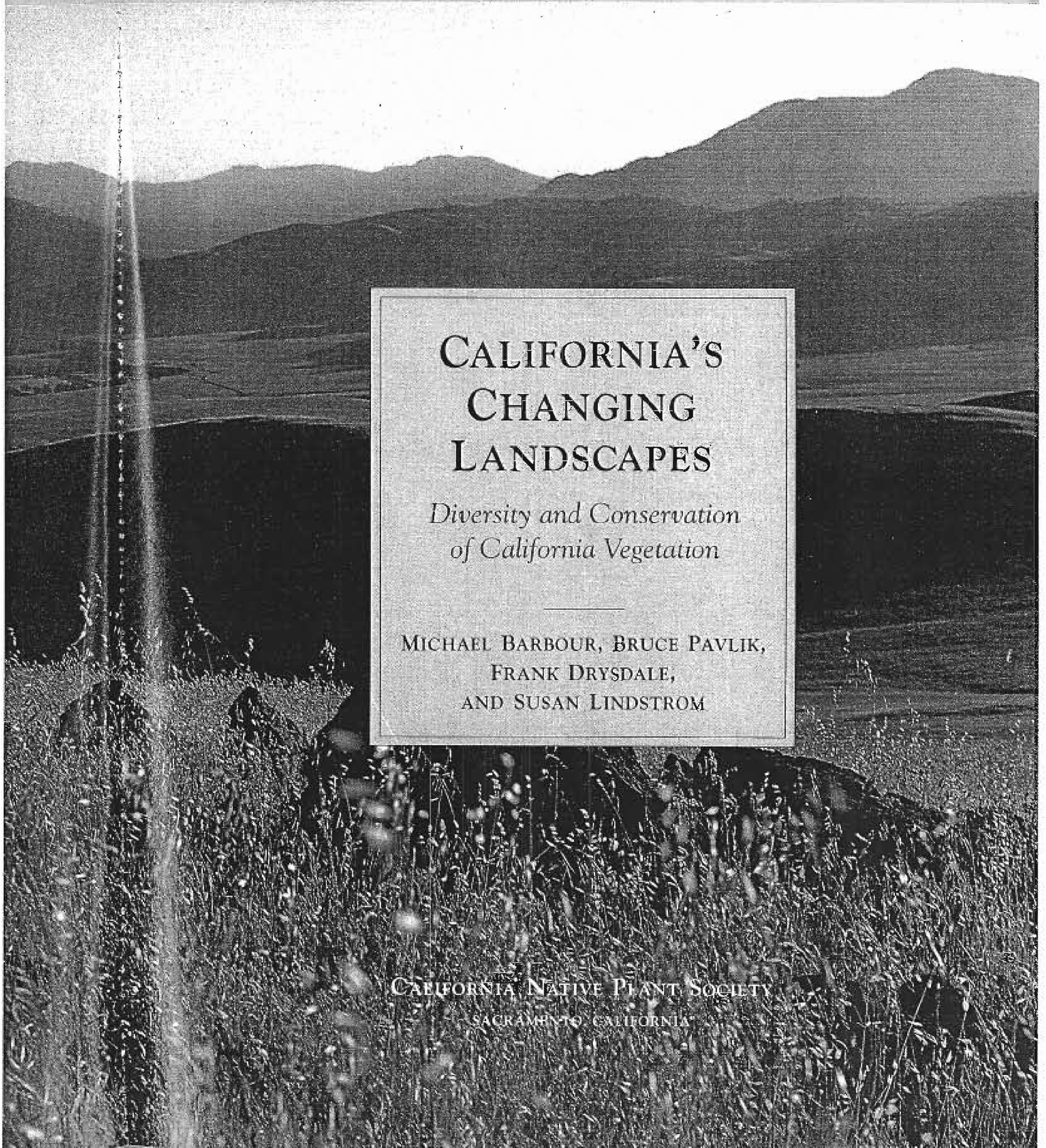

California's Changing Landscapes

Diversity and Conservation of California Vegetation

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California Native Plant Society
Sacramento, California

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Editor: Phyllis Faber
Contributing Editors: Barbara Leitner, Nora Harlow
Designer: Beth Hansen
Typesetting / Linotronic: Beth Hansen / Canterbury Press
Color Conversions: Sieg Photographics
Color Separations: Colortec
Printing: Lorraine Press

This book was set in Goudy and printed on 80# Sterling Gloss.

Printed and bound in the United States.
ISBN 0-943460-17-4
Library of Congress Catalog Card Number: 92-076201

Cover: Grassland wildflowers in spring, northern Los Angeles Co.

Back cover: Soil erosion on Santa Catalina Island caused by overgrazing from goats, pigs and deer.

Title page: Annual grasslands of Merced Co., golden in summer and fall.

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VALLEY HEAT

Riparian forest along the Sacramento River, dominated by Fremont cottonwoods and lianas of California grape.

ON A LATE SUMMER DAY 143 YEARS AGO, EDWARD BELCHER WAS aboard a small boat making its way up the Sacramento River from the delta. A captain in the British navy, he was impressed with the jungle-like wall of vegetation that lined the rivers. He wrote that the banks were:

> *. . . well wooded, with oak, planes, ash, willow, walnut, poplar, and brushwood. Wild grapes in great abundance overhung the lower trees, clustering to the river, at times completely overpowering the trees on which they climbed, and producing beautiful varieties of tint. . . Within, and at the very edge of the banks, oaks of immense size were plentiful. These appeared to form a band on each side, about three hundred yards in depth . . . Several of these oaks were examined. . . The two most remarkable measured twenty-seven feet and nineteen feet in circumference, rose perpendicularly at a (computed) height of sixty feet before expanding its branches, and were truly a noble sight.*

Twenty-five years later John Muir crested the Coast Range on his first walk through California. It was spring, just after his thirtieth birthday, and the sight of the Central Valley spread before him provided him with great passion and joy:

> *When I first saw this central garden. . . it seemed all one sheet of plant gold, hazy and vanishing in the distance. . . Descending the eastern slopes of the Coast Range through beds of gilias and lupines. . . I at length waded out into the midst of it. All the ground was covered, not with grass and green leaves, but with radiant corollas, about ankle-deep next to the foothills, knee-deep or more five or six miles out. . . The radiant, honey-ful corollas, touching and overlapping, and rising above one another, glowed in the living light like a sunset sky—one sheet of purple and gold. . . Sauntering in any direction, hundreds of these happy sun-plants brushed against my feet at every step, and closed over them as if I were wading in liquid gold. The air was sweet with fragrance, the larks sang their blessed songs, bees stirred the lower air with their monotonous hum. . . and small bands of antelopes were almost constantly in sight, gazing curiously from some slight elevation and then bounding swiftly away with unrivaled grace of motion.*

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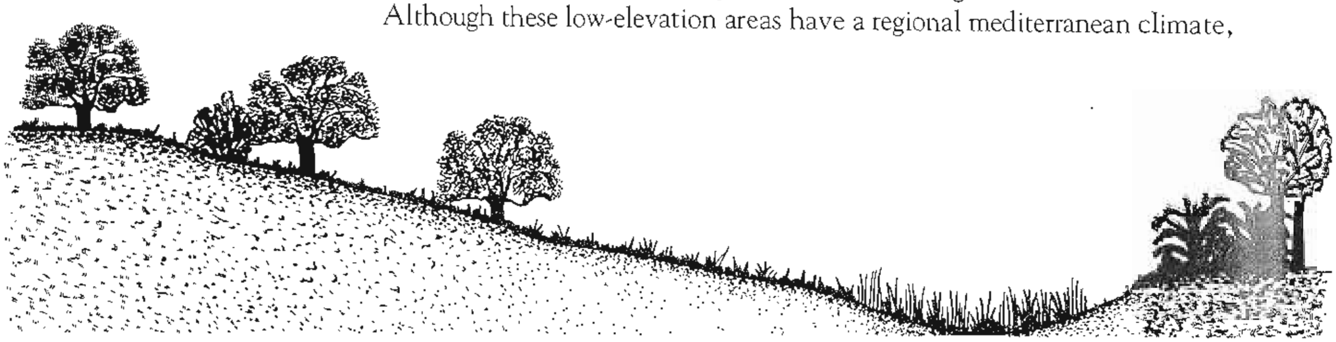
Poppys and bush lupines (right) on the edge of foothill woodland in the Central Valley.

Cross-section of the western half of the Central Valley (below), as it appeared a century ago. Foothill woodland (a) leads down to savanna and finally grassland (b), then to tule marsh in the depression (c), and finally to riparian forest (d) on natural levees built from flood-borne sediments. Distances are not to scale.

The Central Valley of California, measuring sixty miles wide by 400 miles long, includes fifteen percent of the state's total area. In Captain Belcher's day, and even in Muir's, it contained a rich assortment of vegetation: wet tule marshes, tangled riparian forest, open prairies, rolling oak woodland, and dry chaparral on steep hillsides. Today, most of this vegetation has been dramatically changed by a post-gold rush human population which cleared, drained, cultivated, and built upon the land. Settlers also introduced weedy, aggressive plants from other mediterranean-climate regions of the world, and these have contributed to the displacement of vegetation native to the Central Valley.

A similar range of vegetation types, in a similar landscape, occurs along the central coast in the Salinas Valley and along the southern California coast from the Los Angeles Basin to San Diego and on into rolling hills east of there.

Although these low-elevation areas have a regional mediterranean climate,



one of the vegetation types present is an ancient relict of a summer-wet climate that existed in California more than twenty million years ago. This vegetation has been able to persist because it lives in a microenvironment that has abundant summer moisture from creeks, streams, and rivers: the riparian habitat.

The Riparian Forest

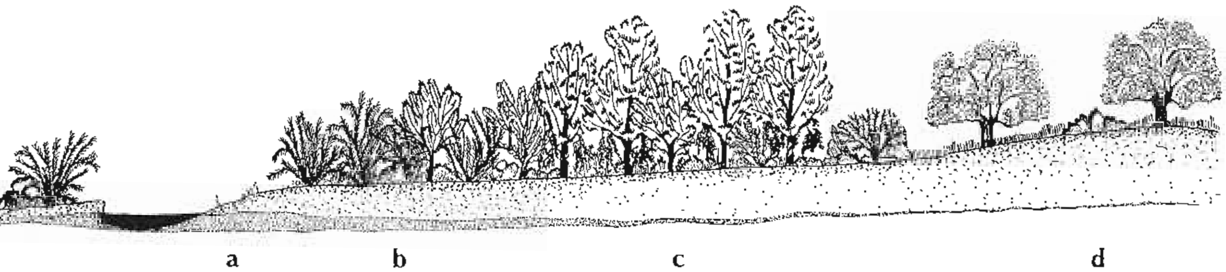
The word riparian comes from the Latin *ripa*, a stream bank or river bank, or *riparius*, growing along a bank. Riparian vegetation is the vegetation along the shores of bodies of fresh water. Along low-elevation rivers in California riparian vegetation is typically a rich forest with a mixture of genera that make Easterners feel at home: oak, maple, willow, sycamore, walnut, ash, alder. Riparian vegetation creates a diversity of wildlife habitat. Fish and amphibians thrive in the cool waters of sheltered stream banks, while a wealth of birds and mammals feed, breed, and migrate within the riparian overstory.

Approximately twenty million years ago, when the north temperate zone was wetter and less seasonal, much of North America was covered by a nearly continuous forest belt of these broadleaved species, mixed with some conifers. As mountains rose and the climate warmed and dried, the continent's center became too severe for this mesic forest. The forest segregated into two parts. It continued to have broad coverage in what today is the eastern United States, which experiences cold winters and wet, humid summers. But in drier western areas it became restricted to the riparian zone. Along these waterways the trees sink roots down to a shallow, permanent water table and thus are able to compensate for dry summer weather. Despite the fact that Central Valley winters are mild, these trees retain a cold-winter ancestral trait: they drop their leaves in winter. A winter-deciduous habit is rare in low-elevation California, yet most woody species of the riparian forest are winter-deciduous.

Flooding often inundates shrubby willows and cottonwoods adjacent to major rivers.

As a river meanders, there is an eroding bank on one side and accumulating sediment on the other. On the sediment side vegetation zones spatially replace each other. First there is sediment kept bare by the frequency and duration of flood waters. Few species are capable of tolerating continuous flooding, which prevents roots from obtaining adequate oxygen and causes poisoning of plant tissues by an accumulation of the chemical products of incomplete respiration. Some riparian trees with tiny, wind-blown seeds require bare sand or silt on which to germinate, but they will survive only if the frequency and duration of flooding lessens—exactly the situation just a bit higher and farther from the water.

Slightly above the continuously flooded area is a shrub zone dominated by willows. The shrubs grow densely and their branches and roots trap sedimenr,

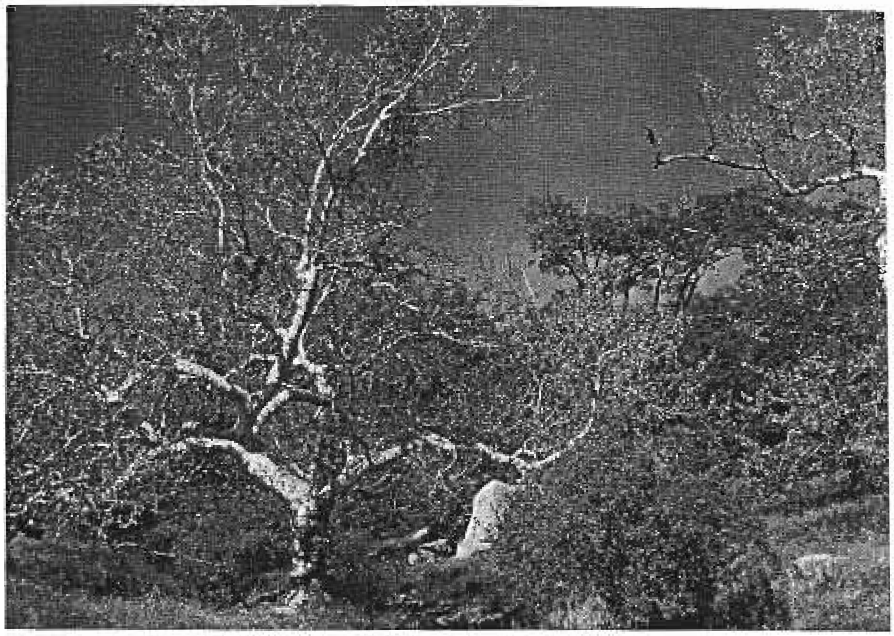


Cross section through the riparian zone. Nearest the water is an almost bare strip (a) frequently scoured by river flows. Above this is a shrub-dominated area of willows (b). Yet higher is the riparian forest (c), with several canopy layers and dominated by Fremont cottonwood. Highest and least frequently flooded, is valley oak woodland or savanna (d).

creating a natural levee. Young Fremont cottonwoods (*Populus fremontii*) may be seen growing up through the willows. Still higher, on banks five to twenty feet above the water, is the riparian forest described by Belcher. Its overstory averages eighty feet tall and is dominated by cottonwood associated with valley oak (*Quercus lobata*), white alder (*Alnus rhombifolia*), arroyo willow (*Salix lasiolepis*), and Oregon ash (*Fraxinus latifolia*). Tree density is high, averaging 100 individuals per acre. About forty percent of all the trees in this area are cottonwood. California black walnut (*Juglans hindsii*) is commonly found in this zone, but its distribution has been extended by humans, who planted it and encouraged it because of its food value. Below are layers of sub-dominant box elder (*Acer negundo* ssp. *californicum*), coyotebrush (*Baccharis pilularis* ssp. *consanguinea*), blackberries (*Rubus* ssp.) sand wild rose (*Rosa californica*), and many annual and perennial herbs. California grape (*Vitis californica*), poison oak (*Toxicodendron diversilobum*), and Dutchman's pipe (*Aristolochia californica*) climb up tree trunks and into the tangled canopy.

The cottonwood zone of the riparian forest has the most complex architecture of any California vegetation, and the richest collection of animal species. More species of birds nest in this forest, for example, than in any other California plant community. Also, twenty-five percent of California's 502 kinds of native land mammals depend on riparian habitat. Of these, twenty-one are facing threats of extinction through habitat loss.

A fourth zone, farther back from the water, is the valley oak forest or woodland. Though its overstory contains many species of rhe cottonwood zone, about seventy-five percent of the trees are valley oak. Valley oak is one of the largest oaks in the world, and trees can reach trunk diameters of twelve feet, heights of 150 feet, crown diameters of 150 feet, and ages of 300 to 500 years. Equally large California sycamores (*Platanus racemosa*) accompany the oaks, and these massive trees appear evenly spread in a park-like setting over a continous ground cover of grasses and forbs. Both oak and sycamore grow best where the water table is about thirty-five feet below the surface and flooding is occasional, in contrast to alder and cottonwood, which dominate where the water table is only ten to twenty feet deep and flooding is frequent.



Cleared of trees, the coarse levee soils have proven ideal for orchards of pears, peaches, apricots, and walnuts. Some of the most expensive farmland in the state exists today where riparian forest once stood. As a result, less than ten percent of the Central Valley's original riparian cover remains. Two centuries ago the Central Valley had more than 900,000 acres of riparian forest. About 800,000 acres remained in 1848, and today less than 100,000 riparian acres still exist, more than half of which is degraded and in poor condition.

Freshwater Tule Marsh

In pristine times the riparian forest extended away from the major rivers for a distance of three miles on either side. The natural levees, built up of coarse sediment deposited by annual floods, gradually dropped off in height away from the river and led into low-lying land which held flood waters or rain runoff for months at a time. These lowlands, up to five miles across on either side of rivers, supported dense stands of tules or bulrushes (*Scirpus acutus*, *S. californicus*) (Chapter 2). Tules are reed-like plants which reproduce vegetatively from rhizomes and send up green, leafless stems five to ten feer tall.

The original two million acres of tule marsh provided essential habitat for migratory waterfowl along the Pacific flyway. Nineteenth-century settlers found it easier to navigate this part of the Central Valley by boat than by land during winter and spring. Malaria, introduced to the west coast by Captain Cook's crew, was a serious ptoblem in this part of California. During the twentieth century tule marshes wete diked, drained, cleared, and planted with vegetables to such an extent that today only local ribbons or patches of marsh remain.

A dramatic example of the loss of marshland was the extermination of Tulare Lake. An extensive tule marsh once existed around rhe shores of this San Joaquin

Winter-deciduous California sycamores and evergreen oaks form a narrow riparian zone along this small stream.

Valley lake. Nineteenth-century surveyors and settlers described it as over 700 square miles in area, reaching depths of over sixty feet. Its size varied from year to year, depending on snowpack in the Sierra Nevada. The lake was fed by the Kings, Kaweah, White, and Tule rivers and was situated in a region that otherwise received only six inches of annual precipitation. Lake waters filled a basin with no outlet. Surrounding it was a band of tules two to three miles wide. Tulare comes from the Spanish word for tules, *tulares*.

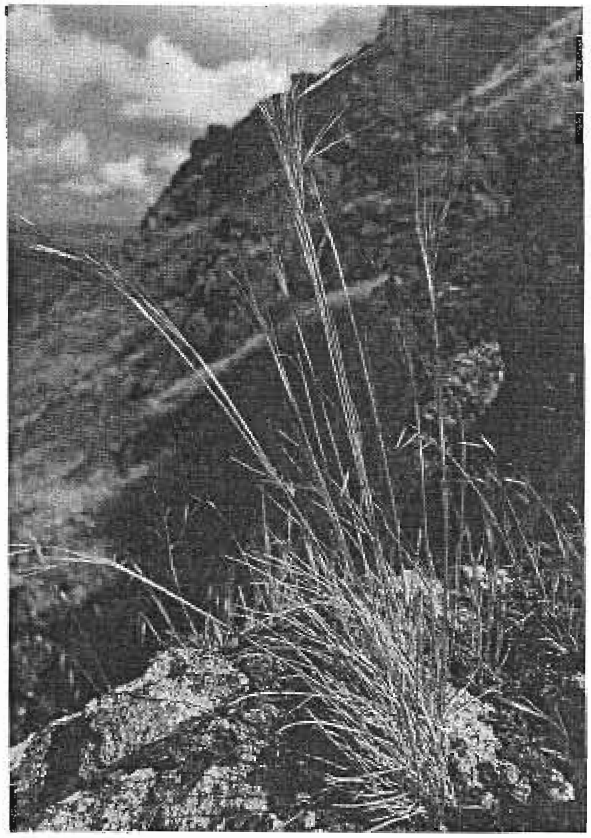
The local Yokuts traveled over the lake's surface on rafts made of tules, much as other Native Californians traveled in the San Francisco Bay area. According to historian Gerald Haslam, food was so plentiful in the area that the Yokuts had no stories of starvation in their oral history. Turtles, fish, beaver, and otters were abundant. Jedediah Smith took 1,500 pounds of beaver pelts in a single visit during the 1820s. Terrestrial animals such as antelope, bear, coyote, and elk were also common. Wildfowl were there in "multitudes," according to John Fremont during an 1844 visit. Professional hunters and fishermen sent waterfowl, fish, frogs, and turtles north to San Francisco until the turn of the century.

During the early part of the twentieth century the Homestead Act promoted settlement in the San Joaquin Valley and diversion of river water to irrigation, rather than to Tulare Lake. Dam construction in the 1930s dried the lakebed, and the surrounding tule area was converted to farmland. "The sloughs, the channels, the tules are gone," Haslam writes in his article, When Bakersfield was an Island. "So are the antelope and Yokuts who once prospered there. In fact, Tulare Basin is gone—drained, plowed, transfigured. It remains only a haunting geography of the mind. . . a ghost fading from even the possibility of memory."

Tule marsh, however, does preserve some memory of the vanished ecosystem. Soil beneath tule marsh is black from partly decomposed organic matter, and it is this organic storehouse which makes tule soils so fertile. Wherever black soil is visible between crop plants, there is a former tule marsh. One problem associated with farming organic soil is that aeration promotes decomposition, and the land surface falls. Cumulative subsidence in some delta areas now amounts to twenty feet, so that the tops of orchard trees are level with delta water, kept back only by surrounding levees. When a break in a levee occurs—as has been common every year in the delta of the San Joaquin and Sacramento rivers—flood waters rapidly fill the new lowlands and expensive pumping is required to reestablish dry land.

Grassland

The original California grassland blanketed much of the Central Valley and low elevations along the central and southern coast. It covered more than thirteen million acres and an additional nine-and-one-half million acres with an oak overstory. The original grassland supported large herds of pronghorn antelope, deer, and tule elk. Several of these animals had populations which were genetically unique to the Central Valley, suggesting a lengthy association between vegetation and grazing animals.



Purple needlegrass, a native perennial bunchgrass that once dominated Central Valley grassland. Here it thrives on a rocky outcrop beyond the reach of domestic livestock.

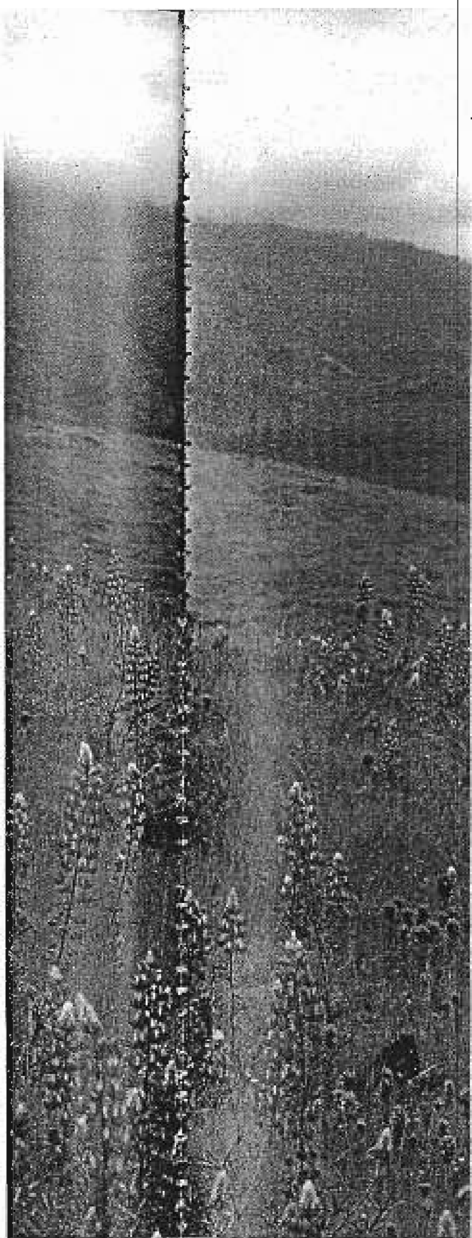
Geologists call the Central Valley a trough of mud—not very flattering to those who live there, but historically accurate. The grasslands that cover rolling upland slopes of the Central Valley sit upon sediments deposited as mud on the floor of ancient seas. The oldest sediments date to 140 million years ago; by 1.5 million years ago the sea had been displaced by its own sediment, and the Centtal Valley became dry land. Thereafter, additional sediments deposited wete of material eroded from Coast Range and Sierra Nevada uplands, and of volcanic ejecta thrown down from Mount Shasta, Mount Lassen, and Sutter Buttes. Soils that have since developed from these parent materials are generally deep, brown, loamy, and rich in nutrients.

The Central Valley grassland was floristically different from the cooler, wetter northern coastal prairie. The original grassland no longer exists. What it once looked like and contained can never be known fot sure, because early accounts by travelers were too vague. The best guess—and it is only a guess—is that it was dominated by two species of needlegrass (*Stipa cernua, S. pulchra*), both of which are perennial bunchgrasses with flowering stems that grow to several feet above the ground. In the open space between the clumps of grass grew annual grasscs and annual and perennial forbs such as those described by Muir on his century-old trek. In spring these forbs grew lush and flowered in a spectacular show, so at that time they—not the bunchgrasses—were the dominants of the grassland. But the annuals were gone by June, and the bunchgrasses remained. Most grazing animals moved upslope, out of the grassland, in summer and returned when winter rains brought new germination and growth of the herbs.

Natural fires started by dry lightning strikes and fires purposely started by Native Californians probably burned large parts of the grasslands every year. Fire cteated a nutrient-rich ash and removed thatch, stimulating luxuriant regrowth of herbs the following wet season. Fire also prevented woody plants from becoming established.

in a cluster above ground and unprotected, is not adapted to heavy grazing. An entire plant can easily be grazed to death.

There is some controversy about the tolerance of bunchgrasses to grazing. Stephen Edwards, director of the East Bay Regional Parks District, has pointed out that the Ice Age collection of grazing-browsing-trampling animals in California grasslands was diverse and numerous, and that bunchgrasses therefore evolved with more grazing pressure than some ecologists believe. Furthermore, bunchgrasses dominate the animal-rich east African savanna, where they are seasonally grazed to a level of only one to two inches. The key word is probably seasonal. Pristine California grasslands and modern African savannas survived only episodic or seasonal grazing. When livestock were introduced to California, the animals no longer ranged upslope off the grassland in summer, as native grazers had, but remained all year.

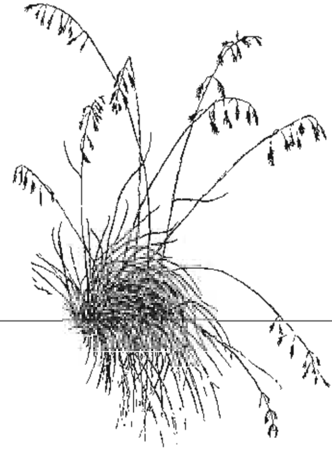


Native annual forbs, such as lupine and owlclover (left), produce showy grassland displays during the early spring months. In the original Central Valley grassland, these species probably clustered in patches between native bunchgrasses.

In the Central Valley grassland of today, native lupine and owlclover (right) are often scattered across a sea of non-native annual brome grass (Tehachapi Pass, Kern Co.).

Cattle ranching in California began in 1769 on the coast, when the Spanish brought about 200 head of cattle to San Diego. By 1823 livestock raising was an established activity, to various degrees, at all twenty-one missions. Mission San Gabriel, near Los Angeles, owned seventeen cattle and horse ranches and fifteen for raising sheep, goats, and pigs. It is estimated that by the early 1820s San Gabriel had close to 100,000 head of cattle alone. The San Francisco Bay missions had more than 40,000 cattle, as well as other livestock. Mission Dolores used the east side of San Francisco Bay as a sheep ranch. At its peak, the missions may have had more than 400,000 cattle grazing one-sixth of California's land area.

In contrast, grazing in the Central Valley was light until the gold rush period



California Fescue.

after 1850. Large wild animals diminished while domestic animals rapidly increased. In 1860 the U.S. Census reported nearly one million beef cattle (not including open range cattle), just ovet one million sheep, and 170,000 horses and mules for all of California. As range quality declined, sheep ranching gained in favor. The numbet of sheep peaked at 5.7 million in 1880. By this time overgrazing and a decade of drought had taken a permanent toll on the perennial Central Valley grassland.

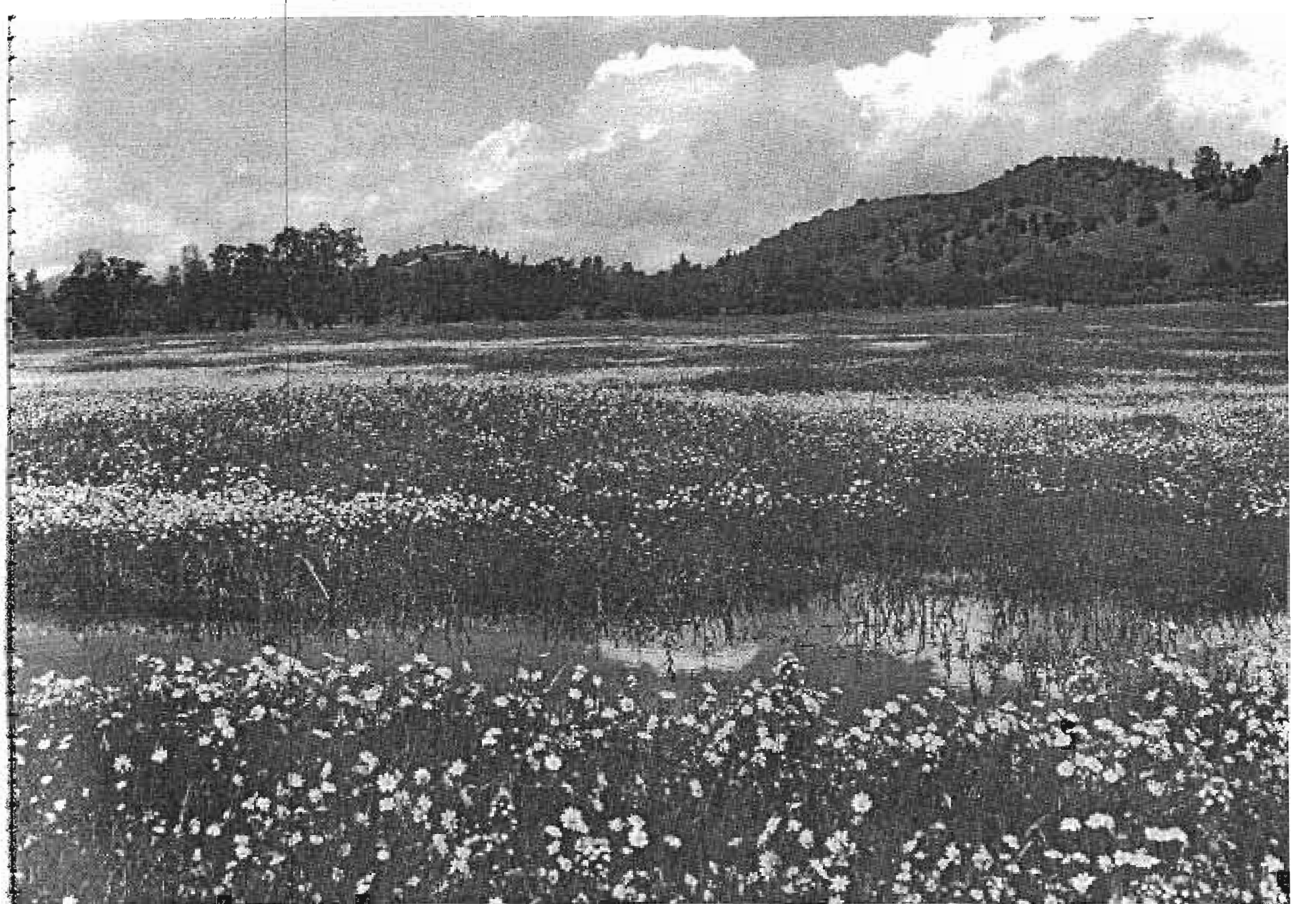
The second source of change in the grasslands was competition from introduced annual plants, most originating in Europe and Asia. When a perennial grass and an annual grass germinate together in a bare spot, the annual tends to win the race for domination because it produces a deeper, more extensive root system more quickly than the petennial. The annual robs the perennial of soil moisture and soil nutrients, then channels these stolen resources to its own shoot system. It produces more leaves and stems and again exploits the neighboring perennial—this time of sunlight. So while livestock were chewing back perennials, weed seeds from other parts of the world were invading the bare site created by grazing and further inhibiting the perennials.

Another factor weighing heavily against the survival of bunchgrasses is the relative palatability of native grasses compared with introduced annuals. Introduced annuals, because of their shott life spans, are unavailable for grazing most of the yeat. Some, such as tipgut btome (*Bromus diandrus*), possess long, stiff awns on flowering stalks, which mechanically deter grazers. Others have a lower nutritional value than the native perennials. For all these reasons, domestic livestock tend to feed more intensively on native species.

Experimental fenced exclosures, which have kept livestock out of grassland fot decades, typically show little recovery by native perennials. Apparently the annual weeds are such aggressive competitors and occur in such large numbers that they inhibit the return of perennials even when grazing stress is removed. Aggressive plants were inadvertently introduced by Father Serra and the first Euroamerican settlers. The numbers of both weeds and settlers have grown ever since. Today 500 weed species are well established in the Central Valley. The most common grassland dominants now are all introduced European annuals: filaree (*Erodium* spp.), soft chess (*Bromus mollis*), wild oat (*Avena fatua*), ripgut btome, ryegtass (*Lolium* spp.), foxtail (*Hordeum jubatum*), fescue (*Festuca* spp.), and California bur-clover (*Medicago polymorpha*).

The standing water in this vernal pool is surrounded by concentric rings of goldfields, tidy tips, annual lupines, and owlclover (near Jolon, Monterey Co.).

Cultivation also contributed to the replacement of the original grassland with annuals. Gtassland soils are excellent agricultural soils, supporting such crops as alfalfa, corn, sugar beets, cotton, tomatoes, and grapes. The largest acreage ever cultivated was during the 1880s, despite the fact that it was all dry land fanning without any extensive irrigation. During the twentieth century some previously cultivated land proved unprofitable and was allowed to revert to pasture or unmanaged cover.

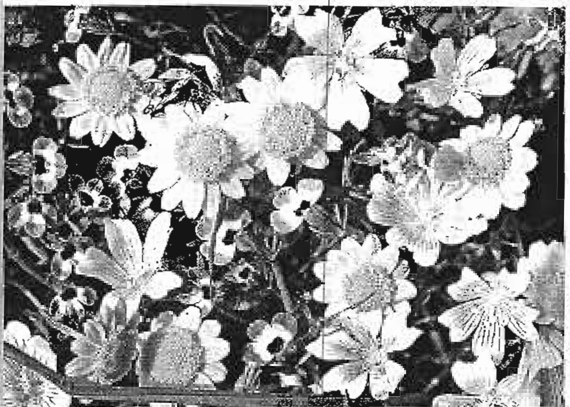


Islands in the Grass: Vernal Pools

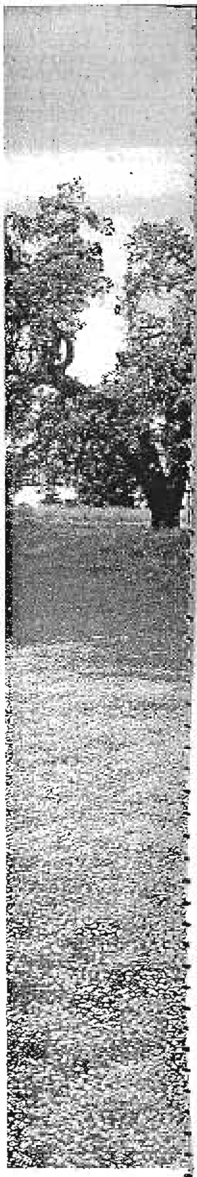
Certain areas within grassland are intensely, dramatically splashed with blue, yellow, and white in spring. Viewed from above, the drops of color on the landscape are shaped into circles, lines, and swirls that sometimes connect and sometimes are separate from one another. On the ground, at eye level, it is easy to detect a rolling, hillocky topography, and to see that the radiance of color comes from basins between hillocks. This is a special California place, the land of vernal pools.

The elevational difference between hillock tops and bottoms is only a few feet, but that difference turns out to be important to grassland plants. A layer of rock-hard soil, about two feet below the basins and four feet below the hillock tops, underlies these local areas. In winter the hardpan prevents water from penetrating deeper into the soil. The upper soil becomes saturated and water fills the basins, forming pools. As rainfall stops and temperatures rise in late spring, rings of vegetation left above the evaporating pool of water grow and flower, creating patches of explosive color. These basins are called vernal pools, and the plants which grow in them are called vernal pool species.

Some of the best known vernal pool species are collectively called goldfields



(*Lasthenia* spp.)—small but intensely yellow members of the sunflower family. Other colorful and equally small vernal pool plants include meadowfoam (*Limnanthes* spp.), popcornflower (*Plagiobothrys nothofulvus*), downingia (*Downingia* spp.), butter-and-eggs (*Orthocarpus erianthus*), and checker-bloom (*Sidalcea* spp.). Less colorful but characteristic plants include coyote thistle (*Eryngium vaseyi*), annual hairgrass (*Deschampsia danthonioides*), tidy tips (*Layia fremontii*), spike rush (*Eleocharis* syn. *Heleocharis* spp.), and woolly marbles (*Psilocarphus tenellus*). All are annual herbs, and all are native species. Vernal pools have not been invaded by the introduced annuals which dominate surrounding grassland and hillock tops, probably because introduced species are not able to tolerate flooded soils low in oxygen.



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Possibly all vernal pools would have disappeared by now were it not for the fact that the underlying hardpan makes the land unproductive and expensive to improve. In winter the soil is saturated, leaving crop roots without sufficient oxygen, and in summer the shallow topsoil dries, leaving crop roots stranded, unable to penetrate to deeper, wetter, layers. To farm such land, hillocks and basins must be leveled, then the land ripped by a massive clawed rig dragged behind a large tractor. As many as three passes, in different directions, are necessary to disrupt the hardpan. To plant an orchard, the entire area need not be ripped, but a hole must be blasted for every sapling.

The vivid yellow flowers of this vernal pool contrast with the deep greens of the surrounding valley oak savanna (near left). Close inspection often reveals a wealth of species, including the blossoms of meadowfoam (white) and goldfields (yellow) near the higher, outer edges of the pool (top). As the pool slowly dries, a mixture of downingia (violet and white) and tricolor monkeyflower may be found towards the pool center (middle). With additional drying the lowest, muddy bottom may be dominated by tricolor monkeyflower later in the spring (bottom).

Why hardpan forms in some soils and not in others is poorly understood, but a long passage of time seems to be required. Vernal pool soils such as those beneath pygmy forest are among the oldest in the world—up to 600,000 years old, in contrast to most soils which are 20,000 years of age or younger. During this long period of time, clay, iron, sand (silica), and organic material are leached down into the soil profile, eventually cementing together. Some hardpans consist primarily of clay and then are best called claypans, while others are constructed of iron and silica. Alkali pools in Solano and Merced counties have hardpans made of lime and silica, and pools on the Mesa de Colorado in Riverside County owe their existence to a shallow soil over a hard volcanic patent material.

Every Central Valley county contains vernal pools, but they are most abundant in Fresno, Madera, Merced, Placer, Sacramento, Solano, Tehama, and Yuba counties. Pools also occur outside the Central Valley in several southern California counties and within vegetation types above grassland, such as oak woodland and chaparral. Most pools are less than 7,000 square feet in area, but a few cover tens of acres and are temporary lakes. In pristine times vernal pools may have covered one percent of the state's area, but conversion to agriculture or urbanization has reduced this by eighty percent.

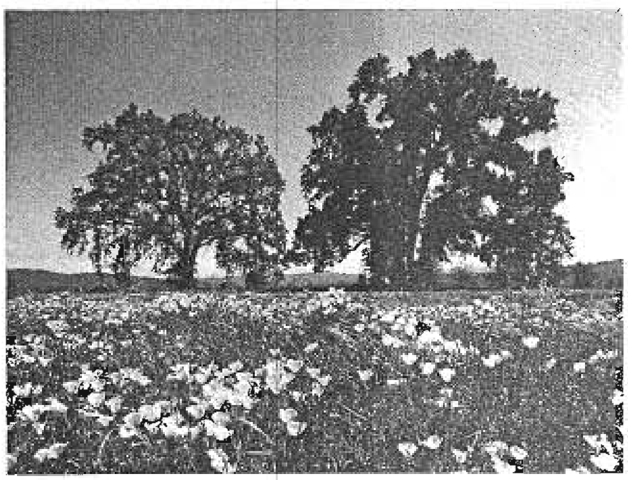
The destruction of vernal pool habitat is a profound aesthetic loss to the original grassland landscape. It is also a loss for science, because vernal pools are excellent natural laboratories for the study of plant evolution. Each pool is like an island or mountain peak, surrounded by inhospitable land unsuited for plant colonization. As a result of this isolation, many vernal pool genera contain swarms of species and varieties, each restricted to a few pools in a local area. Indeed, the vegetation in each pool is probably genetically unique, representing an evolutionary result of tens of thousands of years of geologic time. Because many species are rare and endangered, vernal pools should be fully protected.

Above the Grass: Foothill Woodland

If the citizens of California were to select a state vegetation type, as they already have selected a state flower, state bird, state mineral, and state butterfly, then foothill woodland would be a logical choice. Oaks in the foothill woodland nurtured the highest densities of Native Californians in the entire state. The chain of Spanish missions and the early network of Spanish land grants paralleled

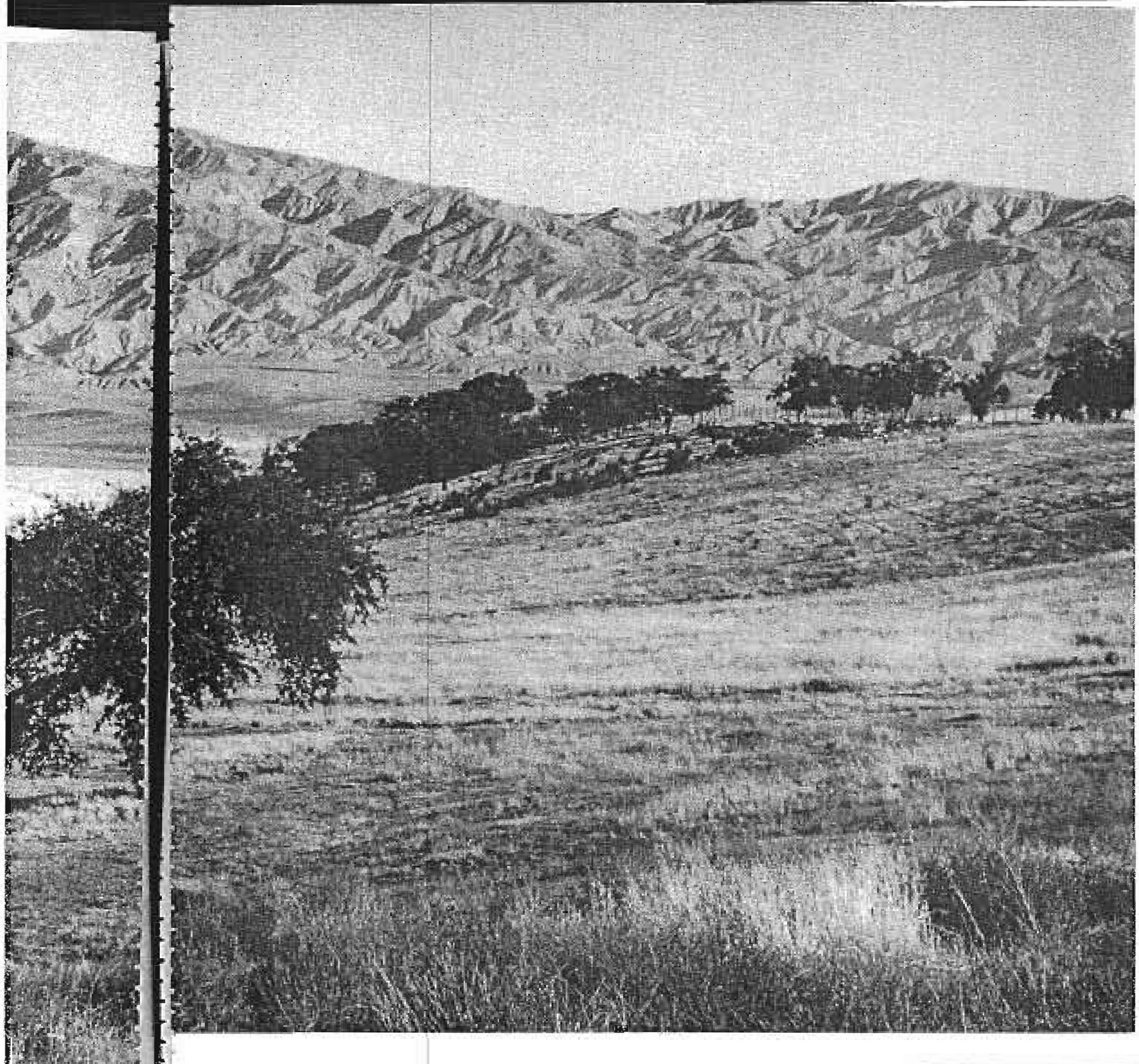
Foothill woodland of blue oak (right) in the dry Cuyama Valley (Santa Barbara Co.). The trees are widely spaced along the edge of the stand, forming a savanna in some places. Surrounding areas with less rainfall and south-facing slopes are dominated by annual grassland and chaparral.

A remnant savanna of valley oak (below) with a grassy understory of ripgut brome and California poppy.



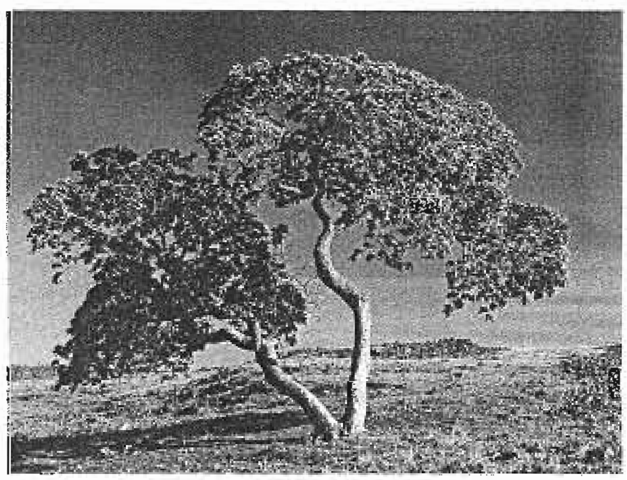
the distribution of oak woodlands, and later activity by miners, ranchers, farmers, and home builders also centered in what had been pristine foothill woodland and savanna. In terms of its historic importance, the large area of the state it covers, its familiarity to us all, and its unique trees, most of which are found nowhere except in California, foothill oak woodland qualifies as the state vegetation type.

A nearly continous ellipse of oak woodland surrounds the Central Valley, about 900 miles in circumference and occupying a foothill band between 300 and 3,000 feet in elevation. The lower edge of this band is a savanna, made up of large, widely spaced valley oak trees shading grassland herbs. Tree canopy covers less than thirty percent of

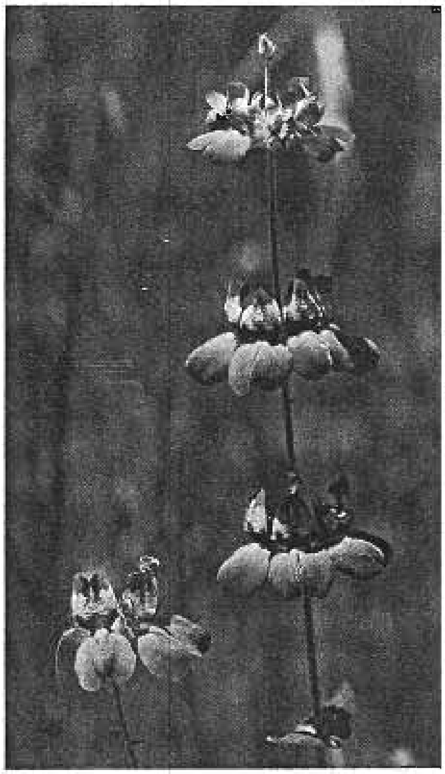


California buckeye (below), a drought-deciduous tree that is often found among the driest portions of a foothill woodland.

the ground, and there are fewer than twenty trees per acre. Woodland vegetation, just upslope, has thirty to sixty percent tree cover and more than sixty ttees per acre. Woodland trees are small, only fifteen to forty-five feet tall and usually less than two feet in diameter. Sometimes they are crowded together with more than 200 rrees per acre, but canopy cover is still open enough to support a grassland beneath.



The species of trees which dominate foothill woodland change with distance from the moist Pacific Ocean. Close to the coast, the dominant oaks are California black oak (*Quercus kelloggii*) in the north and coast live oak. Along the interior, drier foothills—those facing the Central Valley—the dominant trees are blue oak (*Quercus*



Chinese houses, an annual herb common in oak woodlands.

douglasii), interior live oak (*Quercus wislizenii* var. *wislizenii*), and foothill pine (*Pinus sabiniana*). A small tree, often growing in clusters, is California buckeye (*Aesculus californica*). Buckeye is drought-deciduous, losing its leaves in late summer, whereas blue oak is winter-deciduous. Leaves of both are soft to the touch, in contrast to the spiny, thick, leathery, evergreen leaves of interior live oak.

The leaves of most California evergreen plants, such as live oaks, share a number of traits: they have thick cuticles; the inner sandwich of tissue is also thick; they tend to be small, often spiny, and have a leathery texture which prevents them from wilting; they are rich in tannins and other chemicals offensive to herbivores; they give off little water vapor; and they conduct photosynthesis at a low rate. As a class, such leaves are called sclerophylls (hard leaves). In terms of time and energy, they are expensive for a plant to manufacture. A lot of carbohydrate must be invested in thick walls in the numerous cells which make up the tissue. Energy-rich fats and lipids must be produced for constructing thick cuticles. Certain metabolic by-products must be accumulated for herbivore defense. The compact leaf tissue prevents evaporation and loss of water, but it also slows the rate at which carbon dioxide can diffuse into the leaf. As a result, sclerophyllous plants usually grow more slowly than soft-leaved species.

Shrubs also can be either sclerophyllous or soft-leaved. Scattered shrubs characteristically make up a second canopy layer within the foothill woodland. California coffeeberry (*Rhamnus californica*), Christmas berry (*Heteromeles arbutifolia*), and manzanita (*Arctostaphylos* spp.) are all sclerophyllous. Redbud (*Cercis occidentalis*), poison oak, and squaw bush (*Rhus trilobata* var. *pilosissima*) are all soft-leaved. They all also occur in nearby chaparral. Below them are grasses and forbs from the grassland, plus a few new ones which show that the twenty inches of annual rainfall make the woodland a bit wetter than the central valley grassland. Woodland herbs include goldback fern (*Pityrogramma triangularis* var. *triangularis*), Chinese houses (*Collinsia* spp.), hedge nettle (*Stachys rigida*), buttercup (*Ranunculus* spp.), melic grass (*Melica californica*, *M. torreyana*, *M. imperfecta*), and fescue bunchgrasses (*Festuca californica*, *F. idahoensis*, *F. occidentalis*, *F. rubra*).

Plant and Animal Interactions

Animal diversity is higher in the foothill woodland than in adjacent grassland and conifer forest. More than 100 species of birds live in woodlands during breeding season, and sixty species of mammals use oaks in some way for feeding, nesting, or perching. Blacktail deer rely heavily on oaks as food—eating acorns in fall and leaves in spring. The species of foothill oaks most favored by deer are California black oak, blue oak, and interior live oak. Deer also feed on the lichens which grow on lower limbs. Acorn woodpeckers use oaks for nest sites, perching, and foraging. They eat acorns and make holes in the trunk to store acorns; they excavate larger holes in the trunk and eat the sap which collects in them; in spring they feed on swelling buds and flowers.

Vegetation such as oak woodland, which is heavily utilized by a variety of animals, tends to be rich in species and structurally complex. The complexity creates a variety of habitats thar can be occupied by different animals. For example, the gray fox prefers young woodlands with dense trees smaller than six inches in diameter, while the titmouse prefers older woodlands with scattered trees more than twenty-four inches in diameter. Both are part of the foothill woodland, but their niches are separate.

Oaks may be on the decline. Studies in the foothills show that oak populations do not have the age distribution expected of healthy, vigorous populations. Blue oak populations show a narrow cluster of middle-aged trees with few young or old ones. If this pattern continues for another two centuries, trees that today are eighty to 100 years old would reach the limits of their natural life span and

Appearance of foothill woodland during the summer–blue oaks with a golden understory of dead annual grasses.

disappear from the land. Some other plant community would then replace the oak woodland. Prior to the 1870s the environment permitted blue oaks to regenerate successfully, but not since. What has changed?

In Monterey County, Dr. Jim Griffin of the University of California has spent decades planting oak seedlings and watching their success under a variety of conditions. He has concluded that lack of young oaks is not due to a lack of acorns. As many as twenty acorns per square foot fall beneath oak trees each year, and most of these germinate. Death comes in the next few years from several sources: inability of young roots to penetrate soils packed hard by herds of grazing animals, late summer drought for those seedlings which germinate away from shade or on south-facing slopes, browsing by pocket gophers, browsing by above-ground rodents, and browsing by deer and cattle.

Griffin marked thousands of seedlings, and only those on north-facing slopes, in partial shade, and protected by fencing from all rypes of grazing survived as long as six years. Everywhere else, mortality was 100 percent. Lack of reproductive success over the past 100 years thus may have been due to drier climate, deforestation, and overgrazing by gophers, deer, and cattle. John Menke, also a professor at the University of California, has more recently been testing the competitive ability of oak seedlings against introduced annual grasses. He has found that grazing animals are an important, but not the only, cause of oak decline.

Not all foothill woodland plants are edible; many are poisonous. Poisonous plants have killed cattle, horses, sheep, people, and native animals. Some cause death if as little as one percent of the animal's weight in forage is eaten. The most important, common, and dangerous of these plants include Klamath weed (*Hypericum perforatum*), tree tobacco (*Nicotiana glauca*), bracken fern (*Pteridium aquilinum* var. *pubescens*), California buckeye, several species of larkspur (*Delphinium* spp.), monkshood (*Aconitum columbianum*), death camas (*Zigadenus venenosus*), and milkweed (*Asclepias* spp.).

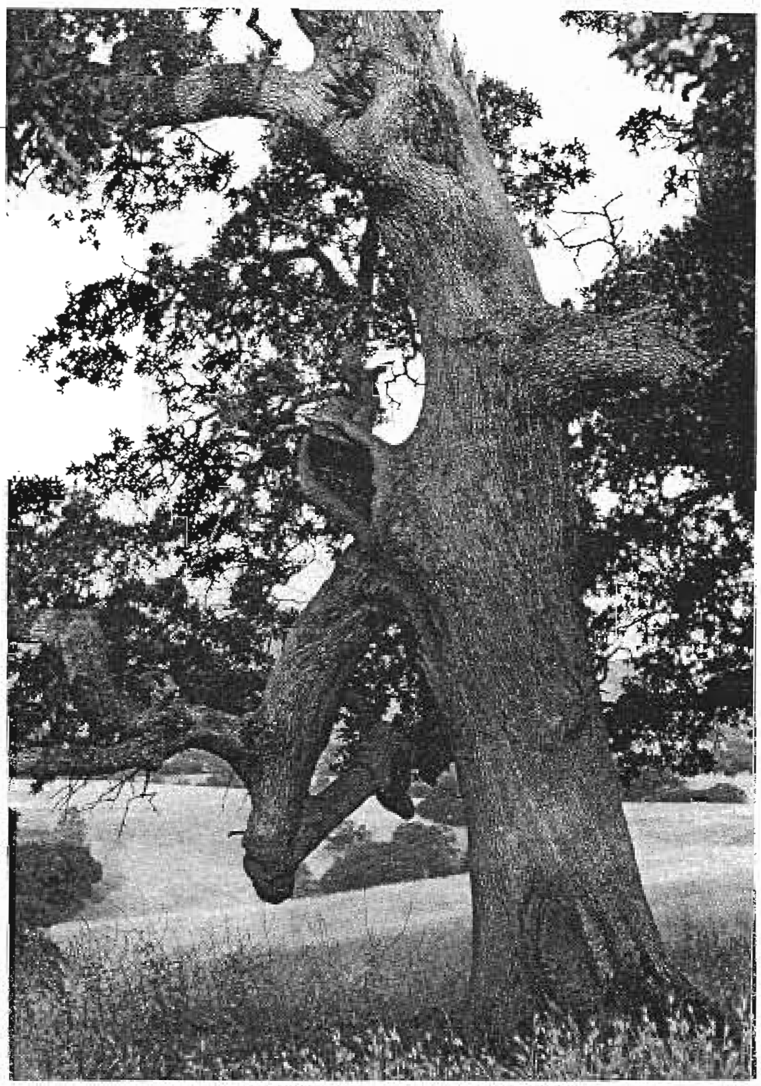
Some of these are introduced plants. Many contain alkaloids in all parts of the plant, and the alkaloids induce weakness, collapse, and lack of muscle control. The toxin in Klamath weed (see Chapter 2) is unique in that it causes sores only on unpigmented skin, such as around the muzzle of livestock. This irritation indirectly leads to weight loss or death because the animal is unable to feed. Bracken fern is usually avoided by stock unless other forage is in short supply, so it is not often a problem. Its poison is cumulative and causes internal bleeding. Buckeye leaves and fruits contain saponins that can induce abortion in grazing animals and humans. In addition, the nectar is poisonous to bees.

Harvesting the Woodlands

Early settlers realized that valley oaks were indicators of rich farm soil and a shallow water table; consequently, valley oak savannas and riparian forests were cut and planted to agricultural crops. Blue oaks have also been cleared from many thousands of acres of rangeland because of a mistaken notion that they suppress optimal forage production of herbs that grow beneath them. Recent research indicates that forage quantity and quality actually may be improved by blue oak cover.

Oak wood has high density, great strength, a pleasing grain, and high heat content upon burning. These traits make it well suited for use as fuel, charcoal, mine timbers, fence posts, lumber, furniture, tool handles, paneling, parquet, pallets, and cabinets. Even the sawdust is used. Recently, some sawmills in California have developed saws capable of handling short oak logs of small diameter and irregular shape. This invention permits more intensive use of oak trees for lumber.

The popularity of wood-burning stoves increased the importance of oak as firewood. At the same time, the high cost of fossil fuel has led power companies to investigate the practicality of using oaks and other plant products for energy production. It is estimated that our remaining oak woodlands produce 3.5 million dry tons of biomass per year. If oak woodlands were to be used on a sustained basis, only this annual growth could be harvested. As fuel, the annual increment would supply only about one percent of the state's annual energy requirements, so there is little future in oak biomass conversion for energy.



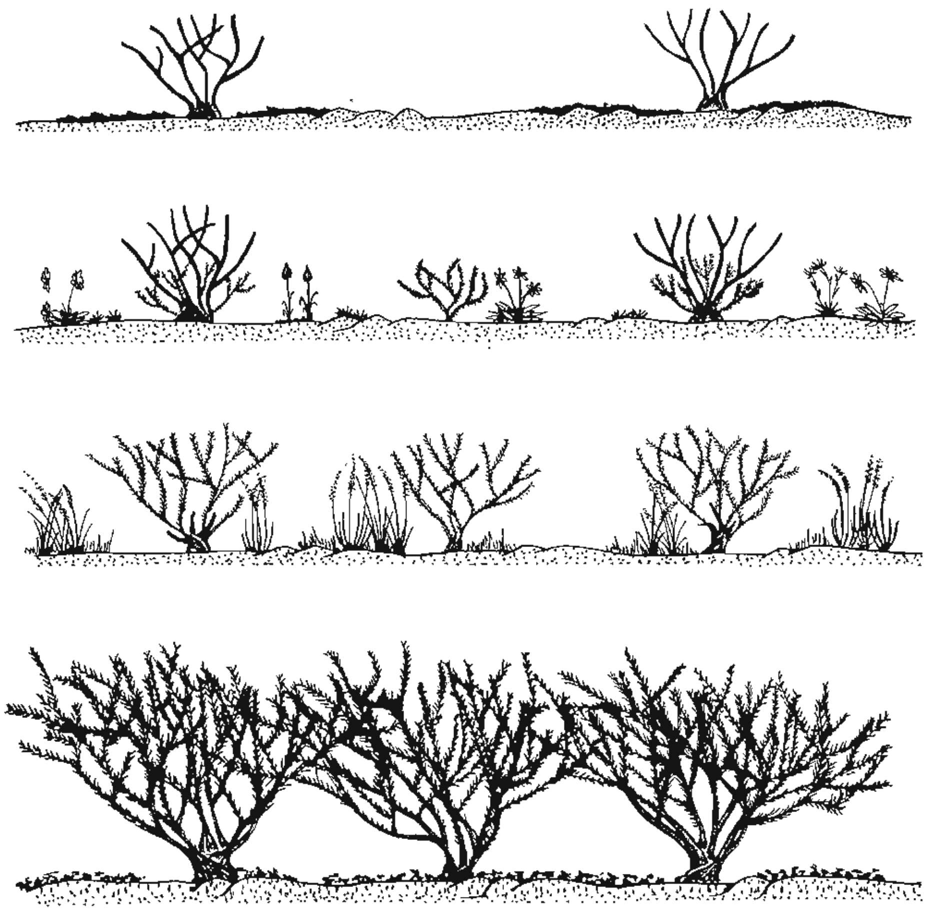
Many large blue oaks have been cut to clear woodlands for grazing and to provide fuelwood.

The negative side effects—ecosystem damage from continual harvest and air pollution from combustion—far outweigh any benefits. Wood burning releases so much carbon dioxide and particulate matter into local airsheds that many communities now strictly control the number and use of wood-burning stoves. The Environmental Protection Agency has imposed pollution standards on wood- burning stoves, and only those meeting these standards can be imported into or manufactured in the United States. Conservation efforts are being mounted by the Sierra Club in some counties to stop the cutting of all oak trees, even on private property, until regional woodlot plans are adopted by public agencies and boards.

Side by Side with Woodland: Chaparral and Fire

Seen from the air or from the ground, the texture of the landscape of the California foothills is varied. Each turn seems to bring something different: first woodland comes into view, then the next hillside is covered with dense shrubs; cresting a hill we are in open savanna and grassland, then we plunge down into a densely wooded canyon. And then the sequence of scenery repeats all over again. Each piece of the mosaic has its own color and texture: woodland is irregularly bumpy, dotted with gray-green foothill pine and blue-green oak; grassland is open and golden-brown; shrubland is uniformly muddy green, the vegetation so tightly intertwined and closely fitted to the topography that it is difficult to distinguish individual plants from a distance. Spanish explorers adopted the word chaparral from the Spanish *chaparro*, a low growing type of vegetation.

Chaparral covers about ten million acres of California. Many important watersheds which collect water for agricultural and urban needs are vegetated by



Succession in burned chaparral. Immediately after the fire (top), only skeletonized shrub canopies and ash remain above-ground. With the onset of winter rains, shrubs stump-sprout, shrub seeds germinate, and fire-following annual herbs germinate (next cross-section). Over several years, shrub canopies grow larger and the herb layer becomes dominated by grasses. Finally (bottom), after about six years, shrub canopies have regrown to their pre-fire stature and the herbs have disappeared.

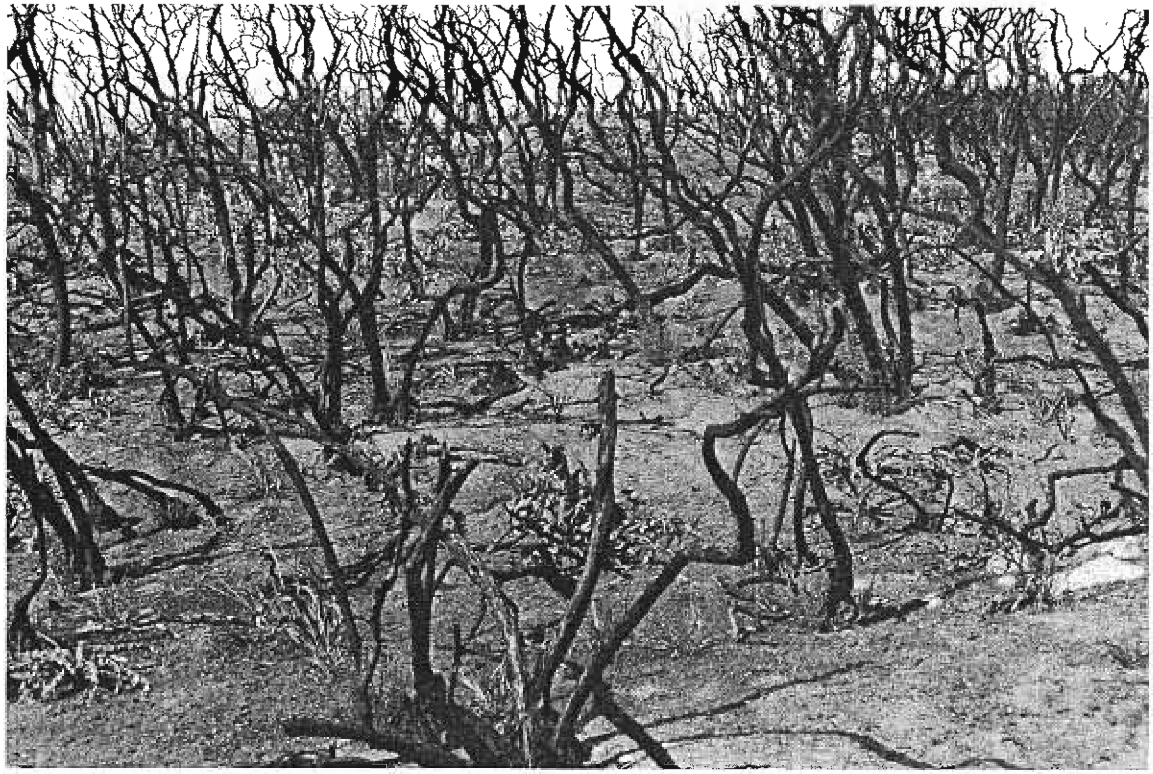
chaparral. Chaparral occupies the same 300 to 3,000 foot elevation belt as grassland, savanna, and woodland. In terms of annual rainfall and the progression of seasonal temperatures, there is no difference between a chaparral site and an oak woodland or grassland; the macroenvironment or regional climate is the same. These communities coil about and mix with each orher in intricate patterns because of local differences in soil depth and chemistry, frequency of fire, and slope steepness and aspect.

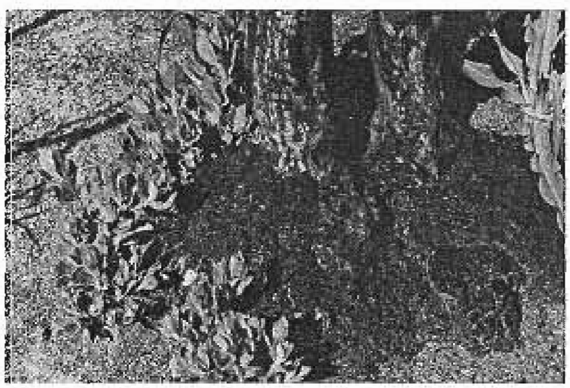
Typically, chaparral vegetation is a single layer of impenetrable shrubs four to eight feet tall, with evergreen, sclerophyllous leaves and rigid, intricately branched, interlacing canopies. The ground is bare of plants, stony, and covered with dry litter. An occasional California bay tree (*Umbellularia californica*), clump of cypress, or foothill pine overtops the shrub layer, and only a few perennial herbs—such as soap plant (*Chlorogalum pomeridianum*), melic grass, and globe lily (*Calochortus albus*)—fleck the ground, but most of the biomass is in a single shrub layer. Chaparral shrubs are twiggy, rather than leafy. The leaves which are present are small and vertically oriented, so the shrubs cast meager shade and lose little water. Chaparral is a drought-tolerant landscape cover.

The most common shrubs in Central Valley chaparral are chamise (*Adenostoma fasciculatum*), scrub oak (*Quercus dumosa*), Christmas berry, California coffeeberry, and more than twenty species each of manzanita and ceanothus. Several other shrubs are common in southern California chaparral: yucca (*Yucca whipplei*), red shanks (*Adenostoma sparsifolium*), laurel sumac (*Rhus laurina* syn. *Malosma laurina*), and lemonadeberry (*Rhus integrifolia*).

Chaparral occurs in a fire-prone region of California. Fires are hot, all-consuming crown fires because there may be fifty tons of dry shrubs per acre, and the shrubs accumulate flammable oils. The intensity of fire is expressed as BTUs released per second per foot of fire front. While grassland fires are relatively cool, releasing 150 BTUs per second per foot of fire front, and produce soil surface temperatures of 300°F, chaparral fires release 12,000 BTUs per second per foot in winds of only six miles per hour (much more in higher winds), and produce soil surface temperatures of 1,000°F—hot enough to melt aluminum. Chaparral fires are so intense that they creare local wind storms such as occurred in the Oakland hills fire of October 1991. (It is thought that the intensity of this devastating fire was augmented by heat from burning homes and eucalyptus trees.) Fire bombs of hot air and burning wood can be hurled tens of yards in front of the fire, easily crossing fire breaks. Chaparral fires are hard to control because of these high temperatures, the leaping fire front, and the rugged terrain on which chaparral typically grows. Suburban growth in California has expanded into chaparral, exposing homeowners to potential catastrophe. Since fire is an integral part of this landscape, development of chaparral is economically unwise.

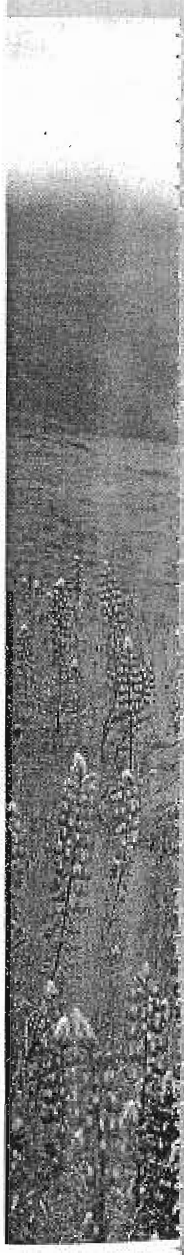
After fire, chaparral architecture changes in predictable ways. Above the ground, fires leave skeletons of shrubs and trees and a thick layer of ash. The area





looks devastated, but the promise of revegetation already lies in the soil. Seeds and roots deeper than a few inches below the surface remain alive because the insulating quality of the earth keeps them safe from the intense heat. Although temperatures high enough to melt aluminum persist for as long as twenty minutes on any surface square foot of ground during the fire, temperatures three inches below the surface reach only 150° for half that time. Roots and seeds deeper than three inches and animals in burrows are merely warmed for a few minutes. Since many chaparral shrub species have enlarged root crowns covered with dormant buds, and generally these are deep enough in the soil to survive, the shrubs have an excellent chance of surviving the fire by crown-sprouting.

With the onset of winter rains, seeds germinate, buds sprout, and roots resume growth. A carpet of herbs, shrub seedlings, and shrub sucker shoots covers much of the ground by the following spring. Most of the herbs which grow and flower this first year are not seen again until the next fire. They either have seed coats which do not permit germination unless cracked by high temperatures,



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or they have embryos which require some chemical released from burned chaparral wood. Until these conditions are met, seeds lie dormant in the soil, sometimes for decades.

Stump-sprouting in chamise chaparral a few months after the fire and rain. The wavy-leaved herb is soap plant, a perennial whose bulb is protected from fire by a couple of inches of soil. A close-up (below) of manzanita sprouting from a large rootcrown or burl.

For several years after the fire the shrub suckers and seedlings grow larger while the mix of herb species shifts in composition. Annual grasses become more numerous, while fire-following forbs eventually decline ro a dormanr seed pool. Within six years of the fire the shrub canopy has closed and almost all herbs have disappeared. Changes in soil chemistry and the numbers of small mammals cause the disappearance of hetbs, not shade cast by growing shrubs. When leaves of chamise (and perhaps other shrubs) drop and decay, they release chemicals which inhibit the germination and root growth of most herbs, and of shrub seedlings as well. Fire removes living leaves and consumes leaf littet on the ground, eliminating the source of inhibition. The inhibitor effect does not return until the canopy closes over once again. Changes also are created by small rodents which nest beneath shrub cover. They forage for grains and young shoots most intensively near their nest sites. When chaparral burns the cover is lost and these animals move or die, releasing the site to herb growth. As the canopy closes back, animals re-enter the site and chew back the herb cover to its previous low level.

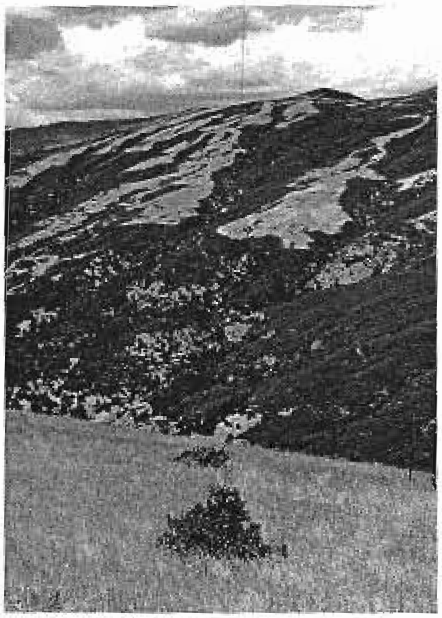
For the next thirty to forty years shrub growth continues, but at a slower pace. Woody plants which have short life spans die during this period. These short-lived shrubs are species which re-invade a burned site by seed only because they lack the capacity to stump sprout. Over time the community becomes simpler, and gradually comes to include only shrubs which sprout following fite. The dormant seeds of missing shrubs and herbs are in the soil, and will be triggered into germinating by the next fire and following winter rains. In many places chaparral fires follow each other on a twenty to twenty-five year cycle, and it is rare to find an unburned chaparral stand older than fifty years. When such old stands do burn, as they did on Mt. Diablo (Contra Costa County) in the 1970s, the firestorm is especially intense because of the high biomass of accumulated living fuel.

Chaparral Management

Chaparral vegetation can be managed if it is purposely burned more often than every twenty years, but this approach is conrroversial. Burned every decade, the community becomes simplified into chamisal—chaparral composed essentially of chamise shrubs only. All other species become exhausted of seed reserves or root reserves by frequent fire and finally fail to reproduce. If chamisal burns every one to two years for several years, it too reaches a point of exhaustion and fails to regenerate. At this time the site is bare and can be planted to other vegetation. Range managers typically drill in seeds of perennial grass and convert the site to grassland. The grasses used are not natives, but introduced species such as canary grass. Within two years of planting the grass cover is almost complete, and it is able to suppress any shrub seedlings which germinate from seed blown in.

The purposeful change of chaparral into grassland is called type conversion.

The supposed advantage of type conversion is increased access by the public for recreation, increased habitat for livestock, deer and other game animals, and improved fire control. Raging chaparral fires turn into cool, ground-hugging, slow-moving fires when they reach grassland, and the grassland also provides access for firefighting crews. Ecologically, however, the result is a major alteration of the landscape, the watershed, and natural patterns of diversity. The presence of type conversions and fuelbreaks also may promote the construction of homes in chaparral areas, which escalates the demand for yet more fire protection, illustrating how stubbornly people choose to disregard the nature of their surroundings. Intense fire is an important and predictable part of the chaparral ecosystem. On a purely cost-benefit basis, the suppression of chaparral fire probably requires more effort, money, and ongoing maintenance than is reasonable.



Here type conversion of chaparral has created expanses of annual grassland over a period of more than a decade.

If harvested, chaparral has some economic use in energy production. Detailed ecological and economic studies of chaparral's potential for biomass conversion into electrical energy have been made in southern California. A pilot project including harvest of chaparral for a generating plant near San Diego has been underway for several years with some success. Enormous mobile cutting and chipping machines have been built to mow through chaparral in a single pass and reduce it to wood chips that are trucked to the power plant and used in place of coal or fuel oil. Removing shrub tops by cutting will release dormant buds for sprouting, just as fire does. However, there is no ash to promote regrowth nor high temperatures to stimulate seed germination. We should not, therefore, expect chaparral harvested for wood to recover as fast or as completely as it does from fire.

Type conversion and biomass conversion are both controversial management options. Chaparral conveys stability to the steep hillsides on which it typically grows. Its presence no doubt affects the hydrology of watersheds, in this way having an enormous impact on water supplies for the human-made landscapes downslope. Its resilience to fire assures that vegetation recovers quickly from the natural fires which predictably come—a fire regime which cannot be entirely controlled by humans. And the natural mosaic of scrub with woodland and grassland already provides the habitat diversity required for native animals. The ecological repercussions from disturbance of chaparral for biomass harvest or type conversion should be weighed with the real economic costs and assumed benefits.

The Changing Landscape

More than thirty-one million acres today are farmed or grazed, an area equaling nearly one-third of the state. Crops have replaced large amounts of certain plant cover types. For example, rice has replaced tule marsh, and orchards have replaced riparian forest. Grazing has altered millions of acres of native grassland and woodland.

Farming and grazing give us abundant food, but modern agriculture has created toxic conditions affecting surrounding lands. For example, cotton is widely grown in the southern San Joaquin Valley in a part of the valley that receives less than six inches of rain per year. In order to grow cotton huge amounts of water with dissolved salts are imported from the delta of the San Joaquin and Sacramento rivers. Cotton farms also use large amounts of pesticides and herbicides. Those chemicals, and salts from the soil, are leached by percolating irrigation water which passes through the soil and is eventually removed from the farm in a system of drainage tiles, ditches, and canals. Over time the concentration of salts and chemicals builds up and reaches toxic levels in the drain water. Because it is toxic, the drain water cannot be reused. Early plans were to send the salt- and chemical-laden water back to the Sacramento and San Joaquin River Delta via the San Luis Drain. Fortunately, the San Luis Drain was never completed, but the waste water now drains into the infamous Kesterson National Wildlife Refuge. One of the toxic chemicals, selenium, has killed and malformed large numbers of waterfowl living in the refuge.

Soil erosion is another serious consequence of farming and grazing. It affects almost two million acres of cropland and seven million acres of grazing land. Much of the affected land is eroding at rates that will not allow sustained use of the land. In Kern County alone 17,900 acres of cropland and 526,000 acres of grazing land suffer erosion by water. Wind is eroding another 250,000 acres of cropland and 446,000 acres of grazing land. Peat soils of agricultural islands in the delta of the Sacramento and San Joaquin rivers are decomposing, blowing away, and sinking. The land has subsided in places below the foundations of protecting levees, and catastrophic flooding often results.

Agriculture has increased the number of acres of saline soils, although naturally occurring saline soils have always existed in California. Some native vegetation can grow on such soil, but most cultivated crops are too sensitive and die back if there is more than 0.5 percent salt in the soil (Chapter 2). Salinization now affects at least 1.6 million acres of cropland, mostly in the Imperial and San Joaquin valleys.

Rain, streams, and ground water carry significant amounts of minerals, and when such water is applied for irrigation, it is a two-edged sword: water comes to otherwise dry land, but salt comes with it. When the water evaporates or passes through the soil, traces of minerals are left behind. Low rainfall, high rates of evaporation, frequent irrigation, and clayey soils that retain salts are all factors that promote salinization. Salts prevent water from flowing from the soil into plants, and plants wilt from physiological drought (Chapter 2). Installing drains and using even more irrigation water to flush the soil can help reverse salinization, but this results in a larger demand for water and the creation of yet more non-reusable waste water.

Urbanization is also reducing agricultural land supply and productivity. From

1950 to 1980 more than one million acres of agricultural land were urbanized. About half of this occurred during the 1970s at a rate of 44,000 acres per year. This is twice the rate of conversion from 1950 to 1970. In five years alone—1977 to 1982—the southern California counties of Los Angeles, Orange, San Bernardino, and Riverside urbanized 100,000 agricultural acres; San Diego County converted 60,000 acres; the San Francisco Bay area counties of Contra Costa, Alameda, Santa Clara, San Mateo, and Marin lost 41,000 acres; and in the San Joaquin Valley 65,000 acres were converted to urban uses. Another one million acres of agricultural land will most likely be urbanized between 1992 the year 2002.

This farmland near Covelo (Mendocino Co.) was developed on the rich, deep soils once dominated by oak woodland and riparian forest. It is likely that these remnant oaks will grow old and die rather than replenish the landscape with young trees.

Most of low-elevation California has been irreparably changed during the past two centuries. Expanses of bunchgrass prairie, vernal pools, tule marsh, and riparian forest are gone; wispy relicts hint at what once was dominant. Gone with them are tule elk, pronghorn antelope, and grizzly bear. It is no longer the same view that so moved John Muir.

The consequences of loss and change radiate out to the larger ecosystem. The shade of riparian trees, for example, provides many direct and indirect benefits to fish. Streambank cover reduces erosion and sedimentation and controls the release of nutrients to the aquatic environment. Overhanging tree canopies prevent the water from warming and losing its dissolved oxygen. Streambank vegetation also provides habitat for numerous invertebrates that are food for aquatic and terrestrial life.

There are complex bonds between vegetation and streams. When vegetative cover is removed, soil erosion is increased. Soil particles wash into streams, settling and clogging the stream bed. The sediment reduces spawning habitat for fish and increases the chance of flood. The effects of soil erosion can be long lasting. Hydraulic gold mining from 1850 to 1875 produced large sediment loads, and for a hundred years afterwards that sediment was deposited in drainages far removed from the diggings.

Where the riparian zone has been removed, or scarcely exists, fertilizer and animal wasres can seep into streams and ground warer. An intact riparian zone acts as a filter between streams and agriculture, removing large quantities of nitrogen and phosphorus. Healthy riparian cover is the starting poinr of sound watershed management.

Whether in broad valleys or narrow canyons, riparian forests are among the world's most productive natural ecosystems, and among the richest in wildlife diversity. With clearing or degradation of riparian plant cover, the natural riparian ecosystem ceases to exist. Rigorous protection should be given to riparian vegetation because of its importance as a filter, its vulnerability, and its threatened extinction.

The cost of California's economic and cultural growth has been the loss and alteration of natural plant covet. If this trade of biotic resource for growth continues, we may match the history of countries such as Italy, Greece, and Israel which line the Mediterranean tim. The cradle of western history and culture surrounding the Mediterranean Sea once nestled among forests of pine, evergreen oak, laurel, ash, and myrtle. That cover has all been harvested and replaced with a modern landscape of degraded scrub. Ecologist and historian J.V. Thirgood saw a moral here for North America, a lesson which applies well to California:

> *It can be argued that environmental ruin was the price paid for the glory that was Greece. . . No other part of the world so strikingly drives home the story of man's failure to maintain his environment. . . Here may be seen the fate of the newly opened lands of the new continents if man fails to achieve a balanced relationship with the land—an equilibrium between use of the land and human practice and culture.*