

LIVING AMONG THE OAKS

A Management Guide for Woodland Owners and Managers

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What is more characteristic of the California landscape than the oak? Round-crowned oaks dapple the rolling hills, solitary monarchs shade our rural roads, and valley giants stretch skyward in banners of leaves and lichen. Both past and present-day travelers have stopped in awe of our native oaks, and countless photographs and memories are framed by their spreading, weather-worn branches. The oak is particularly emblematic of the inland regions of California, where scattered oaks, rolling pastures, and distant cattle are common elements of an infinitely variable and ever-changing landscape.

In this region—often called the hardwood range or oak woodlands by land managers—the vistas of oaks, pasture, and livestock bestow a tranquility that sometimes belies the fourth element: people. Like the earliest Californians, people today come to the oak woodlands for food, shelter, and beauty. Many consider

oak woodlands a landscape of California that symbolizes values we hold dear—strength, beauty, adaptability, and longevity.

But intensifying land use in oak woodlands has brought problems along with it: soil erosion, reduced forage production, poor regeneration for some oak species, and degraded wildlife habitats. Oak woodlands today are clearly showing the effects of the last 200 years of human habitation.

Oaks provide

- shade and shelter
- wildlife and fisheries habitat
- soil protection (erosion control)
- increased property values
- beautiful landscapes
- food and fuel
- recreational opportunities

All Californians can assist in the protection and enhancement of native oak resources, but nobody is in a better position to do so than the owners and managers of oak woodlands. Those who own homes or property in the oak landscape can help shape the future by their decisions, which collectively direct the management and land use of more than 7 million acres (2.8 million hectares) of the state. This publication is designed primarily for the owners of home lots or small acreages, but owners and managers of larger properties can also apply much of the information, especially to areas where native oaks grow around the ranch home. It brings together helpful information about living—and making a living—among the oaks. The University of California Oak Woodland Conservation Workgroup hopes that you will find this information useful as you manage your land and make decisions that shape the future of California's oaks and oak woodlands.

OAKS OF THE HARDWOOD RANGE

California has 21 native species of oak in the genus *Quercus*, 10 of which grow to tree size. Of these, 8 are conspicuous members of the oak woodland plant community. All are relatively slow growing and long lived.

Valley oak (*Q. lobata*)



Alice B. Addicott

This tall, spreading, winter-deciduous oak was once an important member of the Central Valley's riparian forests, but agricultural conversions and development have greatly reduced the acreage it occupies. From Shasta County to Los Angeles County, it is still a conspicuous oak in the landscape, especially in valley bottoms and on deep alluvial soil. It is the largest oak in California.

Blue oak (*Q. douglasii*)

This deciduous oak is the dominant oak in the woodlands from Shasta County to Kern County, growing in the foothills of the Sierra Nevada, Coast, and Transverse mountain ranges. It often grows in association with interior live oak (*Q. wislizeni*) and foothill pine (*Pinus sabiniana*) and tolerates relatively harsh sites.

In addition to dropping its leaves in winter, it exhibits drought deciduousness—that is, the capacity to shed foliage earlier than normal in response to drought.



Hart Gordon Bailey

Coast live oak (*Q. agrifolia*)



Hart Gordon Bailey

This evergreen oak occurs from southern Mendocino County southward into northern Baja California, primarily in the Coast Range. On favorable sites it often attains a rounded, spreading appearance. It is a member of the black oak subgenera and is one of four California oak species that is susceptible to Sudden Oak Death.

Interior live oak (*Q. wislizeni*)

This evergreen oak is widely distributed in California from Siskiyou County south to Baja California. It is abundant in the Sierra Nevada foothills, and in the Coast Range it occupies higher, drier, and more inland sites than does coast live oak. It is generally found in more heavily wooded sites than blue oak, and in chaparral habitats or other dry locations it often develops a shrubby form.



Geri Hulse Stephens

Engelmann oak (*Q. engelmannii*)



Hart Gordon Bailey

This semideciduous oak has a narrow distribution, primarily in western San Diego County, where it replaces blue oak as the dominant species. It has been severely impacted by agricultural conversions and, along with blue oak and valley oak, is not regenerating well.

California black oak (*Q. kelloggii*)

This species is a member of the black oak subgenera and loses its leaves in winter. It most commonly grows in mountainous areas, and in the Sierra Nevada it is an important component of the mixed-conifer forests. It typically receives more than 25 inches (64 cm) of annual precipitation and produces a strong reddish-brown wood that is compared to northern red oak (*Q. rubra*). Its acorns were considered the best tasting by many tribes of Native Americans throughout the state.



Oregon white oak (*Q. garryana*)

This deciduous white oak is common in northern California and extends far north, all the way to Vancouver Island in British Columbia. It prefers a moderate climate with warm summers and freezing winters and between 20 and 50 inches (51 and 128 cm) of precipitation. In California it grows in a variety of habitats and is often associated with bay laurel (*Umbellularia californica*), Douglas fir (*Pseudotsuga menziesii*), black oak, Pacific madrone (*Arbutus menziesii*), and tanoak (*Lithocarpus densiflorus*).



Canyon live oak (*Q. chrysolepis*)

This evergreen species has a broad distribution, extending from Oregon to Baja California, and it can grow from sea level to high in the mountains. The wood is very strong and close grained and was originally used for tools and implement handles; hence one of its common names is maul oak. Another common name is gold cup oak, because it has fine yellow powder covering the acorn cup, or cap.



Needs and Conflicts

In designing and building homes, gardens, orchards, and places for animals, your decisions are shaped by your overall objectives for your land. Whether your land is a residential site, used for grazing, or maintained as natural open space, you will need to consider various management options. As you choose management approaches for your land, also take into account your oak trees and evaluate whether or not your planned activities are compatible with oak conservation and the basic needs of the trees. Remember that well-managed oak woodlands can also help enhance other natural resources, such as soil and water. Careful planning and design can often provide benefits for both people and oaks.

Past development among the oaks has revealed specific areas of conflict. Often impacts to oaks have not been adequately addressed in planning documents and mitigation requirements. But a 2004 California state law (Public Resources Code § 21083.4) requires mitigation if projects in oak woodlands have significant impacts on the environment. It has also become apparent that, in addition to the removal of trees, certain construction practices can seriously injure or kill oaks. Construction activities can increase (or decrease) fire hazards, creating liability and management problems. Gardening practices such as amending the soil, planting lawns, or irrigating under established oaks can damage them. Domestic animals, as well as insect and disease pests, also can take a toll. In combination,

these elements can present formidable obstacles to the health and survival of oak trees. However, harmful effects can be minimized by thoughtful management practices. And how we manage oak woodlands will likely become even more critical under the stresses associated with climate change.

Building around Oaks: Protecting the Root Zone

The most vulnerable part of a mature oak tree is the root system and, in particular, the root crown at the base of the trunk. Although most oaks do have a deep taproot, many oak roots are relatively shallow and extend outward from the root crown, reaching some distance beyond the tree's drip line (the outermost edge of a tree's foliage). For management purposes, think of a tree's root zone as extending out at least one-third farther than the distance to the drip line. Ideally there should be no disturbance within this zone. This means no grading, digging, trenching, using of fill soils, covering the ground with asphalt or concrete, or landscaping with plants that require more than two or three summer waterings. Also, excessive foot traffic, operating heavy equipment, and parking vehicles (particularly heavy ones) should be avoided in this zone to avoid compaction. It is preferable to retain natural litter (fallen leaves, twigs, and bark) or add mulch to cover the soil surface. If modifications are unavoidable, strive to keep this area in as natural a condition as possible, and keep ground disturbance as far away from a tree's trunk as possible.

Threats to the Root Zone

The following human activities are the ones that most commonly alter a tree's root environment, potentially damaging or killing it.



Changes in grade. This includes any changes in the ground level under the tree, either by mounding up soil or removing it. Excavating soil can directly cut and destroy roots and expose them to damage from surface activities. Mounding up soil can reduce oxygen to the roots. Depending on climate and soil moisture, additions of soil can also encourage root rots. Use retaining walls outside of the drip line to protect the natural grade under the tree. If there is no alternative to adding soil within the drip line, consult a qualified arborist specializing in oaks for strategies to minimize injury. Also, review the publications listed in the "References" section.

Changes in drainage. Irrigation and changes in the drainage around an oak can result in water in the root zone during the summer when soil temperatures are high and soils are normally dry. This can promote the

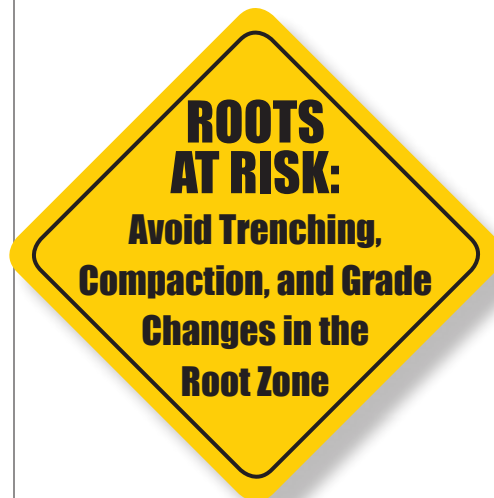
proliferation of harmful soil microorganisms that injure roots. Saturated soils can also inhibit oxygen movement into the root zone. These factors can ultimately result in tree death.



Soil compaction. Heavy foot traffic or the operation of heavy equipment can cause soil compaction, especially when the soil is wet. Compaction causes the spaces between soil particles to become compressed, reducing gas exchange. Since gas exchange is needed for root function, compaction can cause significant injury to oaks. When the ground is covered with nonporous materials such as asphalt or concrete, the free passage of moisture, air, and other gases within the root zone is impeded. In addition, soil compaction can occur in preparation for and during paving. As an alternative to common paving materials (asphalt and concrete), there are porous materials that are more compatible with the oak environment and make excellent ground coverings. Regardless of the permeability of the ground covering, nothing should be placed within a 6-foot (1.8 m) radius of a tree's trunk. This is the minimum area

that should always be left undisturbed and preferably covered with mulch.

Trenching. Trenching is a leading cause of tree mortality. When utility trenches are dug into the root zone, major portions of a tree's root system may be cut or damaged. When several large roots are damaged, tree death may follow. Trenching in the root zone should be avoided whenever possible. If trenching cannot be avoided, identify the location of lateral roots using a pneumatic trenching tool. Probably the best alternative to trenching is to place utilities in a conduit that is bored through the soil. If utility conduits are unavailable, try to have all utilities placed in a single trench, as multiple trenching causes greater damage.



Disturbance beyond the root zone. Beyond the root zone mature oaks are usually less affected by landform and drainage changes, soil compaction, paving, and trenching activities. But indirect effects must still be considered. Avoid fill materials that could alter flow patterns, resulting in water collecting around trees. Consider the effects of nearby ponds or swimming pools on

local soil moisture, and watch for bank or hillside cuts that could alter drainage patterns.

Fire in California's Oak Woodlands

Californians are keenly aware that fires regularly occur in our state and can have devastating consequences. Recently there have been some catastrophic fires in oak woodlands. The severity of these fires was partially due to fire suppression activities during the last 100 years that have increased fuel loads and made it more difficult to suppress or contain woodland fires that do start, especially during extreme fire weather. Also, more people are now living within these fire-prone ecosystems, which complicates fire-fighting activities. One consequence of the recent spate of fires was the revision of the California state law that requires fuel reductions around homes and the removal of vegetation that could help fires spread (Public Resources Code § 4291). Increasing clearances and removing "ladder fuels" can greatly reduce the risk that homes in the paths of fires will be lost.

Once the fires have passed and the embers have cooled, property owners want to know if their oaks have been killed. Often they haven't been. Even if all of the leaves on an oak tree have been scorched and the tree looks dead, new leaves will often emerge and start to grow the following spring—or even sooner—and the tree may suffer little long-term damage. It is therefore important to wait until the following year to determine if trees have been killed from fire. And even if the aboveground trunk has

NATIVE PLANTS COMPATIBLE WITH OAKS

Below is a selection of California native plants that require little water and can therefore be used in landscaping under and around oak trees. Once established—usually after a year—they require little care, minimal water, and offer beautiful foliage. Sometimes they have showy blossoms with pleasant fragrances as well. When planting near oaks, avoid injury to roots while digging planting holes, and stay outside the drip line if possible. Also add mulch after planting to help conserve soil moisture.

Shrubs (partial shade)

Carpenteria californica, carpenteria
Ceanothus spp., wild lilacs:
C. griseus, *C. thyrsiflorus*,
C. maritimus, plus cultivars:
C. Joyce Coulter, *C. Ray Hartman*.
Cercis occidentalis, western redbud
Cercocarpus betuloides,
 mountain-mahogany
Eriogonum arborescens, Santa Cruz
 Island wild buckwheat
Garrya elliptica, silk-tassel bush
Heteromeles arbutifolia, toyon
Mahonia spp., barberries and mahonias:
M. dictyota, *M. fremontii*,
M. haematocarpa, *M. pinnata*
Prunus ilicifolia, holly-leaf cherry
Rhamnus californica, coffeeberry
Ribes spp., gooseberries:
R. aureum var. *gracillimum*,
R. malvaceum,
R. speciosum, *R. sanguinum*,
R. viburnifolium
Rosa californica, California wild rose
Rosa californica, Plena, double
 California rose
Salvia clevelandii, San Diego wild sage
Salvia leucophylla, coastal white sage

Shrubs (full sun)

Fremontodendron californicum,
F. mexicanum and cultivars,
 Fremontia, flannel bush,
 California Glory, Pacific Sunset
Galvezia speciosa, island snapdragon
Lupinus albifrons, silver bush lupine
Lupinus chamissonis, Chamisso bush
 lupine
Mimulus aurantiacus, bush monkey
 flower
Mimulus puniceus, red monkey flower
Penstemon clevelandii, Cleveland's
 penstemon, and other species
Romneya coulteri, matilija poppy

Ground Covers

Baccharis pilularis ssp. *pilularis*,
 dwarf coyote bush
Ceanothus griseus var. *horizontalis*,
 Carmel creeper
Ceanothus maritimus, Hoover ceanothus
Ribes viburnifolium, Catalina currant

Evergreen Herbaceous plants

Dryopteris arguta, wood fern
Eriogonum umbellatum var. *polyanthum*,
 buckwheat
Heuchera maxima, giant alum root
Iris douglasiana and hybrids
Viguiera deltoidea var. *parishii*

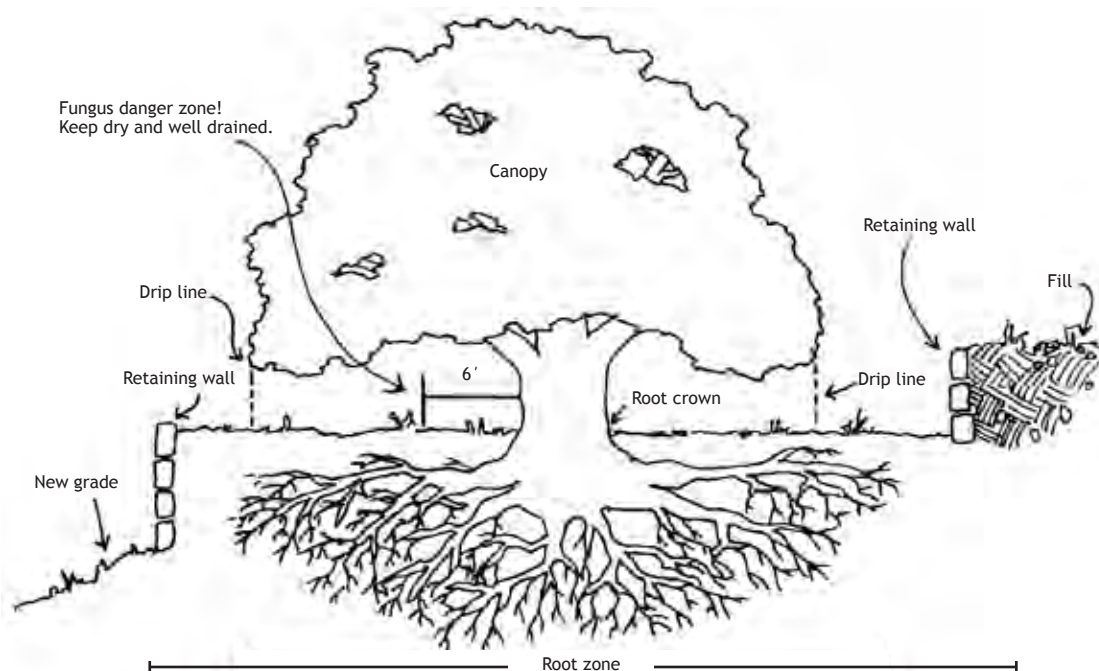
Deciduous or Annual herbaceous plants

Clarkia spp., clarkias
Collinsia spp., Chinese houses
Dodecatheon clevelandii, shooting stars
Eschscholzia spp., poppies
Montia perfoliata, miners lettuce
Nemophila menziesii, baby blue eyes
Oenothera spp., evening primroses
Sisyrinchium bellum, blue-eyed grass
Viola pedunculata, yellow pansy
Zauschneria californica, California wild
 fuchsia

Bulbs

Brodiaea species and related genera:
Dichelostemma pulchellum
Triteleia laxa
Calochortus spp., Mariposa lilies
Chlorogalum pomeridianum, soap plant
Lilium pardalinum, leopard lily
Trillium chloropetalum, common trillium

For more information about these and other California native plants compatible with oak gardens, including which species are native to your part of California, contact local arboreta, botanical gardens, and the California Native Plant Society (see "Online Resources").



It is essential to limit activities in the root zone that could damage the tree's roots.

been so severely damaged that the tree dies and has to be cut down, oaks will generally sprout from their stump. These sprouts can eventually grow into a new tree, and much more quickly than when planted as acorns. While fires are generally not good for trees, oaks have evolved in an environment where regular fires have always occurred. As a result, they are well adapted to survive this natural phenomenon.



Bill Tietje

Fire in California's oak woodlands is an ongoing threat.

Oak Pests

Oaks in natural settings are relatively resistant to severe damage from pests, especially native pests that have co-evolved with oaks (but see the section on Sudden Oak Death, below). However, when compromised by soil compaction, changes in soil moisture, or other disturbances, trees can have difficulty fending off organisms that cause injury. In some cases,

by the time symptoms appear, the tree is declining and remedies may be too late. A qualified arborist should be called when the following symptoms are noticed:

- Loss of tree vigor, twig dieback and wilting, abnormally yellowish leaves, and wounds on the bark that ooze rust-colored fluid. These symptoms are indicators of crown rot (*Phytophthora* spp.).
- Foliage turning brown, and the oozing of a dark brown, viscous fluid from the trunk. These symptoms are often accompanied by the presence of bark beetles and fruiting bodies of *Hypoxylon* fungus on the trunk of the tree. These are symptoms of *Phytophthora ramorum*, the agent responsible for Sudden Oak Death (see below).
- Dieback of branches, emergence of honey-colored mushrooms at or near the base of the tree in the early winter, often accompanied by a white fan-shaped fungus growth between the bark and sapwood, and black shoestringlike structures in the soil. These are indicators of a serious disease called oak root fungus, *Armillaria mellea*.

Armillaria is often present on the roots of wildland oaks, even when there are no obvious outward symptoms. Under natural conditions this disease is rather benign, and it is held in check by summer drought. However, *Armillaria* thrives in warm, moist conditions—a situation that is created when the area under a tree is watered during the summer. Once the roots of a tree are seriously infected, the fungus can persist in soil organic material for many years and can

later infect other trees—even after the death and removal of the host plant. Fruit trees and landscape plants nearby, particularly those that are irrigated during the summer, may also be subject to infections.



Doug McCreary

Heart rot is common in mature oaks.

Another fungal malady, called heart rot, occurs when one of several wood decay fungi degrades the heartwood of an oak. Although this does not usually impair the tree's vigor, it does weaken it structurally. Weakened branches can break off and a weakened trunk may not be able to support the crown, especially during a windstorm. Heart rot commonly develops in large pruning wounds. Regular examination of the tree and judicious pruning and bracing can prolong the life of an oak with heart rot.

Mistletoes

These parasitic plants grow in the branches of many oaks and can cause structural weaknesses that make the tree more vulnerable to branch breakage. Small infestations may affect the appearance of a tree but generally have little impact on tree health or vigor. Even large infestations, which



Jack Kelly Clark.

Coast live oaks laden with Spanish moss.

Laurence R. Costello

can weaken trees, rarely kill them. Mistletoes can be controlled in a variety of ways, including removing the infected branches or using registered herbicides. It should be noted that mistletoes are native and beneficial for a variety of bird species that eat the berries and even for deer, which will eat mistletoe foliage that has fallen to the ground.

Spanish moss

The Spanish moss that grows in California is actually not a true moss but a lichen. (The Spanish moss that grows in the southern states is neither a moss nor a lichen, but a bromeliad.) It is not parasitic so is not a serious threat to oaks. Tree growth may be slightly reduced due to shading of leaves in a tree heavily laden with Spanish moss, but the situation is not life threatening and can be reduced by pruning infested branches. Many people consider Spanish moss an attractive adornment to their oak trees.

Insect pests

Innumerable insects live on the leaves, branches, trunk, and roots of oak trees, usually without much adverse impact—especially if the tree is vigorous and healthy. Most oak galls, for example, are harmless swellings in response to enzymes released when small gall wasps lay their eggs and the larvae begin to feed. Some of these galls look like dangling Christmas ornaments, while others form exotic multicolored shapes on oak leaves that can resemble sea urchins, sponges, or Chinese hats.



Jack Kelly Clark, courtesy of UC Statewide IPM Program

Colorful galls caused by gall wasps are common on twigs, branches, and leaves.

Some insect pests do cause injury, however. For instance, pit scales (appearing as pinhead-size scales on the bark of twigs and small branches), oak moths, and other leaf-eating insects are relatively common on a number of oak species and can have striking effects during severe outbreaks. However, even when trees are completely defoliated, they usually recover the following year with little long-term damage, although growth during defoliation is minimal because of greatly reduced photosynthesis. Some insecticides are registered to treat oak insects, but often by the time the symptoms become evident, it is too late for treatment. Oaks and the associated native insects have evolved together and rarely are trees seriously damaged or killed by them. A serious new insect pest, however, believed to have recently arrived from Arizona or Mexico, is the golden spotted oak borer (*Agrilus coxalis*), which is actively spreading and killing coast live oaks in San Diego County.



Tom W. Coleman, courtesy of USDA Forest Service

The golden spotted oak borer is killing oaks in San Diego County.

Mammal pests

In most cases, mammals pose little threat to mature oaks. Browsing or grazing animals may inhibit natural regeneration by chewing on small seedlings, but rarely do they seriously damage mature trees. There have been cases, however, where populations of ground squirrels or other



Pavel Svihra

Sudden Oak Death continues to kill oaks in 14 coastal counties.

ground-dwelling rodents have caused damage to oak roots or girdled young stems. Take measures to control these populations if oak vigor is diminished or if there is extensive excavation by animals in the root zone. The aboveground part of seedlings or saplings can be protected by fencing, wire cages, or treeshelters (see below). The roots of seedlings planted in such areas can be protected belowground by covering the root ball at the time of planting with a wire cage.

Sudden Oak Death

Sudden Oak Death (SOD) is a relatively new disease that affects several native California oak species. It is caused by *Phytophthora ramorum*, a funguslike water mold that causes bark cankers which can girdle and kill mature trees. To date, four of

California's 21 species of native oaks are susceptible to this disease: coast live oak, California black oak, Shreve's oak (*Q. parvula* var. *shrevei*), and canyon live oak. Currently it does not appear that members of the white oak subgenus, including blue and valley oaks, are susceptible. As of 2009, SOD had been confirmed in 14 coastal counties, extending from Monterey to Humboldt, with locally devastating effects. Fortunately, it appears that conditions further inland (e.g., the Central Valley and the Sierra Nevada foothills) are too hot and dry to permit its spread there. There is an extensive research, monitoring, and education program—coordinated by the California Oak Mortality Task Force—to curtail the spread of this disease and minimize its impact.

MANAGING AND ENHANCING OAK RESOURCES

Livestock grazing has been the dominant land use throughout a majority of the oak woodlands since European settlement, and this use has contributed to the open, pastoral character of much of California's countryside. But it is also in portions of this region that the regeneration for several oak species has been poor, especially during the last 100 years. Cattle are the oft-named culprits since they consume acorns and seedlings and browse saplings and mature trees. They can also compact rangeland soils and remove organic matter. Compaction makes it harder for young roots to grow downward, and removing organic matter can diminish soil fertility.

However, there are situations where oak regeneration remains poor even when livestock are absent. Obviously the oak regeneration problem is more complex, and factors other than livestock are also involved. These may include the replacement of native perennial bunchgrasses by introduced Mediterranean annuals; greater hare, deer, gopher, and ground squirrel populations; insect and soil fauna changes; and alterations in the populations of acorn- and seedling-eating animals. Whatever the causes, it appears that management intervention is now needed—of both land and oaks—if oak trees are to continue their traditional and ecological role as a keystone species on the hardwood range.

OAK HEALTH CHECK



Check for tree growth

- Tree size is not a good indicator of health. Oaks growing on steep, dry sites may be smaller than others nearby but may still be very healthy.
- Twig growth for the season can vary greatly. If twig growth is less each year, however, the tree may be declining.
- Look for bark growth cracks on a tree's trunk. Cracks appear as widening fissures on existing bark. Tissue in the cracks should be bright green or pink when scratched. Loose bark indicates dead tissue.

Check for pests and stress

- Watch for disease or insect infestations indicated by leaf loss, changes in leaf color, twig dieback, sooty foliage, wet sticky foliage, or other significant changes in appearance.
- Watch for twig and branch dieback. This can be an indication of disease, root loss, or other root-zone problems.
- Watch for emergence of clumps of honey-colored mushrooms at or near the base of a tree in the fall and early winter. These are often accompanied by a white, fan-shaped fungal growth between the bark and sapwood. These symptoms accompany oak root fungus, *Armillaria mellea*.
- Early leaf loss may signal declining vigor—but not always. Deciduous oaks have been noted as being drought deciduous. This occurs during dry years when soil moisture is depleted early and oaks shed their leaves early to help conserve moisture. Deciduous oaks normally do not lose their leaves until late November—but under very dry conditions, they can shed leaves in midsummer. Early leaf loss appears to cause little long-term damage.

Check for structural weakness

- Oaks growing in a natural setting usually do not require pruning. However if dead or dying branches pose a safety hazard or threaten buildings, have them pruned or cabled by a qualified arborist.
- Watch for developing structural weaknesses caused by wood decay, mistletoe, heavy foliage, or poor branch structure. Co-dominant stems, branch attachments with included bark, long horizontal limbs, extensive decay in branches, and cracks developing in crotches are all indications of weak structure. Consult a qualified arborist to determine if pruning will improve structural stability.
- Avoid damage to structural roots.

Check for poor drainage

- Standing water should not be present within a tree's root zone.
- Building, landscaping, or other activities near oaks should not alter drainage patterns in a way that increases water in the root zone.
- Avoid compaction in the root zone.

Check the root crown condition by digging carefully at the base of the tree

- A characteristic root flare at the base of the tree should be obvious. If not, the trunk has been buried and the soil should be excavated to the original grade.
- Large decay pockets at the root crown may indicate a dangerous condition, and a qualified arborist should evaluate the tree for structural integrity.

In managing land, animals, plants, and other resources, there are many things landowners can do to encourage healthy, vigorous oak populations. Some basic management considerations are discussed in the following section. But, in making management decisions that affect your oaks, your greatest guidance may come from your own observations and experiences. Oaks, and the ecological settings where they grow, vary tremendously from place to place, meaning that no one type of management is appropriate for all situations. So, before making decisions, study what is actually taking place on your land and experiment with what you do. You may discover techniques that could also be useful to other landowners.

Oaks and Grazing Animals

Grazing and browsing animals are ubiquitous components of oak woodlands, but they can damage mature trees as well as seedlings. Watch your trees for signs of damage and take care that the number of animals congregating under them does not cause excessive soil compaction, expose the root crown at the base of the trunk, or expose surface roots. Also watch for excessive chewing on tree trunks. Horses and goats can kill trees by chewing off the bark around the entire circumference of the tree, thereby girdling it. These types of problems are more likely in pastures where animals are concentrated. Measures such as reducing numbers of animals, alternating pastures in use, and installing exclosures, screens, treeshelters, or other protective devices to keep animals away from sensitive

trees or seedlings can help alleviate problems. If damage is severe, you may want to consult a qualified arborist for remedial treatments.

Pasture management

In managing your pastures, always remember the general recommendation against summer watering of oaks. If your pastures are irrigated in the summer, adjust irrigation systems to apply water outside of the root zone only. Adjusting watering schedules to infrequent but long periods of irrigation will also reduce stress on oaks. Always try to keep the base of the tree dry. Observe the location of watering devices and other water sources to make sure that the area beneath an oak's canopy does not become wet from leaky water lines, valves, holding tanks, or from animals splashing in troughs.

Promoting Oak Regeneration

As noted previously, there is evidence that several species of native oaks in California—particularly blue oak, valley oak, and Engelmann oak—are

not regenerating well in certain areas of the state. In addition to poor natural regeneration, the total acreage of these species has been depleted from residential and commercial development, range improvement, agricultural conversions, and firewood harvesting. To ensure that these species remain important components of the natural landscape of California, it may be necessary to encourage natural regeneration or to actively restore oaks by planting acorns or seedlings. During the last 20 years, much has been learned about what works and what does not. Based on research and field trials, we now feel we can successfully regenerate native oaks, although it is often necessary to carefully plant and maintain them. Below are general guidelines for encouraging natural regeneration; collecting, storing, and planting acorns; growing seedlings in containers; and outplanting acorns and seedlings in the field. Additional information is available in *Regenerating Rangeland Oaks in California*, UC ANR Publication 21601 (see “References”).



Acorn production among California oaks is highly variable from tree to tree and from year to year.

Encouraging natural oak regeneration

Areas particularly favorable to natural regeneration include north-facing slopes, regions with average annual precipitation greater than 20 inches (50 cm), deep or alluvial soils, swales, or other places with subsurface water. Because seedling mortality is usually high, regeneration possibilities are best in areas that can remain free from grazing animals for several years and where existing mature trees provide acorns. Sites offering some natural protection, such as rocky or shrubby areas, or steep slopes that naturally exclude or impede the movements of deer and livestock, may also be favorable. In some areas small seedlings are abundant but larger saplings are rare or nonexistent. This often occurs because both domestic and wild animals repeatedly browse small seedlings, killing them or keeping them stunted. To enhance growth, seedlings can be protected from damaging animals by creating fenced areas, called exclosures, that protect seedlings from animals. Treeshelters (see description below) can be used to protect single seedlings, or larger exclosures can protect entire groves. In pastures grazed by cattle, research has shown that the season of grazing can influence damage levels. Damage is usually greatest in the summer and early fall when few other green plants are available. Grazing only during the green season, when other forage is abundant, can lessen damage and encourage greater seedling growth. Strategically placing water and feed supplements away from potential oak regeneration areas can also reduce damaging impacts to oaks.

Acorn collection, storage, and planting

Acorns are the seeds of oak trees. They begin to develop on the tree in spring, following pollination and fertilization, at about the same time the new leaves are starting to form. Oaks are wind pollinated, so environmental conditions at the time of flowering can affect the size of the acorn crop. Warm, dry, and windy conditions allow the pollen from male flowers, or catkins, to find receptive female flowers, resulting in larger acorn crops. Acorns ripen in the fall, usually in October and November. The acorns of some oak species ripen in a single year, while it takes 2 years for other species. When they mature in the fall, they begin to change color from green to yellow to brown, and the attachment to the acorn cup, or cap, loosens to eventually allow them to fall to the ground. However, one can pick acorns directly from tree branches before they fall to the ground and are consumed by birds, squirrels, or deer, or dry out and decline in quality. Acorns are ripe when they can easily be dislodged from the cup by gentle twisting. When the acorns are ripe, they can also be collected by hitting tree branches with long poles to dislodge them, then collecting them from the ground.

Once collected, all of the acorn cups should be removed before placing the acorns in a container of water. This float test helps separate healthy acorns from damaged or immature ones. Floaters are much less likely to be viable and should be discarded. Sinkers are surface dried and then put in plastic bags and placed in a refrigerator or cold storage unit maintained between 32° and 40°F (0° and 4.4°C). Acorns

rapidly lose viability if they dry out, so it is important to place them in plastic bags in cold storage soon after they are collected. They can be stored for several months, but members of the white oak subgenera, including both blue and valley oak, will germinate in cold storage and begin to grow a radicle, or new root. Acorns do not store well, and it is therefore important to plant them as soon as the soil becomes sufficiently moist after the first rains in the fall. They should be placed on their sides and planted between 0.5 and 1.0 inch (10 and 25 mm) deep. The chances of vigorous initial growth can be improved by excavating a hole several inches wide and up to 1.5 feet (50 cm) deep prior to sowing (and filling the hole back up with soil), which allows the initial root to more easily grow downward. Direct planting of acorns eliminates the root disturbance that occurs with transplanting seedlings and allows more natural root development.



Doug McCreary

Acorns can be collected from the branches of oak trees.

Growing oak seedlings in containers

An alternative to directly sowing acorns is to grow oak seedlings in containers and then plant them in the field. These seedlings often have higher survivorship than directly planted acorns, but they also cost far more. It appears that overplanting with acorns is often more cost effective per surviving seedling than planting container stock. When planting on a small scale, however, it may make little difference.

There are a variety of container types and sizes that can be used, but because oaks rapidly grow a deep taproot, it is preferable to use tall, narrow containers instead of short, wide ones. It is also important to prevent seedlings from growing so much that their roots fully occupy the available soil space in the container, causing the seedlings to become pot-bound. Before this occurs they should either be transplanted to a larger pot or planted in the field. Generally, oak seedlings should not be grown in containers of one gallon (3.8 liter) or less for more than a year. It is also critical to plant seedlings in the field early in the season—generally by the end of January—so that they can begin to grow roots before the soil starts to dry out.

Seedling planting and protection

Most oak woodlands in California have an understory of dense, non-native annual vegetation. These plants compete with oak seedlings for moisture and nutrients and can severely limit their growth and survival. It is therefore important that these plants be controlled. Eliminating weeds near planted oaks by scalping (i.e., hoeing),



Jack Kelly Clark

In a study at the Sierra Foothill Research and Extension Center, treeshelters were shown to help oaks become established.

spraying herbicides, or mulching can make the difference between survival and death for young oak seedlings. It can also enhance growth rates. Research suggests that maintaining a weed-free circle, with a 2-foot (60 cm) or larger radius, around seedlings for the first couple of years after planting increases soil moisture and promotes better survival and growth (McCreary 2001). Augering holes prior to planting can also improve seedling field performance on certain sites by allowing seedling roots to more easily penetrate downward where they can obtain soil moisture unavailable at shallower rooting depths. Fertilizing seedlings with slow-release fertilizer tablets at the time of planting has also resulted in significant increases in both diameter and height growth on certain sites.

However, even if healthy seedlings are planted correctly at the right time of year and competing

vegetation is removed, there still may be significant obstacles to overcome since a variety of animals seem intent on eating them. Oaks are vulnerable to herbivory from a range of animals, from small insects and slugs, to hares and rodents, to deer and cattle. One device that has proven particularly effective in protecting seedlings from a wide range of animals is a treeshelter. This is a double-walled, plastic tube that is placed over individual seedlings. It not only excludes a variety of animals, but it also stimulates seedling growth by acting as a mini-greenhouse.

If acorns or seedlings are planted after heavy rains when soils are moist, watering is not needed. Otherwise, it is a good idea to water planting sites thoroughly at the time of planting. Periodic watering during the first 2 or 3 years usually improves survival and growth, but it may not be logistically feasible for remote planting

sites. In these instances it is even more essential to eliminate competing vegetation. Although it is always helpful to remove competing weeds, supplemental irrigation may or may not be necessary. Average annual rainfall can also influence whether or not to irrigate. In areas that receive less than 15 inches (38 cm) of rainfall, watering the first couple of years, may be essential, while in areas that receive more than 20 inches (51 cm) of average rainfall, watering is often not necessary.

Maintaining genetic integrity

Regardless of whether you are planting acorns you collected yourself or seedlings grown by yourself or others (e.g., native plant nurseries, youth groups, or service clubs), it is important to use local seeds for all wildland plantings. Local ecotypes, or strains of species, have evolved in response to local conditions and are therefore best adapted for survival. Planting off-site material (i.e., acorns collected far from the planting site) is risky since unforeseen events (a rare freeze, for instance) can threaten their survival, even years after the initial planting.

Summary

Oak regeneration studies to date suggest that the survival and growth of native California oaks in a natural setting are often limited by harsh environmental conditions (McCreary 2001). However, by providing a more favorable environment through weed control, augering, watering, and protective tubes, rapid juvenile growth can be stimulated. This allows seedlings to quickly grow above the level where they are particularly vulnerable

to browsing pressures and thus helps ensure the success of regeneration plantings.

Wildlife Enhancement

Oak environments are among the richest wildlife habitats in the state; 110 species of birds use oak habitats during the breeding season, and 35 percent of California's land mammals utilize oaks during some time of their lives. California's deer herds are particularly dependent on oak habitats. By maintaining the health of your oak woodlands, you promote wildlife health and increase the abundance and diversity of both terrestrial and aquatic species.

Although a few animals can adversely affect oak seedlings, wildlife generally does not harm mature oaks and often provides important benefits through maintaining ecological

balances. For instance, blue jays are important acorn planters because they cache large numbers of acorns in the soil but do not retrieve all of them. Some of these germinate and develop into seedlings. The presence of wildlife also adds beauty to a woodland and value to property. Landowners can take some measures to increase the abundance and diversity of wildlife on their lands. Here are a few suggestions:

Leave brush piles in areas where they do not pose a fire hazard. These environments are used by quail for cover and by small animals for food and shelter, and they can provide nurseries for the natural regeneration of trees and shrubs.

Large, old trees, especially deciduous species, are particularly valuable for wildlife. They have abundant foliage for foraging birds and insectivorous bats, deeply furrowed



Bob Keiffer

Mule deer are common residents of California's oak woodlands.



Although oaks are long lived, all trees eventually die. Adequate regeneration is necessary for a species to survive and prosper.

bark that provides wildlife cover and insect prey, abundant acorns, and nesting cavities in large limbs and trunks, both living and dead. Fallen leaves and other material from the canopy provide nutrients under these trees that support a host of soil invertebrates. At the landscape scale, a large, lone tree provides connectivity between wooded patches, adds structural diversity, and may provide a safe stopping point for migrating birds. Large trees have been referred to as a keystone species; that is, their ecological benefits are disproportionate to their numbers. Large dead trees in woodlands, called snags, are generally rare, but they provide important cavity and perch sites. They should

therefore be retained, unless they pose a fire hazard or safety concern.

Coarse, woody debris (fallen limbs and trees) is valuable for invertebrate and vertebrate wildlife alike. Among terrestrial vertebrates (birds, mammals, amphibians, reptiles), large logs are especially valuable for reptiles and amphibians. However, recent research has shown that large wood is in short supply in over half of California's oak woodlands, apparently due to landowner efforts to reduce fire risk and to keep the woodlands looking clean and well maintained. It is therefore beneficial to retain large, woody debris whenever possible, as long as it will not interfere with other management practices, including fire-hazard reduction.

Shrub cover—that intermediate layer between tree canopy and ground cover—influences the existence of many small animals. It may supply all of life's requisites for some of these species, such as shrub-obligate birds. Examples of native shrubs that provide cover, as well as food, for wildlife include coffeeberry (*Rhamnus californica*), toyon (*Heteromeles arbutifolia*), and manzanita (*Arctostaphylos* spp.). Shrubs can increase the number of wildlife species inhabiting an area and may also function as refugia for wildlife during extended periods of drought.

Manage vegetation for diversity.

The diversity of wildlife depends upon the diversity of habitats and age classes of vegetation. If you maintain a diverse structure at the landscape scale (grassland, woodland, shrubland), as well as a diverse structure at the local scale (tree, shrub, and ground covers), you encourage a greater diversity of wildlife. Mixed stands of oaks (i.e., both evergreen and deciduous species) are also advantageous since they provide a greater variety of habitat elements.

Wetlands. Probably no component of oak woodland habitat is more important for wildlife than riparian and other wetland areas. Because of the multiple layers of vegetation in wetlands (ground, shrub, and tree), wetlands support numerous species of wildlife, including many threatened and endangered species. However, wetland areas are particularly sensitive to management practices, such as intensive grazing, and so they should be monitored carefully. Oaks along streams help stabilize the banks, and

by shading the stream, they help keep the water cool for native trout and other fish. If dead oaks or branches fall into streams, consider leaving them if they do not present a flooding hazard. Woody debris in streams helps to create pools and provides structure and cover for native fish, including trout, and for amphibians and invertebrates.

Thinning. Individual oaks and groves of oaks can be thinned to meet specific landowner needs. Thinning can increase residual tree growth, stimulate young trees, produce firewood, encourage wildlife, increase forage for livestock, and improve fire safety. The degree of thinning and the selection of trees depend on the nature of the woodland and the objectives of the landowner, but it is important to avoid thinning too heavily. Generally, it is a good idea to leave at least 30 to 40 percent canopy cover following thinning.

Commercial endeavors. Because of ever-increasing demands of a growing human population on dwindling open space resources, owners of rural and semirural woodland areas can use their lands for a variety of commercial ventures that ideally are compatible with native oaks. Some potential crops are Christmas trees, specialty nursery plants, or mushrooms. You can also open your lands for fee-based recreational uses such as camping, hiking, hunting, horseback riding, bird watching, photography, fishing, or mushroom picking. Increasing income to owners of large woodland parcels may help them retain their properties as wildlands rather than selling them to developers.

COMMUNITY ACTIVITIES

Throughout California, landowners are coming together to solve common problems in their oak woodlands. Many regional problems can only be solved by landowners working together in innovative ways. Here are a few examples of landowner efforts:

Landowner associations. In many areas, particularly newer subdivisions, landowner associations are working on a variety of issues, including fire safety, regional landscaping, and woodland protection. One excellent example initiated over 20 years ago is the Portola Valley Ranch, a Hardesty Associates project. This planned unit development in the foothills of the Santa Cruz Mountains includes areas of shared oak-woodland open space that are managed and maintained by the Ranch Homeowners Association.

Open space easements and dedications of land. In many areas individual landowners, entire developments, and local land trusts are dedicating lands to open space uses through conservation easements and a variety of other legal tools. Landowners dedicating such lands often receive tax relief and, in some instances, cash payments. Conservation easements restrict future development but allow normal management activities, including grazing, farming, and even tree harvesting. The Nature Conservancy, the Trust for Public Land, and the California Rangeland Trust are just a few of the organizations that operate such programs, along with many small community land trusts.

Community and watershed groups. These have developed throughout California to sponsor a variety of education, protection, and woodland enhancement activities. These groups pursue public awareness and educational programs, tree planting projects, registry programs for significant individual trees, and lobbying efforts with local jurisdictions to protect a variety of natural resources, including trees. Two excellent examples are the Sacramento Tree Foundation and the Putah Creek Council, both of which have been in operation for more than 20 years.

Carbon Sequestration

There is a wealth of scientific data indicating that carbon dioxide concentrations in the atmosphere have increased dramatically in the last century. Many believe this will result in climate change and, more specifically, global warming. California has become a leader in committing to reduce greenhouse gas emissions that contribute to elevated atmospheric CO₂ concentrations. One new approach has been to promote a cap-and-trade system whereby those generating emissions can purchase carbon offsets equal to the amount of carbon they emit. Since oak woodlands store considerable carbon in tree biomass, including roots, property owners may soon be able to sell carbon credits to emitters. While this approach is new and it is hard to predict how effective it will be in reducing emissions, California and its California Air Resources Board (CARB) are at the forefront of implementing this new approach.

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Online Resources

- California Oak Mortality Task Force Web site, <http://nature.berkeley.edu/comtf/>.
- California Oak Foundation Web site, www.californiaoaks.org/.
- California Native Plant Society Web site, www.cnps.org/.
- UC Oak Woodland Web site, http://ucanr.org/sites/oak_range/.
- Wildlife Conservation Board Web site, www.wcb.ca.gov/.

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