorer Juan Rodríguez Cabrillo anchored in San Pedro Bay in October of 1542, it was the chaparral fires that gave him the signal that the coast was occupied by humans (Kelsey 1986, p.143) (Map 19.1). A succession of explorers, missionaries, and settlers coming to California thereafter would continually note in their journals the "smoky air" from these fires in every corner of the state—in the coastal redwood (*Sequoia sempervirens*) forests, the tule (naked-stemmed bulrush [*Schoenoplectus* spp.]) marshes of the Delta, the southern oak (*Quercus* spp.) woodlands, the mixed-conifer forests, and the northern hazelnut (*Corylus* spp.) flats (Thompson [1916] 1991, Sutter 1939, Timbrook et al. 1993).

The success of indigenous economies depended on setting fires. A large proportion of most tribes' food supplies depended directly or indirectly on management of plants and habitats with fire. In many areas of California, setting fires was also integral to the maintenance of cordage and basketry production systems—two essential cultural-use categories that required enormous quantities of high-quality plant material to satisfy human needs. Only widespread, careful, and effective fire management could have supplied the phenomenal quantities of food and raw materials required to support the large numbers of people—estimated to have been about 310,000 (Cook 1971)—that lived in prehistoric California. Given the large populations and its needs, estimates of the area that was burned annually by California's earliest humans are impressive. Martin and Sapsis (1992) estimated that between 2.3 and 5 million ha (5.7–12.4 million ac) of California burned annually under both lightning-caused and indigenous peoples' fires. A more recent synthesis by fire ecologists yields the similar estimate of area burned annually, which equates to 6–16% of California per year (excluding the southern deserts) (Stephens et al. 2007).

California Indians used a number of technologies including digging sticks, seed beaters, knocking sticks, knives, stone axes, and deer antlers that may appear "primitive" and unable to affect vast areas. But once Indians developed fire-making technologies—which probably occurred even before their entry into California—they had at their disposal a powerful tool that could alter whole landscapes. By rapidly rotating a slender wooden shaft in a hole in a stationary board to create intense heat by friction (drilling) or by striking two stones together to create sparks (percussion), Indians could make fire when needed (Driver and Massey 1957). Most tribes could also transport fire and start it without the aid of a fire drill by utilizing a slow match or torch, which consisted of a tightly packed flammable material that would smolder at one end for a considerable period of time (Dixon 1905, Barrett 1907). With these technologies, California Indians could start fires in nearly any kind of vegetation when weather conditions were advantageous.

Former indigenous burning patterns are a significant part of the historical ecology of many environments in California—a

MAP 19.1 The territories associated with California Indian language groups. Names in bold represent a language family of two or more languages and multiple dialects.

fact that makes this topic relevant to ecologists, conservation biologists, and land managers interested in restoring various areas to their pre-European settlement condition.

Native American Uses of Fire

Native Americans' uses of fire pervaded their everyday lives. Many of the food items they ate and many of the cultural objects they used and wore owed their existence, at least in part, to fire. They used fire to keep the country open, provide forage for wildlife, drive and capture animals, fell trees, manage pests and diseases, encourage the growth of plant material that could be used to manufacture cultural items—particularly baskets—and enhance the growth of plants, plant parts, and fungi used for food and medicine.

Keeping the Country Open

Burning areas to "decrease the brush" was a nearly ubiquitous practice in California. It facilitated hunting, made travel easier, increased visibility, and enhanced safety—thick underbrush could hide enemies and harbor dangerous animals such as rattlesnakes.

Writing about the Indians of northern California, de Massey (1926) reported: "The Indians, particularly in the spring and autumn, set the stubble in the pastures on fire to destroy the insects and reptiles, and to make hunting easier." The former openness of the country is substantiated by the fact that numerous tribes ran down deer, which would have been impossible in a brushy landscape.

Keeping the country open also had the advantage of reducing the chances of severe fire which, in a tribal territory, would not only have meant immediate loss of life, but would have spelled disaster for the long-term well-being of a village. If, for example, the kind of stand-replacing fire witnessed in modern times had occurred, it would have eliminated thousands of hectares of important tree food resources. Although these trees would eventually have been replaced through seed or vegetative means, it would not have been within the lifetime of the inhabitants or their children (Anderson 1993). Thus, it was not in tribes' best interest to allow catastrophic fires to occur. During a study conducted on indigenous burning in the Yosemite, Sequoia, and Kings Canyon regions, Native American elders commonly stressed that Indian-set fires "did not hurt the big trees" (Anderson 1993). Burning to keep the brush down provided the environmental context within which more localized burning could then be conducted for specific cultural purposes.

Managing and Hunting Wildlife

An important reason for setting fires was to increase forage for wildlife. Anthropologist Harold Driver (1939) recorded that the Wiyot burned every two or three years to increase feed for deer. José Joaquin Moraga, a chronicler of the second Anza expedition, jotted down in 1776 that "The heathen [probably the Ohlone] had burned many patches [southeast of the Mission of San Francisco], which doubtless would produce an abundance of pasturage."

Today, Native American elders from different tribes substantiate the importance of burning for wildlife. Sierra Miwok elder Bill Franklin learned about burning from his father and grandfather: "They said the Indians used to burn in the fall—October and November. They set the fires from the bottom of the slope to decrease the snowpack, get rid of the debris so there's no fire danger and they burned in the hunting areas so there was more food for the deer. They burned every year and in the same areas."

In addition to using fire to increase the food supply for valued animals, Native Californians employed it in an abundant number of ingenious ways to lure, capture, or drive wildlife. The Tubatulabal waved torches under trees where quail were roosting at night; as the birds flew down they were easily clubbed (Voegelin 1938). Ishi (Yahi) told of hunters using fire to kill black bears (*Ursus americanus*). A number of men would surround an animal, building a circle of fire about him. They then would discharge arrows at him, attempting to shoot him in the mouth. If the bear charged an Indian, he defended himself with a firebrand (Heizer and Kroeber 1979). The California golden beaver (*Castor canadensis* subsp. *subauratus*) was hunted by the Sierra Miwok by first burning off the tule around its pond, thus exposing the entrances to the animal's house, and creating bare ground in which to dig out the beaver (Barrett and Gifford 1933). Many tribes drove deer using fire, including the Pit River and the Owens Valley Paiute (Steward 1935, Olmstead and Stewart 1978). The use of fire to capture red-legged grasshoppers (*Melanoplus femurrubrum*) was a widespread phenomenon in California. It was a tool of the Yuki, Pomo, Pit River, and many other tribes (Foster 1944, Merriam 1955, Olmstead and Stewart 1978). Both grasslands and meadows were burned to retrieve grasshoppers, including the grassland understory within mixed-conifer forests.

Creating Plant Material for the Manufacture of Baskets and other Cultural Items

Cultural items made from plant material constituted the bulk of the material culture of all California Indian tribes. These fire-dependent cultural items included weapons, armor, cordage, household utensils, tools, fire drills, structures, baskets, traps and snares, fishing gear, fish weirs, musical instruments, clothing, ceremonial regalia, games, and boats. California Indians burned two general types of plants to create materials for cultural items: in one group were shrubs and trees, and, in the other group, perennial grasses. Each group responds in somewhat different ways to fire and produces materials with different characteristics and usages.

Although older wood made significant contributions to tribes' material cultures—particularly in the form of firewood and the support members of structures—it was not utilized in nearly as diverse ways as the young material produced by plants after burning.

After many shrubs and trees are burned, the young shoots they produce—termed "sprouts" or "suckers" by horticulturists and "epicormic" or "adventitious" shoots by plant morphologists—have vigorous growth characterized by both an upsurge of vertical development and retardation of lateral branching. In general, sprouts have a suite of characteristics that make them suitable for use in making cultural items: they are flexible, straight, long, unvarying in diameter, and free of lateral branches, buds, and blemishes. These shoots also tend to exhibit juvenile characteristics; flowering is generally absent until the shoots have reached a certain stage of maturity. These specialized growth forms do not occur readily in nature in the absence of perturbations (e.g., flooding, fire, herbivory); they are adaptive traits that enhance the plants' survival and regeneration in environments with frequent disturbance (Keeley and Zedler 1978, Philpot 1980, Kauffman and Martin 1990).

Of all the cultural items made from postfire sprouts, baskets were simultaneously the most important and the most demanding of raw materials with very specific properties. Baskets were the single most ubiquitous and essential possessions of a family (Anderson 2005a); each woman utilized workbaskets several times every day for activities as varied as seed harvesting, transport, food storage, and cooking. Because baskets often required precise construction for both aesthetics and functionality, they could be woven only from materials that met exacting criteria (Fig. 19.1) (Bates 1984, Anderson 1993, 1999, Mathewson 1998). To a large extent, plants produced satisfactory materials for baskets only when managed with fire. Pruning could also yield suitable sprouts (and was also used extensively to manage basketry materials), but it was more labor-intensive and did not have the auxiliary benefits of burning. In the absence of management, shrubs and trees used for basketry materials are largely composed of old, brittle, and crooked branch growth that is useless for basketry and sometimes harbors insects and diseases besides (Anderson 1999).

Among the shrub and tree genera used most widely for basketry materials and managed with burning were redbud (*Cercis*), California lilac (*Ceanothus*), hazelnut (*Corylus*), sumac or sourberry (*Rhus*), and willow (*Salix*) (Merrill 1923, Potts 1977, Farmer 1993, Anderson 1999). These genera have widespread distributions, exhibit suitable characteristics for basketry and

FIGURE 19.1 Eliza Coon, a Pomo woman, weaving a basket. Note the long straight branches protruding from the basket, signifying that the shrub from which the branches were obtained was pruned or burned prior to harvest (photo courtesy of the Smithsonian Institution, National Anthropological Archives, #47,749-D; photo taken by H. W. Henshaw, circa 1892–1893).

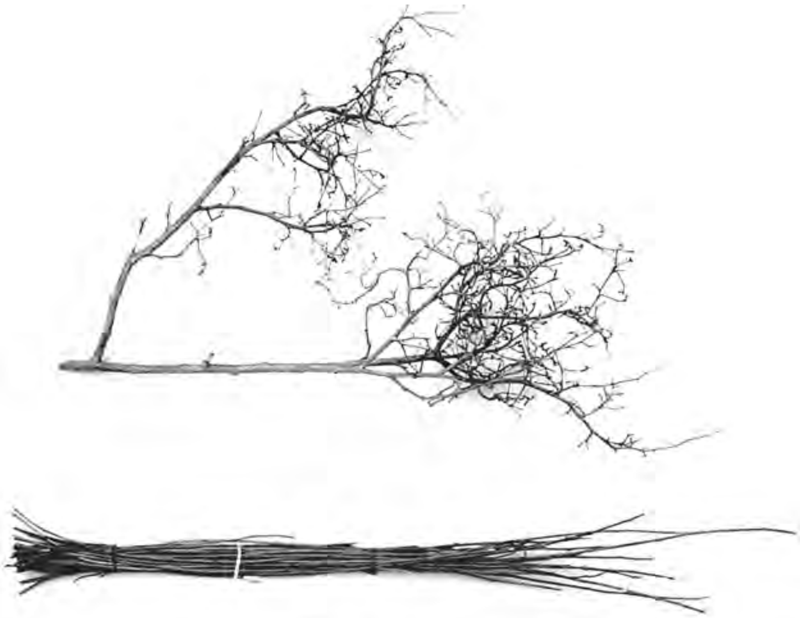

FIGURE 19.2 Contrasting plant architectures of managed versus wild sourberry (*Rhus trilobata*) (read from bottom to top). Weavers select branches with strict parameters: they must be flexible, straight, long, and with no lateral branching. Weavers burn or prune shrubs to create this young growth. Wild growth, which is several to many years old, on the other hand, exhibits many short lateral branches that are crooked and unsuitable for weaving.

other cultural items, and readily regenerate after repeated burning or pruning. Less widely used genera included dogwood (*Cornus*), maple (*Acer*), oak (*Quercus*), and plum (*Prunus*). Large quantities of young shoots from these plants were needed for basketry; one cradleboard, for example, required 500 to 675 sourberry sticks from at least six separate patches that had been burned or pruned prior to being harvested (Figs. 19.2 and 19.3).

The perennial bunchgrass most extensively used as a source of materials for baskets in California was deer grass (*Muhlenbergia rigens*), a large native bunchgrass occurring below 2,150 m (7,000 ft) along streams and in chaparral, oak woodland, and other plant community types (Peterson 1993). It was used as basketry material by tribes whose territories covered more than half of California. The part of the plant used for basketry was the flower stalk, which was essential in making the foundation of many kinds of coiled baskets (Merrill 1923). Like woody plants, deer grass was traditionally managed with fire, but the burning served a different function. Fire did not cause the plant to produce material with particular characteristics, as was the case for woody plants; rather, fire was necessary for maintaining populations, ensuring the vigor of individual plants, and maximizing the production of flower stalks. Fire had these effects because it decreased detritus, reduced competition, and recycled nutrients (Shipek 1989, Anderson 1996) and because it helped create and maintain the openings in the canopy conducive to the sunlight requirements of deer grass (Lathrop and Martin 1982).

Because of the importance of deer grass for basketry and the large quantity of flower stalks needed for a single basket—a Western Mono cooking basket would take about 3,750 flower stalks to complete, a quantity that required harvest from at least three dozen large bunchgrass plants—it must have existed in great abundance in former times (Beetle

FIGURE 19.3 Wahnomkot (Wukchumni Yokuts) displaying coils of split basketry materials that come from hundreds of branches of young shrubs and rhizomes from sedges (courtesy of the Yosemite Museum, Yosemite National Park; photograph by Frank F. Latta).

1947). Although deer grass is still gathered today by weavers of various tribes, it is more and more difficult to find in large colonies; plants are usually found in small, scattered populations of less than a dozen plants along roads, streams, and in meadows. And frequently the grasses contain very few stalks. This decline in deer grass populations may be due to the cessation of indigenous management with fire (Anderson 1996).

Bear-grass (*Xerophyllum tenax*) was another important source of basketry material that requires periodic burning. The young leaves of this plant were gathered by the Wailaki, Karuk, Tolowa, Yurok, and other tribes in northern California for the making of baskets (Clarke Memorial Museum 1985, Turnbaugh and Turnbaugh 1986) and are still highly valued by contemporary basket weavers (Heffner 1984). Because they are more pliable, stronger, and thinner than older leaves, the new green leaves produced after a burn makes the best basketry material. Burning of areas to enhance bear-grass has been recorded among the Karuk, Yurok, and Chilula in northwestern California (Gifford 1939, Kroeber 1939, Gibbs 1851, Clarke Memorial Museum 1985, p.51).

Enhancing Food Production

Many food plants with edible parts—bulbs, leaves, fruits, and seeds—occurred in open woods, meadows, prairies, or grasslands in California and required systematic burning to keep their populations healthy and abundant, and to keep surrounding vegetation from encroaching. These food plants included the oak trees of various species, which produced the acorns that were the staff of life for Native American cultures. Many tribes in California used fire as a vegetation management tool to ensure continual yields of high-quality acorns (Fig. 19.4) (Schenck and Gifford 1952, McCarthy 1993).

Also important for food were the seeds of many native grasses and diverse wildflowers, and tribes assured abundant harvests of these foods by burning the areas in which they grew at the appropriate times. Burning of areas supporting seed-producing food plants was carried out to facilitate harvesting, stimulate seed production, protect the perennial stock, replenish the annual stock, recycle nutrients, and remove detritus to allow for new growth. Burning meadows and open hillsides for these purposes has been documented for indigenous groups in many parts of California (Driver and Massey 1957, Anderson 2005a). The Paiute, for example, burned the brush in the hills near their winter villages and then broadcast seeds of blazing star (*Mentzelia* spp.) and pigweed (*Chenopodium* spp.) (Steward 1938).

Another food source was the underground swollen stems, bulbs, corms, and tubers of the various geophytic species referred to as "Indian potatoes," and these, too, were managed with fire. Their habitats, as well as specific plant populations, were burned to reduce plant competition, facilitate gathering, recycle nutrients, and increase the size and number of bulbs and tubers (Baxley 1865, Anderson 1993) (Fig. 19.5). There is solid archaeological evidence for the use of bulbs, corms, and tubers for food in California beginning over 9,000 years ago (Eric Wohlgemuth, archaeologist, pers. comm. 2015).

Fire was also used to enhance the production of greens, the edible leaves and stems of various herbaceous plants, which were attractive for their vitamins and minerals. Many plant species that produce edible greens required regular burning to maintain their quality and quantity. Clover (*Trifolium* spp.) patches, for example, were burned by the Wukchumni Yokuts, North Fork Mono, and Pomo (Peri et al. 1982, Anderson 1993). Aginsky (1943) records the "burning of herbage for better wild crops" among the Valley Yokuts, Chukchansi Yokuts, Western Mono, and Southern, Central, and Northern Miwok. The Maidu burned areas to encourage the growth of bulbs and greens (Duncan 1964).

Fruits were gathered in substantial quantities and often dried and stored for winter use. Fire was used as a management tool to maintain or increase the fruit production of native shrubs such as manzanita (*Arctostaphylos* spp.), elderberry (*Sambucus* spp.), western choke-cherry (*Prunus virginiana* var. *demissa*), strawberry (*Fragaria* spp.), blackberry (*Rubus ursinus*), California wild grape (*Vitis californica*), and currants (*Ribes* spp.). The Pit River, for example, burned fields and forests to stimulate the growth of seed and berry plants (Garth 1953). Peri et al. (1982) reported that the Pomo people burned manzanita shrubs and that their berries provided food. The Karuk burned huckleberry areas to enhance shrub growth and productivity (Harrington 1932). The Maidu, Foothill Yokuts, Western Mono, and Miwok tribes burned shrubs in order to thin dense canopies, reduce insect activity, and increase fruit production (Jewell 1971, Anderson 1993).

Fire also played a role in managing the substantial food source represented by various species of fungi. Tribes gathered many kinds of edible fungi in grasslands, shrublands, and forests, cutting the aboveground fruiting bodies with a

FIGURE 19.4 Mrs. Freddie, a Hupa woman, pouring water from a basket cup into acorn meal being leached in a hollow in the sand. To her right is an acorn-collecting basket. Setting fires under various kinds of oaks ensured a continual supply of nonwormy, disease-free acorns (photo courtesy of the Phoebe A. Hearst Museum of Anthropology and the Regents of the University of California: photographed by Pliny E. Goddart, 1902 Catalog No. #15-3329).

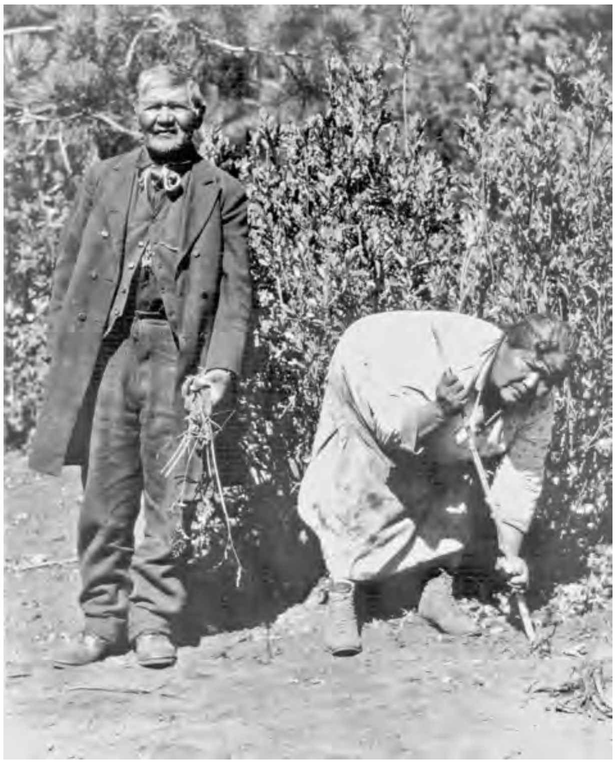

FIGURE 19.5 Alferetta and Grapevine Tom (both Pit River) digging *búlidum'* (*Lomatium californicum*) near Black Tom Bar (courtesy of the Santa Barbara Museum of Natural History, circa 1931–1932). The tubers were probably used medicinally and ceremonially. It was a common practice in many parts of California to dig the many different kinds of bulbs and tubers with hardwood digging sticks, replant propagules, and burn over areas to increase the numbers, densities, and size of these wild plants' subterranean organs.

stone knife and leaving undisturbed the "fine threads" (mycelium) under the ground (Anderson and Lake 2013). The mushrooms were dried in large quantities and prepared by baking, boiling, or roasting. Some tribes set fires to foster the growth of mushrooms; species known to benefit from fire include coccora (*Amanita calyptroderma*), sweet tooth (*Hydnum repandum*), fried chicken mushroom (*Lyophyllum decastes*), black morel (*Morchella elata*), woodland cup (*Peziza sylvestris*), coral fungus (*Ramaria violaceibrunnea*), and ponderosa mushroom (*Tricholoma magnivelare*). Traditional burning made mushrooms more plentiful and increased their size, likely by stimulating mycelial growth and releasing mineral nutrients, and cleared away thick duff that would block mushroom emergence. Today Native Mono elders comment that with years of fire suppression in the mixed-conifer forests of the Sierra Nevada, the "duff is too thick and it needs to have a fire come through." According to a Yurok woman interviewed by Lake (2007, p.649), "a lot of the underbrush" in the mixed evergreen forests of northwestern California "should be taken out" by "light burns, controlled burns" in order to "let the mushrooms grow."

Fire to Combat Insects and Diseases

A wide range of insects and diseases were in direct competition with Indians for plants important for their foods, technologies, and medicines in aboriginal California. Native people used fire as one method for controlling these pests and pathogens. Without the effective biological-control effects of fire, pathogenic and insect agents—capable of rendering plant parts completely useless for weaving or consumption—would likely have been a more significant cause of malnutrition and starvation, and indigenous fiber technologies might never have reached the level of sophistication they achieved.

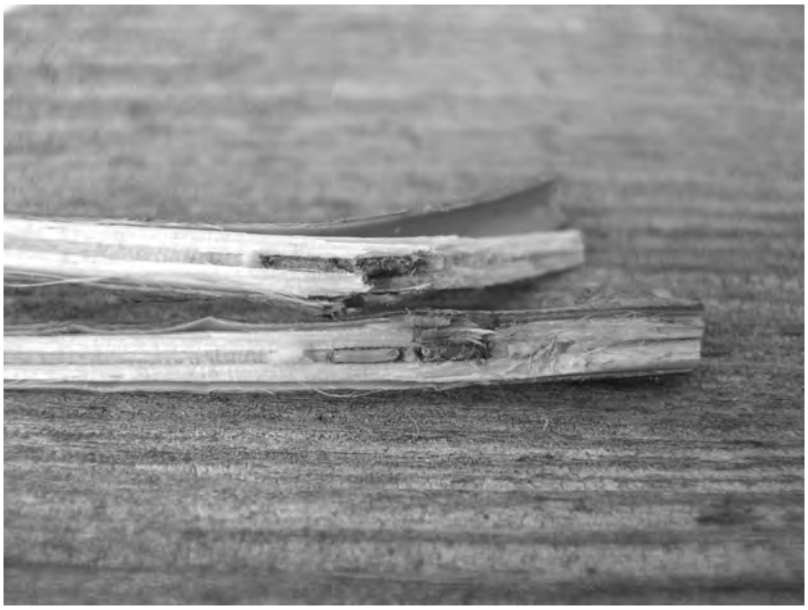

FIGURE 19.6 Basketry willow (*Salix exigua* var. *exigua*) with Agromyzidae (Diptera) larval chambers, probably *Hexomyza simplicoides* (photo by Frank K. Lake, Forest Service, in 2005; insect identified by Stephen Heydon, Senior Museum Scientist, Bohart Museum, UC Davis).

John Hudson interviewed Pomo basket weavers in the early 1900s who explained that the young branches of narrow-leafed willows (*Salix exigua* var. *exigua*) important for their craft contained a parasite "which destroys the product" (Hudson, n.d.). This may have been sawflies (*Euura* spp.), which are also a problem for Southern Sierra Miwok weavers in the Yosemite region and Karuk and Yurok weavers that use willows in northwestern California (Fig. 19.6) (Anderson, unpublished field notes 2001, Lake 2007). Pathogenic fungus can also cause gross deformities in plants important for basketry. Black knot (*Apiosporina morbosa*), for example, infects limbs of western chokecherry (*Prunus virginiana* var. *demissa*), an important basketry material to the Sierra Miwok, Maidu, and other tribes, forming cankerous swellings and dieback. Showy milkweed (*Asclepias speciosa*), an important plant for cordage and medicine, is susceptible to leaf spot (*Passalora* spp.) that blackens the leaves, pods, and stems and can sweep through whole stands (David Rizzo, Professor of Plant Pathology, UCD, pers. comm. 2013). Leaf blight (*Alternaria alternata*) attacks yerba santa (*Eriodictyon californicum*), a medicinal plant with widespread tribal use, causing lesions and appearing as a brown mold (Sinclair et al. 1987, Michael Davis, pers. comm. 2014).

Insects and diseases presented a formidable threat to food crops as well as to basketry materials and medicinals. For example, the achenes of mule's ears (*Wyethia* spp.) are subject to attack by a host of different insects, such as fruit flies in the genera *Neotephritis* and *Trupanea* that prey on developing ovules and maturing seeds, causing significant reductions in total seed yields in wild populations (Johnson 2008). Similarly, filbert weevils (*Curculio* spp.) and filbertworms (*Cydia latiferreana*) can damage a high percentage of the acorns produced by an oak tree (Fig. 19.7) (Swiecki and Bernhardt 2006).

FIGURE 19.7 Acorn of blue oak (*Quercus douglasii*) with insect damage of filbert weevil (*Curculio pardus*) in the larval stage. Different tribes burned under black, blue, and tanoak trees to help rid areas of this pest (courtesy of and photographed by Tedmund Swiecki, Principal/Plant Pathologist, Phytosphere Research).

Because diseases can infect whole stands or patches of plants through wind dispersal, wildlife dissemination, or other means, and insects can fly from one plant to the next, control efforts focused on individual plants are only minimally effective (Hardison 1976). Furthermore, insects and pathogens reproduce prolifically and pathogens can spend long periods of inactivity as dormant propagules, making them difficult to eradicate and a menace to economic security (Strange and Gullino 2010, Schumann and D'Arcy 2012). Indigenous people realized that the application of fire to patches and stands of plants covering small to large areas was the most effective tool for biological control of these organisms.

Dry Creek and Cloverdale Pomo weavers informed David Peri et al. (1982, p.117) that one of the main reasons for burning was to eliminate "parasites occurring on trees and shrubs." Florence Shipek's (1977, p.118) Luiseño consultants told her that "regular burning destroyed insect pests and parasites, such as dodder, which damaged food crops" and she recorded burning by the Luiseño to eliminate insect pests and parasites that damaged seed crops. In the fall of the year, the Yurok burned patches of oak, California hazels (*Corylus cornuta* var. *californica*), and California huckleberries (*Vaccinium ovatum*) to eliminate fungus and insects and improve the crop of nuts and berries (Warburton and Endert 1966).

Possible Ecological Impacts of Indigenous Burning

Although indigenous use of fire was carried out to realize specific cultural objectives, as discussed above—reinvigorating a particular patch of bear-grass to increase its production of basketry materials, for example, or capturing a deer to eat on a feast day—these uses of fire all had ecological consequences. Whether such consequences were the intended result of the burning or not, indigenous use of fire, in aggregate and over long periods of time, had impacts on the ecosystems, vegetation, and landscapes of California. The requirements for substantial amounts of raw materials with precise, fire-shaped qualities and the food needs of the large numbers of people who lived in many areas of the state point to extensive and regular use of fire over broad areas. Further, Native Californians' ability to produce very specific results through burning strongly suggests that they understood very well the reproductive responses of plants to fire, as well as its ecological effects at different levels of biological organization (Blackburn and Anderson 1993, Anderson 2005a). Combining these observations with the well-documented fact that indigenous people burned specifically to alter the character of vegetation, it becomes apparent that at the time Europeans first came on the scene, the landscapes, vegetation, and ecosystems of much of California had been significantly altered from their unpeopled, pristine conditions by California Indian tribes' use of fire.

The slow match or torch gave Native Americans the technological capability to burn both small patches and extensive tracts of vegetation in a systematic fashion. The existence of vegetation types—such as grasslands—that occur as continuous fuelbeds meant that fires could conceivably burn uninterrupted for miles. Fire was used for type conversions of areas for villages and, in southeastern California, for conversion of riparian habitat and floodplains for farming. Burning and hand weeding of young conifers or hardwoods were used in tandem to keep trees from encroaching on meadows or prairies. Galen Clark, guardian of the Yosemite grant for many years, observed burning and weeding among the Southern Sierra Miwok/Mono Lake Paiute in Yosemite Valley (Clark 1894). During the period of European settlement, fire was so commonly used by Native Americans as a habitat management tool that it threatened the agricultural, ranching, lumbering, and gold mining plans of the new settlers, causing the white authorities to draw up edicts, agreements, and proclamations prohibiting burning by American Indians.

Indigenous burning had discernable effects at every level of biological organization. It affected individual organisms, populations of plants and animals, the structure and composition of ecological communities, and the overall makeup of the landscape. And because it was practiced over many millennia, indigenous burning was likely to have influenced organisms at the genetic level, thus playing a role in the evolution of the flora.

Individual Organisms

Specific shrubs and trees were manipulated through spot burning, weeding, pruning, and knocking to enhance production, improve the quality of desired plant parts, and shape plant architecture (Fig. 19.8). Tribes in different parts of California purposefully pruned individual shrubs and trees repeatedly or piled brush onto individual shrubs and set them on fire to induce the sprouting of young shoots for arrows, looped stirring sticks, musical instruments, traps, baskets, regalia, cages, and many other items. These practices tended to keep plants in a physiologically young state, which may have prolonged their life spans.

Plant Populations

The tending of plant populations by burning—and by other techniques that often accompanied burning, such as sowing, tilling, and weeding—changed the distribution of the populations in space, affecting species' densities and abundances. Burning and sowing seeds of wildflowers such as gray mule's ears (*Wyethia helenoides*), farewell-to-spring (*Clarkia* spp.), and blazing star (Hudson 1901, Steward 1938) probably promoted high concentrations of these favored species in an area, and encouraged them to grow in a clumped or aggregated patterns. Over time, Native Americans assert, these techniques expanded the size of the gathering tracts of certain species. Selection for these desirable species probably led to the reduction of other less desirable species that grew in association with them.

The effect of encouraging populations of plant species at particular gathering sites was a high degree of "patchiness," with many medium-scale areas devoted to a single species. Many journals of early settlers describe landscapes made up of wildflower patches, each of a different color (Purdy 1976, Mayfield 1993). Patches of basketry grasses also were encouraged, such as deer grass colonies in ponderosa pine forests, chaparral, and blue oak woodlands. These patches were burned to increase flower stalk production for basketry, decrease dead material, and expand the tract.

Plant Communities

Indigenous burning practices were likely to have changed the physiognomy, structure, and composition of many communi-

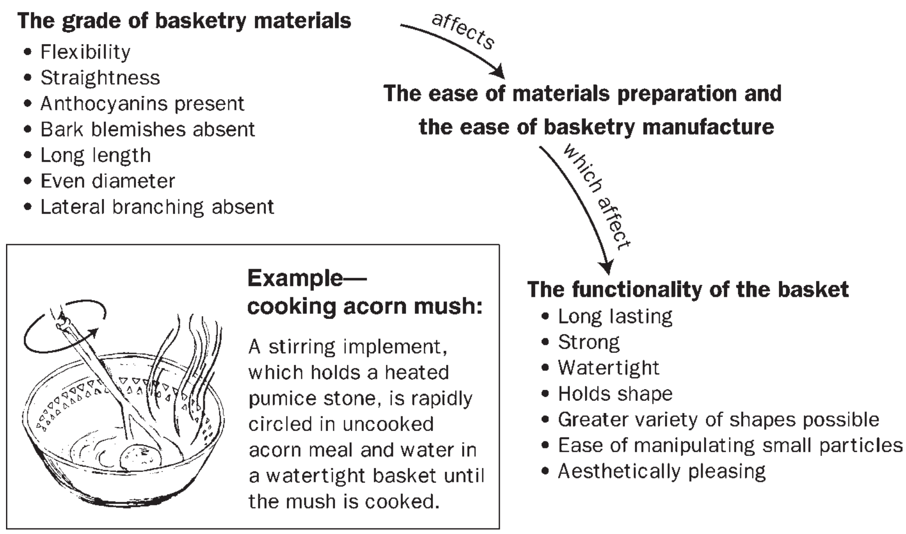

FIGURE 19.8 There are strong links between quality and quantity of plant material, ease of manufacture, and functionality of finished product. Frequently, native plants were not abundant enough or of the proper grade in their wild state, necessitating fire management.

ties. Burning, along with pruning, weeding, sowing, and replanting of bulblets, encouraged a higher level of species diversity than would have existed otherwise because it increased spatial heterogeneity, regularly reintroduced "intermediate" disturbance, and offered more efficient cycling of nutrients. Under indigenous burning regimes, hardwood and softwood forests, for example, had wider spacing between trees and greater proportions of large, mature trees compared to their unmanaged counterparts. In these communities, increased insolation on the forest floor and larger areas of exposed soil heightened the seed germination rates of herbaceous plants, and probably led to an increase in plant species diversity on an area basis (Fig. 19.9). Furthermore, Indian burning created and maintained larger areas of transition zones or ecotones than would have existed without anthropogenic fire, expanding the abundance of edge-effect niches and thus the populations of organisms that require them. Similarly, Indian burning tended to produce a mosaic of areas at different stages of succession within plant communities because Indian economies depended on foods and raw materials produced in the greatest quantities and in the best condition by plants and patches at different stages of growth and maturity (Anderson and Rosenthal 2015).

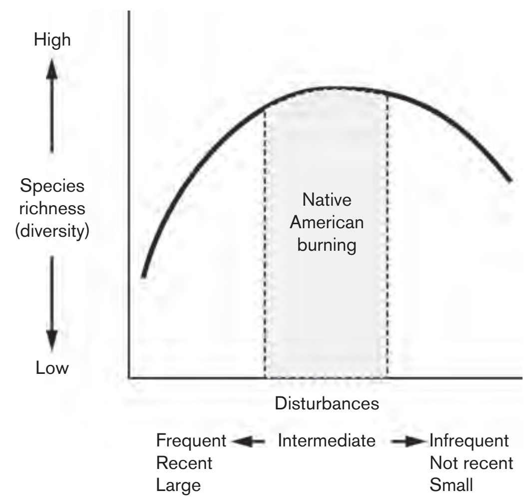

FIGURE 19.9 Intermediate disturbance hypothesis, after Connell 1978. It can be postulated that the temporal and spatial scales of Native American burning and other indigenous disturbances most closely fit the "intermediate" zone (gray region).

The plant communities exhibiting the greatest effects from indigenous management were those subjected to the most frequent burning. Typically these were communities that harbored a diversity of different resources, each of which required a different regime of fire-based management. The black oak–ponderosa pine forests in the Sierra Nevada of California are a good example; they were managed by the Western Mono, Sierra Miwok/Mono Lake Paiute, Foothill Yokuts, and other tribes for at least eight purposes: increasing woodland cup and black morel production, facilitating acorn collection, increasing rapid elongation of epicormic branches on oaks for the manufacture of items, reducing the incidence of the insect pests that inhabit acorns (filbert weevils and filbertworms) (Fig. 19.7), curtailing diseases that attack the trees with smoke from ground fires, promoting useful understory grasses and forbs, promoting a vegetative structure that increased acorn production, and eliminating brush to inhibit catastrophic fires (Anderson 1993). In resource-rich communities such as these, an anthropogenically created plant community structure was both the indirect consequence and the intended goal of indigenous management with fire.

Native American groups recognized that some plant community types covering small land surface areas, such as ponds, marshes, meadows, and prairies, harbored extremely useful and varied plant and animal life and therefore merited special attention in the form of hand clearing and careful burning. Burning maintained and may have expanded some of these special plant community types and subtypes by arresting the process of succession (in the case of dry meadows surrounded by forest, for example) and aiding in the cycling of nutrients held in dead biomass (such as in patches

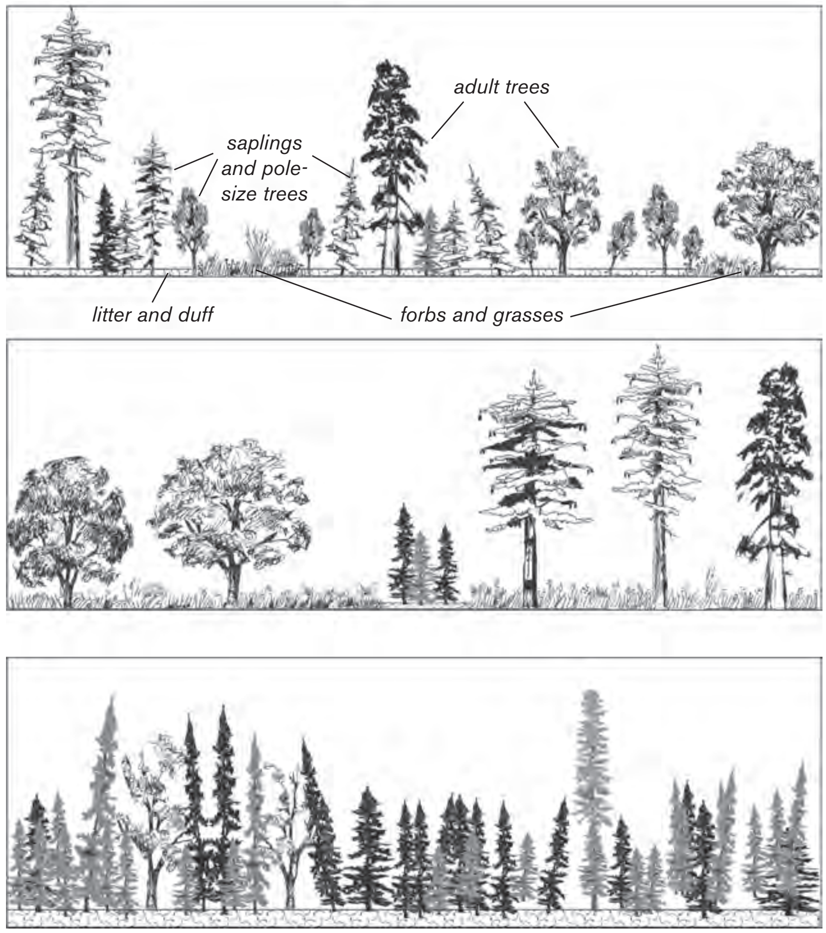

FIGURE 19.10 Mixed-conifer forest types created by three local fire regimes. At top, medium-density forest with fires due to lightning only (every 15 years); medium biodiversity, with medium rate of nutrient cycling and medium depth of litter and duff. In the middle, park-like, pine-dominated forest with fires due to Native American burning (every 2 to 5 years) and lightning (every 15 years); greatest biodiversity, with highest rate of nutrient cycling and thinnest layer of litter and duff. At bottom, dense, fir-dominated forest due to fire suppression management or rocky area not susceptible to burning by lightning or Native Americans; least biodiversity, with lowest rate of nutrient cycling and thickest layer of litter and duff (adapted from Anderson and Barbour 2003).

of tules and cattails [*Typha* spp.] in marshlands) (Anderson 1993, Anderson and Moratto 1996).

The removal of burning by Indians has contributed to the loss of certain forests that are defined by the dominance of large, culturally significant trees such as sugar pine (*Pinus lambertiana*), California black oak (*Quercus kelloggii*), and tanoak (*Notholithocarpus densiflorus* var. *densiflor*us), which harbor tremendous vertebrate and invertebrate biodiversity. These forests include black oak–ponderosa pine-sugar pine forest in the Sierra Nevada, Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*)–tanoak forest in the North Coast Ranges, and black oak in mixed-conifer forests of the Western Klamath Mountains (Fig. 19.10) (Bowcutt 2015, Long et al. 2015). Grassland and meadow communities once favored and kept open through burning are also shrinking in number and size. These include prairies in coastal redwood forests, coastal prairies, valley grasslands, montane meadows, thousands of smaller stringer meadows in our mountain ranges, and grassy-forb understories of open woodlands and forests.

The Landscape

Landscapes can be viewed as mosaics of ecosystems, generated by physical and ecological processes (Pickett 1976). By influencing some natural processes and altering the constituent ecosystems, Indian management with fire had effects at this broadest scale of biological organization. In particular, it probably maximized landscape heterogeneity in many areas of the state (Fig. 19.11). Greater spatial heterogeneity in the landscape resulted from the maintenance and expansion of certain valued community types such as meadows, the intentional maximization of heterogeneity within forest and woodland communities with broad extent, and the variability deriving from the uneven pattern of indigenous occupation on the land.

The distribution of some plant communities over the California landscape today, along with their composition and extent, may be in part a product of Indian burning. As the climate changed, causing woody species to invade coastal habitats and the incidence of lightning to decline, Indians continued to keep some habitats open with fire in a kind of holding pattern. In fact, entire habitats may be dependent upon this continued human intervention for their survival; these include coastal prairies, open woodlands and forests, and early successional Labrador tea (*Rhododendron columbianum*) wetlands along the northern California coast (Blackburn and Anderson 1993, Guerrant et al. 1998).

Indigenous use of fire also had effects on the landscape's physical processes. Native people assert, for example, that regular burning promoted an abundance of water in springs and creeks (Duncan 1964, James Rust, Southern Sierra Miwok, pers. comm. 1989). This phenomenon may have been the result of fire reducing the total leaf surface area of plant com-

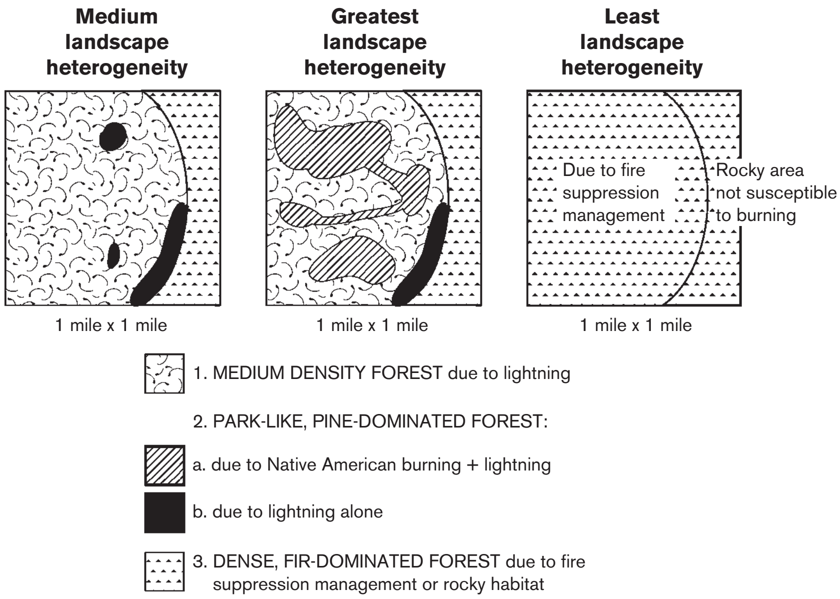

FIGURE 19.11 Hypothetical mosaic as seen from above of mixed-conifer forest types created by three different regional fire regimes. Types 1, 2, and 3 are those shown in Figure 19.10. It can be postulated that lightning and Native American burning resulted in the greatest landscape heterogeneity.

munities, which would have reduced transpiration and the uptake of soil moisture. In the Sierra Nevada, burning at mid-elevations was for the express purpose of shaping the nature of the snowpack. By removing shrub and duff layers and reducing foliage interception of snow, burning promoted a more tightly assembled, denser snowpack that melted off more slowly in the spring, reducing flooding and causing ephemeral creeks and streams to run longer in the summer (Jewell 1971).

Extent and Degree of Fire-Mediated Human Influence

Given California's diverse habitat types and wide variations in their likelihood of carrying a fire, along with the spatial unevenness of indigenous occupation, the influence of indigenous burning across the landscape was far from uniform. While fire was applied regularly and intensively in many areas, others probably experienced very infrequent Indian-set fires. Among the places in the latter category were the subalpine forests, the driest desert regions of southern California, and the alkali flats and serpentine balds with widely spaced plants, all of which do not burn readily. Also largely excluded from Indian burning were some remote mountainous areas not frequently visited by Native Americans and certain areas in many tribes' territories that were considered off limits to burning.

The unevenness of indigenous application of fire on the California landscape can be viewed as a continuum from very little or no Native American influence to fully human-created ecosystems. The serpentine barrens and subalpine areas of various parts of California would qualify as uninfluenced wilderness at one end point, and the agricultural fields of the Mojave, the coastal prairies of the northwest coastal tribes of California, and the desert fan palm oases of the Cahuilla in southern California would be among the heavily fire-influenced communities at the other end point. Other communities and vegetation types fall somewhere in between these two extremes, each reflecting some degree of indigenous influence with fire. The most heavily influenced landscapes make up perhaps 20% of California.

In the regions, communities, and vegetation types in which fire was undoubtedly a significant factor in shaping the vegetation, there is still some debate about the relative importance of human-set versus lightning-ignited fires. The incidence of lightning increases substantially from the coast up to the higher elevations of the Sierra Nevada (van Wagtendonk and Cayan 2008), leading most fire ecologists to conclude that prehistoric fire regimes in Sierra Nevada montane forests, as indicated by fire scar records, are more a function of natural ignition and vegetation inflammability than of Indian burning. Additionally, if fire ecologists can show that fire regimes are intimately linked to wet and dry cycles, then they are apt to conclude that fires are correlated with climate changes and therefore are natural, not of Indian origin (Swetnam 1993).

During the past few decades, however, researchers have been increasingly able to tease apart the history of human- and lightning-caused fires by using interdisciplinary studies incorporating archaeological and ethnographic data; new techniques such as charcoal analysis of soils, phytolith analysis, and pyro-dendrochronological studies; paleoecological data from pollen analyses; and data from the automated lightning detection systems now in place all over the state. This new research is providing strong correlations between human activity, fire, and vegetation in such places as Yosemite Valley, the southern Sierra Nevada, and the western Klamath Mountains (Crawford et al. 2015, Klimaszewski-Patterson et al. 2015). For example, in Yosemite Valley, a dramatic increase in oak pollen and a decline in pine pollen after Miwok settlement 500 years ago corresponded with increased fire and anthropogenic activity. Lightning fires are relatively infrequent in the valley and thus a direct cause-and-effect relationship was inferred between human-set fires and vegetation change (Anderson and Carpenter 1991). Ecologists Bill Kuhn

FIGURE 19.12 Michael Bonillas, Amah Mutsun, conducting a cultural burn in deer grass (*Muhlenbergia rigens*) habitat in Pinnacles National Park to recycle nutrients, stimulate new growth, and increase flower stalks for basketry. This is a collaboration between the Amah Mutsun, Pinnacles National Park, and UC Santa Cruz (photograph by Rick Flores, U.C. Santa Cruz Arboretum, 2011).

and Brent Johnson (2008) support this conclusion, arguing that Native Americans changed the fire regime in Yosemite Valley substantially, instituting a regime of frequent fires that created this iconic landscape.

Research in the past 25 years has also found that in zones with very low frequency of lightning strikes, such as along California's coast, whole ecosystems exist that are clearly fire-dependent. These coastal ecosystems, which include bishop pine (*Pinus muricata*) forests, Oregon oak (*Quercus garryana*) woodlands, coastal redwood forests on drier sites, and early successional Labrador tea wetlands, show evidence of relatively frequent fire in prehistory, most of which must have been set by humans because lightning would have been insufficient. What has happened to these coastal ecosystems since the removal of indigenous cultures and their fire management is further evidence that they were managed and maintained by Indian burning: they are all in decline, and whole habitat types with their unique suites of species are disappearing (Guerrant et al. 1998, Stuart and Stephens 2006). Further, ecologists are recognizing that a general decline in biodiversity in coastal areas is likely linked to the absence of indigenous management with fire.

Martin and Sapsis (1992) offer a way of transcending the debate over whether the prehistoric fire regime in California was driven by human or natural causes. They believe that Indian-set and lightning fires together resulted in a high level of *pyrodiversity*, which had the beneficial effect of creating greater biodiversity. This fire-dependent biodiversity was reflected in more diverse habitat types, more diverse physiognomies in woodlands and forests, more mosaics of resources at different stages of succession, and greater representation of species in forests that are "keystones" both ecologically and culturally (Long et al. 2015).

Because indigenous people had the technological capability and the economic motivation to expand the season of burn and to light fires in hard-to-reach places with varying topographies and soils whenever and wherever conditions permitted, they were able to push beyond the spatial and temporal constraints of lightning ignitions. They did this to varying extents in different parts of the state, but nowhere did they rely on lightning alone to start the fires their economies required. By intervening to change the frequency, season, intensity, and pattern of burning, they effectively took over control of the fire regime in certain areas.

Implications for Management Today

The legacy of Indian burning has much meaning for environmental management today. Most fundamentally, perhaps, the recognition that many of the "wild" landscapes and plant communities that we value for their biodiversity, ecological services, resources, and aesthetic values were in fact shaped and maintained by indigenous burning provides important perspective on both the role of fire in environmental management and on management itself. It validates management as an activity, reveals the wrong-headedness of fire suppression, puts into question the leave-it-alone approach to wilderness and wilderness-quality wildlands, and brings to the forefront of management policy the concept that in many ecosystems indigenous burning existed as *part* of ecological processes.

Indian burning also lends itself to emulation by non-Indian land managers. Many of the cultural goals that Native Americans set for burning various habitats in the past are consistent with the goals of contemporary ecologists and forest and range managers of our public and private lands, land trusts, fire safe councils, and communities today. Native people, like non-Indians, valued beauty in the natural world, great plant and wildlife diversity, stewardship of resources that provide for human needs, low levels of insect and disease pests, and the safety of human communities. These goals can be accomplished today by judicious application of burning that mimics what Native people did.

FIGURE 19.13 Skip Lowry, Yurok, Maidu, and Pit-River, conducting a cultural burn on the Yurok Reservation to rejuvenate a hazelnut (*Corylus cornuta* subsp. *californica*) patch for future basketry material and foods. According to Skip, these cultural burns are essential to restoring the ecological health of the land and responsibly bringing back the traditional ways of the ancestors. This is a collaboration between the Yurok, Cultural Fire Management Council, the Nature Conservancy's Fire Learning Network, and Terra Fuego Resource Foundation (photograph by Elizabeth Azzuz, Yurok, CFMC Secretary, March 2015).

Redwood National Park's prescribed burning program in the Bald Hills honors Native American burning practices by simulating their techniques. It has increased feed for Roosevelt elk, encouraged the oaks, kept the prairies open, and fostered the sun-loving plants in the prairies just as the Hupa, Karuk, and Yurok once did with their fire management. In Whiskeytown National Recreation Area, where black oak woodlands were traditionally managed with fire by Wintu cultural groups, prescribed burning and silvicultural treatments favoring black oak and open diverse understories are restoring these landscapes by preventing encroachment by Douglas-fir. Significantly, this program seeks restoration specifically for the sake of "tribal values" (Long et al. 2015).

Fire-based management informed by knowledge of prehistoric practices is also being carried out by Native people themselves (Figs. 19.12 and 19.13). Some tribal elders and indigenous resource managers still retain detailed knowledge of how, why, and when to apply fire to the land. With a grant from the USDA NRCS, Lois Conner Bohna (Mono/Chukchansi) removes brush and burns under California black oak trees on leased land near the town of O'Neal to bathe the trees with smoke to curtail mistletoe and kill insects that overwinter in the duff, as her ancestors had done for eons (see Sidebar 19.1). Members of the Amah Mutsun Land Trust, a tribally owned trust, are bringing back onto their traditional lands the practices of seed beating, tillage of sedge beds for basketry, and burning of deer grass and other plants in partnership with Pinnacles National Park, UC Santa Cruz, and the Midpeninsula Open Space District in the San Francisco Bay Area. In Northern California, the Orleans/Somes Bar Fire Safe Council and private non-Indian land owners are teaming up with the Karuk to treat tanoak stands with fire to get better acorn crops and burn hazelnut flats to generate better basketry material. The US Forest Service is working with the Karuk and local communities around Happy Camp to restore controlled burns to high country ridge systems to create landscape-level fuel breaks. The US Fish and Wildlife Service Recovery Plan for the Western lily (*Lilium occidentale*), an important food plant to the Karuk, recognizes that "burning by Native Americans may have been a significant factor" in maintaining its habitat in early successional bogs and recommends research on the use of fire as a possible management approach for recovering endangered populations.

As valuable as fire can be as a management tool, it must be used with great care on today's landscapes. Since frequent, patchy, low-severity fires have not swept the land since indigenous people ceased to be its stewards a century or more ago, the wildfire cycle is out of kilter in many areas, increasing the threat of large and destructive fires like the 2014 Rim Fire, the largest in Sierra Nevada history. In today's overstocked forests, woodlands, and shrublands, fire may exhibit very different behavior than it would have in prehistory, thus creating vastly different ecological effects. Many of the nonnative weeds advancing into various habitats thrive with burning, so reintroducing fire where they have established may result in the exact opposite of what managers intend. At the same time, the arrival of exotic diseases and insects such as sudden oak death and the golden spotted oak borer—which have indiscriminately killed millions of tanoaks and coast live oaks, drastically changing the composition of some of our forests—introduces new wildcards for land managers and restorationists to consider. Climate change brings further complexities, putting forests under greater stress, drying out fuels earlier in the season, and increasing the frequency of weather patterns conducive to severe fires. Under these circumstances, the reintroduction of indigenous-type fire management may offer important benefits as long as it is pursued as part of management and restoration plans that take into account the new variables and changed environmental context. Indigenous-type burning may have as its most important role the stemming of the overall decline in diversity that we are seeing at all levels of biological organization. When guided by traditional ecological knowledge, prescribed burning of the sort applied by Native Americans can be essential in promoting species recovery and restoring declining habitats.

SIDEBAR 19.1 THE IMPORTANCE OF GOOD FIRES FOR BLACK OAK USED BY NATIVE AMERICANS

Jonathan W. Long and M. Kat Anderson

Native Americans have traditionally used fire in tending groves of California black oak to produce large amounts of high-quality acorns, a substantial food source that has remained important since ancient times. Many Native American families have long depended on being able to gather hundreds of pounds of black oak acorns, which are often preferred over any other acorn except tanoak. Beyond the tremendous utilitarian value of acorns and wood products from black oak, Native Americans cultural traditions celebrate black oak through first acorn ceremonies and emphasize the importance of the tree for sustaining valued wildlife species.

For millennia, Native Americans have set low-intensity fires (Figs. 19.1.1 and 19.1.2) that consumed litter, duff, damaged acorns, and dead branches; kept risk of severe fires low; controlled acorn pests such as the filbert weevil and filbert worm; and promoted desired understory plants and other conditions favorable for gathering to sustain people (Anderson 2005a). In addition, burning stimulated formation of sprouts used for basketry, tools, clothing, and other items. Oral histories indicate that 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 (Anderson 2005a), with fire return intervals below the typically reported median of 7 years to 9 years for the ponderosa pine and dry mixed-conifer forests that commonly have black oak trees (Van de Water and Safford 2011). Over time, tending practices are likely to have promoted desired conditions for high acorn production that include widely spaced oaks with broad, rounded crowns, large girth, and low branches. In contrast, wildfire-dominated systems appear to promote narrower trees without low branches (Fig. 19.1.3).

California black oaks are vulnerable to damage from fire, as McDonald (1969, p.15) described fire as "black oak's worst enemy"; however, large black oaks appear to tolerate fire and indeed thrive under the frequent low-intensity burning practiced by Native Americans and often emulated by Euro-American settlers and land managers. Frequent fires provide shade-intolerant black oak with openings and resources needed to flourish within forests otherwise dominated by conifers. Douglas-fir, ponderosa pine, incense cedar, and white fir tend to grow underneath black oaks (Fig. 19.1.4) and eventually overtop them (Fig. 19.1.5), which reduces the amount of light available to the oaks (Cocking et al. 2012). As California forests have become more overgrown without frequent fires, oaks often appear spindly, less vigorous, and produce fewer

FIGURE 19.1.1 During a cultural burn under California black oaks (*Quercus kelloggii*) to prepare the grounds at an Indian Mission site for the traditional bear dance (photos by Danny Manning).

FIGURE 19.1.2 After a cultural burn under black oaks to prepare the grounds at an Indian Mission site for the traditional bear dance (photos by Danny Manning).

FIGURE 19.1.3 A tall, narrow black oak maintained by wildfire in the Beaver Creek Pinery (photo by Carl Skinner).

FIGURE 19.1.4 A large black oak encroached by conifers on the Sierra National Forest (photo by Jonathan Long).

FIGURE 19.1.5 An overtopped black oak in Yosemite National Park (photo by Jonathan Long).

acorns, except where roadsides and other openings allow them to grow fuller crowns. The absence of fire encourages accumulations of needles, branches, small trees, and other fuels that increase the likelihood that oaks will be damaged when fire returns.

California black oaks have a distinctive capacity to resprout; in the wake of wildfires that kill tree overstories, this adaptation gives them a competitive edge over conifer trees and even allows them to quickly overtop understory shrubs. When fires have returned to forests under modern fuel and weather conditions, they have often been at intensities that have killed the trunks of mature black oaks (Fig. 19.1.6). Furthermore, fire can also be so intense that it completely kills black oak trees. Even with resprouting, recovery of mature oaks capable of producing acorns in large quantities may be set back by 80 years or more (McDonald 1969). Consequently, severe fires constitute a loss of important ecosystem services, even though black oaks, as a species and as a dominant forest type, may even increase as wildfires, temperatures, and drought take a toll on competing conifer trees.

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 large trees. By keeping fuel loads low, Native American tending would have perpetuated such outcomes. Studies of historical fire patterns based upon fire scars indicate that forests with black oak experienced frequent fires, and that Native burning likely increased that frequency in many areas. Restoring frequent, low-severity fire, particularly in formerly harvested groves and other areas that are accessible to gatherers, would help promote and conserve large black oaks that are not only important to Native Americans, but also to many birds, mammals, and other wildlife that depend on acorns and large cavities. Black oak also provides valuable functional diversity as a deciduous, drought-tolerant tree capable of resprouting within forests dominated by evergreen conifers. Consequently, mature black oak is an important focus for restoring heterogeneity and reestablishing the critical role of frequent fire in California forests.

FIGURE 19.1.6 A dead trunk of black oak (with curving black fire scar) within a stand of conifers within a high-severity patch of the Rim Fire (photo by Jonathan Long).

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