United States
Department of
Agriculture

Forest Service

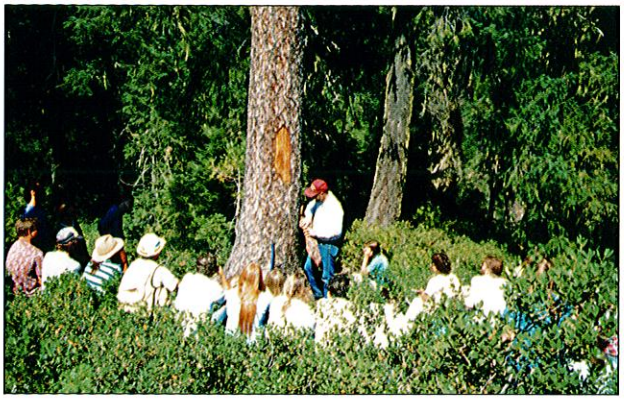
Pacific
Southwest
Region

R5-FPM-PR-002

December 1996

California Forest Health

In 1994 and 1995



Abstract:

Dale, John W., tech. coord. 1996. California Forest Health in 1994 and 1995. Rep. R5-FPM-PR-002. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture. 63 p.

This report covers forest health conditions in California for 1995 and 1996. Fire, weather, animal damage, two vector-borne diseases, and the most important forest insects and diseases are included. Organization is based on province and sections of the Forest Service National Hierarchical Framework of Ecological Units. One chapter reports results from forest health baseline measurements, 1992 to 1995.

Key words:

Air pollution, California, fire, forest health, forest health monitoring, forest insects, ozone, tree diseases, weather.

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Cover:

Smog inversion on the Hot Springs Ranger District, Sequoia National Forest (top); a field training session on forest health and managing forest insects, disease and animal damage (middle); and feller-buncher thinning a pine plantation to release leave trees, McCloud District, Shasta-Trinity National Forests (bottom)

Trade names and commercial enterprises mentioned are solely for information and do not imply endorsement. This publication neither recommends any pesticide uses reported, nor implies that they have been registered by appropriate governmental agencies.

The source of photographs and data for graphs is Forest Pest Management, Pacific Southwest Region, San Francisco, CA, unless otherwise noted.

California Forest Health
In 1994 and 1995

John W. Dale, technical coordinator

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U.S. Department of Agriculture
Forest Service
Pacific Southwest Region

R5-FPM-PR-002

December 1996

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Summary

In this document, we define forest health as the condition that provides desired sustainable ecosystems where biotic and abiotic influences do not threaten resource management objectives (USDA Forest Service 1993, 1994). During 1994 and 1995, some influences on forest health changed and some did not. The influences causing change are the nucleus of this document, and those that did not cause change are only briefly mentioned. Limited historical information is used, and historical information previously presented (USDA Forest Service 1994) is repeated only if relevant to 1994 and 1995.

Damage from defoliators, both insects and pathogens, was minimal and localized. The known ranges of dwarf mistletoe and annosus and other root diseases remain much the same as they were in 1993. The most important damaging animals continue to be deer, pocket gophers, and black bear. The number of male gypsy moths trapped in California remained low, and eradication treatments were unnecessary.

During 1994 and 1995, tree mortality declined markedly in many areas of California, but it remained high east of the Pacific crest from Mammoth Lakes northward through the Lake Tahoe basin and Sierraville areas, the southern Cascades, and across the northern tier of counties to the Klamath Mountains. Mortality of Jeffrey pine was conspicuous in Lassen Volcanic National Park and adjacent areas to the north and east. True fir and lodgepole pine remained a large component of total mortality. Many factors caused the mortality: continuing effects of drought stress, overstocked stands, true fir growing offsite, and large populations of the Jeffrey pine beetle, fir engraver, and mountain pine beetle. Mortality along the western slopes of the Sierra Nevada and in southern California declined sharply from 1993 to 1995.

Port-Orford-cedar root disease was found in previously uninfested tributaries of the Smith River and in a tributary of the Klamath River—the first identification in native stands outside of the Smith River drainage. Pine pitch canker was identified in the Cambria stand of Monterey pine and is now present in all three of the native stands in California. Damage from white pine blister rust continues on sugar pine, and western white pine is becoming increasingly affected. Known infections of other five-needle pines are currently not affecting survival.

Two Australian insects were discovered on eucalyptus in southern California: the yellow phoracantha, similar to the eucalyptus longhorned borer; and the eucalyptus snout beetle, a serious defoliator of eucalyptus in Australia and other countries where it has been introduced.

Use of prescribed fire continues to gain momentum as a part of ecosystem management; the average size of individual burns and interagency cooperation are increasing. Much remains to be done to manage fuels on a landscape scale, however.

More than 10,000 starts burned 526,219 acres in California in 1994. Almost 223,000 acres burned on National Forest lands. Three large fires—the Barkley, Crystal, and Cottonwood—accounted for 45% of the National Forest total. The 1995 wildfire season was below average; only 22,125 acres burned on National Forest lands, and 8,492 starts resulted in 209,815 acres burned in all of California.

Drought reappeared in 1994, but 1995 brought much-needed relief in the form of abundant rain and snow pack. Flooding, heavy snows, and severe winds caused damage in several locations in northern California in 1995.

Chronic ozone injury to crowns of ponderosa and Jeffrey pines decreased at monitoring plots in the San Bernardino Mountains from 1983 to 1988. The injury index increased between 1991 and 1995, however. Injury has also been identified in the Angeles and Los Padres National Forests. Evidence of ozone injury can be found throughout the Sierra Nevada, increasing in severity from north to south.

Plague and hantavirus continue to require animal and site management. The impending movement of Africanized honey bees into the recreational forests of southern California will create special challenges for land managers.

The fourth year of the baseline national Forest Health Monitoring Program was completed in California in 1995. Thus far, results indicate that most of California's trees and forests are free of immediate health problems. As the program enters its second four-year cycle of monitoring, understanding the complex data and trend relationships is the challenge ahead.

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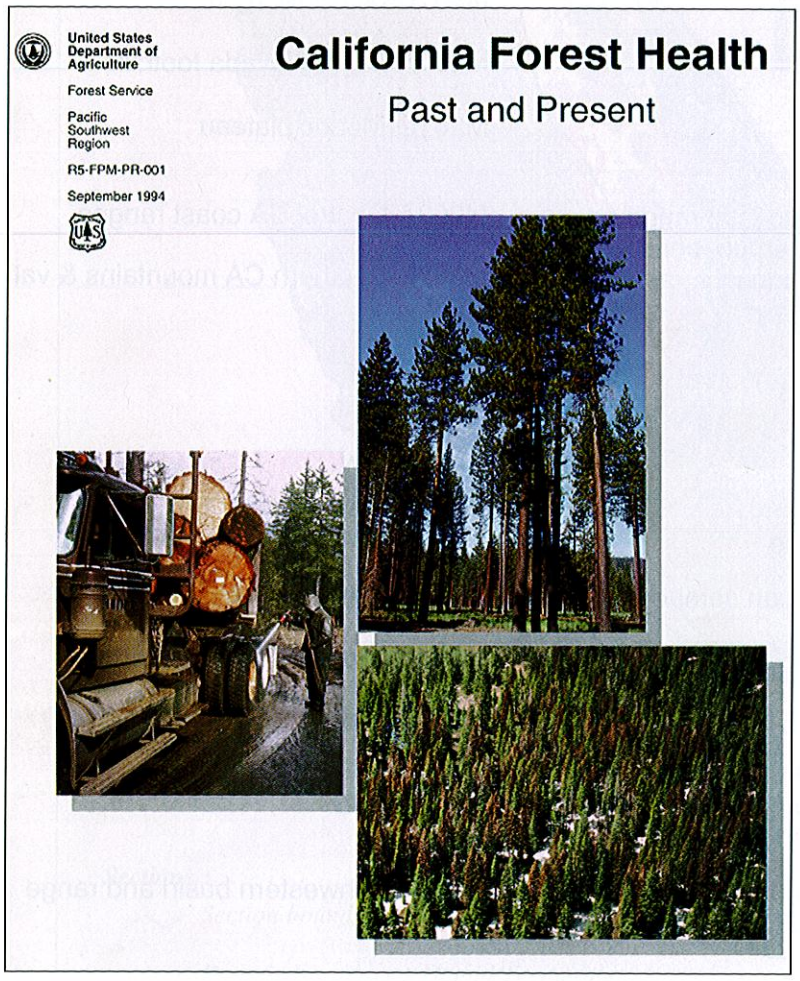
Introduction

This report reviews the influence of major biotic agents and abiotic events on forest health in California in 1994 and 1995. *California Forest Health Past and Present* (USDA Forest Service 1994) provides a historical view of forest health conditions for prior years. Covering just two years in this report will allow future reports to coincide with the four-year reporting cycle of the national Forest Health Monitoring Program. *California Forest Pest Conditions* will continue to be published annually by the California Forest Pest Council, with emphasis on the status of forest insects, diseases, and animal damage in California's forests.

Organization of this report is based on provinces and sections of the National Hierarchical Framework of Ecological Units (table 1). The Framework is a system for stratifying the Earth into progressively smaller units of increasingly uniform ecological potential (Avers et al. 1993). Influences that affect vegetation throughout the state, such as weather and fire, are covered individually in chapter 3. Disturbance agents that affect the majority of the sections in a province are discussed at the province scale in chapter 4. The remaining agents are discussed as forest health issues present during 1994 and 1995 and are grouped by tree species affected. Current forest health activities that address some of the issues close each section. Ecological descriptions of the sections were given in USDA Forest Service (1994) and will be limited in this document. Table 2 briefly describes climatic and physical characteristics of each section. For more detailed descriptions of provinces and sections, the reader is referred to McNab and Avers (1994) and Bailey (1995).

The CALVEG classification of vegetation is used to give the reader information about the vegetation in the provinces and sections (fig. 1). This map represents the existing vegetation in California. The vegetation types may have more extensive distributions, but because of the map's scale, the total distribution may not appear. Other classifications of California's vegetation exist, such as Sawyer and Keeler-Wolf (1995), but they are not yet available in map form.



A brief explanation of the national Forest Health Monitoring Program in chapter 5 is followed by an analysis of some data collected in California from 1992 to 1995. The sixth and final chapter looks to the future health of California's forests during the next forest health monitoring cycle, 1996 to 1999.

California Forest Health - Past and Present *is the predecessor of this report and the first in a series whose goal is to describe the trends in forest health in California.*

Table 1 — Hierarchy of ecological units in California

HUMID TEMPERATE DOMAIN

Division	Province	Section
260-Mediterranean	261-CA coastal chaparral forest and shrub	261A-Central CA coast
		261B-Southern CA coast
	262-CA dry steppe	262A-Great Valley
	263-CA coastal steppe, mixed & redwood forest	263A-Northern CA coast
M260-Mediterranean regime mountains	M261-Sierran steppe, mixed & coniferous forest & alpine meadow	M261A-Klamath mountains
		M261B-Northern CA coast ranges
		M261C-Northern CA interior coast ranges
		M261D-Southern Cascades
		M261E-Sierra Nevada
		M261F-Sierra Nevada foothills
		M261G-Modoc plateau
	M262-CA coastal range open woodland, shrub, continuous forest, meadow	M262A-Central CA coast ranges
		M262B-Southern CA mountains & valleys

DRY DOMAIN

Division	Province	Section
320-Tropical/ subtropical desert	322-American semi-desert & desert	322A-Mojave desert
		322B-Sonoran Mojave desert
		322C-Sonoran Colorado desert
340-Temperate desert	341-Intermountain semi-desert & desert	341D-Mono
	342-Intermountain semi-desert	342B-Northwestern basin and range

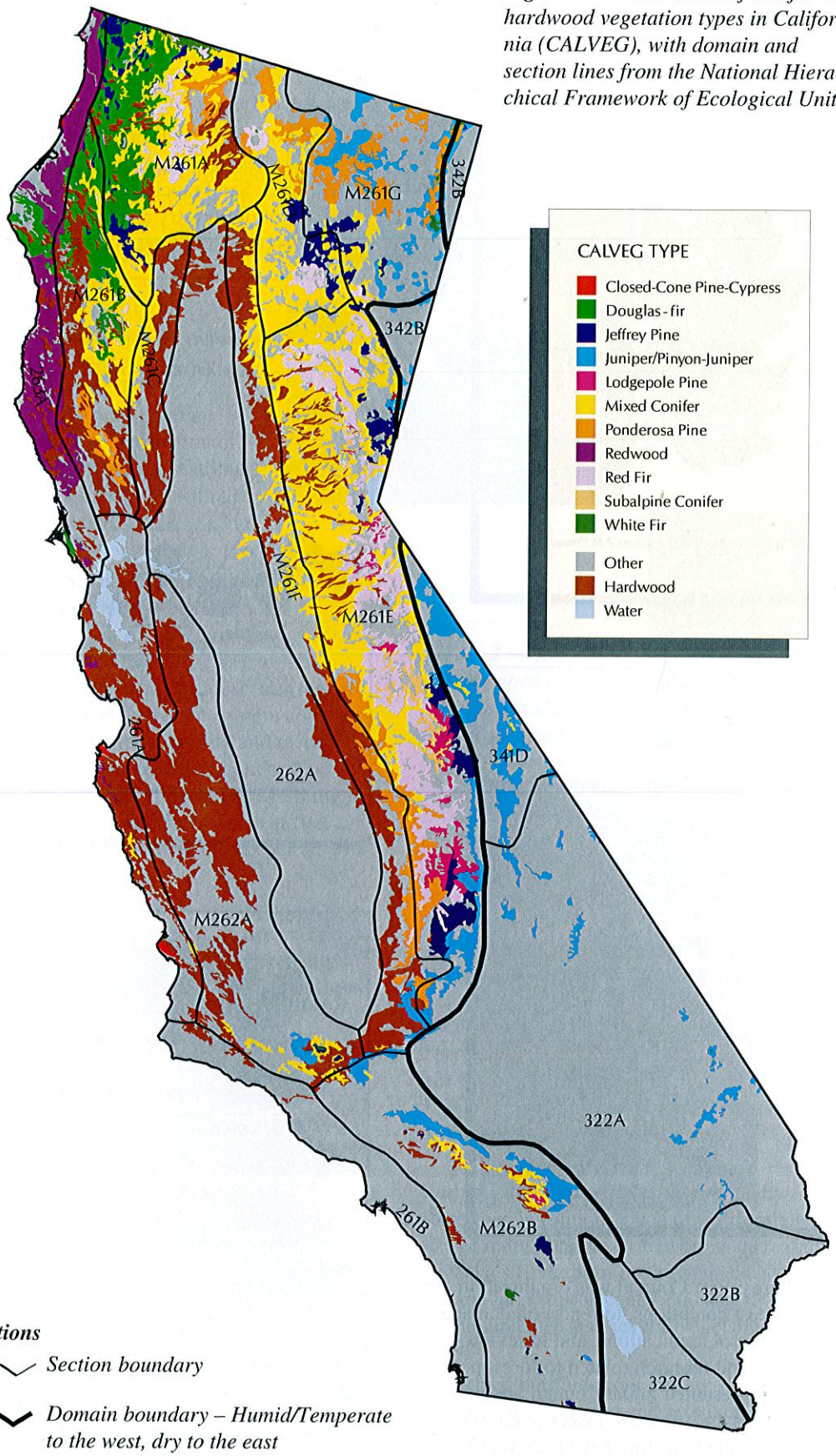
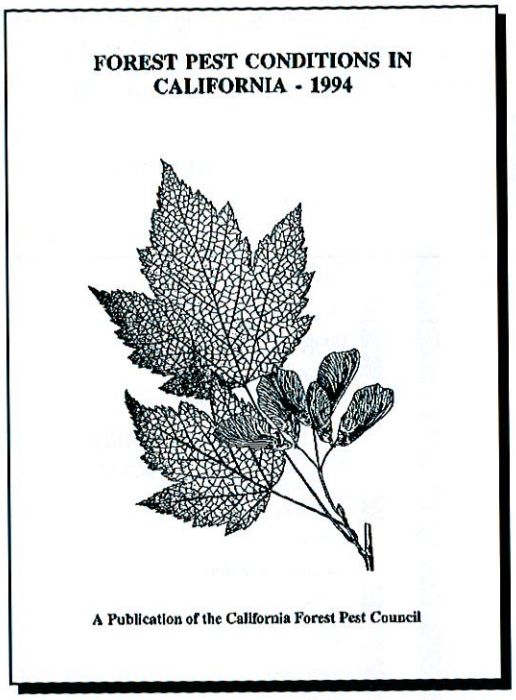


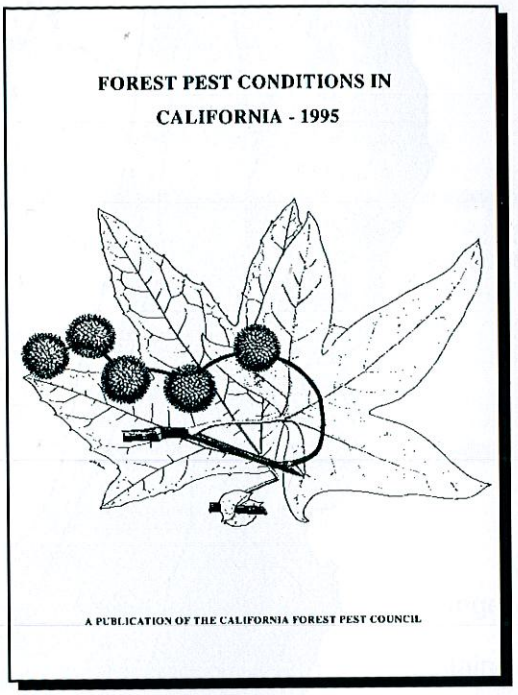
Figure 1 *— Distribution of conifer and hardwood vegetation types in California (CALVEG), with domain and section lines from the National Hierarchical Framework of Ecological Units.*

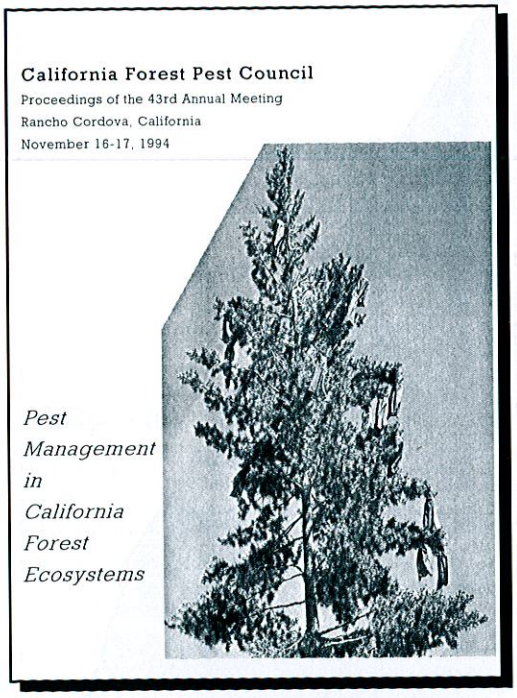
Related Publications

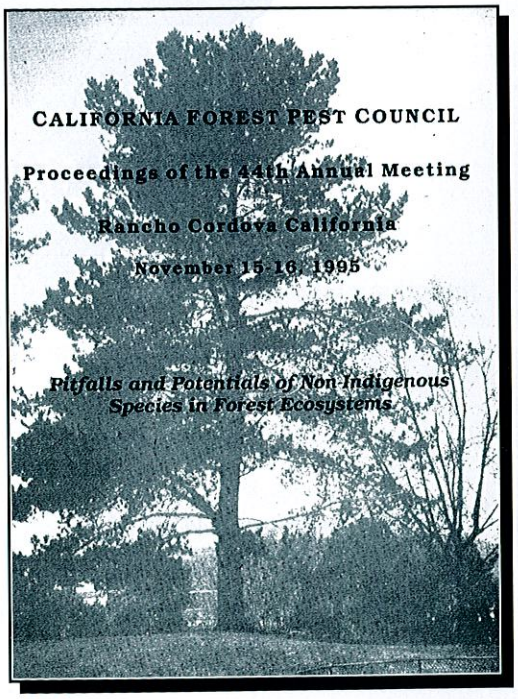


Forest Pest Conditions in California is compiled and published annually under the auspices of the California Forest Pest Council for public and private forest land managers and other interested parties to keep them informed on conditions on forested land in California.

For information on the California Forest Pest Council, contact Forest Pest Management, U.S. Forest Service, 630 Sansome Street, San Francisco, CA 94111, or the California Department of Forestry and Fire Protection, Forest Protection, 1416 Ninth Street, Sacramento, CA 95814.







The California Forest Pest Council was organized in 1951 to evaluate forest pest conditions, to report on damage, to recommend pest control applications, and to review policy, legal issues, and research related to forest pest control. Subjects represented in the Council are air pollution, animal damage, diseases, insects, and weeds. Proceedings of the annual meeting have been published since 1990.

Influences on Forest Ecosystems

Fire

Before the arrival of European settlers, fire had a central role in the evolution and function of California's extremely diverse ecosystems. Fire that was ignited both naturally and by people played an important role, and the predictable frequency and severity on a landscape scale were largely determined by climate, patterns of fuel accumulation, and ignition sources. On a finer scale, slope, aspect, and topographic positions were important factors controlling the spatial distribution of fire. Since European settlement, the distribution of fire has changed dramatically with the changes in attitude toward fire.

During the past century, fire has often been portrayed as a destructive force that should always be eliminated to "protect" ecosystems. Ignition sources have changed from a combination of lightning and use of fire as a tool by American Indians, to the suppression of most fires regardless of cause. Suppression has altered ecosystem composition and structure by changing the mortality and recruitment patterns of many tree species. Fire frequency has generally decreased, but the proportion of acres burning in stand-replacing fires has increased. Less frequent fires allow greater fuel accumulation and more trees per acre to persist on the landscape.

Logging practices have been as important as fire exclusion in increasing the severity of fires in many timbered areas. Spatially diverse, relatively open-canopy forests dominated by large trees were often replaced by closed-canopy forests, some of which are single-layered and others are vertically diverse. Forests with closed canopies of small trees or with multilayered, variable canopies are more susceptible to stand-replacing fires than are open-canopy forests dominated by large trees. Thinning programs in the closed-canopy forests have reduced susceptibility over thousands of acres.

Attitudes toward fire are shifting once again: the awareness of the role of fire in ecosystem dynamics and function is increasing. In California's Mediterranean climate, the question is not whether fire will happen, but when, where, and what kind. Managing fire frequency and intensity will help maintain biological diversity, integrity, and sustainability.

Current Forest Health Activities

Prescribed burning programs in California are shifting toward managing ecosystems, recognizing the importance of fire in California's ecosystems, and gradually gaining increased funding. Although slash burning is still a large part of the programs, the focus is shifting to treatment of natural fuel accumulation, and restoring fire as a natural process (fig. 2).

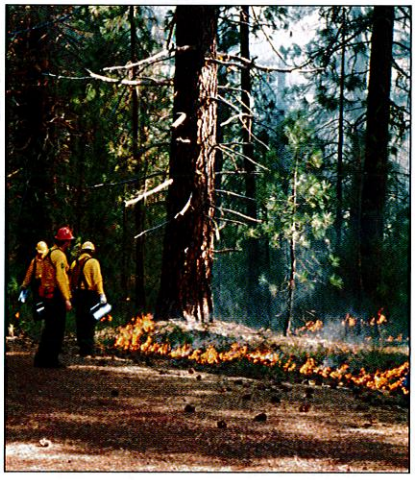


Figure 2 — The focus of prescribed burning programs is shifting from slash treatments (top) to treatment of natural fuel accumulation and restoration of fire as a natural process (right).

Some 287,250 acres of National Forest land in California were treated with prescribed fire from 1990 to 1995. The number of acres per forest differed greatly, with fuel treatments such as slash removal and site preparation for tree planting accounting for much of the acreage. In 1993, 35,865 acres were treated. In 1994, another 29,368 acres were treated with prescribed fire.

During 1995, the weather was especially favorable for prescribed burning in much of California. The average size of individual prescribed burns increased; the Stanislaus River burn on the Stanislaus National Forest was the largest project at 4,800 acres. This project was also notable because several vegetation types were burned.

Prescribed burning programs are shifting from the district scale toward the forest and province scales. This shift encourages the selection of large, landscape-scale projects and the pooling of resources to execute complex burns.

The increase in interagency cooperative burns is an example. The Cleveland and Eldorado National Forests cooperated on burns with the California Department of Forestry and Fire Protection; the Modoc and Stanislaus National Forests cooperated on burns with National Parks in 1995.

Many current forest management practices are designed to reduce the potential of a forest to burn in large, high-severity fires. These practices include salvage sales, large-scale thinning, and the creation of defensible fuel-profile zones around communities and other strategic locations. Some stands are being mechanically treated to reduce hazardous fuels. Because of extensive conifer mortality on the east side of the Sierra Nevada, fire cannot be reintroduced without first removing trees and dead material. Therefore, defensible zones are being constructed, with plans to underburn in the future. The results of these and other practices must be monitored carefully to determine how the treatments change the distribution and effects of fires.

Fire and fuel management are now central issues in forest planning on a watershed scale. Fuel treatments are being tailored to consider the vegetative potential and historical fire regimes in an effort to match unique qualities and situations found in each area. Fire and fuel specialists are being asked to participate in designing projects that restore fire as a natural ecosystem process. Fuel treatments must be large and strategically placed to decrease the incidence of large, severe fires. Treatments must be reapplied at appropriate intervals to maintain the ecosystem, or areas will quickly revert to their prior condition.

The prescribed burning program in California is gaining momentum, but its scope is dwarfed by the fire suppression program. Although awareness of how important fire and fuel management are to ecosystem management is growing, progress toward managing fire on the landscape is slow. Full suppression of all fires is still the norm. The number of acres in natural fuel being treated is still only a fraction of what is needed to manage fuel on a landscape scale.

Wildfire Activity

The 1994 fire season in California was more intense and longer than usual. Much of the state suffered drought, and fuel conditions were extreme. Fortunately, the incidence of lightning and Santa Ana winds were not as high as usual, so the potential for large fires was only partially realized. A total of 10,269 fires burned 526,219 acres and 2,234 of these fires burned 222,872 acres in National Forests (fig. 3). About 30,000 acres of National Forest lands will require investments to reforest. Several wildfires were significant in 1994; among them were the Barkley Fire on the Lassen National Forest, and the Crystal and Cottonwood fires on the Tahoe National Forest.

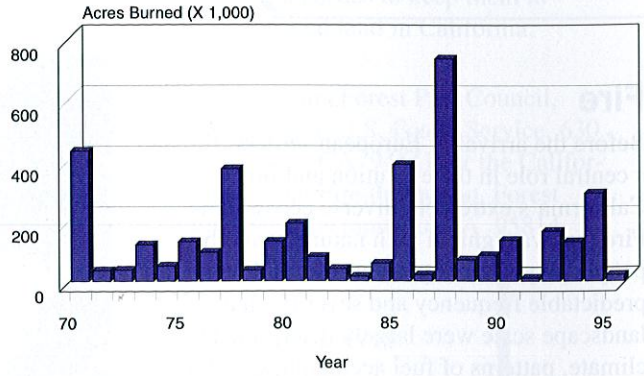


***Figure 3** — Total acres burned on National Forest lands in California, 1970 to 1995; the average year is 1992.*

On September 18, 1994, lightning started the Barkley Fire. The fire burned in mixed conifer forest, oak woodland, and grassy areas on steep rocky slopes in the Deer Creek drainage. Temperatures in the high nineties with Foehn winds (warm, dry winds coming off the lee slopes of a mountain range) and 10 to 15% relative humidities hampered suppression efforts. A wind shift on September 24 provided higher humidities, aiding suppression efforts. A total of 44,430 acres burned, a large proportion of which was within the Campbell/Ishi Wilderness.

Between August 4 and September 4, 1994, two large wildfires burned on the Tahoe National Forest. The Crystal Fire covered 7,310 acres and the Cottonwood Fire 46,800 acres. The areas burned were in eastside pine at lower elevations, mixed conifer at mid elevations, and red fir on the ridgetops. Several decades of fire exclusion had allowed dense stands of white fir to occupy formerly open, eastside pine and mixed conifer forests. Several years of drought and bark beetle infestations left large patches of standing dead trees (fig. 4). Past logging practices left other areas of deep slash with heavy fuel loading. The fires were both high intensity and stand replacing over most of the burned areas. Similar fuel conditions persist in unburned areas adjacent to the burned areas.

Figure 4 *— Crystal Fire, 1994. Fire exclusion combined with drought and tree mortality resulted in heavy fuel loadings that increased the potential for high-intensity fire.*

The 1995 wildfire season was below average: 8,492 fires burned 209,815 acres, of which 1,526 fires burned 22,125 acres of National Forest lands. Only 250 acres of National Forest land required investments to reforest. The winter of 1994-95 was unusually wet, and the typical California summer pattern of high-pressure ridge did not form until late summer. It stayed in the area until late in the season, resulting in low fuel moisture in southern California, and fire activity remained low.

Weather

Information from two sources illustrates meteorological conditions in California over the past few years: the Palmer Drought Indices and data collected by the California Department of Water Resources. The Palmer Drought Index is an indicator of drought or moisture excess and ranges from -6 to +6, with the negative values denoting degree of drought. The annual average indices for the seven climate zones in California indicated that all zones experienced moderate to extreme drought in 1994 (fig. 5). Drought conditions subsided in 1995 throughout the state (fig. 6).

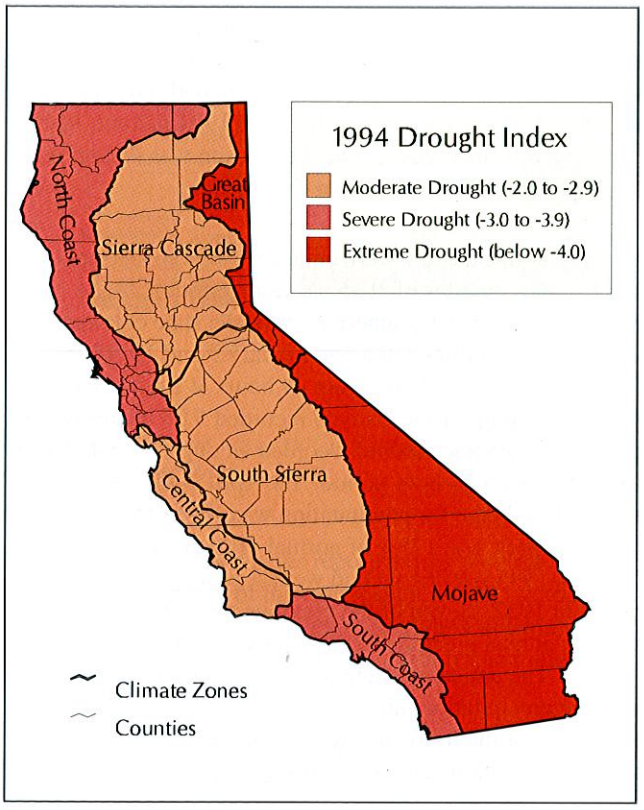


Figure 5 *— Palmer Hydrologic Drought Index for 1994 by climate zone.*

Source: California Department of Water Resources

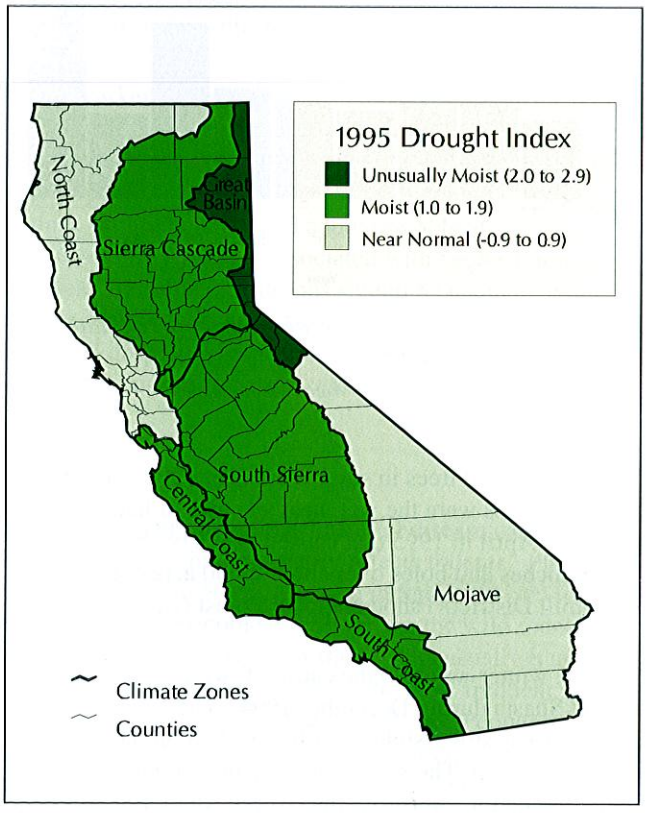


Figure 6 *— Palmer Hydrologic Drought Index for 1995 by climate zone.*

Source: California Department of Water Resources

Except for a few storms in early December and February, dry weather prevailed in northern California during the winter of 1993-94. Northern California had only 80% of its normal snowpack by March 1, and 1994 had the 14th driest March since 1895. The wet season was disappointing (fig. 5), except in southern California.

Precipitation and snow were unusually high in December and the early months of 1995. Serious flooding in the northern and coastal southern parts of the state culminated with a record-setting deluge on January 9 and 10, 1995. Rainfall totaled 17.36 inches in 48 hours at Brandy Creek, west of Redding. Blue Canyon recorded 5.05 inches of rain, and downtown Sacramento recorded an unprecedented 4.45 inches within a 24-hour period. By April 1, the 1995 statewide average for precipitation was 165% of normal, and the snow pack was 175% of normal. For the northern Sierra Nevada, 1995 was the second wettest year since records began in 1922. Seven of the previous nine years had average annual precipitation and snowpack below normal (fig. 7). The annual average or "norm" was derived from the average precipitation rates for the years 1922 to 1995; July 1 to June 30 of the following year mark the beginning and end of a "precipitation year" in California.

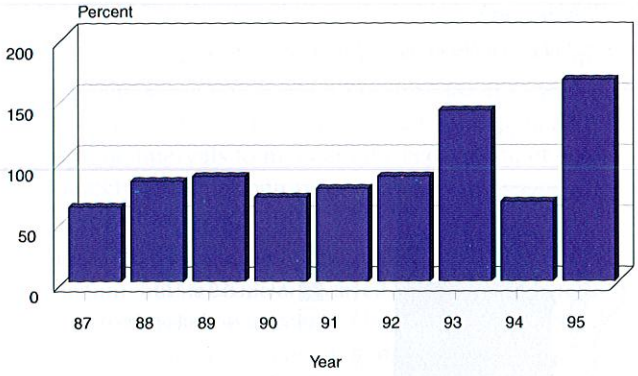


***Figure 7** — Percentage of average annual precipitation in California, 1987 to 1995.*
Source: California Department of Water Resources

Storms damaged trees in several areas in 1994 and 1995. Serious storms were the wet, heavy snows of late March and early April in 1995 that caused extensive breakage of tree branches and boles over about 2,000 acres of the Foresthill District, Tahoe National Forest (fig. 8).

The wet winter was also the cause of two avalanches on Mount Shasta during December 1994. The larger of the avalanches is still visible from Interstate 5 on the west side of the mountain. The smaller avalanche, on the south side of the mountain, cut across the Everett Memorial Highway near Panther Meadows. The major tree species damaged was Shasta red fir—more than six million board feet. In

***Figure 8** — Ponderosa pine broken by heavy snow in early spring of 1995, Foresthill District, Tahoe National Forest.*

late 1994, a strong windstorm leveled knobcone pine over about 120 acres near Lake Siskiyou, Siskiyou County. Most of the trees were salvaged, and the site is being regenerated.

Winter storms in early December 1995 brought winds clocked at 103 miles per hour (mph) at Eureka and 86 mph at Redding. Windthrow during this or other storms in the winter of 1995-96 affected more than 20,000 acres outside of wilderness areas on the Six Rivers and Shasta-Trinity National Forests (Sections M261A and M261B). More than 30 million board feet of timber was damaged in an area of high-value fisheries and late-successional reserves. Concentrations of blowdown fell at South Fork Mountain, Stuart Gap, and Rat Trap Gap on the Shasta-Trinity. Damage to oaks, especially canyon live oak and valley oak, was widespread in the northern part of the Sacramento Valley. The winds also damaged stands on the Almanor District, Lassen National Forest. Heaviest concentrations of damage were in the Swain Mountain Experimental Forest, on Morgan Summit, and in Grizzly Campground near HumBug Pass (Section M261D). Losses across all the Lassen National Forest were near 30 million board feet (MMBF). The same storm felled an estimated 1,000 trees in Golden Gate Park in San Francisco.

Winter needle dessication affected ponderosa pines on about 1,000 acres of private and National Forest lands on the northeast side of Goose Valley (Shasta County). Many of the affected trees died as a result of needle drop and bark beetle attacks.

Animal Damage

Tree seeds, foliage, bark, and cambium form part of the normal diet of many animals. Although most animals do not cause serious damage, a few species create severe problems. Annual reports by the California Forest Pest

Council from 1962 through 1995 (e.g., California Forest Pest Council 1994) show that pocket gophers, deer, porcupines, and black bears cause more than 80% of the animal damage on National Forest lands. Other animals that also occasionally cause damage include rabbits and hares, squirrels, woodrats, meadow mice, mountain beavers, stream beavers, elk, domestic livestock, and some birds [1].

Pocket gophers, the most destructive vertebrate in the state, damage seedlings and saplings by clipping and girdling roots and stems, usually killing the tree. Increased tree mortality from pocket gophers often can be traced to vigorous growth of competing vegetation that provides suitable habitat (Crouch 1982, Teipner et al. 1983). All major forest types throughout the state suffer animal damage, but most problems are in eastside pine, mixed conifer, and true fir stands.

Deer feed on the foliage of seedlings, which causes suppression, growth loss, and sometimes death of recently planted seedlings. Deer feeding causes injuries throughout the state in all major forest types.

Porcupines girdle seedlings, saplings, and poles, causing growth loss, deformity, and dead tops. Porcupines primarily cause damage in eastside pine and true fir stands of northeastern California.

Black bears are primarily a problem in Douglas-fir and redwood stands on private timber lands in the Northern California Coast Section (263A). They peel the bark from pole-sized to mature trees to feed on the cambium. The wounds become entry points for boring insects and decay fungi; girdling results in dead tops and tree mortality. The injury is repeated annually, often in the same vicinity, and ranges from 1 to 60 trees per acre.

The number of acres affected by vertebrates differs considerably from year to year (fig. 9). Losses range from 1 to 500 trees per acre. Protection from animal damage is needed on more than 50,000 acres of National Forest land each year, but currently only about half of these acres are treated (unpublished survey data, California National Forests).

In 1995, species rankings based on the acres of damage differed considerably from previous years: woodrat (25% of the acres), porcupine (23%), black bear (20%), deer (20%), pocket gopher (6%), and all others (6%). This change in ranking of species is the result of one new respondent reporting large numbers of acres affected by woodrats and porcupines. This respondent also reported a total of 336,813 acres for four species, which also accounts for the substantial increase in the total acres reported over previous years (2 to 3 times). Removal of this one response to the annual animal damage control questionnaire of the California Forest Pest Council would give about 139,000 acres and rankings similar to previous years.

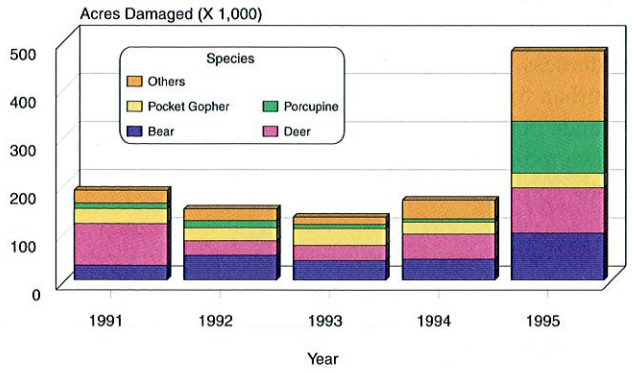


Figure 9 *— Forest acres in California with reported animal damage, 1991 to 1995.*

Vector-Borne Diseases in Forested Environments

Vector-borne diseases are not inherently a part of forest health, but managing forest sites for human health, particularly recreational sites, often involves managing plants and animals. Therefore, this topic is included in the report.

Forest workers, rural workers, and outdoor enthusiasts are probably at higher risk of exposure to vector-borne diseases associated with forested environments than is the general public. Workers and others in potentially high-risk settings should be informed about possible areas of exposure and symptoms associated with vector-borne diseases. Sensible precautions should be taken to avoid contact with rodents and other mammals, their burrows, dens, and droppings, especially in rural settings. Plague and hantavirus are two diseases of concern.

Plague

Plague is a highly infectious bacterial disease caused by *Yersinia pestis*, which primarily affects rodents. Plague, first recognized in North America in San Francisco in the early 1900s, has become established in the wild rodent populations of many western states. It is usually transmitted between rodents by flea bites; the most frequent route of transmission to people is also by fleas. People may also be infected by direct contact with the tissues of rodents, rabbits, and other wildlife or domestic animals.

Plague in California occurs in the foothills, plateaus, mountains, and the coastal belt (fig. 10) but is absent from

[1] Scientific names of all organisms mentioned in this report are given in appendix A.

the southeastern desert and the Central Valley. Areas posing the most threat to people are the recreational, wilderness, and rural parts of the state, as well as the suburban foothill areas of some of the large cities. Campgrounds in the Sierra Nevada that are inhabited by rodents known to be carrying the plague are often closed to the public and chemically treated.

Figure 10 *— Area of plague incidence in California.*

In 1994, plague was recorded in 18 counties. Two human cases of plague were diagnosed: one in Inyo County and a second in El Dorado County. One case of unknown source was fatal. Other counties known to have plague areas during 1994 were Butte, Plumas, Alpine, Siskiyou, Kern, Los Angeles, Mono, Mariposa, Nevada, Riverside, San Bernardino, Sierra, San Luis Obispo, Tuolumne, and Ventura.

In 1995, plague was reported in 15 California counties. Two human plague cases were found in Kern county, one of which was fatal. In the fatal case, exposure may have been primary pneumonic exposure from an unknown animal source. In the second case, all indications point to flea bite exposure from a household pet. Other counties with areas of known plague during 1995 were Butte, El Dorado, Inyo, Los Angeles, Mono, Mariposa, Nevada, Riverside, San Bernardino, San Diego, Sierra, San Luis Obispo, Tuolumne, and Ventura.

Sin nombre virus (hantavirus)

In May 1993, the Centers for Disease Control and Prevention and local health officials investigated an outbreak of a severe acute respiratory disease in people living in the Four Corners region of the southwestern United States. The investigation led to the discovery of a newly recognized strain of hantavirus in North America. The disease in people is now referred to as hantavirus pulmonary syndrome (HPS). The causative agent in the western United States has been named sin nombre virus (SNV). Recognized hantavirus strains are each associated with a primary rodent reservoir. Studies in the Four Corners region identified the deer mouse as the reservoir host for SNV.

In California, about 6,500 mammals of 44 species in 12 families have been tested for antibodies to SNV. The deer mouse appears to be the primary reservoir for SNV in California. Antibodies have been found, though rarely, in a few other wild rodent species: wood rat, ground squirrel, and kangaroo rat. Domestic and wild carnivores have not shown evidence of infection. Mice testing positive for antibodies (seropositive) have been identified in 18 counties (fig. 11).

Engaging in activities that result in exposure to rodents, particularly deer mice, is considered a primary risk factor. Occupying poorly ventilated places with heavy rodent infestations, such as cabins and trailers, may be particularly hazardous. Several patients have reported cleaning infrequently used, rodent-infested buildings or other structures before becoming ill.

From 1980 to 1995, 13 California residents were diagnosed with HPS; 8 of them died. One case was diagnosed in 1993, three in 1994, and five in 1995. Four HPS cases were diagnosed retrospectively from 1980 to 1992 by testing stored serum samples, preserved tissue specimens, or both. The probable sites of exposure were Mono, Nevada, Kern, Inyo, Plumas, and Santa Barbara counties. Notably, the majority of California cases are spatially clustered in the eastern Sierra Nevada.

Multiple-Agent Interactions and Mortality

Insects and diseases kill many more trees than does fire, and they also cause substantial growth loss. More recently recognized are the interactions of insects, diseases, climate, and site and stand factors and their roles in tree mortality. Much of the mortality so visible in California's forests during the recent drought (1986 to 1994) can be attributed to combinations of these biotic and abiotic elements. The combinations, which are common and predictable—

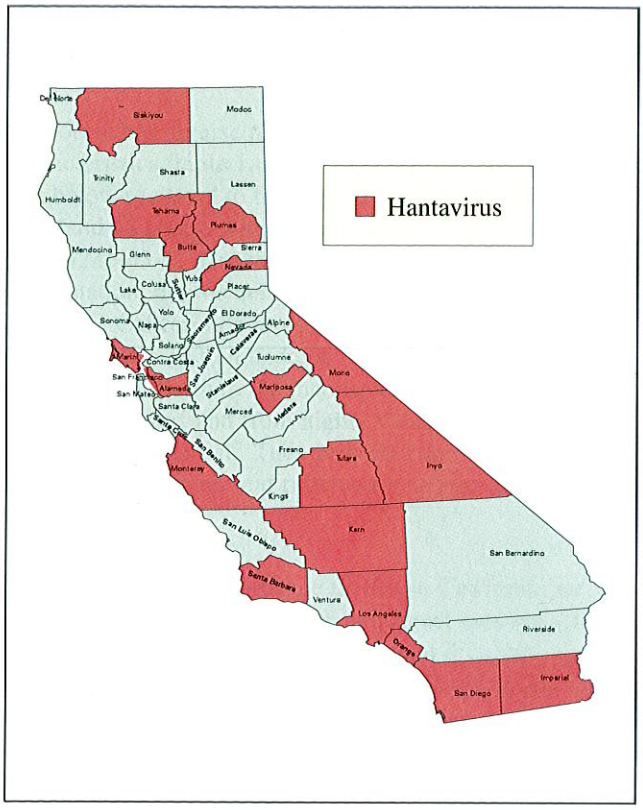


Figure 11 — Counties with seropositive mice, indicating exposure to sin nombre virus (hantavirus).

particularly in drought years—are now referred to as "pest complexes." Three common complexes are:

- Dwarf mistletoe and bark beetles;
- Root disease and bark beetles; and
- Drought with overstocking and bark beetles.

Drought is a frequent visitor to California's forests. Trees of poor vigor because of root disease, dwarf mistletoe infections, or other pathogens frequently succumb to bark beetle attack in a short-term drought or early in a drought of longer duration. Trees that are relatively healthy, but growing on adverse sites or trees in overstocked stands, usually become susceptible to bark beetle attack later in a longer drought cycle. After precipitation returns to "normal" annual amounts, adverse effects of the drought and increased insect populations can continue to result in mortality of trees well above usual rates.

Aerial and ground surveys of National Forests in 1994 and 1995 found tree mortality primarily in overstocked stands, on poor tree-growing sites, and on sites inappropriate for the tree species dying (figs. 12,13,14). Large pines and firs were also frequent casualties. North of Highway 50, mortality continued to be high even though acreage and volume decreased substantially in 1995. The fir engraver in overstocked fir stands and the mountain pine beetle in overstocked lodgepole pine stands were largely responsible for the losses. Jeffrey pine beetle continued to kill large Jeffrey pines throughout much of the region.

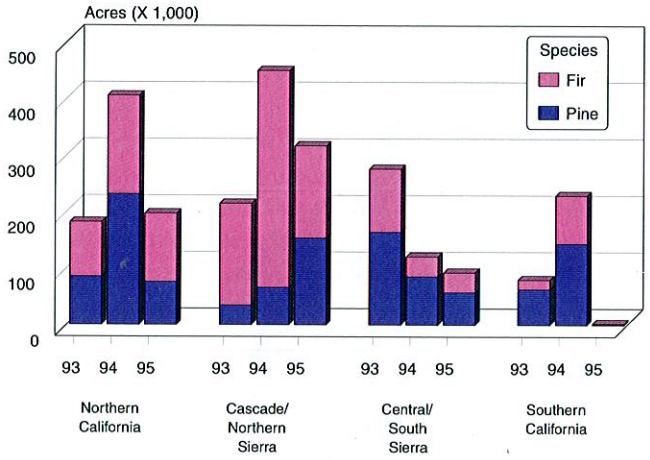


Figure 12 — Acres of pine and true fir mortality on National Forests in four regions of California, 1993 to 1995.

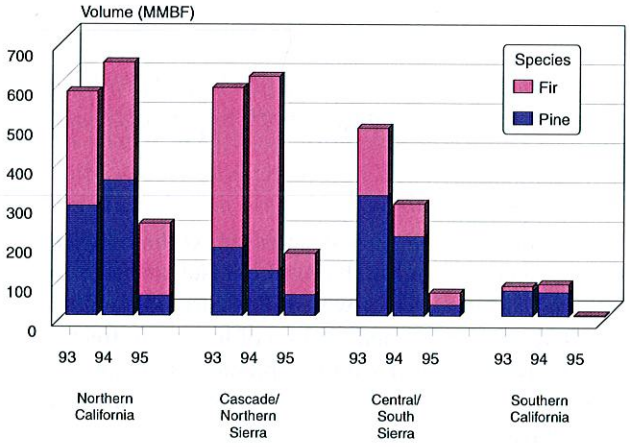


Figure 13 — Volume of pine and true fir mortality on National Forests in four regions of California, 1993 to 1995

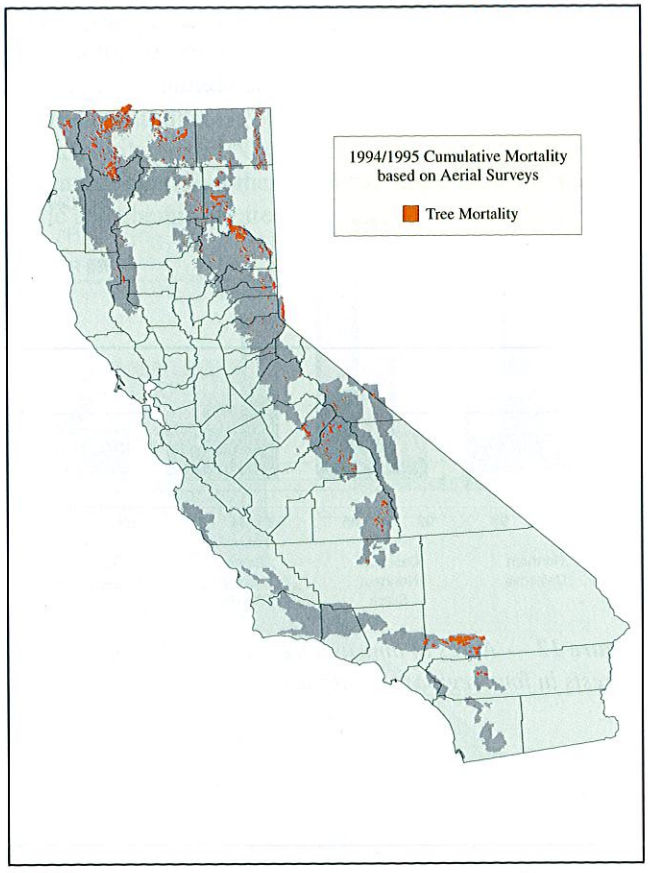


Figure 14 *— Areas of cumulative tree mortality in California National Forests, 1994 and 1995, based on aerial surveys.*

The most dramatic declines in acres and volumes affected were in the central and southern Sierra Nevada and southern California. Trees were killed early in the drought cycle in these regions, and the loss of low-vigor trees and an earlier return to nearly normal precipitation may account for the declines. Southern California showed a variation from this trend in 1994.

Ecological Sections

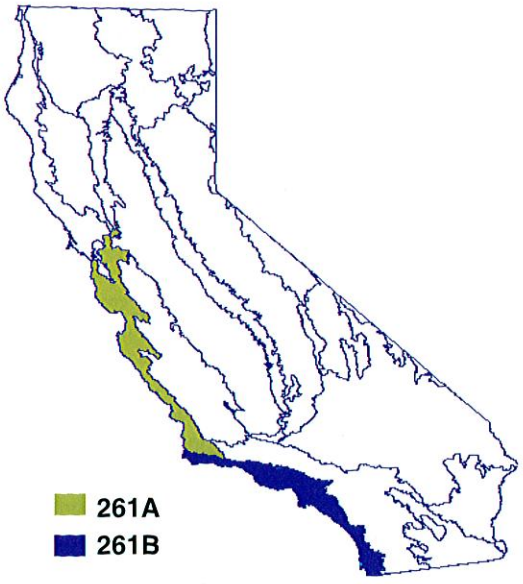
California has diverse physical, climatic, and vegetational characteristics (table 1, fig. 1). Elevations range from 300 feet below sea level to the highest peak (14,495 feet) in the mainland 48 states, with average temperatures ranging from 42 to 65°F. Growing seasons are some of the longest in the nation, but the amount of precipitation varies widely (table 2). California's forests also vary widely; trees range from magnificent to mundane, from the largest living organisms on Earth to the inconspicuous, from abundant to restricted ranges, and from highly valuable to economically inconsequential. They provide goods and services ranging from lumber and firewood to scenic quality and nesting habitat.

Natural and other disturbance factors in California are likewise diverse. Forest health and forest uses are affected by insects and pathogens, fires, frequent droughts, air pollution, animal damage, avalanches, flooding and flash floods, urban encroachment, seismic events, and volcanic activities. Fortunately, not all of these disturbances happen in any one year or at frequent intervals.

Province 261
California Coastal Chaparral Forest and Shrub

261A-Central California Coast

261B-Southern California Coast



Ecology

The northern half of these coastal sections extends from the San Francisco Bay area south to the Santa Maria Valley and Point Sal; the southern section comprises the coast from Point Sal to the Mexican border. The southern coast (261B) includes the most highly urbanized areas of the state as well as great biological diversity in remaining natural areas. The climate of both sections is more moderate than that of the interior, and coastal fog delivers some moisture in the summer (Bailey 1995). Hardwoods, particularly oaks, are common throughout these sections, but conifers dominate certain areas of the Central Coast (261A), reaching greatest abundance and diversity in the Santa Cruz and Santa Lucia Mountains. The southern limit of coast redwood is at the border between Monterey and San Luis Obispo counties. Six conifer species have limited native ranges in these sections: Monterey pine, Torrey pine, Santa Lucia fir, and Santa Cruz, Gowen, and Monterey cypresses. Areas of coastal sage, perennial grassland, or chaparral prevail in the north; coastal sage scrub and chaparral dominate the undisturbed habitat in 261B (Gordon and White 1994).

Forest Health Issues

Monterey pine. Native Monterey pine stands are confined to three coastal locations in the fog belt of central California. Related populations are also on Guadalupe and Cedrus islands in Mexico. Monterey pine grows well and is planted widely throughout the Central Coast section. It is often planted as an ornamental at lower elevations throughout California but is short lived in hot, dry, summer climates. It is commonly grown as a Christmas tree, with most production in coastal southern California.

Many pests attack Monterey pine, but trees planted outside of native stands are particularly prone to damage. Although this pattern appears common for many pests, it may not be true for the exotic disease pine pitch canker, first discovered in California in 1986. The pest complex, consisting of the pine pitch canker fungus and native insect vectors (primarily bark beetles), has contributed to the death of thousands of ornamental Monterey pines in the Central Coast section. Disease symptoms, progression of crown dieback, and tree mortality were first documented in these ornamental trees. In 1995, pine pitch canker was confirmed in the Cambria native stand and is now present in all three native stands in California. The disease has been present near the Ano Nuevo native stand for many years, but only at the end of 1995 did symptoms become widespread (Lud McCreary, personal communication). These observations in native Monterey pine stands are discouraging, but the full effects of pitch canker will not be known for many years.

Table 2 — General descriptions of some sections in California

Section	Geomorphology	Elevation (feet)	Precipitation (inches)	Temperature (° F)	Growing Season (days)	Major Disturbances
		Range	Range	Range	Range	
261A ***Central CA Coast***	Parallel ranges and valleys	0-2400	14-50	50-63	200-330	Fire, seismic
261B ***Southern CA Coast***	Narrow ranges and broad fault blocks	0-3000	10-25	61-65	250-360	Fire, seismic
262A ***Great Valley***	Low fluviatile plain	0-800	05-30	55-66	230-350	Fire
263A ***Northern CA Coast***	Parallel ranges	0-3000	40-100	50-55	250-310	Fire, seismic
M261A ***Klamath Mountains***	Monadnock ranges	1500-8000	40-120	45-55	60-250	Fire, drought, seismic
M261B ***Northern Coast Ranges***	Parallel mountain ranges	1000-7500	30-80	45-59	80-250	Fire, drought, seismic
M261C ***Northern Interior Coast Ranges***	Parallel mountain ranges	200-2500	20-40	55-64	120-270	Fire, drought
M261D ***Southern Cascades***	Volcanic mountains	1500-14,162	20-80	42-58	30-200	Fire, drought, volcanic
M261E ***Sierra Nevada***	Block mountain range	1000-14,495	20-80	42-60	20-230	Fire, drought, seismic
M261F ***Sierra Nevada Foothills***	Block mountain	500-3500	20-40	55-64	200-320	Fire, drought
M261G ***Modoc Plateau***	Mountains with lake beds, cinder cones	3000-9900	12-30	42-52	70-140	Fire, drought
M262A ***Central CA Coast Ranges***	Parallel mountain ranges	500-3500	10-30	55-64	120-270	Fire, drought
M262B ***Southern CA Mountains and Valleys***	Narrow mountain ranges	500-11,500	10-40	45-64	100-200	Fire, drought, seismic, air pollution
322A ***Mojave Desert***	Plains with isolated mountains	300-11,000	03-10	50-75	200-300	Fire, flash flood

Monterey pine is unlikely to remain a favored landscape tree because of the losses in ornamental plantings. The potential spread of pitch canker and the lack of disease-resistant planting stock has led the California Department of Forestry and Fire Protection to stop sales of Monterey, Bishop, and Monterey X knobcone pine seedlings from its nurseries.

The Central Coast section has the highest incidence of pitch canker, but infested areas are also found in the following sections: 263A-Northern Coast; M261B-Northern Coast Ranges; M262A-Central Coast Ranges; and 261B-Southern Coast. Diseased trees are found in 15 coastal and adjacent inland counties from Mendocino to San Diego (fig. 15). Most infected trees in California are Monterey pines, followed by Bishop pines. Other naturally infected native trees include seven pine species and Douglas-fir (Dallara et al. 1995). Pine pitch canker has not been found in native stands of any potential host species in southern California, and it is currently limited to planted Monterey pines in Santa Barbara and in Christmas tree farms in other locales.

Figure 15 — Known locations of pine pitch canker disease in California, 1995.

Oaks. The primary agents affecting oaks in the Central Coast section are the California oak moth and fungal pathogens that cause twig blight and branch dieback. The oak moth has outbreaks that last between two and three years and recur roughly every four to six years. Outbreaks can result in complete defoliation of trees, but tree mortality is seldom a direct outcome. Coast live oak is the principal host, although other oaks are susceptible to damage.

Oak twig blight and oak branch dieback are widely distributed in California, but most reports have come from Mendocino County south to Santa Barbara County. Coast live oak is the primary host for twig blight fungi, but the disease has also been detected on valley, blue, interior live, and Oregon white oaks. In the San Francisco Bay area, twig blight usually is an annual problem on coast live oaks (Ken Meyer, personal communication). Branch dieback has been observed on coast live, valley, and black oak (Hecht-Poinar et al. 1987, Costello et al. 1989).

Live and deciduous oaks are dominant tree species along the southern California coast. The most noticeable pests of live oak are the Pacific oak twig girdler and various defoliators, including the California oakworm and tent caterpillars. The fruittree leafroller is the most significant defoliator of California black oak. Oak pit scales cause stress and dieback, particularly in times of drought. Damage from arthropod galls is slight and sometimes just cosmetic. Wood-boring insects may cause branch dieback, and in times of drought, both wood borers and many leafy mistletoe infections can cause tree mortality (Brown 1980). Heart rot is common in oaks and presents a significant problem in recreation areas where hazardous trees must be pruned or removed. The oak root fungus is a common infection in oaks, but typically does not cause problems in native stands, unless trees are irrigated (Raabe 1980).

Current Forest Health Activities

Research at the University of California, Berkeley and Davis, continues on pine pitch canker and associated insects. Storer et al. (1995) provide a summary of findings. In response to the continuing spread of the disease, a Pine Pitch Canker Task Force was formed in December 1994, sponsored by the California Forest Pest Council. The Task Force is a statewide coalition of governmental, private, and nonprofit groups. In its first year, the Task Force analyzed the pitch canker threat, considered options and proposed priority actions to combat the threat, and alerted professionals and the public about the need to slow disease spread. Two documents, *Pitch Canker Research* and *Pitch Canker Action Plan*, outline research, management, and educational priorities identified by the Task Force (Pine Pitch Canker Task Force 1995a,b). The most critical Task Force effort will be to secure funding for implementing its proposals.

Possibilities for managing pine pitch canker are limited because no direct control or preventive treatments for individual trees have been developed. The Task Force recommends the following: carry out educational efforts

and regulatory actions to prevent transporting infected plant material to uninfested areas, establish procedures to monitor and assess disease spread, incorporate information about pitch canker into resource management and conservation plans for native Monterey pine stands, and use local, native seed and seedlings when regenerating native Monterey pine stands, preferably of disease-resistant stock.

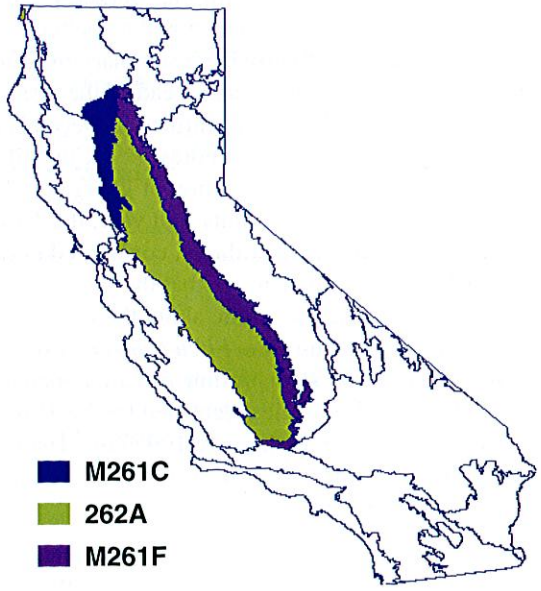
To predict and limit both the spread and effects of pine pitch canker requires answering many questions. Research priorities include determining the survival of the fungus in green waste, assessing effects of pitch canker on native Monterey pine forests, identifying resistant genotypes and the mechanism of resistance, evaluating the potential effects to native conifers, investigating seed transmission and ways to prevent it, and evaluating potential economic effects.

Province 262 California Dry Steppe Province and Province M261 Sierran Steppe - Mixed Forest - Coniferous Forest - Alpine Meadow

262A-Great Valley,

M261C-Northern California Interior Coast Ranges, and

M261F-Sierra Nevada Foothills



Ecology

Blue oak, gray pine, and interior live oak are the most representative trees in these sections, although many other species are locally abundant. Both the Northern California Interior Coast Ranges and the Sierra Nevada Foothills are relatively dry; few streams and rivers flow through the Interior Coast Ranges to the Great (Central) Valley, but many flow from the Sierras through the foothills. Undisturbed portions of rivers and streams are bordered by lush riparian forests in the Valley, where agriculture and urban development dominate the landscape.

Forest Health Issues

Blue oak. The harvest of blue oak for commercial firewood remains the major threat to this species. In addition, the expansion of urbanized areas into foothill woodlands is causing the loss of trees (Bolsinger 1987), either directly by removal or indirectly by poor building and landscaping practices.

Interior live oak and valley oak. Hurricane-force winds in December of 1995 broke and toppled many interior live and valley oaks in the Interior Coast Ranges. Expansion of the urban-rural interface into oak types means that property is increasingly at risk when these species are damaged or uprooted by storms.

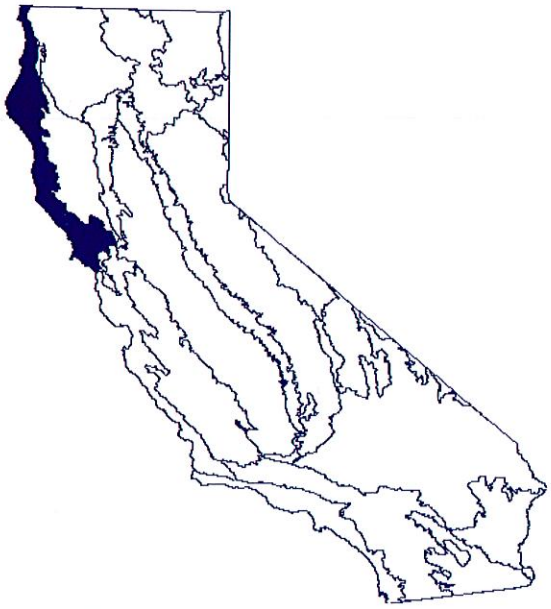
Sustainability of valley oak and riparian woodlands remains an issue in the Great Valley. Riparian woodlands in the Sacramento Valley, of which valley oak is a primary component, are currently estimated to occupy between 1 and 2% of the land occupied in 1850 (Rossi 1980). Pressures from urban expansion raise the possibility of further losses.

Current Forest Health Activities

Oak regeneration has declined during the twentieth century because of several interacting factors, both human and natural. The potential for further losses of oak woodlands has prompted continuing programs of research on California oaks and their resilience and sustainability in the landscape. Results of some of this work are given in Plumb and Pillsbury (1987) and Standiford (1991).

Province 263
California Coastal Steppe, Mixed Forest, and Redwood Forest

263A-Northern California Coast



Ecology

The Northern California Coast supports coastal redwood, mixed evergreen, mixed hardwood, and coastal cypress and pine forests. The principal tree species include redwood, Douglas-fir, Port-Orford-cedar, Sitka spruce, grand fir, western hemlock, Bishop pine, Monterey cypress, tanoak, coast live oak, and Pacific madrone. Less forested areas have many plants in the coastal shrub series.

Forest Health Issues

Forest health conditions in 263A have changed little since the previous report for most tree species. Bears injuring redwoods and Douglas-firs, black stain root disease on Douglas-fir, and Port-Orford-cedar root disease continue to be the primary agents of concern, although some foliage and canker fungi, as well as sucking insects, have been of interest.

California black oak. Septoria leaf blight defoliated black oaks in many places. Damage at only one location caused crown dieback in 1994 and 1995 (see section M261A).

Douglas-fir. Two defoliators have recently been reported on Douglas-firs. One of the defoliators, a newly named walkingstick, *Timema douglasi*, has defoliated Douglas-firs in several locations and, in at least one instance, has caused tree mortality. The second defoliator is citrus thrips or a close relative. This insect causes a curling of the needles of Douglas-firs and reduces their value as Christmas trees. Insecticidal controls are being tested; at this time, results are inconclusive.

Damage from both of these insects appears to be decreasing, but the long-term effects their presence may have on forest health over larger areas is not known. Whether these insects on Douglas-fir are new or their damage has just recently been recognized is also not known.

Monterey pine. Pine pitch canker was identified in landscape plantings of Monterey pine near Santa Rosa and Ukiah. These cities are the northernmost known extension of the disease. Damage has not increased and appears to have stabilized. The fungus has not spread beyond these locations.

Port-Orford-cedar. Port-Orford-cedar root disease was identified in several ornamental plantings outside the natural range of the host and south of the general extent of the disease. The disease was reported in similar landscapes outside the general range of the disease. Soil and infected plants moved by the public are a concern because they are a means of transport to new areas for the fungus causing the disease.

Current Forest Health Activities

The spread of Port-Orford-cedar root disease continues to be a concern. Measures are incorporated into timber harvest and road construction activities on federal and private lands to reduce the risk of spread. Because of the large amount of private lands with Port-Orford-cedar in this section, the California Department of Forestry and Fire Protection and the USDA Forest Service are increasing the awareness of industry, state agencies, and the general public to the root disease and its control.

Province M261
Sierran Steppe - Mixed Forest - Coniferous Forest - Alpine Meadow

Current, Province-wide Forest Health Activities

Rust-resistant sugar pine program. The resistance screening of the Rust-Resistant Sugar Pine Program has been accelerating the restoration of sugar pine to regeneration plantings. The program is designed to identify and produce sufficient rust-resistant seed for reforesting federal, state, and private lands. Currently, the Placerville Nursery seed inventory contains about 1,800 pounds of resistant seed, but not all seed zones are sufficiently represented.

In 1994 and 1995, 410 trees were identified with major gene resistance. These identifications increased the number of registered resistant sugar pines to 985 in National Forests in California. Almost 25,000 trees with major gene resistance have been planted at Happy Camp, CA, to determine if they have other forms of resistance. Selections from the oldest of these trees will continue for enlarging clone banks for future breeding and seed production. About 96,000 seedlings are being tested for slow rusting mechanisms at Pondorado High School in Camino, CA.

Work on other susceptible white pines was increased during 1994 and 1995. Seed collected from 89 foxtail pines, 123 whitebark pines, and 100 western white pines will be investigated for resistance.

Research is focused on unraveling the genetic structure of the fungus. By knowing its genetic structure and the nature of the resistance in the trees, the reliability of rust resistance can be predicted for the sugar and western white pines produced by the program. New races of the rust could exist or develop with the potential to overcome the resistance in selected pines. The probability of this development is low because the variation in the rust is low.

Dwarf mistletoe resistance program. Dwarf mistletoes are parasitic seed plants that grow on conifers throughout California. Forest Pest Management and the Genetic Resource Program initiated a search in 1993 for resistance in both ponderosa and Jeffrey pines. The goals of this program are to identify individual trees that show a potential for resistance to dwarf mistletoe; to develop simple guidelines for identifying and evaluating other resistant candidates; to develop and evaluate screening methods for resistant candidates; and to identify the mode and degree of resistance inheritance for candidates and their progeny.

Guidelines have been developed, and 65 ponderosa pines and 35 Jeffrey pines on the Lassen and Plumas National Forests have been selected for possible resistance. In addition, 10 ponderosa pines and 5 Jeffrey pines with heavy mistletoe infections have been identified as highly susceptible controls for comparison. Artificial inoculation with dwarf mistletoe seed was initiated on six of the resistant candidates in 1993. Inoculation test evaluations will begin in 1996.

Annosus root disease. Annosus root disease, which infects a range of conifer tree species and a few hardwoods and shrubs, has been found in all areas of California with conifer hosts (fig. 16). The most important hosts in California include ponderosa pine, Jeffrey pine, white fir, red fir, and incense-cedar. This root disease causes tree mortality, slowed growth, lost site productivity, and decay of the lower bole, depending on the host species. Two strains, or biological species, of annosus have been identified in the state that act differently and have different host species.

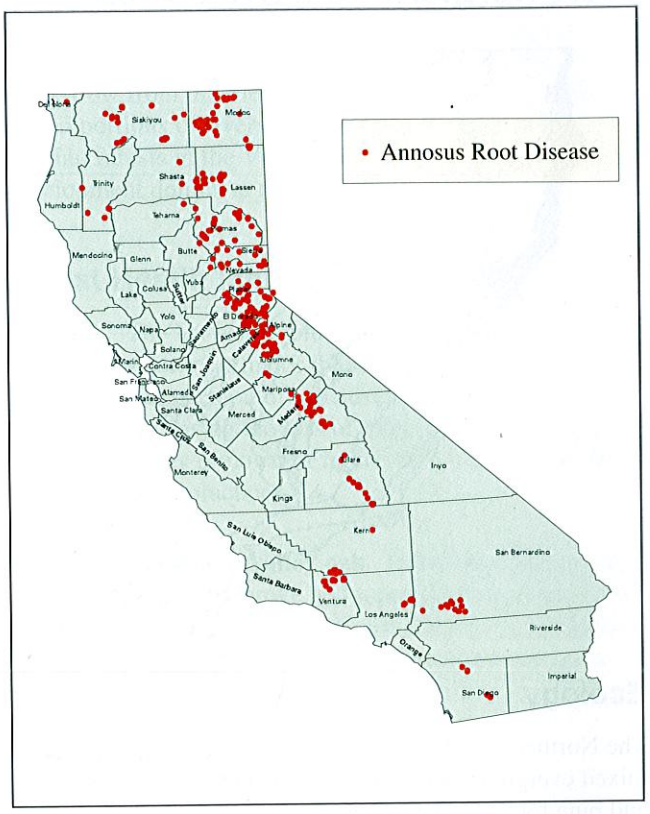


Figure 16 *— Known locations of annosus root disease in California.*

Not all forest areas suffer the same amount of damage. The damage in true firs is greatest in stands composed largely or solely of true firs. The Sierra Nevada and southern California mountains have the highest incidence of annosus root disease in true firs. Pines suffer the most losses in the eastside pine type of northeastern California and the eastern side of the Sierra Nevada, as well as the mountains of southern California.

Surveys of the forest land in much of California were completed in the 1970s and early 1980s to determine the incidence of annosus root disease. In the 12 National Forests of northern and central California, Slaughter and Parmeter (1989) estimated that almost 2.5 million true firs died between fall of 1977 and summer of 1979. Of this 2.5 million, 634,000 were infected by annosus root disease. The dead infected trees contained an estimated 68 million board feet. This volume was about 5.2 percent of the true fir annual growth. In addition to the dead trees, an estimated 12.3 million live true firs, with a volume of 1.46 billion board feet, were infected.

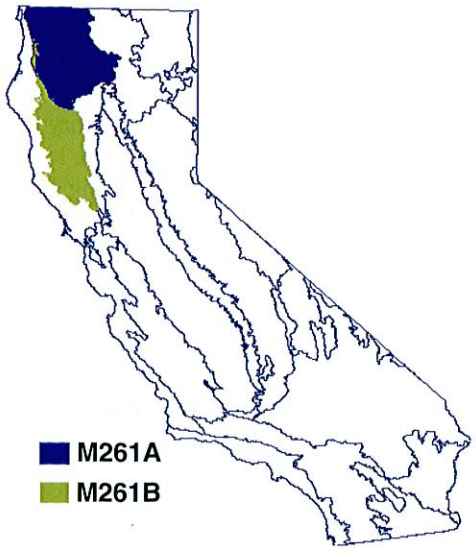
In 1976, an estimated 60 million board feet of pine mortality was at least partially a result of infection by annosus root disease (Smith 1984). The incidence in live trees is not known, but it is not as substantial as in true firs because of the more rapid mortality in pine hosts.

Annosus root disease causes considerable loss and damage in recreational and developed areas. Mortality and root failure of live trees are the principal concerns. Developed sites were surveyed in the 1970s in Yosemite National Park after considerable damage by annosus root disease. Ponderosa pine and incense-cedar were examined in developed areas of Yosemite Valley, and 102 annosus root disease centers were identified (Marosy and Parmeter 1989). Campgrounds in the pine forests of southern California also have a high incidence of annosus root disease.

Annosus root disease is controlled by preventing infection of freshly cut stumps by airborne spores of the fungus that causes the disease. Borate compounds have been found highly effective in protecting freshly cut stumps. The Forest Service routinely has pine stumps treated in many areas of eastside pine forests as well as some true fir stands in the transition and westside zones. In 1994, about 16,600 pounds of material were applied to stumps on nearly 58,000 acres of National Forest lands. In 1995, the amount used exceeded 22,800 pounds on about 51,500 acres. This use was mostly for timber sales, but recreational and developed areas were also treated.

M261A
Klamath Mountains

M261B
Northern California Coast Ranges



Ecology

The Klamath Mountains and the Northern California Coast Ranges sections share at least three vegetation categories: montane forest, mixed evergreen, and montane chaparral. The Northern Coast Ranges are slightly drier than the Klamath Mountains, which may account for why blue oak and gray pine are more common in M261B. Tree species common to both sections are Douglas-fir, ponderosa pine, white fir, Port-Orford-cedar, sugar pine, Pacific madrone, canyon live oak, tanoak, Oregon white oak, California black oak, and bigleaf maple. Red fir, mountain hemlock, Jeffrey pine, incense-cedar, and western white pine are more common in the Klamath Mountains.

Forest Health Issues

California black oak. Black oaks along many drainages were defoliated by septoria leaf blight, but damage to the trees was minimal. Trees are defoliated sporadically when temperature and moisture conditions in the spring are conducive to infection. This type of defoliation may not significantly affect forest health, but can influence public perceptions because of its visibility.

Douglas-fir. Black stain root disease is commonly observed on small Douglas-firs, especially along roads. Evidence that the disease is causing decline and mortality of larger Douglas-firs is increasing, however; although not always apparent, some form of past disturbance is usually associated with the decline. Whether the disease is actually increasing or only being better recognized is unknown. If it is increasing, management activities may be causing the increase.

Drought has caused Douglas-firs in some overstocked stands to be quite susceptible to the Douglas-fir beetle and the flatheaded fir borer. Douglas-fir dwarf mistletoe is often a factor in the mortality. Mortality associated with these beetles is higher than has been seen in recent years, but it is still low compared with the more ubiquitous pine bark beetles.

Incense-cedar. Incense-cedars are generally hardy, with few aggressive insects or pathogens that attack them. During the last few years, however, incense-cedars have been declining and dying over a wide area. All sizes of trees are affected, but most of the damage has been in smaller trees. The majority of this damage has been on low-quality sites with dense vegetation. Some bark beetles were identified in these trees, but the underlying cause of damage is drought.

Pacific madrone. Pacific madrone suffered a foliage blight along the Klamath and Trinity River drainages in 1994 and, to a lesser extent, in 1995. During the spring of

1994, the bare reddish-brown stems of Pacific madrone were evident on the slopes because of defoliation. Several fungi were involved; the most common was *Coccomyces arbutifolius*. The trees refoliated after bud break, but the blight continued through 1995. Damage was limited to branch dieback and some tree mortality.

Ponderosa pine. Ponderosa pine mortality was higher than normal in many areas of the section as a result of drought and bark beetles and engravers (fig. 17). The beetles contributing to the mortality included the western pine beetle, pine engravers, red turpentine beetle and, to a lesser extent, the mountain pine beetle. Areas where ponderosa pine mortality was prevalent included the major river corridors, such as the Sacramento and Trinity Rivers, and also around large valleys. The lower elevation valleys receive less precipitation than do the surrounding mountains. Outside of the major valleys, particularly in the Northern Coast Ranges, the most common pattern of pine mortality was large areas with scattered dead trees.

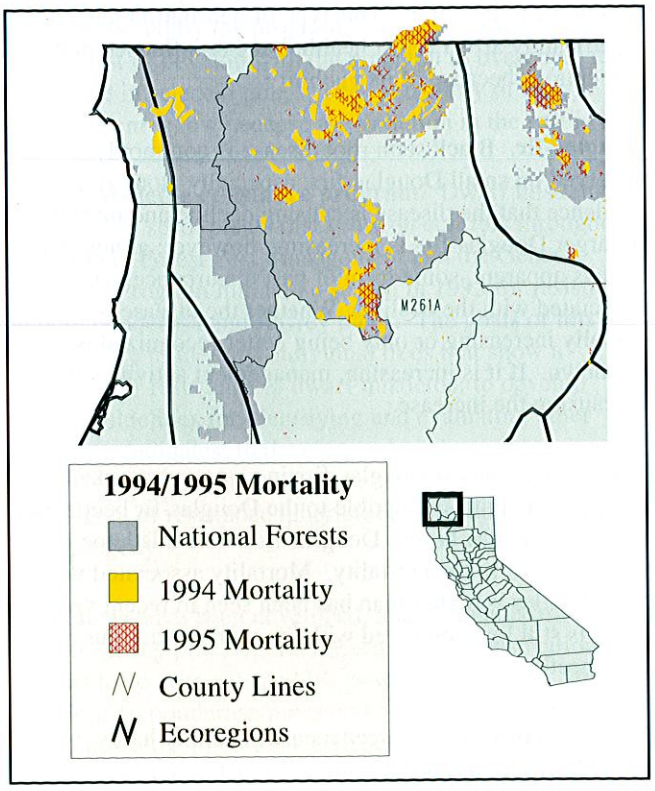


***Figure 17** — Aerially surveyed tree mortality in the Klamath Mountains, 1994 and 1995.*

Port-Orford-cedar. Port-Orford-cedar root disease is still the most significant concern affecting the health of the species. In 1994 and 1995, additional locations of this disease were identified in previously uninfested tributaries of the Smith River. Spread of this root disease is expected to continue in infested areas because of the limited ability to control access to all areas.

In 1995, the disease was confirmed in a tributary of the Klamath River. This identification is the first in a native stand in California outside the Smith River drainage. The site of infection is several miles from the Klamath River confluence, but the tree species grows along the entire tributary system leading to the river. This infection puts downstream Port-Orford-cedar at risk in this watershed. It also increases the risk of transporting the pathogen into watersheds farther up the Klamath River.

Red fir. Dwarf mistletoe infections of red fir are moderate to high in many locations, and cytospora canker is common in the branches of red fir, especially in areas with dwarf mistletoe. These two agents reduce the amount of live branches in trees and weaken them. The weakness, combined with drought stress, increased successful attacks by the flatheaded fir borer and tree mortality. As a result, red fir continues to decline and die in many areas (fig. 17), particularly in old-growth stands.

White fir. Concentrated white fir mortality was observed in the Taylor/Carter Meadows Late-Successional Reserve on the Klamath National Forest. Extended drought and attacks by the fir engraver were responsible for the mortality. Damage has been so severe that an analysis was necessary to determine whether conditions had shifted outside the natural range of variability of late-successional reserves.

White pine. White pines in this section include sugar pine, western white pine, foxtail pine, and whitebark pine. Foxtail and whitebark grow near timberline on the highest mountain peaks. White pine blister rust is common throughout much of the section; it arrived in the 1930s and 1940s. Most of the damage is to sugar pine, but western white pine is becoming increasingly affected. Limited surveys of the two high-elevation species found light infection by blister rust. Damage by this fungus is not currently affecting survival of either foxtail or whitebark pine in the Klamath Mountains.

Sugar pine mortality caused by drought and mountain pine beetle increased in 1994. Both large, overstory trees and visibly vigorous 20 to 80-year-old trees were killed. Sugar pine mortality continued at a high rate during 1995, particularly on the Six Rivers National Forest and the western part of the Klamath National Forest. The most common pattern of mortality in the Northern Coast Ranges was large areas with scattered dead sugar pines.

Current Forest Health Activities

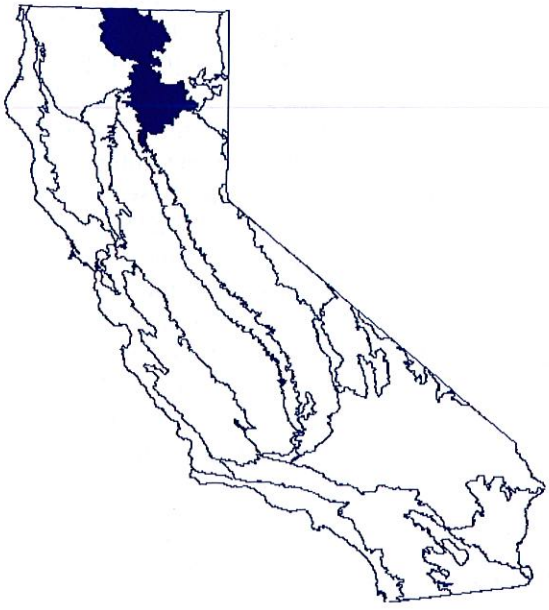
Permanent and seasonal road closure is a primary means of preventing spread of Port-Orford-cedar root disease. Soil that may contain the fungus is washed from vehicles and equipment before they enter and work in uninfected areas. Seedlings from more than 300 parent trees are being

screened for potential resistance to the root disease. If resistant trees are identified, they will be protected, and the seed will be collected for future regeneration. Training and information activities are increasing public awareness of how to prevent spreading the disease.

In 1995, the Klamath National Forest began evaluating the Taylor/Carter Meadows Late-Successional Reserve in response to the severity of white fir mortality from 1993 to 1995. The goal in late-successional reserves is to protect and enhance conditions of late-successional and old-growth forest ecosystems, which serve as habitat for species dependent on old-growth, including the northern spotted owl. These conditions may have been compromised by the mortality of white fir.

The Salmon River District, Klamath National Forest, sprayed three rust-resistant sugar pines with carbaryl in 1995 to protect them from bark beetle attacks. Numerous attacks on sugar pines, including those near the resistant pines, put the trees at risk. All three of the sprayed trees survived.

M261D
Southern Cascades



Ecology

The Southern Cascades section extends north from the Sierra Nevada to the Oregon border and lies between the Modoc Plateau to the east and the Klamath Mountains to the west. At low elevations, the coniferous vegetation is gray pine, and as elevation increases, vegetation is a mixture of ponderosa and sugar pines, Douglas-fir, and white fir. Mid-elevation zones have white fir with some sugar and ponderosa pines, and incense-cedar. At high elevations, red fir, lodgepole pine, and whitebark pine are found; Jeffrey pine also grows at the high elevations and on drier sites.

Forest Health Issues

The extended dry period continues to affect most conifer species in this section. Normal or above normal precipitation has been observed in only 2 of the past 11 years—1993 and 1995 (see weather discussion). Pine and fir mortality in 1994 and 1995 was above normal in many areas because of extreme moisture stress and bark beetle and engraver attacks. Insect damage that is of minor importance was more pronounced on many conifer species because the drought reduced individual tree resiliency.

Jeffrey pine. Jeffrey pines are characterized as being drought tolerant, but the number of Jeffrey pines killed by Jeffrey pine beetle increased markedly over the past two to three years in this section, despite the relief from the drought during 1993. Groups of dead trees were concentrated in Lassen Volcanic National Park and adjacent areas to the north and east on the Hat Creek and Eagle Lake Districts, Lassen National Forest (fig. 18). Several groups of attacked trees in the general vicinity of each other are commonly visible. These groups of dead trees sometimes cover several acres of a drainage. One infestation near Lost Creek, in Lassen Volcanic National Park, started about three years ago as a small group attack, and during 1994, more than 800 trees were attacked in this area.

Large, individual trees have been attacked and killed over the past three years around Manzanita Lake, Manzanita Lake Campground, administrative sites, and Butte Lake at the north end of Lassen Volcanic National Park. Affected trees included some of the largest specimens (>50 inches dbh) known for this species.

Forest health concerns in young Jeffrey pine are few, although insects occasionally cause damage. An outbreak of pine needle sheathminer caused extensive damage to Jeffrey and ponderosa pines in a mixed plantation in the Pondosa Burn, east of Pondosa, Siskiyou County. The infestation in 1994 was estimated at more than 1,000 acres, and several hundred of these acres on the east side of the plantation were heavily defoliated. Although 1995 populations were significantly less than in 1994 (1.8 larvae per shoot vs. 9.4 larvae per shoot), they were high enough to cause noticeable defoliation.

Lodgepole pine. Lodgepole pine mortality from attacks by the mountain pine beetle increased over the past two to three years. A substantial proportion of the lodgepole pines around Crater Lake and Crater Lake Campground,

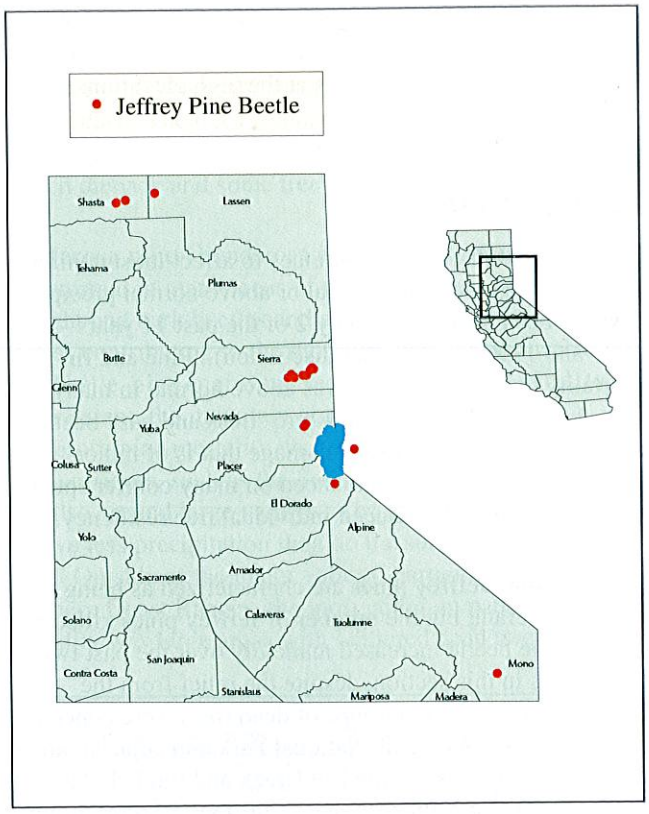


Figure 18 — Concentrations of pine mortality caused by the Jeffrey pine beetle, 1994 and 1995.

Lassen National Forest, died during 1994. Chronic mortality from beetle attack exists between Butte and Snag Lakes in Lassen Volcanic National Park. North of the Park, groups of lodgepole pines were killed by mountain pine beetles in the Thousand Lakes Wilderness, Lassen National Forest.

Ponderosa pine. Western pine beetles, mountain pine beetles, and the effects of prolonged drought were the most common causes of ponderosa pine mortality in the southern Cascades. In some areas, the number of affected trees decreased, but mortality remained above normal. The greatest increases in mortality were on the Goosenest District, Klamath National Forest; on the drier sites near McCloud Flats, eastward to Pondosa; and in the Lake Britton-Burney basin area, Shasta-Trinity National Forest. Mortality of individual trees and groups of ponderosa pines were common on the Eagle Lake and Hat Creek Districts, Lassen National Forest. Mountain pine beetles were associated with smaller trees, and western pine beetles were found in the larger trees.

Other insects damaged trees in several areas. Snow breakage and increases in populations of California fivespined ips during 1993 resulted in top-killed groups of ponderosa pine on McCloud Flats, McCloud District, Shasta National Forest, in 1994. Pine needle sheathminer caused extensive damage to ponderosa and Jeffrey pine in a mixed plantation in the Pondosa Burn (see Jeffrey pine, this section). An infestation of western pine shoot borer reduced terminal growth in several thousand acres of ponderosa pines in the Pondosa Burn. Infestation rates in 1994 were similar to those detected in 1993, with 20 to 40% of terminals infested.

Sugar pine. Sugar pine mortality caused by drought and mountain pine beetle has continued to increase across northern California since the early 1990s. Overstory trees were killed as in previous years, but mortality was also detected in younger age classes. Killed trees were scattered throughout the Lassen National Forest.

White fir. White fir mortality continues in eastside vegetation types throughout the Southern Cascade section. Fir engravers, overstocking, overabundance of white fir, and drought have contributed to extremely high mortality in white fir. Mortality has been chronic in the Ball Mountain Late-Successional Reserve, Goosenest District, Klamath National Forest. Scattered white fir mortality is visible from almost any viewshed where the species exists on the Lassen National Forest. Mortality on the Lassen continued to be noted on PegLeg, Antelope, and Harvey Mountains, Eagle Lake District, and around the Thousand Lakes Wilderness Area, Hat Creek District. The rapid deterioration of the white fir after mortality has altered forest stand structure, added to the fuel loading, and increased the amount of sunlight reaching the ground.

Aspen. Many aspen clones have declined in extent or disappeared altogether in northeastern California. This decline is due in large part to decades of season-long grazing access by domestic livestock, and to changes in fire occurrence. Two situations are common: remnant trees in meadows with sparse or absent regeneration, and mature or old aspen stands that are being overgrown with conifers such as white fir, lodgepole, and western juniper. In contrast, a few clones appear vigorous and healthy with a full-crowned overstory and abundant regeneration in several different size classes (Sydney Smith, personal communication).

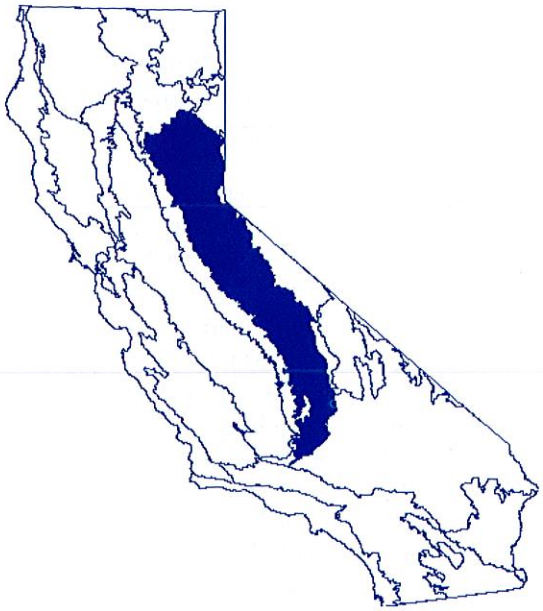
Current Forest Health Activities

Several forest-health restoration projects are underway on the Lassen National Forest; they were initiated because of increased tree mortality and include both salvage and thinning. Several analyses have determined pre-European forest conditions, which ecosystems are outside of the natural range of variability, and what efforts can restore these ecosystems to their desired state. Thinning in plantations and natural stands are in progress, with the goal of preventing future mortality related to bark beetles and engravers and reducing fuel buildup.

Studies to monitor Jeffrey pine beetle outbreaks were initiated in three areas during 1995: Lost Creek, and Manzanita Lake Campground and its administrative sites, both in Lassen Volcanic National Park; and the Pole Springs area, Eagle Lake District, Lassen National Forest. All infested trees were tagged and recorded. Monitoring will continue until the outbreaks decline.

In northeastern California, the number of male Douglas-fir tussock moths caught in monitoring traps increased from 1994 to 1995. The most pronounced increase was on the Eagle Lake District, Lassen National Forest. Larval sampling will be conducted in the summer of 1996. (See "Current Forest Health Activities," M261E).

M261E
Sierra Nevada



Ecology

Vegetation at foothill elevations on the west side of the Sierra Nevada section is dominated by blue oak, interior live oak, and gray pine; ponderosa pine, incense-cedar, and black oak become prevalent as elevation increases. The mid-elevations are characterized by ponderosa pine, sugar pine, incense-cedar, white fir, and Douglas-fir (north of the Merced River); ponderosa pine decreases and white fir increases as elevation increases. Hardwood species in these areas include canyon live oak, maple, dogwood, and black oak. Red fir is found on both the west and east slopes from about 7,000 to 9,000 feet. The subalpine areas consist of western white pine, lodgepole pine, and mountain hemlock, with Jeffrey pine replacing ponderosa pine at the higher elevations and colder sites. On the east side of the Sierra Nevada, Jeffrey pine dominates in the mid-elevations in association with white fir, incense-cedar, and lodgepole pine. Hardwoods include alder, willow, and at higher elevations, quaking aspen. The Sierra Nevada vegetation has been influenced by grazing, forestry, mining, recreational activities, and changes in fire patterns.

Forest Health Issues

In the late 1980s and early 1990s, mortality of ponderosa and sugar pine was high in many areas throughout the Sierra Nevada section where those species predominated. The mortality was caused by a combination of drought, root disease, dwarf mistletoe, overstocking, and the western and mountain pine beetles. Since 1994, mortality of these two tree species has returned to rates seen in the early 1980s.

Giant sequoia. The long-lived giant sequoias are often thought to be impervious to insect and pathogen effects. As giant sequoia ecosystems are more closely monitored, however, pest effects may become more noticeable. On a calm morning in May of 1992, a living 13-foot-diameter (dbh) sequoia fell near Round Meadow (Giant Forest area) in Sequoia National Park. The tree had decay in several large support roots and was growing on the edge of an annosus root disease center. A study in the 1970s (Piirto 1977) concluded that this disease was the most common factor found in the failure of giant sequoia root systems (12 of 29). The 1992 failure and the study information convinced Park officials to close an administration building and adjacent parking lot next to a leaning, 21-foot-diameter giant sequoia, which was also growing in an annosus root disease center.

Pest problems of planted 10-year-old giant sequoia seedlings appeared in a plantation on the Hume Lake District of the Sequoia National Forest in 1994. Thirteen saplings died in two years in an area of about 1 acre. One overstory sequoia, 49 inches in dbh, also died. Conks of the annosus fungus were found in white fir and incense-cedar stumps in the plantation, and mycelial fans of *Armillaria* sp. were present at the root collar of each dead tree. Tests are in progress to determine what species of Armillaria are present. No evidence has yet been discovered to explain what triggered the mortality.

Jeffrey pine. Increasing Jeffrey pine mortality became evident in 1990 around the east and south sides of Lake Tahoe. Death of Jeffrey pines is often the result of interactions between moisture stress, the Jeffrey pine beetle, overstocking, and annosus root disease in some locations. The mortality is of particular concern because it is in high-use, developed sites and dispersed recreation areas, as well as on private properties. Such mortality causes unwanted reductions in vegetative cover, increases in fuels, and—depending on location—hazardous trees.

Concentrated mortality has also appeared in several locations from the Sierraville area on the Tahoe National Forest in the north to the Mammoth Lakes area on the Inyo National Forest in the south (fig. 18). Between 1993 and 1995, 950 Jeffrey pines were killed by the Jeffrey pine beetle over about 166 acres near the Inyo Craters on the Mammoth District. More than 2,000 Jeffrey pines were killed over about 500 acres of developed recreation sites around the Lake Tahoe basin, along with more than 5,000 Jeffrey pines in a 100-acre dispersed recreation area near Spooner Lake. Additional concentrations of Jeffrey pine were killed by the beetle in Rice Canyon, Cold Creek, Antelope Valley, Onion Valley, and Smithneck Creek on the Sierraville District; in the Truckee River drainage along Highway 89 south of Truckee; near Secret Harbor, Slaughterhouse Canyon, Skunk Harbor, Glenbrook, and Logan House on the east side of Lake Tahoe (fig. 19); near Tahoe Valley on the south shore of Lake Tahoe; and in the Deadman Creek area on the Mammoth District.

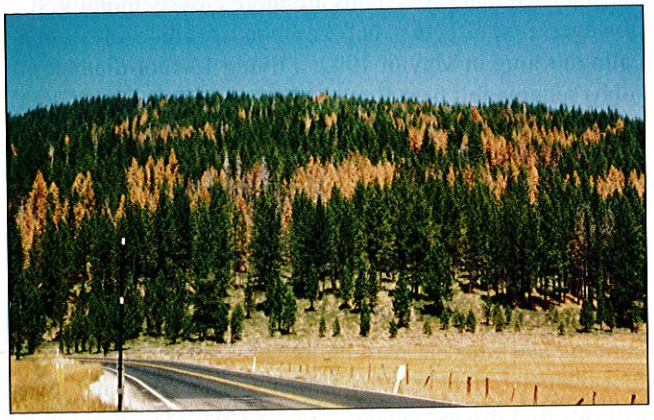


Figure 19 *— Jeffrey pines killed by Jeffrey pine beetle on the east side of Lake Tahoe, August 1995.*

White fir. High mortality continues in some white fir stands in the northeast part of the Sierra Nevada section and around Lake Tahoe. Most of the mortality is related to interactions of drought, overstocking, and fir engraver. The species composition of some eastside ecosystems has shifted from pine-dominated stands with small amounts of white fir to almost complete dominance by white fir. White fir regeneration and growth coincides with adequate or above normal moisture, which allows this species to occupy sites once dominated by more drought-tolerant pine species. During protracted drought periods, however, white fir mortality exceeds acceptable amounts and affects management goals in many watersheds. Although the majority of the white fir mortality associated with the recent drought happened before 1994, some areas are still experiencing dramatic increases in tree decline and death. Areas still experiencing high mortality include the east side of the following Districts: Eagle Lake District, Lassen National Forest; Beckwourth District, Plumas National Forest; the Sierraville and Truckee Districts on the Tahoe National Forest; and areas around Lake Tahoe.

Lodgepole pine. In the northeast part of this ecological section, lodgepole pine is mainly in frost pockets or along riparian areas. Many stands have chronic mortality despite normal precipitation. During droughts, increased mountain pine beetle activity contributes to even higher rates of tree mortality. Over the past two years, increases in tree mortality have been observed primarily on the Truckee District, Tahoe National Forest, and at Donner Memorial State Park. Tree mortality is apparent along the Truckee River in and around campground sites and in undeveloped areas. Mortality over the past few years now covers about 100 acres in Donner Memorial State Park; this area is the largest reported contiguous area of lodgepole pine mortality.

Conifer health declined suddenly near Horseshoe Lake on the Inyo National Forest in 1992. Extensive mortality and severe needle loss were observed on 15 acres, which included primarily lodgepole pine but also red fir, mountain hemlock, and western white pine. All trees of these species within the 15 acres were affected. Investigations eliminated insects and pathogens as the primary causes. The mortality spot increased to over 30 acres by 1995, and new areas of similar damage were found. Recently, the mortality has been linked to geothermal activity that has produced very high concentrations of carbon dioxide in the soil.

Red fir. Red fir in the northern part of this section has had continual mortality over the past three to five years. Mortality of large trees is associated with attacks by fir engravers and inadequate precipitation; however, small trees (<5 inches in dbh) are also dying directly from drought, without fir engraver attacks. The recent red fir mortality in this section is on the southern edge of the Eagle Lake District, Lassen National Forest. Several special-emphasis wildlife habitat areas have been negatively affected.

Western white pine. Western white pine grows at higher elevations throughout the Sierra Nevada. As a five-needle pine, the species is susceptible to white pine blister rust. In California, however, concerns have focused on sugar pine, a far more abundant and valuable timber resource. In recent years, questions about the distribution of blister rust on western white pine have increased, but only limited surveys have been completed. In one stand on the Stanislaus National Forest at about 7,000 feet elevation, virtually every western white pine is infected with blister rust. Surveys of drainages in Sequoia and Kings Canyon National Parks during 1995 showed that blister rust infection frequencies of 20% were common in western white pine stands. This percentage implies that blister rust is still spreading to new sites in California and threatens the higher elevation five-needle pines. To date, the rust

has not been observed above 7,500 feet elevation in the John Muir Wilderness. Western white pine, whitebark pine, and the alternate hosts (*Ribes* spp.) of the pathogen were free of rust, although conditions seemed favorable (R.S. Smith, Jr., personal communication).

Air pollution. Ozone is the major plant-damaging component of photochemical oxidant air pollution (smog), and the air pollutant most damaging to conifers in California. Nitrogen dioxide and hydrocarbons from automobiles and other sources react with sunlight to produce ozone (Scharpf 1993). When ozone enters the needles through the stomates, it destroys the chlorophyll and impairs metabolic processes (Tainter and Baker 1996).

Ozone injury to trees in the Sierra Nevada was first reported in 1971. Currently, two plot networks are established to assess ozone effects on pines in this section: the Forest Pest Management network includes long-term vegetation assessment plots that were first installed on the Sierra and Sequoia National Forests in 1977; and Project FOREST (Forest Ozone REsponse STudy) is a multi-agency network that includes ozone-monitoring instrument sites and associated vegetation-assessment plots on three National Parks and five National Forests from Lassen National Park south to the Sequoia National Forest (fig. 20). The Project FOREST area also includes sites on the San Bernardino National Forest. Data on this network were collected between 1991 and 1994. Both of the networks use the foliar symptom called "chlorotic mottle" (fig. 21) produced by ozone on conifer needles as the primary indicator of injury.

Project FOREST data shows the status of ozone on a very large forested federal land base over a short period. Symptoms of ozone injury have been found throughout the Sierra Nevada; injury is lowest in the north (Lassen National Park) and generally increases toward the south. The most heavily affected plots in the southern Sierra Nevada (Grant Grove and Giant Forest in Sequoia and Kings Canyon National Parks) fall in the range of injury found on the San Bernardino National Forest in southern California east of Los Angeles.

The Forest Pest Management network traces ozone injury over 18 years but on a relatively small land base (two National Forests); the categories of ozone injury ratings for plots on the Sierra and Sequoia National Forests in 1977 and 1994-95 are given in figures 22 and 23. Plots having no injury decreased proportionally on each forest during the period of observations; moderate and severe injury became more prevalent.

In summary, evidence of ozone injury is found throughout the Sierra Nevada and increases in severity from north to south. All chlorotic mottles do not translate into measurable damage to trees, however, and slight amounts of injury may simply have cosmetic effects.

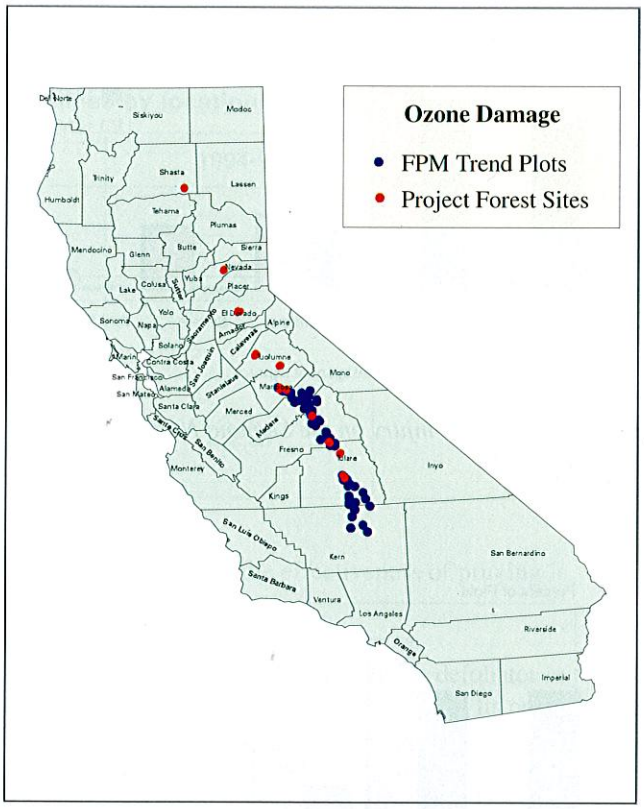


Figure 20 — Two plot networks for monitoring ozone injury in the Sierra Nevada.

Figure 21 — Chlorotic mottle of ponderosa pine needles caused by ozone.

Current Forest Health Activities

Insect and pathogen considerations are an integral part of landscape-scale ecosystem analyses. These analyses evaluate current conditions, define desired conditions for diverse resources, such as vegetation structure and compo-

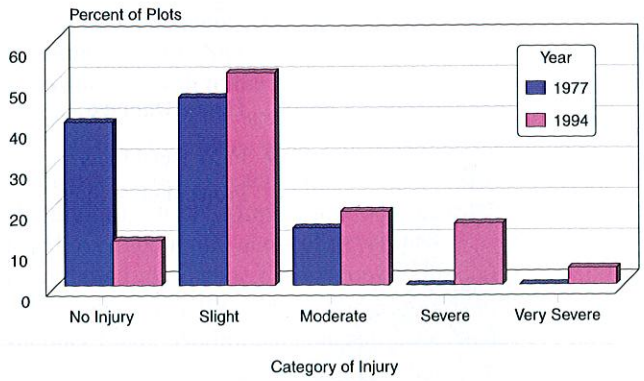


Figure 22—Ozone injury on the Sequoia National Forest, 1977 and 1994

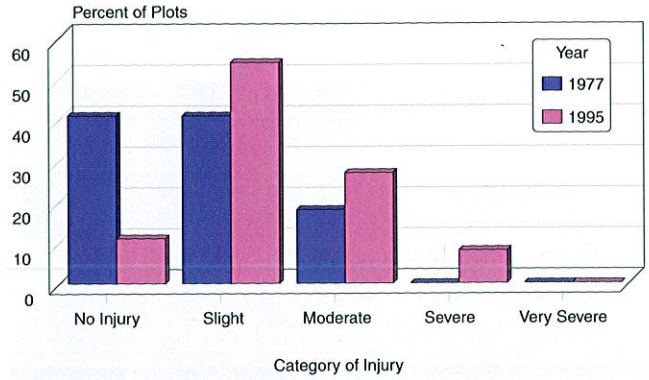


Figure 23 — Ozone injury on the Sierra National Forest, 1977 and 1995.

sition, and identify and set priorities for potential projects for subsequent site-specific analyses. The site-specific projects include insect and pathogen prevention and management components, such as thinning and the removal of trees infested with dwarf mistletoe.

In 1995, the Donner Ecosystem, covering 96,000 acres, was analyzed by the Truckee District, Tahoe National Forest. Project implementation is planned for 1996-97. In the Lake Tahoe basin, the North Shore Project Environmental Impact Statement was completed in 1996, covering 20,000 acres between Tunnel Creek (Washoe County, NV) and the Truckee River corridor (Placer County, CA). Activities will be implemented over about 7,000 acres of the analysis area beginning in 1996. Also in the Lake Tahoe basin, the East Shore Project, initiated in 1994 over 6,600 acres, continued in 1995 and included Jeffrey pine beetle suppression and preventive thinning. Analysis of the West Shore was initiated in the spring of 1996. Other projects with a specific thinning component aimed at bark beetle prevention include the North Fork Project on the Minarets District, Sierra National Forest; the Basin Biomass Thinning Project on the Summit District; and the Sawmill Mountain Thinning Project on the Groveland District, Stanislaus National Forest. In addition, a cooperative project between the Nevada-Tahoe Conservation District, the Kingsbury General Improvement District, and the Forest Service was initiated to prepare and implement a Forest Stewardship Plan for the Kingsbury area.

A cooperative change-detection project will begin in 1996 for the southern Sierra Nevada, covering lands of multiple ownerships from Calaveras County south to Kern County. The purpose of the project is to implement a procedure to produce baseline landscape-change data. Such information has several applications, including assessing land-use patterns, analyzing riparian areas, and monitoring changes in vegetative cover resulting from, for example, management practices, tree mortality, or fire. Landsat Thematic Mapper satellite imagery from 1990 and 1995 will be used. In addition to the Forest Service, cooperating agencies include the California Department of Forestry and Fire Protection, the National Park Service, and the Bureau of Land Management.

Annual Jeffrey pine beetle suppression in the Lake Tahoe basin has been implemented because of continuous, unacceptably high Jeffrey pine mortality in high-use, high-value, developed recreation sites. Jeffrey pine beetle biology and past observations imply that removing infested trees from overstocked areas or mortality groups should help reduce further mortality in the immediate treated area. The annual removal of infested trees over 165 acres in the South Shore Recreation Complex at Lake Tahoe reduced mortality 99%, from 330 trees in 1983 to 4 trees in 1987. Since 1994, the Lake Tahoe Basin Management Unit has conducted annual suppression activities in 14 developed sites, about 600 acres. Ultimately, more than 40 sites covering more than 1,100 acres may be included in the effort to suppress Jeffrey pine beetle in the Lake Tahoe basin. In addition, the Inyo National Forest plans to implement suppression activities for Jeffrey pine beetle on about 160 acres near the Inyo Craters Trailhead, Mammoth District, in 1996.

In 1992, Forest Pest Management initiated a study to evaluate the effectiveness of Jeffrey pine beetle suppression by comparing the number of trees killed by Jeffrey pine beetle in areas where infested trees are removed annually (treated areas) with the number of beetle-killed trees in areas where the infested trees are not removed (untreated areas). A summary of preliminary results to date indicate that, for selected areas in Lake Tahoe between 1993 and 1995, mortality was reduced by 87% in the treated areas, and mortality in the untreated areas increased 182% (table 3).

Actions were also taken in 1995 to reduce lodgepole pine mortality caused primarily by mountain pine beetle. Two

Table 3 — Results of Jeffrey pine beetle suppression on the Lake Tahoe Basin Management Unit, 1993-1995

	---------- Infested Jeffrey pines by location (number) ----------			
Status	**1992-93**	**1993-94**	**1994-95**	**Increase/decrease**
Treated **Nevada Beach and Zephyr Cover developed sites (136 sites)**	909	240	121	-87%
Untreated **Spooner Summit (98 acres)**	1,213	1,966	2,213	+182%

treatments were implemented in the historic Donner Camp area on the Truckee District, Tahoe National Forest. The objectives were to reduce the number of lodgepole pine killed by mountain pine beetle and maintain the older lodgepole pine. In early spring, infested trees were identified, felled, and removed before the emergence of mountain pine beetle adults. In addition, five plots were established surrounding the camp area at 1/4-mile intervals. Each plot had three traps containing the aggregation pheromones of the mountain pine beetle. The purpose of the traps was to direct the mountain pine beetles away from the immediate camp area to areas planned for thinning in 1996, thus reducing lodgepole pine mortality near Donner Camp.

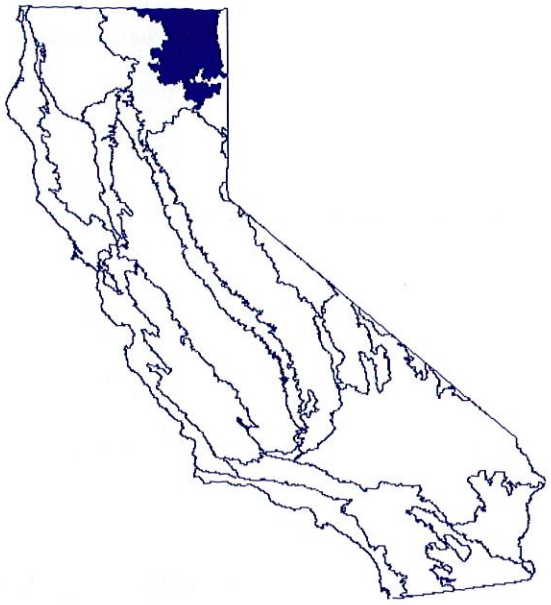
Tree removal and trapping appear successful. The number of infested lodgepole pine declined from 149 trees in 1994 to 11 in 1995. Seventy-eight pines associated with the pheromone trap plots were infested by the mountain pine beetle. A total of 8,133 mountain pine beetles were caught in the pheromone traps between July 6 and October 12, 1995. All lodgepole pines infested in 1995 were felled and bucked in late October. Similar efforts will be implemented in 1996.

The California fivespined ips heavily infested wind and snow breakage in a ponderosa pine plantation on the Foresthill District, Tahoe National Forest, in 1995 (see weather section). To keep the ips population from emerging and attacking residual trees, 364 acres were treated by felling standing green snags, chipping, and lopping and scattering slash.

In 1995, branch pruning of sugar pine infected by white pine blister rust was completed over 70 acres of 12-year-old mixed conifer plantations on the Foresthill District, Tahoe National Forest. Sugar pine represented between 20 and 40% of the growing stock. Trees with lethal stem cankers were removed. Three different pruning treatments were used to evaluate the effectiveness of pruning in reducing later infections.

The Douglas-fir tussock moth is a native defoliator in western North American coniferous forests. Its preferred host in California is white fir. In 1980, an early-warning system of detection traps was established throughout the Sierra Nevada and northeastern California. The purpose of the monitoring network is to identify where tussock moth populations may increase to outbreak and focus more intensive detection efforts there. Trap catches remained low since an outbreak from 1987 to 1989, but populations at a few sites began to increase in 1994. This increasing trend continued in 1995 and indicated the potential for an outbreak in several locations in the Sierra Nevada. Intensive egg-mass surveys and larval sampling will be conducted in the spring and summer of 1996 in areas ranging from Tuolumne County in the south to Plumas County in the north. These surveys will provide area-specific information on which to base further resource management decisions.

M261G
Modoc Plateau



Ecology

Jeffrey pine, ponderosa pine, and white fir are dominant species on the Modoc Plateau, but western juniper woodlands cover the largest area. A mixture of other species can be found, including incense-cedar, lodgepole pine, western white pine, and whitebark pine. Red fir, sugar pine, and knobcone pine can be found near the borders with the Southern Cascades and the Sierra Nevada sections.

Forest Health Issues

Conifers on the Modoc Plateau exist in a climate that is harsher, colder, and drier than most of northern California. The extended dry period observed over the past decade has caused mortality of pine and white fir to increase substantially. Bark beetles and engravers were the primary cause of the mortality, but root pathogens were also present. Over the past decade, information from the annual Palmer Drought Index for the Modoc climate zone indicates that only 1993 and 1995 had near-normal precipitation. Extreme drought conditions were noted from 1987 to 1992 and then again in 1994.

Jeffrey pine and other species. The Jeffrey pine resource on the Plateau has not been affected by Jeffrey pine beetle as it has been in the Southern Cascades and Sierra Nevada sections. The effect of insects and pathogens was minimal on western juniper in the past few years. All five-needle pines are susceptible to white pine blister rust; even though they are a minor forest component in this section, losses without replacement would lead to a decline in forest biodiversity.

Ponderosa pine. Ponderosa pines are commonly attacked by either mountain pine beetle or western pine beetle, but both bark beetles can be found in some trees. Mortality on the Modoc Plateau increased in the past few years, but other sections to the south had ponderosa pine mortality increase during the late 1980s and early 1990s. During 1994, western pine beetle attacked groups of trees across several thousand acres in the Big Valley Mountains. Ponderosa pine mortality during 1995, associated with both western and mountain pine beetle, increased across the Big Valley and Double Head Districts, Modoc National Forest.

Black stain root disease centers in ponderosa and Jeffrey pine continue to be discovered on the Modoc and Lassen National Forests. These centers become more evident when bark beetles and black stain combine to cause mortality. Black stain is present primarily on wetter sites in overstocked stands that have been previously disturbed (fig. 24).

***Figure 24** — A black stain root disease center on the Modoc National Forest.*

White fir. Fir engraver, high stand densities, and low annual precipitation resulted in white fir mortality in several areas of Modoc County. During 1994, about 42,000 acres of the Warner Mountain District, Modoc National Forest, had a reddish hue from white fir mortality. In 1995, the number of acres affected in the Warner Mountains increased 15% above 1994 estimates. During 1994 and 1995, several areas of white fir mortality were apparent on the Big Valley District. White fir continues to die on Fredonyer Peak in the southern part of this section. Mortality in excess of 80% of stand volume can be found in some of these areas. Some stands have been reduced to only a few nonhost species and a few remaining white fir.

Incense-cedar. Cedar bark beetles, juniper scale, and wood borers were associated with the decline and death of incense-cedars on the Big Valley District in 1995. Mortality and top-kill were evident in the Niles Flat and Roney Flat areas. Since the onset of the drought, this year is the first that incense-cedar mortality has increased.

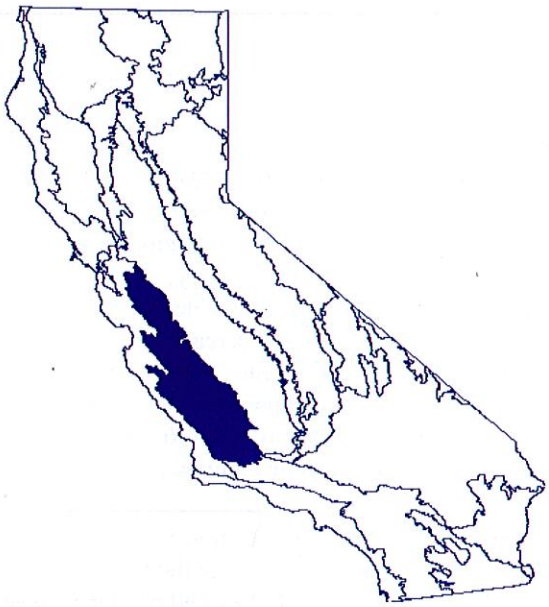
Current Forest Health Activities

Aggressive salvage and thinning programs have been in progress on the Modoc National Forest for the past several years because of increased mortality. Salvage sales facilitate the removal of the dead trees while they still have some economic value and reduce the amount of standing and down fuels. Thinning stands with the intent of reducing intertree competition and removing trees unsuited to the sites have been effective in reducing mortality from bark beetles.

Catches of male Douglas-fir tussock moths in early-warning, monitoring traps indicated an increase in the number of trap locations with an average of more than 25 moths per trap from each plot from 1994 to 1995. Elevated trap catches were noted in plots on the Warner Mountain District, Modoc National Forest, and around the Goose Lake area, Modoc County. Intensive egg-mass surveys and larval sampling were conducted in these areas in the spring and summer of 1996.

Province M262 California Coastal Range Open Woodland - Shrub - Coniferous Forest - Meadow

M262A Central California Coast Ranges



Ecology

The Central California Coast Ranges are found between the central California coast and the central California valley. Much of the vegetation is Oak Woodland or Foothill Woodland, but in southern ranges, Coastal Sage Scrub and Lower Chaparral are important, particularly on south-facing slopes. Throughout the Coast Range, the predominant community is Foothill Woodland, in which the dominant tree species include blue oak and gray pine. Other oaks include coast live, interior live, and valley. Mixed Evergreen Forest is restricted to north-facing slopes at higher elevations. True Yellow Pine Forests are on only a few high peaks such as Figueroa Mountain in Santa Barbara County, where Jeffrey pine is the dominant species. Coulter pine, gray pine, bigcone Douglas-fir, canyon live oak, blue oak, coast live oak, and interior live oak can also be found.

Forest Health Issues

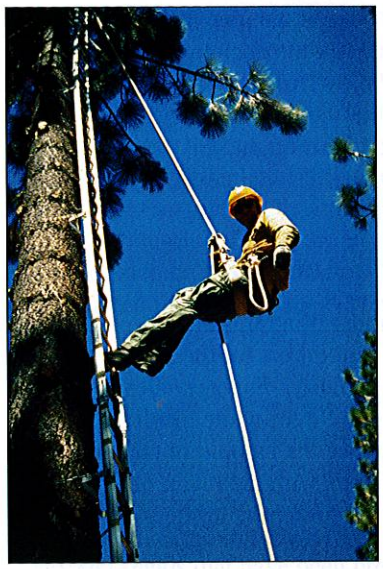
Livestock grazing, fuelwood harvesting, and urbanization have affected and will continue to affect oak woodlands. Trees left during urbanization are often adversely affected by site disturbance and incompatible landscaping practices, such as summer irrigation. Pathogens have caused the decline and death of many summer-irrigated oak species.

Blue oak. The decline and mortality of mature blue oaks on the Los Padres National Forest is mostly associated with long-term infection by cankers and trunk rot fungi. Oak canker rot is the most common. Decline of blue oak would bring about an important vegetational change because it typically dominates harsh sites with thin soils, low precipitation, and high temperatures.

Jeffrey pine. Infections of dwarf mistletoe have caused decline and mortality of Jeffrey pines on the Mount Pinos and Ojai Districts, Los Padres National Forest. Heavily infected trees can die prematurely when stressed by drought or injury. Trees sometimes die even without attacks by bark beetles.

Various oak species. Recreation areas throughout the lower elevations on the Los Padres National Forest are dominated by several oak species including coast live, canyon live, interior live, black, valley, and blue oaks. Oaks as a group have been responsible for more accidents or near accidents in California recreation areas than any other type of tree. Over the years, oaks have sustained root and bole damage along with poor pruning. The wounds have allowed canker and decay fungi to enter trees and cause hazardous trees in some recreation sites.

Air pollution. The Los Padres National Forest established 20 plots with 5 trees each to ascertain the location and severity of ozone damage to Jeffrey and ponderosa pine on the Forest. The most severe damage was found in the Tecuya Mountains on the Mount Pinos District, which is adjacent to the San Joaquin basin. The least damage was found adjacent to the Pacific coast on the Monterey District.



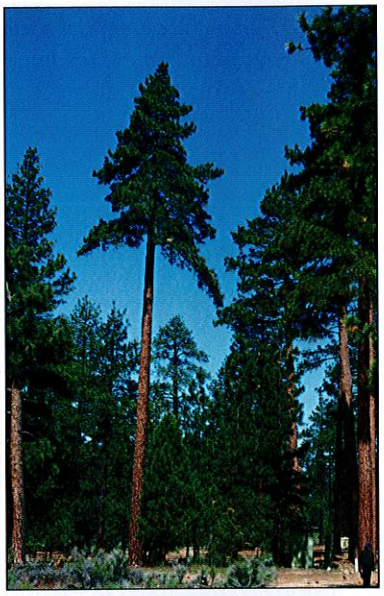


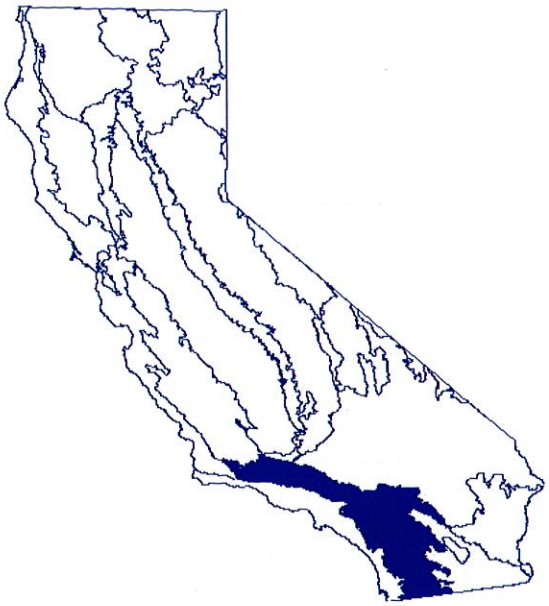
Figure 25 — A climber rappels from a pruned pine during training (top); a pine pruned of most of its dwarf mistletoe infections (right).

Current Forest Health Activities

Campgrounds in the coniferous forests of the Central California Coast Ranges have sustained heavy losses from continuous dwarf mistletoe infections. The Pacific Southwest Region has set up a Five-Year Dwarf Mistletoe Suppression Program in federal forest recreation areas in southern California to maintain and enhance forest health in southern California (Allison 1993). This program includes pruning of mistletoe brooms and plants to reduce the moisture and nutrient drain from the infected trees, thereby increasing their longevity (fig. 25). It also includes thinning trees to reduce intertree competition and reduce the spread of dwarf mistletoe. The Mount Pinos and Ojai Districts are participating in this suppression program.

Two additional activities are planned for 1996. Hazardous trees will be surveyed on the Monterey District, Los Padres National Forest, and the Forest will install additional permanent plots to monitor ozone damage.

M262B
Southern California Mountains and Valleys



Ecology

The Southern California Mountains and Valleys section lies to the north and east of the major urban centers of southern California and is dominated by a series of mountain ranges and valleys. Forests in these mountains are on north-facing slopes and wetter sites. Major conifer species are ponderosa pine, white fir, Jeffrey pine, Coulter pine, sugar pine, incense-cedar, singleleaf pinyon, and bigcone Douglas-fir. Major hardwoods are oaks—California black, canyon live, interior live, and Engelmann. In general, the portion of the area now supporting conifer forests appears to be about what it was in 1900 (McKelvey and Johnson 1992). Residential and commercial development of private forest lands and numerous exotic plant species are modifying land-use patterns, however. Other influences on the forests include changes in fire frequencies and intensities, historical grazing patterns (McKelvey and Johnson 1992), and timber removal in the late 1800s and from 1954 to 1977.

Forest Health Issues

Drought is the primary factor driving widespread mortality in southern California, particularly in overstocked stands. The years from 1992 to 1995 have been relatively wet (rainfall above the mean for most locations), however, and mortality has been low.

Fire suppression in the San Bernardino Mountains this century has resulted in a change from open stands of old growth to stands of increased density, decreased age, and with compositional changes from ponderosa and Jeffrey pines to white fir and incense-cedar (Minnich et al. 1995).

Sugar pine. Sugar pine is a component of mixed conifer stands in the Transverse Range and, to a lesser extent, the Peninsular Ranges. White pine blister rust has not yet been found in this section, and sugar pine mortality is associated with native insects and diseases, including armillaria root disease, dwarf mistletoe, and bark beetles.

Pinyons. Two species of singleleaf pinyons occur in southern California. One, *Pinus californiarum*, grows at lower elevations (3,600 to 4,800 ft) in the Little San Bernardino Mountains and in portions of the Peninsular Ranges, particularly in Anza-Borrego Desert State Park. Little is known of the pests associated with this species, and minimal mortality has been noted. This species has only recently been separated from singleleaf pinyon (Bailey 1987).

Singleleaf pinyon grows at 4,200 to 7,800 feet and has a much greater geographical range than does the newly identified species, with extensive stands in California, Nevada, and Utah. Wildfire is the most significant source of mortality for this species in southern California. Before this century, stand-replacing fires in pinyon were common but small (12 to 200 acres), probably because of the sparseness of the undergrowth (Minnich 1988). Recent fires have been much larger; in 1995, 12,000 acres of singleleaf pinyon burned in the Devil Fire (San Bernardino National Forest). Trees on the periphery of the fire were not killed directly, but were subsequently killed by pinyon engravers (Merrill 1994b). Pinyons are difficult to regenerate, and regeneration has not been possible with previous stand-replacing fires on the San Bernardino National Forest. Black stain root disease, often in conjunction with pinyon engravers, consistently causes moderate mortality near Baldwin Lake on the east side of the Forest. Trees do regenerate in the disease centers, but whether the percentage of tree cover has changed in this heavily infested stand is not known.

Parry pinyon grows in the Santa Rosa and Laguna Mountains, and south into Baja California. Little is known of its pest associates, and recent widespread mortality has not been observed.

Ponderosa and Jeffrey pines. Ponderosa and Jeffrey pine are the most sensitive of the native pines to ozone pollution, and they continue to suffer foliage loss and mortality where ozone concentrations are highest, particularly in the west end of the San Bernardino Mountains. Damage has been observed throughout much of the San Bernardinos, in portions of the San Gabriels, and on Alamo Mountain, Los Padres National Forest. Annosus root disease is common because of previous tree felling without treatment of stump

surfaces with borate, and dwarf mistletoe has increased in some areas because of fire suppression. These two agents combine to stress trees and render them susceptible to mortality by bark beetles and flatheaded wood borers, even in nondrought years.

Coulter pine. Coulter pine has suffered severe mortality associated with drought and the western pine beetle. The most recent period of widespread mortality ended in 1992. Rainfall has been at or above average since then, but Coulter pines continue to die in low numbers in native stands and in much higher numbers where the species has been planted offsite. Trees tend to be large and long lived where Coulter pine grows in mixed-conifer stands. Coulter pine commonly invades chaparral, however, where it is much more susceptible to mortality from drought and insect attack or from fire. Coulter pine has adapted to chaparral ecosystems with short intervals between fires through early reproduction (often at 10 to 15 years of age) and serotiny (Borchert 1985). Serotinous cones are those that remain on the tree, unopened, for one or more years after they mature, usually considered an adaptation to fire. High mortality in young stands growing in chaparral or on the forest-chaparral interface should be expected in the next drought.

Other pine species. Gray, limber, knobcone, and lodgepole pines are minor components of forests in southern California. Forest health problems have not been reported in native stands, but knobcone and knobcone x Monterey crosses were extensively planted offsite in the past. These stands are now highly susceptible to mortality from bark beetles, particularly the California fivespined ips. Many clearwing moth larvae have been found in a plantation of knobcone hybrids in the San Jacinto Mountains. These insects typically have high populations only where trees are injured or stressed.

White fir. Mortality of white fir is most commonly associated with pest complexes, usually combinations of annosus root disease, mistletoe, wood borers, and fir engraver. Because of past fire suppression, white fir has invaded stands formerly dominated by pine, and trees in these situations are particularly susceptible to attack by pests. White fir has not invaded pine stands in this section to the extent that it has in northeastern California, and mortality is more scattered.

Bigcone Douglas-fir. Bigcone Douglas-fir grows on north-facing slopes and in steep canyons at low elevations; it provides important habitat for spotted owls and other wildlife. Wildfire currently presents the most significant threat to this tree, particularly because natural fires have been suppressed, allowing for increased undergrowth and more intense fires.

Hardwood species. Some hardwoods, particularly California black oak, are important components of mixed-conifer stands; most are in low-elevation woodlands or in riparian habitat. The fruittree leafroller is the most noticeable of the pests of California black oak. This species periodically goes into outbreak, most recently in the San Bernardino Mountains in 1993 and on Mount Palomar in 1995.

Alder flea beetles have caused substantial defoliation and some mortality in riparian areas. Outbreaks have been observed in the San Jacinto Mountains and in the San Bernardino Mountains. Insects have also caused defoliation on other hardwoods, such as California sycamore and cottonwood.

Air pollution. A decline in vigor of ponderosa pine reported in 1957 was confined to the Arrowhead-Crestline area in the San Bernardino Mountains. Further surveys and long-term monitoring plots in these mountains showed that ponderosa and Jeffrey pines were the most sensitive to ozone, the principal plant-damaging gas in photochemical air pollution. California black oak and white fir were less sensitive. Incense-cedar and sugar pine rarely show injury symptoms. Between 1974 and 1983, mortality in the young-mature age-class (50-99 years) of ponderosa pine was 33% at plots in the zone of highest ozone exposure, compared to 7% in the same age-class at plots with the lowest ozone exposure. The chronic injury to crowns of ponderosa and Jeffrey pines at these plots was less severe in 1988 than in 1983.

The index describing the amount of ozone injury ranges from 0 (no injury) to 100 (very severe injury). This index increased from 38 to 47 between 1991 and 1995 at three locations annually evaluated in the Barton Flats area of the San Bernardino Mountains. The index is 65 at Camp Paivika on the western edge of the mountains. Ozone injury to ponderosa and Jeffrey pines has also been identified at monitoring plots in the Angeles and Los Padres National Forests.

Exotic pests. Exotic pests can present a threat, although none of significance to native forests are established in this section. Pine pitch canker is established to the north and west in parts of the Central and Southern California Coast sections and in agricultural settings in valleys adjacent to the Transverse and Peninsular Ranges of southern California. This disease may move into native stands. The proximity of the southern California mountains to major ports increases the likelihood of infestation by exotic pests.

The first Africanized honey bees in California were found in October 1994. Since then, the bee has expanded its range to include much of southeastern California (fig. 26). In the near future, this insect is expected to colonize much

of southern California, including the forested areas. Because of its extremely defensive stinging behavior, this bee will be hazardous to forest workers and recreationists. A new management challenge will arise in recreation areas and in wildfire suppression (Merrill 1994a, Merrill and Visscher 1995).

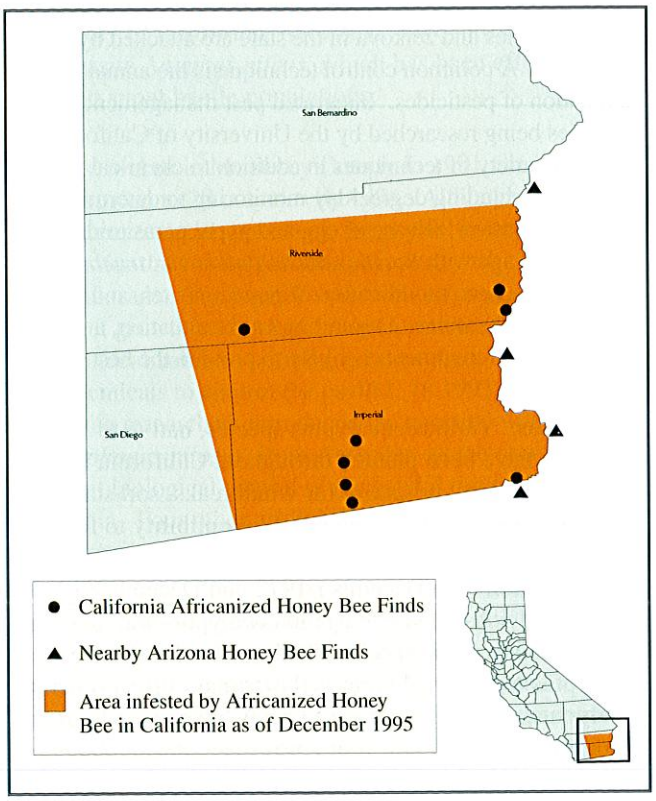


Figure 26 — Area of California infested by Africanized honey bees in December 1995.

Urbanization. In some areas, urbanization presents the greatest threat to native woodlands. Low-elevation species have already suffered severe habitat loss, including certain native oak species, native walnuts, and others (Davis et al. 1995). Still other native species, such as the Cuyamaca and Tecate cypresses, have extremely limited distributions and are at risk from wildfire or other catastrophic events.

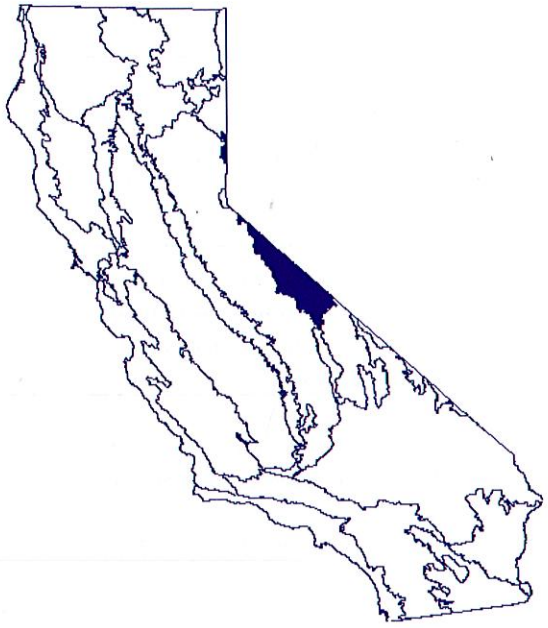
Current Forest Health Activities

Suppression of dwarf and true mistletoes continue to be important for forest health in campgrounds, recreation areas, and other high-value stands. Suppression projects to increase tree longevity will continue.

In 1995, pinyons in a campground were sprayed to prevent attack by bark beetles after the Devil Fire. Because of previous pruning for dwarf mistletoe, the fire went to the ground at the campground, sparing those trees, but the stand surrounding the campground was completely destroyed. Survival of the trees in the campground is important for recreation and to serve as a seed source for pinyon regeneration in the surrounding area.

Province 341 Intermountain Semi-Desert and Desert

341D Mono



Ecology

The Intermountain Semi-Desert and Desert is east of the Sierra Nevada, south of Lake Tahoe, and north of the Mojave Desert. Its geomorphology is characterized by isolated block mountain ranges separated by desert plains, alluvial fans, and basins. Two of the more prominent ranges along the California-Nevada border are the White and Inyo Mountains. Elevations range from 4,000 to 14,200 feet and precipitation ranges from 10 to 25 inches, mostly as winter snow. Rivers and streams flow in deep canyons with bedrock channels or alluvial channels that terminate in basins or lakes in the area or in the Mojave Desert. Fires are infrequent and range from low- to high-intensity surface and stand-replacing fires. The area is seismically active with shaking, ground rupture, lava flows, and ash fall, all within the past 200 years (McNab and Avers 1994). Mining, grazing, forestry, and recreational activities have affected some plant communities since the mid-1800s and early 1900s. Mining booms beginning in the late 1800s and water diversion projects for the Los Angeles basin beginning in the early 1900s have resulted in additional ecological modifications.

The vegetation in the lower elevation basins is dominated by sagebrush in association with antelope bitterbrush, rubber rabbitbrush, and wing scale (fourwing) saltbush. Singleleaf pinyon, western juniper, and Jeffrey pine are the common conifers in the low- to mid-elevations, with bristlecone and limber pines present in the high montane areas.

Forest Health Issues

Antelope bitterbrush is an important browse species in the Western United States and is eaten by wildlife, especially deer, and domestic livestock. Of the 80 or more insects and mites that have been found associated with antelope bitterbrush, the western tent caterpillar has been of most interest (Giunta et al. 1978). Tent caterpillar larvae feed on the foliage, and the resulting defoliation can cause reduced twig growth and seed production as well as branch and plant dieback. The amount of bitterbrush mortality associated with tent caterpillar outbreaks has not been well documented but appears variable and may be associated with plant condition at the time of defoliation. Plants under stress from previous defoliation, heavy grazing, age, or lack of moisture may be more severely affected by tent caterpillar feeding than are young, healthy plants. Some heavily defoliated plants refoliate later in the year after tent caterpillar feeding has ceased.

Tent caterpillar outbreaks, which have ranged from about 1,000 to 18,000 acres, have happened in the Mammoth Lakes-Mono Lake area in 1937-38, 1943-44, 1973-77, and 1983-87 (Clark 1956, Wenz 1983). Outbreaks have also occurred periodically in the Truckee basin (M261E) and in Modoc County (M261G) in 1943-45 (50,000 to 70,000 acres) and 1983-85 (20,000 to 25,000 acres). Outbreaks are terminated by natural factors, including a nucleopolyhedrosis virus. The long-term effects of tent caterpillar defoliation, interacting with other factors, on sustained range productivity and condition have not been established.

Urban Forests

Urban forests provide economic, scenic, and environmental benefits to a community. Healthy trees of all sizes can add to property values, aid energy conservation by providing shade and protection from wind, reduce noise and air pollution, provide wildlife habitat, and increase scenic quality. Many abiotic conditions affect the condition of urban forests: air pollution, soil compaction, drought, improper irrigation, incompatible landscape vegetation, construction-related injuries, and thermal radiation from pavement, sidewalks, and buildings. Following are some hosts that are currently being affected by insects and pathogens.

Elm trees. Various species of elms and the related Japanese zelkova are among many exotic tree species that have been successfully introduced into the state. An estimated 2.5 million elms have been planted in California (Svihra 1980). Dutch elm disease and elm leaf beetle are two of the most destructive agents affecting these trees. The statewide Dutch Elm Disease Program was eliminated in 1993; detection and removal of infected trees is now performed by local governments.

All elm species and zelkova in the state are attacked by elm leaf beetle. A common control technique is the annual application of pesticides. Integrated pest management strategies being researched by the University of California rely on a variety of techniques in addition to chemical pesticides, including degree-day monitoring to determine the need for treatment, release of egg and pupal parasitoids, spraying foliage with *Bacillus thuringiensis* var. *tenebrionis*, control of suckers, modification of pupation sites, and nematode applications. Depending on the situation, a combination of treatments is likely to provide the best control.

Eucalyptus. Various eucalyptus species, native to Australia, have been planted throughout California in areas with mild winters, primarily for windbreaks, soil stabilization, fuelwood, and landscaping. Susceptibility to frost damage limits where eucalyptus can be grown. Record low temperatures in December 1972 and December 1990 resulted in widespread damage to eucalyptus and many other non-native tree species (Sanborn 1991). The eucalyptus longhorned borer is the primary insect threat to eucalyptus. Several other insect pests have recently been introduced to California from Australia.

Since its discovery in 1984 in Orange County, the eucalyptus longhorned borer has steadily expanded its range to include 23 counties. The northernmost infestation in 1995 was in Glenn County. Trees of low vigor and certain species of eucalyptus are more prone to damage and mortality than are other eucalyptus. Moisture stress is especially important in predisposing trees to attack. An egg parasite and several braconid wasp parasites are being released as part of a biological control program conducted by the University of California. Preventive measures include proper tree care, planting resistant eucalyptus species, and proper disposal of wood that serves as a breeding site (Paine et al. 1995). The borer's range is expected to continue expanding.

A closely related longhorned borer, the yellow phoracantha, was discovered in Riverside and Orange Counties in 1995. Its appearance and biology are similar to those of the eucalyptus longhorned borer, but it prefers to colonize the upper portion of the tree rather than the lower trunk. Observations from other countries are that the yellow phoracantha and eucalyptus longhorned borer are often equally abundant and will attack trees together.

The eucalyptus snout beetle, a serious defoliator of eucalyptus in Australia and other countries, was discovered in Ventura County in 1994. It was subsequently found in Los Angeles County. Both larvae and adult weevils feed on eucalyptus leaves. Two or three generations per year are expected in California. A rate of spread of 60 miles per year has been noted after introductions in other countries (Cowles and Downer 1995). Researchers at the University of California, Riverside, have introduced the egg parasite *Anaphes nitens*, which has been effective at reducing snout beetle populations.

First discovered in Monterey County in 1991, the blue gum psyllid spread to 28 counties by 1994. Although of little direct harm to eucalyptus trees, the psyllid created a serious problem for the eucalyptus foliage industry which supplies the floral trade. The psyllid's preference for young, succulent growth meant that foliage-producing nurseries were an ideal habitat. Initially, growers frequently sprayed with chemicals to control the psyllid. In 1993, University of California researchers introduced the parasitic wasp, *Psyllaephagus pilosus*, from Australia, which now provides excellent biological control of the psyllid throughout California. Four other psyllid species from Australia are known to attack eucalyptus in California.

Eugenia. Eugenia is a small tree native to Australia that is planted as an ornamental in coastal California. The eugenia psyllid is a well-established pest that attacks young leaves, causing them to disfigure as they mature. A eulophid parasitoid, *Tamarixia* sp., initially released in Orange, San Diego, San Luis Obispo, and Alameda Counties, can reduce pysllid numbers by up to 90%. Wet, cool weather limits the parasitoids effectiveness, however, so supplemental control may be needed in some areas at certain times of the year. Pruning new tips from infested trees and leaving them on site is being investigated as a compatible treatment. It allows the removal of psyllid eggs and preserves parasitoid populations.

London plane. Wood decay is a common problem associated with large pruning wounds on London plane trees in San Jose and probably elsewhere. Trees that had been severely topped had extensive decay and were of low vigor. A wood-decay fungus, *Inonotus arizonicus*, was found fruiting on some of these trees and appears to be the major cause of decay. London plane is a new host and San Jose is a new geographic record for the fungus, which had previously been reported only on California and Arizona sycamores from southern California and parts of Arizona and New Mexico.

Multihosts. An ongoing threat to urban trees of all species is the practice of topping. A recent survey of California cities found that an average of 21% of urban trees have been topped (Bernhardt and Swiecki 1993). Topping can harm trees in several ways, including increasing damage from insects and diseases and weakening limb structure. Educational efforts that explain the harmful effects and alternatives to topping are an important means of preventing this practice.

The ash whitefly was first discovered in California on ash trees in Los Angeles County in 1988. Since then, it has spread throughout the state in areas where suitable hosts and habitats exist. California hosts include citrus, apricot, pomegranate, toyon, pear, California redbud, and ash. Two imported natural enemies, a parasitic wasp and a ladybird beetle, provide control. The parasite, *Encarsia inaron*, was released in 43 counties from 1990 to 1992. Statewide, whitefly numbers were very low in 1995, although some isolated outbreaks were reported.

The gypsy moth, both European and Asian strains, has tremendous potential to damage trees throughout California in both urban and wildland settings. Many native and introduced ornamental trees are suitable hosts. To prevent the gypsy moth from becoming established, the California Department of Food and Agriculture uses a three-step strategy consisting of exclusion, detection, and eradication.

Every year, gypsy moths are introduced to California. Most finds have been in major metropolitan areas and along Interstates 5 and 80. If an infestation is confirmed, an eradication program is conducted. No eradication programs were conducted in 1994 and 1995, but one is possible for Felton, Santa Cruz County, in 1996.

In 1994, more than 20,700 gypsy moth traps were deployed throughout California, catching 10 gypsy moths in nine counties, each from a different trap. No additional life stages of the moth were detected during later field surveys. Three of the moths were misidentified as Asian gypsy moths, but subsequent analysis determined they were European.

In 1995, more than 19,000 traps were deployed, catching 19 moths in eight counties. Six trapping sites caught single moths and three sites caught more than one. At a multiple-catch site in Santa Cruz County, additional life stages were found; considered the only confirmed infestation, it apparently originated from a new resident moving to California from infested areas in the eastern United States.

Many native and introduced pine species are growing in California's urban areas. Pine pitch canker could significantly affect these hosts. The greatest damage to date has been on ornamental and landscape plantings of Monterey pine. Recently, the disease has been confirmed in all three of California's native Monterey pine stands on the central coast. Substantial tree mortality in these stands could have major economic effects on local communities and threaten a limited natural resource (see section 261A, Central California Coast).

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Forest Health Detection Monitoring Results, 1992-95

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Introduction

The Forest Health Monitoring Program is a cooperative, multiagency national effort to monitor, assess, and report on the long-term status, changes, and trends in forest ecosystem health in the United States (Appendix B). Data from permanent field plots and other sources are used to prepare annual summaries and periodic regional and national reports on forest health. People interested in ecosystem condition and concerns are the general public, universities, resource managers, and Congress (fig. 27).

Important national and regional assessment questions that can be answered from field data collected uniformly and annually are:

- What proportion of forest has reduced growth because of observed damage?
- Where is risk of reduced growth and poor condition increasing or decreasing?
- Are aesthetic qualities of forests decreasing because of observed damage?

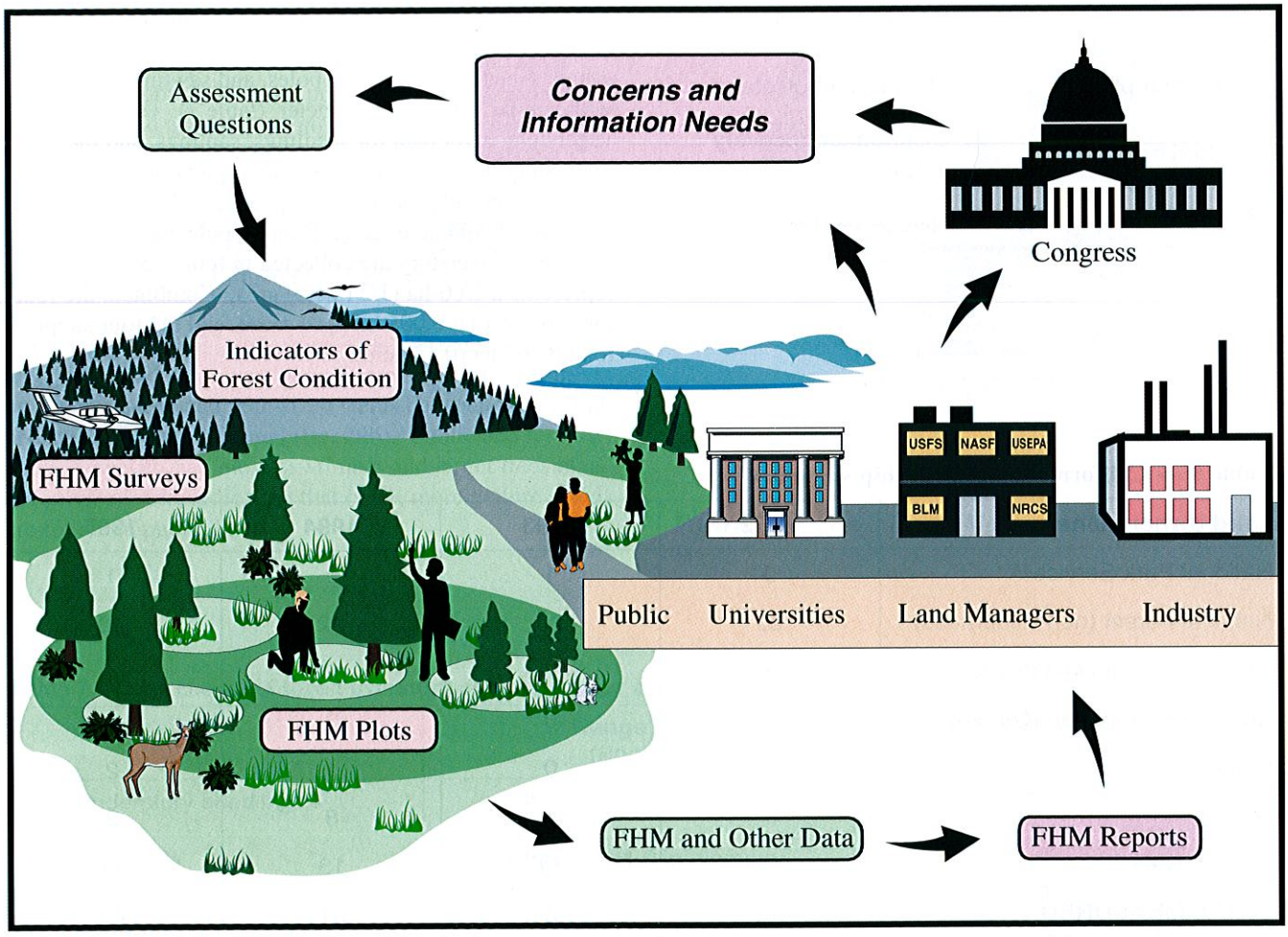


Figure 27 *— Implementing the national Forest Health Monitoring Program.*
Step 1: measure indicators of forest condition from permanent field plots, aerial surveys, and ground surveys;
Step 2: analyze and interpret the results for various user groups;
Step 3: use existing and future information to answer specific (assessment) questions about forest ecosystems at national and regional scales.

Many forest health monitoring indicators (table 4) have been tested for six or more years in regional pilot studies across the United States. Objectives of these studies were to test the ease of measuring various indicators under different environmental conditions and to familiarize state and federal cooperators with actual field sampling protocols (Liegel 1995).

Table 4 — Forest Health Monitoring indicators to assess forest ecosystem condition

Indicator	Indicator (cont.)
Growth	Regeneration
Crown condition	Mortality
Leaf area	Tree damage
Plant species composition	Soils
Lichen community structure	Acidification index
Bioindicator plants	Organic carbon status
Songbird habitat	Disturbance recovery index
	Nitrogen index

In California, forest health monitoring work began in 1992 (LaBau 1993). The following sections summarize 4-year California data on mensuration, crown rating, damage, and 1.0-ha indicators measured during the summers of 1992 to 1995. These four years are the baseline against which subsequent measurements are compared to detect yearly changes or trends in indicator measurements.

General Site and Species Characteristics

A total of 221 sites were forested and 196 had measured trees (table 5). Access denials plus dangerous and inaccessible plots averaged about 10% over the 4 years. About 39% of the total sites were privately owned, and 61% were publicly owned. Elevations ranged from <500 to 3600 m (<1,640 to 11,800 ft); stand ages ranged from <50 to 300 years (table 6). Predominant forest types measured were oak and pine, followed by mixed conifer, true fir, and tanoak.

Plot data help distinguish stands with unique overstory and understory traits from other stands with similar or different species. Managers commonly summarize characteristics of small and large trees by looking at groups (seedlings, saplings, poles, and sawtimber trees) with similar height and diameter (table 7). Ground vegetative-cover data for seedlings, saplings, and the understory are recorded in four microplots offset at 90 degrees from subplot centers (fig. 28); each represents a 1/750-ha (1/300-acre) area. Data on pole and sawtimber trees in the overstory are collected in four subplots; each represents a 1/60-ha (1/24-acre) area. Combined, the four microplots total 0.005 ha (0.01 acre), and the four subplots total 0.067 ha (0.17 acre).

Table 5 — California land ownership summary

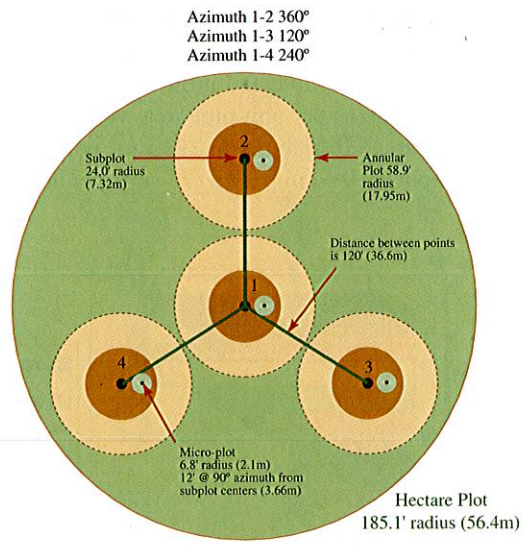
Land owner/manager	1992	1993	1994	1995
National Park Service	0	1	2	1
National Forest (non wilderness)	23	20	22	20
National Forest (wilderness)	3	7	2	4
Bureau of Land Management	2	0	3	4
State	3	0	1	2
Industry	9	4	8	2
Small private	15	14	13	11
TOTAL MEASURED	**55**	**46**	**51**	**44**
Dangerous/inaccessible	0	3	1	3
Access denied	6	4	6	2
TOTAL FORESTED	**61**	**53**	**58**	**49**

Table 6 — Summary of site and species conditions

Forest type	1992	1993	1994	1995
Oak	29%	23%	27%	18%
Pine	18%	27%	18%	10%
Mixed Conifer	11%	18%	22%	21%
Fir-spruce	11%	11%	14%	16%
Tanoak	13%	<10%	<10%	<10%
Age range (yr)	<50-250	<50-300	<50-190	<50-200
Elevation range (m)	<500-3600	<500-3300	<500-2800	<500-3200

General stand structure characteristics were similar for all four years. Saplings averaged about 4, poles about 12, and sawtimber (hardwood and softwood) about 6 individuals per plot (table 8). The greatest yearly variation was for unit-area (1.0-ha) sapling number. Private lands had about 40% more seedlings per unit area than did public lands (fig. 29a), probably because private lands are generally more disturbed and have younger stands. Woodlands had the lowest unit-area seedling number. Woodlands are generally dry, have high damage percentages, and severe grass competition, all of which limit seedling recruitment. For stems ≥ 2.5 cm (≥1 in), public and private lands had an almost equal number of stems per unit area.

For all seedling and larger stems (fig. 29a), reserves and woodlands had the fewest per unit area. Differences in unit-area sapling and pole-sized stems between public and private lands were minimal (fig. 29b). Public and reserve lands, however, had more sawtimber and larger trees than did private lands, indicating that older, more mature stands are found on public lands.



National FHM plot layout is designed around four points (subplot centers)

***Figure 28** — Forest Health Monitoring Program field plot layout.*

Table 7 — Size classes of forest overstory and understory components

Class	Range limit (English)	Range limit (metric)
Understory seedling %	<1 ft. tall	<0.3 m tall
Seedlings	≥1 ft tall & <1.0 in diameter	≥0.3 m tall & <2.54 cm diameter
Saplings	≥1.0 to 4.99 in diameter	≥2.54 to 12.69 cm diameter
Poles	5.0 to 10.99 in diameter	12.7 to 27.89 cm diameter
Sawtimber trees (hardwood and softwood)	at least 11.0 in diameter	at least 27.9 cm diameter

Table 8 —Yearly average number of stems per plot and per unit area

Data	1992	1993	1994	1995
Number of plots with trees	54	46	51	45
Saplings (2.5-12.7 cm)	3.2 (600/ha)	4.7 (866/ha)	3.9 (723/ha)	2.7 (509/ha)
Poles (12.8-27.8 cm)	13.1 (194/ha)	11.6 (172/ha)	11.5 (171/ha)	13.2 (197/ha)
Sawtimber (>27.8 cm)	6.6 (98/ha)	5.2 (77/ha)	5.2 (77/ha)	5.9 (87/ha)

Live basal area is the total cross-sectional bole area of trees in a stand at breast height. High values indicate that more cross-sectional area is wood. Whether this bole wood is partitioned across many small or a few large stems determines economic value and influences habitat diversity. Live basal areas per unit plot area were very similar for all four years: 5.0 sq m per ha (22 sq ft per acre) for poles and about 17.0 sq m per ha (74 sq ft per acre) for sawtimber (table 9). For all species, total live basal area per plot averaged about 22 sq m per ha (96 sq ft per acre).

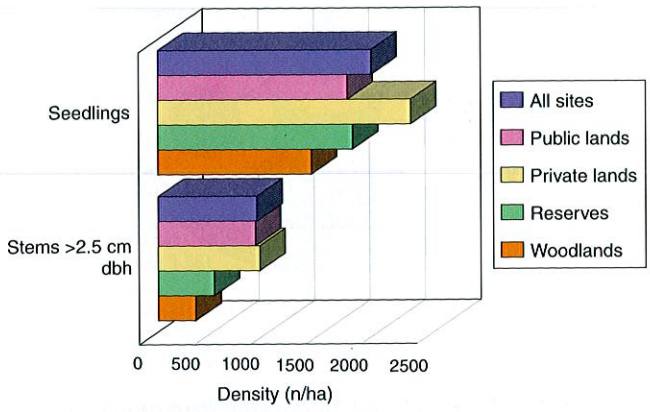


Figure 29a — Tree density by seedling and larger stems.

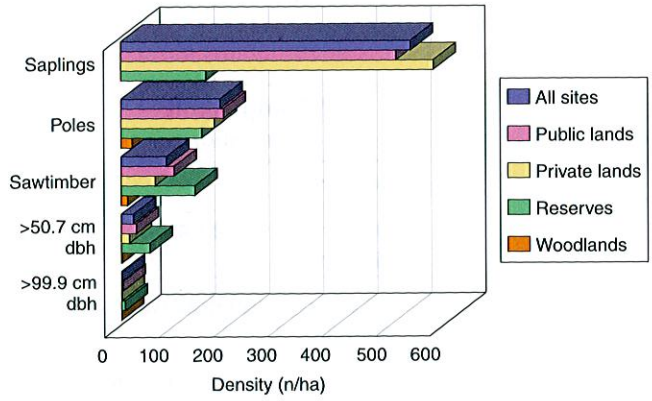


Figure 29b — Tree density by sapling and larger size classes from 1992 to 1995.

Live basal area is a function of stand density, stand age, and species type. Young stands generally have lower basal areas than do older stands. Per-unit-area values in California fall within ranges for major species found in Pacific coast forests (table 10).

Understory vegetation on microplots indicates status of seedling regeneration and the percentage of various vegetation groups that may be competing with new or established seedlings for soil moisture and nutrients. Cover by seedlings, ferns, mosses, and lichens ranged from 1 to 4%; shrub and herb cover ranged from 14 to 28% (fig. 30). Most percentages were consistent for all four years; exceptions were 1992 herb and 1992-93 shrub percentages, which were greater than other years. These exceptions are not readily explained, however, either by biotic and environmental conditions or possible observer error in recording percentage cover.

Crown Ratings

Crown evaluations indicate tree condition by indirectly assessing an individual tree's ability to capture light and produce carbohydrates by photosynthesis. Crown conditions assessed in California were sapling vigor (fig. 31) and three crown indicators: crown density, crown dieback, and foliage transparency (fig. 32). Trees with **high scores** for sapling vigor and crown density and **low scores** for crown dieback and foliage transparency generally have high potential for photosynthesis and nutrient storage and, therefore, greater potential for survival and reproduction. Except for sapling crown vigor, graph values represent the average of pole and larger trees from all crown positions.

Sapling crown vigor is a visual measure of sapling condition. The middle or average group (class 2) has a condition midway between the extremes of "good"

Table 9 —Yearly live basal area (sq m) averages per plot and per unit area

Size class	1992	1993	1994	1995
Poles 12.7-27.89 cm dbh	0.3 (5.4/ha)	0.3 (5.1/ha)	0.3 (4.9/ha)	0.4 (5.5/ha)
Sawtimber >27.89 cm	1.1 (15.8/ha)	1.1 (16.0/ha)	1.3 (18.8/ha)	1.1 (15.8/ha)
All >12.69 cm	1.4 (21.2/ha)	1.4 (21.1/ha)	1.6 (23.7/ha)	1.5 (21.3/ha)

Table 10 — Basal areas typically found for different species and age classes in Pacific coast forests

Species (age range in years)	Basal area (sq m/ha & sq ft/acre)	
Douglas-fir (0-750)	5-40+	20-180+
Western hemlock (100-500+)	10-40	40-180
Western redcedar (100-500+)	0-20+	0-80+
Red alder (0-100)	0-5	0-20
Big-leaf maple (100-400)	0-5	0-20

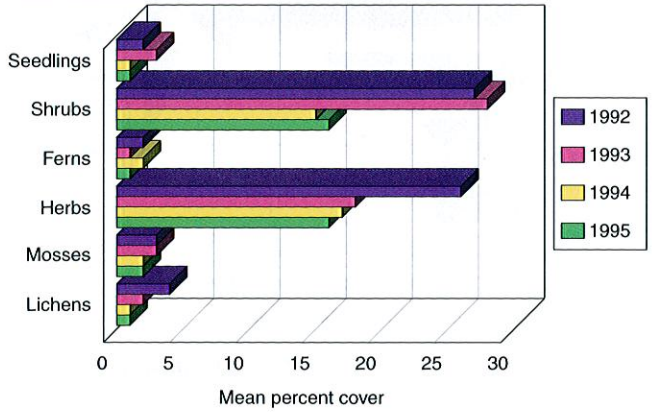


Figure 30 — Understory vegetation percentages; note that percentage cover is not additive.

saplings (class 1) and "poor" saplings (class 3) — all others are placed in class 2. Differences between hardwoods and softwoods were minimal for good and average condition (fig. 33); some 60% were classified as good and 30% as average. About 5 to 8% had poor vigor, and hardwoods had twice as many crowns in this condition as did softwoods.

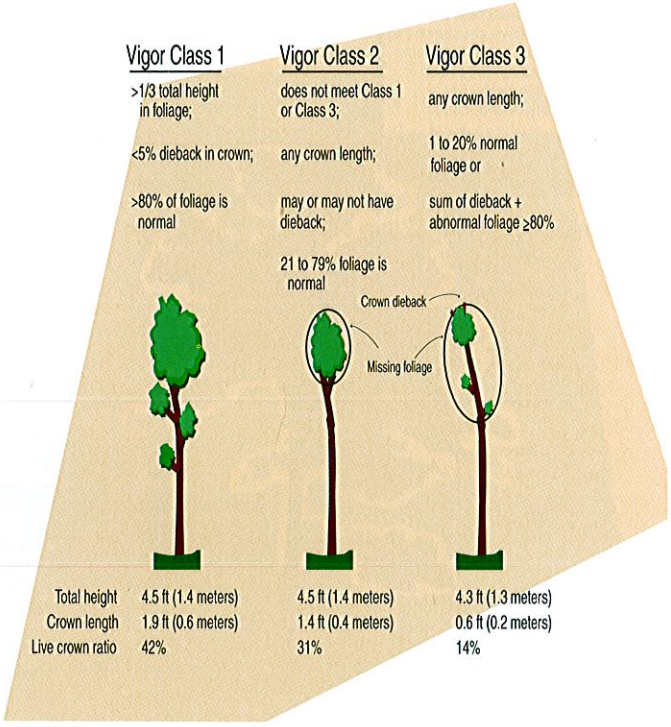


Figure 31 — Three sapling-vigor classes.

Crown density is a measure of how complete an individual tree crown is when compared to a full-crown outline (fig. 32). Density values >20% indicate more active crown areas and healthier trees; values ≤20% indicate "poor" crown condition because little foliage is available to produce photosynthates. Some 48% of hardwoods and 61% of softwoods had "good" (≥50%) density values over four years (fig. 34). The hardwood group contains many old oaks that have broken crowns and low density values. The sum of good plus "average" (21-50%) crown-density values was 90% or higher for all trees over four years.

Oaks and pines had the most individuals in the "poor" (<20%) crown-density class for all four years (fig. 35). For these species groups and others, percentages of low values were generally higher in 1992-93. Interpreting the yearly and species differences for the poor density values

is difficult. Oaks and pines have less dense crowns than do other species and a seven-year drought through 1992 affected growing conditions statewide. Integrating yearly climatic data, other inventory information, and remeasurement of baseline conditions will help refine future interpretations.

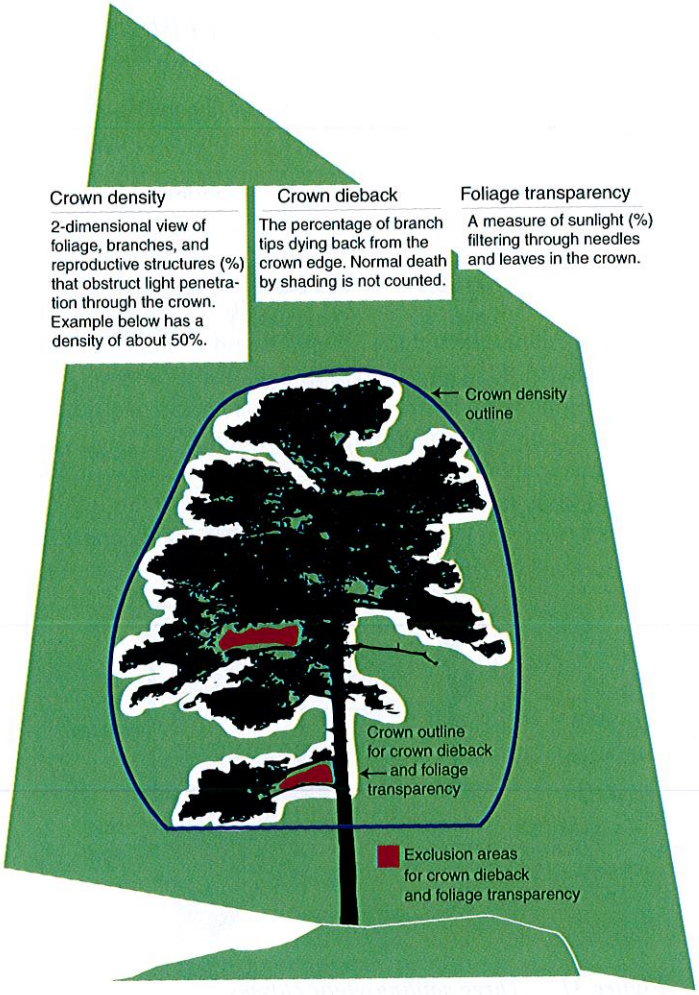


Figure 32 — Three crown-rating indicators: crown density, crown dieback, and foliage transparency.

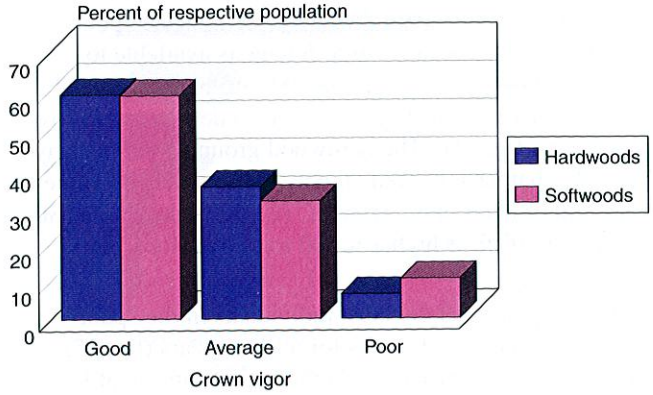


Figure 33 — Sapling crown-vigor classes for hardwoods and softwoods on all sites, 1992 to 1995.

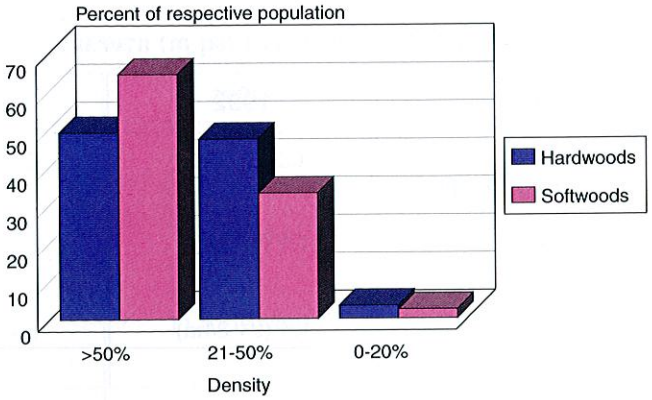


Figure 34 — Crown density of hardwoods and softwoods on all sites, 1992 to 1995.

Crown dieback is the percentage of branch tips dying back from the crown edge to the tree center, except dieback from natural shading. Dieback is caused by severe shock to root systems, drought, or disease. Some species also show light dieback as part of normal growth. High values indicate unhealthy trees. For softwoods and hardwoods and for both pole and sawtimber trees (not shown), some 80 to 90% of all trees had 0 to 5% dieback (fig. 36). In the other dieback classes, hardwoods usually had twice as much dieback as did softwoods.

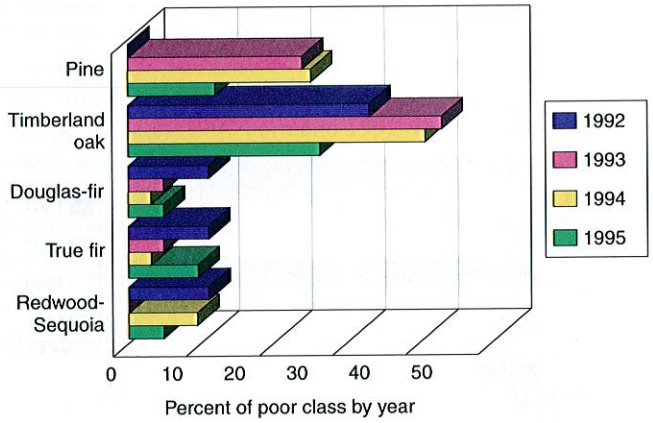


Figure 35 — Poor (<20%) crown density of trees ≥12.7 cm dbh for major species groups.

Poor (>50%) dieback was noted for all major species groups but some species were affected more in certain years (fig. 37). Douglas-fir, oak, redwood-sequoia, and true fir all had severe dieback in 1992, only oaks in 1993 and 1994, and oaks and pine in 1995. Once again, the proportion of severe dieback values reflects the little understood interactions between yearly environmental changes and inherent species growth-form characteristics.

Both public and private lands also had about 90% of all trees in the 0 to 5% crown-dieback class (fig. 38). Wood-

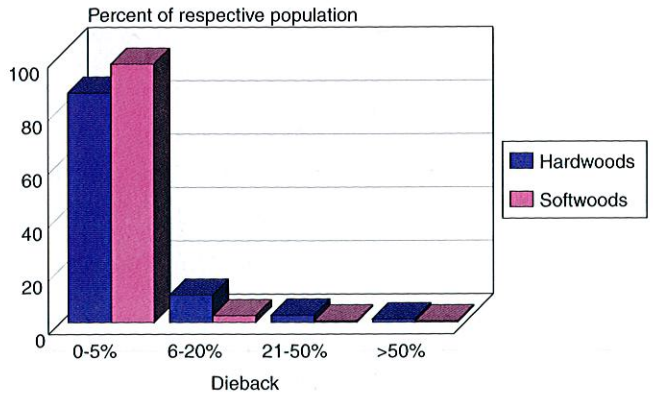


Figure 36 — Crown dieback for hardwoods and softwoods on all sites, 1992 to 1995.

lands consistently had highest percentages in the other dieback classes; these areas are constantly stressed by high temperatures and low soil moisture. Little dieback was seen in reserves.

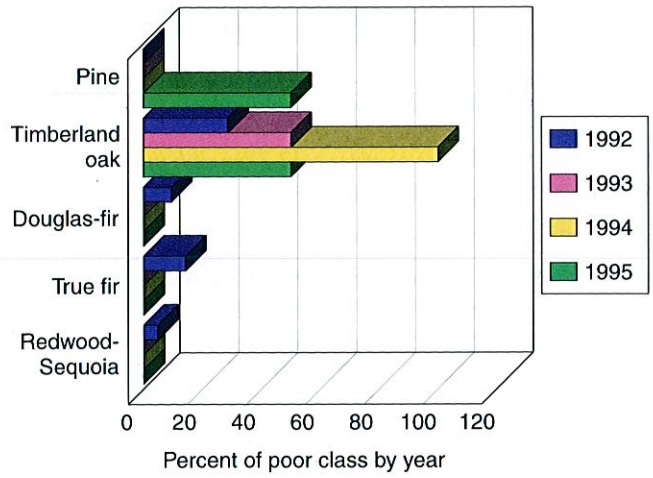


Figure 37 — Yearly severe (>50%) dieback of trees ≥ 12.7 cm dbh for major species groups.

Foliage transparency is an indicator of light filtering through needles and leaves in the upper one-third of the crown. Transparency values differ by species and depend on natural branching habit and foliage orientation. High transparency values (>50%) indicate unhealthy crown conditions because less foliage is available for photosynthesis. Reduced foliage can be caused by insects, disease, and other stressors. More than 95% of all hardwoods and softwoods and pole and sawtimber trees (not shown) had good (0-30%) transparency ratings (fig. 39).

Species with the highest percentages of poor (>50%) transparency values were pines (including mixed conifers) in 1992-93 and oaks in 1992 and 1994 (fig. 40). Foliage

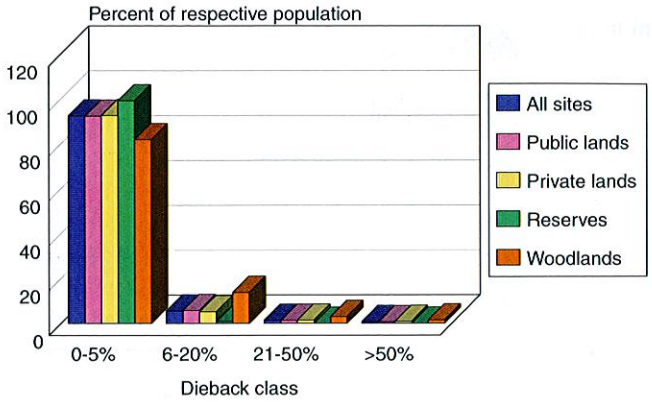


Figure 38 — Crown dieback for trees ≥12.7 cm dbh. by land ownership, 1992 to 1995.

transparency is the only crown indicator for which pines had severe ratings in 1992. In 1993, oaks had severe density and severe dieback but not severe foliage transparency. These results suggest that deteriorating crown conditions do not occur at the same rate or during the same year for a single species group. Understanding the

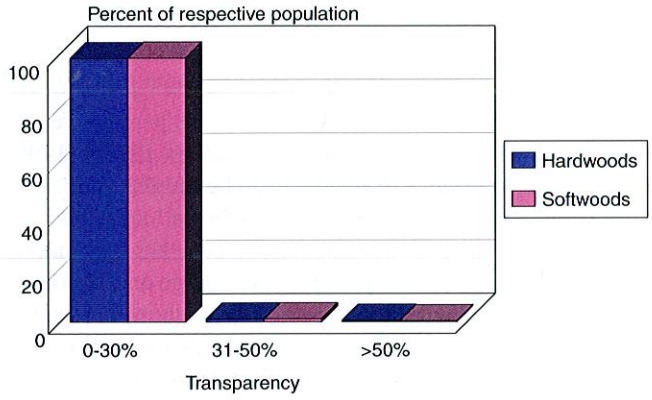


Figure 39 — Crown transparency for hardwoods and softwoods on all sites, 1992 to 1995.

complex species, year, and indicator-specific relationships is the challenge ahead for those working in the Forest Health Monitoring Program.

Damage

Pathogens, insects, air pollution, and other natural or human disturbances all cause damage. Recording observable damage signs and symptoms provides valuable information to assess forest health by detecting possible deviations from previously measured baseline conditions. Field personnel recorded damage symptoms if the observed damage could kill the tree or affect its long-term survival. Up to three kinds of damages were recorded per tree in 1993 to 1995, but only the first (damage 1) is reported here. No damage was seen on about 70 to 75% of

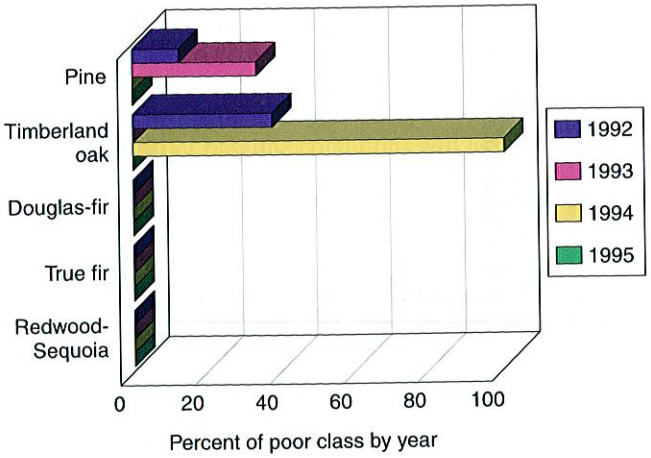


Figure 40 — High (>50%) foliage transparency ratings for trees ≥12.7 cm dbh for major forest groups, 1992 to 1995.

all trees for all three years, with some small yearly variation (fig. 41). The common forms of damage were "breakage and wounding" and "conks," which are external growths on tree stems that indicate internal fungal decay. Both damage groups affected less than 10% of measured trees. Resinosis and canker were less common and affected fewer than 5% of all trees.

Public and private lands had about the same percentage of trees with no damage symptoms: 70% across 1993 to 1995 (fig. 42). Percentages of breakage and wounding and conk damage were also similar for public and private lands. Woodlands, where many species of oaks predominate, had the highest percentages of breakage and wounding and conk damage. Reserves had the highest incidence of resinosis, perhaps because of older, higher elevation, stressed red fir stands that grow within them.

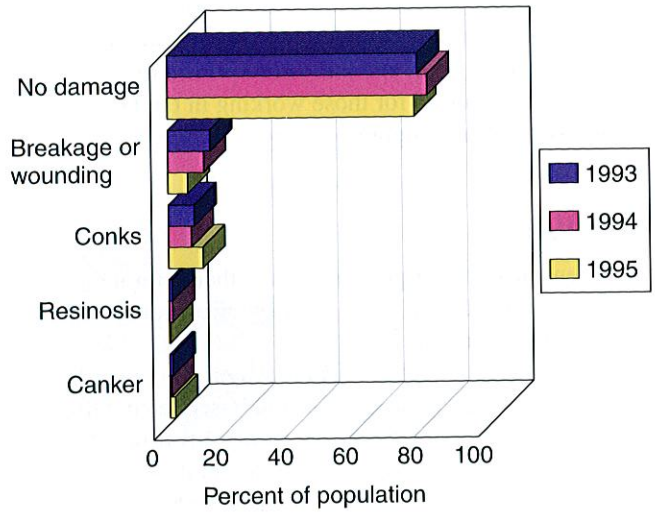


Figure 41 — Summary of damage (damage 1 only) to trees ≥12.7 cm dbh, 1993 to 1995.

Standing Dead Trees

Snags are upright dead stems that are ≥12.7 cm (≥ 5 inches) in dbh and ≥1.37 (≥4.5 ft) tall. Many snags indicate past or present insect and disease attacks, fire, and other major stressors. Unit-area numbers of standing dead stems are important for assessing wildlife habitat, risk of lightning strikes, and potential accumulation of woody debris on the forest floor. Number of standing dead trees

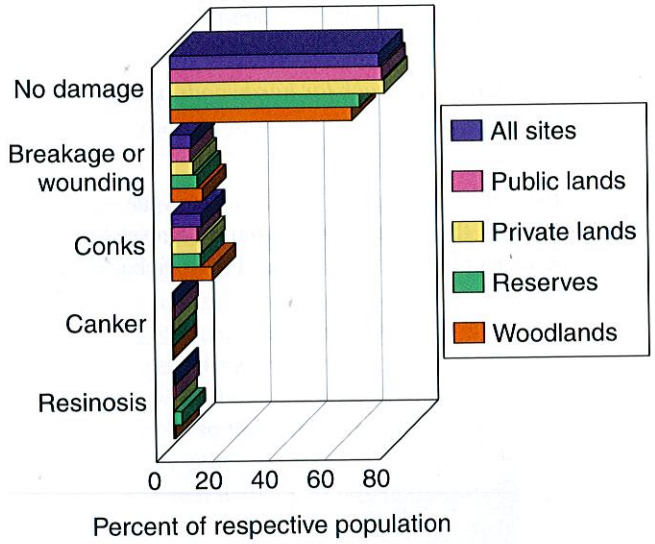


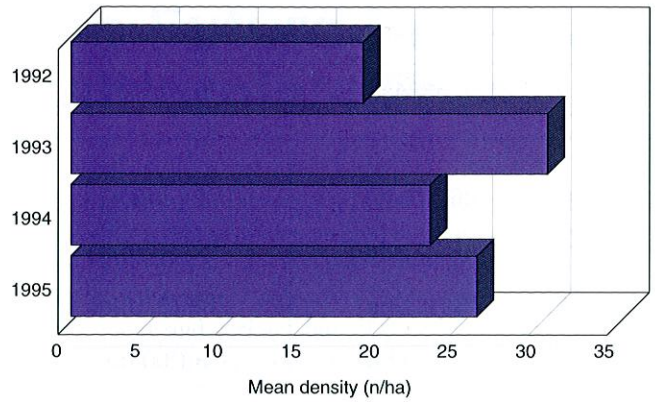
Figure 42 — Damage to trees ≥12.7 cm dbh in different land ownerships, 1993 to 1995.

per unit area varied from 18 in 1992 to almost 30 per ha (7-12 per acre) in 1993 (fig. 43a). Species groups with the most snags were true fir, oak, and pine (fig. 43b).

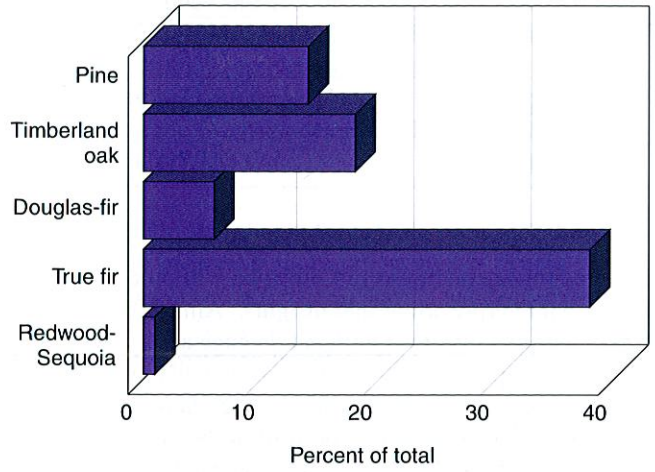
Pole-sized stems comprised the greatest number of snags per unit area; numbers of snags on public and private lands were similar (fig. 44). Highest numbers of sawtimber and large standing dead stems were on public and reserve lands, both of which have older, more mature stands compared to private lands.

1.0-Hectare Tally

Throughout the United States, Forest Health Monitoring Program field plots are 1.0 ha (2.47 acres), but all measurements of overstory and understory vegetation are taken in smaller subplots and microplots (fig. 28). Before California field work began in 1992, a pre-pilot study was done in summer 1991 on a transect across the southern Sierra Nevada. One of the 10 established plots fell within a sequoia forest. Because no large-diameter (≥27.9 cm or ≥ 11.0 in) recent dead or live trees were found in any of the four subplots at this site, both state and federal cooperators thought that the national Program's field design



a. Snags > 1.37 m tall



b. Proportion of all snags > 1.37 m tall, 1992-1995

Figure 43*— Differences in standing dead stems ≥ 1.37 m tall: (**a**) yearly; (**b**) by species group, 1992 to 1995.*

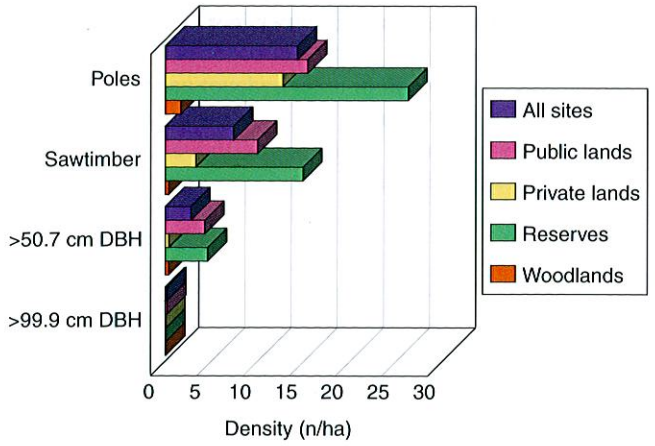


Figure 44 *— Standing dead stems ≥1.37 m tall, by size class and land ownership, 1992 to 1995.*

might exclude the large-diameter stems that are common in older western stands.

In 1992, California cooperators modified national field protocols to include a separate tally of large stems, dead in the last five years and found anywhere within the 1.0-ha boundary, not just within the four subplots (fig. 28). In 1993 to 1995, field crews tallied such recent dead stems again plus large live stems ≥100 cm (≥40 in) found within the 1.0-ha perimeter.

The average per-1.0-ha density of recent dead stems ranged from 1.4 (0.6 per acre) in 1993 to 2.3 (0.9 per acre) in 1994 (table 11). Estimates based on subplot-only measurements ranged from 1.3 per ha (0.5 per acre) in 1993 to 4.4 per ha (1.8 per acre) in 1994, or sometimes a twofold difference compared to 1.0-ha tallies. Differences for three-year 1992 to 1994 data were statistically significant (Busing et al. 1996, Liegel et al. 1996) and imply that subplot-only data do not provide accurate unit-area densities of recent dead stems. Because unit-area yearly estimates of recent dead stems may be a more sensitive indicator of forest condition than are unit-area snags, these results have wide implications for inventory and monitoring of forest resources on both public and private lands in the Western United States.

The average plot density of large live stems (≥100 cm or ≥ 40 in) in 1.0-ha plots ranged from 0.3 to 1.4 per ha (0.1 to 0.6 per acre). Subplot-only estimates were again greater, from 1.0 to 2.9 per ha (0.4 to 1.2 per acre, table 12). Differences were not statistically different, however, probably because of the large variation in actual numbers of large stems recorded in subplot and 1.0-ha plots (Busing et al. 1996, Liegel et al. 1996).

The 1.0-ha tally results demonstrate that subplot-only data are insufficient to estimate unit-area numbers of recent dead or large live trees in California. Large plot sizes are needed to characterize true forest overstory conditions in Pacific coast forests where large trees are major components of the overstory. These results are significant for planning additional forest health monitoring operational field work in Oregon and Washington, tentatively scheduled for summer 1997. These results should also be considered in choosing field designs that evaluate management strategies to be tested in regional adaptive management areas.

Conclusions

A four-year baseline of Forest Health Monitoring Program plots now exists in California. For the 1992 to 1995 measurements, yearly differences were minimal for stand structure characteristics such as numbers of sapling, pole,

Table 11 — Subplot and 1.0-hectare recent mortality estimates (Trees > 27.8 cm dbh dying 0-5 yr prior to sampling)

Numbers	1992	1993	1994	1995
Plots sampled	52	46	51	44
Plots with mortality	27 (52%)	13 (28%)	26 (51%)	21 (48%)
Hectare tally total	114 (2.2/ha)	66 (1.4/ha)	116 (2.3/ha)	74 (1.7/ha)
Annular plot tally total	N/A	39 (2.1/ha)	43 (2.1/ha)	38 (2.1/ha)
Subplot tally total	12 (3.5/ha)	4 (1.3/ha)	15 (4.4/ha)	9 (3.0/ha)

Table 12 — Subplot and 1.0-ha estimates for large (>100-cm or >40-inch) live trees

Plot Size	1993	1994	1995
1.0 ha	41 (0.9/ha)	72 (1.4/ha)	13 (0.3/ha)
subplot	9 (2.9/ha)	7 (2.0/ha)	3 (1.0/ha)

and sawtimber trees per unit area and for live basal area per unit area. Private lands had the greatest number of saplings and reserve areas (National Parks, Wilderness Areas) had the greatest number of sawtimber-sized trees. Yearly variation in understory vegetation was slight except for shrubs in 1992-93 and herbs in 1992. Crown conditions generally indicated healthy forests, but severe (unhealthy) crown conditions were noted in one or more years for crown density, crown dieback, and foliage transparency indicators assessed for five major species groups. Interpreting the severe ratings is difficult because of the complex relations of specific crown indicators; inherent differences in crown growth dynamics between species; and yearly variation in soil moisture, temperature, and other site factors. Integrating inventory data from other sources and remeasurement of the 1992 to 1995 baseline forest conditions in California will produce additional interpretations and insights. Almost 80% of the trees measured had no significant damage across all sites and ownerships. The no-damage baseline was about 60% for forest reserves that have older, more mature trees and woodlands that are stressed for most of the growing season. Yearly differences existed for standing dead (snag) trees and ranged from 18 to 30 stems per ha. True fir, oak, and pines comprised about 40, 20, and 15%, respectively, of all snags. In Pacific coast forests where large trees are major components of the overstory, large plot sizes, up to and including 1.0 ha, seem more suitable to characterize overstory conditions for recent dead trees (≥27.9 cm in diameter). Other plot designs are needed to tally large live trees (≥100 cm in diameter) that occur sporadically on the landscape across most forest types.

The Future Health of California's Forests

In the beginning of this report, forest health was defined as the condition that provides desired sustainable ecosystems where biotic and abiotic influences do not threaten resource management objectives. Management objectives may be many and various, but all should point toward a forest that is resilient across the landscape, can recover from a range of disturbances, and can provide for current and future needs of people. Needs vary between and within generations and govern the values and uses of the forest. The values and uses are seen in the choices and activities of Californians. These choices and activities, along with drought, are the most influential forces on forest health in California. The quality of the choices and activities we impose have determined and will determine forest health in California.

Forest health monitoring indicates that most of California's trees are free of immediate health problems. Those problems that do exist for trees, stands, and landscapes can be addressed by appropriate practices and policies. All of California's forests can be relatively healthy. However, it will take time, patience, management, citizen involvement, monitoring, research, financial support, and above all, reason and judgment.

The first full report of trend information from the statewide forest health monitoring program will be compiled in 1999-2000. In the meantime, abiotic and biotic influences in California's forests will be reviewed and reported annually in the California Forest Pest Council's *Forest Pest Conditions in California* and other reports.

Drought is an unpredictable, frequent and an often formidable visitor to California. Other influences on forest health have been touched upon in this report—fire, animal damage, weather events other than drought, and native and exotic insects and diseases. Some approaches to maintaining or improving forest health follow; in no way is this a comprehensive list.

Fire

The number of large, severe wildfires has increased as fuels, fuel ladders, and stand densities have increased.

What can be done?

- Continue to implement and further develop practices designed to reduce the potential of a forest to burn in large, high-severity fires.
- Continue to develop underburning and cooperative projects between agencies and all forest land owners.
- Use management treatments that result in reduced moisture stress on trees and stands and the likelihood of successful bark beetle attack during drought. Tree mortality—particularly high, localized rates of mortality—will be less likely, as would the accompanying increase in dead fuels.

Weather

Little can be done about weather, but as with earthquakes, the effects of the most important weather factor in California, drought, can be minimized. California has had seven periods of drought in the past 100 years (unpublished report, Forest Pest Management, San Francisco) and future droughts are certain.

What can be done?

- Use forest management activities, such as thinning, that will result in minimizing moisture stress during the next drought.

Animal Damage

Recent annual reports of animal damage indicate a trend; about half of the acres needing treatment for control of animal damage will receive treatment each year.

What can be done?

- Increase support for this long-neglected aspect of forest health, including funds for more research.

Defoliators

California is fortunate in that tree defoliatiors have never been a widespread forest health problem, although localized outbreaks have happened. The first recorded, large outbreak of a budworm (*Choristoneura carnana californica*) in California defoliated Douglas-fir in Trinity County from 1982 to 1985. The most recent infestation of Douglas-fir tussock moth defoliated white fir in Plumas and Lassen Counties in 1988 and 1989. Defoliation from budworm was visible in Trinity County in 1996. Recent trap catches (1995 and 1996) of male Douglas-fir tussock moths and 1996 surveys for larvae indicate that populations of the tussock moth continue to increase in some areas. The likelihood that some forest areas will have damage from defoliation within the next four years seems to be increasing.

What can be done?

- Maintain tree diversity on sites capable of supporting a diverse forest, e.g., mixed conifer type.
- Use techniques such as underburning to reduce white

fir and Douglas-fir in low elevation or dry sites where pine used to predominate.

- Improve both stand and host-tree resistance; maintain seral forests with mixed host and nonhost species, reasonable stocking density, and low vertical canopy density.

Bark Beetles

Bark beetles and drought have influenced forest health in California. All pine and fir species have their own bark beetle enemies; this relation was so in the widely spaced, open-canopied forest of the past, and it is true in the close-canopied forest with more numerous, smaller tree species of today.

Drought is a favored ally of bark beetles, and now that the recent drought has ended, tree mortality from the drought-insect and drought-insect-disease complexes will return to rates considered to be normal. Such a decrease in mortality happened after the drought of the 1970s. Drought is a frequent visitor to California, however, and forest health will be best served if tree vigor is high at the beginning of the drought.

What can be done?

- Keep trees well-spaced; keep stands at stocking densities where moisture stress will not severely drain tree vigor during the next drought.
- Minimize susceptible hosts by reducing the number of offsite trees and stands.
- Thin young stands before they become overstocked.
- When possible, destroy or remove fading beetle-killed trees before the beetles emerge the following spring or summer, thus reducing the local insect population and the threat to high-value trees at high risk of attack.

Diseases

Insects species wax and wane in the life of a forest stand, but diseases are often more persistent. For instance, dwarf mistletoes are found on 2.2 million acres of National Forest land in California; this figure increases or decreases only gradually. Root diseases, once widely established in a stand, often present difficult management and research challenges.

What can be done?

- Treat freshly cut stumps whenever and wherever appropriate with borate to prevent infection by spores of the fungus causing annosus root disease.
- Minimize the injury of roots and lower stems during harvest operations; such injuries can attract insects that spread black stain root disease in susceptible hosts and provide entrance points for fungal infection.
- Maintain or create multiple species stands wherever conditions are appropriate.
- Use local seed sources for regeneration.
- Incorporate underburning into management practices to prevent invasion of tree species more susceptible to root disease.
- Support the rust-resistant programs for five-needle pines; use available rust-resistant planting stock where appropriate, i.e., where risk of blister rust infection is high.

Urban Forest

Urban forests can be considered to have three parts; the truly urban, the suburban, and the suburban-rural interface. Trees of this forest are constantly exposed to stresses such as air pollution, vandalism, and poor building and landscaping practices. The urban forest is usually the first to be exposed to exotic insects and diseases that gain entry at seaports and airports in goods, containers, dunnage, personal effects, and on or in the transporting vehicles.

What can be done?

- Reduce air pollution. The air is cleaner in many parts of California than it used to be, but—as population increases— policy decisions on standards, strategies, and technologies will be necessary to maintain these gains.
- Support healthy urban and neighborhood tree programs. Increased involvement and support for these programs will help maintain and develop healthy urban forests and reduce the probability of vandalism.
- Follow proper building, landscaping, and gardening practices. Proper practices will provide a healthful environment for sustaining trees over and beyond the lifetime of a homeowner, and they will help native species survive in an exotic environment.

Exotic Diseases and Insects

With increasing world trade and travel, the probability of introducing exotic diseases and insects increases. White pine blister rust, pine pitch canker, and the eucalyptus longhorned borer are three examples. Prevention of introduction is the best approach, but if introduced pests become established, new management strategies will become necessary.

What can be done?

- Support the Quarantine Inspection and Monitoring Programs of the California Department of Food and

Agriculture and the federal Animal, Plant Health, and Inspection Service and the regulations governing import and export. These agencies are the first line of defense against exotic insects, diseases, plants, and animals and will delay or prevent the arrival of exotics damaging to forests, agriculture, and property, and the export of exotics to other states and countries.

- Support programs that monitor, eradicate, or control exotic pests.
- Support and follow the recommendations and guidelines of the Pitch Canker Task Force for managing pine pitch canker.

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Acknowledgments

Additional information was received from the State of California, Department of Food and Agriculture, and the California Department of Forestry and Fire Protection's Urban Forestry Program and Forest and Rangeland Resources Assessment Program.

Don Dahlsten, UC-Berkeley; Steve Dreistadt, UC-Davis; Larry Hanks, UC-Riverside; Jocelyn Millar, UC-Riverside; Tim Paine, UC-Riverside; Richard Penrose, California Department of Food and Agriculture; and Ted Swiecki, Phytosphere Research, provided information for the Urban Forests Section. Paul Stover, Safiya Samman, and Sydney Smith, USDA Forest Service, provided information on tree improvement.

Information and maps on vector-borne diseases were provided by Kenneth Townzen, California Department of Health Services, Vector-Borne Disease Section, and Michele T. Jay, Sacramento County Department of Health and Human Services.

Maurice Roose, Chairman of the Hydrology Division, State Department of Water Resources, provided information on climate.

Outside review was provided by: Barbara Conkling, Research Triangle Park, NC; Manfred Mielke, St. Paul, MN; Sue Danner, John Kliejunas, and Mike Landrum, San Francisco; Tom Simonson, Susanville, CA; Bill Burkman, Asheville, NC; Bruce Roettgering, Sunnyvale, CA; and Dave Adams, Davis, CA.

Martha Brookes, Pacific Northwest Forest Experiment Station, Corvallis, OR, provided professional advise and review for writing and editing. She was assisted by Leiah Greene, student intern from Oregon State University. Map production was by Pacific Meridian Resources, Emeryville, CA. Desktop publishing and editorial assistance was by Gary Chase, Shasta-Trinity National Forests. Donna Dell'Ario provided invaluable assistance on layout, printing and publishing.

The vegetation coverage, A classification of California Vegetation (CALVEG), was produced by the Regional Ecology Group, USDA Forest Service, Pacific Southwest Region, in 1994 (fig. 1). The ecological units were digitized from the map, **Ecoregions and Subregions of the United States** 1994, edited and integrated by W.H. McNab and R.G. Bailey, in cooperation with the ECOMAP Team of the USDA Forest Service. The vegetation coverage, A Classification of California Vegetation, CALVEG, was produced by the Regional Ecology Groups, USDA Forest Service, Pacific Southwest Region in 1994.

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Appendix A

Common and Scientific Names

Common and scientific names of animals, pathogens, and plants mentioned in this report are listed in alphabetic order by common name.

Insects

Common name	Scientific name
Bark beetles	
California fivespined ips	*Ips paraconfusus*
Cedar bark beetles	*Phloeosinus* sp.
Douglas-fir beetle	*Dendroctonus pseudotsugae*
Fir engraver	*Scolytus ventralis*
Fir engravers	*Scolytus* spp.
Jeffrey pine beetle	*Dendroctonus jeffreyi*
Mountain pine beetle	*Dendroctonus ponderosae*
Pine engravers	*Ips* sp.
Red turpentine beetle	*Dendroctonus valens*
Western pine beetle	*Dendroctonus brevicomis*
Defoliators	
Alder flea beetle	*Altica ambiens*
California oakworm	*Phryganidia californica*
Douglas-fir tussock moth	*Orgyia pseudotsugata*
Elm leaf beetle	*Xanthogaleruca luteola*
Eucalyptus snout beetle	*Gonipterus scutellatus*
Fruittree leafroller	*Archips argyrospilus*
Gypsy moth (European)	*Lymantria dispar*
Walkingstick	*Timema douglasi*
Western tent caterpillars	*Malacosoma* spp.
Tree regeneration insects	
Clearwing moth	*Synanthedon* sp.
Pine needle sheathminer	*Zelleria haimbachi*
Western pineshoot borer	*Eucosma sonomana*
Wood borers	
Eucalyptus longhorned borer	*Phoracantha semipunctata*
Flatheaded fir borer	*Melanophila drummondi*
Pacific oak twig girdler	*Agrilus angelicus*
Yellow phoracantha	*Phoracantha recurva*

Other

Africanized honey bee	*Apis mellifera scutellata*
Ash whitefly	*Siphoninus phillyreae*
Blue gum psyllid	*Ctenarytaina eucalypti*
Citrus thrips	*Scirtothrips citri*
Encyrtid wasp	*Psyllaephagus pilosus*
Eugenia psyllid	*Trioza eugeniae*
Eulophid wasp	*Tamarixia* sp.
Juniper scale	*Carulaspis juripani*
Mymarid wasp	*Anaphes nitens*
Oak pit scales	*Asterolecanium* spp.

Pathogens

Common name of the disease	Scientific name of pathogen
Cankers	
Cytospora canker	*Cytospora abietis*
Oak canker (branch dieback)	*Diplodia quercina*
Pine pitch canker	*Fusarium subglutinans* f. sp. *pini*
Dwarf mistletoes	
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*
Pinyon dwarf mistletoe	*Arceuthobium divaricatum*
Red fir dwarf mistletoe	*Arceuthobium abietinum* f. sp. *magnifica*
Sugar pine dwarf mistletoe	*Arceuthobium californicum*
Western dwarf mistletoe	*Arceuthobium campylopodum*
White fir dwarf mistletoe	*Arceuthobium abietinum* f. sp. *concoloris*
Foliage diseases	
Leaf spot of arbutus	*Coccomyces arbutifolius*
Powdery mildew	*Mycosphaerella fraxinicola*
Septoria leaf blight	*Septoria* spp.
Root diseases	
Annosus root disease	*Heterobasidion annosum*
Armillaria root disease	*Armillaria ostoyae*
Black stain root disease	*Leptographium wageneri*
Oak root fungus	*Armillaria mellea*
Port-Orford-cedar root disease	*Phytophthora lateralis*
Rusts	
White pine blister rust	*Cronartium ribicola*
True mistletoes	
Leafy mistletoe	*Phoradendron* spp.
Wilts	
Dutch elm disease	*Ophiostoma ulmi*

Other

Oak twig blight	*Cryptocline cinerescens*
Oak anthracnose (twig blight)	*Discula quercina*
Oak canker rot	*Inonotus andersonii*
No common name	*Inonotus arizonicus*

Trees (Conifers)

Common name	Scientific name
Cypresses	*Cupressus* spp.
Cuyamaca cypress	*Cupressus stephensonii*
Gowan cypress	*Cupressus goveniana*
Monterey cypress	*Cupressus macrocarpa*
Santa Cruz cypress	*Cupressus abramsiana*
Tecata cypress	*Cupressus forbesii*
Pines	*Pinus* spp.
Bishop pine	*Pinus muricata*
Bristlecone pine	*Pinus aristata*
Coulter pine	*Pinus coulteri*
Foxtail pine	*Pinus balfouriana*
Gray (foothill) pine	*Pinus sabiniana*
Jeffrey pine	*Pinus jeffreyi*
Knobcone pine	*Pinus attenuata*
Limber pine	*Pinus flexilis*
Lodgepole pine	*Pinus contorta* var. *murrayana*
Monterey pine	*Pinus radiata*
Parry pinyon	*Pinus quadrifolia*
Pinyon	*Pinus californiarum*
Ponderosa pine	*Pinus ponderosa*
Singleleaf pinyon	*Pinus monophylla*
Sugar pine	*Pinus lambertiana*
Torrey pine	*Pinus torreyana*
Western white pine	*Pinus monticola*
Whitebark pine	*Pinus albicaulis*
True firs	*Abies* spp.
Grand fir	*Abies grandis*
Red fir	*Abies magnifica*
Santa Lucia fir	*Abies bracteata*
Shasta red fir	*Abies magnifica* var. *shastensis*
White fir	*Abies concolor*
Others	
Bigcone Douglas-fir	*Pseudotsuga macrocarpa*
Douglas-fir	*Pseudotsuga menziesii*
Giant sequoia	*Sequoiadendron giganteum*

Incense-cedar	*Libocedrus decurrens*
Mountain hemlock	*Tsuga mertensiana*
Port-Orford-cedar	*Chamaecyparis lawsoniana*
Redwood	*Sequoia sempervirens*
Sitka spruce	*Picea sitchensis*
Western hemlock	*Tsuga heterophylla*
Western juniper	*Juniperus occidentalis*

Hardwoods (Oaks)

Oaks	*Quercus* spp.
Blue oak	*Quercus douglasii*
California black oak	*Quercus kelloggii*
Canyon live oak	*Quercus chrysolepis*
Coast live oak	*Quercus agrifolia*
Engelmann oak	*Quercus engelmannii*
Interior live oak	*Quercus wislizenii*
Oregon white oak	*Quercus garryana*
Valley oak	*Quercus lobata*

Hardwoods (California natives)

Alder	*Alnus* sp.
Ash	*Fraxinus* spp.
Bigleaf maple	*Acer macrophyllum*
California buckeye	*Aesculus californica*
California-laurel	*Umbellularia californica*
California redbud	*Cercis occidentalis*
California sycamore	*Platanus racemosa*
Cottonwood	*Populus* sp.
Elms	*Ulmus* spp.
Maple	*Acer* sp.
Pacific dogwood	*Cornus nuttallii*
Pacific madrone	*Arbutus menziesii*
Quaking aspen	*Populus tremuloides*
Tanoak	*Lithocarpus densiflorus*
Willow	*Salix* sp.

Hardwoods (exotics)

Apricot	*Prunus armeniaca*
Arizona sycamore	*Platanus wrightii*
Citrus	*Citrus* spp.
Eucalyptus	*Eucalyptus* spp.
Japanese zelkova	*Zelkova serrata*
London plane	*Platanus acerifolia*
Pear	*Pyrus communis*

Shrubs

Common name	Scientific name
Antelope bitterbrush	*Purshia tridentata*
Current, gooseberry	*Ribes* spp.
Pomegranate	*Punica granatum*
Rubber rabbitbrush	*Chrysothamnus nauseosus*
Sagebrush	*Artemisia* spp.
Wingscale (fourwing) saltbush	*Atriplex canescens*
Toyon	*Heteromeles arbutifolia*

Animals

Common name	Scientific name
Mammals	
Beaver	*Castor canadensis*
Black bear	*Ursus americanus*
Deer	*Odocoileus hemionus*
Deer mouse	*Peromyscus maniculatus*
Elk	*Cervus elaphus*
Ground squirrels	*Spermophilus* spp.
Hares	*Lepus* spp.
Kangaroo rats	*Dipodomys* spp.
Meadow mice (voles)	*Microtus* spp.
Mountain beaver	*Aplodontia rufa*
Pocket gophers	*Thomomys* spp.
Porcupine	*Erethizon dorsatum*
Rabbits	*Sylvilagus* spp.
Western gray squirrel	*Sciurus griseus*
Woodrats	*Neotoma* spp.
Birds	
Northern spotted owl	*Strix occidentalis caurina*

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Appendix B

The national Forest Health Monitoring Program (often abbreviated as *FHM*) began in 1990 in 10 northeastern states. It was a national cooperative effort that included the United States Department of Agriculture (USDA) Forest Service, both the Research and Forest Pest Management and Forest Insect and Disease staffs; the U.S. Environmental Protection Agency; state forestry agencies; and the National Association of State Foresters. Today, cooperators also include the U.S. Department of Interior's Bureau of Land Management, Fish and Wildlife Service, National Park Service, the USDA National Resources Conservation Service, and forestry organizations in eight additional states. The main objective is to determine status, trend, and condition of forest resources nationwide.

The national Forest Health Monitoring WEST Administrative Region includes California, Hawaii, and Alaska plus Oregon and Washington (fig. 45). Field work began in California in 1992 when some 55 forested plots were measured across the state. A different set of about 50 forested plots were measured yearly from 1993 to 1995. This complete four-year dataset comprises the forest ecosystem baseline for California. Each baseline year is a separate estimate of forest conditions in the state. The only other field effort in the West coast region is a Pilot Study, in which Douglas-fir habitats were assessed on 25 plots in western Oregon and Washington in 1994. Initial baseline forest conditions will be assessed across Oregon and Washington in the summer of 1997.

Three separate but parallel activities comprise the Forest Health Monitoring National Program. In **detection monitoring**, field crews measure selected biotic and abiotic features called **indicators** of forest condition during a baseline period. These same features are then remeasured at yearly or other intervals. Forest changes between the baseline and remeasurement condition indicate a response to natural forest change or ecosystem disturbance. The ecosystem indicators are analogous to general blood pressure, pulse, and blood chemistry data recorded for people in routine medical exams. Infant, juvenile, adult, and mature age-groups have certain values that indicate normal health. Values outside the normal ranges indicate possible anomalies that should be checked by a specialist.

Evaluation monitoring begins when the cause of a significant and detected change is unknown. Activities include intensive field sampling and combined interpretations by ecologists, entomologists, hydrologists, pathologists, silviculturists, and others. These resource specialists are like heart, kidney, lung, and other medical experts who are asked to diagnose blood chemistry results that fall outside normal values or that result from traumatic injury.

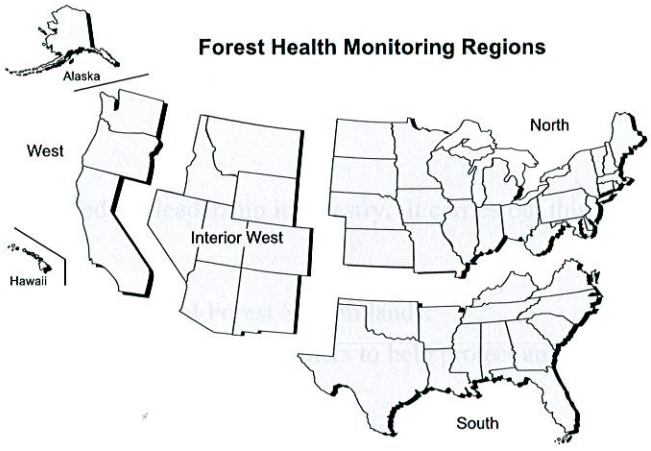

Figure 45 — The four Forest Health Monitoring Program research administrative regions: West (Pacific Northwest and Pacific Southwest Stations), Intermountain (Intermountain and Rocky Mountain Stations), North (North Central and Northeastern Stations), and South (Southern Forest Station).

Intensive site ecosystem monitoring combines knowledge from evaluation monitoring and results from long-term, watershed-scale research at a few sites with diverse forest types and biomes typical of those found in the United States. The best example in the West is the H.J. Andrews Experimental Forest near Blue River, Oregon, where forest research work has been documented since the 1940s.

Combining information from all three monitoring activities allows predicting where and how future ecosystems might change under given environmental and management conditions. One example could be a changing climate that produces drier fall and winter seasons; a possible effect is severely reduced seedling germination and recruitment, compared to those percentages that have been observed over many decades. In industrialized and urbanized regions, another example might be increasing ozone concentrations that damage both seedlings and overstory trees, making both more susceptible to disease and pathogens.

The Forest Service, U.S. Department of Agriculture, is responsible for federal leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands;
- Cooperation with state and local governments, forest industries, and private landowners to help protect and manage nonfederal forest and associated range and watershed lands;
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas;
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Region represents the Forest Service in all points , except for research, in California, Hawaii, American Samoa, and the western Pacific.

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