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Chaparral and Associated Ecosystems Management: a 5-year research and development program

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INTRODUCTION

Chaparral—evergreen, sclerophyllous shrubs with associated ecosystems of grass, sage scrub, broadleaved and conifer plant communities—is the dominant vegetative type in the wildlands of central and southern California. Until recently, chaparral was considered of little value, and management strategy focused mainly on fire suppression. But this rapid suppression of fires under moderate weather and fuel conditions over the years has resulted in a heavy buildup of fuels in large areas. Under hot, dry, windy conditions, these heavy fuels become large, uncontrollable fires, setting the stage for larger fires in the future. In the wildland-urban interface, homes and other improvements are often lost in these conflagrations.

The continuation of large, disastrous wildfires, despite large-scale suppression efforts, led resource managers to implement new fire and vegetation management methods. Also, the growing awareness of the value of chaparral for purposes of watershed, wildlife habitat, recreation, livestock grazing, and potential energy production suggested a prescription for change. Until then, chaparral vegetation generally had been viewed as worthless, good for little more than fuel for wildfire. But attitudes began to change. Managers were encouraging the search for tools and techniques that could enhance these resources.

This increased awareness in the value of chaparral and associated ecosystems led to the establishment of the Chaparral Program. In 1976, the Pacific Southwest Forest and Range Experiment Station and the Pacific Southwest Region, Forest Service, U.S. Department of Agriculture, began a 5-year research and development program: Vegetation Management Alternatives for Chaparral and Related Ecosystems. Headquartered at Riverside, California, the program was designed as a framework for chaparral-related research and to accelerate the development of urgently needed management techniques. The program's charter specified research with brush-type vegetation as well as woodlands and certain conifer forests.

This report provides a nontechnical overview of the program's accomplishments. It summarizes the program's intensive efforts of technology development and transfer to diverse user groups, and describes the changing management philosophy throughout the program. This report bears special importance for managers and landowners in planning and implementing efficient land management policies related to chaparral and associated ecosystems.

CHAPARRAL AND ASSOCIATED ECOSYSTEMS

California chaparral communities range from 500 to 3000 feet (150 to 900 m) elevation in the north and from 1000 to 5000 feet (300 to 1500 m) elevation in the south. Associated vegetative types grow adjacent to chaparral—above it, below it, or intermingled with it, as along drainages. Typical chaparral species include chamise *(Adenostoma fasciculatum),* scrub oak *(Quercus dumosa),* several manzanita species (*Arctostaphylos* spp.), and several ceanothus species (*Ceanothus* spp.) (Conrad 1985). Usually, chaparral species begin to grow in midwinter in southern California and in late winter in northern California. Growth continues until early summer in most years. Associated woodlands, often dominated by oak trees and several conifer species, begin growth later than chaparral and continue growing later into summer. Woodlands with better soil moisture availability also produce more herbaceous undergrowth than chaparral (Hunter 1982b, Paysen 1982, Paysen and others 1982).

The sage scrub vegetative type commonly associated with chaparral—often called soft chaparral—is dominated by drought-deciduous, semiwoody shrubs, and frequently has a herbaceous component. The semiwoody shrubs species include sage (*Salvia* spp.), sagebrush *(Artemisia californica),* buckwheat *(Eriogonum fasciculatum),* and brittlebush (*Encelia* spp.). Each year, several component species produce more aromatic compounds than most chaparral shrubs, as well as a significant quantity of semiherbaceous or at least soft woody material. This semiherbaceous growth annually matures, much of it dying back to a more hardened woody component. Above-normal precipitation—especially if during the growing season of important sage scrub species—results in above-normal growth of the semiherbaceous parts of plants. As a result, the species produces dead material in above-normal amounts due to this above-normal rainfall and growth. The typical sage scrub type is associated with low-elevation chaparral which pervades to sea level. Annual growth often begins with the onset of significant fall or winter rains and ceases soon after the last rainfall in spring. Chaparral and woodlands are associated with the moister, cooler margins of sage scrub. Grasslands are another vegetative type often found adjacent to sage scrub. Usually, however, it is difficult—if not impossible—to identify clear and consistent ecosystem properties to explain the shift from sage scrub to grassland.

Fire and Plant Community Relationships

Chaparral, sage scrub, and associated herbaceous plants adapt to harsh environmental conditions. They can tolerate extended summer drought, poor soils, unstable slopes, and desiccating winds. The plants have been especially successful in adapting to fire. In fact, periodic burning is integral to the life cycle of chaparral communities (Hunter 1981, Radtke and others 1982).

Chaparral and associated ecosystem vegetation have adapted to fire in two major ways: (1) These species have mechanisms of regenerating successfully after a fire by quickly sending up sprouts from the root collar or by fire-stimulated germination of seeds; and (2) they have various chemical, physical, and physiological characteristics that tend to make them flammable. These characteristics ensure that old, nonproductive stands burn readily, making way for vigorous regeneration (Philpot 1979, 1980).

The tendency for chaparral vegetation to burn presents a problem for land managers, mainly since more than 10 million people live or work within chaparral areas or benefit from watershed values and recreation provided by these wildlands. Historically, wildfires—and the flooding and erosion that often follow—have cost dearly in terms of life and property. Therefore, any management strategy must account for the relationship between chaparral ecosystems and fire.

When heavy fuels dominate large areas, wildfires frequently burn on extensive flaming fronts for long distances. When old stands of chaparral and associates, including accumulated dead material, intermingle with or are adjacent to even more flammable sage scrub plant communities, fire can grow at remarkably uneven rates. Fire tends to move more rapidly on south-facing slopes where the vegetation is likely to be sage scrub or chamise chaparral, and the air temperature and humidity are more extreme.

Commodity Resource Potential

A chief aim of the Chaparral Program was to protect lives and reduce property loss rather than to improve forest biomass yield. Chaparral and associated ecosystems probably have no significant potential for economically producing commercial biomass on a large scale. Water, on the other hand, is of significant value. About one-third of the water demand, about 1 million acre-feet (28,000 m^3) of usable water, is obtained from this source each year by the Metropolitan Water District of southern California. Most of this water, which is stored in underground basins of southern California, originates from upland sources.

Converting shrub and tree stands to vegetation that demands less water results in a higher water yield. But the excess erosion from increased water yield often outweighs the benefits. On the San Dimas Experimental Forest in Los Angeles County, a steep watershed that was converted to grass in 1961 produced 2¼ times more sediment after conversion (Wells 1982a). Therefore, a major value of forests, woodlands, and shrublands is to provide watershed stability and ensure maximum delivery of potable water to underground storage.

Benefits less tangible than water also derive from chaparral and associated ecosystems, including aesthetic, recreational, and wildlife values (Hunter 1982). Another benefit, though difficult to measure, is the ability of vegetation to use carbon dioxide and even some chemicals considered pollutants to produce biomass (Conrad 1982, Riggan and Dunn 1982). Many managers and landowners realize that these indirect benefits are significant but require a better understanding of fundamental ecosystem processes.

THE CHAPARRAL PROGRAM

To implement the Chaparral Program, an extensive survey was conducted to assess user suggestions and needs. Workshops focused on areas of concern to researchers and practitioners from the Forest Service and cooperating agencies and universities. Managers and researchers were an especially valuable resource during the assessment phase. Significant needs of the program were also addressed at an international symposium, Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems (Mooney and Conrad 1977), held at Stanford University, in August 1977. Program personnel became informed and acquainted with field managers through field trips. For example, a tour of the 130,000-acre Laguna-Morena Demonstration Area in San Diego County, California, in April 1977, clarified much of the program's intent. The area subsequently became the site of most program demonstrations.

Some research supported by the program leaned strongly toward understanding basic chaparral processes, since data available from sound fundamental research were scant. At the beginning of the program, knowledge in some areas was insufficient for high-quality applied research in chaparral or woodland ecology. The physiology of fire on oak and other woodland species were, for the most part, unknown and currently remain only slightly studied. Existing research showed that several chaparral species were capable of symbiotic nitrogen fixation, but the nature and occurrence of those processes remained elusive. Moreover, we continue to have only broad, untested theories to explain the relationships among oak, conifer, and chaparral ecosystems. As a result of the program, however, the complexities of these associated ecosystems are better understood.

User groups contributed substantially to the program's resources by developing technology, publishing research findings and user guides, participating in training and demonstrations, as well as reporting program activities. For example, a team developed the Vegetation Classification System (Paysen and others 1980). Its members were from the California Department of Fish and Game, Southern California Edison Company, as well as National Forests. Substantial research was sponsored by the program through cooperative agreement with universities. Such research has benefitted both public and other public and private land resources in the southwestern United States, the Mediterranean basin, and countries such as Australia, Chile, Mexico, and South Africa.

RESEARCH AND DEVELOPMENT

Understanding Chaparral Ecosystems

Management of chaparral ecosystems is complicated: the components of the ecosystems are constantly changing. Soil on steep, unstable slopes is subject to gravitational movement that is aggravated by fire, rain, wind, and animal activity. The stages of succession cause distinct shifts in plant species following fire or other disturbance. In turn, nutrient cycles and wildlife populations fluctuate with the fire cycle and successional changes in vegetation. Also, physiological changes in vegetation occur with age, seasonal changes in temperature, and water availability.

Understanding the interrelationship of these mutable processes is requisite to effective chaparral management. The Chaparral Program sponsored several studies that focused on the dynamics of the chaparral ecosystem. These studies included vegetation classification, water-repellent soils, hydrology and sediment relationships, nutrient cycling, physiological relationships, and photo-oxidant effects.

Vegetation Classification

A Vegetation Classification System was designed for California (Paysen 1983; Paysen and others 1980, 1982). The system is compatible with the vegetation elements of the Component Land Classification for the United States, developed by the Resources Evaluation Techniques Program, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, and the international system for classifying vegetation. The Vegetation Classification System represents the efforts of a multiorganizational group. Consequently, the resulting system has applicability over a broad area, as evidenced in its adoption by the State of Hawaii as a framework for its own resource inventory and vegetation system.

The Vegetation Classification System is designed to aid all disciplines in natural resource management *(fig. 1)* (Hunter and Paysen 1982). Earlier systems were usually oriented to a specific discipline so that every specialist—ecologist, wildlife biologist, forester, or range manager—required a different classification system. This system provides a standardized

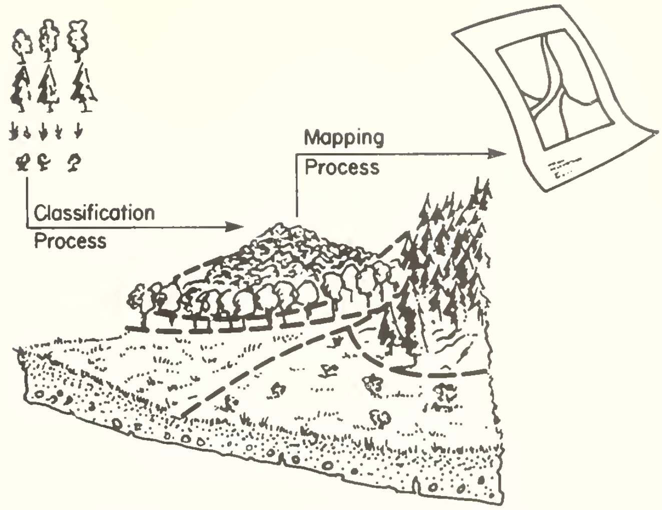

Figure 1—Classification of vegetation in areas of chaparral and associated ecosystems should precede other land management activities such as mapping

vegetation classification procedure and nomenclature, and includes a flexible category for data germane to a specific user. As a result, the system provides a universal language that responds to diverse needs.

Plant communities reflect the composition of their environment—rainfall, soil, and fire, for example. Most managers and biologists accept this. That no clear demarcation separates one plant community from another, however, often causes disagreement. The distribution of sage scrub, chamise chaparral, and mixed chaparral plant communities is related to rainfall *(fig. 2)*. Sage scrub is a common vegetative type typically associated with chamise chaparral. Of 1622 systematic grid map locations in southern California (excluding deserts), 1118 were in these three communities. Of these, 560 locations were in chamise chaparral, 200 in mixed chaparral, and 358 in sage scrub. The other 504 locations were in six additional vegetative types. Both sage scrub and chamise

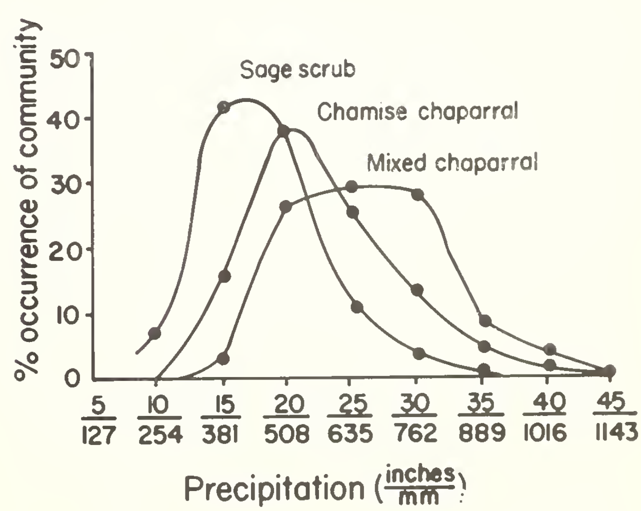

Figure 2—Three associated shrub communities as a percent of 1622 observations in the southern California non-desert zones.

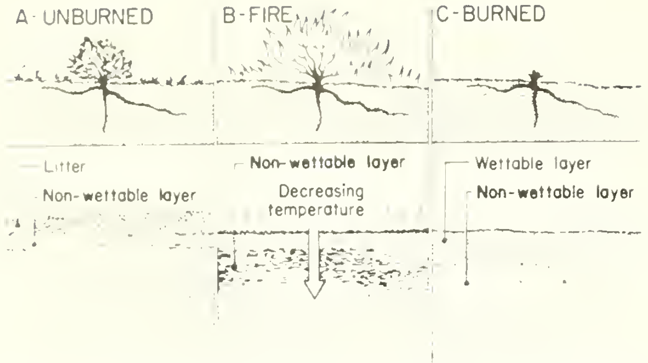

Figure 3—The general theory for the formation of a water-repellent soil layer with fire includes volitalizing chemicals present in a moderately repellent layer by heat, then condensing these water repelling chemicals on soil particles in a more concentrated layer.

chaparral have well-defined peak occurrences at about 16 and 21 inches of precipitation. Mixed chaparral is almost equally abundant in the 20- to 30-inch precipitation range (Conrad and Paysen 1979).

Water-Repellent Soils

Chaparral fires can cause some soils to become water repellent or hydrophobic. The present theory explaining how hydrophobic soils are formed is shown graphically in *figure 3*. The mechanism of hydrophobic soil formation has been explained and identified as important to postfire sediment yields (DeBano and others 1977, 1979). Work sponsored by the Chaparral Program showed the extent to which hydrophobic conditions occur and their effect on nutrient transport from site. One state-of-the-art report (DeBano 1981) discussed the nature of water-repellent soils, kinds of water-repellent substances, effects of soil-water repellency on water movement, fire-induced soil-water repellency, management problems and implications of water repellency, and research needs.

Studies begun during the Chaparral Program have continued, focusing on decomposition rates in hard-to-wet soil layers and the role of these layers in erosion processes such as rill formation. Such research is part of a series of hydrologic studies that identify how the relationships between fire, water-repellent soil, soil texture change, and erosion can be predicted in managing chaparral lands (Wells 1981, 1982a; Dunn and others 1982).

Hydrology and Sediment Relationships

When the Chaparral Program started, little information was available on debris movement as related to fire occurrence and behavior, hydrologic events, and land treatments. Yet this cause-and-effect information was necessary for managers to choose land treatment alternatives such as prescribed burning or seeding of grasses.

A comprehensive sediment model that included all southern California watersheds was a major contribution. The model was produced by the program in cooperation with the California Institute of Technology (Brown and Taylor 1982, Brownlie and Taylor 1981, Kolker 1982, Taylor and Brownlie 1982, Wells and Brown 1982, Wells and Palmer 1982). This model shows that erosion on steep chaparral slopes is best described as an episodic process strongly influenced by complex internal thresholds. The unpredictable response of these slopes to eroding forces is due to the thresholds. Soil movement is a direct result of fire and postfire conditions (Duriscoe and Wells 1982; Fall 1981; Tiedemann and others 1979; Wells 1981, 1982a).

A major change in understanding soil erosion in chaparral areas is attributable to Chaparral Program research. Previously, all erosion was considered undesirable. This attitude stemmed from experience with agricultural lands where rich topsoil is a valuable resource and erosion reverses the natural depositional process. But on steep, naturally unstable chaparral slopes, undemanding ecosystems have developed mechanisms for adequately replacing or foregoing lost nutrients. In the chaparral ecosystem, erosion is natural, and in the long term unpreventable. The real management issues created by erosion are flooding and sedimentation that occur in populated valleys below (Nat. Acad. Sciences 1982, Taylor and Brownlie 1982, Wells 1982b, Wells and Brown 1982, Wells and Palmer 1982).

Nutrient Cycling

Nutrient cycling in chaparral ecosystems was a major target of Chaparral Program research. Little was known about this subject before the program began. Both the chemical and biochemical aspects of nutrient cycling were investigated with emphasis on nitrogen loss and replacement, especially after fire. We learned that the effect of fire on nutrients is limited chiefly to the volatilization of nitrogen and, to a lesser degree, potassium. In addition, small quantities of all nutrients may be transported on windblown particles and smoke (DeBano and Conrad 1976, 1977; Dunn and Debano 1977; Dunn and Poth 1979; Riggan 1979; Wells and others 1979).

A common conclusion is that erosion by water is responsible for large postfire losses of all nutrients; certainly, a large amount of surface soil is lost (Kolker 1982; Wells 1981, 1982b). Soil particles removed by erosion carry some of all nutrients (DeBano and Conrad 1976, 1977; DeBano and Dunn 1982). A major reason for prescribed fire, therefore, is to reduce nutrient loss by reducing fire-related erosion (DeBano and Dunn 1982).

Nitrogen merits special consideration, since it is easily volatilized by heat and must be replenished after fire. Also, it is the absence of this nutrient that most likely limits plant growth. Data are now available that quantify nitrogen loss during and after fires of varying intensity from soils of varying moisture content. Managers can use these data to reduce nitrogen loss or estimate tradeoffs when considering prescribed burning (DeBano and Conrad 1977).

Some mechanisms by which nitrogen is recovered or replaced have been identified. Nitrogen-fixing legumes such as lupine (*Lupinus* spp.) and deerweed (*Lotus* spp.), nonleguminous plants such as California lilac (*Ceanothus* spp.), as well as nitrogen-fixing organisms have been investigated, but the extent of their roles is less certain. Also, all nitrogen replacement observed on chaparral sites cannot be attributed by the above cures, based on current measurement techniques (Poth 1980, 1982; Poth and Dunn 1982; Riggan and Lopez 1982).

The interrelationships among soil microorganisms, heating rates associated with wildfires or prescribed burns, soil moisture at the time of a fire, and various nitrogen-fixing plant species have been studied, but much remains to be learned about the dynamics of nutrients in chaparral systems. Little is understood about the transfer of nitrogen and other nutrients through the ecosystem from the rooting zone into stream water, the role of *Ceanothus* spp. in postfire nitrogen replacement, and how nitrogen replacement varies by parent material, fire intensity, existing vegetation, and species of microorganism (Dunn 1980; Dunn and Reynolds 1979; Mishler 1978).

Despite many unanswered questions, substantial information of value to chaparral land managers has resulted from the Chaparral Program.

Physiological Relationships of Chaparral Species

Program scientists and cooperators investigated several areas related to the physiology of chaparral plant species. Studies focused on how plants vary by species, age, and season in their water-use patterns, photosynthesis and carbon metabolism, growth patterns, and response to fire. Understanding these variables is requisite to evaluating the effects of prescribed burning, biomass harvesting, herbicides, and other management tools practiced within the chaparral community.

Data on photosynthetic rates and plant water status for several important chaparral species were developed through cooperative research with the Systems Ecology Group, at San Diego State University (Hastings and Oechel 1982, Lawrence and Oechel 1982, Oechel and Lawrence 1979, Oechel and others 1981, Oechel and Mustafa 1979). Photosynthetic rates, which depend largely on sunlight, carbon dioxide, water, and certain trace minerals, indicate the effectiveness of the plant to accumulate energy and carbon for growth, reproduction, and buildup of reserves. Species with relatively high photosynthetic rates generally have high ground cover and competitive advantage over species with lower rates. Management techniques that alter the relative photosynthetic rates among species may also alter the species composition of the affected community (Oechel 1982).

Photosynthesis varies not only by species, but by season, elevation, slope, plant moisture status, and age as well. During the first months after fire, maximum photosynthetic rates by resprouts were observed at rates several times greater than for mature plants. Yet resprouts in a hand-cleared area had photosynthetic rates similar to those observed in mature plants (Hastings and Oechel 1982, Oechel and Hastings 1983). These findings suggest that chaparral stands may not be able to rally after repeated biomass harvesting in the same way that they respond to periodic burning. Nevertheless, current information on biomass accumulation after harvesting remains scant (Oechel 1982).

The response of various oak species to fire was investigated (Plumb 1980a, 1980b; Plumb and McDonald 1981). Species were rated according to their fire tolerance. Also, variables thought to affect fire tolerance—bark surface texture and thickness, age, trunk diameter, and crown height—were studied. Based on this research, the chances for postfire recovery of an oak—given the species, size, and degree of charring—can now be predicted. A guide to postfire treatment of oak stands has been developed (Plumb 1980b, Plumb and Gomez 1983). Acorn production management was also studied, including the timing and methods for collecting, storing, and germination (Plumb 1981, 1982).

Photo-oxidant Effects

Air pollution—a force largely caused by humans—influences the dynamics of chaparral and associated ecosystems. The Los Angeles Basin, for example, is subject to high levels of air pollution due to its topography, meteorological characteristics, and high population density. The smog drifts east and intensifies as it reaches higher elevations in the San Bernardino Mountains *(fig. 4)*. The Chaparral Program, in cooperation with the University of California and Environmental Protection Agency, sponsored research to determine the effects of airborne pollutants on plant communities, concentrating specifically on the conifer forests of the San Bernardino Mountains where pollution damage has been severe (Axelrod and others 1980, James and others 1980, Miller and Erdman 1977, Miller and others 1982, Miller and Kickert 1985, Miller and others 1979, Miller and White 1977, Winer and others 1981).

Research efforts focused mainly on the pollutant ozone (O_3), the primary component of smog that damages plants. Symptoms were identified and guides developed for identifying the extent and severity of ozone damage to trees. The relative sensitivities of native and frequently planted tree species were determined. As a result, the most sensitive species are now known: ponderosa pine, Jeffrey pine, western white pine, and the Jeffrey-Coulter pine hybrid (Miller 1980a, 1980b, 1983a, 1983b; Miller and others 1978, 1980; Miller and Van Doren 1982).

Chaparral shrubs are relatively insensitive to airborne pollutants. In a study of susceptibility of several common chaparral species to ozone injury, seedlings developed more symptoms of injury than mature plants (Stolte 1982). Also, the

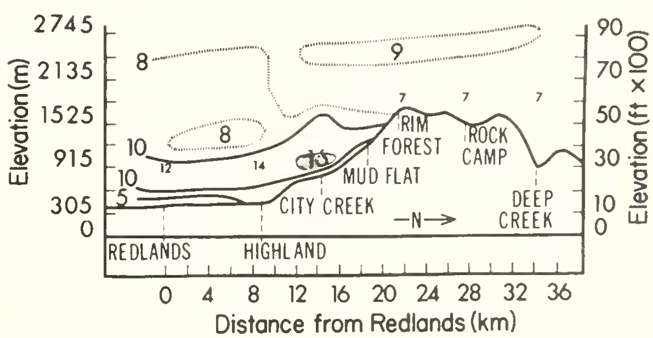

Figure 4—Concentration of oxidant air pollutants in parts per hundred million at 9:00 A.M. on a typical smoggy day in the San Bernardino Mountains of southern California.

severity of injury was negatively correlated with the amount of thick and leathery leaf characteristics developed. Because leaves of seedlings are softer (more mesophyllous) than leaves of mature plants, damage is more severe. With regard to seedlings, chaparral whitethorn *(Ceanothus leucodermis)* was most severely damaged, followed by chamise *(Adenostoma fasciculatum)*, bigberry manzanita *(Arctostaphylos glauca)*, and scrub oak *(Quercus dumosa)*. On the other hand, chaparral whitethorn was the only mature chaparral plant that showed cause for concern due to susceptibility to dosage levels in its habitat range.

Some air pollution effects on plant communities may be positive. By acting as a sink for airborne chemicals, trees and shrubs may conserve the chemicals and convert them to plant biomass rather than allowing them to be exported in percolated water to streams (as in grasslands). Future studies should emphasize both the positive and negative interactions of air pollution with nonpollution-related environmental stresses. These interacting forces may well favor some species, thereby influencing forest succession and management practices.

Managing Chaparral Ecosystems

Pursuing an understanding of chaparral is important for managers of chaparral and associated ecosystems. The preceding discussion has shown that these ecosystems are dynamic and complicated. But managers must also deal with factors other than chaparral ecology. The complex interactions between man and nature are recognized worldwide. Hunter (1982a) found that management objectives related to Mediterranean-type ecosystems were surprisingly similar worldwide. The objectives most often mentioned by international experts are grazing, recreation, watershed protection, aesthetics, and nature conservation. Of recurring significance in achieving those objectives is fire and fuel technology. This is nowhere more apparent than in southern California.

Prescribed Burning

Planned burning of chaparral fuels is not new. California ranchers have been burning for range improvement under permit from the California Department of Forestry since 1945. Burning for human benefit has a much longer history in California, but records do not include how early fires were planned. Even so, the idea of burning chaparral fuels on public land was still rather bold and controversial when the Chaparral Program began. Many recognized the potential value of fire for achieving resource objectives related to fire-hazard reduction, range improvement, sediment and flood management, and wildlife habitat. The focus centered on safety and containment of large-scale burning in highly flammable vegetation such as chaparral. Few managers in the Pacific Southwest Region were experienced in prescribed burning. Moreover, few experienced in fire suppression felt confident that they could plan and carry out a prescribed burn.

A comprehensive report on prescribed burning and predicting burn results was compiled for land managers (Green 1981). This guide and parts which were released serially helped to introduce safe and productive prescribed fire practices on public lands in California. Although much remains to be learned, much is now known about fire behavior and its effects in relation to diverse weather conditions, plant species, fuel moisture and age, season, and aspect. Most important, chaparral land managers are now armed with the basic information required to use prescribed burning as an operational tool (Green 1978, 1980, 1982; Hunter and Philpot 1982; Dougherty and Riggan 1982).

The moisture content of living chaparral fuels is one of the more significant variables when predicting fire behavior. To standardize the determination of fuel moisture content, procedures were developed for both field sampling and laboratory analyses (Countryman and Dean 1979, McCreight 1981). This method of monitoring changes in fuel moisture content was adopted in a statewide system of permanent sampling plots set up by the Forest Service and the California Department of Forestry (Countryman and Bradshaw 1980). Resource managers now use this method to assess live fuel moisture on specific sites for which prescribed burns are planned.

The helitorch is one of the most significant tools developed for prescribed burning since the program was started. It was first tried in California brushfields on the Mendocino National Forest in 1979 (Bungarz 1982). Since then it has become almost indispensable. Burning globs of jellied gasoline drop from a torch slung a safe distance below the helicopter *(fig. 5)*. The flaming globs of jellied gasoline fall through the brush and ignite dead material under the green canopy. With the helitorch, brush can be burned when it contains more moisture, fire can be laid onto almost any spot in the brushfield, and ignition can be completed quickly or slowly, depending on the prescription. An expert helitorch pilot can lay fire on a precise perimeter line or a ground crew can set the perimeter fire and the helitorch can then build a hot interior fire that drafts the fire into the project area.

Several experimental burns were planned cooperatively between National Forests and the Chaparral Program, each contributing significantly to assessing preburn preparation, worker requirements, and equipment needs. For some experimental burns, data such as fire behavior and intensity, soil moisture, and season of burn were recorded and extrapolated to postfire conditions such as soil effects, successional patterns, and sediment production (DeBano and Conrad 1976, DeBano and Conrad 1977, DeBano and others 1977, Dunn and DeBano 1977). Four burns on the Cleveland National Forest (Dougherty and Riggan 1982) as well as a series of test burns on the Los Padres National Forest and other southern California forests contributed to our prescribed burning procedures.

A few understory burns were prescribed beneath mixed-conifer or oak canopies. Based on these experimental burns and the known sensitivity of specific oak species to fire (Plumb 1980b), prescriptions for underburning have been

Figure 5—The helitorch drops flaming globules of jellied gasoline that carries fire through the brush igniting dry sticks and leaves.

recommended (Green 1980, 1981). These prescriptions, however, are considered preliminary and need further testing and refinement.

Other Fuel Management Techniques

Although prescribed fire received the most attention from the Chaparral Program, other fuel management techniques were examined. These procedures included mechanical equipment, hand labor, and herbicides (Bentley and Estes 1978; Green 1977a, 1977b, 1978; Hield and others 1984; Plumb and Goodin 1982; Plumb and others 1977; Roby and Green 1976). An assessment of biological methods focused on the use of browsing animals, in this case goats, for brush control.

Goats best serve in controlling young regrowth, such as brush on cleared fuelbreaks. Although goats eat a greater variety of plants than other livestock species (Green and others 1978; Green and Newell 1982; Sidahmed 1981; Sidahmed and others 1981, 1982), they become increasingly selective as the shrubs age. Goats should not be expected to control tall, mature brush, but they provide a promising alternative to herbicides for controlling brush regrowth (Green and others 1978). Goats pose specific problems in chaparral: the need for roads, fencing or herding, water, and supplemental feeding. They must also be protected from predators, disease, and poisonous plants. A comprehensive survey on goat control of regrowth is available (Green 1982).

One fuel management approach investigated early in the program was the planting of low-volume and slow-burning vegetation on clearings such as fuelbreaks. Since the 1940's, the search for such plants has been sporadic. Test plantings revealed about 20 shrubs and an equal number of grasses that showed promise for planting on brush-cleared areas (Nord and Green 1977). But collecting seeds and propagating and establishing plants on harsh wildland sites have proven large-scale planting to be impractical. However, many species studied are used for home landscaping in wildland areas (Radtke 1981, 1982, 1983).

Managing for Wildlife

Chaparral management techniques diversely affect wildlife and wildlife habitat (Quinn 1982). The scant data on chaparral ecosystem fauna makes it difficult to properly assess the impact of management plans on wildlife. Cooperating university scientists have reviewed and evaluated available information on chaparral mammals (Bayless 1980; Quinn 1979a, 1979b; Wirtz 1977), insects (Force 1979), birds (Alten 1981; Dutton 1981; Wirtz 1979a, 1979b), and reptiles (Simovich 1979).

The abundance and diversity of wildlife in California's chaparral is not commonly recognized. Chaparral habitat supports about 49 species of mammals alone (Quinn 1979b). During a 2-year period, 85 species of birds were observed in burned and unburned grassland and chaparral areas on the San Dimas Experimental Forest (Wirtz 1979a). In a larger scale study on the San Dimas Experimental Forest and adjacent areas, 128 species of birds representing 36 families were documented. Ninety-nine of the bird species were at 3000 to 4200 feet (900 to 1300 m), the mid-elevation zone of chaparral and associated plant communities; 110 species were sighted at 4600 feet (1400 m) (Wirtz 1979b, 1982). Flower-attracted insects, especially bees, are more abundant and species-rich in chaparral than in any other California vegetation and are responsible for most pollination (Force 1979).

The effects of wildfire and prescribed fire upon chaparral wildlife were of special interest to the program. By altering the structure and composition of the plant community, fire in chaparral can profoundly affect the animal community. Fortunately, these changes in the plant and animal communities are normally temporary. Nevertheless, it is of value to know the fluctuation patterns of various animal communities as they relate to the fire cycle and to plant succession. It is also of value to know how fire frequency, intensity, and size affect animal communities. Postfire succession of birds (Alten 1981, Wirtz 1979a), reptiles (Simovich 1979), mammals (Quinn 1979a, Wirtz 1977), and insects (Force 1982) has been studied. Currently, information suggests that, in general, wildlife habitat may be optimized by maintaining chaparral in many age classes, by restricting the size of burned or treated areas, by protecting trees, and by enhancing water sources (Quinn 1979b).

A wildlife habitat guide is in preparation by National Forest cooperators that comprehensively describes the mammal, reptile, and bird species currently inhabiting California's chaparral (Loe and Kenney 1985). The guide will comprehensively review the literature and include data on distribution, special habitat requirements, territory requirements, and breeding and feeding habitats. A map of specific bird sightings will be included.

Managing Woodlands and Riparian Zones

Interest in actively managing woodland and riparian zones in California is increasing. In most of California, the highest current values of these zones are for wildlife habitat, watershed protection, recreational and aesthetic character, and some livestock grazing; but they also contain a large reservoir of fuel and fiber. Woodland and riparian species commonly intermingle along drainages or other moister areas within chaparral zones and require special management considerations due to their high value.

By defining management options, the Chaparral Program emphasized the significance of woodland management. A regional symposium—the first of its kind—was sponsored in 1979 that brought together researchers and managers interested in the ecology, management, and utilization of California oaks (Plumb 1980a). Chaparral Program researchers contributed on oak inventory and distribution records (Paysen 1980), the role of prescribed fire in oak management (Green 1980), nutrient-microbial considerations (Dunn 1980), damage to oaks by fire (Plumb 1980b), and air pollution effects on California black oak (Miller and others 1980).

Oak regeneration received some attention from Chaparral Program researchers. Acorn storage techniques, germination rates, and planting techniques were studied (Hunter and Van Doren 1982, Plumb 1981, Plumb 1982, Plumb and McDonald 1981). Results suggested that viable scrub oak *(Quercus dumosa)* acorns can be picked 1½ to 2 months before normal drop, but the tip of the pericarp must be removed on these immature acorns to obtain satisfactory germination. Pericarp removal is unnecessary in mature acorns. Cold stratification increased germination percentages for early collections of California black oak *(Q. kelloggii)*, canyon live oak *(Q. chrysolepis)*, and interior live oak *(Q. wislizenii)* (Plumb 1982).

Substantial tree-to-tree differences in germination percentage and rate were found for acorns collected from California black oak and coast live oak *(Q. agrifolia)* mother trees. Average moisture content of acorns at the time of collection ranged from 37 to 66 percent for mother trees of California black oak and from 45 to 65 percent for mother trees of coast live oak. In general, germination was poorer for acorns with higher moisture contents (Hunter and Van Doren 1982).

Continuing Fire Problems

In spite of attempts to prevent fire and manage fuel, wildfire and to some extent large-scale conflagrations will continue in California's chaparral region. This is inevitable due to the climate and flammability of chaparral vegetation. Successful suppression during this century has undoubtedly contributed to fuel buildups that result in large, intense wildfires. Major fires in California have a history that antedates the arrival of Europeans, occurring an average of once every 65 years in the coastal area near Santa Barbara and once every 30 to 35 years further inland (Byrne 1979, Byrne and others 1977). Evidence of fossil charcoal and pollen from layered (varved) sediments from the floor of the Santa Barbara Channel discredits the theory that prehistoric wildfires in this area were frequent, low-intensity events. On the contrary, it indicates that conflagrations were common, especially in coastal areas.

In recent decades, interest in chaparral fire has increased due to the effects on people. The population of southern California has grown rapidly. Homes and buildings push the borders of the wildlands. Areas that a few years ago would have caused little concern if threatened by fire now harbor residential communities and isolated homes as well. One objective of the Chaparral Program was to apprise residents in this wildland-urban interface of the fire and watershed problems associated with these areas. Two in-depth reports were addressed to wildland managers, developers, land use planners, zoning agencies, and interested lay public (Radtke 1982, 1983). Both publications discuss the fire-flood-erosion cycle, sound building designs and locations relative to topography, home landscaping for fire and watershed safety, and actions to take when a house is threatened by fire.

An analysis of west coast wildfire hazard and prevention showed that some communities deal with these problems more effectively than others (Lee 1980, 1982). The analysis pressed for studies involving a cross-section of California, Oregon, and Washington counties. These studies would examine previous exposure to wildfire, the number of organizations in each county dedicated to fire hazard and prevention, and the extent to which community organizations or operations are responsive to fire issues. An analysis was also urged of existing precautionary measures to wildfire hazard in the wildland-urban interface. An analysis of the relationships of the variables would help to characterize communities that are more likely to adopt successful programs for managing interface fire hazards. The findings would give federal and state agencies an improved basis to cooperate more effectively and to allocate limited funds and technical assistance more efficiently.

INFORMATION AND TECHNOLOGY TRANSFER

Information and technology transfer from researchers to users and from one agency or land manager to another required the collection and interpretation of research and management experience. In turn, that information was made available to managers and landowners as an aid in developing their own management policies, objectives, and treatment techniques. The information also served scientists in formulating research analyses, objectives, funding requests, and studies.

Information distribution began immediately after the program was established. The Chaparral Program was given broad exposure through demonstrations, user guides, training and technical sessions, field trips, symposia, extension education, and consulting.

Extension Services

Demonstrations

Demonstrations were conducted primarily at the Laguna-Morena Demonstration Area, east of San Diego. The area includes land owned by several state and federal agencies and private landowners. The Cleveland National Forest is the largest landowner whose personnel were most active in the program. Vegetation treatment demonstrations included mechanical, chemical, biological (goat grazing), and prescribed fire methods. By concentrating on the demonstrations in one area, visitors could compare the results of various vegetation management techniques.

Prescribed fire demonstration participants included private landowners, as well as representatives from the Forest Service, California universities, all levels of State and civic units, and three U.S. Department of Interior agencies—National Park Service, Bureau of Land Management, and Bureau of Indian Affairs.

Training

Training sessions and technical workshops were conducted in vegetation classification, mapping, fuel moisture sampling, prescribed burning, oak management, chaparral management, and fire behavior. Program personnel also participated in training classes planned by cooperating agencies or groups. Some sessions, especially in prescribed burning, included hands-on field experience at local sites as far away as Marana, Arizona.

Field Trips

Field trips effectively exposed managers, cooperators, foreign visitors, and others to current research and management issues. Field trips were made to the Laguna-Morena Demonstration Area, the San Dimas Experimental Forest, or one of the National Forests, usually in conjunction with meetings, training sessions, or symposia. These trips were often conducted jointly with the National Forest System or other agencies such as the Los Angeles County Fire Department. Occasionally, field trips were conducted to apprise the cooperators of current Chaparral Program activities.

Consulting

The program provided consulting services similar to those provided by the University of California Extension. Consultants reviewed research proposals, wildlife management plans, and prescribed burning programs for national forests, national parks, and state parks. They served on several interdisciplinary multiagency teams to aid in developing forest management plans and to deal with special problems such as fire safety in the wildland-urban interface. The program staff presented papers at conferences and symposia supported by other organizations and served as guest lecturers at universities and training sessions. They chose a variety of forums—from Sierra Club meetings to public television—to discuss chaparral management and program goals.

Publications

User guides provide a means of disseminating information to a widespread audience. They serve as a quick and ready reference. The Chaparral Program published or supported the following user guides:

- Measuring moisture content in living chaparral (Countryman and Dean 1979)
- Fire behavior program for hand-held, programmable calculators (Bradshaw 1980, Bradshaw and Dean 1980)
- Vegetation classification system applied to southern California (Paysen and others 1980, Hunter and Paysen 1982)
- Identification and postfire management of California oaks (Plumb and Gomez 1983)
- Burning prescriptions for chaparral (Green 1981)
- Use of goats in managing chaparral (Green and Newell 1982)
- Living more safely in the chaparral-urban interface (Radtke 1982, 1983)
- Managing water-repellent soils (DeBano 1981)
- Wildlife-habitat relationships in chaparral (Loe and Keeney 1985)
- Identification of important southern California shrub species (Conrad 1985).

In addition to these publications, the program sponsored the CHAPS Newsletter. Ten issues of CHAPS went to press, each with a different management theme. The newsletter mailing list grew from 90 to about 550 during its 5-year history. The Agriculture Extension Service at the University of California, San Diego, agreed to continue the newsletter service.

Symposia

Symposia provide opportunities for exchange of ideas, exposure to diverse topics, presentation and critique of research, and a published reference of the proceedings.

The program cosponsored three international symposia and two regional symposia:

- International Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems, August 1-5, 1977, Palo Alto, California (Mooney and Conrad 1977)

Table 1—*Changes in policy and practice concerning chaparral and associated ecosystems during the Chaparral Research and Development Program, 1977-1982*

1977	1982
1. Federal and state agencies concerned with wildlands management express interest in vegetation and fuels management, but make only small-scale applications, with little or no activity in southern California.	1. Most agencies have full-scale training programs and actively use a variety of vegetation and fuels management techniques.
2. California Department of Water Resources has no plans for chaparral management to augment water supplies to the State Water Project.	2. California Department of Water Resources does feasibility study to augment water supplies through chaparral management at Oroville, Thomes-Newville, and Castaic reservoirs; works with California Department of Forestry on statewide watershed analysis for similar management.
3. Most land management agencies lack active prescribed burning programs in California. All brushlands receive limited treatment herbicidally or mechanically. Active management of shrublands is rare due to high costs of alternatives.	3. Agencies become active as instigators and cooperators in statewide chaparral management projects on thousands of acres per year, with prescribed fire the major tool.
4. Bureau of Indian Affairs occasionally takes part in chaparral management projects on extensive land areas in the State.	4. Bureau of Indian Affairs is active in several areas. California Department of Forestry seeks ways to allow Chaparral Management Program on Indian lands within the State's area of fire protection responsibility.
5. Private landowners manage shrubland only where active Range Improvement Associations exist, primarily in Santa Barbara, Kern, and Shasta counties. High costs of mechanical methods and fear of liability from escaped prescribed fires are frequently cited as reasons for inaction by this group.	5. Private landowners respond to California Department of Forestry Chaparral Program in its first year with applications to treat 100,000 acres. Another 176,000 acres are projected for the second year. California Department of Forestry Range Improvement Program, projects treatment of 30,000 to 60,000 acres per year on private lands.
6. Land vegetated by chaparral species are considered worthless brushland by most managers and agencies.	6. Chaparral is viewed as a resource, such as for watershed, wildlife habitat, recreation, livestock grazing, and possible energy production. Agencies require that brushlands be managed for their resource values. Supplements are added to Forest Service manuals recognizing chaparral management.
7. Federal, state, and local agencies and landowners deal with brushlands independently, with little cooperation.	7. Strong cooperative effort prevails among organizations concerned with chaparral management, with many mutually compatible goals and objectives, and sharing of experience and knowledge.
8. Prescribed burning in chaparral is not large scale; therefore, specialized equipment and technology are lacking.	8. Equipment and technology (notably, the flying drip torch, or helitorch) is developed to increase size and safety of burns and decrease cost.
9. General public has little interest in, or knowledge of, prescribed burning.	9. Interest in prescribed burning is evidenced by articles in magazines such as *Arizona Highways*, *Omni*, *American Forests*, and *National Geographic*. Sierra Club and other conservation organizations express support for prescribed burning.
10. Research or management of woodland and riparian zones associated with chaparral is scant.	10. Woodland and riparian vegetation is often recognized and managed as a valuable resource. A California riparian systems symposium is held at Davis, California, in 1981.
11. Few chaparral researchers or managers have the opportunity to learn about similar ecosystems in other Mediterranean-type regions of the world.	11. International symposia in 1977 and 1981 increase awareness of researchers and managers to the international nature of many problems. Information exchange increases with program-sponsored study tour to Spain and France.
12. Homeowners in or adjacent to wildland areas are unaware of or inadequately informed of dangers associated with living in chaparral-urban interface.	12. Homeowner awareness of chaparral-urban interface problems increases, evidenced by neighborhood organizations that deal with watershed and fire hazards. Public demand for information is met by publications on how to deal with these problems.
13. All erosion and sediment movement in chaparral areas is viewed as undesirable. Preventive measures are always desirable.	13. Managers begin to recognize that erosion and fire are natural processes that characterize the commonly steep chaparral watersheds. Fire by prescription that allows limited erosion on a limited area is viewed as a sediment management tool.
14 Managers commonly view all fire as extremely detrimental to wildlife populations.	14. Managers become more aware of wildlife benefits from managed fire in chaparral and associated ecosystems. Managers begin to recognize that the effect on wildlife populations is generally beneficial, though the direct effects on individual organisms may be severe.

• Ecology, Management, and Utilization of California Oaks, June 26-28, 1979, Claremont, California (Plumb 1980a)

• Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems, June 22-27, 1980, Riverside, California (Miller 1980a)

• Dynamics and Management of Mediterranean-Type Ecosystems: An International Symposium, June 22-26, 1981, San Diego, California (Conrad and Oechel 1982)

• Classification and Distribution of California Chaparral Ecosystems, December 28, 1979, Pomona, California.

CONCLUSIONS

Due to information and technology transfer, user attitudes and operations changed significantly during the 5-year Chaparral Research and Development Program *(table 1)*. The program developed, tested, and demonstrated vegetation management alternatives designed to maintain or enhance productivity of chaparral and associated ecosystems. In the interests of information and technology transfer, the program sponsored three international and two regional symposia; prepared user guides relevant to chaparral and associated ecosystems management; communicated with diverse user groups as well as agencies of the federal and state governments; provided extension services through demonstrations, training sessions, field trips, and consulting; and published proceedings of several symposia and reports on matters of chaparral management.

The changes affected by the program and its cooperators were timely. Interest in chaparral management was high and communication among managers and researchers was needed. Timing, skilled leadership, well-focused research, and participation of cooperators helped the program to achieve its goals.

REFERENCES

Alten, Gary Ray. **Postfire avian community ecology.** Pomona, CA: California State Polytechnic University; 1981. 50 p. Dissertation.

Axelrod, M. C.; Coyne, P. I.; Bingham, G. E. and others. **Canopy analysis of pollutant injured ponderosa pine in the San Bernardino National Forest.** In: Miller, Paul R., tech. coord. Proceedings of the international symposium on effects of air pollutants on Mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980: 227.

Bayless, Charles B. **Microhabitat in a chaparral rodent community.** Pomona, CA: California State Polytechnic University; 1980. 65 p. Dissertation.

Bentley, Jay R.; Estes, Kenneth M. **Control of brush regrowth with herbicides on pine plantations in northern California.** Res. Paper PSW-134. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1978. 13 p.

Bradshaw, Roger L. **The TI-59 fire behavior print program: a user's guide.** Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980. 15 p.

Bradshaw, Roger L.; Dean, William A. **Adding print capability to your TI-59 fire behavior CROM.** Fire Manage. Notes 41(4):7-8; 1980 Fall.

Brown, William M., III; Taylor, Brent D. **Inland control structures.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains and shoreline. Part D, Special inland studies. EQL Rep. 17-D. Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1982: 1-26.

Brownlie, William R.; Taylor, Brent D. **Coastal sediment delivery by major rivers in southern California.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains, and shoreline. Part C. EQL Rep. 17-C. Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1981: 1-314.

Bungarz, Denny. **Use of the helitorch in prescribed burning on the Mendocino National Forest.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 511-514.

Byrne, Roger. **Fossil charcoal from varved sediments in the Santa Barbara channel: an index of wildfire frequencies in the Los Padres National Forest (735 AD to 1520 AD).** 1979. 69 p. Unpublished draft supplied by author.

Byrne, Roger; Michaelsen, Joel; Soutar, Andrew. **Fossil charcoal as a measure of wildfire frequency in southern California: a preliminary analysis.** In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. Gen. Tech. Rep. WO-3. Washington, DC: Forest Service, U.S. Department of Agriculture; 1977: 367-461.

Conrad, C. Eugene. **Utilization of biomass in Mediterranean-type ecosystems: a summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 193-197.

Conrad, C. Eugene. **A guide to important shrubs of chaparral and associated ecosystems of southern California.** 1985. Unpublished draft supplied by author.

Conrad, C. Eugene; Oechel, Walter C., tech. coords. **Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA.** Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 637 p.

Conrad, C. Eugene; Paysen, Timothy E. **Classification and distribution of California chaparral and associated plant communities.** 1979. Unpublished draft supplied by authors.

Countryman, Clive M.; Bradshaw, Roger L. **Statewide system for sampling fuel moisture in chaparral.** In: Proceedings of the 6th conference on fire and forest meteorology; 1980 April 22-24; Seattle, WA: Soc. of American Foresters and American Meteorological Soc.; 1980: 83-87.

Countryman, Clive M.; Dean, William A. **Measuring moisture content in living chaparral: a field user's manual.** Gen. Tech. Rep. PSW-36. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1979. 27 p.

DeBano, Leonard F. **Water repellent soils: a state-of-the-art.** Gen Tech. Rep. PSW-46. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1981. 21 p.

DeBano, L. F.; Conrad, C. Eugene. **Nutrients lost in debris and runoff water from a burned chaparral watershed.** In: Water Resources Council; Proceedings of the 3rd federal interagency sedimentation conference; 1976 March 22-25; Denver, CO: Sedimentation Committee, Water Resources Council; 1976: 3-13 to 3-27.

DeBano, L. F.; Conrad, C. Eugene. **The effect of fire on nutrients in a chaparral ecosystem.** Ecol. Soc. Am. Ecol. 59(3):489-497; 1977.

DeBano, L. F.; Dunn, Paul H. **Soil and nutrient cycling in Mediterranean-type ecosystems: a summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1979: 358-364.

Dougherty, Ron; Riggan, Philip J. **Operational use of prescribed fire in southern California Chaparral.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 502-510.

Dunn, Paul H. **Nutrient-microbial considerations in oak management.** In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980: 149-160.

Dunn, Paul H.; DeBano, Leonard F. **Fire's effects on biological and chemical properties of chaparral soils.** In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. Gen. Tech. Rep. WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977: 75-84.

Dunn, Paul H.; Poth, Mark. **Nitrogen replacement after fire in chaparral.** In: Gordon, J. C.; Wheeler, C. T.; Terry, D. A. Symbiotic nitrogen fixation in the management of temperate forests; 1979 April 2-5; Oregon State University, Corvallis, OR: Oregon State University Press; 1979: 287-293.

Dunn, Paul H.; Reynolds, Don. **The influence of chaparral soil series and chaparral plant series on filamentous fungal communities in California.** 1979. Unpublished draft supplied by authors.

Dunn, Paul H.; Wells, Wade G., II; Dickey, Juliana; Wohlgemuth, Peter. **Role of fungi in postfire stabilization of chaparral ash beds.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 378-381.

Duriscoe, Dan M.; Wells, W. G., II. **Effects of fire on certain physical properties of selected chaparral soils.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 594-595.

Dutton, Debbie. **Resources partitioning and seasonal variation in an old, north slope chaparral avian community.** Pomona, CA: California State Polytechnic University; 1981. 60 p. Dissertation.

Fall, Edward W. **Regional geological history.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains, and shoreline. Part A. EQL Rep. 17-A. Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1981: 1-33.

Force, Don C. **Ecology of insects in California chaparral.** 1979. Unpublished draft supplied by author.

Force, Don C. **Postburn insect fauna in southern California chaparral.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; Forest Service, U.S. Department of Agriculture; 1982: 234-240.

Green, Lisle R. **Fuelbreaks and other fuel modification for wildland fire control.** Agric. Handb. 499. Washington, DC: U.S. Department of Agriculture; 1977a. 79 p.

Green, Lisle R. **Fuel reduction without fire—current technology and ecosystem impact.** In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. Gen. Tech. Rep. WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977b: 163-171.

Green, Lisle R. **Fuelbreak and other fuel modifications for wildland fire and fuelbreaks.** In: Proceedings of the 30th annual California weed conference; 1978 January 16-18; Monterey, CA. 1978: 92-98.

Green, Lisle R. **Prescribed burning in California oak management.** In: Plumb, Timothy R., tech. coord. Proceedings of the symposium of the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S Department of Agriculture; 1980: 136-142.

Green, Lisle R. **Burning by prescription in chaparral.** Gen. Tech. Rep. PSW-51. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1981. 36 p.

Green, Lisle R. **Prescribed burning in the California Mediterranean ecosystem.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 464-471.

Green, Lisle R.; Hughes, Catherine L.; Graves, Walter L. **Goat control of brush regrowth on southern California fuelbreaks.** In: Hyder, Donald N., ed. Proceedings of the 1st international rangeland congress; 1978 August 14-18; Denver, CO: Soc. Range Manage.; 1978: 451-455.

Green, Lisle R.; Newell, Leonard A. **Using goats to control brush regrowth on fuelbreaks.** Gen. Tech. Rep. PSW-59. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 13 p.

Hastings, S. J.; Oechel, W. C. **Photosynthesis and water relations of mature and resprout chaparral vegetation.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 602-603.

Hield, Henry; Plumb, Timothy R.; Hemstreet, Stuart. **Plant growth regulator influences on chaparral and native grasses.** In: Proceedings of the third symposium on environmental concerns in right-of-way; 1982 February 15-18; State College, MS: Mississippi State University; 1984: 389-401.

Hunter, Serena C. **Chaparral fires: are they inevitable?** Am. For. 87(9):24-27, 44-45; 1981 September.

Hunter, Serena C. **Perspectives on managing Mediterranean-type ecosystems: a summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982a: 64-68.

Hunter, Serena C.; Paysen, Timothy E. **A user's guide to a vegetation classification system for use in California.** 1982. Unpublished draft supplied by authors.

Hunter, Serena C.; Philpot, Charles W. **Fire behavior and management in Mediterranean-type ecosystems: a summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 520-522.

Hunter, Serena C.; Van Doren, Robert. **Variation in acorn and seedling characteristics of two California oaks.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San

Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 606.

James, R. L.; Cobb, F. W., Jr.; Miller, P. R.; Parmeter, J. R., Jr. **Effects of oxidant air pollution on susceptibility of pine roots to *Fomes annosus*.** Phytopathology 70(6):560-563; 1980.

Kolker, Oded C. **Inland artificial sediment movements.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains and shoreline. Part D, Special inland studies. EQL Rep. 17-D. Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1982: 27-49.

Lawrence, W. L., Jr.; Oechel, W. C. **Photosynthetic production of perennial species in the Mediterranean zone of central Chile.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 615.

Lee, Robert G. **Alternative institutional arrangements for reducing fire hazards on the residential wildland interface—a problem analysis and study plan.** 1980. 66 p. Unpublished draft.

Lee, Robert G. **Residential wildland interface fire hazards, protection, and precautionary adjustments in three fire-prone counties.** 1982. 39 p. Unpublished draft supplied by author.

Loe, Steve A.; Keeney, Thomas W. **California wildlife and their habitats: southern California.** 1985. Unpublished draft supplied by authors.

McCreight, Richard W. **Microwave ovens for drying live wildland fuels: an assessment.** Res. Note PSW-349. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1981. 5 p.

Miller, Paul R., tech. coord. **Proceedings of the symposium on effects of air pollutants on Mediterranean and temperate forest ecosystems; 1980 June 22-27; Riverside, CA.** Gen. Tech. Rep. PSW-43. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980a: 256 p.

Miller, Paul R. **Oxidant dose—canopy response subsystem.** In: Taylor, O. C., ed. Photochemical oxidant air pollution effects on a mixed conifer forest ecosystem—final report. EPA-600/3-80-002. Corvallis, OR: Environmental Protection Agency. 1980b: 38-64.

Miller, Paul R. **Air pollution and forests.** In: Davis, Richard, ed. Encyclopedia of American forest and conservation history. Santa Cruz, CA. Forest History Society. 1983a: 6-8.

Miller, Paul R. **Ozone sensitivity of selected western conifers.** Plant Dis. 67:1113-1115; 1983b.

Miller, Paul R.; Elderman, Michael J., eds. **Photochemical oxidant air pollutant effects on a mixed conifer forest ecosystem—a progress report.** EPA Ecological Res. Series 600/3-77-104. Corvallis, OR: Environmental Protection Agency; 1977. 338 p.

Miller, P. R.; Kickert, Ronald N. **Terrestrial ecosystem impacts by gaseous air pollutants.** In: Legge, Allan H.; Krupa, Sagar V., eds. Proceedings of the international conference on air pollutants and their effects on the terrestrial ecosystem; 1980 May 10-17; Banff, Alberta, Canada. New York: John Wiley & Sons, Inc.; 1985: in press.

Miller, Paul R.; Longbotham, G. J.; Van Doren, R. E.; Thomas, M. A. **Effect of chronic oxidant air pollution exposure on California black oak in the San Bernardino Mountains.** In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980: 220-229.

Miller, P. R.; Pitts, J. N., Jr.; Winer, A. M. **Factors in summer ozone production in the San Francisco air basin.** Science 203:81-82; 1979.

Miller, P. R.; Quick, T. C.; Vincent, P. L.; Van Doren, R. E.; Thomas, M. A. **Relationships of cumulative transpiration and oxidant dose to foliage injury development of ponderosa and Jeffrey pines.** In: Proceedings of 70th annual meeting, American Phytopathological Society. St. Paul, MN: 1978: 153 p.

Miller, Paul R.; Taylor, O. Clifton; Wilhour, R. G. **Oxidant air pollution effects on a western coniferous forest ecosystem.** EPA 600/D-82-276. Corvallis, OR: Environmental Protection Agency; 1982. 10 p.

Miller, Paul R.; Van Doren, Robert. **Ponderosa and Jeffrey pine foliage retention indicates ozone dose response.** In: Conrad, C. Eugene; Oechel, Walter C. tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 621.

Miller, P. R.; White, M. **Ecosystems.** In: National Research Council Committee on Medical and Biologic. Effects of Environmental Pollutants. Ozone and other photochemical oxidants. Washington, DC: National Academy of Sciences. 1977: 586-642.

Mishler, Brent Drennen. **Mosses of the chaparral: the systematics and ecology of the class Musci in the San Dimas Experimental Forest, California.** Pomona, CA: California State Polytechnic University; 1978. 170 p. Dissertation.

Mooney, Harold E.; Conrad, C. Eugene. **Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems, 1977 Aug. 1-5; Palo Alto, CA.** Gen. Tech. Rep. WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977. 498 p.

National Academy of Sciences. **Selecting a methodology for delineating mudslide hazard areas for the National Flood Insurance Program.** Washington, DC: National Academy Press; 1982. 35 p.

Nord, Eamor C.; Green, Lisle R. **Low-volume and slow-burning vegetation for planting on clearings in California chaparral.** Res. Paper PSW-124. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1977. 41 p.

Oechel, W. C. **Carbon balance studies in chaparral shrubs: implications for biomass production.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 158-165.

Oechel, W. C.; Hastings, S. J. **The effects of periodic fire on photosynthesis in chaparral resprouts.** In: Kruger, F. J., ed. The role of nutrients. Ecological Studies Vol. 43. New York: Springer-Verlag; 1983: 274-285.

Oechel, W. C.; Lawrence, W. **Energy utilization and carbon metabolism in Mediterranean scrub vegetation of Chile and California. I. Methods: a transportable cuvette field photosynthesis and data acquisition system and representative results for *Ceanothus greggii*.** Oecologia 39:321-335; 1979.

Oechel, W. C.; Lowell, W.; Jarrell, W. **Nutrient and environmental controls on carbon flux in Mediterranean shrubs from California.** In: Margaris, N. S.; Mooney, Harold A., eds. Components of productivity of Mediterranean-climate regions, basic and applied aspects. The Hague, Netherlands: Junk Publishers; 1981: 51-59.

Oechel, W. C.; Mustafa, J. **Energy utilization and carbon metabolism in Mediterranean scrub vegetation of Chile and California. I. The relationship between photosynthesis and cover in chaparral evergreen shrubs.** Oecologia 41:305-315; 1979.

Paysen, Timothy E. **Inventory and distribution records of oaks in California.** In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980: 67-74.

Paysen, Timothy E. **Vegetation classification—California.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 75-80.

Paysen, Timothy E. **Classification and mapping: fundamental differences.** 1983. Unpublished draft supplied by author.

Paysen, Timothy E.; Derby, J. A.; Black, Hugh, Jr. [and others]. **A vegetation classification system applied to southern California.** Gen. Tech. Rep. PSW-45. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980. 33 p.

Paysen, Timothy E.; Derby, Jeanine A.; Conrad, C. Eugene. **A vegetation classification system for use in California: its conceptual basis.** Gen. Tech. Rep. PSW-63. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 14 p.

Philpot, C. W. **Fire dynamics in chaparral.** In: Koch, David L., ed. Cal-Neva wildlife transaction 1979; 1979 February 3; Long Beach, CA. Western Section of Wildlife Society and Cal-Neva Chapter of American Fisheries Society; 1979: 102-103.

Philpot, Charles W. **Vegetative features as determinants of fire frequency and intensity.** In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. Gen. Tech. Rep. WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1980: 202-215.

Plumb, Timothy R., tech. coord. **Proceedings of the symposium on the ecology, management, and utilization of California oaks.** 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980a. 368 p.

Plumb, Timothy R. **Response of oaks to fire.** In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980b: 202-215.

Plumb, Timothy R. **Collecting, storing, and germinating acorns of southwestern oaks.** Gen. Tech. Rep. NC-26. St. Paul, MN: North Central Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 1981. 10 p.

Plumb, Timothy R. **Factors affecting germination of southern California oaks.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 625.

Plumb, Timothy R.; Gomez, Anthony P. **Five southern California oaks: identification and postfire management.** Gen. Tech. Rep. PSW-71. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 56 p.

Plumb, Timothy R.; Goodin, J. R. **Control of California scrub oak with soil-applied chemicals.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 626.

Plumb, Timothy R.; Hield, Henry; Hemstreet, Stuart. **Plant growth regulator influences on chaparral and native grasses.** In: Proceedings of the third symposium on environmental concerns in right-of-way; 1982 February 15-18; San Diego, CA. Unpublished manuscript provided by authors.

Plumb, Timothy R.; McDonald, Philip M. **Oak management in California.** Gen. Tech. Rep. PSW-54. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1981. 11 p.

Plumb, Timothy R.; Norris, L. A.; Montgomery, M. L. **Persistence of 2,4,5-T in chaparral soil and vegetation.** Bull. Environ. Contam. Toxicol. 17:1-8; 1977.

Poth, Mark. **Legume dinitrogen fixation in chaparral ecosystems.** Fullerton, CA: California State University; 1980. 17 p. Dissertation.

Poth, Mark. **Biological dinitrogen fixation in chaparral.** Conrad, C. Eugene; Oechel, Walter C., tech. coords. In: Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 285-290.

Poth, Mark; Dunn, Paul H. **Legume dinitrogen fixation in chaparral ecosystems.** 1982. Unpublished draft supplied by authors.

Quinn, Ronald D. **Effects of fire on small mammals in the chaparral.** In: Koch, David L., ed. Cal-Neva wildlife transaction 1979; 1979 February 3; Long Beach, CA. Western Section of Wildlife Society and Cal-Neva Chapter of American Fisheries Society; 1979a: 125-133.

Quinn, Ronald D. **Habitat preferences and distribution of mammals in California chaparral.** 1979b. Unpublished draft supplied by author.

Quinn, Ronald D. **Research and management of animals in Mediterranean-type ecosystems: summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 276-278.

Radtke, Klaus. **An urban viewpoint of wildland fire problems.** In: Proceedings of the 1980 national conference of the Society of American Foresters; 1980 October 5-8; Spokane, WA: Society of American Foresters; 1981: 117-122.

Radtke, Klaus W. H. **A homeowner's guide to fire and watershed management at the chaparral/urban interface.** Los Angeles, CA: County of Los Angeles, Department of Forester and Fire Warden; 1982. 33 p.

Radtke, Klaus W. H. **Living more safely at the chaparral/urban interface.** Gen. Tech. Rep. PSW-67. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 51 p.

Radtke, K. R.; Arndt, A. M.; Wakimoto, R. **Fire history of the Santa Monica Mountains.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 438-443.

Riggan, Philip J. **Nitrogen cycling in the chaparral ecosystems.** 1979. Unpublished draft supplied by author.

Riggan, Philip J.; Dunn, Paul H. **Harvesting chaparral biomass for energy—an environmental assessment.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 149-157.

Riggan, Philip J.; Lopez, Ernest N. **Nitrogen relations in a *Quercus dumosa* chaparral community.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 631.

Roby, George A.; Green, Lisle R. **Mechanical methods of chaparral modification.** Agric. Handb. 487. Washington, DC: U.S. Department of Agriculture; 1976. 46 p.

Sidahmed, Ahmed Eltigani. **Selection, intake, and utilization of browse by goats.** Davis, CA: University of California; 1981. 176 p. Dissertation.

Sidahmed, A. E.; Denham, S. C.; Morris, J. G.; Koong, L.; Radosevich, S. **Precision of microhistological estimates of goats' diets from fecal analysis and cell wall passage through the gastrointestinal tract (GIT).** In: Proceedings of the western section, American Society of Animal Science of British Columbia, Vancouver; 1981: 201-204.

Sidahmed, A. E.; Morris, J. G.; Radosevich, S. R.; Koong, Ling J. **Seasonal changes in chaparral composition and intake by Spanish goats.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 258-263.

Simovich, Marie A. **Postfire reptile succession.** In: Koch, David L., ed. Cal-Neva wildlife transaction 1979; 1979 February 3; Long Beach, CA.

Western Section of Wildlife Society and Cal-Neva Chapter of American Fisheries Society; 1979: 104-113.

Stolte, Kenneth W. **The effects of ozone on chaparral plants in the California south coast air basin.** Riverside, CA: University of California; 1982. 100 p. Dissertation.

Taylor, Brent D.; Brownlie, William R. **Inland sediment movement by natural processes.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains, and shoreline, Part B. EQL Report 17-B. Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1982: 1-107.

Tiedemann, Arthur R.; Conrad, C. Eugene; Dietrich, John H. [and others]. **Effects of fire on water—a state-of-knowledge review.** Forest Service national fire effects workshop; 1978 April 10-14; Denver, CO. Gen. Tech. Rep. WO-10. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 28 p.

Wells, Carol G.; Campbell, R. E.; DeBano, Leonard F. [and others]. **Effects of fire on soil—a state-of-knowledge review.** Gen. Tech. Rep. WO-7. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 34 p.

Wells, Wade G., II. **Some effects of brush fires on erosion processes in coastal southern California.** In: Davies, T. R. H.; Pearce, A. J., eds. Erosion and sediment transport in Pacific Rim steeplands. Christchurch, NZ: Int. Assoc. Hydrol. Sci. Publ. 132; 1981, 305-342.

Wells, Wade G., II. **The storms of 1978 and 1980 and their effect on sediment movement in the eastern San Gabriel front.** In: Brooks, Norman H., ed. Proceedings of the symposium on storms, floods, and debris flows in southern California and Arizona, 1978 and 1980; 1980 September 17-18; Pasadena, CA. Rep. CSS-CND-019. Washington, DC: National Academy Press. 1982a: 229-242.

Wells, Wade G., II. **Hydrology of Mediterranean-type ecosystems: a summary and synthesis.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982b: 426-430.

Wells, Wade G., II; Brown, William M., III. **Effects of fire on sedimentation processes.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains and shoreline. Part D, Special inland studies. EQL Report 17-D, Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1982: 83-122.

Wells, Wade G., II; Palmer, Nancy R. **Role of vegetation in sediment processes of southern California.** In: Brooks, Norman H.; Koh, Robert C. Y., eds. Sediment management for southern California mountains, coastal plains and shoreline. Part D, Special inland studies. EQL Report 17-D, Pasadena, CA: Environmental Quality Laboratory, California Institute of Technology; 1982: 51-81.

Winer, A. M.; Fitz, D. R.; Miller, P. R. **Investigation of the role of natural hydrocarbons in photochemical smog formation in California.** Final report Contract A8-135-31. Riverside, CA: California Air Resources Board. Statewide Air Pollution Research Center, University of California; 1981; 124 p.

Wirtz, William O., II. **Vertebrate postfire succession.** In: Mooney, Harold A.; Conrad, C. Eugene, tech. coords. Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems; 1977 August 1-5; Palo Alto, CA. Gen. Tech. Rep. WO-3. Washington, DC: U.S. Department of Agriculture, Forest Service; 1977: 46-57.

Wirtz, William O., II. **Effects of fire on birds in chaparral.** In: Koch, David L., ed. Cal-Neva wildlife transaction 1979; 1979 February 3; Long Beach, CA. Western Section of Wildlife Society and Cal-Neva Chapter of American Fisheries Society; 1979a: 114-124.

Wirtz, William O., II. **Seasonal distribution, habitat utilization, and reproductive phenology of avifauna in southern California chaparral.** 1979b. Unpublished draft supplied by author.

Wirtz, William O., II. **Postfire community structure of birds and rodents in southern California chaparral.** In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems; 1981 June 22-26; San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982: 241-246.

Conrad, C. Eugene; Roby, George A.; Hunter, Serena C. **Chaparral and associated ecosystems management: a 5-year research and development program.** Gen. Tech. Rep. PSW-91. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 15 p.

Chaparral is the dominant vegetation in the wildlands of central and southern California. It has evolved fire adaptions that make it flammable and trigger postfire regeneration, thereby ensuring plant community rejuvenation. To provide a framework for chaparral-related research and accelerate development and demonstration of urgently needed management techniques, the Forest Service, in 1976, began a 5-year research and development program. The Vegetation Management Alternatives for Chaparral and Related Ecosystems Program was organized by the Pacific Southwest Forest and Range Experiment Station and the Pacific Southwest Region, and headquartered at Riverside, California. This report provides a nontechnical overview of the program's 5-year accomplishments. The results should be useful to managers and landowners in planning and managing chaparral and associated ecosystems.

Retrieval Terms: chaparral, wildland management, prescribed fire, research and development, California

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**Pacific Southwest
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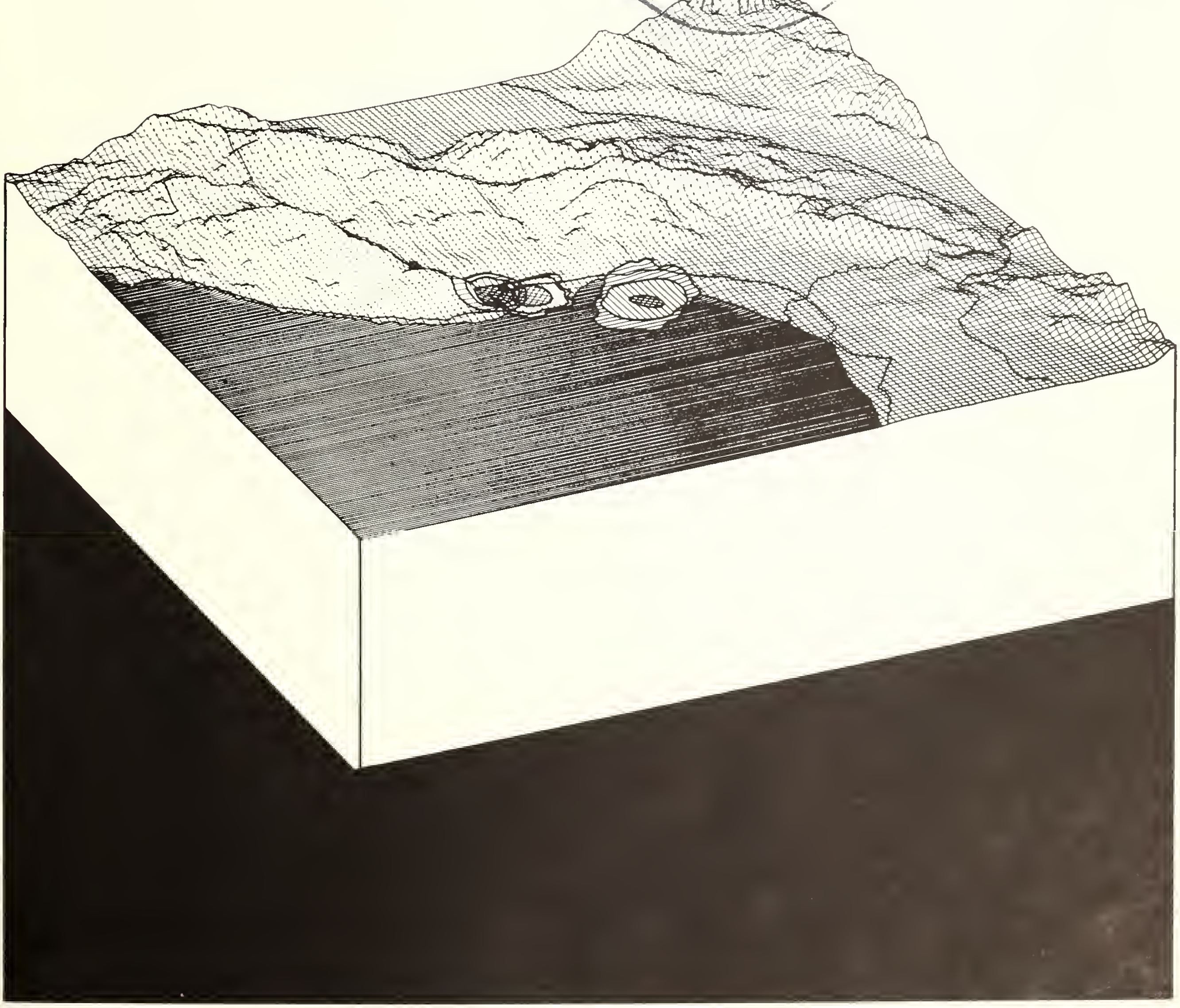
KRISSY: user's guide to modeling three-dimensional wind flow in complex terrain

Michael A. Fosberg   Michael L. Sestak



Fosberg, Michael A.; Sestak, Michael L. **KRISSY: user's guide to modeling three-dimensional wind flow in complex terrain.** Gen. Tech. Rep. PSW-92. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 7 p.

KRISSY is a computer model for generating three-dimensional wind flows in complex terrain from data that were not or perhaps cannot be collected. The model is written in FORTRAN IV. This guide describes data requirements, modeling, and output from an applications viewpoint rather than that of programming or theoretical modeling. KRISSY is designed to minimize meteorological requirements—particularly for upper air data. It also includes a program option that derives vertical motion from a solution of the wave equation with momentum conservation. KRISSY differs from other mass-conserving wind flow models in these features and, therefore, is applicable to a broader range of meteorological conditions.

Retrieval Terms: wind flow models, computer program, meteorology

KRISSY: user's guide to modeling three-dimensional wind flow in complex terrain

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Cover: Computer simulation of long range transport of gypsy moth larvae from a source north of Santa Cruz, California. The three dimensional wind patterns were produced by KRISSY.

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INTRODUCTION

KRISSY[1] is a mass-conserving, three-dimensional wind flow model for complex terrain. The model uses observed data from scattered surface and upper air stations to generate within a rectilinear grid a full three-dimensional wind field depiction at points where measurements were not or perhaps cannot be taken.

This guide to KRISSY is designed to aid the meteorologist or other specialist who requires the generation of three-dimensional wind fields from sparse data. It focuses on data requirements, setup, and output of the model. Neither the mathematical theory nor the computer implementation technique of the model are described. Mathematical or computational techniques are discussed only in terms of constraints and options to the user.

The KRISSY model is written in FORTRAN IV and was tested on an IBM 3090 computer. We attempted to remain as close as possible to standard FORTRAN, but differences in implementation of even standard features sometimes occur between machines. Potential problems in transferring the code to another machine are, therefore, briefly described.

The KRISSY program is available upon request to:

Computer Services Librarian
Pacific Southwest Forest and Range Experiment Station
P.O. Box 245
Berkeley, California 94701

Send a reel of one half-inch computer tape with your request. Specify the progam you want and include any instructions for writing the tape. Blocked tapes of the source codes and data can be written ASCII or EBCDIC.

If you use a computer in the Forest Service's distributed processing system and are connected to the U.S. Department of Agriculture Network (DPNET), you can contact the Station's Statistics and Computer Services at network address SCS:S27A and request instructions for retrieving KRISSY files. Mail to this address may be routed through your regional CEO mailroom.

CHARACTERISTICS OF THE MODEL

The KRISSY model is based on the MATHEW model of Sherman (1978) and modified by Davis and others (1984) to a terrain following a coordinate system. Three improvements have been introduced in the KRISSY model: compressible flow was introduced, the interpolation technique was changed to one more suitable for use with sparse data, and a mountain wave equation was added in the calculation of vertical motion with conservation of momentum. This latter change allows the study of situations such as severe downslope winds in complex terrain. Also, the results can be presented in either terrain following coordinates, where each vertical level is a constant distance above ground level, or in Cartesian coordinates, where each vertical level is a constant distance above mean sea level. The model concepts, equations, and performance characteristics were described in earlier publications by Fosberg (1984, 1985b).

Compressibility was introduced into the solution by allowing the density in the steady-state continuity equation to be space dependent. The initial density variation is determined primarily by the temperature field generated by interpolation from the upper air soundings.

The second modification to the model is in the method of interpolation. Interpolation is used to convert the wind and temperature observations from scattered stations to a first estimate of the three-dimensional grid of the wind components, u, v, and w as well as the temperature and pressure fields. The MATHEW model uses Cressman's (1959) $1/R^2$ interpolator for surface wind data and for upper air observations by locating each upper air station over the nearest surface station. The KRISSY model uses a straight $1/R^2$ interpolation of the data for only the surface stations. KRISSY modifies a technique of Goodin and others (1979, 1980) for the upper air stations. These observations are used directly at the locations of each upper air station but the profiles are used to calculate the vertical derivatives of the variables to be interpolated. These vertical derivatives are then interpolated using the $1/R^2$ method. Profiles are then reconstructed at each grid point for the levels to be modeled to provide the initial data fields. This technique reduced the model data requirements, particularly for upper air observations. Information is significantly greater about the real variation of the meteorology in the vertical derivatives of the soundings than in the spatial variations between soundings.

Both Sherman's MATHEW model and the later derivative ATMOS 1 neglect momentum transport in their set of governing equations. Also, both calculate the vertical motion as a residual variable. Because applications such as severe downslope winds require a model that addresses momentum conservation, a procedure was sought to introduce a mountain wave solution into the ATMOS 1/MATHEW solution. In the most desirable solution, the wave equation would be contained in the expression of vertical motion. Crapper (1959) developed an analytical solution for the three-dimensional mountain wave, but this solution did not meet the specific requirements of model development. Onishi (1969) adapted Crapper's analytical model to a numerical solution that more closely meets the needs for introducing momentum into KRISSY and is essentially the solution in the model.

[1]KRISSY is not an acronym, but named after the senior author's daughter.

The model is intended for mesoscale applications where the distance between adjacent grid points is at least 200 m and can range up to several kilometers. With larger grid scales, the lack of terrain information reduces model effectiveness. For smaller scales, the physics of the model are not appropriate. Also, one constraint occurs on the size of the area to be simulated due to the algorithm that solves the differential equations. The number of grid points in the north-south direction must be a number of the form 2^{k-1} (where k is any positive integer), such as 7, 15, and 31. For the vertical resolution, the amount of detail available in the upper air soundings will largely determine how many levels can be discriminated. This constraint refers primarily to the upper air wind profiles, since the program defaults to the U.S. Standard Atmosphere if no temperature profiles accompany the wind profiles. Placement of the vertical levels to be modeled is arbitrary; they are not required to be evenly spaced. Thus, levels can be closely spaced where detailed information is desired and widely spaced at others. Placement of levels depends on the application. The finest vertical resolution is probably on the order of 30 to 50 meters.

DATA REQUIREMENTS

The KRISSY model uses three types of input data: model control and site description parameters, terrain elevations, and meteorological observations. Guidelines for the number of surface and upper air stations or their locations are described (Fujioka, 1985). In addition, the user should maintain certain meteorological practices to obtain reasonable results. As with any diagnostic model, the greater the input, the better the expected results. These results, of course, must offset the cost of obtaining additional observations. Also, one must consider boundary conditions when choosing stations or siting them. Good results are not expected if all stations are clustered. Also, if the terrain is dissected into discrete sections having potentially different wind patterns, at least one station should represent each section. Moreover, stations should represent the conditions near the dissecting topographic feature. Since this is a three-dimensional model, at least one upper-air wind profile is required. These are general considerations which must be assessed in terms of station placement and their effects on boundary conditions even though no actual model constraints enforce them.

Missing data occurs in any measurement program. However, many models operate only on a complete data set. The procedure by which a model handles missing data is therefore very important. In the case of KRISSY, a specific code indicates missing data for each meteorological variable. The initial fields for each variable are generated within the model by an objective analysis routine. Therefore, when a missing value code is encountered in the data stream for a particular variable, it is simply ignored. The objective analysis is then performed using all good values entered. As with station number, the greater the data, the better the results. The program does not, however, contain any other data validation checks. Quality control of the observations should be made before they are entered in the model, and bad observations should be converted to missing data codes.

Terrain

Basic terrain data consists of an elevations file at each point on the grid for the area where a wind field is to be generated. The elevations can be entered in meters or feet. A numerical code indicates if the data requires conversion to meters. The elevations file should be organized so that the first line starts at the north end of the study area and each line proceeds south. Individual elevations on each line should proceed from west to east. Again, the number of grid points in the north-south direction must be dimensioned as 2^{k-1} (where k is any positive integer).

Each elevation is specified at the intersection of grid lines in some rectilinear (Cartesian) coordinate system. One of the best coordinate systems for this purpose is the Universal Transverse Mercator coordinates (UTM) on U.S. Geological Survey (USGS) maps which specify distances on a 1-meter grid. For this model, it is more convenient to consider UTM's every kilometer (that is, the interval at which they are recorded on maps of 1:24000 scale, as commonly used in regional studies). Each surface and upper-air meteorological station must also be specified in the same coordinate system as the elevation grid. Two parameters are required to define the relation between the standard coordinates and the grid spacing along the north-south and east-west direction in order to record station locations in UTM's or other standard coordinate systems.

A record containing control information is needed with the elevation file. The first parameters in this record define the distance in meters between grid points in the north-south and east-west directions. Next, the origin of the grid—the southwest corner—must be specified in the coordinate system to locate meteorological stations. Then, the elevation is given, which serves as a base to report the results of each upper level in the atmosphere when Cartesian (rather than terrain) coordinates are specified for output. If this level is set to zero, the minimum terrain elevation is automatically selected as the base elevation. Otherwise, it can be set to specific upper levels at round elevations above mean sea level (MSL). Finally, the parameters that describe the relation between the spacing of the elevation grid and the coordinate system must be given. For example, if the coordinate system is based on UTM's in kilometers and the elevation grid spacing is 500 meters, the spacing parameter must be specified as 2.0. Using the same coordinate system and an elevation grid spacing of 2 km, the spacing parameter is 0.5. The spacing parameter converts the absolute coordinate system to array indices. The spacing can be independently specified for the north-south and east-west directions.

Although it may not seem so initially, obtaining a data base of elevations for the study area can be the most difficult task in a large project. For the United States, computer tapes are available from the National Geophysical and Solar-Terrestrial Data Center, National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado (Dietrich and Childs, 1982). The minimum distance between points on these tapes is 30 seconds latitude and longitude. This is not precisely a rectangular grid; but for an area not too large, the error in fixed linear distances is about 1 percent (900 m per 100 km). The largest error, resulting from the difference in distances between the 30 sec latitude and longitude, is compensated by allowing a different grid spacing in the east-west and north-south directions. Digitized maps of finer resolution are available from companies that supply data to mineral exploration firms. These companies will often digitize new areas. Finally, one can always draw a grid over a mapped area and tick off elevations, especially if the study area is relatively small.

Surface Meteorology

The meteorological observations required for each surface station are windspeed, wind direction, and temperature. The elevation (in meters or feet) and location of each station (in any rectilinear coordinate system such as UTM's) are also required. Wind direction is entered in degrees from the north. Windspeed is entered in any common unit: m/s, mi/h, km/hr, or knots. As with other variables, an appropriate conversion code allows the model to accept any input/output units, although m/s units are used internally. Temperature is input in degrees Celsius (C), Fahrenheit (F), or Kelvin (K) and is converted to potential temperature for use within the model. Potential temperatures can also be entered. A special flag on the station observation record indicates if potential or thermodynamic temperature is used. Since the surface and upper air stations are entered together in the same format, another flag indicates if a record is from a surface or an upper air station.

Upper Air Meteorology

Since KRISSY is a three-dimensional model, at least one upper air profile is required to interpolate the wind field. Because the interpolated winds are derived from the vertical derivatives of the observations, at least one sounding should extend to the height of the highest terrain plus the highest level to be modeled. This prevents the usually stronger low-level wind shear from being propagated into the upper levels. As with surface observations, the interpolation is aided by as many soundings as possible, up to the highest level. An actual temperature profile allows calculation of the space-dependent density to account for compressible flow. However, if temperature profiles are not available, the model provides the U.S. Standard Atmosphere as a default. Each upper air observation is placed on a single record in the same format as a surface station observation. However, all records for a single upper air station must be consecutive and ordered from lowest to highest levels. Also, the elevation must be expressed as height above sea level. As for surface stations, one flag indicates potential or thermodynamic temperature and another flag indicates surface or upper air stations.

MODEL RESULTS

Printed Results

The model printout is in five parts: data list, model results, error statistics, vertical cross-section model results, and divergences. The first part is a listing of input data. The second part consists of model results, listing wind direction, windspeed, potential temperature, and vertical motion for all grid points on each desired level. If the output specification for vertical motion is for units of cm/s or ft/min and the output exceeds the three-digit range of the print format, the program automatically defaults to m/s or hundreds of ft/min, as appropriate. The output units for each variable are listed at the head of the model results. Before listing model results, the space averaged profile of the wind components, potential temperature, and stability (Scorer l^2, see Fosberg 1984) are printed if the momentum conservation solution is specified. This listing serves primarily as a diagnostic of internal calculations and verifies any significant impact by stability or momentum transport.

Third, errors statistics are calculated for all of the observations. This listing of the model results, observations, differences, and some simple statistics provide a simple summary of the model's reliability. Fourth, vertical cross sections of the model results of the wind components and the potential temperature are listed to assist the user in analyzing the model results.

The fifth part consists of the three-dimensional divergence printed as an error check on the mass balance calculations. Not all applications need a printout, in which case a user option creates only a file containing the wind field components. The only printed output is a data list and the modeled wind error statistics of the input, the model options, and any run stream error messages.

Mass Storage Files

Three-dimensional data are difficult to assimilate in tabular form. Therefore, they are often converted to contour plots or other graphic forms, or used in other models that require three-dimensional wind field input. For this reason, the elevations, wind components, and potential temperature can be written to a disk or tape storage file for further processing. In the current version, three-dimensional data are written to this file line by line, layer by layer, using a (22F6.1) format.

MODEL RUN SETUP

Three steps must be completed to run the KRISSY model. A data file must be built, the dimensions and several control parameters in the main program must be set, and the appropriate job control code must be produced. This manual deals principally with the first two steps. Since each job control code is designed for specific operating system, only basic data about the model can be supplied. These data must then be tailored to each operating system's unique job control code.

Data Setup

All model input is read from a single input unit. Therefore, from a data management standpoint, it may be convenient to store the data in more than one file and merge these at run time; the data input is described as a single file. In some cases, logical breaks for file management are described. However, the following line-by-line description shows how the data would appear in a single file. Some lines describe a block of data, all of which have the same format as the meteorological data. In these cases, the type and extent of the data required are indicated.

Upper air and surface stations lack separate data formats. Both use the same format and may be interspersed within their section of the file. However, a restriction is placed on how the observations for each upper air station are entered. The observations for each level of an upper air station are coded on separate lines, as if individual surface stations. All lines for an individual sounding must be consecutive and ordered from the lowest to the highest level above ground. This facilitates the calculation of vertical derivatives for the objective analysis routine. If the data are not so organized, the observations for upper air stations will not be correctly recognized and the objective analysis will have no vertical derivatives.

Many input variables can be entered in a number of measurement units. For these variables, a code indicates conversion from recorded units to those used within the model:

Code	Data input conversion
0	No conversion, data in model units
1	No conversion, data in model units
2	Feet to meters
4	Degree F to degree K
5	Degree C to degree K
8	Knots to m/s
9	mi/h to m/s
10	km/h to m/s
	Data output conversion
3	Meters to feet
6	Degree K to degree C
7	Degree K to degree F
11	m/s to knots
12	m/s to mi/h
13	m/s to km/h
14	cm/s to m/s
15	m/s to cm/s
22	m/s to ft/min
23	m/s to 100 ft/min

Table 1—*Allowed unit conversions*

Variable	Input units	Model units
H (agl)[1]	Feet, meters	Meters
ELEV (msl)[2]	Feet, meters	Meters
ZORG (msl)[2]	Feet, meters	Meters
SPD[3,4]	mi/h, km/h knots, m/s	m/s
DIR[3,5]	Degrees	
TMP[5]	Degrees C, F, K	Degrees K
ZPT (msl)[2]	Feet, meters	Meters

[1] Above ground level.
[2] Mean sea level.
[3] Converted to u and v wind components.
[4] Missing code: −9.9.
[5] Missing code: −99.

Table 1 lists the variables, input units, model units, and code for missing data.

The format of each input data line for the model is specified in *table 2*. Some formats are designed for an entire model input segment. Some formats are designed for an entire segment of record input, such as the elevation grid and meteorological data. Each segment of more than one line is described along with the format for each line of that block.

Line 1 represents the input format for the first 8 model elevations. For more than 8 levels, additional data lines are required.

Line 3 represents the input format for the entire elevation grid, though it gives the format for only one record of 10 grid points. A single grid line may require multiple data lines. A series of grid lines certainly requires multiple data lines, since each grid line must start at the beginning of a new data line. The grid of elevations is entered in lines from north to south and from west to east across each line.

Line 6 describes the format for all meteorological, surface, and upper air data. Each surface station is one line in this format. Each level of an upper air observation is a single line in this format. Upper air and surface stations may be intermixed, but all observation lines for an upper air station must be consecutively ordered from the lowest to highest level.

The model accepts input data in any unit commonly used for required observations. Output can be in the same units or converted. Internally, the model expresses all speeds in meters per second, lengths in meters, temperatures in degrees Kelvin, and pressures in Pascal. The conversion codes specified above are used to convert to model units. As noted, the conversions are reversed for output options.

Main Routine

Two changes must be made when setting up a new problem: redimensioning arrays and setting control variable values. Since the program uses variable dimensioning and two- and three-

Table 2—*Input data formats*

Line	Variable	Column	Format	Description
1	H	1-80	(8(5X,F5.0))	Height (m) above ground of upper levels to be modeled, first level must be the surface (0.0)
2	INV	2-3	I2	Conversion code for terrain elevations units
2	JMPRND	11	L1	Indicator, T = MATHEW, F = momentum solution
2	TFAL	13	L1	Indicator, T = terrain following, F = Cartesian coordinates
2	NUPOB	15-16	I2	Number of upper air profiles
2	INZ	18-19	I2	Conversion code for vertical levels and z origin units
2	MSFILE	21	L1	Indicator, T = mass storage files only, F = printed output also
3	ELEV	1-80	(10(2X,F6.1))	Elevations MSL at each grid point
4	DX	9-16	F8.2	Meters between grid points in east-west direction
4	DY	18-25	F8.2	Meters between grid points in north-south direction
4	XORG, YORG	27-48	F10.2,2X F10.2	Location of the southwest corner of the grid, such as UTM
4	ZORG	51-56	F6.2	Base from which upper level heights are calculated, if zero, lowest terrain elevation is used
4	NSUBX, NSUBY	59-73	F6.2,2X F6.2	Conversion factors from data coordinates to array indices[1]
5	HDR	1-80	40A2	Header for printed output describing model run, location, or meteorological data used
6	DIR	1-4	F4.0	Wind direction (degrees)
6	SPD	9-11	F3.1	Windspeed
6	IVOB	13-14	I2	Conversion code for windspeed units[2]
6	TMP	16-19	F4.1	Temperature
6	ITMOB	21-22	I2	Conversion code for temperature units[2]
6	XPT,YPT	34-49	F6.2,5X, F6.2	Location of station in the coordinate system such as UTM's
6	ZPT	54-59	F6.2	Elevation of station above sea level
6	IZOB	61-62	I2	Conversion code for units of station elevation
6	TTYPE	64	L1	T = potential temperature; F = thermodynamic temperature
6	SFC	66	L1	T = surface station; F = upper air station
7	−999	1-4	F4.0	End of data indicator

[1] See "Data Requirements" for description of coordinate system.
[2] See "Model Run Setup" for conversion codes and values.

Table 3—*Main routine variables to be reset*

Routine variable	Function
II	Number of grid points in the east-west direction.
JJ	Number of grid points in the north-south direction; must be in the form 2^{k+1}, where k is any positive integer.
KK	Number of vertical levels to be modeled.
NMOBMX	Maximum number of meteorological observations expected (anything greater than or equal to the total number of meteorological observations in order to reserve array space).
IOUT	Conversion code for units of output of horizontal windspeed. Converts internal m/s of model to desired output units.
IWOUT	Conversion code for units in vertical windspeed output. Converts internal m/s of model to desired output units. If cm/s of ft/min are specified and the results exceed the output format, the model automatically defaults to m/s or hundreds of ft/min.

dimensional arrays, the dimensions in the main routine must be set to the grid size in each new problem. Variables representing these array dimensions *(table 3)* and other options must be initialized in the main routine. The dimensions of the arrays must be initialized in the main routine. The dimensions of the arrays must be changed along with the variables which correspond to each index of the arrays *(table 4)*. The key variables are:

Main arrays	Interpretation
ELEV	Gridded terrain elevation
U	Gridded wind vector in the east-west direction
V	Gridded wind vector in the west-east direction
W	Gridded vertical motion
THETA	Gridded potential temperature
H	Height of compilation levels

Job Control

Three elements are required to produce job control instructions to run the KRISSY model: the FORTRAN input/output unit numbers accessed, the amount of memory required, and total execution time of the job.

All input is from unit 1. Printed output goes to unit 2. The elevation wind components u, v, and w, and potential temperatures are written to unit 4 and stored in a permanent data file.

For example, on the IBM 3090 at the University of California at Los Angeles, a sample run with 15 by 22 grid and 7 levels required about 300 K bytes of memory and was executed in 10 CPU seconds, for a total cost of $1.50. This includes model compilation time.

Table 4—*Main routine arrays requiring redimensioning*

ELEV(II,JJ,KK)	U(II,JJ,KK)	V(II,JJ,KK)
W(II,JJ,KK)	THETA(II,JJ,KK)	P(II,JJ,KK)
DIVG(II,JJ,KK)	WNDSPD(II,JJ,KK)	WNDDIR(II,JJ,KK)
SIGMA(II,JJ,KK)	UPR(II,JJ,KK)	VPR(II,JJ,KK)
DUMMY(II,JJ)		
AM(II)	AN(JJ)	H(KK)
BM(II)	BN(JJ)	UBRR(KK)
CM(II)	CN(JJ)	VBRR(KK)
BMS(II)	BNS(JJ)	THBRR(KK)
		LSQ(KK)
		HO(KK)
DIR(NMOBMX)	SPD(NMOBMX)	TMP(NMOBMX)
XPT(NMOBMX)	YPT(NMOBMX)	ZPT(NMOBMX)
UOB(NMOBMX)	VOB(NMOBMX)	IVOB(NMOBMX)
ITMOB(NMOBMX)	IZOB(NMOBMX)	ZU(NMOBMX)
ZV(NMOBMX)	ZTH(NMOBMX)	TTYPE(NMOBMX)
SFC(NMOBMX)		

PROGRAM STRUCTURE

The KRISSY model program consists of three basic routines: the main program, subroutine WNDMO, and subroutine BLKTRI. The main program sets up the array dimensions and initializes some model parameters. Subroutine WNDMO, the main model subroutine, contains the basic model logic and controls the calculations. The final group of routines are used by WNDMO to perform the detailed model calculations. All arrays pass from the main routine to the subroutines using variable dimensions. Therefore, when the program is set up for a new problem, only the main routine needs to be changed and recompiled. All other routines are compiled once, stored, and linked at run time.

All but one set of subroutines use standard variable dimensioning where the array name and its dimensions are sent as arguments through the subroutine call statement. Subroutine BLKTRI and the routines it calls are an elliptic differential equation solver obtained from the National Center for Atmospheric Research (NCAR), Boulder, Colorado. This routine does not use the call arguments to redimension the arrays, but sets all array dimensions to one. It then uses the array dimension argument to index the array, assuming it was properly dimensioned in the calling routine. This is compatible with all FORTRAN compilers, since they send only the address of the first element of the array to the subroutine. However, few compilers copy the array to a temporary location when a subroutine is called, then copy the results back to the original array when the subroutine exists. If, as in BLKTRI, the dimensions in the subroutine are less than in the calling routine, only part of the array is copied and available for manipulation. Access beyond the dimensions in the subroutine results in exceeding array bounds and creating error messages or the changing of variables not intended. Therefore, in its present format, BLKTRI does not work with this type of compiler. Also, BLKTRI takes into account that even if the initial index of a DO loop is larger than the final index, FORTRAN IV always goes through the loop at least once. In FORTRAN 77, the code within a loop is executed only while the loop control index is less than or equal to the final index. Therefore, the KRISSY model cannot be converted for use on a FORTRAN 77 compiler without major revision of the BLKTRI routine.

ERROR MESSAGES

All error messages *(table 5)* are written to the same unit as the printed output. This unit should be specified in the job control stream for output, even if printed output is not required, to isolate any program errors. Error messages signal program faults and briefly describe the causes.

Table 5—*Error messages*

Error message	Cause
WARNING ON KK DIMENSION	The number of vertical levels specified in the main program is less than 4. It warns that the momentum solution cannot be used in this case, but the ATMOS 1 solution can.
KK IS TOO SMALL FOR THE MOMENTUM TRANSPORT SOLUTION	The momentum solution is specified and the vertical level is less than 4. The program halts. No solution is possible with this specification (in WNDMO).
ERROR IN BLKTRI, IERROR = X	BLKTRI returns an error code other than zero. The program is halted. The cause of each error code follows.
IERROR = 1	The east-west dimension (II) is less than 2.
IERROR = 2	The north-south dimension (JJ) is not of the form 2^{k-1}, k being any positive integer.
IERROR = 3	This message should never occur for this use of BLKTRI.
IERROR = 4	BLKTRI failed while computing results which depend on coefficient arrays AN, BN, and CN. Check these arrays.
IERROR = 5	The maximum east-west dimension specified (IDIMY) is less than the actual east-west dimension specified (II).

REFERENCES

Crapper, G. D. **A three-dimensional solution for waves in the lee of mountains.** J. Fluid Mech. (6): 51-76; 1959.

Cressman, G. P. **An operational ohjective analysis system.** Mon. Weather Rev. 87: 367-374; 1959.

Davis, C.G.; Bunker, S.S.; Mutschlecner, J. P. **Atmospheric transport model for complex terrain.** J. Climate Appl. Meteorol. 23(2): 235-238; 1984.

Dietrich, D.L.; Childs, J.E. **Organization and structure of the NOAA/EDIS/NSDC 30-sec average elevation data: final report.** Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 45 p.

Fosberg, M.A. **A diagnostic three-dimensional mass and momentum conserving wind model for complex terrain.** In: Proceedings, third conference on mountain meteorology; 1984 October 16 to 19; Portland, OR. Boston, MA: American Meteorological Society; 1984: 13-16.

Fosberg, M.A. **Modeling regional smoke transport patterns from climatology: an example from fall agricultural burning in the Sacramento Valley.** In: Proceedings, 17th conference on agricultural and forest meteorology; Scottsdale, AZ. Boston, MA: American Meteorology Society; 1985a: 157-160.

Fosberg, M.A. **Modeling smoke plume patterns in drainage flows.** In: Proceedings, eighth conference on fire and forest meteorology; 1985 April 29 to May 2; Detroit, MI. Washington, DC: Society of American Foresters; 1985b: 153-158.

Fujioka, F.M. **Objective methods for fire weather network designs.** In: Proceedings, eighth conference on fire and forest meteorology; 1985 April 29 to May 2; Detroit, MI. Washington, DC: Society of American Foresters; 1985: 216-221.

Goodin, W. R.; McRae, G. J.; Seinfield, J. **A comparison of interpolation methods for sparse data: application to wind concentration fields.** J. Appl. Meteorol. 18: 761-771; 1979.

Goodin, W. R.; McRae, G. J.; Seinfield, J. **An ohjective analysis technique for constructing three-dimensional urban scale wind fields.** J. Appl. Meteorol. 19: 98-108; 1980.

Onishi, Gaishi. **A numerical method for three-dimensional mountain waves.** J. Meteorol. Soc. Jap. 47: 352-359; 1969.

Sherman, C. A. **A mass consistent model for wind fields over complex terrain.** J. Appl. Meteorol. 17: 312-319; 1978.

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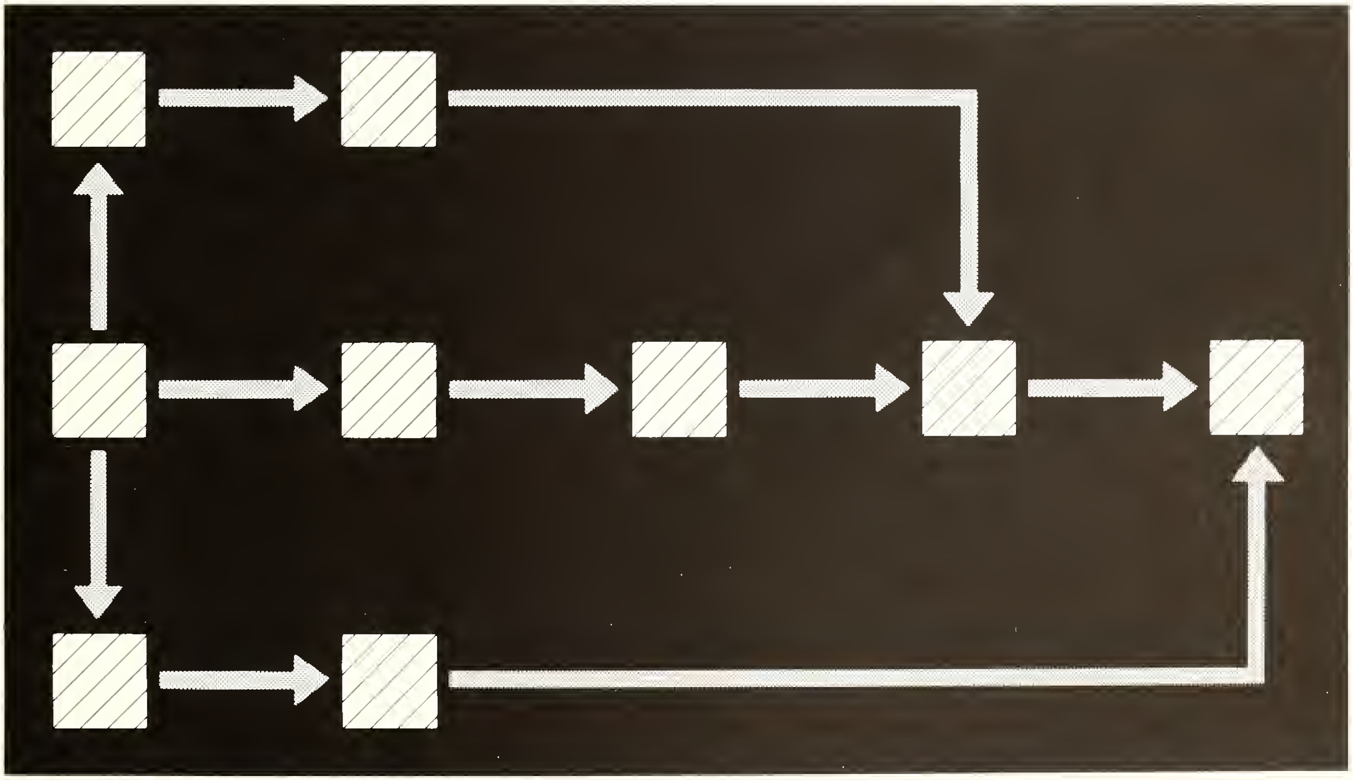
Critical Path Method Applied to Research Project Planning: Fire Economics Evaluation System (FEES)

Earl B. Anderson R. Stanton Hales



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CONTENTS

INTRODUCTION

Network techniques are often used in scheduling projects that contain many interrelated activities. One approach that has been widely used is the critical path method, in which a network diagram depicts precedence among activities. This method also calculates their starting, float, and finishing times to identify critical activities, and it constructs a time chart to display possible project schedules.

Typically, network techniques have been used in large and complex projects consisting of thousands of activities, such as major construction and engineering projects. In the 1950's, a critical path technique called PERT (program evaluation and review technique) was developed by the U.S. Navy for managing the Fleet Ballistic Missile (Polaris) submarine project. CPM (critical path method) was developed by the DuPont Company and Remington Rand Univac for managing plant maintenance and construction work.[1] Differing—for the most part—only in the level of importance that probabilistic concepts have in their use, these mathematical optimization techniques are referred to collectively as PERT-CPM or simply CPM.

Despite the success of PERT-CPM in hardware-oriented programs, its application in resource management problems was initially limited (Davis 1968). But as CPM techniques were modified and designed to operate on the smaller new computer systems, they proved useful in smaller projects such as design and marketing of new products, maintenance and shutdown schedules, and research and development programs. Its potential was apparent for scheduling and monitoring development of the Fire Economics Evaluation System (FEES). This simulation model is being developed by the Forest Service's Pacific Southwest Forest and Range Experiment Station to relate alternative fire management activities to changes in fire management program costs and resource net values (Mills and Bratten 1982).

A survey of more than 30 available computerized CPM systems from more than 20 software suppliers showed that most routines had specific applications and were adapted to specific computer languages and hardware. None were ideally suited nor could be reasonably modified to meet the needs of developing the FEES project. Therefore, a computerized CPM package was developed under a cooperative agreement with the Mathematics Clinic of the Claremont Colleges, Claremont, California.

Since the FEES package was developed, software routines have been created elsewhere and are available for application to other small projects. Therefore, before selecting or developing a CPM system, software operable on the potential users' hardware should be thoroughly searched.

This report describes the critical path method, explains the mathematical concepts behind it, and—using the FEES project as an example—illustrates how a computerized CPM approach can be applied to a resource management or other research project.

CRITICAL PATH METHOD (CPM)

Translating a project's needs into a mathematical system requires an understanding of general stages within which the CPM routines may be applied: planning, scheduling, and controlling (more appropriately termed "monitoring" for research application).

The greatest advantage of CPM is seen at the planning stage. Here the user is required to think through a project logically and with sufficient detail to establish firm, clear project objectives, activities, and specifications. This minimizes the chance of overlooking necessary activities and goals of a project.

In the scheduling stage, CPM provides a realistic and disciplined method for determining how to attain the project objectives and for communicating and documenting the project plans clearly and concisely. A time chart is constructed to show the start and finish times for each activity, and the amount of leeway or "float" corresponding to each activity's relationship to other activities in the project.

The monitoring stage helps to focus management's attention where it is most needed: on the activities that most constrain the schedule. As activities are completed ahead of or behind schedule, CPM will generate new schedules which allow for those activities, and as technical or procedural changes are considered, CPM will indicate the effect these changes would have on the overall schedule.

In the planning and scheduling phases of CPM analysis, three basic steps are carried out:

[1]Commercial enterprises are mentioned only for information. No endorsement by the U.S. Department of Agriculture is implied.

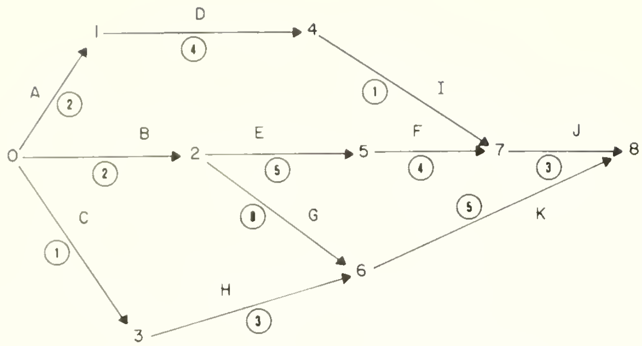

Figure 1—A network or arrow diagram for a project shows the order in which activities are to be carried out. Arrows represent activities (capital letters), arrowheads indicate the order of activities, and nodes or points (numbers) denote beginning and end of activities. Circled numbers are durations of activities in time units.

1. Constructing a network diagram to depict precedence among activities
2. Calculating start, finish, and slack or float times
3. Constructing a time chart to display results of steps 1 and 2.

Constructing a Network Diagram

The first step in CPM analysis is constructing a network, or arrow, diagram that graphically shows the precedence relationships among project activities, i.e., the order in which activities are to be carried out. An arrow represents an activity; arrowheads indicate the order of those activities. A "node" or point denotes the beginning and end of an activity. Each node then is labeled and represents an event, defined to be the completion of all activities leading into that node. In general, integers represent nodes and capital letters represent activities.

A network diagram can be constructed given the following information: a list of all activities involved in a project and, for each activity, a list of its precedences, i.e., the other activities that must be completed (immediately) before beginning that particular activity. For example, the network diagram in *figure 1* was constructed from the following sample information (duration is expressed in time units, such as weeks or months, appropriate for a specific project):

Activity	Precedences	Duration
A	-	2
B	-	2
C	-	1
D	A	4
E	B	5
F	E	4
G	B	8
H	C	3
I	D	1
J	I, F	3
K	G, H	5

Four basic rules guide construction of a network diagram (Taha 1971):

Rule 1—*Each activity is represented by one arrow in the network.*

Rule 2—*"Dummy" activities are created whenever needed to portray the logic of the relationship between activities.* A dummy activity is depicted as a dotted arrow and represents an activity which takes no time and uses no resources. It is needed when a logical relationship between activities cannot otherwise be represented correctly. For example, suppose that in a certain project both activities C and D must precede activity F, and only activity C must precede H:

Activity	Precedences
F	C, D
H	C

To represent this situation correctly, onc must make use of a dummy activity. The incorrect and correct representations of a dummy activity are shown in *fig. 2.*

Rule 3—*No two activities should be identified by the same beginning event and by the same end event.*

Rule 4—*The following questions must be answered as each activity is added to the network, to insure the network correctness:*

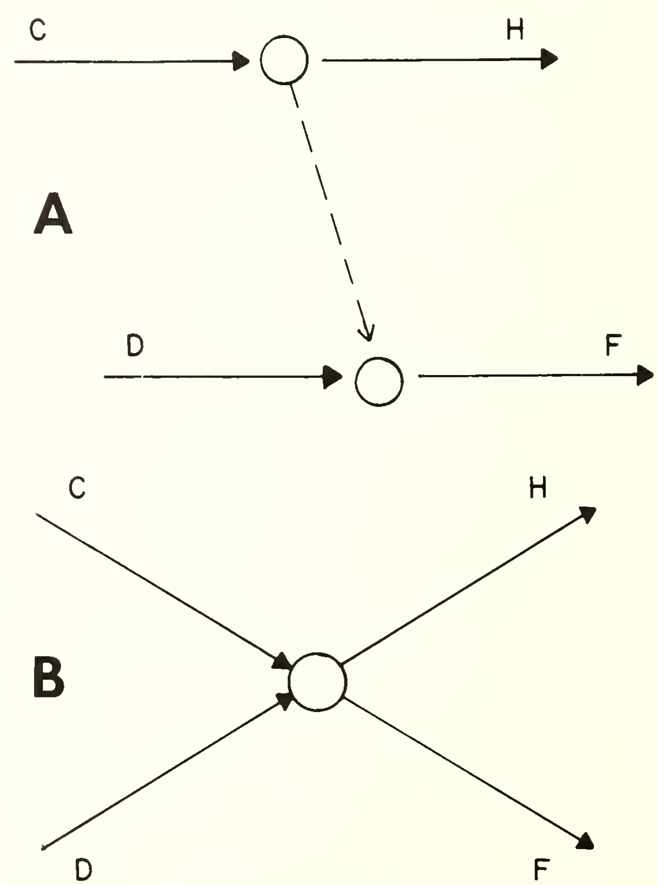

Figure 2—(A) A dummy activity (dashed arrow) correctly represents a relationship between activities that cannot otherwise be logically depicted: activities C and D must both precede F, and only activity C must precede H. (B) Incorrect representation of same relationship.

• *What activities must be completed immediately before this activity can start?*

• *What activities must follow this activity?*

Using these four rules, one can create by hand or by computer the network diagram associated with a project. However, many CPM computer routines do not explicitly create the network diagram. Instead, they store activity duration times as a (vector) list of numbers, and immediate precedences as a Boolean matrix (tables of 0's and 1's) and deal with them algebraically. They are thus able to use the information that a network diagram provides without actually plotting it, and thus only make implicit use of the diagram.

Calculating Start and Finish Times

The second step in CPM analysis is calculating start and finish times for activities. Times are calculated using the precedence relationships shown in the network diagram and their durations. Start and finish times are used to determine float times associated with each activity. Float times are used to identify critical activities.

The calculations involve two phases: the "forward pass" and the "backward pass." The forward pass involves a sequence of calculations beginning at the start of the network and moving forward toward the end of the network. This phase computes the earliest possible finish time. The backward pass involves a sequence of calculations beginning at the end of the network and moving backward toward the start of the network. This phase computes the latest possible finish time.

Each activity of the network diagram *(fig. 1)* can be denoted either by its end nodes (i, j) or activity name (I). Let the earliest time event i, ETE(i), be the earliest possible starting time of the activities emanating from node i, given that the ETE of the start event is 0. For the end event, the ETE is defined as the earliest possible starting time of an activity emanating from the final node, if there were such an activity.

Let D(i, j) denote the duration of activity (i, j). Note that the dummy activities are assigned duration times of 0. Then knowing the ETE(i) for all events preceding event j, one may calculate ETE(j) with

$$ETE(j) = \max [ETE(i) + D(i, j)]$$

where max (the maximum) is taken over all nodes *i* for which (i, j) is a defined activity.

For example, in the project in *fig. 1*, ETE(0) = 0 because it is the start node,

$$ETE(2) = \max [0 + 2] = 2, \; ETE(3) = \max [0 + 1] = 1$$

and

$$ETE(6) = \max [1 + 3, 2 + 8] = 10.$$

The ETE(i) can thus be calculated by beginning at the start of the network and moving toward the end of the network. These calculations, or an equivalent set of calculations, constitute the forward pass.

It is conventional to define the project time as the ETE of the end event. In this case, the project time is the minimum amount of time needed to finish the project. Occasionally, however, the project manager may choose to redefine the project time by lengthening it.

Now let the latest time event i, LTE(i), be the latest possible finish time of all activities coming into event i, given that the LTE of the end event is set equal to the project time. Thus, LTE(i) represents the latest time event i may occur, with the condition that the project time is still met.

Then, knowing the LTE(j) for all events succeeding i, one may calculate LTE(i) by using the following formula:

$$LTE(i) = \min [LTE(j) - D(i, j)]$$

where min (the minimum) is taken over all nodes j for which (i, j) is a defined activity.

For example, in the project in *fig. 1*, LTE(8) = 15 because it is the finish node,

$$LTE(6) = \min [15 - 5] = 10$$

and

$$LTE(7) = \min [15 - 3] = 12.$$

The ETE and LTE values for this network are these:

Event	ETE	LTE
0	0	0
1	2	7
2	2	2
3	1	7
4	6	11
5	7	8
6	10	10
7	11	12
8	15	15

The LTE(i) can thus be calculated by beginning at the end of the network and moving toward the start of the network. These calculations, or an equivalent set of calculations, constitute the backward pass.

Using the results of forward and backward passes, one completes the basic CPM calculations by using early and late times for events to determine the allowable start, finish, and float times for individual activities.

We must define several terms. Let ES(i, j) denote the earliest possible starting time for activity (i, j) and let LS (i, j) denote the latest possible starting time. Let EF (i, j) denote the earliest possible finish time for activity (i, j) and let LF (i, j) denote the latest possible finish times. By convention, ES(i, j) = 0 for any activity (i, j) that has no precedences, and LF(i, j) = project time for any activity (i, j) that has no successors.

Now ES(i, j) = ETE(i) because the activity (i, j) may begin as soon as all of its precedences are completed, i.e., as soon as event i occurs, and LF(i, j) = LTE(j) because the activity (i, j) must finish before event j occurs. The EF(i, j) and LS(i, j) are then easy to calculate:

Table 1 — *Earliest start (ES), earliest finish (EF), latest start (LS), and latest finish (LF), for the sample project* (fig. 1)

Activity	ES	EF	LS	LF
A	0	2	5	7
B	0	2	0	2
C	0	1	6	7
D	2	6	7	11
E	2	7	3	8
F	7	11	8	12
G	2	10	2	10
H	1	4	7	10
I	6	7	11	12
J	11	14	12	15
K	10	15	10	15

$$EF(i, j) = ES(i, j) + D(i, j) = ETE(i) + D(i, j)$$
$$LS(i, j) = LF(i, j) - D(i, j) = LTE(j) - D(i, j)$$

Table 1 shows the ES, EF, LS, LF times for the project in *fig. 1*. Four floats are associated with each activity: total float, free float, safety float, and independent float *(table 2)*.

Total float (TF)—Given a schedule in which each activity is initially slated to start as early as possible, the total float of activity (i, j) is the maximum amount of delay allowed in performing it, possibly delaying succeeding activities as well, but such that the project time will not be affected. That is,

$$TF(i, j) = LTE(j) - ETE(i) - D(i, j) = LS(i, j) - ES(i, j)$$

Free float (FF)—Given a schedule as that above, the free float of activity (i, j) is the maximum amount of delay allowed in the performance of the activity without affecting any succeeding activity. That is,

$$FF(i, j) = ETE(j) - ETE(i) - D(i, j) = ETE(j) - EF(i, j)$$

Safety float (SF)—Given a schedule in which each activity is initially scheduled to start as late as possible, the safety float of activity (i, j) is the maximum amount of "speeding up" allowed in the performance of the activity without affecting any preceding activity. Speeding up does not mean shortenii the activity duration, but rather means beginning work (that activity before it was initially scheduled to begin. That i

$$SF(i, j) = LTE(j) - LTE(i) - D(i, j) = LS(i, j) - LTE(i)$$

In such a schedule, the total float is also the maximum amount of speeding up allowed in the performance of the activity, possibly speeding up preceding activities as well, but such that the project does not start before time 0.

Independent float (IF)—The independent float of activity (i, j) is the amount of slack (if any) available in the scheduling of the activity, assuming that the activities preceding it occur as late as possible and that those succeeding it occur as early as possible. That is,

$$IF(i, j) = \max [0, ETE(j) - LTE(i) - D(i, j)]$$

Calculating float times completes the basic CPM calculations.

For every activity

$$TF \geq FF \geq IF \geq 0$$

and

$$TF \geq SF \geq IF \geq 0.$$

In general, no conclusions can be drawn about the relationship between FF and SF *(table 2)*.

An activity for which total float is minimal, over all activities, is said to be critical. In the normal case, where the project time is chosen as the earliest possible finish time of the project, such an activity has zero total float and no delay or speeding up is allowed in the performance of that activity. All other activities are noncritical. A critical path through the network diagram consists entirely of critical activities. There will always be at least one critical path in the network. Critical activities must be identified because they are the activities for which the greatest effort should be made to stay on schedule; any delay in one of them will delay project completion.

Table 2 — *Total float (TF), free float (FF), safety float (SF), and independent float (IF), for the sample project* (fig. 1)

Activity	TF	FF	SF	IF
A	5	0	5	0
B	0	0	0	0
C	6	0	6	0
D	5	0	0	0
E	1	0	1	0
F	1	0	0	0
G	0	0	0	0
H	6	6	0	0
I	5	4	0	0
J	1	1	0	0
K	0	0	0	0

Constructing a Time Chart

The third step in CPM analysis is constructing a time chart that displays, in a useful manner, start and finish times for each activity and the floats associated with each activity. Also, the chart may show the relationship of each activity to other activities in the project.

Because many of the activities of a project have favorable total float, many time charts could represent a possible project schedule. A schedule is possible in the sense that, if available resources are unlimited, the project could be completed at the scheduled time. The two extremes are the schedule in which every activity starts as early as possible *(fig. 3a)* and the schedule in which every activity starts as late as possible *(fig. 3b)*.

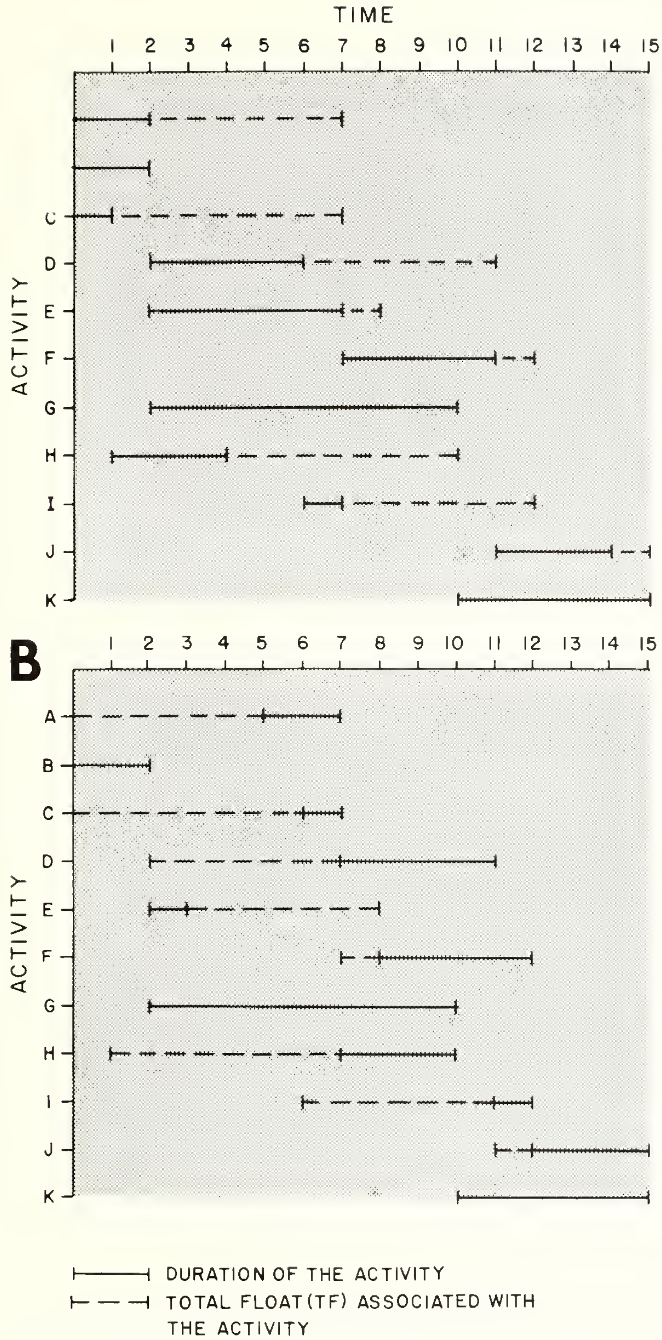

Figure 3—Time charts represent possible project schedules for the sample project *(fig. 1)*. (A) Schedule in which each activity will start as early as possible. (B) Schedule in which each activity will start as late as possible.

METHODS OF SCHEDULE SELECTION

The task of choosing between different possible schedules is ultimately left to the project manager. However, methods of analysis were designed to aid in making this decision. Two of these are resource analysis and cost analysis.

Resource Analysis

Resource analysis refers to a body of techniques used to find a schedule in which the resource allocation of the project is in some sense good, such as being feasible and somewhat constant.

For example, the project in *figure 1* requires the use of two resources, A and B, and each activity of the project requires the following amounts of the resources:

Activity	Units of Resource A	Units of Resource B
A	3	0
B	6	0
C	3	0
D	0	2
E	0	2
F	2	0
G	4	4
H	5	0
I	4	0
J	0	5
K	2	0

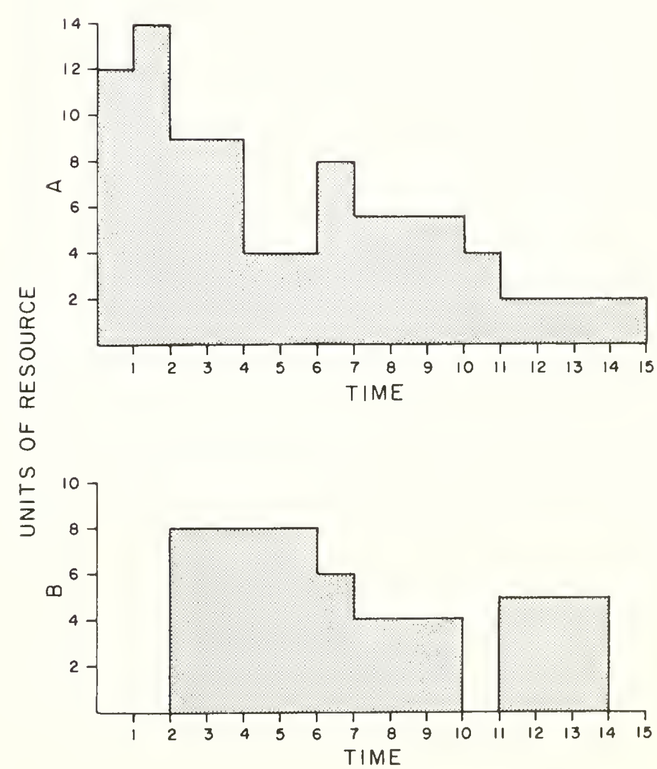

Figure 4—Amounts of resources required to complete the sample project *(fig. 1)* under the early start schedule *(fig. 3a)* fluctuate between time periods.

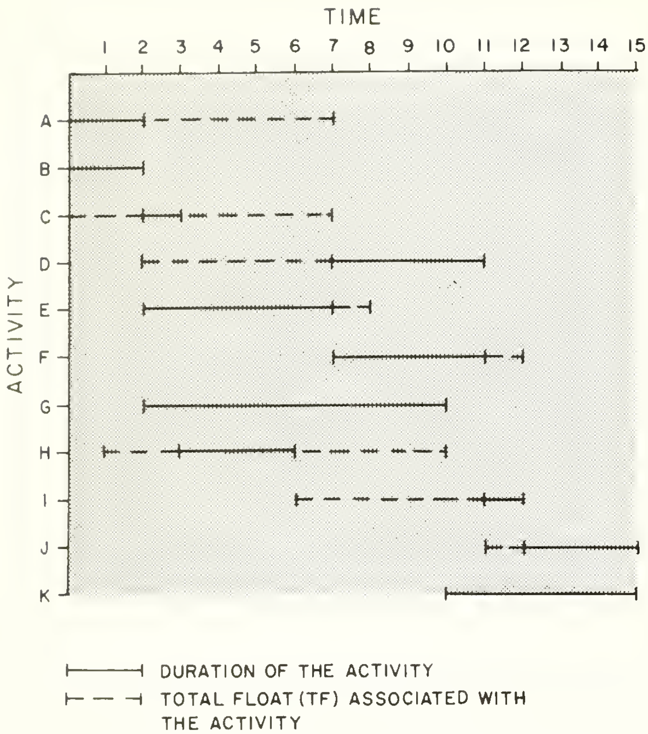

Figure 5—A schedule may not be desirable if it requires large quantities of resources during some time periods.

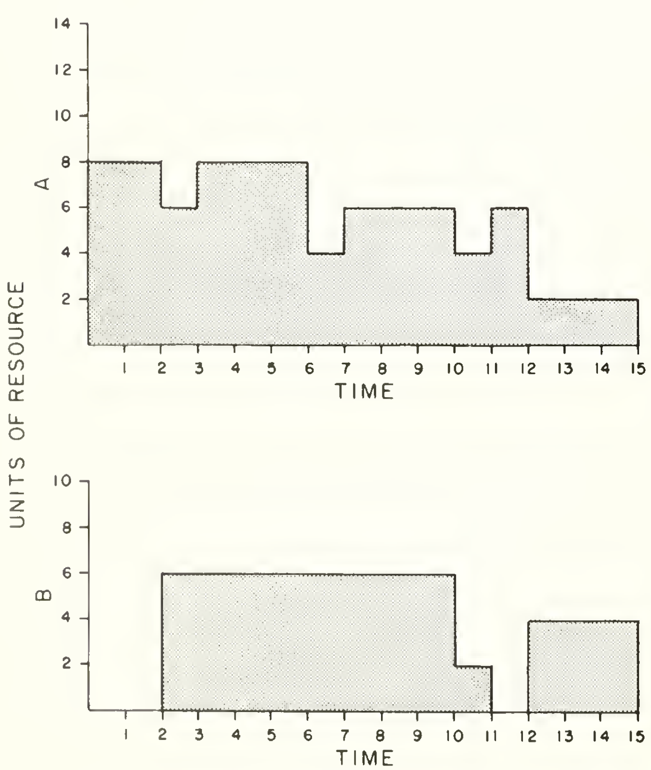

Figure 6—A schedule in which resource requirements are relatively level over time is desired, because overhead costs of obtaining varied amounts of resources will be low.

The total amounts of resources needed for each time period of the project under the early start schedule of *table 1* would be as shown in *figure 4*.

If, at most, 10 units of resource A are available at any given time, then this schedule is of no use. On the other hand, if sufficient resources are available for this schedule, it still may not be desirable because of the large quantities of resources needed during some time periods. A better schedule would be one in which the amounts of resources needed are somewhat level, for then the overhead costs of obtaining varied amounts of resources are low. A better schedule would be that shown in *figure 5*, from which the amounts of resources needed are relatively level over time *(fig. 6)*.

There is no natural or agreed-upon measure of optimality for resource schedules, and no known resource analysis technique will yield the best schedule because of the mathematical complexity involved. However, many heuristic routines find good schedules and are often used. A computer can be used to generate schedules between the early start *(fig. 3a)* and late start schedules *(fig. 3b)* to find a schedule *(fig. 5)* in which resource levels are relatively constant *(fig. 6)*.

Cost Analysis

To further analyze possible schedules for a project, the project manager may use cost analysis. Cost analysis is the study of time-cost tradeoffs and of the corresponding possible schedules for a project, and is aimed at finding a project schedule for which the overall project cost is acceptable. The duration of many activities in a project may be shortened by adding more resources to the performance of the activity. That is, a time-cost tradeoff exists for many activities. Increasing the resources (and therefore the cost) spent on a few activities may decrease the time required to finish the project sooner and thereby reduce the overall cost of the project. Techniques of cost analysis differ, but for some projects none are feasible due to the complexities of time-cost calculations and indirect project costs.

FIRE ECONOMICS EVALUATION SYSTEM

The following broad subjective requirements were established to guide development of the CPM system for the FEES project:

- Ability to display selected activities of a small-to-medium project in a time-phased, event-keyed mode,
- Means of tracking interrelationships between project activities to provide information, such as the total slip in the project schedule resulting from a change in schedule of one activity or the change in the schedule of all activities caused by a change in schedule of one activity,

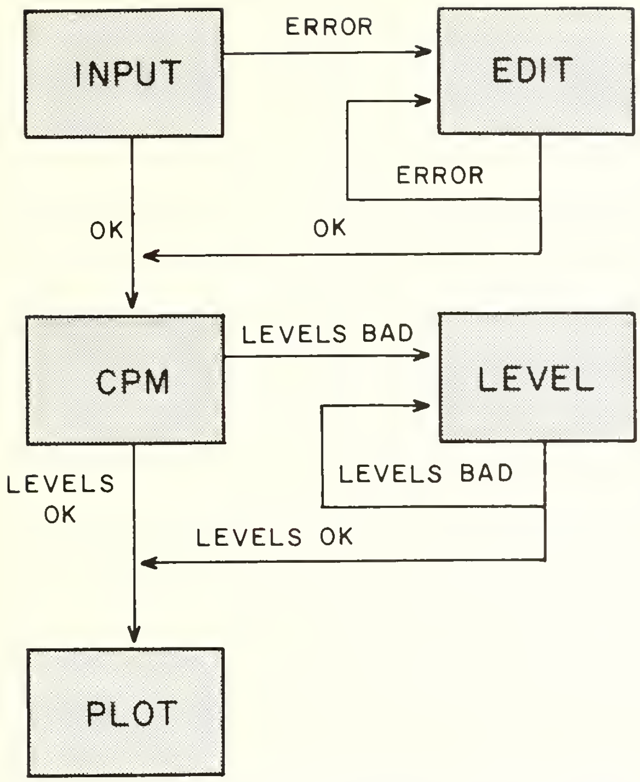

Figure 7—The computer programs (INPUT, EDIT, CPM, LEVEL, PLOT) in the routine developed for the Fire Economics Evaluation System are run in a natural order.

• Features such as operational flexibility and ease of update as a high priority.

The hardware available required that procedures developed had to run on an IBM 370 computer, accessed either through a DATA 100 card system or through a PRIME computer driven from interactive terminals. In reality, the PRIME computer served only as a front-end component to the IBM 370, similar to the DATA 100 card system. A 30-inch CALCOMP Plotter could be accessed through the IBM 370 if plotted graphics output of the schedules generated was desired. The program was also to be written in FORTRAN. These constraints caused some difficulty in developing the CPM computer package. An additional complicating factor was that the package would be developed on the IBM 4341 computer at Pomona College and then transferred to the Forest Service's Forest Fire Laboratory at Riverside for final installation and checkout.

The CPM package that was developed consisted of five major interconnected components: INPUT, EDIT, CPM, LEVEL, and PLOT.

INPUT allows for entering into the computer all data necessary for the CPM analysis of a project;

EDIT allows for changing the data in any way, without unnecessarily repeating unchanged data;

CPM performs all CPM calculations on the data (forward pass, backward pass, calculation of float times, and identification of critical activities), and produces complete information on three different schedules: early start, late start, and a third schedule with effort levels improved by an automatic leveling routine;

LEVEL allows further improvement of effort levels by altering any of the three schedules produced by CPM, one activity at a time;

PLOT graphically produces high quality bar charts of any chosen project schedule with full labeling, float and precedence indicators, and other aids to project management.

These programs are run in their natural order *(fig. 7)*. For a new project, INPUT is used first to create the set of data. CPM may then operate directly on this data set, or EDIT may be used to modify the data before CPM is run. The output of CPM consists of three basic schedules and the labor requirements implied by each. PLOT may then be called to draw the bar chart for any of these schedules, or LEVEL may be used to create modified schedules before PLOT is asked to draw any of them. For projects with data sets that have been created previously, one may begin directly with EDIT or CPM and proceed as above. For projects with data sets that have been processed by CPM, one may begin directly with LEVEL or PLOT.

Comparing Schedules

The CPM package analyzed an example data set describing 47 activities for the FEES project *(table 3)* and initially produced three schedules:

• Early start, in which each activity begins at its earliest possible time;

• Late start, in which each activity begins at its latest possible time; and

• Automatic, in which the computer checks many randomly generated schedules and automatically selects one with the lowest sum of squares of the effort levels. (This is one reasonable measure of the "levelness" of the resource requirements of a schedule. A lower sum of squares indicates a more level schedule; constant effort levels produce a minimum sum of squares.)

The automatic and late schedules were similar in form, and both appeared more level than the early schedule. However, the late schedule appeared to offer the greatest choice of moves to decrease high effort levels (*tables 4, 5—table 5* is on page 12). The LEVEL program was then used to alter the late start schedule, one activity at a time, until a fourth schedule with more balanced levels of effort was reached. This is the optimized schedule *(tables 6, 7)*.

Eleven activities were identified as critical to the FEES project:

CXXX	Develop Initial Attack Module
FXXX	Check Out Initial Attack Module
GXXX	Develop Fire Behavior Module
IIXX	Document Final Probability Model
KKXX	Document Final Fire Behavior Model
MMXX	Document Final Fire Behavior Module
OOXX	Document Final Cost Model
QQXX	Document Final Fire Effects Model
SSXX	Develop Large Fire Gaming Process
TTXX	Conduct Large Fire Gaming Exercises
UUXX	Prepare Final User Documentation

The automatic schedule left 4 activities at their early time, 12 at their latest, and 20 in between. The optimized schedule puts only 3 at early times, leaves 26 at late times, and only 7 in between.

The four schedules were compared on the basis of criteria related to the "levelness" of scientist efforts: sum of squares of individual efforts by month (converted to decimals), the maximum level of effort over the project, the number of scientist levels over 100 percent, the number of scientist levels equal to 0 percent, and the number of scientists who at some time have a level over 100 percent *(table 8)*. Order of preference of the schedules is supported by each criterion. The optimized schedule is best in every one of the criteria compared.

Updating the Routine

Since the original development of the CPM network routine, a series of modifications have been made to simplify data manipulation, reduce running time, and to take advantage of equipment and executive software changes. The program has been used with updated activity information and has prove to be particularly helpful in determining critical activities th require management attention to achieve project objectiv under restricted manpower allocation and reasonable tin limitations.

REFERENCES

Davis, James B. **Why not PERT your next resource management problem?** J. For. 66(5): 405-408; 1968 May.

Mills, Thomas J.; Bratten, Frederick W. **FEES: design of a Fire Economics Evaluation System.** Gen. Tech. Rep. PSW-65. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 26 p.

Taha, Handy A. **Operations research. An introduction.** New York: Macmillan Co.; 1971. p. 357-390.

Table 3—*Forty-seven activities for the FEES project were analyzed with the CPM package*

Activity	Acronym	Duration (time units)	Scientist-months	Scientist initials	Precedences
Develop probability model	AXXX	6	4	FB	——
Collect C29 data base	BXXX	2	2	FB	——
Develop initial attack module	CXXX	6	4	PH	——
Collect arrival time information	DXXX	2	1	PH	——
Collect production rate information	EXXX	2	1	PH	——
Check out initial attack module	FXXX	2	2	PH	BXXX,CXXX, DXXX, EXXX
Develop fire behavior module	GXXX	6	4	LS	——
Develop detection size relationships	HXXX	2	2	LS	——
Collect detection size data	IXXX	2	1	LS	——
Obtain detection size results	JXXX	1	1	LS	AXXX, HXXX, IXXX, GXXX, JXXX
Check out fire behavior module	KXXX	1	1	LS	——
Develop fire effects module	LXXX	4	4	DP	——
Collect fire effects data	MXXX	4	2	DP	LXXX, MXXX
Obtain behavior/effects relationship	NXXX	2	2	DP	——
Develop cost module	OXXX	4	2	AG	——
Obtain per-unit cost data	PXXX	4	1	AG	——
Obtain mopup data	QXXX	4	1	AG	——
Develop cost/activity relationships	RXXX	2	2	AG	OXXX, PXXX, QXXX
Develop resource values	SXXX	4	1	TM	——
Develop net value change relationships	TXXX	4	1	TM	——
Integrate preliminary system	UXXX	2	2	FB	FXXX, KXXX, NXXX, RXXX, SXXX, TXXX
Verify results	VXXX	1	1	FB	UXXX
Collect Z12 data base	WXXX	2	1	FB	BXXX
Collect Z12 arrival information	XXXX	2	1	PH	DXXX
Collect Z12 production rate data	YXXX	2	1	PH	EXXX
Collect Z12 detection size data	ZXXX	2	2	LS	IXXX
Collect Z12 fire effects data	AAXX	4	2	DP	MXXX
Collect Z12 cost data	BBXX	2	1	AG	PXXX
Collect Z12 mopup data	CCXX	2	1	AG	QXXX
Develop Z12 resource values	DDXX	2	1	TM	SXXX
Modify preliminary system	EEXX	4	4	FB	VXXX
Integrate new data base	FFXX	2	1	FB	WXXX, XXXX, YXXX, ZXXX AAXX, BBXX, CCXX, DDXX, EEXX
Verify results	GGXX	1	1	FB	FFXX, TTXX
Document probability model	HHXX	2	2	FB	VXXX
Document final probablity model	IIXX	2	2	FB	GGXX
Document fire behavior model	JJXX	2	2	LS	VXXX
Document final fire behavior	KKXX	2	2	LS	GGXX
Document initial attack module	LLXX	2	2	PH	VXXX
Document final fire behavior model	MMXX	2	2	PH	GGXX
Document cost model	NNXX	2	2	AG	VXXX
Document final cost model	OOXX	2	2	AG	GGXX
Document fire effects model	PPXX	2	2	DP	VXXX
Document final fire effects model	QQXX	2	2	DP	GGXX
Document resource values	RRXX	2	2	TM	GGXX
Develop large fire gaming process	SSXX	6	4	PH	FXXX
Conduct large fire gaming exercises	TTXX	6	6	PH	SSXX
Prepare final user documentation	UUXX	2	2	TM	IIXX, KKXX, MMXX, OOXX, QQXX

Table 4—*Late schedule for FEES project*

Activity[1]	Scientist's initials	Months[2]																								
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
AXXX	FB	S[3]	S	S	D	D	D	D	D	D																
BXXX	FB	S	S	S	S	D	D																			
CXXX	PH	D	D	D	D	D	D																			
DXXX	PH	S	S	S	S	D	D																			
EXXX	PH	S	S	S	S	D	D																			
FXXX	PH							D	D																	
GXXX	LS	S	S	S	S	D	D	D	D	D	D															
HXXX	LS	S	S	S	S	S	S	S	D	D																
IXXX	LS	S	S	S	S	S	S	S	D	D																
JXXX	LS							T	T	T	D															
KXXX	LS								T	T	T	D														
LXXX	DP	S	S	S	S	S	D	D	D	D																
MXXX	DP	S	S	S	S	S	D	D	D	D																
NXXX	DP					T	T	T	T	T	D	D														
OXXX	AG	S	S	S	S	S	D	D	D	D																
PXXX	AG	S	S	S	S	S	D	D	D	D																
QXXX	AG	S	S	S	S	S	D	D	D	D																
RXXX	AG					T	T	T	T	T	D	D														
SXXX	TM	S	S	S	S	S	S	S	D	D	D	D														
TXXX	TM	S	S	S	S	S	S	S	D	D	D	D														
UXXX	FB									T	T	T	D	D												
VXXX	FB											T	T	T	D											
WXXX	FB			T	T	T	T	S	S	S	S	S	S	S	S	S	S	D	D							
XXXX	PH			T	T	T	T	S	S	S	S	S	S	S	S	S	S	D	D							
YXXX	PH			T	T	T	T	S	S	S	S	S	S	S	S	S	S	D	D							
ZXXX	LS			T	T	T	T	T	T	T	S	S	S	S	S	S	S	D	D							
AAXX	DP					T	T	T	T	T	S	S	S	S	S	D	D	D	D							
BBXX	AG					T	T	T	T	T	S	S	S	S	S	S	S	D	D							
CCXX	AG					T	T	T	T	T	S	S	S	S	S	S	S	D	D							
DDXX	TM					T	T	T	T	T	T	T	S	S	S	S	S	D	D							
EEXX	FB												T	T	T	D	D	D	D							
FFXX	FB																T	T	T	D	D					
GGXX	FB																					D				
HHXX	FB												T	T	T	S	S	S	S	S	S	S	S	S	D	D
IIXX	FB																						D	D		
JJXX	LS												T	T	T	S	S	S	S	S	S	S	S	S	D	D
KKXX	LS																						D	D		
LLXX	PH												T	T	T	S	S	S	S	S	S	S	S	S	D	D
MMXX	PH																						D	D		
NNXX	AG												T	T	T	S	S	S	S	S	S	S	S	S	D	D
OOXX	AG																						D	D		
PPXX	DP												T	T	T	S	S	S	S	S	S	S	S	S	D	D
QQXX	DP																						D	D		
RRXX	TM																						S	S	D	D
SSXX	PH									D	D	D	D	D	D											
TTXX	PH															D	D	D	D	D	D					
UUXX	TM																								D	D

[1]See *table 3* for explanation of acronyms.

[2]Letters represent months beginning with July.

[3]S represents the period of safety float in which the activity may be moved up without affecting any preceding activity (and hence occurs only pefore the scheduled period). D represents the scheduled period of performance of an activity. T represents the additional period of total float in which the activity may be moved earlier or later without affecting the overall project time, but possibly affecting activities that precede or follow it. F represents the period of free float, in which the activity may be delayed without affecting any following activity (and hence occurs only after the scheduled period).

Table 6—*Optimized schedule for FEES project*[1]

Activity	Scientist's initials	Months																								
		J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
AXXX	FB	S	S	S	D	D	D	D	D	D																
BXXX	FB	D	D	T	T	T	T																			
CXXX	PH	D	D	D	D	D	D																			
DXXX	PH	S	S	D	D	T	T																			
EXXX	PH	S	S	S	S	D	D																			
FXXX	PH							D	D																	
GXXX	LS	S	S	S	D	D	D	D	D	D	T															
HXXX	LS	S	D	D	F	F	F	T	T	T																
IXXX	LS	D	D	T	T	T	T	T	T	T																
JXXX	LS							T	T	T	D															
KXXX	LS								T	T	T	D														
LXXX	DP	S	D	D	D	D	T	T	T	T																
MXXX	DP	S	S	S	S	S	D	D	D	D																
NXXX	DP					T	T	T	T	T	D	D														
OXXX	AG	S	S	S	S	S	D	D	D	D																
PXXX	AG	S	S	S	S	S	D	D	D	D																
QXXX	AG	S	S	S	S	S	D	D	D	D																
RXXX	AG					T	T	T	T	T	D	D														
SXXX	TM	S	S	S	S	S	S	S	D	D	D	D														
TXXX	TM	S	S	S	S	S	S	S	D	D	D	D														
UXXX	FB								T	T	T	D	D													
VXXX	FB										T	T	T	D												
WXXX	FB			T	T	T	T	S	S	S	D	D	F	F	F	F	T	T	T							
XXXX	PH			T	T	T	T	S	S	S	S	S	S	D	D	F	T	T	T							
YXXX	PH			T	T	T	T	S	S	S	S	D	D	F	F	F	T	T	T							
ZXXX	LS			T	T	T	T	T	T	T	S	S	S	S	S	S	S	D	D							
AAXX	DP					T	T	T	T	T	S	S	S	S	S	D	D	D	D							
BBXX	AG					T	T	T	T	T	S	S	S	S	S	S	S	D	D							
CCXX	AG					T	T	T	T	T	S	S	S	S	S	S	S	D	D							
DDXX	TM					T	T	T	T	T	T	T	S	S	S	S	S	D	D							
EEXX	FB												T	T	T	D	D	D	D							
FFXX	FB																T	T	T	D	D					
GGXX	FB																					D				
HHXX	FB												T	T	T	S	S	S	S	S	S	S	S	S	D	D
IIXX	FB																						D	D		
JJXX	LS												T	T	T	S	S	S	S	S	S	S	S	S	D	D
KKXX	LS																						D	D		
LLXX	PH												T	T	T	S	S	S	S	S	S	S	S	S	D	D
MMXX	PH																						D	D		
NNXX	AG												T	T	T	S	S	S	S	S	S	S	S	S	D	D
OOXX	AG																						D	D		
PPXX	DP												T	T	T	S	S	S	S	S	S	S	S	S	D	D
QQXX	DP																						D	D		
RRXX	TM																						D	D	F	F
SSXX	PH									D	D	D	D	D	D											
TTXX	PH															D	D	D	D	D	D					
UUXX	TM																								D	D

[1]See *table 3* for explanation of terms.

Table 5—*Levels of effort for late schedule for FEES project* (table 4), *by scientist's initials and month*

Month	FB	PH	LS	DP	AG	TM
	Percent per month					
J	0	66	0	0	0	0
A	0	66	0	0	0	0
S	0	66	0	0	0	0
O	66	66	0	0	0	0
N	166	166	66	0	0	0
D	166	166	66	150	100	0
J	66	100	66	150	100	0
F	66	100	216	150	100	50
M	66	66	216	150	100	50
A	0	66	166	100	100	50
M	0	66	100	100	100	50
J	100	66	0	0	0	0
J	100	66	0	0	0	0
A	100	66	0	0	0	0
S	100	100	0	50	0	0
O	100	100	0	50	0	0
N	150	200	100	50	100	50
D	150	200	100	50	100	50
J	50	100	0	0	0	0
F	50	100	0	0	0	0
M	100	0	0	0	0	0
A	100	100	100	100	100	0
M	100	100	100	100	100	0
J	100	100	100	100	100	200
J	100	100	100	100	100	200

Table 7—*Levels of effort for optimized schedule for FEES project* (table 6), *by scientist's initials and month*

Month	FB	PH	LS	DP	AG	TM
	Percent per month					
J	100	66	50	0	0	0
A	100	66	150	100	0	0
S	0	116	100	100	0	0
O	66	116	66	100	0	0
N	66	116	66	100	0	0
D	66	116	66	50	100	0
J	66	100	66	50	100	0
F	66	100	66	50	100	50
M	66	66	66	50	100	50
A	50	66	100	100	100	50
M	50	116	100	100	100	50
J	100	116	0	0	0	0
J	100	116	0	0	0	0
A	100	116	0	0	0	0
S	100	100	0	50	0	0
O	100	100	0	50	0	0
N	100	100	100	50	100	50
D	100	100	100	50	100	50
J	50	100	0	0	0	0
F	50	100	0	0	0	0
M	100	0	0	0	0	0
A	100	100	100	100	100	100
M	100	100	100	100	100	100
J	100	100	100	100	100	100
J	100	100	100	100	100	100

Table 8—*Possible schedules for FEES project, by various measures of "levelness"*

Schedule	Sum of squares	Maximum level	Levels over 100 pct	Levels equal to 0	Scientists over 100 pct
Early	115.93	216	24	66	5
Late	108.01	216	17	59	5
Automatic	94.39	200	15	47	4
Optimized	85.73	150	9	45	2

Anderson, Earl B.; Hales, R. Stanton. **Critical path method applied to research project planning: Fire Economics Evaluation System (FEES).** Gen. Tech. Rep. PSW-93. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 12 p.

The critical path method (CPM) of network analysis (a) depicts precedence among the many activities in a project by a network diagram; (b) identifies critical activities by calculating their starting, finishing, and float times; and (c) displays possible schedules by constructing time charts. CPM was applied to the development of the Forest Service's Fire Economics Evaluation System (FEES)—a simulation model for evaluating fire program options. A computerized CPM package analyzed 47 activities, and produced basic schedules and labor required for each. One program in the package was used to alter a basic schedule to produce one that required less variable levels of labor. The CPM approach can be applied to a variety of resource management and other forestry-related projects.

Retrieval Terms: research planning, CPM, PERT, project scheduling

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Vegetation Classification System for California: user's guide

Serena C. Hunter   Timothy E. Paysen

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CONTENTS

GLOSSARY

Biogeographic: Geographic distribution of an organism in relation to the mechanism or process that caused distribution. For example, disjunct populations of a conifer species on mountain tops may be the result of seed dispersal by animals followed by extreme geomorphic action and climatic shifts (glaciation, then heating and drying).

Broadleaf: Angiosperm; leaf that is not needlelike or scalelike. See *Conifer*.

Canopy: Aggregate tree and shrub crowns forming a layer (often broken) of cover above ground.

Chaparral: Shrubs with sclerophyllous (leathery, waxy skinned) evergreen leaves, generally adapted to Mediterranean-type climate (hot, dry summers; wet winters). Often refers to a conglomerate of vegetation characterized by these shrubs, in the same sense as *forest*. Specific class in the Subformation category of the Classification System.

Codominant: Plant species that shares stand dominance with another species in the overstory canopy or any subordinate layer. See *Vegetation layer*.

Community: Assemblage of plants with a characteristic species composition that occurs under uniform environmental conditions.

Conifer: Cone-bearing tree with evergreen needle or scalelike leaves. Includes the genera *Pinus* (pine), *Calocedrus* (incense-cedar), *Juniperus* (juniper), and *Cupressus* (cypress).

Crown cover: Vertical projection of a tree or shrub crown perimeter to the ground.

Cryptogam: Primitive plant (moss, club moss, lichen, or fern) that lacks true flowers or seeds, and reproduces by spores.

Cushion plant: Forms a low-growing mat of vegetation. Individuals spread at the outer edge, sometimes rooting at nodes or branch tips.

Diameter at breast height (d.b.h.): Diameter of a tree trunk at 4.5 ft (1.37 m) above ground.

Dominant: Plant in a vegetation unit that exerts a controlling influence on the environment by reason of size or numbers. For this publication, group of plants that provides more cover than others in a given layer of vegetation.

Ecotone: Transition zone between two ecological units, most often characterized by vegetation changes.

Forb: Broadleaved herbaceous plant.

Forest: Plant community whose overstory is dominated by tree crowns that (mostly) touch (60 percent crown cover or greater). See *Woodland*.

Graminoid: Grasslike, or relating to grasses. At the Formation level, refers to communities dominated by such plants.

Grass: Herbaceous plant with narrow leaves, of the family Poaceae.

Herbaceous: Herblike, or composed of herbs. Describes plants with soft, usually green leaves and no woody tissue.

Levels of community organization: The resolution and perspective with which associated entities are perceived for the purpose of defining a system and its distinctive components.

Overstory: Taller plants in a vegetation type that form the uppermost canopy layer, providing crown cover of at least 25 percent. Not necessarily a tree layer that humans walk beneath. Though unconventional, overstory can be a grass layer. Here, cover must be at least 2 percent, and the canopy is such only to very small creatures.

Physiognomy: Characteristic structure of vegetation. Physical configuration of a vegetation unit, including its vertical profile and physical structure of plants in a given layer.

Riparian: Generally, a kind of terrestrial ecosystem strongly associated with water. Also designates components of such an ecosystem; plants along the bank of a stream, river, or lake zone are called riparian vegetation. A strict definition is lacking and the term varies. Water above ground is not imperative; for example, sycamores in a swale may be termed riparian vegetation by some classifiers.

Savannah: Generally, grassland containing scattered trees or shrubs.

Sclerophyllous: Leatherlike; thick, hard, resistant to water loss. Describes leaves such as those that characterize chaparral species.

Sedge: Grasslike or rushlike herb of the family Cyperaceae. Distinguishable from grass by its leaves, commonly three-ranked (occur at three sides of the stem). Grass leaves are always two-ranked. Sedge stems are commonly angled, often triangular in cross-section.

Shrub: Short, low-branching woody perennial; sometimes several main stems arise from a central point in the root system. Multiple stems, though not unique to shrubs, are often cited as the defining characteristic. Genetic shortness is the only true criterion. Woody plant species generally accepted as short, or less than 15 ft (5 m).

Succulent: Characteristic of water storage in the cells of stems or leaves, making these parts soft and thick in texture.

Understory: Plants with canopy heights at a lower level than the tallest vegetation layer in a vegetation unit.

Vegetation layer: Vertical level of canopy or plant crowns that can be seen in vegetation. For example, the overhead canopy of trees constitutes a layer; a canopy of brush constitutes another layer. Some vertical layers are easy to distinguish, others blend with one another and are distinguishable only through careful observation.

Woodland: Plant community dominated by tree crowns that for the most part are not touching, forming an open canopy whose overstory crown cover is between 25 and 60 percent. Any kind of tree can form a woodland.

INTRODUCTION

The Vegetation Classification System for California is an unbiased system of defining and naming units of vegetation. The concept was devised by an interagency, interdisciplinary team (Paysen and others 1980, 1982). The system derives its uniqueness from its impartiality to any particular agency or resource discipline, thus providing a long-needed link between diverse classification methodologies. The user must meet only three system rules: to identify accurately (preferably by species) the herbs, shrubs, and trees of the classification site; to understand the concept of a plant community as it relates to the system; and to be able to differentiate these communities on the ground.

The classification system is universal. The system does not require a specific vegetation, zone, or region. The system, for example, has been adopted by the State of Hawaii in its cataloging of tropical vegetation (Buck and Paysen 1984). It is compatible with the Land (Site) Classification System for the United States, developed by the Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture (Driscoll and others 1983), and can be a source of input to the international system for classifying and mapping vegetation (United Nations Educ. Sci. Cult. Org. 1973).

This report explains the design and use of the Vegetation Classification System for California. It offers practical suggestions for simplifying the classification process.

DESIGN OF THE SYSTEM

The user should first understand the basic design of the classification system and what it classifies.

Basic Classification Unit

The basic unit of this classification system is the plant community—a general term for a group of plants that, because of its composition and apparent link to a specific set of environmental conditions, has an observable group identity. Such groups are observable at many levels of community organization. A community organization can be seen within a vegetation layer on a small site (the microflora beneath a dandelion rosette, for one example) or the plant cover on a large region of land (the plant community of the Great Basin region of the United States, for another). Thus, different plant communities are discernible at different levels of organization. *Plant community* as interpreted by the Classification System for California is intermediary to these two extremes *(fig. 1)*.

The term *plant community* as defined by this system is site-specific: that community organization which is observable by standing at one point and viewing the surrounding vegetation layers. The community's character is distinguishable by the unique combination of plant species that compose each vegetation layer. In this report, the term *plant community* as defined above is restricted to the Vegetation Classification System for California. No other interpretation is implied.

Structure of the System

The system has four hierarchical levels. In order of increasing descriptive detail, they are:

- Formation
- Subformation
- Series
- Association

Generally, each Formation is composed of several Subformations; each Subformation, several Series. A plant community can be classified broadly (the Subformation level) or specifically (the Association level). Any level of the hierarchy can be qualified by the *Phase* category to dilineate functional or technical detail *(fig. 2)*. To distinguish classes and levels in the system as it is applied to California, consult the criteria *(tables 1 and 2)*.

Formation is the broadest level in the hierarchy. Classes at the Formation level are defined according to physiognomic criteria, or physical appearance. For example, a plant com-

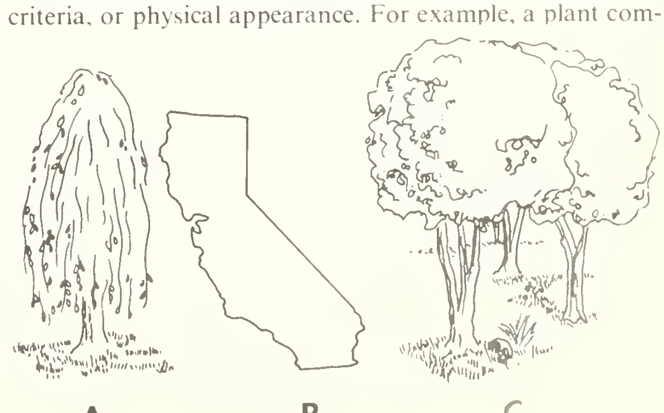

Figure 1—Plant community is a general term applied at any scale or level of precision. For the purposes of this classification system, community levels (A) and (B) are too narrow and too broad, respectively. Community level (C) should be applied.

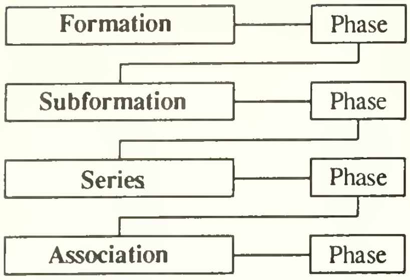

Figure 2—Components of the vegetation classification system. Four hierarchical levels constitute the basic classification categories. The optional Phase category qualifies classes at any level in the hierarchy.

munity with a closed forest structure obviously belongs to the closed forest Formation. Five Formations currently are recognized in California:

- Closed forest
- Woodland
- Shrub (including succulent-stemmed species such as cactus, not normally classified as shrubs)
- Dwarf shrub
- Herbaceous

To determine the Formation for a plant community, consult the key *(fig. 3).*

Subformation is determined by the leaf and stem morphology (structure) of the dominant species in the overstory of a plant community *(fig. 4).* For example, with the closed forest Formation, some plant communities are dominated by needle-leaved trees, others by broadleaved trees; these communities belong to the conifer and broadleaf Subformations, respectively. To identify each Subformation in California, consult the criteria *(table 1).*

Series is determined by the dominant overstory species in a plant community (usually that species which constitutes more than 50 percent of the total overstory crown cover) *(fig. 5).* For example, any community whose dominant overstory species is interior live oak is in the interior live oak Series.

Occasionally, Series reflects the genus of the dominant overstory vegetation when it seems impractical to distinguish species. Several species in the genus *Ceanothus* may be similar in morphology and play essentially the same ecological role, but at different locations. In this case, the benefits gained by identifying individual species may not be worth the added detail in a list of Series names for an area. On the other hand, individual species within a genus (say, *Ceanothus leucodermis*) may be distinct or important enough to be classified in a Series separate from other species within its genus. When in doubt, classify by species, not genus.

A list of suggested Series names published earlier for use in southern California (Paysen and others 1980) has been expanded, and other lists are in progress for other parts of the State. Ideally, a set of standard Series names should be established and periodically updated by committee review. Until

Table 1—*Class identification criteria for the Formation and Subformation levels of the classification system*

	Formation
Closed Forest	Overstory of deciduous or evergreen trees; 15 ft (5 m) tall; crowns mostly interlocking; overstory crown cover 60 percent or greater
Woodland	Overstory of deciduous or evergreen trees; 15 ft (5 m) tall; crowns not touching; overstory crown cover 25 to 60 percent
Shrub	Overstory of shrubs 1½ to 15 ft (0.5 to 5 m) tall at maturity (includes succulent-stemmed species); overstory crown cover 25 percent or greater
Dwarf Shrub	Overstory of shrubs 1½ ft (0.5 m) tall or less at maturity; overstory crown cover 25 percent or greater
Herbaceous	Overstory of grasses, sedges, rushes, forbs, or freshwater plants; herbaceous crown cover 2 percent or greater
	Subformation
Conifer Forest	Overstory dominated by conifers
Broadleaf Forest	Overstory dominated by broadleaf species
Conifer Woodland	Overstory dominated by conifers
Broadleaf Woodland	Overstory dominated by broadleaf species
Succulent Woodland	Overstory dominated by succulent-stemmed or succulent-leaved species
Chaparral	Overstory dominated by plants that have sclerophyllous leaves and woody stems and twigs, such as chamise
Soft Chaparral	Overstory dominated by plants that have softly sclerophyllous leaves and semiwoody stems, such as black sage
Woody Shrub	Overstory dominated by plants that are as Chaparral but have membranous leaves, such as rose spp.
Succulent Shrub	Overstory dominated by plants that have succulent leaves or succulent stems, such as *Opuntia* spp.
Cushion Plant	Overstory dominants are cushion plants, usually of genus *Eriogonum*
Woody Dwarf Shrub	Overstory dominants are nonsucculent dwarf shrubs that are not cushion plants
Succulent Dwarf Shrub	Overstory dominants are succulent dwarf shrubs
Graminoid	Grasses and grasslike plants dominate
Forb	Broadleaved herbaceous plants dominate
Aquatic	Dominants require water for structural support
Cryptogam	Dominated by Cryptogam species

then, users of the system should document exactly which dominant overstory species are included in the Series designations that they use.

An *Association* is a plant community, specified by the dominant overstory species (the Series designation) plus the dominant species in each subordinate layer (midstory, understory) *(fig. 6)*. It is the most specific classification level in the system hierarchy. It reflects the character of all vegetation layers in a plant community. The nomenclature of the Association reflects the dominant species in each layer; for example, pinyon pine/mountain mahogany/phlox, or interior live oak/manzanita/needlegrass. Because of their great number, the Associations found in California cannot be described here; they must be identified by the classifier in the field.

The classifier should strive to discriminate as many layers as necessary to distinguish the unique character of a community. However, caution against extremes. Do not associate a distinct layer with every conceivable height class in a plant community. Doing so will severely limit the value of a classification. Overzealous classification of communities will lead only to a cumbersome data base. The supposedly distinct communities will be difficult to bring into relationship with

Table 2—*Rules of nomenclature for plant Associations and Series*

Classification level and criteria	Nomenclature rule	Example
	Association	
Single-layered	Name by dominant species	Chamise Association, Red fir association
Multilayered	Name by dominant species in each layer; start with the herb layer, if present. Separate layer names with a slash (/).	Jeffrey pine/Sagebrush/Squirreltail grass Association
Multilayered overstory	Name overstory layer by component layers	Bigcone Douglas-fir/Canyon live oak Association
Single species dominant in a layer	Name by dominant species in the layer	Jeffrey pine/Sagebrush Association (overstory dominated by Jeffrey pine; shrub layer dominated by sagebrush)
Mixed species dominant in a layer; proportion of layer cover allocated to each codominant species is within 10 percent of that of each of the other codominants	Name the layer by codominant species separated by hyphens. Where distinct synusia within a layer characterize an Association, treat as codominants.	Jeffrey pine-White fir/Greenleaf manzanita Association; Chamise-Scrub oak Association
Sparse overstory layer; species is ecologically significant but insufficient to define a Formation (10 to 25 percent cover)	Include sparse layer in parentheses	Foxtail fescue-Black mustard (Blue oak) Association; Plicate coldenia/Desert dichoria (Creosote bush) Association
	Series	
Association overstories dominated by a widespread species in an ecological zone or region, or by a species with distinct geographic/environmental affinities	Name by unique Series name for the dominant species	*Ceanothus leucodermis* Series; Red fir Series
Association overstories dominated by a locally important species or species that has ecological homologues in the same genus in adjacent ecological regions, zones, subregions, etc.	Name by genus of the dominant species	Ceanothus Series Manzanita Series Sagebrush Series Cypress Series
Mixed species dominant in overstory; proportion of overstory allocated to each codominant species is within 10 percent of that of the other codominants	Name the Series by codominant species separated by hyphens. Where distinct synusia within the overstory characterize a series, treat as codominants	Jeffrey pine-White fir Series Chamise-Scrub oak Series
Multilayered overstory in Associations	Series name is a combination of component layers	Bigcone Douglas-fir/Canyon live oak Series
	Association and Series	
Local usage	Use common names if available	Foxtail fescue-Black mustard (Blue oak) Association Manzanita Series
Official correspondence outside of administrative region, community documentation, scientific reports, etc.	Use Latin or scientific names	*Festuca megalura-Brassica nigra (Quercus douglasii)* Association *Arctostaphylos* Series

one another, and will be hard to deal with operationally. Avoid this pitfall. Try to recognize simple tree, shrub, and herb layers, then characterize distinctions within each layer. For example, some ecosystems are characterized by plant communities of two or more tree layers, each composed of distinct species that occupy different vertical layers within that plant community *(fig. 7)*. A maximum of four layers should be sufficient to describe Associations in California.

Phase, used in conjunction with the other levels of the hierarchy, accounts for the variability within classes. For example, Phase can specify growth stages such as size class of timber *(fig. 8)*, or condition of vegetation such as percent of dead fuel in chaparral. The Phase category is intentionally adaptable and flexible. This category links the Vegetation Classification System for California with traditional inventories. You can design Phase categories that correspond to commonly accepted timber, wildlife habitat, fuel, and other classification schemes in specific geographic areas. However, Phase schemes must be clearly documented and consistent in any given application *(Appendix)*.

A community can be described by more than one Phase category. The Phases illustrated for the closed forest Formation *(Appendix)*, for example, are based on six d.b.h. size class ranges, two overstory cover ranges, and five understory ranges. A Phase code or index can simplify the field recording process. A community in the closed forest Formation might be dominated by trees that average 15 inches in diameter and provide a crown cover of 90 percent. Understory vegetation

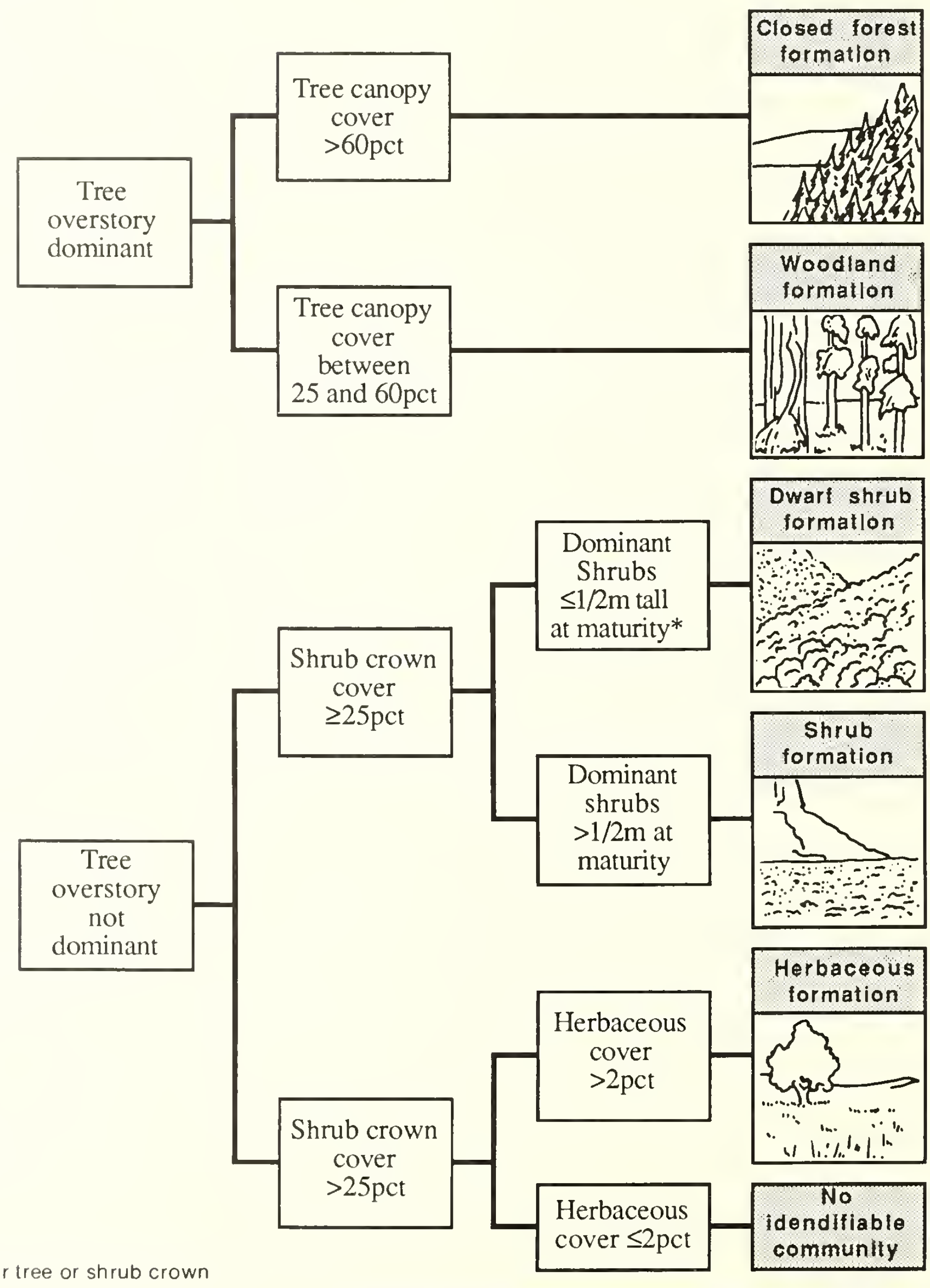

Figure 3—Key to Formations. See *Table 2* for tree or shrub crown cover between 10 and 25 percent.

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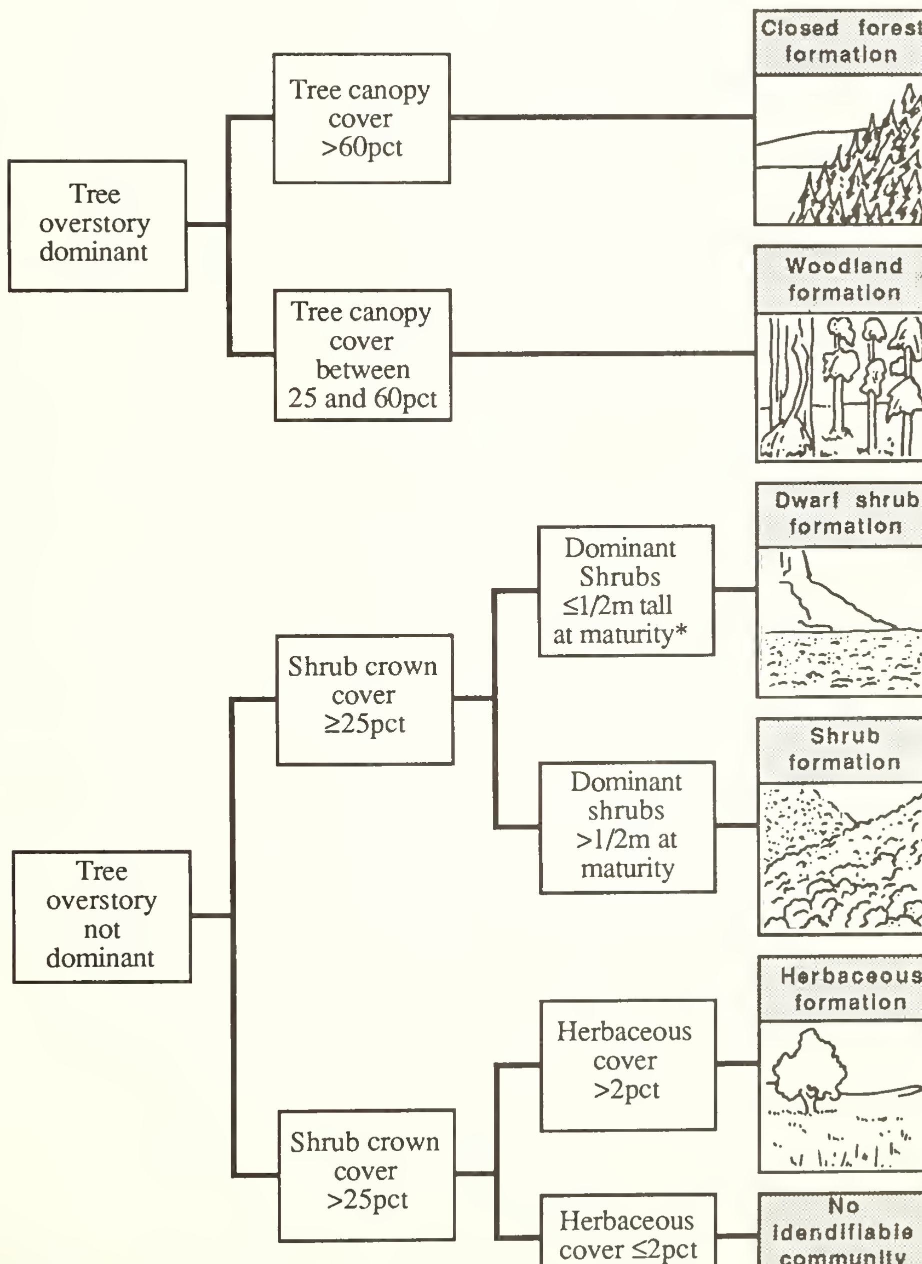

Figure 3—Key to Formations. See *Table 2* for tree or shrub crown cover between 10 and 25 percent.

*10-20 years after disturbance for most sites, more for Alpine

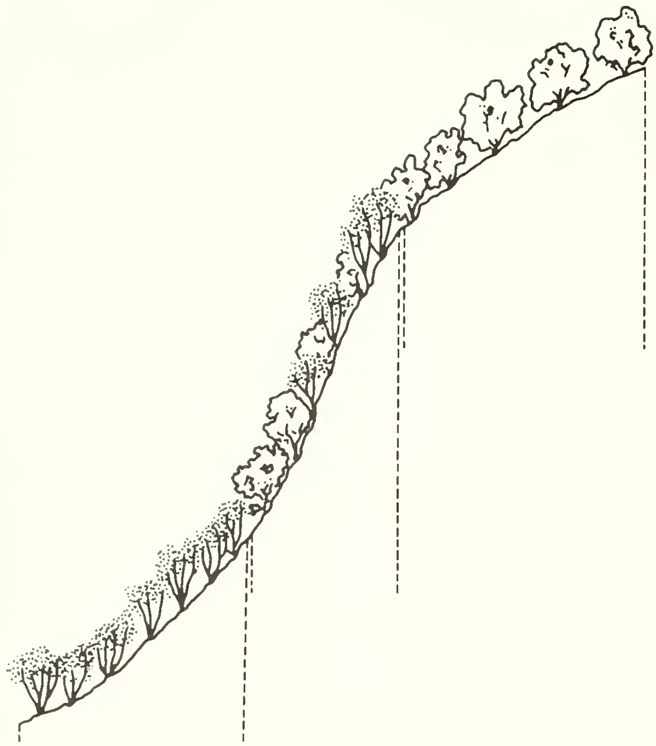

Figure 15—The ecotone — or transition zone — between two distinct communities may or may not be classified as a distinct community. Though not absolute determinants, clues are size of the zone and whether or not the vegetation mix is repeated over the landscape.

environmental basis for detecting a unique community. For example, the vegetation between two species-rich communities may contain representatives of both communities; distinctions between the transition zone and the two communities may be difficult to pin down. In another instance, a transition may be between two communities whose plants are characteristically distributed in clusters, or pockets, of one species or the other. Looking at the boundary of one of these pockets, you may wonder if the seemingly distinct change in a vegetation layer is signaling the existence of a different community, or is it yet another instance of a community already defined? In both of these cases, the character of the transition zone must be carefully assessed, particularly in relation to the communities on either side of it *(fig. 14).*

The size of a transition zone and the extent to which its species complement is repeated in the landscape are helpful in determining if vegetation in that ecotone rates community status. When the vegetation of an ecotone does not rate community status, the logical boundary between two adjacent communities may be on either side or within the area of changing vegetation *(figs. 15, 16).*

In defining a community, look for a unique cause and effect relationship between the community and its environment. Incorporate as much information as possible about the history of the site. Realize, however, that obvious environmental causes may not always be associated with vegetation changes. You must rely principally on recognition of vegetation patterns.

Naming the Plant Community

The rules for naming a plant community and identifying a plant community are identical. The dominant species in a layer or layers of vegetation, which identify a community at a given classification level, are used to name the community at that classification level. For example, the dominant overstory species that identifies a community Series is also used as the Series name.

The Association name is the most informative. It is also the most complex classification level and the one with which users of the system will have the most difficulty—both in identifying and in naming. Therefore, more rules are required to name Association than any other system level. All rules are logical combinations of basic naming conventions for a specific layer of vegetation. These comprehensive rules of nomenclature—applicable to different situations—have been compiled, with examples of each *(table 2).*

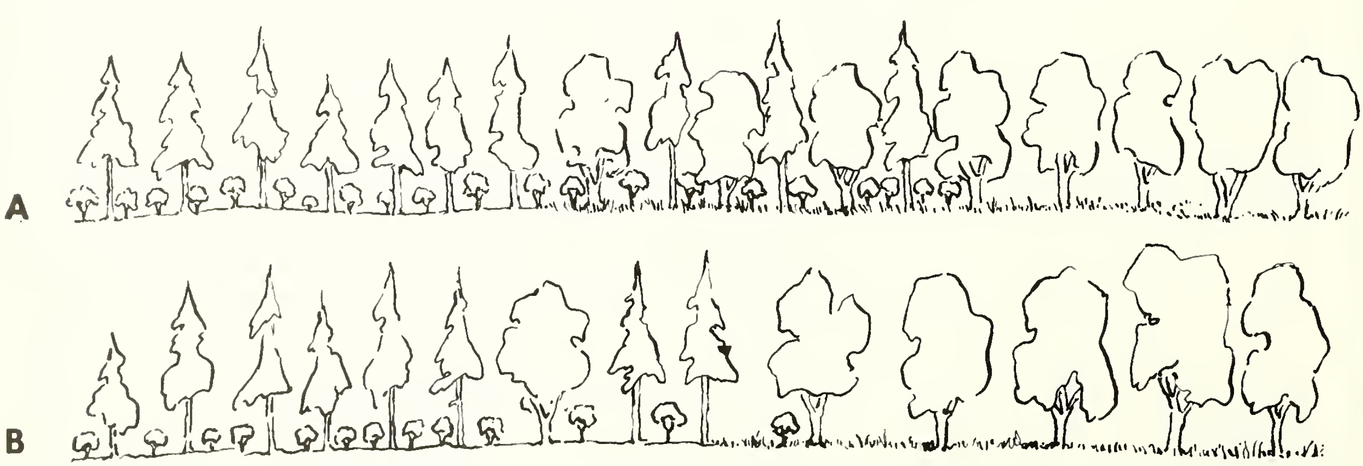

Figure 16—Transition zones. A distinct pattern of vegetation characterizes an identifiable zone between conifer and broadleaf communities (A), which might qualify as a distinct community. In contrast, the nondescript area between the conifer and broadleaf communities (B) simply represents a change from one community to another.

Figure 4—Two distinct Subformations within the Closed Forest Formation, distinguished by the leaf and stem morphology of the dominant overstory species, are Conifer and Broadleaf.

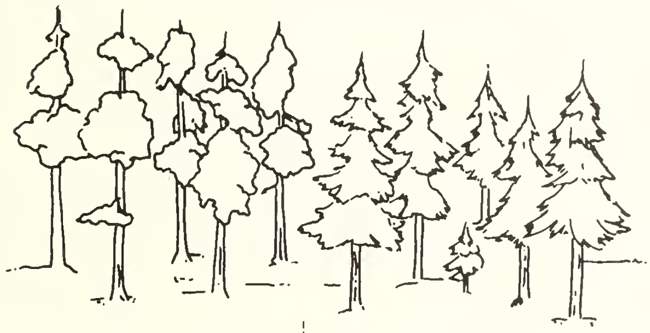

Figure 5—Two communities that represent two distinct Series within the Conifer Subformation, since different conifer species dominate the overstory in the two communities.

Figure 6—Two communities that represent two distinct Associations within a Series. They share the same dominant overstory species, but differ in understory species.

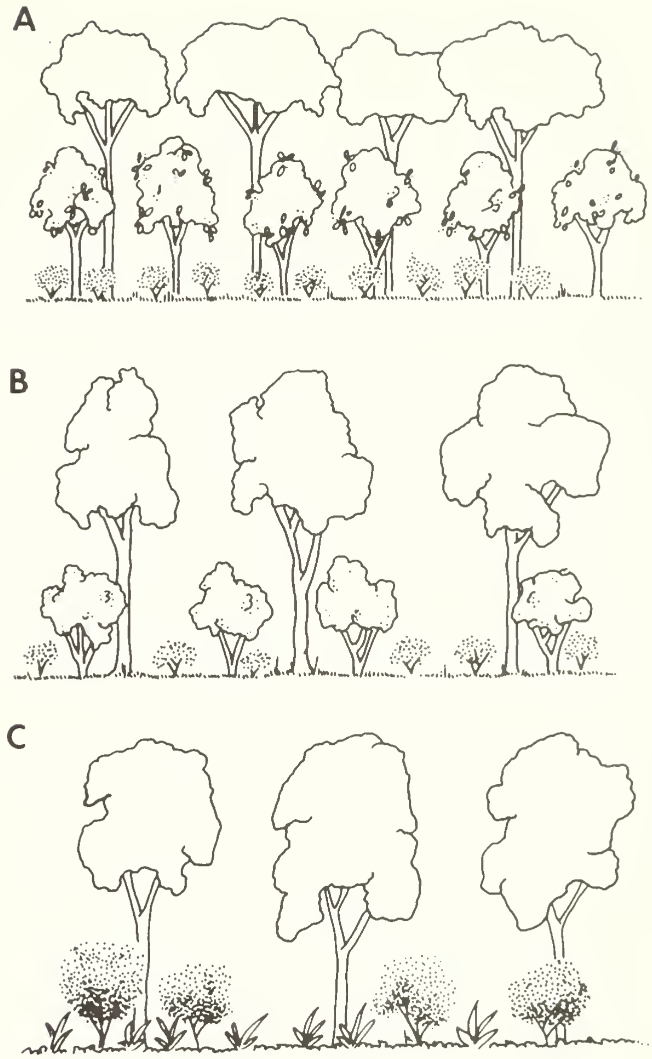

Figure 7—Some communities may have more than one tree (A), shrub (B), or herb (C) layer. These layers emerge from species characteristics, rather than transient differences in age among individuals.

might provide a cover of 40 percent. Based on the sample Phase categories in the *Appendix*, the community within the closed forest Formation would be designated 4-3-3.

IDENTIFYING THE PLANT COMMUNITY

Proper use of this classification system requires a sound grasp of the plant community concept. A plant community is defined as an assemblage of plants of characteristic species composition that occurs under a uniform set of environmental conditions (Ecol. Soc. Am. 1952, Schwartz and others 1976). However, subjectivity in identifying a community is inescapable. For this reason, some practical guidelines are offered.

The plant community may vary in size, but each Formation must have in its overstory layer enough vegetation to establish a measure of cover. A single plant would not normally be enough: a single-tree community would always have 100 percent crown cover in the overstory—hardly reason enough to call it a closed forest. Shifts in species composition of any layer of a plant assemblage must be extensive enough to establish distinct, new overstory/understory relationships for multilayered communities. One manzanita bush beneath an extensive overstory of Jeffrey pine is not enough to establish a unique overstory/understory relationship in the community sense; the relationship exists only in the single plant sense.

The plant community may vary in shape. For example, plant communities associated with riparian systems may be linear, sometimes as narrow as the width of a stream bank. A community that springs up along a fence row would have a linear shape. The plant community in a small wet meadow may be round; communities in a vernal pool may look like a set of concentric rings; a community with a ridgetop affinity may look like a broken set of hound's teeth. The possibilities are endless.

A candidate community must be evaluated in relation to surrounding communities and to its physical environment. The distribution patterns of plant species in surrounding communities and the arrangement of environmental factors are important clues to the individuality of a plant assemblage.

The bounds of the plant community are determined by the interaction of several environmental factors, including soil, light, moisture regime, natural and human disturbance, slope, aspect, and biogeographic history. Changes in these factors over a landscape may also create apparent changes in vegetation *(figs. 9, 10)*. The effects of some environmental factors are obvious; for example, a plant community may appear on the north aspect (direction of slope), but not the south. The importance of some physical features as clues to environmental change may not be obvious at first. For example, rocks and swales often affect the moisture regime; or the aspect of a slope along with its steepness and shape (concave, convex) can affect moisture, light, soil depth, and other conditions. Therefore, gently undulating terrain may produce a distinct pattern of plant communities *(fig. 11)*. And the top of a hogback, or sharply crested ridge, may have a plant community that is different from the communities on the side slopes. Therefore, it is important that the classifier develop a sensitivity to changes in the environment and to physical patterns over the landscape.

Precise identification of community boundaries is not important in the classification process. Boundaries become critical to the inventory process and when mapping plant communities or estimating areas covered by communities. When moving from one community to another, it is sufficient simply to describe a change in composition.

Community boundaries may be distinct, as where disturbances such as fire, logging, or clearing have caused radical vegetation changes. Or these vegetation changes may be gradual, in which case community boundaries are less precise. Such examples are ecotones—transition zones—between two distinct communities, or transitional ecological zones where a gradual shift occurs in the predominant plant community.

The key to correctly distinguishing communities is proper visual perspective. Observe the surrounding area. Look for overstory and understory patterns. Often, you must move beyond the specific area of concern to achieve the needed perspective. Sometimes natural variability in a community is distorted when viewed from one location. Is a particular cluster of one species signaling a unique community, or simply representing the nature of species distribution within a larger, more complex community *(fig. 12)?* It usually is beneficial to survey an area to determine species dominance and apparent species-site relationships before attempting to classify individual communities *(fig. 13)*.

Ecotones exist between two plant communities. Sometimes these areas are imprecise and hard to distinguish. At other times, an ecotone supports vegetation unique enough to be designated a distinct community. Ecotones can be small, with quick transition from one vegetation complex to another; or large, with gradual transition. Ecotones can be identified relative to any plant species or vegetation layer. They are often associated with a predominant overstory species.

Normally, the rules for defining a community (based on percent cover and dominance) and accurately recognizing change in a vegetation layer are sufficient to determine if an ecotone qualifies as a distinct community. However, sensitivity to the nuances of natural variability and significant change help to prevent overclassifying plant communities.

Difficulties in determining transition zones arise when species distribution patterns are obscure, with no observable

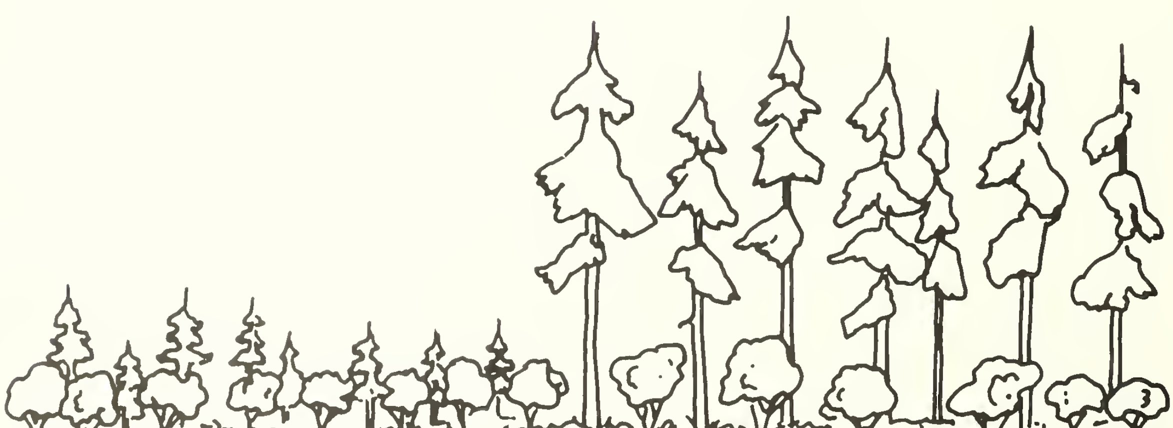

Figure 8—Communities may share the same dominant overstory and understory species and represent the same Association, but Phases could vary due to size or age differences. The Phase category extends classification to those characteristics that are important to the classifier.

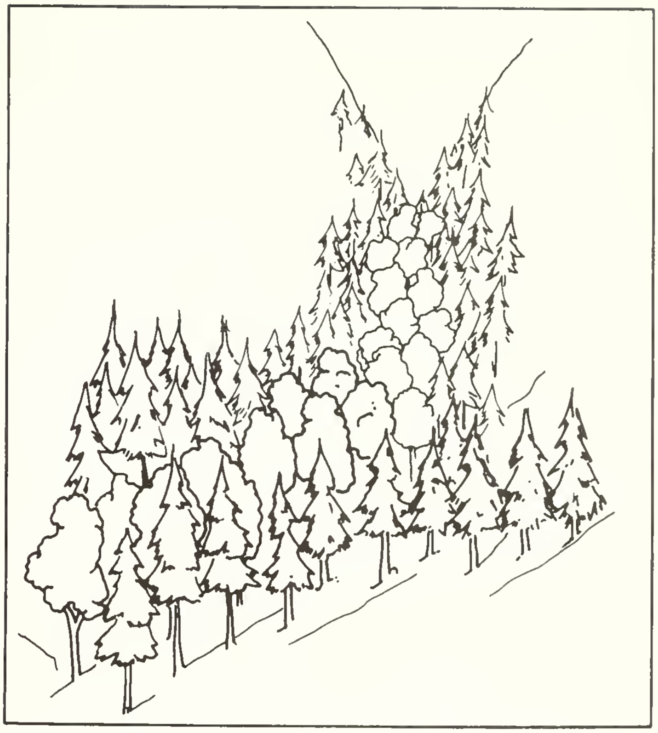

Figure 10—At least two distinct communities are represented here. Broadleaf trees occupy the canyon where soil is deeper and moisture is more available. Conifers occupy the higher, drier slopes.

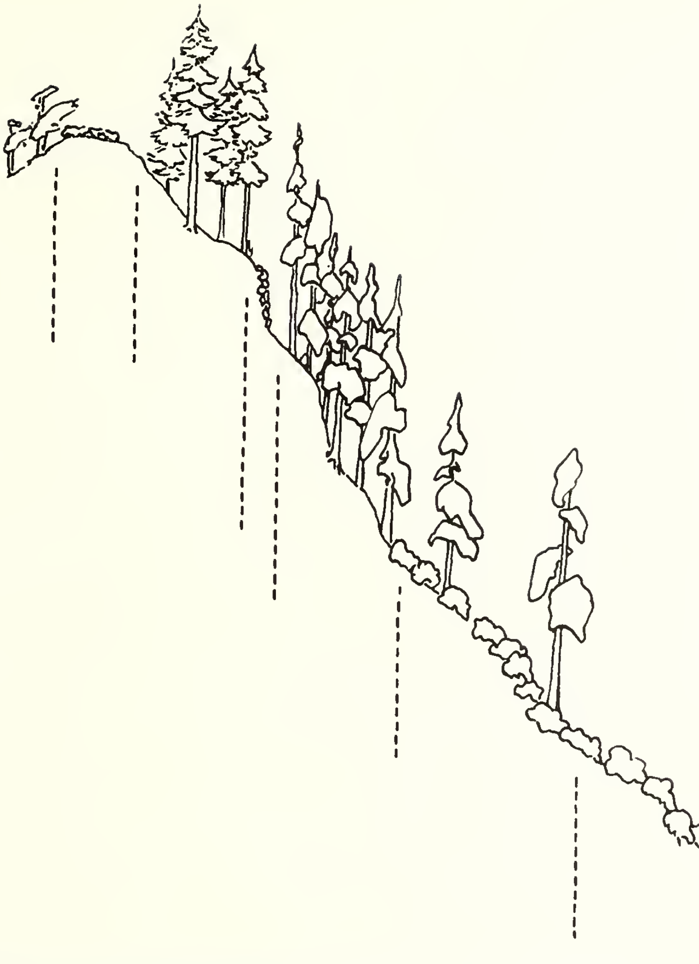
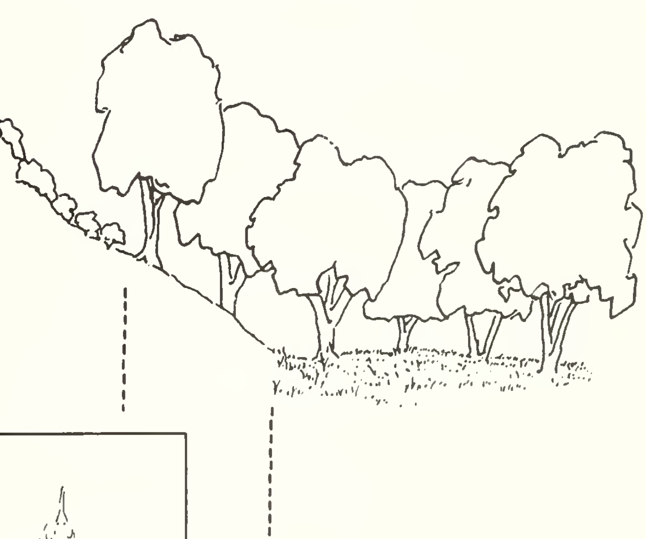

Figure 9—Changes in elevation or percent slope may change the plant communities present. Sometimes the boundaries between adjacent communities are difficult to distinguish.

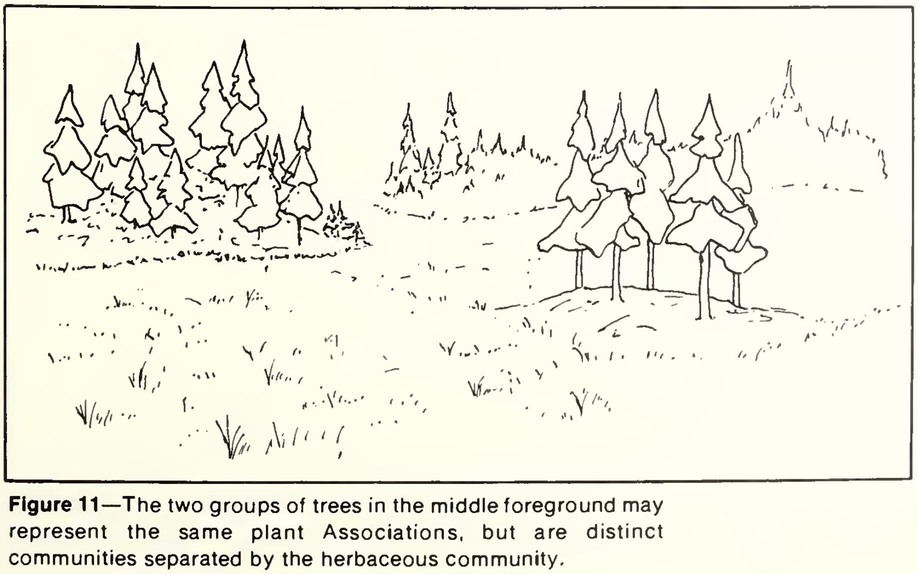

Figure 11—The two groups of trees in the middle foreground may represent the same plant Associations, but are distinct communities separated by the herbaceous community.

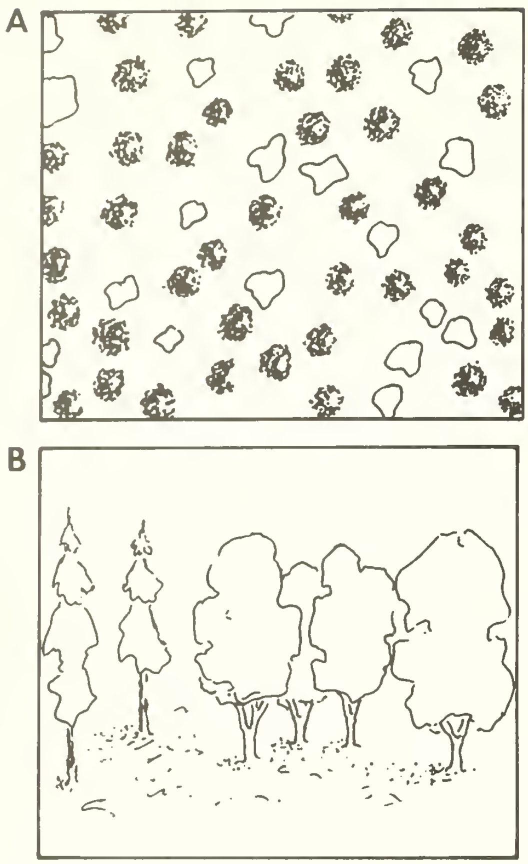

Figure 12—The simulated aerial view (A) of a Woodland community with clumped patterns of conifer and broadleaf trees in the overstory shows why it is important to evaluate what you are looking at in relation to what surrounds you. The pocket of broadleaf trees in (B) could well be a small, unique community, but is actually a pattern element from the community in (A).

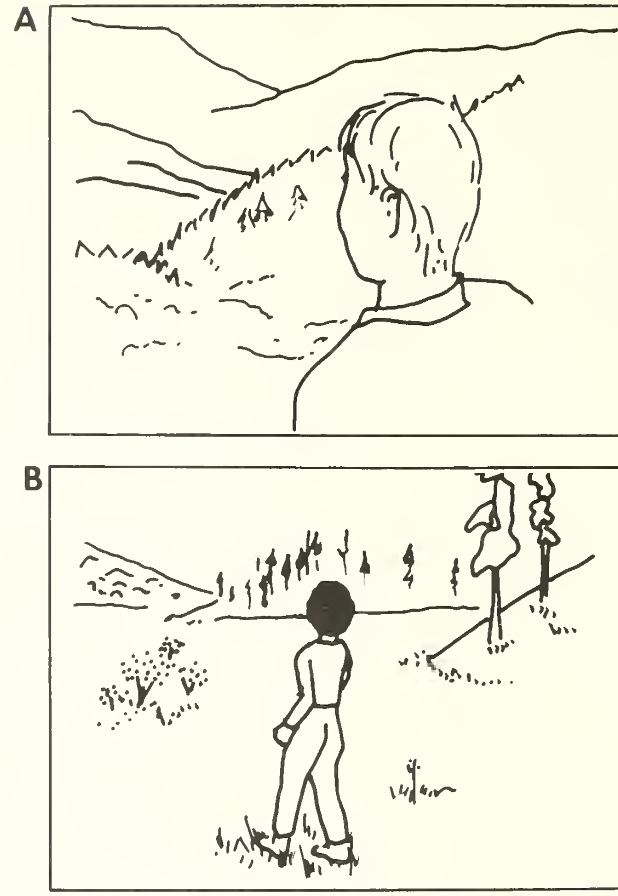

Figure 13—Before attempting to classify a community, establish some perspective with regard to species dominance patterns over the landscape. Gain a broad visual perspective if possible (A), and walk through communities in an area to establish a sense for possible site relationships (B).

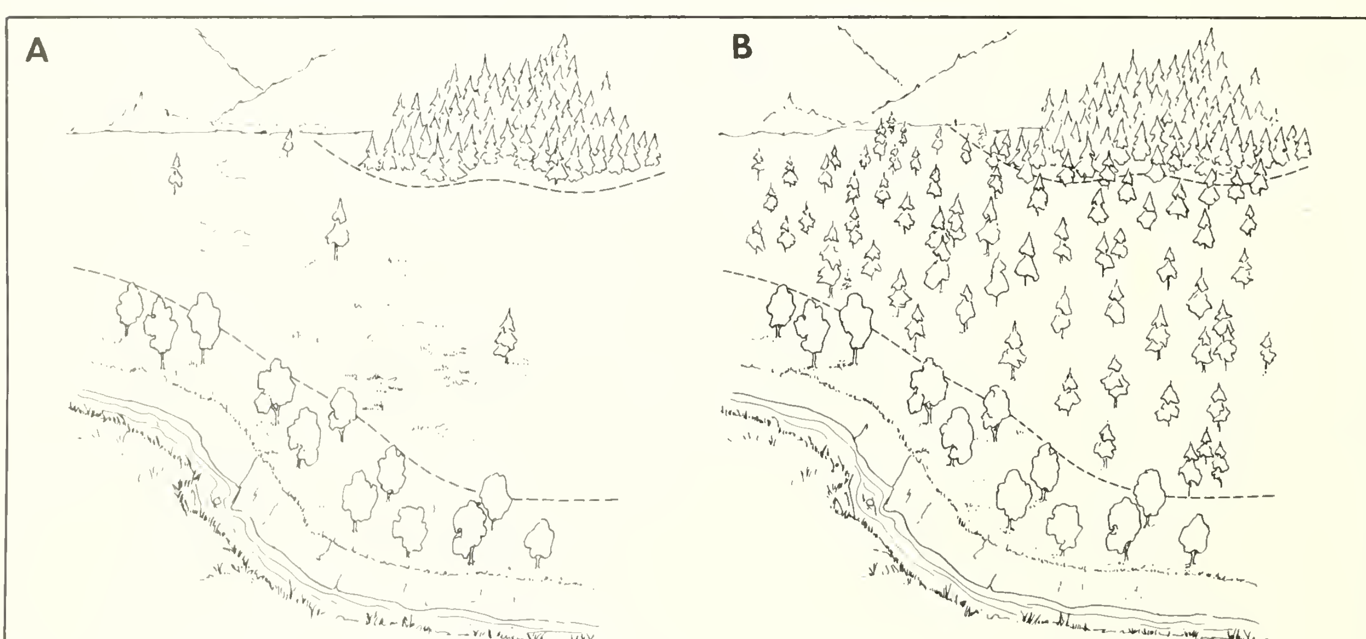

Figure 14—The sharp breaks between conifer, herbaceous, and broadleaf communities (A) simplify delineation of community boundaries even though isolated conifers occur in the grassy area. However, community boundaries become less clear when density decreases more gradually (B). Look at understory patterns as well as the crown cover of overstory dominants when identifying communities.

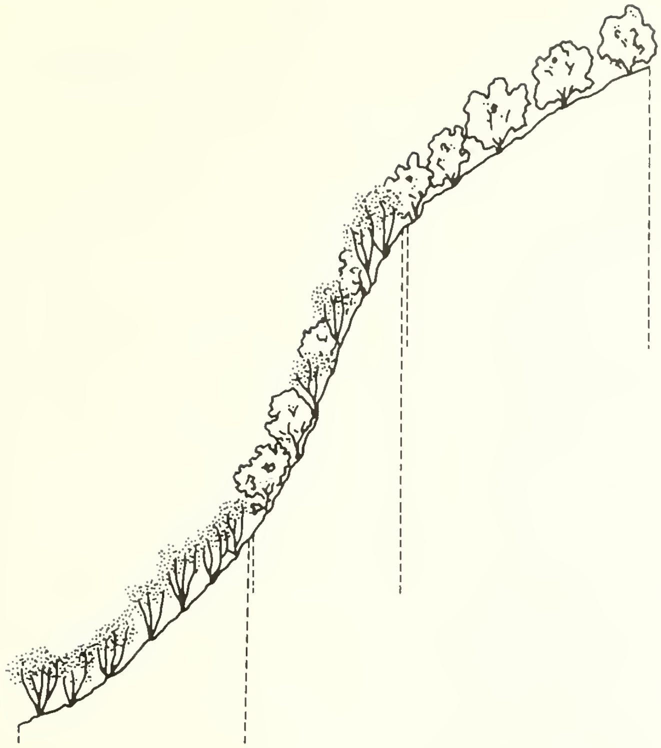

Figure 15—The ecotone — or transition zone — between two distinct communities may or may not be classified as a distinct community. Though not absolute determinants, clues are size of the zone and whether or not the vegetation mix is repeated over the landscape.

environmental basis for detecting a unique community. For example, the vegetation between two species-rich communities may contain representatives of both communities; distinctions between the transition zone and the two communities may be difficult to pin down. In another instance, a transition may be between two communities whose plants are characteristically distributed in clusters, or pockets, of one species or the other. Looking at the boundary of one of these pockets, you may wonder if the seemingly distinct change in a vegetation layer is signaling the existence of a different community, or is it yet another instance of a community already defined? In both of these cases, the character of the transition zone must be carefully assessed, particularly in relation to the communities on either side of it *(fig. 14)*.

The size of a transition zone and the extent to which its species complement is repeated in the landscape are helpful in determining if vegetation in that ecotone rates community status. When the vegetation of an ecotone does not rate community status, the logical boundary between two adjacent communities may be on either side or within the area of changing vegetation *(figs. 15, 16)*.

In defining a community, look for a unique cause and effect relationship between the community and its environment. Incorporate as much information as possible about the history of the site. Realize, however, that obvious environmental causes may not always be associated with vegetation changes. You must rely principally on recognition of vegetation patterns.

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A

B

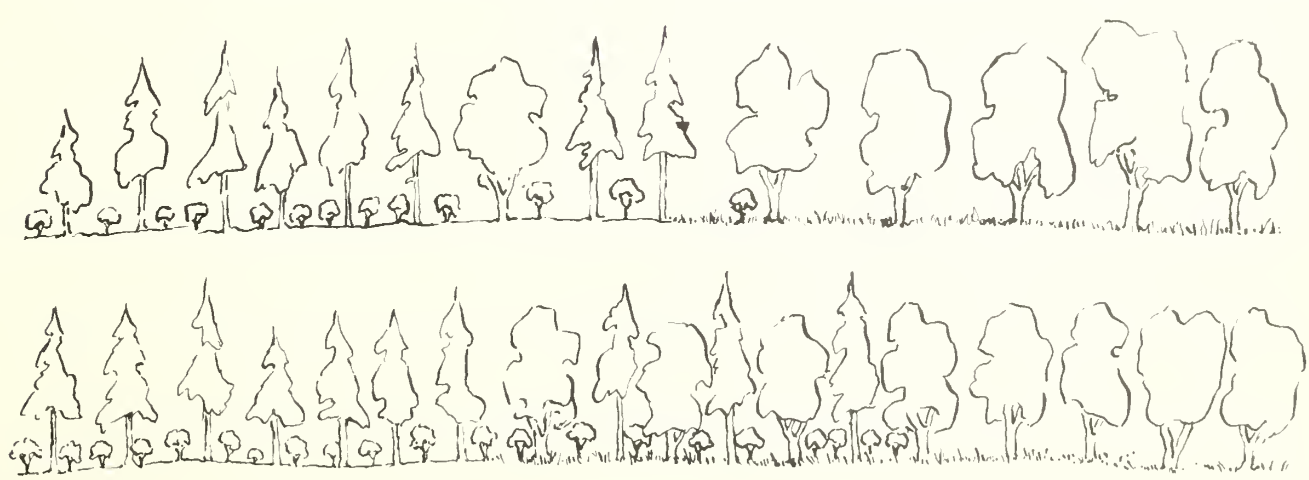

Figure 16—Transition zones. A distinct pattern of vegetation characterizes an identifiable zone between conifer and broadleaf communities (A), which might qualify as a distinct community. In contrast, the nondescript area between the conifer and broadleaf communities (B) simply represents a change from one community to another.

Survey Procedures for Classifying Vegetation

Any technique that provides a properly classified community is sufficient. A strict, formal procedure is not really necessary. Classification of community structure and composition is often a matter of simple observation; at other times, sampling techniques may be necessary to determine species dominance in complex communities.

The procedures used depend on the size and topography of the area inventoried, the level of classification, the complexity of the vegetation, and the skill of the person using the system. Formation and Subformation designations can be based on aerial photographs with a minimum of ground verification. Where vegetation types are fairly uniform, Series and (to some extent) Associations may also be identified on aerial photos. The more detailed the classification, the greater the need for verification.

The percent of crown cover can be estimated in several ways. One simple method is to delineate a square area, either on the ground or on an aerial photograph. Then mentally move into one corner of the square all individuals of a given species from the canopy layer being sampled. By visualizing the individuals grouped crown to crown, you can estimate what percent of the area of the square the group occupies. Another method is to use a dot grid on an aerial photograph. If accuracy is important, the ground surface area covered by each plant can be measured directly.

Steps to Classification

Regardless of the inventory technique, the classification process is the same. The steps in classifying a plant community to the Association level are:

1. Identify the limits of the community you wish to classify by noting understory/overstory vegetation patterns as they have been influenced by environmental factors.
2. Identify the Formation *(fig. 3)* by determining the dominant overstory in the community to be closed forest, woodland, shrub, dwarf shrub, or herbaceous.
3. Identify the Subformation by studying the leaf and stem morphology of the dominant overstory vegetation *(table 1)*.
4. Identify the Series by determining the dominant or codominant overstory species as determined by the 10 percent rule *(table 2)*.
5. Identify the most characteristic associated species. If the stand is multilayered, identify the dominant species in each layer (tree, shrub, herbaceous). Designate an Association name that reflects the order of dominance in the Association as specified by the nomenclature *(table 2)*.
6. Optionally, classify the community or portions of the community by Phase categories.

In order to complete step 1, you will in practice need to assess steps 2 to 6, since the limits of the community will be defined by changes in vegetation characteristics. As you become familiar with this system and its classification procedure, the process of evaluating a site will become increasingly automatic.

APPENDIX

SAMPLE PHASES CODED FOR THE FIVE CLASSIFICATION FORMATIONS

Closed Forest

Size (d.b.h., 2 in)	Overstory cover (pct)	Understory cover (pct)
1. <1	1. <25	1. <10
2. 1-5	2. 25-60	2. 10-25
3. 6-11	3. >60	3. 26-50
4. 12-21		4. 51-70
5. >21, <180 yrs		5. >70
6. >21, >180 yrs		

Woodland

Size (d.b.h., 2 in)	Overstory cover (pct)	Understory cover (pct)
1. <1	1. <25	1. <10
2. 1-5	2. 25-60	2. 10-25
3. 6-11		3. 26-50
4. 12-21		4. 51-70
5. >21		5. >70

Shrub

Overstory cover (pct)	Understory cover (pct)	Annual cover (pct)	Litter cover (pct)
1. <5	1. <5	1. <2	Expressed in percent cover and composition
2. 5-10	2. 5-10	2. 2-10	
3. 11-25	3. 11-25	3. 11-25	
4. 26-50	4. 26-50	4. 26-50	
5. 51-70	5. 51-70	5. 51-70	
6. >70	6. >70	6. >70	

Dwarf Shrub

Cover (pct)	
1. <2	4. 26-50
2. 2-10	5. 51-70
3. 11-25	6. >70

Herbaceous

Productivity	Living vegetation cover (pct)	Litter cover (pct)
Pounds per acre (optional)	1. <2	1. <25
	2. 2-25	2. 25-50
	3. 26-50	3. >50
	4. 51-70	
	5. >70	

REFERENCES

Buck, Michael G.; Paysen, Timothy E. **A vegetation classification system applied to Hawaii.** Gen. Tech. Rep. PSW-76. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1984. 11 p.

Driscoll, Richard S.; Merkel, Daniel L.; Hagihara, James S.; Radloff, David L. **A component land classification for the United States: status report.** Tech. Note 360. Denver, CO: Bureau of Land Management, U.S. Department of the Interior; 1983. 30 p.

Ecological Society of America. **Report of the Committee on Nomenclature.** Durham, NC: Ecological Society of America and Duke University Press. 1952; 115 p.

Paysen, Timothy E.; Derby, Jeanine A.; Black, Hugh, Jr.; Bleich, Vernon C.; Mincks, John W. **A vegetation classification system applied to southern California.** Gen. Tech. Rep. PSW-45. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980. 33 p.

Paysen, Timothy E.; Derby, Jeanine A.; Conrad, C. Eugene. **A vegetation classification system for use in California: its conceptual basis.** Gen. Tech. Rep. PSW-63. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1982. 14 p.

Schwartz, Charles F.; Thor, Edward C.; Elsner, Gary H. **Wildland planning glossary.** Gen. Tech. Rep. PSW-13. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1976. 252 p.

United Nations Education, Science, and Cultural Organization. **International classification and mapping of vegetation.** Paris: Ecol. and Conserv. Serv., Educ., Science, and Cult. Organ., United Nations; 1973. 93 p.

Hunter, Serena C.; Paysen, Timothy E. **Vegetation Classification System for California: user's guide.** Gen. Tech. Rep. PSW-94. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 12 p.

A system for classifying plant communities has been developed. Guide lines for recognizing plant communities in the field require that a practitioner be able to identify and inventory plant species. No formal sampling technique is required. Rules for naming plant communities to one or more of four different classification levels are based upon cover dominance by species in each vegetation layer found in a given community. A flexible phase category enhances the description of plant communities or links classification categories to other systems of classifying vegetation.

Retrieval Terms: vegetation classification, plant community classification, vegetation types, plant communities

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United States
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Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

General Technical
Report PSW-95

Proceedings of the Workshop on

Management of Giant Sequoia

May 24–25, 1985, Reedley, California

Cover: Management objectives for giant sequoia include restoring and maintaining natural ecosystem processes, protecting "showcase" areas or "specimen" trees, and producing timber. Photos show, clockwise from left: General Sherman Tree, Sequoia and Kings Canyon National Parks; prescribed burning for site preparation after whitewood removal, Bearskin Grove, Sequoia National Forest; and young giant sequoias, Sequoia National Forest.

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December 1986

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Management of Giant Sequoia

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Technical Coordinators

C. Phillip Weatherspoon   Y. Robert Iwamoto   Douglas D. Piirto

CONTENTS

PREFACE

Since its discovery in the mid-nineteenth century, giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) has been noted for its enormous size and age, and its rugged, awe-inspiring beauty. Because the species has broad public appeal and a restricted natural range, most groves of giant sequoia have been accorded protected status. In some groves, however, and increasingly outside the natural range of the species—both in the United States and in many other countries—giant sequoia is being utilized for timber production. Many foresters consider its rapid growth and favorable wood characteristics to indicate a substantial potential for it to become a major timber-producing species. Giant sequoia also is widely planted and highly regarded as an ornamental.

The first-ever workshop designed to bring together the state-of-knowledge on giant sequoia and its management—"Management of Giant Sequoia"—was held at Kings River Community College in Reedley, California, May 24 and 25, 1985. It was sponsored by the University of California Cooperative Extension—Forestry and the Northern California Society of American Foresters. The intent of the workshop was to address the history, silvics, genetics, growth and yield, wood properties and products, insect and disease relationships, appropriate management strategies by different agencies and landowners, and recommendations for future management of giant sequoia.

The second day of the workshop included a field trip to view first-hand and to discuss management activities in Sequoia National Forest, and Sequoia and Kings Canyon National Parks. A short summary and handouts from the field trip are in the appendix.

Because of the considerable public and professional interest in giant sequoia, the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, agreed to publish the proceedings of the workshop to make the information available to a larger audience. These proceedings are a useful reference for resource managers, foresters, naturalists, ecologists, and the interested public.

The views expressed in each paper are those of the author(s) and not necessarily those of the sponsoring organizations. Trade names and commercial enterprises are mentioned solely for information and do not imply the endorsement of the sponsoring organizations. The tree names currently accepted for use by the Forest Service are *Sequoiadendron giganteum* and giant sequoia. Other names, however, are also used in these proceedings.

We thank the many people who assisted in the workshop and field trip—Linda Parham, Robert Cannell, Paul Roche, Tom Nichols, and the staff from Kings River Community College, Sequoia National Forest, and Sequoia and Kings Canyon National Parks. We appreciate the excellent work done by Roberta Burzynski, Pacific Southwest Forest and Range Experiment Station, in editing these proceedings. Most importantly, we thank the speakers and field trip leaders and coordinators for willingly devoting their time and efforts in preparing the workshop papers, and their organizations for making their time available. Finally, special thanks go to the participants who contributed to the discussion and to the sharing of ideas that made the workshop a success.

C. Phillip Weatherspoon, Pacific Southwest Forest and Range Experiment Station
Technical Coordinator
Y. Robert Iwamoto, Sequoia National Forest
Workshop Co-chairman and Technical Coordinator
Douglas D. Piirto, Sierra National Forest
Workshop Co-chairman and Technical Coordinator
(now at California Polytechnic State University)

Evolution and History of Giant Sequoia[1]

H. Thomas Harvey[2]

Abstract: Ancient ancestors of the giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) were widespread throughout much of the Northern Hemisphere during the late Mesozoic Period. Climatic conditions changed, forcing the more recent ancestors of present giant sequoia into the southwestern United States. The native range is now restricted to the west slope of the Sierra Nevada. Although seen in 1833 the effective date of discovery by the Europeans was 1852. Soon after that specimen trees were cut, and then extensive logging removed about a third of the big trees. Preservation of groves started in 1864 and gained momentum in 1890 with creation of Sequoia and Yosemite National Parks. Numerous scientific studies have been conducted during the last century from paleobotany to genetics of these great trees, but much is still unknown.

EVOLUTION

The earliest close relatives of the giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) were present in the Cretaceous Period (late Mesozoic) throughout much of the Northern Hemisphere (Chaney 1951). Because they appear to differ significantly from the present giant sequoia, they are not considered their immediate ancestors (Axelrod 1959). The oldest sequoia fossil (*Sequoiadendron chaneyi*) that is probably the lineal ancestor of the present giant sequoia is from the Miocene Epoch about 10 to 20 million years ago. The sequoia fossil not only resembles the modern giant sequoia, but the plants associated with the fossil are similar to those in present sequoia communities (Axelrod 1964).

During the late Miocene Epoch, the giant sequoia's ancestors were in what is now western Nevada. As conditions became cooler and drier, along with the rise of the Sierra Nevada, the survivors managed to prosper at the southwestern edge of the mountain range. Eventually they migrated to the western slope of the relatively low incipient Sierra Nevada and may have existed as isolated groves or as a continuous belt about 300 miles (482.2 km) long (Harvey and others 1981). Although the disjunct groves at present are genetically distinct, no firm conclusions can be drawn regarding the duration of genetic isolation (Fins and Libby 1982). And thus it remains unknown whether the giant sequoia followed isolated routes across the mountains or if it advanced on one broad front to be dissected into widely separated groves in the northern part of its present range.

[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

[2]Ecologist, Harvey and Stanley Associates, Alviso, CA 95002.

Gen. Tech. Rep. PSW-95. Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986.

DISCOVERY

The earliest human encounters with giant sequoia probably occurred shortly after the first Native Americans arrived in North America tens of thousands of years ago. According to Hartesveldt (1975), in 1877 Powers recorded "that the people of the Mokelumne Tribe referred to the sequoia as 'woh-woh-nau,' which in the Miwok tongue was a word supposedly in the imitation of the hoot of an owl, the guardian spirit of the great and ancient trees." The interactions between people and the giant sequoia were thus benign for millennia.

When Europeans arrived on the scene things changed. In the mid 1800's the giant sequoia were first discovered by Europeans, even though colonization of the West had begun a century earlier and explorers had visited California two centuries before that. Two dates—1833 and 1852—are noted by Hartesveldt (1975) as landmarks. The Walker Party in late autumn 1833 crossed the Sierra Nevada and described "trees of the Redwood species, incredibly large—some of which would measure from 16 to 18 fathoms round the trunk at the height of a large man's head from the ground" (Hartesveldt 1975). In other words, at about 6 feet (1.8 m) up the trunk the diameter was estimated at over 30 feet (9.1 m). Probably it was crudely measured by counting people with outstretched arms as each equal to a fathom, and being on a slope possibly would account for such large estimates.

In the summer of 1852 Dowd, a hunter of meat for a water company, discovered giant sequoias in the vicinity of a lumber camp in the Sierra Nevada. As the story goes he returned to camp and told his incredulous tale of gigantic trees. But no one accepted his story, so he made one up that he needed help to bring back a giant grizzly bear that he had shot. The lumberjacks responded to that, and followed him to what is now known as the North Calaveras Grove (Harvey 1978). In June 1852 the *Sonora Herald* reported Dowd's discovery and the news travelled fast throughout the world (Harvey and others 1981). Then followed two reactions—one benign, the other malignant.

Several people claimed to have discovered the trees at an earlier date than did Dowd. But a mystery still unresolved is why no one from the Walker Party recalled their apparently valid earlier claim to fame. All those that did step forward claiming earlier discovery were suspect, for they reported dates later than 1852.

The other reaction was more dramatic and more significant in the history of the giant sequoia. To show the world that California really did have such huge trees, selected trees were stripped or cut down. The first to go was augered down in the North Calaveras Grove in 1852. It took a crew of 25 men working 10 days to drill enough holes to send it crashing down. The next tree to go in the North Calaveras Grove was one called "Mother of the Forest." It was stripped of its bark to about 120 feet (36.5 m) up from the ground and died several years later. This whole procedure upset John Muir who was reported to remark that it was ". . . as sensible a scheme as skinning our great men would be to prove their greatness" (Hartesveldt and others 1975). In 1891 the Mark Twain tree, a fine specimen, was cut down and sections sent to the American Museum of Natural History in New York City and to the British Museum in London where they are still on view (Harvey and others 1981). At least some interest in natural history was generated by the exhibition of portions of these great trees, but the destruction of individual trees soon expanded into logging.

LOGGING

Logging of giant sequoias was begun in 1856 and continued intermittently until the 1950's (Hartesveldt and others 1975). Some modest use of large downed trees and the clearing of a few smaller ones continues to date. The logging of Whitakers Forest from 1873 to 1879 produced devastating conditions that at first were deplored, but second-growth sequoias eventually provided comparative stands with old growth. Not all mature sequoias were logged so that esthetically the Forest was not as devastated as later was Converse Basin (Biswell and others 1966).

The Converse Basin Grove was once one of the largest groves of giant sequoias known in the Sierra Nevada. About 3 miles north of Grant Grove thousands of mature giant sequoias grew in a basin covering several square miles. During its 20 years of operation (1888–1908) the Sanger Lumber Co. cut an estimated 8,000 giant sequoias in the basin (Johnston 1973). Two ironic features of the logging were that not one cent of profit was realized, and that the largest tree was left and named after the logging supervisor Frank Boule.

The reasons for the lack of profit were numerous but paramount was the loss of timber shattered beyond salvaging on falling (Johnston 1973). In addition, trees over 8 feet (2.4 m) in diameter were augered and then sometimes blasted in two. Also, the lumber and time needed to build the over 30 miles (48.3 km) of flume from Millwood in the Sierra Nevada to Sanger in the Central Valley ate into the hoped-for profits. The flume, when extended to Hume Lake, was reputably the longest in the world (Johnston 1973).

Knowledge of several fascinating sequoia attributes was salvaged from the devastation at Converse Basin. Douglass counted rings on several cut sequoia stumps of which one (D-21, about 50 yd. north of the Chicago stump) had 3,200 rings and thus is to date, the oldest known giant sequoia. (The snag that John Muir claimed was about 4,000 years old is only about a mile northeast of D-21.) Less than a quarter of a mile north of D-21 is a stump from which a section was removed by Libby to serve as a yardstick for carbon-14 dating. Shortly after the logging the rings of about 100 giant sequoia stumps were counted by E. Huntington and his graduate students. Those data have been used to correlate diameter with age (Harvey 1980).

Logging moved from Converse Basin to the east when the Hume-Bennett Lumber Co. took over. They operated from 1908 to 1926 cutting giant sequoias in groves near Hume Lake where the mill was located and from which the flume ran to Sanger. Although Mather, the first Director of the National Park Service, attempted to include these sequoia lands in an enlarged park, his efforts fell short.

The impact of the destruction of specimen trees and logging of giant sequoias produced backlash of conservation and preservation. As early as 1873 a State law was enacted that no tree over 16 feet (4.9 m) in diameter could be cut in Fresno, Tulare, or Kern Counties. There is no evidence of the law being enforced (Johnston 1973).

PRESERVATION AND RESEARCH HISTORY

The first outright preservation of sequoia land had begun almost a decade before the State law was enacted, when in 1864 the Federal government deeded the Mariposa Grove to the State of California (Hartesveldt and others 1975). In 1890 Sequoia, General Grant and Yosemite National Parks were created thus protecting considerable sequoia acreage. Over a million signatures on a petition to President Roosevelt spurred a bill in 1909 creating Calaveras Bigtree National Forest including the North and South Calaveras Groves. They later became part of the State park system: the North Grove in 1931 and the South Grove in 1954. Most of the largest sequoia grove, Redwood Mountain Grove, was finally added to Kings Canyon National Park in 1940. On the basis of acreage, giant sequoia lands are presently largely in public ownership with almost 70 percent in National Parks and an additional almost 25 percent under other public agencies. With the protection afforded the giant sequoia, attention was directed toward managing this great natural resource. The history of managing giant sequoia is described in other papers in these proceedings (Benson 1986, Parsons and Nichols 1986, Rogers 1986).

The history of the scientific inquiry into giant sequoia grades into its natural history as well. It is difficult to separate the two and indeed it's probably not worth attempting to do so in the first place. The interest and effort put into investigating the many aspects of these unique trees vary, and the time spent ranges from a few days to several years. Due to restrictions of time and space only a few of those studies best known to the author are mentioned here with apologies for those overlooked. One may also consult the literature cited in works by Axelrod, Biswell, Fins, Hartesveldt, Harvey, Kilgore, Piirto, Rundel, and Stark (nee Beetham).

Among the first to write extensively about the giant sequoia was John Muir. He devoted a chapter to the big trees in his book on Yosemite (Muir 1912), and wrote articles on giant sequoia as early as 1876. In the 1920's Fry and White (1930) studied the natural history of giant sequoias.

In the 1930's Buchholz studied cone development in the sequoias, and though there are some questions about his work, the scientific name (*Sequoiadendron giganteum*) proposed by him is currently widely accepted. From the 1940's to 1960's Axelrod provided considerable information on the paleobotany of the giant sequoia. Also starting in the 1940's Meyer expressed concern for the survival of the giant sequoia. Hartesveldt began studies in 1956 that eventually led to further investigations on giant sequoia ecology (Hartesveldt 1962). Hartesveldt, Harvey, Shellhammer, and Stecker studied sequoia reproductive responses to fire and predation over a decade (Harvey 1980). In the 1960's and 1970's, Biswell along with several fine graduate students contributed to further understanding of fire and the giant sequoia (Biswell 1961), and Rundel contributed basic information on the distribution and ecology of the giant sequoia (Rundel 1969, 1971, 1972). The extensive work of Stark (1968a, 1968b) on seed germination and seedling tolerances has enlightened many "students" of the sequoias ever since. Also starting in the 1960's Kilgore studied breeding bird populations in giant sequoia forests. In the 1970's he continued work on the role of fire (Kilgore 1972, 1975, 1976).

A significant investigation during the 1970's by Piirto (1977) did much to clarify the role of fungi in association with tree failure in giant sequoias. Also in the 1970's spatial patterns and succession in the giant sequoia ecosystem was studied by Bonnicksen (1975). Genetic patterns of variation were investigated by Fins (1981).

Although much has been learned about the giant sequoia in its natural ecosystem, much still remains to be discovered. For example, little is known about the role of fungi during seedling development under natural forest conditions. Almost all the research mentioned above led to more questions than they started with, and perhaps that's the way it ought to be.

REFERENCES

Axelrod, D. I. Late tertiary evolution of the Sierran big-tree forest. Evolution 13:9–23; 1959.

Axelrod, D. I. The Miocene Trapper Creek flora of southern Idaho: Univ. Calif. Publ. Geol. Sci. 51:1–148; 1964.

Benson, Norman J. Management of giant sequoia on Mountain Home Demonstration State Forest. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 30–31.

Biswell, H. H. The big trees and fire. Nat. Parks Mag. 35: 11–14; 1961.

Biswell, H. H.; Buchanan, H.; Gibbens, R. Ecology of the vegetation of a second-growth *Sequoia* forest. Ecology 47(4): 630–634; 1966 Summer.

Bonnicksen, T. M. Spatial pattern and succession within a mixed conifer-giant sequoia forest ecosystem. Univ. of California; 1975. Dissertation.

Chaney, R. W. A revision of fossil *Sequoia* and *Taxodium* in western North America based on the recent discovery of *Metasequoia*. Am. Phil. Soc. Trans. 40(3):171–263; 1951.

Fins, L. Genetic architecture of giant sequoia. Berkeley: Univ. of California; 1981. Dissertation.

Fins, L.; Libby, W. J. Population variation in *Sequoiadendron:* Seed and seedling studies, vegetative propagation, and isozyme variation. Silvae Genet. 31(4):102–110; 1982.

Fry, W.; White, J. R. Big trees. Palo Alto, CA: Stanford Univ. Press; 1930; 126 p. (9th ed. 1948; 114 p.)

Hartesveldt, R. J. Effects of human impact upon *Sequoia gigantea* and its environment in the Mariposa Grove, Yosemite National Park, California. Ann Arbor: Univ. of Michigan; 1962. 310 p. Dissertation.

Hartesveldt, R. J. The "Discoveries" of the giant sequoia. J. Forest Hist. 19(1):15–21; 1975.

Hartesveldt, Richard J.; Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. The giant sequoia of the Sierra Nevada. Washington, DC: U.S. Dep. of Interior; 1975. 180 p.

Harvey, H. Thomas. The sequoias of Yosemite National Park. Yosemite Natural History Association; 1978. 36 p.

Harvey, H. Thomas. Giant sequoia reproduction, survival, and growth. In: Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. Giant sequoia ecology: fire and reproduction. Washington, DC: U.S. Department of Interior; 1980: 41–68.

Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E.; Hartesveldt, R. J. Giant sequoias. Three Rivers, CA: Sequoia Natural History Association; 1981. 77 p.

Johnston, Hank. They felled the redwoods. Corona Del Mar, CA: Trans-Anglo Books; 1973. 160 p.

Kilgore, B. M. Fire's role in a sequoia forest. Naturalist 23:26–37; 1972.

Kilgore, B. M. Restoring fire to national park wilderness. Am. Forests 81(3):16–19, 57–59; 1975.

Kilgore, B. M. From fire control to fire management: an ecological basis for policies. Trans. N. Am. Wildl. Nat. Resour. Conf. 41:477–493; 1976.

Muir, J. The Yosemite. New York: The Century Co.; 1912.

Parsons, David J.; Nichols, H. Thomas. Management of giant sequoia in the National Parks of the Sierra Nevada, California. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 26–29.

Piirto, D. D. Factors associated with tree failure of giant sequoia. Berkeley: Univ. of California; 1977. Dissertation.

Rogers, Robert R. Management of giant sequoia in the National Forests of the Sierra Nevada, California. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW–95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 32–36.

Rundel, P. W. The distribution and ecology of the giant sequoia ecosystem in the Sierra Nevada, California. Durham, NC: Duke University; 1969. 204 p. Dissertation.

Rundel, P.W. Community structures and stability in the giant sequoia groves of the Sierra Nevada. Am. Midland Nat. 85:478-492; 1971.

Rundel, P. W. Habitat restriction in giant sequoia; the environmental control of grove boundaries. Am. Midland Nat. 87:81–99; 1972.

Stark, N. The environmental tolerance of the seedling stage of *Sequoiadendron giganteum*. Am. Midland Nat. 80:85–95; 1968a.

Stark, N. Seed ecology of *Sequoiadendron giganteum*. Madrono 19:267–277; 1968b.

Silvics of Giant Sequoia[1]

C. Phillip Weatherspoon[2]

Abstract: Ecological relationships—including habitat and life history—of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) in natural stands are summarized. Such silvical information provides an important foundation for sound management of the species.

Silvics is defined by the Society of American Foresters (Ford-Robertson 1971, p. 240) as "the study of the life history and general characteristics of forest trees and stands, with particular reference to locality factors, as a basis for the practice of silviculture." Silvics deals primarily with ecological relationships of trees in natural stands. Consequently, the degree to which some specific subject areas of silvics apply directly to management of a species depends on the type of management—i.e., how far the management practice departs from natural stand processes.

Management of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) covers a wide spectrum. Because the species has broad public appeal and a restricted natural range, most groves of giant sequoia have been accorded protected status. In these groves, which generally are managed to maintain the functioning of natural processes, the silvical characteristics summarized in this paper are in large part directly applicable to management. Elsewhere, both within and outside the natural range of the species, giant sequoia is managed for other purposes, such as timber production. Where intensive timber management is practiced, for example, a manager might have limited interest in the characteristics of older trees, associated vegetation occurring in natural stands, and some aspects of natural regeneration (if regeneration is to be achieved through planting). Nevertheless, many aspects of the silvics of giant sequoia comprise an essential foundation for any form of sound management of the species and, as a bonus, tell the ecological story of a fascinating species.

HABITAT

Native Range

The natural range of giant sequoia is restricted to about 75 groves scattered over a 260-mi (420-km) belt, nowhere more than about 15 mi (24 km) wide, extending along the west slope of the Sierra Nevada in central California (Hartesveldt and others 1975). The northern two-thirds of the range, from the American River in Placer County southward to the Kings River, takes in only eight widely disjunct groves. The remaining groves, including all the large ones, are concentrated between the Kings River and the Deer Creek Grove in southern Tulare County (Rundel 1971). Varying in size from 1 to 4000 acres (less than 1 to 1619 ha), the groves occupy a total area of 35,607 acres (14,410 ha) (Harvey and others 1980).

Climate

Giant sequoia is found in a humid climate characterized by dry summers. Mean annual precipitation in the groves varies from about 35 to 55 inches (900 to 1400 mm), with high year-to-year variation. Less than 1.2 inches (30 mm) usually falls between June 1 and September 30. Most of the precipitation falls in the form of snow, between October and April. Mean annual snowfall ranges from 144 to 197 inches (367 to 500 cm), and snow depths of 6.6 ft (2 m) or greater are common in midwinter (Rundel 1969).

Mean daily maximum temperatures for July for typical groves are 75 to 84 °F (24 to 29 °C). Mean minimum temperatures for January vary from 34 to 21 °F (+1 to -6 °C). Extremes are about -12 and 104 °F (-24 and 40 °C) (Rundel 1969, Stark 1968a).

Low temperatures seem to be a limiting factor for giant sequoia at the upper elevational limits of its range, as well as in areas with severe winters where the species has been introduced. Distribution of the species at low elevations is limited mainly by deficient soil moisture during the growing season (Rundel 1972).

Soils and Topography

Soils are derived from a variety of rock types. Most groves are on granitic-based residual and alluvial soils, and three are on glacial outwash from granite. Schistose, dioritic, and andesitic rocks also are common parent materials (Hartesveldt and others 1975, Schubert and Beetham 1962).

Typical soil series are Dome, Shaver, Holland, and Chaix. Characteristic soil families are coarse-loamy, mixed, mesic, Dystric Xerochrepts; coarse-loamy, mixed, mesic Entic (and Typic) Xerumbrepts; and fine-loamy, mixed, mesic Ultic Haploxeralfs. The natural range of the species lies mostly within the mesic temperature regime, extending only a short distance into the frigid regime, and wholly within the xeric moisture regime (Mallory 1981).

Giant sequoia grows best in deep, well-drained sandy loams. Its density also is much greater in the more mesic sites, such as drainage bottoms and meadow edges, than in other

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habitats within a grove. Total acreage of these productive sites is small, however. Relatively shallow and rocky soils support vigorous individuals, some quite large, wherever the trees can become established and where underground water is available to maintain them (Hartesveldt and others 1975, Rundel 1969).

Soil pH ranges mostly from 5.5 to 7.5, with an average of about 6.5 (Mallory 1981). Long-term site occupancy by giant sequoia appears to develop a soil of high fertility, good base status, and low bulk density (Zinke and Crocker 1962).

Adequate soil moisture throughout the dry growing season is critical for successful establishment of giant sequoia regeneration, although seedlings do not survive in wet soils (Schubert and Beetham 1962). One study has shown more available soil moisture within a grove, possibly associated with subterranean flow from higher elevations, than in adjacent forested areas (Rundel 1972). Except for its moisture content, soil apparently plays only a minor role in influencing the distribution of the species, as evidenced by the considerable variability in parent material among groves and the fact that giant sequoia grows vigorously when planted in diverse soils around the world (Hartesveldt and others 1975).

Elevations of the groves generally range from 4600 to 6600 ft (1400 to 2000 m) in the north, and 5600 to 7050 ft (1700 to 2150 m) in the south. The lowest natural occurrence of the species is 2720 ft (830 m) and the highest is 8860 ft (2700 m). The eight northern groves are all on slopes of a generally southern aspect. Between the Kings River and the southern boundary of Sequoia National Park, groves appear on north and south slopes with about equal frequency. Farther south, aspects are predominantly northerly (Rundel 1969).

Associated Forest Cover

Giant sequoia groves lie wholly within the Sierra Nevada mixed conifer type—SAF (Society of American Foresters) forest cover type 243 (Eyre 1980). A grove is distinguished from similar mesic habitats in this type only by the presence of giant sequoia itself: no other species is restricted to the groves (Rundel 1971). Nowhere does giant sequoia grow in a pure stand, although in a few small areas it approaches this condition (Hartesveldt and others 1975).

Based on density or canopy coverage, groves typically are dominated strongly by California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), despite the presence of emergent individuals of giant sequoia that overtop the canopy. Sugar pine (*Pinus lambertiana* Dougl.) is a characteristic associate. Incense-cedar (*Libocedrus decurrens* Torr.) at low elevations and California red fir (*Abies magnifica* A. Murr.) at high elevations may rival California white fir for dominance. Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and California black oak (*Quercus kelloggii* Newb.) often occupy drier sites within the grove boundaries. Trees less commonly associated with giant sequoia include Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), Pacific yew (*Taxus brevifolia* Nutt.), Pacific dogwood (*Cornus nuttallii* Audubon), California hazel (*Corylus cornuta* var. *californica* [A. DC.] Sharp), white alder (*Alnus rhombifolia* Nutt.), Scouler willow (*Salix scoulerana* Barratt ex Hook.), bigleaf maple (*Acer macrophyllum* Pursh), bitter cherry (*Prunus emarginata* Dougl. ex Eaton), and canyon live oak (*Quercus chrysolepis* Liebm.).

Shrub species most often found in giant sequoia groves are bush chinquapin (*Castanopsis sempervirens* [Kell.] Dudl.), mountain misery (*Chamaebatia foliolosa* Benth.), mountain whitethorn (*Ceanothus cordulatus* Kell.), littleleaf ceanothus (*C. parvifolius* [Wats.] Trel.), deerbrush (*C. integerrimus* H. & A.), snowbrush (*C. velutinus* Dougl. ex Hook.), greenleaf manzanita (*Arctostaphylos patula* Greene), western azalea (*Rhododendron occidentale* [T. & G.] Gray), *Ribes* spp., *Rosa* spp., and *Rubus* spp. (Hartesveldt and others 1975, Harvey and others 1980, Rundel 1971, Schubert and Beetham 1962).

Stand structure and species frequency vary substantially with elevation, latitude, exposure, soil moisture, and time since fire or other disturbance. In general, protection of groves from fire has resulted in increased prevalence of white fir, reduced regeneration of giant sequoia and pines, and reduced density of shrubs. The age-class distribution of giant sequoia also varies widely among groves. Most groves today, however, appear to lack sufficient young giant sequoias to maintain the present density of mature trees in the future. In these groves, giant sequoia regeneration evidently has been declining over a period of 100 to 500 years or more (Rundel 1971).

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting

Male and female cone buds form on the same tree during late summer. Pollination takes place between the middle of April and the middle of May when the female conelets are only two or three times as large in diameter as the twigs bearing them. Fertilization usually occurs in August, by which time cones are almost full-size. Embryos develop rapidly during the next summer, and reach maturity at the end of the second growing season. The egg-shaped mature cones, 2 to 3.5 inches (5 to 9 cm) in length, yield an average of 200 seeds each (Hartesveldt and others 1975, Harvey and others 1980, Schubert and Beetham 1962).

Seed Production and Dissemination

Cones bearing fertile seeds have been observed on trees as young as 10 years of age, but the large cone crops associated with reproductive maturity usually do not appear before about 150 or 200 years. Unlike most other organisms, giant sequoia seems to continue its reproductive ability unabated into old age. The largest specimens (not necessarily the oldest) bear heavy crops of cones containing viable seeds (Hartesveldt and others 1975, Schubert and Beetham 1962).

Giant sequoias have serotinous cones which, at maturity, may remain attached to the stems without commencing seed dissemination. For 20 years or more, cones may retain viable seeds and continue to photosynthesize and grow, their peduncles producing annual rings which can be used to determine cone age (Hartesveldt and others 1975, Schubert and Beetham 1962).

A typical mature giant sequoia produces an average of 1500 new cones each year, although variability among trees and from year to year is great. Cones produced during years with ample soil moisture are more numerous (more than 20,000 cones on one large tree in an exceptional year) and yield seeds of greater viability than those produced in dry years. The upper third of the crown generally bears at least two-thirds of the cone crop. Because of extended cone retention, a mature tree may have 10,000 to 30,000 cones at any given time, two-thirds of which may be green and closed, and the remainder opened, brown, and largely seedless (Hartesveldt and others 1975, Harvey and others 1980).

Estimates of percent germination of seeds removed from green cones range from about 20 to 40 percent (Fins 1981, Harvey and others 1980, Stark 1968b). A number of variables, however, account for departures from these average values. Trees growing on rocky sites yield seeds with substantially higher germinability than those on bottom lands with deeper soils. Larger seeds germinate in higher percentages than small ones. In tests of cone age, germination increased from 20 percent for seeds from 2-year-old cones to 52 percent for 5-year-old cones, then dropped to 27 percent for cones 8 years of age. Germinability also varies with cone location in the crown, seed position within the cones, and among groves (Hartesveldt and others 1975). Artificial stratification of seeds for 60 days or more resulted in faster germination, but not in higher germination percent (Fins 1981).

Browning or drying of cones, with subsequent shrinkage of scales and dispersal of seeds, is brought about largely by three agents, two of which are animals. The more effective of the two is *Phymatodes nitidus* LeConte, a long-horned wood-boring beetle. The larvae of the beetle mine the fleshy cone scales and cone shafts, damaging occasional seeds only incidentally. As vascular connections are severed, scales successively dry and shrink, allowing the seeds to fall. Cones damaged during the summer will open several scales at a time, beginning during late summer and fall, and continuing for 6 months to 1 year. Cone and seed insects other than *Phymatodes* have only a minor impact on seed production (Harvey and others 1980).

The second animal having a significant role in giant sequoia regeneration is the chickaree or Douglas squirrel *(Tamiasciurus douglasii)*. The fleshy green scales of younger sequoia cones are a major food source for the squirrel. The seeds, too small to have much food value, are dislodged as the scales are eaten. During years of high squirrel densities, the animals tend to cut large numbers of cones and store and eat them at caches. When squirrels are few, most of the cone consumption is in tree crowns—a habit more conducive to effective seed dispersal. The squirrels are active all year (Harvey and others 1980).

The chickaree prefers cones 2 to 5 years old, whereas *Phymatodes* is most prevalent in cones at least 4 years old. The combined activities of these animals help to ensure that seeds of all age classes are shed, and that rate of seedfall is roughly constant throughout the year and from year to year, despite variability in new cone production. An average rate is about 400,000 seeds per acre (1,000,000/ha) per year (Harvey and others 1980).

The third and perhaps most important agent of seed release is fire. Hot air produced by locally intense fire and convected high into the canopy can dry cones, resulting in release of enormous quantities of seed over small areas—for example, 8,000,000 per acre (20,000,000/ha) (Harvey and others 1980). This increased seedfall coincides both spatially and temporally with fire-related seedbed conditions favorable for seed germination and seedling survival.

Giant sequoia seeds are well adapted for wind dispersal. They are light (average 91,000/lb [200,000/kg]) and winged, and fall in still air at a rate of 4 to 6 ft (1.2 to 1.8 m) per second. Winds common in late summer and winter storms in the Sierra Nevada can disperse seeds more than 0.25 mi (0.4 km) from the tall crowns of mature trees (Hartesveldt and others 1975, Schubert and Beetham 1962).

Birds and mammals exert a negligible effect on giant sequoia seeds on the ground. Because they are small and contain little energy, sequoia seeds consistently rank at or near the bottom in food preference tests that include seeds of associated species (Harvey and others 1980, Stark 1968b).

Seedling Development

Natural reproduction in giant sequoia is an unusually tenuous process. Of the enormous numbers of seeds shed each year, few encounter the combination of conditions necessary for seedling establishment.

In contrast with most coniferous seeds, a large majority of seeds of giant sequoia die from desiccation and solar radiation soon after reaching the forest floor, especially during the summer. In one study, viability of seeds removed from fresh cones and placed on the ground dropped from 45 percent to zero in 20 days. Seeds collected from the forest floor showed an average viability of 1 percent (Harvey and others 1980).

Seed dormancy is not evident in giant sequoia, so surviving seeds germinate as soon as conditions are favorable (Harvey and others 1980). The most significant requirement for germination is an adequate supply of moisture and protection of the seed from desiccation. This is best provided by moist, friable mineral soil that covers the seed to a depth of about 0.4 inch (1 cm), and that is partially shaded to reduce surface drying. A wide range of temperatures is acceptable for germination. The generally sandy soils of the groves normally provide the additional requirement of adequate aeration and the optimum pH range of 6 to 7 (Stark 1968b). Because of rapid percolation, however, moisture retention for germination and initial root development is often marginal.

Seeds dropped just before the first snow or just as the snow melts may have the best chance of germinating and becoming successfully established. Seedlings that produce roots early in the season during favorable soil moisture conditions are more likely to survive the dry summer. The first stage of germination—extension of the radicle—sometimes takes place beneath the snow (Hartesveldt and others 1975).

Thick litter usually dries too quickly for seeds to germinate, and virtually all seedlings that do get started die before their roots can penetrate to mineral soil (Harvey and others 1980, Schubert and Beetham 1962). Only in exceptionally wet years do significant numbers of seedlings become established on undisturbed forest floor. The role of damping-off fungi in the mortality of natural giant sequoia seedlings is not well known (Bega 1981), but they are almost certainly a greater problem on thick litter than on mineral soil. After seedlings are established on more favorable seedbeds, a light covering of litter can moderate soil surface temperatures and retard drying (Stark 1968a).

Seedlings rarely become established in dense grass cover, probably because moisture is depleted in the surface soil early in the season (Schubert and Beetham 1962).

Soil disturbance, along with increased availability of light and moisture, resulting from early logging in some of the groves has led to establishment of several fine young-growth stands dominated by giant sequoia. Mechanical seedbed preparation is currently a legitimate regeneration option in some groves, although such treatment is inconsistent with management direction in most of the natural range of the species.

Of the various types of natural disturbances that may remove litter and bare mineral soil, fire is undoubtedly the most significant. Locally intense or highly consumptive fires are more effective than light surface fires or physical disturbance in promoting germination and subsequent seedling survival and early growth (Harvey and others 1980). The resulting short-lived friable soil condition facilitates seed penetration beneath the surface and root penetration after germination. Increased wettability in the surface soil layers resulting from high temperatures appears to improve water penetration and retention in the zones important for seeds and young seedlings. Fire also may kill some understory trees, thereby providing more light to speed the development (especially root penetration) of the shade-intolerant giant sequoia seedlings. Additional benefits include providing a surge of available nutrients, reducing populations of fungi potentially pathogenic to seedlings, and killing seeds and rootstocks of competing vegetation (Harvey and others 1980).

On the other hand, the dark surface and possibly increased insolation resulting from fire may cause more desiccation and heat killing of giant sequoia seeds and seedlings at the surface. Also, populations of endomycorrhizal fungi may be severely reduced temporarily (Harvey and others 1980). And low-consumption fires, rather than reducing competing vegetation, may instead greatly stimulate germination and sprouting of shrubs. Partially burned litter, in terms of its suitability for successful seedling establishment, ranks between undisturbed forest floor and areas subjected to hot fires (Stark 1968b).

First year giant sequoia seedlings established on treated—bulldozed or burned or both—areas were 30 to 150 times more numerous than those on undisturbed forest floor (Harvey and others 1980). Mortality of first-year seedlings during the 3 summer months on one treated area averaged 39 percent, with an additional 25 percent dying during the next 9 months. Desiccation was the primary cause of mortality in the summer. During a year of increased seasonal precipitation, mortality attributable to desiccation decreased, whereas that caused by insects increased to 25 percent of total mortality. Heat canker, damage by birds and mammals, and fungal attacks were of minor importance.

In the same study, direct mortality of first-year seedlings due to insect predation ranged from 3 to 18 percent of all seedlings present. Some of the significant additional insect damage probably caused delayed mortality. Largest seedling losses were in areas recently disturbed, especially by fire, probably because alternative food sources were reduced temporarily. Insects responsible for the damage were early instars of *Pristocauthophilus pacificus* Thomas, a camel cricket, and larvae of the geometrids *Sabulodes caberata* Gn. and *Pero behrensaria* Packard.

Survival of sequoia seedlings for a 7- to 9-year period was 27 percent on areas subjected to a hot burn as opposed to 3.5 percent on other treated substrates. No seedlings survived in undisturbed areas. In another instance, only 1.4 percent of seedlings established following light surface burning were alive after two summers. Mortality slows substantially after the first 2 or 3 years. At the end of 3 years, surviving seedlings usually have root systems that penetrate the soil to depths that supply adequate moisture through the summer, or to about 14 inches (36 cm).

Height growth of giant sequoia seedlings in the groves is relatively slow during the first few years, presumably due to competition for light and moisture from the larger trees. Seedlings 7 to 10 years old grew at an average rate of about 1.6 inches (4 cm) per year. Periodic annual height increment from 10 to 20 years was only 2 inches (5 cm). Seedlings grew significantly faster on areas subjected to hot burns than they did elsewhere (Harvey and others 1980). In contrast, giant sequoia seedlings in the open grow rapidly, and, given an even start, can outgrow any associated tree species. Height growth up to 24 inches (60 cm) per year is not uncommon (Fins 1979).

Up to 2 or 3 years of age, seedlings growing in dense shade (less than 25 percent of full sunlight) survive about as well as others, but grow poorly and develop abnormally (Stark 1968a). At higher light levels, one study found moderate reduction in height growth compared with seedlings in full sunlight (Stark 1968a), whereas another study found no significant effect of reduced light on height growth (Harvey and others 1980). The adverse effects of shade on older giant sequoias are more conspicuous with respect to both mortality and growth reduction.

Vegetative Reproduction

Giant sequoias up to about 20 years of age may produce stump sprouts after injury (Libby 1981). Unlike redwood (*Sequoia sempervirens* [D. Don] Endl.), older trees normally do not sprout from stumps or roots. Piirto and others (1986), however, reported sprouts on two small stumps from suppressed trees about 85 years old. Giant sequoias of all ages may sprout from the bole when old branches are lost by fire or breakage (Harvey and others 1980, Schubert and Beetham 1962).

Cuttings from juvenile donors root quickly and in high percentages (94 percent average) (Fins 1982).

Sapling and Pole Stage to Maturity

Growth and Yield

One tree species has a greater diameter than giant sequoia, three grow taller, and one lives longer (Hartesveldt and others 1975). In terms of volume, however, the giant sequoia is undisputedly the world's largest tree. The most massive specimen, the General Sherman tree, located in Sequoia National Park, has an estimated bole volume of 52,500 ft^3 (1490 m^3) (Flint 1981). The greatest known height for the species is 310 ft (94.5 m), and the greatest mean diameter at breast height (d.b.h.)—for the General Grant tree, in Kings Canyon National Park—is 28.9 ft (8.8 m). The indicated mean d.b.h. includes a large abnormal buttress. Excluding this abnormality gives a more realistic estimate of the maximum mean d.b.h. for the species—approximately 27.0 ft (8.2 m) (Flint 1981). Mature specimens commonly reach a diameter of 10 to 20 ft (3 to 6 m) above the butt swell and average about 250 ft (76 m) in height (Hartesveldt and others 1975).

A notable characteristic of mature giant sequoias that contributes substantially to their great volume is the slight taper of the bole—a feature more prominent in this species than in any other Sierra Nevada conifer (Hartesveldt and others 1975). In contrast, young open-grown giant sequoias taper markedly.

The greatest known age of a giant sequoia is 3200 years, determined from a stump count of rings (Hartesveldt and others 1975). Calculations based on increment borings yield age estimates of 2000 to 3000 years for many living trees.

Beyond the seedling stage, giant sequoia unhindered by an overstory continues to grow at least as well as associated species of the same age. In a survey of California plantations up to 50 years old in which giant sequoia had been planted, it outgrew other conifers (mostly ponderosa pine) in most instances in which species differed significantly in height or diameter growth. In the best plantations, giant sequoia averaged 1.6 to 2.3 ft (0.5 to 0.7 m) per year in height growth, and 0.5 to 0.8 inch (1.3 to 2.0 cm) in diameter growth per year (Fins 1979).

The growth and yield and wood properties of young-growth giant sequoia are discussed in detail in other papers in these proceedings (Dulitz 1986, Piirto 1986). Suffice it to say here that the species has been planted widely and often successfully in many parts of the world. Not only is it highly regarded as an ornamental, but many foresters see considerable potential for giant sequoia as a major timber-producing species of the world (Libby 1982).

In old-growth groves, rapid height growth continues on better sites for at least 100 years, producing dense conical crowns. At 400 years, trees range in height from about 110 to 240 ft (34 to 73 m). The rate of height growth declines beyond 400 years, and the typical tree levels off near 250 ft (76 m) at an age of 800 years to 1500 years (Harvey and others 1980).

Analysis of a large old-growth population showed average d.b.h. of 1.6 ft (0.5 m) at 100 years, 4.3 ft (1.3 m) at 400 years, 7.2 ft (2.2 m) at 800 years, and 14.0 ft (4.3 m) at 2000 years (Harvey and others 1980).

Although radial growth gradually decreases with age, volume increment generally is sustained into old age. The General Sherman tree, at an approximate age of 2500 years, has a current radial growth rate at breast height of about 0.04 inch (1 mm) per year (Hartesveldt and others 1975). Average volume increment for this tree since 1931 has been estimated by different methods at 40 ft^3 (1.13 m^3) per year (Hartesveldt and others 1975) and 51 ft^3 (1.44 m^3) per year (Flint 1981). Therefore, the world's largest tree also may be, in terms of volume increment, the world's fastest-growing tree. A related conclusion can be applied to the species: the enormous size attained by giant sequoia results not only from its longevity, but also—despite the apparent decadence of most veterans—from its continued rapid growth into old age (Hartesveldt and others 1975).

Rooting Habit

During the first few years, the root system of giant sequoia seedlings consists of a taproot with few laterals—a habit that facilitates survival during dry summers (Schubert and Beetham 1962). The ratio of root length to shoot height during this period is about 2 to 2.5, with drier sites having higher ratios (Harvey and others 1980). After 6 to 8 years, lateral root growth predominates, and elongation of the taproot practically stops (Schubert and Beetham 1962).

Roots of a mature tree commonly extend 100 ft (30 m) or more from the bole in well-drained soils, and occupy an area of 0.7 acre (0.3 ha) or more. Along drainage bottoms or edges of meadows, the radial extent of the root system may be no more than 40 to 50 ft (12 to 15 m). The largest lateral roots are usually no more than 1 ft (0.3 m) in diameter. Few roots extend deeper than 3 ft (1 m) and even less in areas with a high water table. Most of the abundant feeder roots are within the upper 2 ft (0.6 m) of soil. Concentrations of feeder roots often are high at the mineral soil surface (Hartesveldt and others 1975).

Immature trees, both in the groves and in older plantings, are notably windfirm (Libby 1982). Considering the shallowness of the root system and the great above-ground mass of large mature giant sequoias, however, it is remarkable that so many of them—especially leaners—remain standing for so long (Hartesveldt and others 1975).

Root grafting is common in giant sequoia (Hartesveldt and others 1975, Schubert and Beetham 1962).

Reaction to Competition

Giant sequoia is shade-intolerant throughout its life. Of its common coniferous associates, ponderosa pine also is intolerant, sugar pine is intermediate in tolerance, incense-cedar is intermediate to tolerant, and California white fir is tolerant (Harvey and others 1980).

Fires or other disturbances that bare mineral soil and open the canopy characteristically benefit intolerant species, including giant sequoia, and move plant communities to earlier successional stages. In contrast, successful regeneration of giant sequoia in shade and in the absence of disturbance is less likely than that of any associated conifer (Harvey and others 1980). Also, young seedlings cannot tolerate low soil moisture, including that induced by competing vegetation.

Once established and with adequate light, young giant sequoias maintain dominance over competitors through rapid growth, and at maturity are the tallest trees in the forest. In dense thickets, however, young trees stagnate and recover slowly if released (Schubert and Beetham 1962).

Although conspicuous in late successional communities dominated by California white fir, giant sequoia is not a true climax-stage species, because it fails to reproduce itself successfully in an undisturbed forest. Instead, mature trees are successional relicts because they live for many centuries while continuing to meet their light requirements by virtue of their emergent crowns (Hartesveldt and others 1975).

If various natural agents of disturbance—especially fire—operated freely, giant sequoia groves would consist of a roughly steady-state mosaic of even-aged groups of trees and shrubs in various stages of succession. The patchy nature of vegetational units would correspond to the pattern of disturbances. In the absence of disturbance, however, successional pathways converge toward a multilayered climax forest of pure California white fir (Bonnicksen and Stone 1981). Since the advent of fire suppression, density of California white fir has in fact increased markedly, while densities of early successional stage species have decreased (Parsons and DeBenedetti 1979).

Damaging Agents

Fire is the most universal and probably most serious damaging agent of giant sequoia in its natural range (Schubert and Beetham 1962). Seedlings and saplings of giant sequoia, like those of most other tree species, are highly susceptible to mortality or serious injury by fire. However, in those locations most favorable for successful establishment and early growth—that is, mineral soil seedbeds and well-lighted openings—fuels tend to be sparser and to accumulate more slowly than in adjacent forested areas. The more vigorous seedlings and saplings thus may be large enough to survive a light fire by the time one occurs.

Larger giant sequoias, because of their thick nonresinous bark and elevated crowns, are more resistant to fire damage than are associated species. Nevertheless, repeated fires over the centuries sear through the bark at a tree's base, kill the cambium, and produce an ever-enlarging scar. Almost all of the larger trees have fire scars, many of which encompass much of the basal circumference (Hartesveldt and others 1975). Few veterans have been killed by fire alone, but consequent reduction in supporting wood predisposes a tree to falling. Furthermore, fire scars provide entry for fungi responsible for root disease and heartrot (Piirto and others 1984). Decayed wood, in turn, is more easily consumed by subsequent fires. The net result is further structural weakening of the tree. In addition, fire scars have been cited as the main cause of dead tops, so common in older trees (Rundel 1973).

Lightning strikes, besides starting ground fires, sometimes knock out large portions of crowns or ignite dead tops. Mature trees seldom are killed by lightning, however (Hartesveldt and others 1975).

Old giant sequoias most commonly die by toppling. Weakening of the roots and lower bole by fire and decay is primarily responsible (Hartesveldt and others 1975, Piirto and others 1984). The extreme weight of the trees coupled with their shallow roots increases the effects of this weakening, especially in leaning trees. Other causative factors include wind, water-softened soils, undercutting by streams, and heavy snow loads (Hartesveldt and others 1975).

Disease and insect relationships are discussed by Parmeter (1986).

Of various types of human impact on giant sequoia in the groves (Hartesveldt and others 1975, Harvey and others 1980, Piirto and others 1984), the most significant has been fire exclusion. The damage caused by fire is outweighed by its benefits in perpetuating the species. As indicated earlier, fire is necessary to create and maintain conditions favorable for regeneration (Harvey and others 1980). Furthermore, the infrequency of fires has permitted a large buildup of both dead and live fuels and an associated increase in the potential for catastrophic crown fires. Agencies responsible for managing most of the groves have programs designed to reintroduce fire into giant sequoia ecosystems. An important part of these proceedings consists of descriptions by agency representatives of such fire management activities and other aspects of their overall management strategy for giant sequoia (Benson 1986, Harrison 1986, Heald 1986, Parsons and Nichols 1986, Rogers 1986).

REFERENCES

Bega, Robert V., Pacific Southwest Forest and Range Experiment Station, Berkeley, CA. [Telephone conversation with C. Phillip Weatherspoon]. January 1981.

Benson, Norman J. Management of giant sequoia on Mountain Home Demonstration State Forest. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 30–31.

Bonnicksen, Thomas M.; Stone, Edward C. The giant sequoia-mixed conifer forest community characterized through pattern analysis as a mosaic of aggregations. Forest Ecol. and Manage. 3: 307-328; 1981.

Dulitz, David. Growth and yield of giant sequoia. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 14–16.

Eyre, F. H., ed. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters; 1980. 148 p.

Fins, Lauren. Genetic architecture of giant sequoia. Berkeley: University of California; 1979. 237 p. Ph.D. Dissertation.

Fins, Lauren. Seed germination of giant sequoia. Tree Planters' Notes 32(2): 3-8; 1981.

Fins, L.; Libby, W. J. Population variation in *Sequoiadendron:* seed and seedling studies, vegetative propagation, and isozyme variation. Silvae Genetica 31(4): 102-110; 1982.

Flint, Wendell D. [Letter to C. Phillip Weatherspoon]. 1981 March 9. 1 leaf. Located at: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Redding, CA.

Ford-Robertson, F. C., ed. Terminology of forest science, technology, practice and products. Washington, DC: Society of American Foresters; 1971. 349 p.

Harrison, Wayne. Management of giant sequoia at Calaveras Big Trees State Park. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 40-42.

Hartesveldt, Richard J.; Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. The giant sequoia of the Sierra Nevada. Washington, DC: U.S. Department of the Interior, National Park Service; 1975. 180 p.

Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. Giant sequoia ecology. Sci. Monogr. Series 12. Washington, DC: U.S. Department of the Interior, National Park Service; 1980. 182 p.

Heald, Robert C. Management of giant sequoia at Blodgett Forest Research Station. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 37-39.

Libby, W. J. Some observations on *Sequoiadendron* and *Calocedrus* in Europe. California Forestry and Forest Products 49. Berkeley: University of California, Forest Products Laboratory; 1982. 12 p.

Libby, William J., University of California, Berkeley. [Telephone conversation with C. Phillip Weatherspoon]. February 1981.

Mallory, James I., California State Cooperative Soil-Vegetation Survey, Redding, CA. [Telephone conversation with C. Phillip Weatherspoon]. February 1981.

Parmeter, John R., Jr. Diseases and insects of giant sequoia. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 11-13.

Parsons, David J.; DeBenedetti, Steven H. Impact of fire suppression on a mixed-conifer forest. Forest Ecol. and Manage. 2: 21-33; 1979.

Parsons, David J.; Nichols, H. Thomas. Management of giant sequoia in the National Parks of the Sierra Nevada, California. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 26-29.

Piirto, Douglas D. Wood of giant sequoia: properties and unique characteristics. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 19-23.

Piirto, Douglas D.; Hawksworth, W. John; Hawksworth, Marjorie M. Giant sequoia sprouts. J. For. 84 (9): 24-25; 1986.

Piirto, Douglas D.; Wilcox, W. Wayne; Parmeter, John R.; Wood, David L. Causes of uprooting and breakage of specimen giant sequoia trees. Bull. 1909. Berkeley: Division of Agriculture and Natural Resources, University of California; 1984. 14 p.

Rogers, Robert R. Management of giant sequoia in the National Forests of the Sierra Nevada, California. In: Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., tech. coords. Proceedings of the workshop on management of giant sequoia; May 24-25, 1985; Reedley, California. Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986: 32-36.

Rundel, Philip W. The distribution and ecology of the giant sequoia ecosystem in the Sierra Nevada, California. Durham, NC: Duke University; 1969. 204 p. Ph.D. Dissertation.

Rundel, Philip W. Community structure and stability in the giant sequoia groves of the Sierra Nevada, California. Am. Midland Nat. 85(2): 478-492; 1971.

Rundel, Philip W. Habitat restriction in giant sequoia: the environmental control of grove boundaries. Am. Midland Nat. 87(1): 81-99; 1972.

Rundel, Philip W. The relationship between basal fire scars and crown damage in giant sequoia. Ecology 54(1): 210-213; 1973.

Schubert, Gilbert H. (revised by N. M. Beetham). Silvical characteristics of giant sequoia. Tech. Pap. 20. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1962. 16 p.

Stark, N. The environmental tolerance of the seedling stage of *Sequoiadendron giganteum.* Am. Midland Nat. 80(1): 84-95; 1968a.

Stark, N. Seed ecology of *Sequoiadendron giganteum.* Madrono 19(7): 267-277; 1968b.

Weatherspoon, C. Phillip. Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz). In: Silvics of North America. Washington, DC: U.S. Department of Agriculture; [In press].

Zinke, Paul J.; Crocker, Robert L. The influence of giant sequoia on soil properties. Forest Sci. 8(1): 2-11; 1962.

Diseases and Insects of Giant Sequoia[1]

John R. Parmeter, Jr.[2]

Abstract: Giant sequoias (*Sequoiadendron giganteum* [Lindl.] Buchholz) are susceptible to a number of diseases and insects at each state of development from seeds to overmature trees. We presently have little more than a catalog of occurrences. The impacts and the management implications of disease and insect losses have scarcely been investigated or evaluated, and much study is needed to provide data for sound management and protection of giant sequoia stands.

Management implications of disease and insect impacts in stands of giant sequoias (*Sequoiadendron giganteum* [Lindl.] Buchholz) are largely speculative, and available information is mainly descriptive or anecdotal. Review of standard lists of pathogens (Anon. 1960, Bega 1978, Hepting 1971, Peace 1962) or insects (Furniss and Carolin 1977, Keen 1952) of forest trees indicates that few pests of giant sequoia have been described. Giant sequoia is not even mentioned in Boyce's (1948) classic text on forest pathology. Pathogens (Bega 1964), fungi (Piirto and others 1984a), and insects (Stecker 1980a) on sequoia have been listed, and a few nematodes have been described (Cid del Prado and Lownsbery 1984, Maggenti and Viglierchio 1975). Knowledge of sequoia pests is gradually increasing, but—in general—their management implications are assessed mainly by extrapolation from what is known about similar pests of other species.

I have not attempted an exhaustive listing of references to diseases and insects of giant sequoia. I have, rather, selected references that provide good literature lists or that provide information bearing directly on evaluation of pest potentials in managed stands.

Pests become problems when they adversely affect the realization of management goals to an unacceptable degree. Pests do this by interfering with stand regeneration, development, and productivity. In stands managed for recreation or preservation, tree longevity and visitor safety may also be important.

REGENERATION

Factors affecting regeneration of giant sequoia were reviewed by Harvey and others (1980). They indicated that sequoias annually produce large numbers of seeds, the release of which is due in part to the activity of the cone beetle (*Phymatodes nitidus*). Seedling survival is rare in undisturbed duff and litter. Where mineral soil is exposed by fire or scarification, seedlings can become established, but not without considerable loss.

Seedling losses on suitable beds were attributed mainly to insect grazing and to desiccation, of which desiccation was by far the most important (Harvey 1980, Stecker 1980b). Insects variously injured large numbers of seedlings. Final mortality attributed to insects varied on study plots, with averages of about 6–25 percent in different years (Harvey 1980) but almost 30 percent on one plot (Stecker 1980b). Most insect damage occurred on first-year seedlings and was heavier on recent burns than on areas burned 2 or more years before seeding, presumably because in the first year or two after burning, sequoia seedlings were about the only plants available. The camel cricket (*Pristocauthophilus pacificus*) and two geometrids (*Sabuloides caberata* and *Pero behresarius*) were prominent among seedling grazers (Stecker 1980b). Cutworms (*Noctuidae* spp.) have also been reported to destroy giant sequoia seedlings (Metcalf 1948). Any general grazers apparently can kill seedlings.

In closely related coast redwood (*Sequoia sempervirens* [D. Don] Endl.), cone and seed molds are associated with reduced seed viability. Damping-off and rootrot fungi are major factors in preventing seedling establishment in undisturbed duff and litter (Davidson 1971, Muelder and Hansen 1961). Research will likely show a similar situation in giant sequoia, especially since the effects of desiccation and disease can be difficult to separate.

Regeneration by planting requires nursery seedlings, and several pathogens can cause heavy losses of giant sequoia seedlings in nurseries, especially charcoal root disease caused by *Macrophomina phaseoli* and grey mold caused by *Botrytis cinerea* (Peterson and Smith 1975). Cultural and chemical methods are available to control nursery diseases, and care should be taken to see that healthy seedlings are planted.

STAND DEVELOPMENT

Little is known about how diseases and insects might affect developing, young-growth stands, especially those within the native range. Trees planted outside the native range in California (Bega 1964) or abroad (Libby 1981) can be severely damaged by a canker fungus (*Botryosphaeria* sp.) or by *Armillaria mellea*. Stumps of coast redwood are susceptible to colonization by *F. annosus*; therefore, giant sequoia stumps probably would also be colonized (Cobb and Barber 1968). Because *F. annosus* attacks sequoia roots (Piirto and others 1974), managers should recognize the possibility that this pathogen could cause problems in thinned stands or stands established after cutting.

Because a number of insects have been recorded on giant sequoia, some probably could become problems in managed stands. The wood borer (*Trachykele opulenta*) reportedly kills trees stressed by road or stream cuts (Hartesveldt and others

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1975), but killing by other insects is virtually unknown. In fact, Fowells (1965) stated: "None of the insects or diseases reported on giant sequoia has caused the death of a single tree." Giant sequoia is also one of the trees most resistant to "smog" damage (Miller 1978).

MATURITY

Maturity and decline of giant sequoia stands have been studied in some detail because of the recreational and specimen values of large, old trees. Historical, popular, and scientific accounts generally agree that mature giant sequoias seldom—if ever—are killed by insects or diseases. Excluding lethal fire, lightning, or other environmental damage, death of large trees generally results from uprooting or from stem breaking. Of 33 failures of big trees, 7 (21 percent) apparently fell mainly because of poor footing (wet soil, stream undercutting, etc.), 22 (67 percent) because of the failure of decayed roots, and 4 (12 percent) because of stem breaks (Piirto and others 1984b). All but 2 trees (both fell because of poor footing) had decay in either the stem or roots. Carpenter ants were found in 16 trees but appeared to contribute to failure of only 6. Fire scars were present in 27 trees and 26 fell to the fire-scarred side. Hartesveldt and others (1975) reported that 90 percent of the scarred trees fell to the scarred side.

Early beliefs held by Muir and others (see Piirto 1977 for discussion) that giant sequoias have no insect or disease problems are not tenable. While trees in native stands obviously resist much disease and insect attack, they eventually succumb to the sorts of decays and insects that limit the ages of other species of trees. Most records suggest that these effects of diseases and insects occur mainly in very old trees and would be a factor only in the management of "specimen" trees in park and recreational settings. However, because we lack knowledge of the losses that might have occurred in younger trees during grove development, we cannot be comfortable with the assumption that only very old trees will be injured or killed by insects and diseases.

Full assessment of pest impacts in mature sequoias will require additional study, but existing data (Piirto 1977, Piirto and others 1984b) suggest two important management implications:

1. Decay and carpenter ant activity were usually associated with fire scars. This may mean that protection of trees from fire scarring could increase longevity and decrease hazard to visitors. Such protection would involve mainly the removal of fuels from around the bases of specimen trees.

2. White firs serve as "pasture" for the aphids tended by carpenter ants (Tilles and Wood 1982, David and Wood 1980) and are highly susceptible to decay fungi that also attack giant sequoia roots. This may mean that white fir encroachment in giant sequoia stands might lead to increased insect and disease activity. Therefore, prescribed burning to reduce fir encroachment may also reduce the disease inoculum and the support for carpenter ant populations. Contrary to earlier reports (Hartesveldt and others 1975), food left by visitors does not appear to increase carpenter ant populations.

Intensive forest management often leads to increased pest problems, and it would be surprising if this were not the case with giant sequoia. It would certainly be prudent to learn as much as we can as fast as we can if we are to undertake large-scale planting of giant sequoia.

REFERENCES

Anon. Index of plant diseases in the United States. Agric. Handb. 165. Washington, DC: U.S. Department of Agriculture; 1960. 531 p.

Bega, R. V. Diseases of sequoia. In: Diseases of widely planted forest trees. FAO/IUFRO Symposium on internationally dangerous forest diseases and insects; Oxford: 20–30 July 1964. 1964:131–139.

Bega, R. V., tech. coord. Diseases of Pacific Coast conifers. Agric. Handb. 521. Washington, DC: U.S. Department of Agriculture; 1978. 206 p.

Boyce, J. S. Forest pathology. New York: McGraw-Hill; 1948. 550 p.

Cid del Prado, V.; Lownsbery, B. F. Histopathology and host range studies of the redwood nematode *Rhizonema sequoiae*. J. Nematol. 16(1):68–72; 1984.

Cobb, F. W., Jr.; Barber, H. W., Jr. Susceptibility of freshly cut stumps of redwood, Douglas fir, and ponderosa pine to *Fomes annosus*. Phytopathology 58(11):1551–1557; 1968.

David, C. T.; Wood, D. L. Orientation to trails by a carpenter ant *Camponotus modoc* (Hymenoptera, Formicidae) in a giant sequoia forest. Can. Entomol. 112(10):993–1000; 1980.

Davidson, J. G. N. Pathological problems in redwood regeneration from seed. Berkeley: University of California; 1971. 288 p. Dissertation.

Fowells, H. A., comp. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; 1965. 762 p.

Furniss, R. L.; Carolin, V. M. Western forest insects. Misc. Publ. 1339. Washington, DC: Forest Service, U.S. Department of Agriculture; 1977. 654 p.

Hartesveldt, R. J.; Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. The giant sequoia of the Sierra Nevada. Washington, DC: U.S. Department of the Interior, National Park Service; 1975. 180 p.

Harvey, H. T. Giant sequoia reproduction, survival, and growth. In: Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. Giant sequoia ecology, fire and reproduction. Washington, DC: U.S. Department of Interior, National Park Service, Sci. Monogr. Series 12:41–68; 1980.

Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. Giant sequoia ecology, fire and reproduction. Washington, DC: Department of the Interior, National Park Service, Sci. Monogr. Series 12; 1980. 182 p.

Hepting, G. H. Diseases of forest and shade trees of the United States. Agric. Handb. 386. Washington, DC: U.S. Department of Agriculture; 1971. 658 p.

Keen, F. P. Insect enemies of western forests. Misc. Publ. 273. Washington, DC: U.S. Department of Agriculture; 1952. 280 p.

Libby, W. J. Some observations on *Sequoiadendron* and *Calocedrus* in Europe. Calif. For. and Forest Prod. 49. Berkeley: University of California; 1981. 12 p.

Maggenti, A. R.; Viglierchio, D. R. *Sequoia sempervirens* and *Sequoiadendron giganteum:* hosts of common plant-parasitic nematodes of California. Plant Dis. Rep. 59(2):116–119; 1975.

Metcalf, W. Youthful years of the big tree. Pac. Discovery 1(3):4–10; 1948.

Miller, Paul R. 1. Abiotic diseases. In: Bega, R. V., tech. coord. Diseases of Pacific Coast conifers. Agric. Handb. 521. Washington, DC: U.S. Department of Agriculture; 1978:5–41.

Muelder, D. W.; Hansen, J. H. Biotic factors in natural regeneration of *Sequoia sempervirens*. In: Proceedings, 13th Congress, International Union of Forest Research Organizations. Part 2, Volume 1. Vienna; 1961.

Peace, T. R. Pathology of trees and shrubs. Oxford: Clarendon Press; 1962. 753 p.

Peterson, G. W.; Smith, R. S. Jr., tech. coords. Forest nursery diseases in the United States. Agric. Handb. 470. Washington, DC: U.S. Department of Agriculture; 1975. p. 125.

Piirto, D. D. Factors associated with tree failure of giant sequoia. Berkeley, University of California; 1977. 155 p. Dissertation.

Piirto, D. D.; Parmeter, J. R., Jr.; Cobb, F. W., Jr. *Fomes annosus* in giant sequoia. Plant Dis. Rep. 58:478; 1974.

Piirto, D. D.; Parmeter, J. R., Jr.; Wilcox, W. W. Basidiomycete fungi reported on living or dead giant sequoia or coast redwood. Calif. For. and Forest Prod. 55. Berkeley: University of California; 1984a. 4 p.

Piirto, D. D.; Wilcox, W. W.; Parmeter, J. R., Jr.; Wood, D. L. Causes of uprooting and breakage of specimen giant sequoia trees. Bull. 1909. Berkeley: University of California, Div. Agric. and Nat. Resour.; 1984b. 12 p.

Stecker, R. E. Arthropods associated with the giant sequoia. In: Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. Giant sequoia ecology, fire and reproduction. Washington, DC: National Park Service, U.S. Department of the Interior. Sci. Monogr. Series 12:69–82; 156–162; 1980a.

Stecker, R. E. The role of insects in giant sequoia reproduction. In: Harvey, H. T.; Shellhammer, H. S.; Stecker, R. E. Giant sequoia ecology, fire and reproduction. Washington, DC: National Park Service, U.S. Department of the Interior. Sci. Monogr. Series 12:83–100; 1980b.

Tilles, D. A.; Wood, D. L. The influence of carpenter ant (*Camponotus modoc*) (Hymenoptera, Formicidae) attendance on the development and survival of aphids (*Cinara* spp.) (Homoptera, Aphididae) in a giant sequoia forest. Can. Entomol. 114(2):1133–1142; 1982.

Growth and Yield of Giant Sequoia[1]

David J. Dulitz[2]

Abstract: Very little information exists concerning growth and yield of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz). For old-growth trees, diameter growth is the single factor adding increment since maximum height has been obtained. Diameter growth averages 0.04 inches per year in normal old-growth trees but will fluctuate with changes in the surrounding environment. Growth plots in natural California young-growth stands indicate stand yields of 629 board feet per acre mean annual increment at age 86. Planted European stands 76 to 122 years old have shown yields of between 285 and 601 cubic feet per acre mean annual increment. Growth of giant sequoia has far surpassed the volume production from other North American conifers grown in West Germany or Belgium.

Available information on growth and yield of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) is limited, partly due to its restricted natural range and its relative unimportance as a commercial timber species. Giant sequoia has been established in plantations both inside and outside of its natural range. Natural and artificial stands are being considered for timber management in some areas. With this added emphasis on management of the species, along with the maturing of artificially regenerated stands, information on growth and yield has gained importance.

Giant sequoia rarely grows naturally in pure stands. It is most often a minor component in the mixed conifer type in the Sierra Nevada. Estimates of stand growth must be inferred from individual tree growth information, rarely occurring pure natural stands, or from plantations.

Growth of giant sequoia is dependent on site quality. In natural stands giant sequoia tends to dominate high quality sites, Dunnings' site I and II (Dunning 1942). This, in a way, tends to expand the applicability of local yield information over a broad range of natural stands because they occur on similar sites.

OLD GROWTH

Maximum heights of individual old growth trees tend to be site dependent, averaging 250–275 feet (Hartesveldt 1975). Maximum heights tend to decrease towards the south in the tree's natural range. Because maximum height has been obtained in almost all old growth trees, diameter growth is the single factor adding increment to the tree's volume.

Studies in the Mariposa Grove within Yosemite National Park show that in normal undisturbed old-growth trees, radial growth is fairly constant, averaging 0.04 inch per year (Hartesveldt 1962). Fluctuations in diameter growth can occur after a disturbance such as road building, paving, soil trampling, or a change in soil moisture in the vicinity of a tree. In many cases these types of disturbances resulted in an increase in diameter growth. This was mainly due to an increase in soil moisture from a reduction in competing vegetation.

Visual observations of historical diameter growth on windfallen trees in Mountain Home State Forest, Tulare County, show a cyclical growth fluctuation in some cases, which may be due to crown damage from wind, snow, or lightning. This damage would result in a reduction in the photosynthetic potential of the tree's crown. Changes in the surrounding stand may also cause a cyclical diameter-growth pattern due to a change in competition for light or water.

A release study on Mountain Home State Forest showed an increase in diameter growth of individual trees after removal of the surrounding stand in a logging operation. Twelve trees, 24 to 62 inches in diameter, averaged 0.13 inch of diameter growth per year before logging of the surrounding stand. After logging, the trees averaged 0.31 inch of diameter growth per year. These trees in general appearance resembled old growth giant sequoia more than they did young growth, but their sizes, forms, scarcity of fire scars, and their relatively fast growth before logging indicated that they were younger than the typical fire-scarred veteran. These results showed that the diameter growth of individual trees will respond positively to a decrease in competition from the surrounding stand.

YOUNG GROWTH

Growth and mortality plots were established during 1952–1953 on the Mountain Home State Forest, Tulare County, two of which contained a substantial amount of giant sequoia. These plots were selected to represent the typical cutover condition on the State Forest for determining growth and yield of the second-growth stand.

Plot 3 was established at 6,160 feet elevation on a south-facing slope that had been heavily logged in 1945. As a result of soil disturbance during the logging, the site became crowded with reproduction. There were 5,420 seedlings per acre on the plot when it was established. Current analysis of stand composition indicates that 45 percent of merchantable trees on the plot are giant sequoia.

Plot No. 4 was established at 6,250 feet elevation on a south-facing slope. The stand resulted from logging in the area in 1890. The plot was considered to be even-aged, containing 90 percent redwood, when measured in 1976.

[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

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Table 1—*Combined growth data for Mountain Home giant sequoia plots 3 and 4*

Plot and stand age (years)	Total volume	Ingrowth	Mortality	Periodic annual increment	Mean annual increment
	Scribner board foot volumes per acre				
Plot 3					
7	0	0	0		0
13	0	0	0	0	0
18	188	188	0	38	10
22	743	291	0	139	34
31	5,938	2,966	0	577	192
Plot 4					
63	24,237	0	0	572	385
73	35,801	641	0	1,156	490
77	40,320	69	22	1,130	524
83	49,714	295	24	1,566	599
86	54,077	204	0	1,454	629

Because of the similarity of these two plots, the data were combined to provide yield information for a longer range of stand age classes. All trees in growth plot 3 became established after the 1945 logging; stand information exists for ages 7 through 31 years for the trees on that plot. Similarly, for growth plot 4, stand information is available for year 63 through year 86. Volumes for young growth giant sequoia are from local volume tables for Mountain Home State Forest (Wensel and Schoenheide 1971). Results of these 86 years of growth on typical cutover giant sequoia stands on the Mountain Home State Forest are shown in *table 1* and *figure 1* (Cook and Dulitz 1978).

On a ¼-acre, 102-year-old, growth plot of pure giant sequoia on the University of California's Whitakers Forest in Tulare County, the largest trees are 26 to 28 inches in diameter. Maximum height of the trees in the stand was 125–135 feet. Some trees on the plot have grown only 1–2 inches in diameter in 67 years.

Some information is available for young growth giant sequoia plantations in Europe. A 0.62-acre plantation in Belgium, planted in 1906, had an average annual growth of 529 cubic feet per acre in 1951. In 1982, the same stand averaged 628 cubic feet per acre of annual growth (Kleinschmit 1984). A 3.71-acre German plantation, planted in 1862, had a volume of 17,871 cubic feet per acre at an age of 122 years. Maximum heights were 154 feet with mean heights of 127 feet. Maximum diameters were 48 inches at breast height with a mean diameter of 33 inches. Although not fully stocked, this plantation is growing at the rate of 285 cubic feet per acre per year (Kleinschmit 1984). Seven other small plantations in Germany and Belgium exhibited an average annual growth of between 515 and 601 cubic feet per acre per year (Guinon and others 1983, Knigge and others 1983).

Some general observations of the European stands show that the growth of giant sequoia far surpassed the known volume production of other North American softwood species grown in West Germany and Belgium. Investigations of diameter growth, taper, annual ring width, and specific gravity of stands in California were the same as those of European plantings (Knigge and Lewark 1984).

Some of these European yields are greater than those reported from natural stands in California. This difference may be due to the limited natural stand yield data available. Also, it is unknown what volume tables or equations were used to estimate individual tree volumes in Europe. Direct comparisons with other stand data may not be valid.

Giant sequoia will undoubtedly continue to gain importance as a commercial species. More growth information is needed from natural stands to accurately predict yields from the maturing young-growth stands that became established after the extensive logging 80–100 years ago in the Sierra Nevada. Giant sequoia will also continue to be an important plantation tree outside of its natural range. As these plantations develop, growth and yield information will be needed. Current volume tables for this species should be studied and refined to accurately estimate individual tree volume. These research needs will continue to present themselves as challenges in management of giant sequoia.

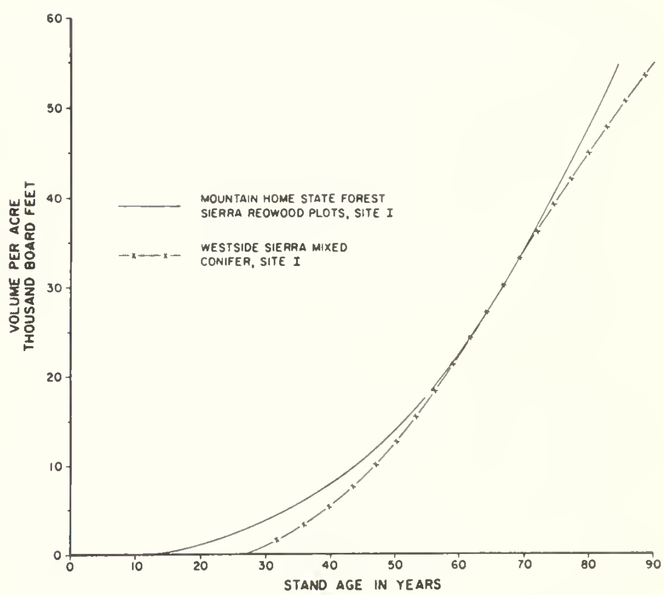

Figure 1—Comparative yield in thousands of board feet (Scribner Log Rule) of giant sequoia growing in a typical cutover stand on Mountain Home State Forest and on a mixed conifer site in the westside Sierra Nevada.

REFERENCES

Cook, Norman W.; Dulitz, David J. Growth of young Sierra redwood stands on Mountain Home State Forest. State Forest Notes No. 72, California Department of Forestry; 1978.

Dunning, Duncan. A site classification for the mixed-conifer selection forests of the Sierra Nevada. Res. Note 28. Berkeley: California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1942.

Guinon, Von M.; Hapla, F.; Lewark, S.; Schroder, C. Die Holzeigenschaften des Mammutbaumes in sechs mitteleuropaischen Versuchsanbauten (Teil 1). Holz-Zentralblatt, Stuttgart, Mittwoch, 27. July 1983.

Hartesveldt, Richard J. The effects of human impact upon *Sequoia gigantea* and its environment in the Mariposa Grove, Yosemite National Park, California. Ann Arbor: Univ. of Michigan; 1962. Dissertation.

Hartesveldt, Richard J. The giant sequoia of the Sierra Nevada, National Park Service, U.S. Department of the Interior; 1975. 180 p.

Kleinschmit, J. Der Mammutbaum Nur Eine Faszinierende Exotenart? Zurich: Veroffentlicht im Beiheft zur Schweizerischen Zeitschrift fur Forstwesen 72: 61–67; 1984.

Knigge, Von W.; Pellinen, P.; Schilling, T. Untersuchungen von Zuwachs, Astigkeit Verkernung und Rindenstarke westeuropaischer Anbauten des Mammutbaumes (*Sequoiadendron giganteum* [Lindl.] Buchholz), Sonderdruck aus Forstarchiv 54(2): 1983; March/April.

Knigge, Von W.; Lewark, S. Investigations on wood quality of giant sequoias from second-growth stands in California. Sonderdruck aus Forstarchiv 55(1): 1984; Jan./Feb.

Wensel, L. C.; Schoenheide, Richard L. Young-growth gross volume tables for Sierra redwood. Hilgardia 41(4): 1971.

Genetic Variation and Early Performance of Giant Sequoia in Plantations[1]

W. J. Libby[2]

Abstract: Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) is genetically less variable than expected; furthermore, it is less variable and its populations are less structured than are several associated or related conifers. Giant sequoia seedlings from open-pollinated seeds of isolated trees or from small outlier groves do not survive and grow as well as those from large groves, and cold susceptibility is related to elevation of origin. On the basis of these observations and other considerations, planting strategies for within and outside the native range are recommended. More information is needed to develop guidelines for nursery and planting practices and for identifying appropriate sites for giant sequoia.

GENETIC VARIATION

Many species of animals such as fruit flies, mice, and humans maintain a great deal of genetic variation within their populations. Unlike most animals, most annual plants cannot escape or modify unfavorable elements of their environments, and perhaps that is why such plants maintain even more genetic variation than do animals. Trees, which must endure all of the physical and biotic variations of their environments for decades and even centuries, on average maintain even more genetic variation than do annual plants (Hamrick and others 1979). One might thus expect that giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz), which often endures for millennia, would be among the most genetically variable species.

My graduate students and I first studied the genetic variability of giant sequoia using enzyme variation as a measure of variation in the genes that code for those enzymes (Fins and Libby 1982). To our surprise, giant sequoia's genetic variation as measured at this enzyme level is distinctly subdued, compared with that of other Sierra Nevada conifers and of other trees in general. This result is supported by a recent study of giant sequoia's early survival, growth, and form (Mahalovich 1985). Trees from 21 of the 23 sampled groves on average survived and grew similarly. The relationship of elevation, latitude, and longitude of the sampled groves to performance of their offspring in the experiment was slight, if present at all. Although giant sequoias differ in such characteristics as foliage color, crown shape, and stem taper, and occasional trees have such deviations as variegated foliage or drooping branches, giant sequoia generally has a more predictable form than is typical of most other conifers.

Cloned giant sequoias were included in our recent study (Mahalovich 1985), and thus we were able to investigate whether genetic differences in growth and form exist between individual trees. Such tree-to-tree differences do exist, and they are biologically, statistically, and (perhaps) economically significant. But, consistent with earlier observations on form and enzymes, they are of much smaller magnitudes than have been found in associated and related conifers, for example, ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), sugar pine (*Pinus lambertiana* Dougl.), or coast redwood (*Sequoia sempervirens* [D. Don] Endl.).

At the population (grove) level, there are two exceptions to the above generalization that are worth special note. First, trees from the northernmost (Placer) and southernmost (Deer Creek) groves grew substantially and significantly slower than, and differed in other respects from, trees of the other 21 sampled groves (Fins and Libby 1982, Mahalovich 1985). The Placer Grove has only 6 trees, and the Deer Creek Grove has about 30. Seedlings from isolated trees have also done poorly (Guinon and others 1982). Small population sizes probably result in inbreeding, which typically results in poor offspring performance.

Second, in tests on some European and New Zealand sites, particularly where many giant sequoias were injured by cold, trees from the Atwell Mill Grove (the southern grove in Sequoia-Kings Canyon National Park and one of the highest of the native groves) usually survived and grew relatively well (Kleinschmit 1982, Thulin 1982). In experiments where such cold damage occurred, it was significantly related to the elevation of the origin groves (Guinon and others 1982).

The above observations lead to a few recommendations for planting giant sequoia:

For planting outside native groves—Plants from isolated parents or of Placer Grove or Deer Creek Grove origins will probably not do as well as other giant sequoias. On a potentially good site for giant sequoia, plants from any of the other groves are, to the best of our current knowledge, equally likely to do well. On sites where cold damage may occur, plants from the Atwell Mill Grove or from other high-elevation populations may be more successful than those from lower elevations.

For planting in or near native groves—Just as designated "specimen" trees in native groves should be protected from human-caused destruction, so should the genetic integrity of these native groves be protected. While subdued, there is

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genetic variation within the giant sequoia species. Groves other than Placer, Deer Creek, and Atwell Mill may contain genetic variation that is interesting or valuable or both, and that is also unusual or even unique. Natural regeneration (probably following fire) is thus preferable to planting. If planting is done in or near native groves, it should be done with seeds or seedlings from that grove. The seeds should be collected from 20 or more representative trees in the grove to ensure an adequate sample of the grove's genetic variation.[3]

ARTIFICIAL REGENERATION

Planted giant sequoias may be placed in four performance classes: (1) they soon die; (2) they grow slowly and never grow well; (3) they grow slowly for about a decade, and then grow rapidly and well for a very long time; (4) they grow rapidly and well, commencing within 2 years of planting. Analyses of these four classes suggest the following:

For class 1, most likely something was wrong with nursery or planting practice, although in some cases the site or weather may have caused the mortality.

For class 2, the site is probably inappropriate for good growth of giant sequoia. Such planting experiences will accumulate, be increasingly understood, and provide guidelines for appropriate sites and conditions for giant sequoia.

For class 3, nursery practice or planting practice or elements of both were likely the problem. This pattern of growth has been commonly observed. It might be considered normal for sites appropriate for giant sequoia, were it not for occasional class 4 performance.

For class 4, nursery, planting and post-planting practices, and site apparently were all correct. As we learn more about these essential components of good plantation performance in reference to giant sequoia, this class will increasingly become the norm for giant sequoia plantations.

[3]If inadequate numbers of seeds are available, cloned material may be available from source-identified clone donors maintained at the Forest Service's Tree-Improvement Center at Chico, phone (916) 895-1176.

MIXED SPECIES PLANTINGS

Given good nursery stock and good planting technique on a site where giant sequoia grows well, giant sequoia will outgrow conifers native to Europe or to the Sierra Nevada—Cascade Mountains of western North America. The differences in growth are frequently large. The only exception frequently observed is European larch (*Larix decidua* Mill.), which may grow faster than giant sequoia during the first decade or so. Observations in Europe (Libby 1981) and in California (Fins 1979, Mahalovich 1985) are consistent with this generalization.

A common practice is planting about 15 percent giant sequoia mixed with one or more other conifer species on about 3-meter (10-ft) centers. One usually has confidence that the other species will successfully grow on the site. If giant sequoia fails, it usually fails early, and an early loss on the order of 15 percent can usually be accepted. If giant sequoia grows well, subsequent silviculture can adjust the developing stand to any percentage of giant sequoia desired.

REFERENCES

Fins, L. Genetic architecture of giant sequoia. Berkeley: University of California; 1979. 258 p. Dissertation.

Fins, L.; Libby, W. J. Population variation in *Sequoiadendron*: seed and seedling studies, vegetative propagation, and isozyme variation. Silvae Genetica 31:102-110; 1982.

Guinon, M.; Larsen, J. B.; Spethmann, W. Frost resistance and early growth of *Sequoiadendron giganteum* seedlings of different origins. Silvae Genetica 31:173-178; 1982.

Hamrick, J. L.; Linhart, Y. B.; Mitton, J. B. Relationships between life history characteristics and electrophoretically detectable genetic variation in plants. Annu. Rev. Ecol. Syst. 10:173-200; 1979.

Kleinschmit, P. C. Lower Saxony Forest Research Station, Escherade, West Germany. [Conversation with W. J. Libby]. September 1982.

Libby, W. J. Some observations on *Sequoiadendron* and *Calocedrus* in Europe. Calif. For. and Forest Prod. 49:1-12; 1981.

Mahalovich, M. F. A genetic architecture study of giant sequoia: early growth characteristics. Berkeley: University of California; 1985. 98 p. Thesis.

Thulin, P. C. New Zealand Forest Research Institute, Rotorua, New Zealand. [Conversation with W. J. Libby]. November 1982.

Wood of Giant Sequoia: Properties and Unique Characteristics[1]

Douglas D. Piirto[2]

Abstract: Wood properties of giant sequoia (*Sequoia gigantea* [Lindl.] Decne.) were compared with those for other coniferous tree species. Wood properties such as specific gravity, various mechanical properties, extractive content, and decay resistance of young-growth giant sequoia are comparable to or more favorable than those of coast redwood (*Sequoia sempervirens* [D. Don] Endl.). It is recommended that giant sequoia be considered for planting stock in managed production forests to increase future supplies of wood having the characteristics so highly valued in coast redwood and other decay-resistant species.

Giant sequoia (*Sequoia gigantea* [Lindl.] Decne.) is one of the oldest and certainly the largest living organism on earth. I have been studying giant sequoia and coast redwood (*Sequoia sempervirens* [D. Don] Endl.) since 1970. Although knowledge of both species is steadily improving, the focus has been on coast redwood, primarily because of its commercial importance. For this reason, correcting the many misleading generalizations about giant sequoia has been a slow and sometimes agonizing process. The wood from giant sequoia trees has had the reputation of being very brash (brittle) and of little use for lumber products. This belief fails to distinguish differences between old- and young-growth trees, and it fails to recognize the wide range of wood products obtainable from forest trees besides lumber, e.g., particleboard, plywood, and paper (Piirto and Wilcox 1981).

This paper has two objectives: First, to compare the wood properties of native grown giant sequoia to coast redwood, incense cedar (*Libocedrus decurrens* Torr.), white fir (*Abies concolor* [Gord. and Glend.] Lindl. ex Hildebr.) and western redcedar (*Thuja plicata* Donn). And, second, to emphasize the value of giant sequoia in both National Parks and in production forestry (e.g., plantations containing giant sequoia). It also highlights key points in the following subject areas: (1) general characteristics and minute anatomy (2) physical and mechanical properties (3) chemical composition (4) natural decay resistance, and (5) utilization.

Several excellent studies on the wood properties of giant sequoia grown outside of its native range have been and are being conducted in several foreign countries (Finogeev and Kuznecov 1969, Liubimirescu and others 1972, Knigge 1983, Knigge and Wenzel 1982, Knigge and others 1983).

GENERAL CHARACTERISTICS AND MINUTE ANATOMY

The wood of giant sequoia closely resembles that of coast redwood (Panshin and deZeeuw 1970). The wood of both species is light in weight, rather soft, considered strong for its weight, and moderately coarse to coarse in texture (Mitchell 1935, 1936). Key points and differences between giant sequoia and coast redwood are these:

- The heartwood of both species is characteristically reddish-brown, but the wood of giant sequoia is darker and has a purplish cast (Panshin and deZeeuw 1970).
- On the average, the corresponding anatomical features of coast redwood are larger than those of giant sequoia (Mitchell 1935, 1936).
- Bands of latewood (one to four tracheids in width) are generally narrower in giant sequoia than in redwood (Panshin and deZeeuw 1970) (*fig. 1*).
- Giant sequoia has 75 percent more ray tissue than does coast redwood (Mitchell 1935, 1936). This is a key diagnostic feature used to separate the wood of the two species.
- Tracheid length (4 to 4.5 mm) for giant sequoia wood is slightly longer than the average length for conifers but significantly shorter than for coast redwood (Cockrell and others 1971, Bannan 1966) (*fig. 2*).

Compression wood, wood formed on the lower side of branches and inclined trunks of softwoods, has been reported in young-growth giant sequoia (Cockrell 1974, Cockrell and Knudson).

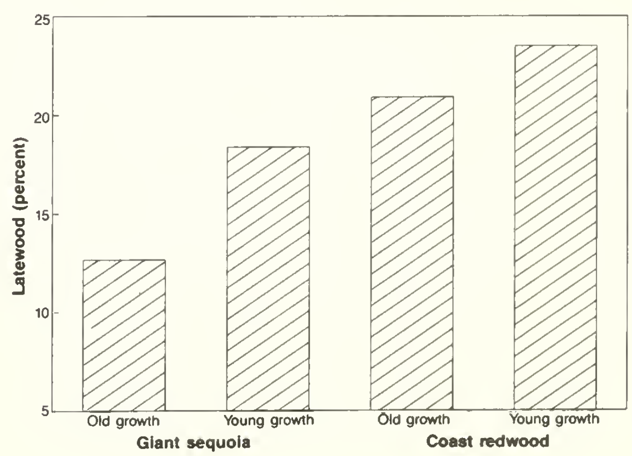

Figure 1—Percentage of latewood in giant sequoia and coast redwood. Values are from Cockrell and others (1971), Piirto and Wilcox (1981), and Resch and Arganbright (1968).

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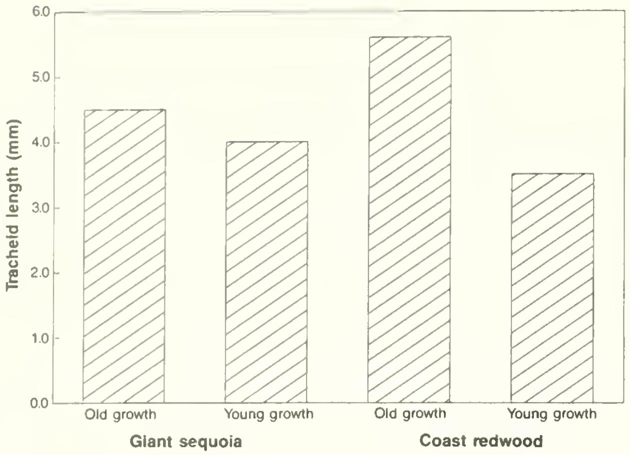

Figure 2—Anatomical characteristics of giant sequoia and coast redwood. Values are from Cockrell and others (1971), and Resch and Arganbright (1968).

PHYSICAL AND MECHANICAL PROPERTIES

The conclusions in the following paragraphs were reached by Piirto and Wilcox (1981) regarding the physical and mechanical properties of giant sequoia.

The average specific gravity (the ratio of the oven-dry weight sample to the weight of a volume of water equal to the volume of the sample at a specified moisture content—e.g., oven-dry weight/green volume) tends to be higher in young-growth (0.35) than in old-growth giant sequoia—0.30 (Cockrell and others 1971, Keylwerth 1954). Young-growth giant sequoia specific gravity is comparable to young-growth coast redwood *(fig. 3).*

Young-growth giant sequoia is heavier and stronger than old-growth giant sequoia (the reverse is true in coast redwood). Old-growth giant sequoia heartwood exhibits a characteristic brash-type failure in static bending and has very low toughness (resistance to sudden shock) values, thus it can be considered very

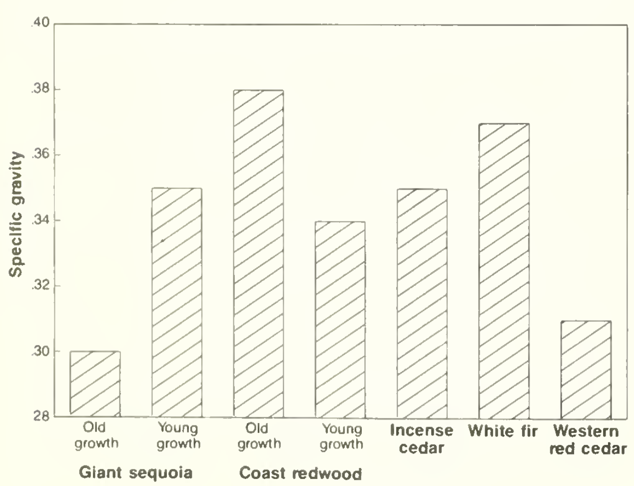

Figure 3—Specific gravity of several woods, based on oven-dry weight and green volume.

brittle. Koehler (1933) provided a good discussion of causes for brashness in wood; however, the mechanisms that cause wood to be brash are not completely understood *(figs. 4 and 5).*

Mechanical properties of young-growth giant sequoia are equal to, or somewhat superior to, white fir, incense cedar, western redcedar and young-growth coast redwood in most of its mechanical properties. Wood from young-growth giant sequoia is acceptable for dimension lumber in light construction (Cockrell and others 1971).

Heartwood of old- and young-growth giant sequoia and old- and young-growth coast redwood shows appreciably lower tangential, radial, and volumetric shrinkage than sapwood (old-growth heartwood decidedly lower than young-growth). Old-growth and young-growth giant sequoia have comparable shrinkage properties to similar categories of coast redwood (Cockrell and others 1971). Tarkow and Krueger (1961) attributed the relatively low shrinkage properties of coast redwood heartwood to the presence of extractives in the cell wall. This basic principle applies equally as well to the heartwood of giant sequoia. Deposition of extractives within the cell walls makes wood more resistant to decay and the compounds more resistant to leaching (Scheffer and Cowling 1966).

CHEMICAL COMPOSITION OF EXTRACTIVES

In addition to its principle cell-wall components (cellulose, hemicellulose, and lignin), wood may contain a great variety of chemical compounds extractable with water and neutral organic solvents such as alcohol, benzene, and ethyl ether. These compounds are called extractives and are not an integral part of the cell wall structure. Color, decay, and insect resistance (Anderson 1961), density and modulus of elasticity (Arganbright 1971), pulping properties (Institute of Paper Chemistry 1945, Hillis 1962, Martin and others 1960), and dimensional stability (Tarkow and Krueger 1961) as well as other wood properties of giant sequoia and coast redwood are specifically related to the quantity and nature of the extractives present. Most of the research on extractive chemistry has focused on coast redwood. However, it is reasonable to assume that giant sequoia would share many of the following key points:

• Amounts of extractives range from 15 to 30 percent of the wood's original oven-dry weight (Anderson and others 1962).

• Extractive compounds vary depending upon their location within the tree and age of the wood (Sherrard and Kurth 1933a). Extractive content of old-growth coast redwood decreases with height in the tree and towards the center of the lower trunk, with extractive content being highest in the outer heartwood of the butt log (Sherrard and Kurth 1933a, Isenberg 1951, Institute of Paper Chemistry 1945, Anderson 1961, Resch and Arganbright 1968). Contrary to this gradient pattern of extractive content in old-growth coast redwood, young-growth shows a tendency for a more uniform distribution of extractives throughout the heartwood (Anderson 1961, Resch and Arganbright 1968). Extractive concentration is significantly greater in the center of young-growth coast redwood than in old-growth. This difference suggests that the extractive gradient pattern in old-growth coast

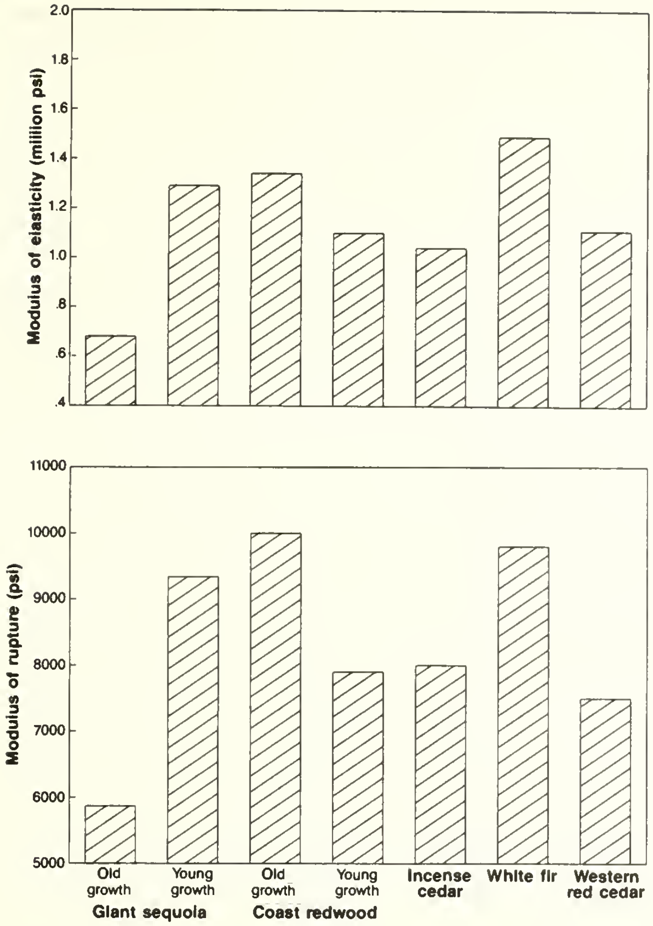

Figure 4—Modulus of rupture and of elasticity for several woods (air-dry condition). Values are based on data from Cockrell and others (1971), and USDA (1974).

redwood may be the result of decomposition, change in solubility, or change in extractive distribution with age (Resch and Arganbright 1968).

• Early reports indicated that these extractives were largely found in the cell lumina of ray and longitudinal parenchymal cells (Institute of Paper Chemistry 1945). However, more recent studies (Kuo 1977) have shown that 77 percent of the total extractive content is present within the cell wall.

• The greatest portion of coast redwood extractives are hot-water soluble (Anderson 1961) and include tannin, cyclitols, polyphenolics, polysaccharides, free sugars, color matter, and other unknown compounds *(fig. 6)*. Cyclitols have been reported as having some taxonomic significance (Anderson and others 1968a,b).

• The water insoluble extractives of coast redwood heartwood include phlobaphenes, polymerized tannin, native lignin, phenols, fatty acids, wax, and other compounds (Anderson 1961) *(fig. 7)*. These are soluble in hot ethanol.

• There is little ether-soluble material (less than 1 percent) in coast redwood indicating the absence of fats, waxes, oils, and resinous substances. However, terpenoids (e.g., alpha pinene and various resin acids) have been reported (Anderson and others

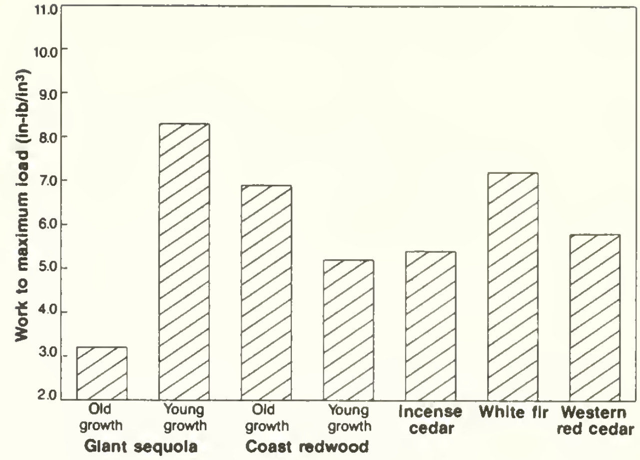

Figure 5—Work to maximum load for several woods (air-dry condition). Values are from Cockrell and others (1971) and USDA (1974).

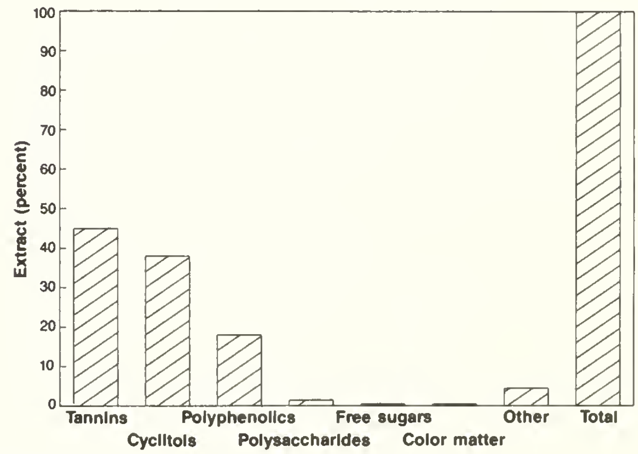

Figure 6—Water-soluble extractives of coast redwood heartwood. Values are from Anderson (1961).

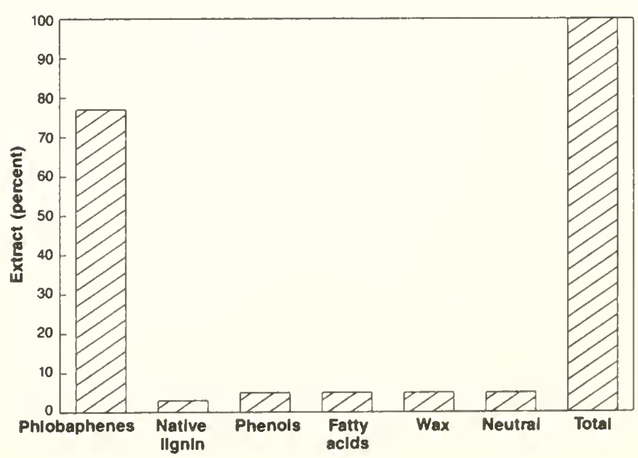

Figure 7—Ethanol-soluble extractives of coast redwood heartwood. Values are from Anderson (1961).

1968a,b) within a sticky viscous resin found in open pockets of coast redwood. Similarly, a resinous, sticky material has been observed on the fire scars of giant sequoia (Piirto 1977).

NATURAL RESISTANCE TO DECAY

Natural resistance to decay can be defined as the ability of wood to resist attack by decay fungi. The sapwood is readily decayed by fungi, but the heartwood of some species is highly resistant to decay. Key points on natural decay resistance of coast redwood and giant sequoia are these:

• The wood of both old- and young-growth giant sequoia is classified as resistant to *Poria monticola* and highly resistant to *Lenzites trabea*. However, giant sequoia shows lower decay resistance than does coast redwood, a highly decay-resistant species *(fig. 8)*.

• Extractives have been reported as the principal contributors to decay resistance. The variation in extractive content within individual coast redwood trees has been found to be directly related to the variation in decay resistance within these same trees (Sherrard and Kurth 1933a, Anderson 1961). The durability of coast redwood and giant sequoia would therefore be highest in the butt log heartwood nearest the sapwood, and the susceptibility to decay would increase towards the pith of the tree and towards the top.

• The unstable labile nature of coast redwood and giant sequoia extractives makes it difficult to determine which component is responsible for the decay resistance. Tannins have been reported as being weak fungicides in laboratory tests. Phlobaphenes have been reported as being nontoxic (Anderson 1961).

Possible explanations for the high decay resistance of coast redwood and giant sequoia are these three: (1) several extractive components (water- and alcohol-soluble) may work together to produce fungi toxicity; (2) extractives may be basically nontoxic and merely operate as bulking agents preventing fungal enzymes from penetrating and subsequently decomposing cell walls; or, (3) some very toxic components may exist but have not been documented.

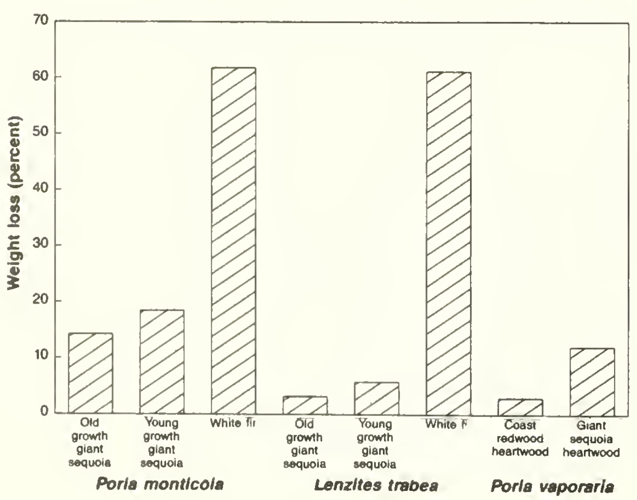

Figure 8—Decay resistance of several woods exposed to various decay fungi. Values are from Piirto and Wilcox (1981) and Rennerfeldt (1956).

UTILIZATION

Old-growth coast redwood is valued for its durability, low shrinkage and texture. It is commonly used for these purposes (USDA 1974):

• Building, particularly in areas of modest decay hazard.

• Siding, sashes, doors, blinds, and finish, and similar products.

• Cooling towers, wood stove pipe, tanks, silos, and outdoor furniture where decay hazard may exist.

• Split products such as fence posts and fence material.

• Decorative plywood.

• Paper manufacture.

Presumably giant sequoia could occupy these same markets, but the use of old-growth giant sequoia is limited by the brittle nature of the wood and the very small supply because the majority of giant sequoia groves have been incorporated into National Parks. Old-growth giant sequoia has been used for fence posts, vineyard stakes, shakes, shingles, and occasionally lumber where decay hazard is high (Panshin and deZeeuw 1970, Meyer 1952).

Young-growth giant sequoia, on the other hand, has favorable wood properties in comparison to white fir and young-growth coast redwood. It is acceptable for use as dimension lumber in light construction (Cockrell and others 1971). Young-growth giant sequoia has veneer properties comparable to coast redwood, which was rated as excellent for decorative siding and intermediate where strength is the primary concern to the plywood consumer (Lutz 1972). Finogeev and Kuznecov (1969) reported similar veneer quality of Russian-grown giant sequoia trees.

I suspected for sometime, and Knigge and others (1983) confirmed that heartwood formation begins early in young-growth giant sequoia and continues steadily following the shape of the stem. Knottiness is one of the biggest problems for all types of utilization of young-growth giant sequoia. As such, early pruning is recommended to produce any appreciable volume of clear lumber within short to medium rotation periods. A more cylindrical stem results from pruning.

Fiber studies by Cockrell and others (1971) and Bannan (1966) indicated that giant sequoia promises to make acceptable pulp.

CONCLUSIONS

Wood properties of young-growth giant sequoia are comparable to or more favorable than those of coast redwood. It seems reasonable, therefore, to consider giant sequoia for planting stock in managed production forests to increase future supplies of wood having the same characteristics that are so highly valued in redwood.

REFERENCES

Anderson, A. B. The influence of extractives on tree properties. Pt. 1. California redwood. J. Inst. Wood Sci. 8: 14–34; 1961.

Anderson, A. B.; Duncan, C. G.; Scheffer, T. C. Effect of drying conditions on durability of California redwood. Forest Prod. J. 12(7): 311–312; 1962.

Anderson, A. B.; Riffer, R.; Wong, A. Chemistry of the genus *Sequoia*-V. Cyclitols from the heartwood of *Sequoia gigantea*. Phytochemistry 7(8): 1367–1371; 1968a.

Anderson, A. B.; Riffer, R.; Wong, A. Chemistry of the genus *Sequoia*-VI. On the cyclitols present in heartwood of *Sequoia sempervirens*. Phytochemistry 7(10): 1867–1870; 1968b.

Arganbright, D. G. Influence of extractives on bending strength of redwood (*Sequoia sempervirens*). Wood and Fiber 2(4): 367–372; 1971.

Bannan, M. W. Cell length and rate of anticlinal division in the cambium of the sequoias. Can. J. Bot. 44(2): 209–218; 1966.

Cockrell, R. A.; Knudson, R. M.; Stangenberger, A. G. Mechanical properties of southern Sierra old- and second-growth giant sequoia. Bull. 854. Berkeley: University of California, Agriculture Experiment Station; 1971.

Cockrell, R. A.; Knudson, R. M. A comparison of static bending, compression and tension parallel to grain and toughness properties of compression wood and normal wood of a giant sequoia. Wood Sci. and Technol. 7(4): 241–250; 1973.

Cockrell, R. A. A comparison of latewood pits, fibril orientation and shrinkage of normal and compression wood of giant sequoia. Wood Sci. and Technol. 8(3): 197–206; 1974.

Finogeev, B. L.; Kuznecov, S. I. Industrial properties of the wood of *Cedrus atlantica, C. deodara* and *Sequoia gigantea*. Bjull. Gos. Nikit. Bot. Sada. 2: 11–13; 1969.

Hillis, W. E., ed. 1962. Wood extractives. New York: Academic Press; 1969.

Institute of Paper Chemistry. Redwood—a report of fundamental investigations and related application studies for the Pacific Lumber Company. Res. Bull. 12(2). Appleton, WI; 1945.

Isenberg, I. H. Pulpwoods of United States and Canada. 2d ed. Appleton, WI: Inst. Paper Chem.; 1951.

Keylwerth, R. Das holz der *Sequoia gigantea*. Holz als Roh- und Werkstoff 12(3): 105–107; 1954.

Knigge, Von W.; Wenzel, B. Variability of fiberlength within a tree of *Sequoiadendron giganteum* (Lindl.) Buchholz. Forstarchiv 53(3): 94–99; 1982.

Knigge, Von W.; Pellinen, P.; Schilling, T. Investigations on growth, branchformation, heartwood-formation and bark-diameter of giant sequoia trees (*Sequoiadendron giganteum* [Lindl.] Buchholz). Forstarchiv 54(2): 54–61; 1983.

Knigge, Von W. Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz), a fast growing wood of the future. Forstarchiv. In press.

Koehler, A. Causes of brashness in wood. Tech. Bull. 342. Washington, DC: U.S. Department of Agriculture; 1933.

Kuo, M. L. Cellular distribution of extractives in redwood (*Sequoia sempervirens*) and incense cedar (*Libocedrus decurrens*) wood. Berkeley: Univ. of California; 1977. Dissertation.

Liubimirescu, A.; Guruianu, M.; Lonescu, R. Physical and mechanical properties of the wood of *Sequoia gigantea*. Revista Padurilor 87(12): 613–616; 1972.

Lutz, J. F. Veneer species that grow in the United States. Res. Paper FPL-167. Madison, WI: Forest Products Laboratory, Forest Service, U.S. Department of Agriculture; 1972.

Martin, J. S.; Simmonds, F. A.; Fahey, D. J. Pulping and papermaking experiments on redwood. Mimeo Rep. 2181. Madison, WI: Forest Products Laboratory, Forest Service, U.S. Department of Agriculture; 1960.

Meyer, F. A. The status of *Sequoia gigantea* in the Sierra Nevada. Report pursuant to Senate Concurrent Resolution 44, 1951 General Session. Sacramento: State of Calif.; 1952. 75 p.

Mitchell, J. N. The comparative histology of the secondary xylem of *Sequoia gigantea* and *Sequoia sempervirens*. Berkeley: Univ. of California; 1935. Dissertation.

Mitchell, J. N. The detailed structure of stem wood of the two sequoias. J. For. 34(11): 988–993; 1936.

Panshin, A. J.; deZeeuw, C. Textbook of wood technology. Vol. 1, 3d ed. McGraw-Hill Book Company; 1970.

Piirto, D. D. Factors associated with tree failure of giant sequoia. Berkeley: Univ. of California; 1977. Dissertation.

Piirto, D. D.; Wilcox, W. Wayne. Comparative properties of old- and young-growth giant sequoia of potential significance to wood utilization. Bull. 1901. Berkeley: University of California, Division of Agricultural Sciences; 1981.

Piirto, D. D.; Wilcox, W. Wayne; Parmeter, J. R.; Wood, D. L. Causes of uprooting and breakage of specimen giant sequoia trees. Bull. 1909. Berkeley: University of California, Division of Agriculture and Natural Resources; 1984.

Rennerfelt, E. The natural resistance of decay of certain conifers. Friesia 5(3–5): 361–365; 1956.

Resch, H.; Arganbright, D. G. Variation of specific gravity, extractive content and tracheid length in redwood trees. Forest Sci. 14(2): 148–155; 1968.

Scheffer, T. C.; Cowling, E. B. Natural resistance of wood to microbial deterioration. Ann. Rev. Phytopathology 4: 147–170; 1966.

Sherrard, E. C.; Kurth, E. F. Distribution of extractive in redwood: its relation to durability. Ind. Eng. Chem. 23(3): 300–302; 1933a.

Sherrard, E. C.; Kurth, E. F. The crystalline colouring compounds in redwood extract. J. Amer. Chem. Soc. 55: 1728–1732; 1933b.

Tarkow, H.; Krueger, J. Distribution of hot-water soluble material in cell walls and cavities of redwood. For. Prod. J. 11(5): 228–229; 1961.

United States Department of Agriculture. Wood handbook: wood as an engineering material. Agric. Handb. 72. Washington, DC: U.S. Department of Agriculture; 1974.

Wilcox, W. W.; Piirto, D. D. Decay resistance in redwood (*Sequoia sempervirens*) heartwood as related to color variation. Wood and Fiber 7(4): 240–245; 1976.

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Recommendations from the Sierra Club for Managing Giant Sequoia[1]

Joseph Fontaine[2]

Abstract: The giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) groves in their natural setting are one of the outstanding scenic features of the southern Sierra Nevada. These groves where they have survived should be managed to protect their natural values and to restore former natural conditions wherever possible. Groves that are essentially intact should have the whitewoods removed that have encroached as a result of over-protection from fire. Pines and firs should be carefully removed to avoid damage to giant sequoias. Once natural conditions are restored, prescribed burning should be the primary technique used to maintain these conditions. Groves that have only a few specimen trees left or only second growth should be inventoried and a large percentage of them selected for restoration, a goal that may not be reached for several decades. The giant sequoia species should be investigated for its timber value, and if feasible, planted and harvested for commercial purposes in the general forest zone.

The scattered pockets of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) groves provide some of the most attractive settings for visitors to the southern Sierra Nevada who seek the magnificence of a primeval forest. The mixture of very large old trees, scattered firs and pines, dogwoods, and fern-carpeted forest floor is unique and rivals the beauty of any forested area in the world.

One cannot help but contemplate what these giant trees have endured in the thousands of years some of them have been alive and what fate awaits them. The huge size and age of these giants is humbling and awe-inspiring as one wanders among them. In a philosophical sense, they are a link to the past—a link we should not break.

I make these remarks about the giant sequoia to emphasize the fact that these trees and their associated ecosystems have a value to the public far beyond their commodity value. With pressure on land managers and foresters to maximize the cut, it would be easy to overlook or minimize these values. But a forest is not just standing sawtimber. The giant sequoia groves have become symbolic to those of us who seek the esthetic and philosophical values to be found in the forest.

The Sierra Club's position is that wherever these groves are found, the basic land management policy ought to be restoring and managing them in as natural a condition as possible. Insofar as they can be identified, the conditions that created these groves in the first place should be perpetuated.

The individual big trees should not be treated as museum pieces without regard for the dynamic natural processes going on around them. A forest is a system of various plant species—in this case with giant sequoia among them—and various other conditions necessary for the plant associations to endure. To perpetuate the sequoia groves an entire ecosystem must be considered and not just the big trees themselves. Natural processes must be allowed to operate insofar as practical without human interference.

The giant sequoia ecosystem requires special soil and water conditions. Fire is also a necessary component. Roadbuilding and skid trails contribute to erosion and soil compaction. Road cuts can interrupt the natural flow of shallow water. These activities will occur in the groves if they are managed as part of the timber base of the forest. If normal logging activities occur around large specimen trees, they will in effect become museum specimens subject to the eventual mortality of all living things. Once these isolated large trees are gone, what then will show there was once a grove of giant sequoia at that location?

Perhaps the biggest threat to some of the groves today is fire. Accumulated fuel and dense stands of fir and pine are a disaster waiting to happen. The Sierra Club has advocated a one-time timber harvest in some groves where whitewoods are too dense. They should be harvested with great care using equipment such as rubber-tired vehicles and techniques such as end lining, that minimize disturbance.

Great care should be taken to avoid damage to standing young trees. Once a natural mix of sequoia and other species has been reestablished, methods such as prescribed burning could be used to maintain natural conditions. In other groves, such as those in the national parks, fire alone might be the proper tool to reestablish natural conditions.

On the national forests the groves range from those where no logging or roadbuilding has occurred to those that were completely cut over with only second-growth to be found. Obviously, all groves of giant sequoia cannot be treated the same.

Those that are untouched, save for overprotection from fire, could be treated in the manner I have already discussed.

Other groves have a few specimens in hard-to-reach places that were passed over, with the rest of the grove cutover and perhaps with a considerable amount of second growth. The temptation to protect the large trees as museum pieces and designate the major portion of the groves as part of the general forest zone would be greatest in these groves. I believe most of the public would regard such a policy as tokenism. When the large old trees die there would be nothing different about that part of the forest. It would be like the rest of the forest—dedicated to normal timber harvest.

Most of the groves that have been completely cut over have heavy second growth. Before these groves are "written off" and become part of the normal timber base they should be examined carefully for any unique characteristics that remain. The giant

[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

[2]Former president, Sierra Club.

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sequoias are only one part, albeit the most spectacular part, of specialized ecosystems that persisted for thousands of years before the advent of the saw and axe. Who among us can say with certainty that there is nothing unique or important left in these ecosystems without further study now that the largest trees are gone?

Giant sequoias are fast-growing trees that are well suited to the conditions of the southern Sierra Nevada. The Sierra Club has no objection to the cultivation of the species for timber harvest. The characteristics of the wood make it useful for many purposes, and the harvest of cultivated giant sequoias could provide a valuable economic commodity. However, the Sierra Club does not believe the management goals of any of the untouched or partially cutover groves should include timber harvest on a permanent basis. Timber harvest might be advisable to restore natural conditions, but then should not be subsequently conducted within the boundaries of the groves. The Club advocates leaving the remains of fallen trees. These giant old logs are an important part of the esthetics of the groves.

The Sierra Club suggests consideration be given to making a start in restoring some of the totally cutover groves. If those trees were standing today, there would be no question about protecting them. It would be a tribute to this generation to begin the process of correcting the mistakes made when these groves were cut. Could not some of the more outstanding sites be selected and managed so that ultimately the second growth would replace the large old trees that were once there? No one alive today would live to see the outcome, but our generation would have the satisfaction of setting the process in motion.

I think that too often people are unable or unwilling to look beyond the pressures and concerns of daily life. These trees have been in the Sierra Nevada for probably millions of years. At one time they must have been one of the predominant species in the forest. Today they are found only in isolated pockets where they escaped the rigors of the Pleistocene. A long-term view is needed to consider what these groves represent from the past and to assure their future.

There is more to trees than allowable cut and boardfeet. The giant sequoias symbolize the beauty of Sierra Nevada forests. In a way the value put on these trees and the groves where they are found is an indicator of the quality of our culture. It will be interesting to see where the line is drawn between the intangible value placed upon beauty and philosophical experiences and the commodity value of the forest. How the giant sequoia groves are treated will, in a way, be a statement about the values of this generation.

Management of Giant Sequoia in the National Parks of the Sierra Nevada, California[1]

David J. Parsons

H. Thomas Nichols[2]

Abstract: Management of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) in Sequoia, Kings Canyon, and Yosemite National Parks focuses on the need for maintaining and, where necessary, restoring natural ecosystem processes. Such a program includes restoration of natural fire regimes, mitigation of impacts from visitor use, support for basic research and monitoring, and careful evaluation. Research includes studying the effects of air pollution. Interpretation translates information on the ecology and management of giant sequoia for the public.

Management of national parks has long been guided by the philosophy of preserving examples of ecosystems unaffected by human activities. In those areas where heroic or otherwise special species grow, placing the value of the total ecosystem above that of individual species often becomes difficult. The giant sequoia or Sierra redwood (*Sequoiadendron giganteum* [Lindl.] Buchholz) is an example. If the long-term survival of a "natural" giant sequoia community is to be assured, managing for a healthy ecosystem is needed and not just protecting individual trees.

Because they are limited to localized groves in the central and southern Sierra Nevada of California, giant sequoias are the focus of public interest and concern (Vale 1975). The giant sequoia represents only one part of a complex ecosystem (Harvey and others 1980). This complexity makes the task of preserving the natural state of the sequoia-mixed conifer forest a difficult one. Management of giant sequoia in national parks must aim at perpetuating the processes that make the environment suitable to the species' regeneration, growth, and survival. Faced with impacts from visitor use, fire suppression, and air pollution, park managers must devise policies that emulate natural ecological conditions despite a limited understanding of the ecosystem processes.

[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

[2]Research scientist and fire ecologist, Sequoia and Kings Canyon National Parks, National Park Service, U.S. Department of the Interior, Three Rivers, California 93271.

HISTORY

Early Protection

The first European settlers to view giant sequoias were awed by their imposing dimensions (Hartesveldt and others 1975, Strong 1975). Recognition of the uniqueness of these giants led to placing the Mariposa Grove—in the area that was to become Yosemite National Park—under State protection in 1864. Concern over threats of exploitation by the timber industry and a desire to protect many prime sequoia groves spurred the creation of Sequoia, General Grant (incorporated into Kings Canyon National Park in 1940), and Yosemite National Parks in 1890. In succeeding decades, giant sequoias were strictly protected by the U.S. Cavalry and later by the National Park Service (after its creation in 1916). In those early years the big trees were specifically protected from logging or fire, but little attention was given to preserving the processes upon which the health of the sequoias depends. National Park Service management focused on the protection of natural objects and the pleasure of visitors (Graber 1983).

Evolution of Policy

The 1963 Report of the Special Advisory Commission on National Parks (Leopold and other 1963) stressed the importance of managing entire ecosystems to preserve examples of natural communities. The report specifically discussed the effects of fire suppression in shifting species composition and increasing hazardous fuels in Sierran coniferous forests. Report recommendations, which were incorporated into National Parks Service policy in 1968 (Bonnicksen and Stone 1982b), provided a unifying direction for management of natural areas in national parks (Graber 1985, Kenner 1985, Lemons and Stout 1984). However, inconsistencies and ambiguities left certain aspects of management policy open to creative interpretation (Bonnicksen and Stone 1982b, Graber 1983).

To preserve natural ecosystem processes, it is necessary to understand the ecological relationships of the communities to be managed. The lack of such information for most presettlement ecosystems presents a serious problem for park managers. Leopold and others (1963, p. 63) recognized this need in advocating a "greatly expanded research program, oriented to management needs." Much of the basic biology of giant sequoia is now understood (Hartesveldt and others 1975, Harvey and others 1980, Kilgore 1973, Rundel 1971, Stark 1968). A continually expanding prescribed burning program (Bancroft and others 1985) has helped to identify additional research needs. These include basic community ecology, expanded monitoring of fire effects, evaluation of impacts of different intensity, seasonality and frequency of burns, and resolution of questions regarding interpretation of National Park Service policy (Parsons and others

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1986). Concern over the potential impacts of visitor use and air pollution on giant sequoias has led to the identification of additional information needs.

CURRENT POLICY

The principal aim of National Park Service resource management in giant sequoia groves, as in other natural areas, is the unimpeded interaction of native ecosystem processes and structural elements. Such a policy requires management intervention only when necessary to (1) reverse or mitigate the effects of human activities (e.g., suppression of wildfire), (2) protect a featured resource (such as a "showcase" or historical area), or (3) to protect life or property. Thus, while the overall goal is to minimize human intervention, such unnatural activities as fire suppression, prescribed burning, and selective cutting or mechanical fuel removal may be desirable under certain conditions (Parsons and others 1986).

Policy concerns, such as the definition of "natural," the precision with which management objectives must be achieved, the methods by which an area is selected to be a featured resource, and the relative importance of "ecosystem" versus "esthetic" values, continue to be the subject of spirited debate (Bonnicksen and Stone 1985, Graber 1985, Parsons and others 1986). One compromise that has resulted in part from such exchange is the concept of showcase areas. Unlike the major area of the Parks, showcase areas are managed primarily for esthetic objectives, and natural processes are not always permitted to operate fully.

The overall giant sequoia management program in the National Park Service includes research, management, monitoring, and interpretation.

1. Research. The research program is designed to provide basic information on giant sequoia ecology and the effects of different management practices. Studies have included fire history; effects of trampling, fire, fire suppression, and air pollution on forest structure and composition; fuel accumulation and decomposition; nutrient cycling; and associated fauna. Research has been designed primarily to understand ecosystem structure and processes and how these have been affected by human activities. The results help to direct the management program.

2. Management. The management program is designed to mitigate the effects of human activities. Management actions include prescribed burning to reduce fuel accumulation resulting from fire suppression, and the removal of roads, buildings, and water and sewer lines from affected areas. For the most part, these programs are designed to reverse the effects of years of misguided management activity, and to allow natural processes to influence ecosystems as fully as possible in the future.

3. Monitoring. Monitoring provides a means of measuring the effects of the management program and of evaluating its success in achieving objectives. Monitoring generally consists of field measurement before, during, and after management actions, and follow-up analysis and evaluation of data. It provides feedbacks to management strategy and tactics (Parsons and others 1985).

4. Interpretation. Interpretation plays the important role of informing park visitors on basic sequoia ecology as well as the reasons behind management actions. Translation of information from research and monitoring programs into a form understandable to both managers and the public is an essential part of the overall program. It helps to build support for, and thus assure, the long-term success of all National Park Service activities.

Fire Management

Research on the importance of periodic fire in maintaining natural giant sequoia forests has justified the need to restore a natural fire regime in those areas where fire suppression has been most effective. The first experimental prescribed burns were carried out in the Redwood Mountain Grove of Kings Canyon National Park in 1964. Research on the effects of these early burns documented the importance of fire in giant sequoia regeneration and in creating a mosaic of vegetation types (Harvey and others 1980)

In the late 1960's and early 1970's, additional prescribed burning was carried out in the Redwood Mountain Grove. Objectives at that time typically called for removal of 100 percent of the dead and downed fuel and removal of 70–100 percent of sapling and small pole trees (Bancroft and others 1985). Small (30–50 acres or 12–20 ha) blocks were burned uniformly with strip headfires. Objectives were met, although occasional foliage scorch over 100–200 feet (30.5–70.0 m) high occurred. These hottest fires interestingly produced the greatest number of sequoia seedlings. In contrast, in the Mariposa Grove of Yosemite National Park, young white fir (*Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.) were manually cut and burned. This labor-intensive approach mimicked some of the effects of fire, but avoided unappealing effects such as dead trees and charred trunks.

A growing recognition of the natural role of fire in creating and maintaining mosaics of different ages and species (Bonnicksen and Stone 1981, 1982a), cycling nutrients (St. John and Rundel 1976), and controlling disease organisms (Piirto and others 1984) led to reevaluation of the fire management program. Today the principal goal of fire management in the giant sequoia groves of Sequoia, Kings Canyon, and Yosemite National Parks is to restore or maintain the natural fire regime to the maximum extent possible so that natural ecosystems can operate essentially unimpaired by human interference (see field trip handout in *appendix*). Prescribed burns are now conducted by igniting fires in a spot pattern, and allowing fuels, weather, and topography to produce a mosaic of fire behaviors and effects. Compared with the early Redwood Mountain burns and the extensive thinning of the Mariposa Grove, both ground and standing fuels are removed less completely. Crown scorch height averages about 30 feet (9.1m), although small areas that contained much deadwood have scorch heights of 60–100 feet (18.3–30.5 m). This mosaic of intensities and fire effects may well approximate the poorly documented historic role of natural fire in the giant sequoia-mixed conifer zone of these parks.

Objectives of individual prescribed burns are carefully designed to reduce fuels to the point where natural (lightning) ignitions can again be allowed to burn. Identifying areas where natural ecosystems have been most altered by fire suppression helps managers to place priorities on prescribed burning of areas to reduce unacceptably high fuel loading. Computer models such as FYRCYCL (van Wagtendonk 1985) can also help managers determine if and when a prescribed burn is needed by identifying the "natural" range or variability of fuel accumulation for a given area. Once fuels have been reduced to more acceptable levels, lightning ignitions will again largely be permitted to determine the fire regime. We anticipate that some natural ignitions will have to be replaced by prescribed burns where natural fires must be suppressed for safety or political reasons. The success of such a fire management program will depend upon the ability to predict fire spread and intensity under varying conditions, the number and size of natural fires allowed to burn, and public acceptance of the program.

Recently, burning prescriptions have been refined to the point where prescribed fire can be successfully used to modify forest structure. However, rather than dictate a given forest structure as desirable, the National Park Service has established the goal of restoring the natural role of fire to the forest and then allowing the structure and function to return to equilibrium. Realizing that the 60 years of successful fire suppression are merely a flash in the ecological time scale of giant sequoia, we consider allowing natural fire after prescribed reduction of fuels to be a conservative approach that minimizes subjective judgment of which trees are good and which are bad.

The use of prescribed fire in Sierra Nevada National Parks can best be viewed as an evolving program. As is the case with many natural processes, it is impossible to know exactly what the long-term impacts of the program will be. For this reason, the program must be carefully monitored and frequently reevaluated. The study of unburned controls as well as areas burned with different intensities will help evaluate the long-term effectiveness of the program in restoring natural fire regimes. At the same time, additional research on fire history, fuel dynamics, fire spread rates, and fire effects is needed to make the conceptual and computer models upon which the management program is based as realistic as possible.

Showcase areas, where evidence of fire is minimized, have been designated in a few high visitation areas. Such areas are limited in size and used either to portray how an area appeared at a given point in time, or to present an esthetically and subjectively pleasing forest where the effects of fire or other disturbance are minimized. Managing to preserve natural processes and managing for an unburned appearance are inherently contradictory. The maintenance of showcase areas is achieved only at a severe biological cost. Even in such areas, the forest depends on fire for nutrient cycling and reproduction. To date, showcase areas are limited to a few heavily visited zones, such as around the General Sherman Tree in Sequoia National Park and around the General Grant Tree in Kings Canyon National Park.

Visitor Use

Early concern over the impacts of human use on giant sequoia groves focused on the fear that soil compaction from foot and vehicular traffic would lead to root damage and the eventual demise of the trees. However, soil compaction actually increased sequoia growth due to decreased evapotranspiration and competition from young trees and herbaceous plants (Hartesveldt 1964). This was an unnatural influence that could have long-term negative impacts, particularly through the exposure of surface roots. Additional impacts from the development of visitor facilities have included cutting roots and covering soil by buildings and asphalt (Vale 1975). Piirto and others (1984) suggested that soil and root disturbance associated with roads, trails, and other construction may initiate premature failure of giant sequoias.

The need to replace water and sewage facilities as well as dilapidated structures in the Giant Forest in Sequoia National Park raised the question of whether such development could continue to be tolerated. Concern over such impacts resulted in moving campgrounds out of the Giant Forest during the 1960's. Proposals and associated environmental assessments to move remaining structures were approved in 1979. The National Park Service and Guest Services Incorporated (the Park concessioner) are building new facilities at Clover Creek and Lodgepole, a few miles to the north, and out of the grove.

Air Pollution

Air pollution recently has been recognized as a potential threat to the health of the coniferous forests of the western United States (Miller 1980, 1985; Roth and others 1985). Ozone, in particular, has been implicated in forest damage in southern California (Williams and others 1971).

While mature giant sequoias are generally considered to be relatively tolerant of ozone, seedlings may be sensitive. Research funded by the National Park Service is investigating the sensitivity of sequoia seedlings to varying levels of atmospheric ozone. This work includes artificial fumigation of sequoia seedlings. Additional comprehensive studies of the potential effects of acid deposition as well as the use of remote sensing to detect changes in forest health are also underway in Sequoia National Park (Parsons and Graber 1985). Such information is critical to the long-term preservation of the giant sequoia ecosystem.

CONCLUSIONS

While an active—but conservative—management program continues, much remains to be learned about the ecology and fire history of giant sequoia ecosystems. The management programs in Sequoia, Kings Canyon, and Yosemite National Parks must still be looked on as partially experimental. It is, and will continue to be, impossible to accurately predict all of the ramifications of management activities. However, while the optimum level of fuel reduction or scorch height during prescribed burns can be debated, one fact remains: the exclusion of fire is unnatural.

All living organisms must eventually die. Giant sequoias are no exception. The fact that sequoia trees may fail due to root disease or fire scars should not in itself be cause for alarm. These are part of the natural ecological process and must be allowed to continue if natural ecosystems are to be preserved. However, it is when changes in these processes result from human activities that managers must be concerned.

REFERENCES

Bancroft, Larry; Nichols, Thomas; Parsons, David; Garber, David; Evison, Boyd; van Wagtendonk, Jan. Evolution of the natural fire management program at Sequoia and Kings Canyon National Parks. In: Proceedings, symposium and workshop on wilderness fire; 1983 November 15–17; Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1985: 174–179.

Bonnicksen, Thomas M.; Stone, Edward C. The giant sequoia-mixed conifer forest community characterized through pattern analysis as a mosaic of aggregations. Forest Ecol. and Manage. 3(4):307–328; 1981.

Bonnicksen, Thomas M.; Stone, Edward C. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology 63(4):1134–1148; 1982a.

Bonnicksen, Thomas M.; Stone, Edward C. Managing vegetation within U.S. National Parks: a policy analysis. Environ. Manage. 6(2):101–102, 109–122; 1982b.

Bonnicksen, Thomas M.; Stone, Edward C. Restoring naturalness to national parks. Environ. Manage. 9(6):479–486; 1985.

Graber, David M. Rationalizing management of natural areas in national parks. The George Wright Forum 3(4):48–56; 1983.

Graber, David M. Coevolution of National Park Service fire policy and the role of national parks. In: Proceedings, symposium and workshop on wilderness fire; 1983 November 15–17; Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1985:345-349.

Hartesveldt, Richard J. An investigation of the effect of direct human impact and of advanced plant succession on *Sequoia gigantea* in Sequoia and Kings Canyon National Parks. San Francisco, CA: National Park Service, U.S. Department of the Interior; 1964. 82 p.

Hartesveldt, Richard J.; Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. The giant sequoia of the Sierra Nevada. Washington, DC: National Park Service, U.S. Department of the Interior; 1975. 180 p.

Harvey, H. Thomas; Shellhammer, Howard S.; Stecker, Ronald E. Giant sequoia ecology. Scientific Monograph Series 12. Washington, DC: National Park Service, U.S. Department of the Interior; 1980. 182 p.

Kenner, Brian C. The philosophical basis for national park management. The George Wright Forum 4(3):22–37; 1985.

Kilgore, Bruce M. The role of fire in a giant sequoia-mixed conifer forest. J. Quaternary Res. 3(3):496–513; 1973.

Lemons, John; Stout, Dean. A reinterpretation of national park legislation. Environ. Law 15:41–65; 1984.

Leopold, A. Starker; Cain, S. A.; Cottam, C. M.; Gabrielson, I. N.; Kimball, T. L. Wildlife management in the National Parks. Amer. For. 69(4):32–35, 61–63; 1963.

Miller, Paul R., tech. coord. Proceedings of symposium on the effects of air pollutants on Mediterranean and temperate forest ecosystems; 1980 June 22–27; Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1980. 256 p.

Miller, Paul R. The impacts of air pollution on forest resources. Forestry Research West. 1985 August:1–5.

Parsons, David J.; Bancroft, Larry; Nichols, Thomas; Stohlgren, Thomas. Information needs for natural fire management planning. In: Proceedings, symposium and workshop on wilderness fire; 1983 November 15–17; Missoula, MT. Gen. Tech. Rep. INT–182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1985: 356–359.

Parsons, David J.; Graber, David M. Integrated watershed research undertaken at Sequoia National Park. Park Sci. 5(2):22–24; 1985.

Parsons, David J.; Graber, David M.; Agee, James K.; van Wagtendonk, Jan W. Natural fire management in national parks. Environ. Manage. 10(1):21–24; 1986.

Piirto, Douglas D.; Wilcox, Wayne W.; Parmeter, John R., Jr.; Wood, David L. Causes of uprooting and breakage of specimen giant sequoia trees. Div. Agric. and Natural Resources Bulletin 1909. Berkeley: Univ. Calif.; 1984. 13 p.

Roth, Philip; Blanchard, Charles; Harte, John; Michaels, Harvey; El-Ashry, Mohamed T. The American west's acid rain test. Res. Rep. 1. Washington, DC: World Resources Institute; 1985. 50 p.

Rundel, Philip W. Community structure and stability in the giant sequoia groves of the Sierra Nevada, California. Amer. Midl. Nat. 85(2):478–492; 1971.

St. John, Theodore V.; Rundel, Philip W. The role of fire as a mineralizing agent in a Sierran coniferous forest. Oecologia 25:35–46; 1976.

Stark, Nellie. The environmental tolerance of the seedling stage of *Sequoiadendron giganteum*. Amer. Midl. Nat. 80(1):84–95; 1968.

Strong, Douglas H. To save the big trees. National Parks and Conserv. Magazine 49(3):10–14; 1975.

Vale, Thomas R. Ecology and environmental issues of the Sierra Redwood (*Sequoiadendron giganteum*) now restricted to California. Environ. Conserv. 2(3):179–188; 1975.

Van Wagtendonk, Jan W. Fire suppression effects on fuels and succession in short-fire-interval wilderness ecosystems. In: Proceedings symposium and workshop on wilderness fire; 1983 November 15–17; Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1985: 119–126.

Williams, W. T.; Brady, M.; Willison, S. C. Air pollution damage to the forests of the Sierra Nevada Mountains of California. J. Air Pollut. Control Assoc. 27:230–234; 1971.

Management of Giant Sequoia on Mountain Home Demonstration State Forest[1]

Norman J. Benson[2]

Abstract: Established in 1946, the Mountain Home Demonstration State Forest, Tulare County, California, is managed by the California Department of Forestry. It is a multiple-use forest with recreation as its primary focus, although timber management has always played an important role. Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) occurs in isolated groves in the Sierra Nevada and grows on about half the acreage of the Mountain Home Forest. Old-growth specimens are protected, and selected young-growth trees are encouraged to grow to old-growth. Young sequoias are a valuable resource and are managed for timber production. A long-term study indicates that logging encourages sequoia reproduction by providing a suitable seedbed.

The California Department of Forestry manages seven State Forests to demonstrate continuous forest production practices, with due regard for conservation of soil, watershed, scenic, wildlife, and recreation values. Four of the seven State Forests are large enough to warrant a full-time staff. One of these—the Mountain Home Forest—occupies 4,562 acres (1846 ha) and has an extensive recreation program with 96 campsites in Tulare County in central California. A unique characteristic of the Forest is an extensive stand of giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz), which occurs only in isolated groves in the Sierra Nevada from Placer County south to Tulare County. Logging on what is now the Mountain Home Demonstration State Forest began in 1880, and most of the area has been cut over at least once. Public outcry against large-scale destruction of old-growth giant sequoias prompted the State Legislature to appropriate $550,000 to purchase the land in 1946 from the Michigan Trust Company.

This paper describes the history, physical characteristics, and management objectives of the Mountain Home Demonstration State Forest, with emphasis on management of giant sequoia. It also describes a study begun in 1966 to determine the benefits of logging on reproduction and survival of giant sequoia seedlings. Seedlings were only produced on the logged plot and not on the unlogged plot, but subsequent brush competition may have reduced survival of seedlings on the logged plot.

MOUNTAIN HOME STATE FOREST

Elevations on the Forest range from 5500 to 7500 feet (1680–2290 m), with mostly moderate slopes. Site quality is high, mostly I and IA. Climate is characterized by cool, wet winters and warm, dry summers. Average annual precipitation, primarily snow, is 40 inches (102 cm).

In contrast to the other six State Forests, which emphasize timber management, the Mountain Home Forest is managed primarily for public recreation. This objective, however, does not exclude timber production. Rather, timber management enhances and complements recreational values. The annual allowable cut is about 1.5 million board feet (Mfbm). Since 1946, the Forest has harvested 57 Mfbm of all tree species—including young-growth sequoia—without depleting the timber inventory. During this time annual recreation use has increased from 1,000 to 51,000 visitor-days.

Practices governing management of giant sequoia on the Forest are:

- Old-growth sequoia are protected during all management activities.
- Young-growth sequoias are considered a valuable and marketable resource.
- Selected young-growth sequoias are encouraged to grow into specimen trees.
- Campgrounds are located away from old-growth sequoias.

Old-growth giant sequoia is characterized by a rounded top with large limbs in the upper part of the bole and with the lower one-third of the bole free of branches. Growth is slow, with annual rings often only a few millimeters wide. The wood is brittle and not suitable for use in construction. Young-growth sequoia is characterized by a pointed top and branches persisting on the entire bole. Growth is rapid, with annual rings often one-half inch (1.3 cm) wide. The wood is considered better than white fir for construction uses.

Continuous Forest Inventory (CFI) data, which include trees over 5 inches (12.7 cm) in diameter at breast height (d.b.h.) indicate that the Forest has 7.8 (19.3/ha) young growth and 0.9 (2.2/ha) old-growth giant sequoias per acre. Old-growth sequoia volume was estimated at 138 Mfbm in 1907 by the James D. Lacy Company of Portland, Oregon (Goldsmith 1945). No estimate of volume for old-growth giant sequoia is available today. There are 5.72 Mfbm of young-growth sequoia. Basal area for old-growth sequoia is 61 ft^2/acre (14 m^2/ha) and for young-growth is 14 ft^2/acre (3.2 m^2/ha), which together make up 39 percent of the total basal area on the Forest.

METHODS

A study was begun at Moses Mountain in 1966 to investigate the long-term effects of logging on the establishment and sur-

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Table 1—*Merchantable trees on one unlogged and one logged 5-acre plot before (1966) and after (1968) logging, Moses Mountain, Mountain Home State Forest, California*

Species	Trees/acres		Volume		Basal area	
	1966	1968	1966	1968	1966	1968
			Tfbm /acre[1]		*ft²/acre*	
White fir:						
Unlogged	39.4	[2]—	39.8	—	143.9	—
Logged	31.0	—	39.7	7.0	129.3	35.3
		15.6				
Sugar pine:						
Unlogged	6.2	—	20.9	—	52.2	—
Logged	8.6	5.0	28.6	11.5	72.3	32.6
Giant sequoia:						
Unlogged	9.8	—	125.0	—	295.6	—
Logged	4.2	3.6	151.4	144.3	299.4	282.9
Total						
Unlogged	55.6	—	185.7	—	492.1	—
Logged	43.8	24.2	219.7	162.8	501.0	350.8

[1]Thousand board feet per acre.
[2]Unlogged plot was not measured in 1968.

vival of giant sequoia seedlings (Schoenheide 1971). Two similar 5-acre (2-ha) plots 0.01 miles (0.016 km) apart were selected in an area where no fire or logging had occurred for more than 60 years. Both plots were inventoried (*table 1*) as follows:

- All trees over 11 inches (28 cm) d.b.h. were measured and labelled with numbered tags.
- Pole-size trees 5 to 11 inches (12.7 to 28.0 cm) d.b.h. were tallied.
- Reproduction was sampled and placed into one of two categories: less than 1 foot (30 cm) tall or 1 foot tall to 5 inches (12.7 cm) d.b.h.
- Other vegetation was sampled and identified.

One of the plots received only custodial care. The other plot was logged in 1968 as part of a timber sale. Over 70 percent of the softwood volume (not counting old-growth sequoia volume) was harvested, to remove the acreage from the tax rolls. This plot was then reinventoried in 1968 (*table 1*). Giant sequoia seedlings were sampled on both plots starting in 1967 using mil-acre strips. The unlogged plot was burned in summer 1985 removing much of the duff and preparing an excellent seedbed. The State Forest staff plans to compare seedling survival on this plot with survival on the logged plot.

RESULTS AND CONCLUSIONS

The unlogged plot has had no sequoia reproduction, but the logged plot had a high number of seedlings immediately after logging, followed by a dramatic decline:

Year	Seedlings/acre
1967	0
1969	332
1971	87
1973	28
1976	17
1981	8

This decline in the number of seedlings was probably due to increasing brush competition. These results indicate that sequoia reproduction can be enhanced by disturbance of the soil during logging, but brush competition can subsequently reduce seedling survival.

The Mountain Home Forest is unique among the public forests in California, because it is managed primarily for public recreation and the other Forests are managed primarily for timber production or multiple use. It is also the only State Forest with giant sequoias, which are managed to perpetuate old-growth specimens and to provide a sustained harvest of young-growth trees.

The State Forest staff plans to conduct further studies on the effects of logging on growth and yield, and to determine optimum stocking levels.

REFERENCES

Goldsmith, Belknap G. [Personal notes]. 1945. Located at: Mountain Home State Forest, Springville, California.

Schoenheide, Richard L. The manipulation of vegetation of Sierra redwood lands on Mountain Home State Forest. 1971. Unpublished report on file at Mountain Home State Forest, Springville, California.

Management of Giant Sequoia in the National Forests of the Sierra Nevada, California[1]

Robert R. Rogers[2]

Abstract: The Forest Service avoided positive management activities within giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) groves after heavy early logging on private lands caused adverse public reaction. However, since 1975 timber sales and prescribed burning have been conducted to encourage giant sequoia regeneration and increase tree vigor. General management direction is contained in supplements to the Forest Service Manual. Management strategies for individual groves will be finalized through the Land Management Planning process, now underway.

In the mid 1960's many people within the Forest Service began to recognize the need for positive management in stands containing giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) trees. This need was indicated by two different observations on National Forest lands:

1. The "groves" were being overtaken by white fir (*Abies concolor* [Gord. and Glend.] Lindl.), and did not appear to be reproducing naturally with giant sequoia.

2. Giant sequoia typically occupied the better timber growing sites, and there were opportunities for increasing timber productivity on National Forest land.

The first observation led to the altruistic decision that the Forest Service should not stand by and watch the giant sequoias, especially spectacular individuals, just pass out of the picture. The second led to a strictly pragmatic decision to manage the groves for timber production. As discussed below, the Forest Service management policy for giant sequoia now accommodates both of these decisions.

About 5 years lapsed between the first serious consideration of management needs and the first specific Forest Service Manual direction (U.S. Dep. Agric., Forest Serv., 1970). Another 5 years lapsed before any projects designed specifically for giant sequoia management were initiated. Even though it is not uncommon to find a delay of 10 years between concept and execution of any new idea, there was some justification for the delay on this issue. In the first place there was a lingering memory of adverse public reaction to heavy logging around the turn of the century, and a desire to avoid reawakening that controversy. Related to the potential for public reaction was a reluctance to begin artificial regeneration of giant sequoias outside of the naturally occurring groves for two reasons: (1) Planted trees might grow into controversial groves where further management would be curtailed; and (2) the wood of older trees was known to be brittle and not much good for lumber—investments from a strictly financial point of view did not make much sense. Thus the Forest Service was aware of the need to manage giant sequoia but unsure about how to begin.

Finally, in 1975 the Forest Service initiated a prescribed burn designed to reduce fuel loading and provide seedbed for giant sequoia regeneration in the Bearskin Grove (a stopping point on the field trip for this workshop. See handout in *appendix*). This particular project was undoubtedly influenced by observations on the prescribed fire research and project work conducted by the National Park Service on nearby Redwood Mountain. Encouraged by the success of the Bearskin burn, the Forest Service then decided to make a modest attempt at logging within the same grove.

Since then, four timber sales that included 60 acres (24 ha) within four groves on the Sequoia National Forest have been completed. All silviculture prescriptions have been directed towards the general goals of preserving existing "specimen" trees and perpetuating the species. Specific prescriptions were for seed tree harvesting with underplanting. In some cases the seed trees were sequoias only, in others mixed conifer species were left as well. At the time this workshop was held, four timber sales were under contract with 250 acres (100 ha) of harvest within four more groves. Prescriptions included seed tree, shelterwood, sanitation and thinning. Five timber sales in the planning stage propose harvests within giant sequoia groves.

Future management of giant sequoia depends on the outcome of the National Forest Land Management Planning effort. The Land and Resource Management Plan for the Sequoia National Forest is expected to be finalized in May 1987. However, of the approximately 14,000 acres (5700 ha) of forest land classified as giant sequoia type, a significant share probably will be managed to stress continuation of natural processes. The obvious candidates for this "preservation" category are groves located within wilderness areas, those that are unique geographically—such as Placer Grove in the extreme north end of the range, and those that deserve special administrative recognition—such as the Calaveras Big Tree National Forest established by act of Congress in 1909. Most of the 14,000 acres probably will be assigned to a management objective that stresses protection of large old trees and perpetuation of the species, but allows positive management actions to emphasize selected resource values. This category of management is defined as "non-intensive" in the Forest Service Manual supplement shown in the Exhibit attached. It accommodates the need for recreational developments in areas such as the Belknap Grove in the Tule River drainage of the Sequoia National Forest. It also allows for vegetation manipulation, including cutting trees and use of herbicides, to open up views of "specimen" trees or to prepare sites for regeneration. The key to non-intensive management action, then, is the selection of resource values to be emphasized.

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Finally there are tens of thousands of acres of National Forest land on the west slope of the Sierra Nevada that would surely support good growth of giant sequoia if the species were planted there. The Forest Service has already begun introducing giant sequoia onto these sites as a component of the mixed conifer forest, and will manage most of it like any other species—primarily for timber production. This "intensive" category of management also applies to all or portions of about 1,000 acres (400 ha) where all of the large old trees were removed in early logging; although reconstructing natural conditions on some of this area may prove desirable.

Most of the philosophy and activities described above pertain to the Sequoia National Forest. It contains about 90 percent of the naturally occurring groves on National Forest land and more than 90 percent of the area they occupy. However, the unique characteristics of the species have also been recognized in other places. On all National Forests in the Sierra Nevada giant sequoias have been planted from time to time, as they have on several other forests in California. In fact, if interest in the species were measured by the amount of seed stored in the Forest Service seed bank at Placerville, then the San Bernardino National Forest runs a close second to the Sequoia. On the San Bernardino about 5,000 to 10,000 seedlings are planted each year, and at least one instance of natural regeneration from some of the early plantings has been observed.

On all National Forests within the natural range of giant sequoia it is generally considered to be a legitimate species for management in the mixed conifer forest type. The Forest Service is clearly committed to the management of giant sequoia. Now it is a question of precisely how and where it should be managed.

REFERENCE

U.S. Department of Agriculture, Forest Service. Supplement No. 91 to Forest Service Manual; Title 2400, Timber Management, Chapter 2405, Multiple Use Coordination. San Francisco, CA: Pacific Southwest Region; 1970.

2471 - HARVEST CUTTING

Giant Sequoia Groves. The giant sequoia (Sequoiadendron giganteum) is remarkable for its great size and long life. Due to the limited occurrence of old, large giant sequoia trees and the aesthetic value of the species, they warrant special treatment.

The management objectives for stands of giant sequoias shall be established by Management Category. The general objectives shall be the perpetuation of the species, the maintenance and preservation of "specimen" trees, and sequoia, live or dead, that has mature characteristics such as: columnar form of stem, deeply furrowed bark, lower stem free of limbs, red bark, etc. In addition, it must be *-older than 150 years and larger than eight feet in diameter at six feet above ground level. To effectively meet the above objectives, the -* compatible practices are recognized by Management Category:

1. Preservation. This Management Category will be reserved for those stands or groves of present or potential high aesthetic or scientific values. Although this designation is generally restricted to large prominent groves, it may also apply to one, or a few, "specimen" trees, the protection of which is desirable because of unique size or location. It may also apply to Research Natural Areas or Botanical Areas.

Groves or stands selected for Preservation management shall have their exterior boundaries posted. No major activities that would be potentially harmful to the giant sequoia trees, such as campground or road construction, or timber cutting, will be permitted. Activities shall be limited to those needed to perpetuate the "specimen" trees and the natural conditions of the associated trees and ground cover, or to improvement such as foot trails to provide for public access. Dead and down giant sequoias shall be left in place. Deviation from these restrictions may be made only with the written approval of the Forest Supervisor.

2. Non-intensive. Mixed conifer stands which contain large, old growth (older than 150 years) giant sequoias as a component and which have not been designated and approved for Preservation will be given special treatment to preserve the old growth giant sequoias in the stand.

The objectives of management shall be to perpetuate the species, improve stand vigor, and develop replacement "specimen" trees. Management flexibility is allowed so that selected values may be emphasized, provided these objectives are met. Values selected for emphasis may vary between groves, and between stands within the same grove.

Silvicultural prescriptions shall be prepared for each stand to meet the objectives of non-intensive management as qualified by management emphasis. Any silvicultural system, even-aged or uneven-aged, may be used which will meet the objectives and the appropriate emphasis. Clearcutting of whitewoods to promote mixed species reproduction and thinning of giant sequoias to improve vigor and size are approved practices. Use of prescribed fire and all techniques for manipulating vegetation are also approved practices in these stands.

No "specimen" giant sequoia is to be cut or damaged. Management activities shall be conducted in a manner to insure protection of these trees from root damage, undue exposure to windthrow, or unacceptable damage which might occur from other trees felled into or against them. Deviation from these constraints shall be allowed only upon the approval of the Forest Supervisor.

3. Intensive. These are areas of National Forest land (primarily those acquired after logging) that support either pure stands of giant sequoia saplings, poles or large young trees, or mixtures of young giant sequoias and other species. In addition, there are areas that are outside of the present natural range of the species which, due to site quality or location, are capable of growing giant sequoias. There are no restrictions on management activities in these stands other than to promote expansion of the giant sequoia range where possible.

*-Giant Sequoia Grove Management.

1. Policy:

a.) A giant sequoia grove will be analyzed in its entirety prior to planning any timber sale or other activity that will affect the given grove.

b.) The need for a separate Grove Management Environmental Assessment (E.A.) will be determined at the time of scoping for the Position Statement. If no significant public issues are identified, the Grove Management Analysis may be included in the Compartment or Timber Sale E.A.

2. Grove Management Analysis:

The Grove Management Analysis will identify areas suitable for:

a. Preservation Management
b. Non-Intensive Management
c. Intensive Management

The rational for the allocation into each category will be documented. Also, the proposed management emphasis for Non-Intensive areas will be noted along with the reasons for the emphasis.

Detailed prescriptions will be developed by the project E.A.'s; i.e., Timber Sale or Compartment E.A.

The following criteria are established for determining the management direction in giant sequoia groves, or portions thereof.

1. Preservation:

All groves in wilderness areas are in this category. Groves outside of wildernesses should have at least one of the following attributes:

a. Comprised of unique specimens, groups, or eco-systems.

b. Offer outstanding recreational opportunities.

c. High public use or interest.

d. Adjacent to developed Recreation Sites or Wilderness Areas.

e. Unique features such as tallest, etc.

f. Second growth stand designated as replacement preservation grove.

Since the theme of preservation management is to allow natural environmental processes to operate, this management category is not necessarily limited to isolated or pristine groves.

2. Non-Intensive Management:

All grove areas not classed as Preservation or Intensive Management will fit into this category. The management emphasis will be identified; e.g., recreation, timber management, etc.

3. Intensive Management:

Lands meeting the following criteria may be considered for intensive management:

a. Second growth giant sequoia stands that have resulted from previous harvest; or

b. Planted giant sequoia stands.

Second growth and planted giant sequoia stands are <u>not</u> precluded from being considered for Preservation Management or Non-intensive Management. -*

Management of Giant Sequoia at Blodgett Forest Research Station[1]

Robert C. Heald[2]

Abstract: Researchers at Blodgett Forest Research Station, University of California, are studying giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) growth under both even-age and selection management in relationship to the presence of several shrub species and five native conifers. The sequoias are also being studied under several types of site preparation, vegetation control techniques, and stand densities. Seven management units are described. In virtually all situations, early (first 18 years) height and diameter growth patterns of sequoia equal or exceed those of native conifers.

FOREST DESCRIPTION

Blodgett Forest Research Station is a 2961-acre (1199 ha) field research station owned by the University of California, Berkeley, and operated by its Department of Forestry and Resource Management. The station provides a location for wildland resource research and demonstrates forest management principles and practices. Most of the property was given to the University by the Michigan-California Lumber Company in 1933 for timber management research. The forest is named in honor of John W. Blodgett, who was then president of the lumber company.

The forest is located in the American River watershed on the western slope of the Sierra Nevada in El Dorado County. All of the property is located between 3900 and 4800 feet (1200 and 1500 m) in elevation on the Georgetown divide. The topography is moderate. Most slopes average less than 30 percent and few are greater than 50 percent.

Blodgett provides excellent examples of the Sierra mixed conifer/oak forest type. More than 400 species of plants are found on the forest. Common tree species include ponderosa pine, sugar pine, California black oak, white fir, Douglas-fir, incense-cedar, and tanoak. Some of the most common brush species are manzanita, deerbrush, whitethorn, bear clover and western azalea. Over 150 species of animals have been seen on the forest including mountain lions, coyotes, rattlesnakes, squirrels, porcupines, hawks, chickadees, and deer.

Four major soil types are found on the forest. All are loams or sandy loams, which are generally well drained, fairly deep, and reasonably resistant to erosion—except when they are on steep exposed slopes. The Holland, Pilliken-Variant, and Musick soils are all developed from granodiorite parent materials. The Cohassett soil type is developed from andesitic lahar. These soils support conifers capable of growing 90 to 110 (35 m) feet tall and 18 to 26 inches (46–66 cm) in diameter at age 50 to 60 years. The average acre can produce 200–250 cubic feet (14–17.5 M^3/ha) or 1000–1250 board feet of wood per year.

Blodgett Forest receives an average of 66 inches (168 cm) of precipitation per year with a 22-year range of 23 to 108 inches (58–274 cm). About 85 percent of the precipitation falls between October and March while less than 5 percent falls during the summer months. Snow is common from November to April, averaging about 100 inches (250 cm) per year. Average daily maximum temperatures range from 48 °F (9 °C) in the winter to 80 °F (27 °C) in the summer. Average daily minimums range from 32 °F (0 °C) in the winter to 57 °F (14 °C) in the summer. Frosts are common from October through May.

There are no native giant sequoias (*Sequoiadendron giganteum* [Lindl.] Buchholz) in the area. The nearest native groves are in Placer County about 10 air miles north across the Middle Fork of the American River and in Calaveras County about 50 air miles southeast. Most of the plantings described below are from seed sources at Whitakers Forest, another University of California field station, located on the west edge of Kings Canyon National Park.

FOREST MANAGEMENT

To provide future opportunities for research, portions of the forest are managed utilizing even-and uneven-aged silviculture. Since the mid 1960's, sequoia has been gradually introduced under both systems. Since virtually all the forest was heavily cutover in the first two decades of this century, all the sequoias planted at Blodgett Forest have been in areas where either young growth mixed-conifer-oak (50- to 70-year-old) forests or brushfields were cleared.

Uneven-Aged Management

Sequoia in uneven-aged management was introduced initially alone and most recently mixed with other native conifers in group selection cuts. These openings have ranged from ¼ to 2 acres (<1 ha). Most such openings also have natural regeneration of native conifers about the same age as the planted sequoias.

One planting is a 10-year-old ½-acre (¼ ha) group selection cut on Holland soil located on a ridgetop at about 4600 feet (1400 m) elevation and a 10 percent east slope. The surrounding canopy is about 70 years old and 120 feet tall.[3] Sequoias range from less than 3 feet tall near the edge of the cut to about 20 feet tall near the center. Competing natural ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and white fir (*Abies concolor* [Gord. & Glend.] Lindl. ex Hildebr.) regeneration at the same age range from 3 to 15 feet tall. Shrub competition is principally deerbrush (*Ceanothus integerrimus*), and is over 6 feet tall despite having been cut to ground level 5 years earlier.

[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

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[3]1 ft = 0.305 m

Gen. Tech. Rep. PSW-95. Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986.

Another unit is a 13-year-old group selection cut of about ¾ acre (⅓ ha) on the same type of site. Sequoia heights range from 10 feet on the group cut edge to 26 feet at the group's center. Diameter at breast height ranges up to 10 inches (25 cm) for the largest trees. Live crown ratios (LCR) are all over 90 percent despite the close spacing of about 6 to 8 feet within the group. Branch diameters are all less than 1 inch (2.5 cm) regardless of tree position in the group. Natural ponderosa pine and white fir regeneration of the same age ranges is up to 18 feet in height. The Northern California Forest Yield Cooperative (NCFYC) site for the surrounding 70-year-old natural stand averages (breast height age 50) about 100 (Bigging and Wensel 1984). Dominant ponderosa pine in the group cut also average about site 100 using Oliver's (1972) pine site classification. Dominant sequoia appear to have an equivalent site index (although no real site index for sequoia exists) of about 130, or 30 percent taller at this age than ponderosa pine.

The oldest group selection planting at Blodgett Forest is 18 years old in a less than ¼-acre (1/10 ha) opening. Dominant sequoias are over 30 feet tall with 60 LCR despite the 120-foot tall surrounding conifer stand. Interestingly, the opening was apparently created by harvesting of a pocket *Fomes annosus*-infected white fir. Several white fir stumps among the planted sequoia have numerous *Fomes annosus* fruiting bodies. The sequoia showed no signs of disease at this writing.

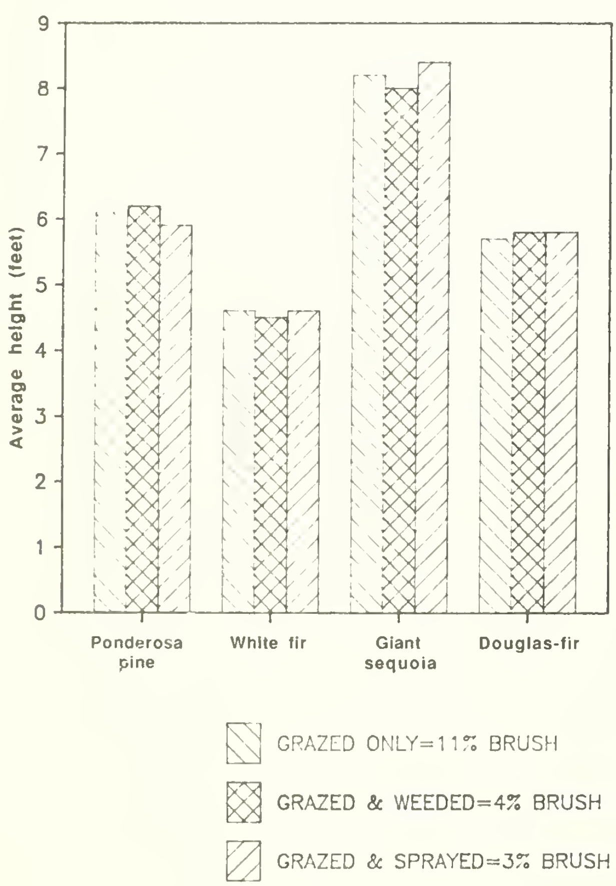

Figure 1—At age 5, planted giant sequoias averaged 8 feet in height on Unit 321-E.

Even-Aged Management

Sequoia has been fully integrated into Blodgett Forest even-aged management regeneration efforts only since 1981. Sequoia is currently included in each clearcut planted at a 10 to 20 percent rate. Unit 321-E is a 15-acre (7 ha) clearcut located on north and east slopes, at 4400 feet (1340 m) elevation. Again it is a Holland soil. Slopes range from 5 to 40 percent. The site was prepared by a crawler tractor equipped with a brushrake. Ponderosa pine, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), white fir, and giant sequoia were planted on 8-foot (2.5 m) spacings in April 1981. Giant sequoias were container stock grown in 8-inch super cell leach tubes at the Simpson Nursery in Korbel, from Whitaker seed source. Sequoias were less than 8 inches (20 cm) tall at the time of planting. Sequoias averaged 12 inches (30 cm) in height at the end of the second growing season but had more than tripled their volume of foliage. By the start of their fifth growing season (May 1985), sequoias averaged 8 feet in height (*fig. 1*). Most sequoia trees had full dense foliage throughout their crown despite average fourth year internodes in excess of 3 feet. Ponderosa pine averaged 6 feet with some individuals up to 8 feet. Douglas-fir averaged 5 feet with some individuals up to 7 feet. The tallest sequoias were nearly 10 feet tall at the beginning of their fifth growing season. On this clearcut competing vegetation is quite sparse. Shrub control is almost entirely the result of range cattle grazing. Inside cattle exclosures, deerbrush averaged 5 feet tall with over 80 percent crown cover on this site. Sequoia survival was greater than 80 percent. Despite heavy cattle and deer use, only one damaged sequoia was found. The damaging agent was not identified.

This pattern of sequoia growth is essentially duplicated on a 10-acre (4.5 ha) clearcut (Unit 200-E) planted at Blodgett in 1981. This second site is a steeper (30 to 50 percent) west-facing slope at 4100 feet (1250 m) elevation on Musick Series soil. The tallest sequoias were over 10 feet at the end of their fourth growing season (*fig. 2*). This location does not have cattle grazing. Shrubs—deerbrush and tanoak (*Lithocarpus densiflorus*)—were controlled in a third of the site by hand grubbing, and in another third by herbicide; one third of the site had no shrub control at all. Deerbrush cover in the control area exceeds 60 percent with average height over 4 feet. Although all trees including sequoia exhibited less dense foliage in areas with heavy shrub competition, only a slight difference in total height of sequoia was evident at the end of the fourth growing season. Ponderosa pine, Douglas-fir, and white fir showed significant reductions in height at age 4, when grown in the untreated brushy area.

On an 11-acre (5 ha) clearcut planted with white fir in 1970, approximately a 1-acre (½ ha) area was planted with giant sequoia in spring 1971. A dense shrubfield of deerbrush and greenleaf manzanita (*Arctostaphylos patula*) over 6 feet in average height has developed since planting. White fir averages less than 3 feet in height with occasional natural ponderosa pine overtopping the brush. Sequoias, on the other hand, average nearly 30 feet in height, with several trees over 35 feet. Diameter at breast height ranges from 6 to 13 inches (15 – 33 cm), despite about 6-foot average spacing in this 14-year-old plantation. This is a

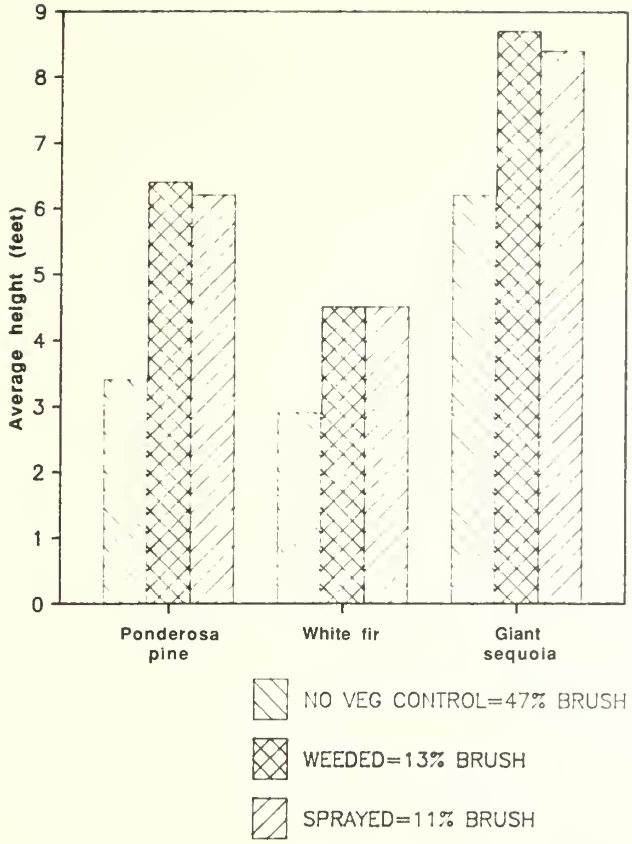

Figure 2—After four growing seasons, the tallest giant sequoias were over 10-feet high on Unit 200-E.

wet site on the edge of a spring. Nevertheless, the sequoias were able to suppress both grass, sedges, and deerbrush (as evidenced by skeletons inside the sequoia stand) that had a 2-year headstart on growth. Indeed, the sequoias on this wet site were actually about 20 percent shorter at age 5 than on the aforementioned 5-year-old plantation, which is on a well-drained hillside. Perhaps the extra moisture on this site partially compensated for early shrub competition. Some individual trees are truly impressive. One tree had a height of 38 feet and d.b.h. of 14.9 inches (38 cm) at age 14. Several trees have been pruned over the last 3 years. They exhibit virtually no epicormic branching. Some apparently minor sapsucker damage is visible.

Another plantation, which is about 16 years old, was originally started as a density study. This site is a dry, eastfacing midslope area at 4200 feet (1280 m) in elevation on Pilliken-Variant soil. The area was a brushfield before clearing and planting with giant sequoia. A dense 6-foot tall greenleaf manzanita, bush chinquapin (*Castanopsis sempervirens*), and bear clover (*Chameabatea foliolosa*) shrubfield again occupied the site by the early 1980's. Natural pine regeneration is scattered throughout the area with heights ranging up to 16 feet. Pine trees and sequoias are taller where tree survival was higher, and tree spacing closer together. Many sequoias survive at or below the general brush canopy height. In 1983, the brush was cut with a chainsaw-powered cutter. Sprouting shrubs were sprayed in 1984. Released sequoias had already increased height growth and greatly increased in crown volume only 2 years after brush control. Typical giant sequoias were 7 to 10 feet tall with about 20 to 40 percent crown height above the brush in 1983.

At this early stage of research, adding sequoia to both even- and uneven-age managed young-growth stands seems quite compatible with existing wood production goals. Increased species diversity may be an additional benefit to wildlife habitat and visual quality. Early sequoia height and diameter growth appears less susceptible to growth reductions due to competition with ceanothus shrub species than are other native Sierra conifers.

REFERENCES

Bigging, G. S.; Wensel, Lee C. Site equations for young growth mixed conifers of northern California. Res. Note 8. Berkeley: Northern California Forest Yield Cooperative, Univ. of California; 1984.

Oliver, William W. Height intercept for estimating site index in young ponderosa pine plantations and natural stands. Res. Note PSW-276. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1972. 4 p.

Management of Giant Sequoia at Calaveras Big Trees State Park[1]

Wayne Harrison[2]

Abstract: The California Department of Parks and Recreation manages two groves of giant sequoia (*Sequoiadendron giganteum*[Lindl.] Buchholz) located in Calaveras Big Trees State Park. Since the 1970's prescribed burning has been an integral part of the management program for these groves, with early indications of successful results. Restrictions have been placed on the program to avoid scorching and charring the soft outer bark of the trees. As high levels of fuels that accumulated during decades of fire suppression are reduced, restrictions are being removed. Future plans call for manual thinning of stands in an attempt to reduce interspecies competition and restore presettlement conditions.

The California Department of Parks and Recreation (CDPR) manages two groves of giant sequoia or Sierra redwood (*Sequoiadendron giganteum* [Lindl.] Buchholz), located at Calaveras Big Trees State Park. Known as the North and South Calaveras Groves, these stands may represent the northern extent of the species' optimum range, because only the small Placer Grove is located at a higher latitude. The Park itself is located 77 road miles (123 km) east of Stockton and 36 road miles (58 km) west of Ebbetts Pass, and is bisected by the North Fork of the Stanislaus River, which also separates the two groves *(fig. 1)*.

NOMENCLATURE

Buchholz (1939) defined the morphological differences between *Sequoia gigantea,* as Sierra redwood was known at the time, and coast redwood (*Sequoia sempervirens*). He showed that—while taxonomically related—the two did not belong to the same genus. It was not until the 1960's, however, that this distinction was given formal recognition, and the binomial *Sequoiadendron giganteum* was adopted. As a result of the change, the State of California decided that the popular common name "giant sequoia" was technically inaccurate and its use inappropriate. The State formally recognized Sierra redwood as the common name, because it established both a distinction and a relationship with the other "redwood" species: coast redwood and dawn redwood (*Metasequoia glyptostroboides*).

DESCRIPTION OF THE GROVES

The Calaveras Groves have different overall characteristics. The South Grove is by far the larger, with nearly 1,000 specimens in 445 acres (180 ha). It is located in a basin formed by Big Trees Creek. The basin is uniformly sloped throughout, with only a few flat areas located along the stream. Sierra redwoods are typically found on these slopes.

The North Grove, on the other hand, has 158 specimens spaced over 60 acres (24 ha). It is also located in a stream basin, but one of generally low relief. One steep, north-facing slope exists along an edge of the grove, but only seven trees are found there. The rest of the mature specimens are found on the flat flood plain formed along the watercourse. A unique biological feature of the North Grove is the close association between Pacific yew (*Taxus brevifolia*) and Sierra redwood. The North Grove represents the southern limit of yews in the Sierra Nevada, and the occurrence is confined to the grove. This is the only known exclusive association involving the Sierra redwood and another plant species.

Histograms of the size frequency of specimens found in each grove are similar, particularly in that both indicate a depression in small- to mid-range frequencies (12–95 inches in diameter at 6 feet or 240–420 cm at 1.8 m) and a peak at mid-range diameter (96–168 inches or 240–420 cm) *(fig. 2)*. This could indicate a general decline in reproduction over the past centuries, or perhaps an extended period in the past during which exceedingly favorable conditions existed.

Cumulative frequency curves *(fig. 3)* further indicate the similarity between the two groves, although the significance of this cannot be determined without comparison with other groves.

At least one case shows evidence that the North Grove—despite its small size—provides an exceedingly favorable growing environment. The infamous "Big Stump," the remnant of the tree deliberately felled simply because it was there, clearly indicates the tree's growth record. Its age has been placed at only 1,300 years, although its girth (less bark) of 24 feet (7.2 m) would indicate a much more venerable tree. An average annual growth of 0.20 inches (5 mm) in diameter supports the notion that the North Grove provides a very favorable habitat.

PRESCRIBED BURNING PROGRAM

As is true of virtually all resource agencies, the California Department of Parks and Recreation has only recently foregone the strict, protectionist theory of resource management—recognizing that prudent stewardship requires more active (and in some cases remedial) measures. The centerpiece of this type of management is an ongoing program of prescribed burning begun in 1975 under the tutelage of Dr. Harold Biswell, Professor emeritus, School of Forestry, University of California, Berkeley. A

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[1]Presented at the Workshop on Management of Giant Sequoia, May 24–25, 1985, Reedley, California.

[2]Associate Resource Ecologist, California Department of Parks and Recreation, Calaveras District, Arnold, California 95223.

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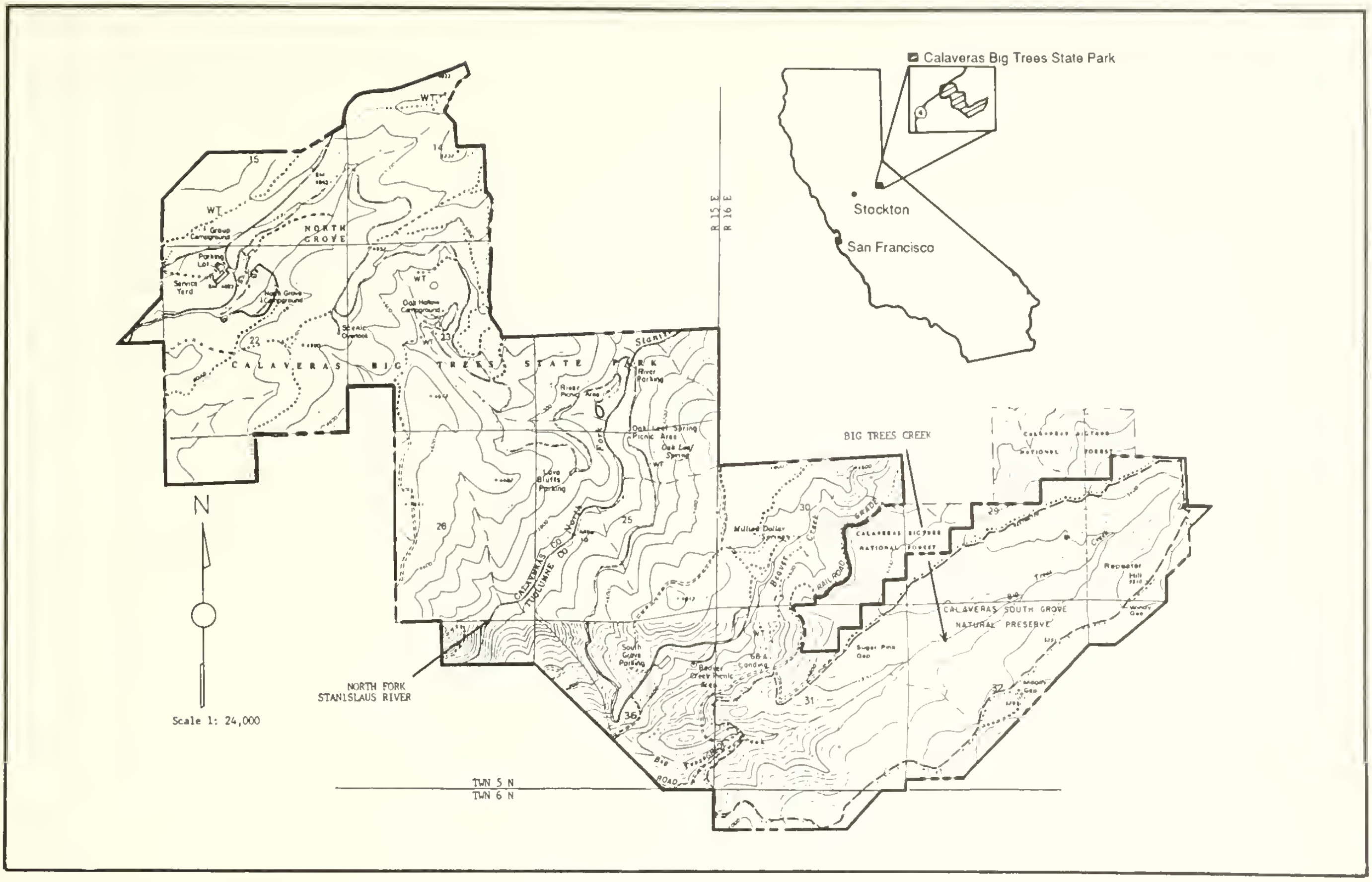


Figure 1—Calaveras Big Trees State Park is located between Stockton and Ebbetts Pass.

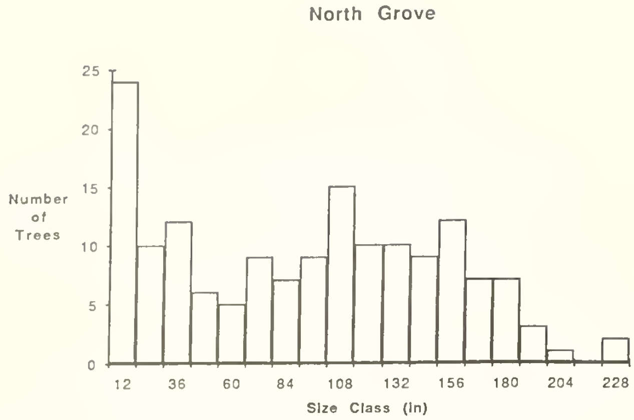
critical aspect of the burning program was that CDPR is not only a resource agency but a recreation agency as well. Moreover, the agency has an administratively close relationship with the public. For example, the CDPR has historically depended upon private organizations such as the Save-the-Redwoods League and the Sempervirens Club for the purchase of park property. In fact, the South Calaveras Grove was acquired in this manner. In a broader scope, a major portion of funding for CDPR comes from bond acts passed by the citizens of California. Therefore, the agency would be remiss if the views of the private sector were not considered in the planning processes. This public opinion has affected the evolution and management of the prescribed burning program.

When the issue of conducting burns in the South Grove was first raised, little concern was expressed over the desirability of such a program: The National Park Service (NPS), U.S. Department of the Interior, had already well established its efficacy. Rather, the public was more concerned over the potentially undesirable visual impact that burning might have on the soft and ignitable outer bark of the Sierra redwood. As a means of mitigation, CDPR cut a line to mineral soil around each of the nearly 1,000 big trees in the South Grove. Other efforts designed to reduce visual and environmental impacts included keeping fire away from riparian zones and stream channels, protecting snags and raking around mountain dogwoods (*Cornus nuttallii*), which are susceptible to cambium damage from fire.

To further complicate matters, unlike the NPS and the Forest Service, U.S. Department of Agriculture, CDPR is not its own fire control agency: all burns have to be conducted with the approval of the California Department of Forestry (CDF). In 1975, CDF was still divided over the question of prescribed burning. When CDPR requested a permit from CDF to start burning in the South Grove basin, the size of each burn was limited to only a few acres. Given the limited burning "windows" available in the spring and fall each year, burning the entire 1,250 acres (506 ha) of the Big Trees Creek basin would have been a monumental task. As CDPR showed that it could conduct burns safely, these acreage limitations were gradually eased, and finally removed.

Similarly, some of the other restrictions already mentioned were dropped when the CDPR began burning in the North Grove in 1984. Only the restriction on charring the Sierra redwoods remained, and each tree was again raked before burning. When the North Grove burn is completed, this final mitigation measure can probably be dropped, and future burns in both groves may be conducted without special protection for the Sierra redwoods. These efforts were always considered to be primarily a response to the unusually high levels of forest fuels resulting from decades of fire suppression. Fires conducted under such conditions could be unnaturally intense and damaging. Now that fuel levels have been lowered, prescribed burns should be possible without producing unacceptable charring of the trees.

When the CDPR began burning in the South Grove in 1975, it was with intense concern over the potential disaster that could result if an uncontrolled wildfire should enter the basin before



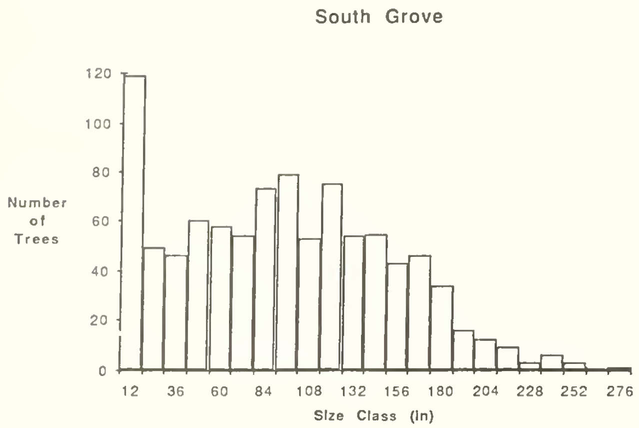


Figure 2—The frequency distribution of Sierra redwood is similar in the North and South Groves.

the unnaturally high fuel loadings could be reduced. Because measured loadings range from 27 to 115 tons per acre (Agee and Biswell 1977), a summer wildfire in such fuels would be cataclysmic. For this reason, conducting prescribed burns in the South Grove was given the highest priority, at the expense of conducting an extensive and detailed preburn monitoring program. Furthermore, during the 5 years that burns were conducted in the South Grove, whenever burning was not possible, crews manually thinned the understory throughout much of the grove. About 20,000 trees were removed in this manner. Once

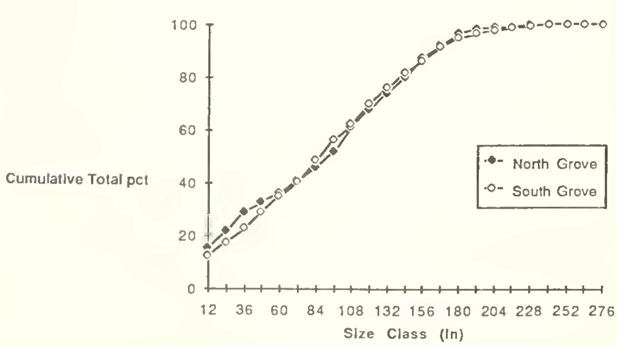


Figure 3–Cumulative frequency curves for Sierra redwood show that the North and South Grove apparently are similar.

again, no pretreatment studies were conducted. Consequently, little substantive data is available on the condition of the grove immediately before these activities and their results can not be measured.

BIOLOGICAL EVALUATION

To rectify this lack of data (albeit belatedly) the CDPR initiated in 1985 a biological evaluation of the South Calaveras Grove and the surrounding basin. This study was designed to provide baseline data on a number of parameters, including growth rates, top condition, tree defects, and population characteristics for the Sierra redwood, plus composition and size characteristics for all other tree species. Permanent reference points and plots have been established so that follow-up studies will have a basis for comparison. It is unknown if this study will result in any management decision, but—at the least—it may be of interest to those who wish to know more about the community dynamics of the grove.

The only previous systematic study of the South Grove population was conducted by the Forest Service in 1924. Oscar M. Evans mapped and measured each Sierra redwood with a diameter of 12 inches (30 cm) or more, in both groves. The histograms *(fig. 2)* and frequency curves *(fig. 3)* were derived from these data.[3] They are the best sources of information available about the North and South Groves but are over 60 years old.

This new study will at least identify changes over this period, although the methods and parameters are not similar to those of the Evans. The prime value of the biological evaluation will not be realized until the studies are replicated, or when other agencies conduct similar programs in the groves they manage. For instance, comparable information on growth rates between groves located at the northern, middle, and southern ranges would at least be interesting, and at the most could provide useful comparisons between different management schemes. I encourage such studies.

FUTURE PLANS

Finally, CDPR is planning an intensive management program in the North Grove. Using backward projection techniques developed by Bonnicksen and Stone (1978), we hope to develop a model of the presettlement characteristics of the grove, and manually thin the stand to reflect those conditions. This program is now in the planning stages, and work should begin during the 1986–87 fiscal year.

REFERENCES

Agee, James K.; Biswell, H.H. Fuels inventory: South Grove, Calaveras Big Trees State Park. 1977. Unpublished manuscript.

Bonnicksen, Thomas M.; Stone, E.C. An analysis of vegetation management to restore the structure and function of presettlement giant sequoia-mixed conifer forest mosaics. 1978. Unpublished manuscript.

Buchholz, J.T. The generic segregation of the sequoias. Am. J. Bot. 26 (7): 535–538; 1939.

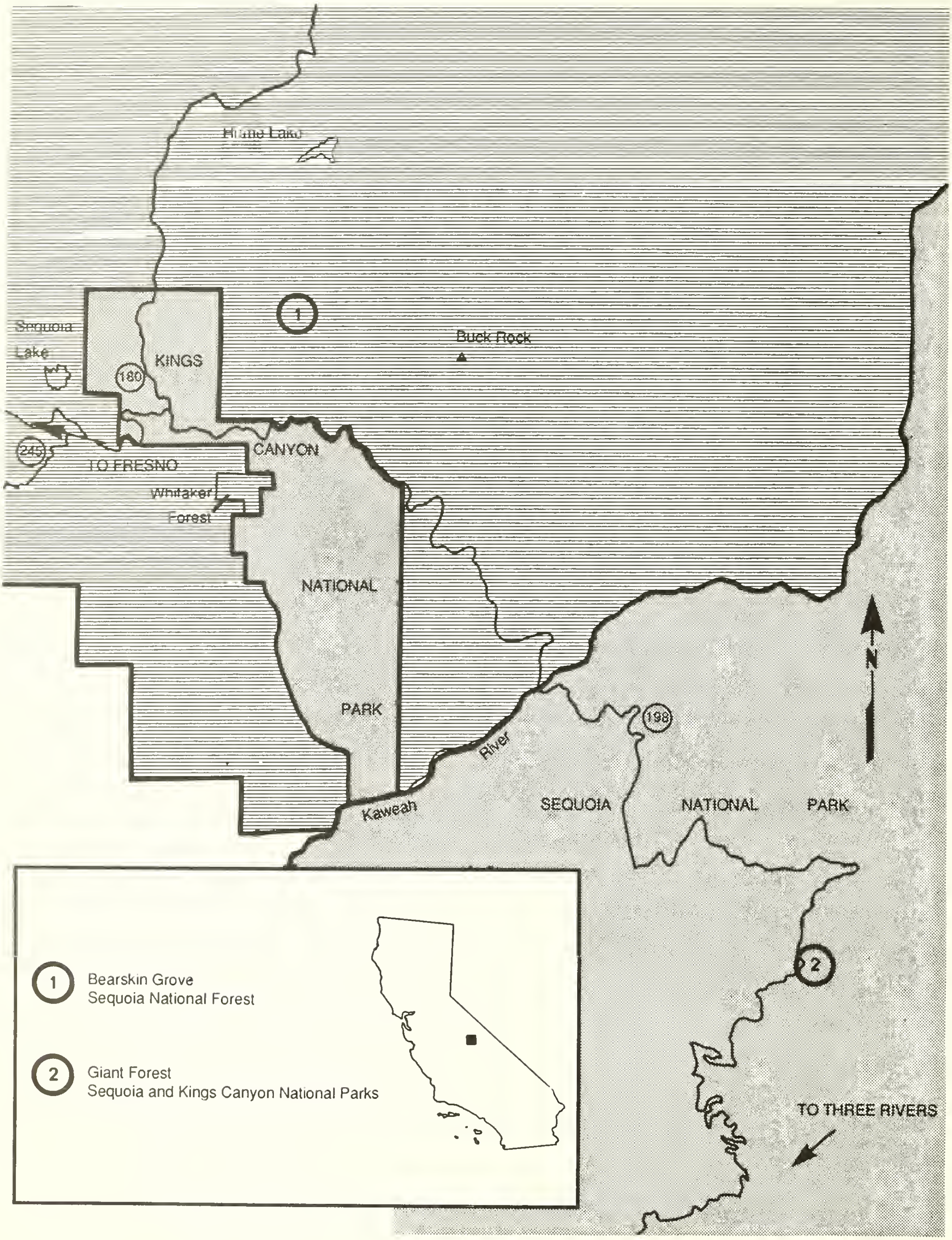
[3]Unpublished data on file, Calaveras District, California Department of Parks and Recreation, Arnold, California 95223.

APPENDIX
Field Trip Summary and Handouts

The field trip held during the Workshop on Management of Giant Sequoia allowed participants to observe first-hand some of the appropriate management activities being practiced by the Forest Service and National Park Service, U.S. Department of the Interior. Two other objectives of the field trip were to stimulate discussion and to encourage the exchange of ideas among the workshop participants, and the research and resource experts in the field. The field trip met all three objectives, and stimulated further interest in the future research and management of the giant sequoia species.

At the Bearskin Grove in the Sequoia National Forest (1 on map), participants observed two seed tree shelterwood units in which all the whitewoods were removed, leaving the residual giant sequoias as a seed source. The two units also enabled comparing the effects of two site preparation methods, broadcast burning and mechanical piling/burning (see handout).

At the General Sherman Grove in Sequoia and Kings Canyon National Parks (2 on map), participants observed results of the prescribed underburning program designed to encourage natural stand structure and composition, and natural giant sequoia regeneration in the Grove. The other management scenario of preservation was also observed (see handout).



Sequoia
Lake
180
KINGS
245
TO FRESNO
CANYON
Whitaker
Forest
NATIONAL
PARK
1
Buck Rock
198
River
Kaweah
SEQUOIA
NATIONAL
PARK
N
2
TO THREE RIVERS
1 Bearskin Grove
Sequoia National Forest
2 Giant Forest
Sequoia and Kings Canyon National Parks

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

MANAGEMENT PROJECTS WITHIN THE BEARSKIN GROVE
SEQUOIA NATIONAL FOREST--HUME LAKE RANGER DISTRICT

Paul Roche, Jr., Field Trip Leader

SPECIFIC INFORMATION:

Grove size - 60 acres.

Legal description - T.13S., R.28E., Sections 34 and 35, MDBM.

Mean elevation - 6,340 feet.

Aspect - Northeast.

Soil - Loamy sand and sandy loam in the A and B horizons, respectively. Granite parent material.

Annual precipitation - 43 inches, primarily snow.

MANAGEMENT PROJECTS:

Bearskin Grove Prescribed in 1975

The objective of this project was to reduce the fire hazard to the Grove and the surrounding areas, and to improve the regeneration capability of giant sequoias in the Grove.

This was to be accomplished through two controlled burns. The first burn was implemented in the spring of 1975 to reduce the ground fuels. The second burn was scheduled for the fall of 1976 to insure an increase in seed germination.

The first burn met the objective. The second burn was never implemented as giant sequoia seedlings were quite abundant the following spring. However, the seedlings did not survive.

Huckleberry Timber Sale in 1983

This timber sale harvested two units within the Bearskin Grove. The objective for these units was to obtain mixed conifer regeneration dominated by giant sequoias.

To achieve this, a seed tree cut was planned for each unit, leaving six to ten trees per acre. Different site preparation methods were selected for each unit so that a comparison of site preparation methods with regards to regeneration could be made. Unit 23, approximately 8 acres in size, was planned to have site preparation accomplished through broadcast burning, while Unit 24, approximately 9 acres, was planned for mechanical site preparation by tractor piling. Herbicide application was planned prior to planting.

Harvesting operations were completed during the summer of 1983. The following year, site preparation was completed in both units. The application of herbicides was deleted. Planting of giant sequoia stock is planned for the spring of 1986.

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

THE FIRE MANAGEMENT PROGRAM IN SEQUOIA AND KINGS CANYON NATIONAL PARKS

H. Thomas Nichols, Field Trip Leader

The Congressional act which established the National Park Service provided that the purpose of parks is to "...conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations." The National Park Service, by its Congressional mandate, is concerned with the perpetuation of a natural environment and the natural processes functioning therein, a policy further enunciated in Management Policies of the National Park Service (Branch of Fire Management, Boise Interagency Fire Center. NPS-18; 1986).

Fire is part of the natural environment. The vegetation-wildlife complex which existed when the first pioneers came through this area developed in the presence of periodic fires. These originated from both Indian burning and from lightning activity. In the sequoia-mixed conifer forest, these fires occurred about every 10-20 years, frequent enough to keep fuel levels low. As a result, fires were generally mild.

In the sequoia-mixed conifer forest, fire performs several functions which include:

1. Removes accumulations of dead fuels on the forest floor, thus reducing the potential for conflagrations that could destroy entire forest communities.

2. Thins young trees, opens the forest canopy favoring the survival of non-shade tolerant sequoia and sugar pine seedlings over shade-tolerant white fir and incense cedar.

3. Removes forest litter and exposes the mineral soil necessary for the germination of sequoia and other species.

4. Provides the heat stimulation necessary to germinate the seeds of many chaparral species and to stimulate the sprouting of existing shrubs, thereby providing newer and higher quality wildlife browse.

5. Recycles nutrients locked up in dead wood and makes them more available to plants as fertilizing ash.

6. Creates a mosaic of vegetation types and age classes, thus creating more habitat types and a greater diversity of plant and animal species.

Following the establishment of the National Parks and National Forests in the Sierra Nevada, fire suppression activities began to have an effect on the forest communities. The suppression of human-caused fires such as those from logging, carelessness, or arson, and many of the lightning fires, was necessary for public safety. It was also believed that fires were a destructive force which should be eliminated from the environment. The suppression of these produced a vegetation-wildlife complex much different from what had existed previously in the presence of fire. Those species which did not require fire for reproduction, such as white fir, became much more prevalent, while species which were fire dependent, such as sequoia, displayed a drastic decrease in reproduction success.

In an effort to recreate fire's beneficial effects and to restore more natural conditions in Sequoia and Kings Canyon National Parks, a fire management program was developed. This program defines any fire as either a wildfire or a management fire, depending on the fire's ability to meet specified, or prescribed, conditions of fire behavior and effects, public safety, and legal considerations such as air quality, threatened or endangered species, and jurisdictional boundaries. All wildfires are promptly suppressed because they do not meet management objectives.

Management fires are either natural fires (started by lightning) or prescribed burns (started by trained National Park personnel). Eighty percent of the Park is in a natural fire management zone. This is primarily above 8,000 feet (2,400 m), where lightning fires are allowed to burn largely unimpeded, subject primarily to air quality considerations and public safety. This program has been active since 1968, and was based upon the knowledge that fire suppression activities had far less impact on the fuels and vegetation of the higher and more remote regions of the Park because of their relative inaccessibility. All such fires are under continual surveillance. These burns are also monitored to determine their effects on the environment and for information applicable elsewhere in national parks and other wildland areas.

Prescribed burns have been used since 1964 in low elevation areas, generally under 8,000 foot elevations, where vegetation and fuels are heavy and have built to dangerous proportions through past fire suppression efforts. Lightning fires could not be allowed to burn as in higher elevations. Here, fire is used under controlled conditions to remove these fuel accumulations and to restore more natural conditions. While these fires are burning, a temporary decrease in local visibility may occur.

Prescribed burning is done only under selected weather and fuel conditions to maximize the beneficial effects of fire upon the environment. Monitoring before, during, and following such burns assures that resources management objectives are being met. As natural conditions are approximated, natural fire will be allowed to play its role to the fullest extent possible. Forests in and near developed areas will be prescribed burned on a rotation simulating the natural frequency, since it would be difficult to allow natural fires, which tend to occur in July and August, to burn and to produce smoke in areas which are intensively used by the public during their busiest period. Therefore, the fire management program attempts to allow fire to be an important process in the dynamic Sierra Nevada ecosystems, while ensuring that the possibility of a destructive fire is kept to a minimum.

Weatherspoon, C. Phillip; Iwamoto, Y. Robert; Piirto, Douglas D., technical coordinators. **Proceedings of the workshop on management of giant sequoia; May 24–25, 1985; Reedley, California.** Gen. Tech. Rep. PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 47 p.

Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) has long been noted for its size and beauty. It is widely planted as an ornamental and increasingly is being utilized for timber production. The workshop was the first ever designed to bring together the state-of-knowledge on giant sequoia and its management. Presentations covered its history, silvics, genetics, growth and yield, wood properties and products, insect and disease relationships, and management strategies. The proceedings are a useful reference for resource managers, foresters, naturalists, ecologists, and the interested public.

Retrieval Terms: giant sequoia, *Sequoiadendron giganteum*, Sierra redwood, mixed conifer forest type, resource management, Sierra Nevada (California)

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California Oaks: A Bibliography

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California Oaks: A Bibliography

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INTRODUCTION

California oaks today attract considerable attention among resource professionals. Moreover, the proliferation of this interest is much in evidence: the symposium on the ecology, management, and utilization of California oaks (Claremont College, in 1979); the California oak heritage conservation conference (University of California, Irvine, 1983); and *Fremontia*'s special issue (October 1983) devoted to oaks are but three more familiar examples. Oak harvesting and management was the focus of the California Department of Forestry's hardwood task force (1983) as well as the statewide meeting of the Society of American Foresters titled "Wood for Energy" (California Polytechnic State University, San Luis Obispo, in 1984).

Such events have suggested the need for a comprehensive bibliography of the extensive but scattered oak literature, including unpublished theses and reports. The oak reference files of the compilers and several colleagues, which comprise the core of the bibliography, were expanded and collated into the present format. However, the list of topics related to California oaks is not exhaustive. Such a comprehensive task would make recovery of data very difficult. The achievement of this bibliography is the convenient access which it provides to a large corpus of the California oak literature.

Owing to the personal preferences and experience of the compilers, some species and related topics have received more attention than others. The species most extensively covered are blue oak (*Quercus douglasii* H. and A.), California black oak (*Q. kelloggii* Newb.), and valley oak (*Q. lobata* Nee). Topics related to geography and taxonomy are relatively complete; topics related to physiology are less so. Also, more information is needed on many topics for all species.

Selected studies from other regions are included for those topics about which no significant California references exist. Only the most complete version or most recent edition is listed for revised or republished material. Only those theses which contain unpublished material are cited. Routine taxonomic listing of all oaks in all California floras is not covered. Relatively obscure historical items on large oaks and historic oak community distributions have been included to help document the changes which have occurred to oaks during the agricultural and urban development of California. The limited number of unpublished reports cited are on file at the Forestry Library, Mulford Hall, University of California, Berkeley.

The references are organized into two systems:

- Topical Outline. References are displayed under key word headings and subheadings. Author-date entries help to locate items by researcher or date.
- *Quercus* Species Index. References contain serial numbers for all species and named hybrids.

Indexing every species and all topics in every citation would have made the outline and indices too cumbersome; the indexing has therefore been selective. However, all references are listed at least once in the topical outline and species index. As the complexity of topics grew and total citations exceeded 750, the opportunity for assigning citations to incorrect or marginal places grew; the compilers accept responsibility for such occurrences. Optionally, the reader can turn directly to the bibliography and search at will through the large collection of references on the natural history, management, and utilization of California oaks which have been accumulated over the last century.

TOPICAL OUTLINE

1. Geologic History

1.1 Modern Species and Related Fossils

Q. agrifolia

Eocene, *Q. distincta*. MacGINITIE 1941.

Pre-Miocene records problematic. WOLFE 1980.

Q. chrysolepis

Pleistocene (Nevada). LESKINEN 1975.

Q. douglasii

Pliocene, *Q. douglasoides*. AXELROD 1937, 1944a,c.

Q. dunnii

Pleistocene (Nevada). LESKINEN 1975.

Miocene, *Q. pliopalmeri*. AXELROD 1939.

Q. engelmannii

Miocene. CONDIT 1944a,b.

P. pre-engelmannii. TUCKER 1952b.

Q. lobata

Pliocene, *Q. moragensis*. AXELROD 1944a,c; 1950.

Q. pre-lobata (Nevada). AXELROD 1958 [according to WOLFE 1980 this was *Acer*]. (Washington) SMILEY 1963.

Q. pre-lobata, Miocene. CONDIT 1944a. (Oregon and Idaho) CHANEY and AXELROD 1959.

Q. lobata-like pollen. AXELROD and TING 1960.

Q. rugosa

Q. temblorensis. RENNEY 1972.

Q. sadleriana

Compared with *Q. pontica* in Turkey. KASAPLIGIL 1981.

Q. tomentella

Q. declinata. AXELROD 1944a,b.

Q. turbinella

Miocene, *Q. dispersa*. AXELROD 1940, 1944b.

Q. virginiana

Q. dayana. RENNEY 1972.

Q. wislizenii

AXELROD 1958.

1.2 Overviews, Reviews, and History

California oaks, Neogene history. WOLFE 1969, 1980.

General. TRELEASE 1918.

History of:

Mediterranean ecosystems. AXELROD 1973.

Mixed evergreen forest. AXELROD 1977.

Oak-laurel forest. AXELROD 1977.

Oak woodland. AXELROD 1977.

Sclerophyll vegetation. AXELROD 1975.

Late Pleistocene. WARTER 1976.

Post Pleistocene. COTTAM [and others] 1959.

Pollen studies. ADAM [and others] 1981, AXELROD and TING 1960, COLE 1983.

Q. agrifolia, *Q. wislizenii*. VASEY 1980.

Riparian species (*Q. lobata*). ROBICHAUX 1977.

2. Systematics

2.1 Subgeneric Taxa

Worldwide treatments. CAMUS 1936-, SCHWARZ 1936.

North American treatments. MULLER 1942, PALMER 1942, TILLSON and MULLER 1942, TRELEASE 1924.

California reviews. TUCKER 1980, 1983.

2.2 Chemical Variation between Species

Acorns. OFCARCIK and BURNS 1971, WAINIO and FORBS 1941.

Miscellaneous. SANTAMOUR 1983 (cambial enzymes), SUTTON and MOGENSON 1970 (leaf primordia).

Phenolics. LI and HSIAO 1973-1974 (leaves), LI and HSIAO 1975-1976a (catkins), LI and HSIAO 1975-76b (twigs).

2.3 Specific Taxa

New species

Q. cornelius-mulleri Nixon and Steele (1981). New species in the *Q. dumosa* complex.

Q. dunnii Kellogg (1879).

Change in status

Q. breweri Engelmann (1880). Now commonly treated as a variety of *Q. garryana*. McMINN 1951.

Q. parvula Greene (1889-1890). NIXON (1980) and FLETCHER (1983) recognized this as a species; TUCKER (1980) treated this as a form of *Q. wislizenii* with possible varietal or subspecies merit. MULLER 1967.

Q. pricei Sudworth (1907). TUCKER (1980) treated this as a synonym of *Q. agrifolia*. SUDWORTH 1908.

Q. shrevei Muller (1938). TUCKER (1980) treated this as a form of *Q. wislizenii* with possible varietal or subspecies merit. K. Nixon is proposing *Q. shrevei* as a var. of *Q. parvula* according to ENGLES and GENETTI (1984).

Q. oxyadenia Torrey (1854). HOWELL 1931 described this as a variety of *Q. agrifolia*.

2.4 Miscellaneous Topics

Floral morphology. ROWLEE and NICOLS 1900, TURKEL [and others] 1955.

Leaf form evolution. TUCKER 1974.

Microsporogenesis and embryogenesis. STAIRS 1964.

Review of names used by U.S. Dep. Agric. LITTLE 1979.

Species concepts. BURGER 1975, VAN VALEN 1976.

Wood characters. WILLIAMS 1939, 1942a,b.

3. Genetics

3.1 Natural Hybrids

Q. agrifolia x *Q. kelloggii*

Q. X *chasei* McMinn, Babcock, and Righter (1949), *Q.* X *ganderi* Wolf (1944). ENGLES and GENETTI 1984, HOWELL 1970.

Q. agrifolia x *Q. wislizenii*

BROPHY and PARNELL 1974; THOMAS, D. 1970; VASEY 1980.

Q. chrysolepis x *Q. dunnii*
TUCKER 1980, TUCKER and HASKELL 1960 (Arizona).

Q. chrysolepis x *Q. tomentella*
TUCKER 1980.

Q. chrysolepis x *Q. vaccinifolia*
MYATT 1975.

Q. douglasii x *Q. dumosa*
TUCKER 1950, 1952a, 1953a, 1980.

Q. douglasii x *Q. garryana*
Q. X *eplingii* Muller (1938). DOBZHANSKY 1941, GRIFFIN 1966.

Q. douglasii x *Q. lobata*
Q. X *jolonensis* Sargent (1918). HOWITT and HOWELL 1973; THOMAS, J. 1961; TWISSELMANN 1967.

Q. douglasii x *Q. turbinella*
Q. X *alvordiana* Eastwood (1905) BENSON 1940, BENSON [and others] 1967; GRIFFIN and CRITCHFIELD 1972, HOOVER 1970; TUCKER 1952b, 1980, 1983; TWISSELMANN 1967, WHITE 1966.

Q. dumosa x *Q. durata*
FORDE and FARIS 1962, TUCKER 1980.

Q. dumosa x *Q. engelmannii*
Q. X *grandidentata* Ewan (1937). BENSON 1962; LATHROP and THORNE 1978; ROBERTS, W. 1983; TUCKER 1980.

Q. dumosa x *Q. garryana*
Q. X *howellii* Tucker (1953b). HOWELL 1970.

Q. dumosa x *Q. lobata*
Q. X *macdonaldii* Greene (1889-1890), *Q.* X *townei* Palmer (1948). MULLER 1967, TUCKER 1980.

Q. dumosa x *Q. turbinella*
TUCKER 1950, 1952a, 1953a, 1980.

Q. durata x *Q. garryana*
Q. X *subconvexa* Tucker (1953b). EASTWOOD 1946, HOWELL 1970.

Q. garryana x *Q. lobata*
ROBERTS, W. 1983; TUCKER 1980.

Q. kelloggii x *Q. wislizenii*
Q. X *morehus* Kellogg (1863), *moreha* according to TRELEASE (1917). ANONYMOUS 1948, CUMMINGS 1985, EASTWOOD 1946, ENGELS and GENETTI 1984, GRIFFIN 1966, GRIFFIN and CRITCHFIELD 1972; HOWELL, J. 1970; HOWITT and HOWELL 1973, JEPSON 1910, McCLINTOCK [and others] 1968, PEQUEGNAT 1951, SUDWORTH 1908, TWISSELMANN 1967, WOLF 1938.

Q. lobata x *Q. turbinella*
Q. X *munzii* Tucker (1968) HOWITT and HOWELL 1973.

Q. sadleriana x *Q. garryana*
MUTH 1976, 1980; TUCKER 1980.

3.2 Artificial Hybrids
Q. douglasii x *Q. gambellii*. COTTAM [and others] 1982.
Q. douglasii x *Q. turbinella*. COTTAM [and others] 1982.
Q. lobata x *Q. gambellii*. COTTAM [and others] 1982.
Q. lobata x *Q. macrocarpa* (eastern U.S.). COTTAM [and others] 1982.
Q. lobata x *Q. robur* (Europe). COTTAM [and others] 1982.
Q. lobata x *Q. turbinella* (Utah). COTTAM [and others] 1982; ROBERTS, W. 1983.

3.3 Miscellaneous Hybrid Topics
Artificial hybridization. COTTAM [and others] 1982; WRIGHT, J. 1953.
Evolutionary influence. MULLER 1952.
Introgression (*Q. durata*). FORDE and FARIS 1962.
Nomenclature. TRELEASE 1917.
Numerical analysis in hybrids. JENSEN and ESHBAUGH 1976a,b.
Reviews. PALMER 1948, TRELEASE 1924, TUCKER 1959.
Spontaneous hybrids in cultivation. OSBORN 1931.

3.4 Cytogenetics
DUFFIELD 1940, IRGENS-MOLLER 1955, SAX 1930.

4. Regeneration

4.1 Sprouting
Q. X *alvordiana*. BENSON 1940, 1962.
Q. dumosa. KEELEY 1981, KEELEY and KEELEY 1981, KEELEY and ZEDLER 1978, MULLER 1951; PLUMB 1963, 1971, 1980; PLUMB and GOODIN 1982.
Q. engelmannii. SNOW 1980.
Q. garryana. MULLER 1951, SUDWORTH 1908 (as *Q. breweri*), SUGIHARA [and others] 1983.
Q. lobata. GRIFFIN 1980a, JEPSON 1910.
Miscellaneous topics. JEPSON 1910, LEONARD and MURPHY 1965, LONGHURST 1956, MULLER 1951, ROY 1955.

4.2 Flowering and Fruiting
Anatomy and morphology. BROPHY 1976, CONRAD 1900, GARRISON and AUGSPURGER 1983, HJELMQUIST 1953, HOSNER 1958; JOHNSON, A. 1940, LANGDON 1939, MERKLE [and others] 1980; MOGENSEN 1966, 1975; OLSON, D. 1974, SHARP and CHISMAN 1961, SHARP and SPRAGUE 1967, TUCKER 1972, TUCKER [and others] 1980, WILLIAMSON 1966.
Climatic interactions. FERET [and others] 1982, NEILSON and WULSTEIN 1980, SHARP and CHISMAN 1961, SHARP and SPRAGUE 1967, WOLGAST and STOUT 1977.

4.3 Acorns
Annual production. GRAVES 1977a, 1980; GRIFFIN 1976, MENKE and FRY 1980.

Dispersal. BENT 1946, GRINNELL 1936, INGLES 1947, SNOW 1972.

Germination. GRIFFIN 1971, HUNTER and VAN DOREN 1982, KNUDSEN 1984, KORSTIAN 1927 (REVIEW), MATSUDA and McBRIDE 1982, McCOMB 1934, MIROV 1945, MIROV and KRAEBEL 1939; PLUMB 1981, 1982.

Review. OLSON, D. 1974, RADTKE 1939.

4.4 Seedling Establishment and Predation

Miscellaneous. BOWYER and BLEICH 1980, CRUZAN 1981; GRIFFIN 1971, 1976, 1980b; HORTON and KRAEBEL 1955, HUNTER and VAN DOREN 1982, KNUDSEN 1984, MATSUDA and McBRIDE 1982, McBRIDE 1974, McCLARAN 1985, PASE 1969, SNOW 1972.

Root growth. CARPENTER and GUARD 1954.

4.5 Problems with Natural Regeneration, Loss of Mature Stands

Q. douglasii. GRIFFIN 1971, 1976, 1977; HOLLAND 1976; JOHNSON, S. 1985; WHITE, K. 1966.

Q. lobata. CALLIZO 1983, CAVAGNARO 1974, DUTZI 1979, FIEBLEKORN 1972; GRIFFIN 1971, 1973a, 1976, 1980b; JOHNSON, S. 1985; KIRN 1982, McCLARAN 1983; McGILL 1975, 1979; PARSONS, J. 1972; ROSSI 1979, 1980; STEINHART 1978; STERN, K. 1977; SWERSKY 1985.

Miscellaneous species. BOWYER and BLEICH 1980, IRVINE 1982; JOHNSON, S. 1985, KIRN 1982; PARSONS, J. 1972; SNOW 1972.

4.6 Artificial Regeneration

Grafting. MIROV and CUMMING 1945, SANTAMOUR 1983, SCHETTLER and SMITH 1980.

Planting. DARNELL 1983, DAWSON 1984, DOBBINS 1976, EVERETT 1957, LaROSA 1984, LOBEL and GEORGE 1983, MUICK 1980, RILLA [and others] 1979; ROBERTS, T. A. and SMITH. C. H. 1982; SAC. CO. OFF. ED. 1976; SCHETTLER and SMITH, M. 1980; WOLF 1941a,b; 1945.

Seeding. CRUZAN 1981, HARRIS and LEISER 1979, RILLA [and others] 1979.

Vegetative propagation. DAVIS, E. 1970; DOBBINS 1976, HARE 1977, MORGAN [and others] 1980; OLSON, J. 1969; SKINNER 1952.

5. Mycorrhizae, Diseases, and Mistletoe

5.1 Mycorrhizae

BECKJORD and McINTOSH 1983, DUNN 1980, MARX 1977.

5.2 Miscellaneous Diseases

Armillaria. RAABE 1975.

"Decline." MORRISON 1965; THOMAS and BOZA 1983.

"Dieback." HECHT-POINAR [and others] 1981.

Drippy nut. HILDEBRAND and SCHROTH 1967, KOEHLER 1978.

Fomes annosus. ANONYMOUS 1974, HUNT [and others] 1974.

Mildew. GARDNER [and others] 1972, GARDNER and YARWOOD 1978.

Miscellaneous. DWINELL 1973, DWINELL and POWERS 1974, HEDGECOCK and LONG 1914, LONG 1913, U.S.D.A. FOREST SERVICE 1958.

Oak wilt. HOLDEMAN 1983.

Phytophthora. MIRCETICH [and others] 1977.

Reviews. HEPTING 1971, KUNTZ 1964, RAABE 1980.

Slime fluxes. CARSON 1951.

5.3 Mistletoe Interactions

ASHCRAFT 1981, BISWELL 1959, HOLLINGER 1983b, THOMSON and MAHALL 1983, WIEN 1964.

6. Insect Interactions

6.1 Acorn Damage

DORSEY 1967; GIBSON 1964, 1969; HILDEBRAND and SCROTH 1967, KOEHLER 1978.

6.2 Oakworms, Predators, and Controls

GLYPHIS 1982, HARVILLE 1955; HORN 1973, 1974; KOEHLER 1982, MASON 1969, MILSTEAD [and others] 1980b, PINNOCK and MILSTEAD 1971, PUTTICK 1982, ROBERTSON 1972; VOLNEY [and others] 1983a,b; WICKMAN 1962; YOUNG 1977, 1980, 1982.

6.3 Other Lepidoptera

DAVIS, D. 1972; EVANS 1970, GREEN 1979; JOHNSON, J. 1980a,b; MILSTEAD [and others] 1980a; OPLER 1971, 1973, 1974a,b; OPLER and DAVIS 1981, ROOT 1966.

6.4 Herbivores and Leaf Chemistry

FAETH 1984, FEENEY 1970, GLYPHIS 1982, MAUFFETTE and OECHEL 1983, MAUFFETTE [and others] 1984.

6.5 Cynipid Galls

BURNETT 1974; CORNELL 1983, 1984, 1985; CORNELL and WASHBURN 1979, DAILEY 1969, DAILEY and SPENGER 1973, DAILEY [and others] 1974, DOUTT 1959, EVANS 1972, FELT 1965; LYON 1959, 1963, 1964, 1969, 1970; MANI 1964, McCRACKEN and EGBERT 1922, MORAN 1974, ROSENTHAL 1968, ROSENTHAL and KOEHLER 1971; RUSSO 1975, 1979, 1983; WASHBURN 1984, WELD 1957.

6.6 Miscellaneous Topics

BROWN [and others] 1975, CARSON 1951; DUNCAN, C. 1922; OKIWELU 1977, PRITCHARD and BEER 1950, ROEPER and FRENCH 1978, SKILES [and others] 1978, WALSH 1977, WINSTON 1956.

6.7 Reviews
BROWN, L. 1980; BROWN and EADS 1965, FURNISS and CAROLIN 1977, KEEN 1958.

7. Vertebrate and Wildlife Interactions

7.1 Birds
Eating and storing acorns
Acorn woodpeckers. BOCK and BOCK 1974, BURGESS [and others] 1982, FISCHER 1906, FLEXNER 1978, GUTIERREZ and KOENIG 1978, JEHL 1979, KOENIG 1980, MacROBERTS, M. 1970; 1974; MacROBERTS, B. and MacROBERTS, M. 1972; 1976; MacROBERTS, M. and MacROBERTS, B. 1976; MICHAEL 1926, MUMME [and others] 1983, RITTER 1938; ROBERTS, R. 1976, 1979.
Jays. BENT 1946, BOSSEMA 1979 (European jay), GRINNELL 1936.
Pigeons. FRY and VAUGHN 1977; SMITH, W. 1968.
Quail. GUTIERREZ 1980, LINSDALE 1936, MILLER and STEBBINS 1964, SHIELDS and DUNCAN 1966.
Wild turkeys. SMITH and BROWNING 1967.
Yellow-billed magpies. LINSDALE 1946b.
Oak communities as bird habitats
Breeding bird censuses and winter bird population studies (selected examples; only earliest season of replicated series listed).
Q. agrifolia forest. COGSWELL 1966, PUGH 1956.
Q. douglasii woodland. PERRONE 1970, PERRONE and REMSEN 1970; WILLIAMS 1979a,b.
Q. dumosa insular woodland. ATWOOD 1977.
Q. durata chaparral. GAINES 1975.
Q. lobata woodland. McKINNIE 1974.
Miscellaneous riparian. BONTRAGER 1974a,b; LOVELESS and LOVELESS 1977, MANOLIS 1972, NAGATA 1982, PUGH 1961, TANGREN 1971; WILLIAMS 1980a,b.
Guild analyses and related community studies. HEJL 1981, HERTZ [and others] 1976, LANDRES and MacMAHON 1983, ROOT 1967, WAGNER 1981.
Miscellaneous. LAWRENCE 1966, MICHNY [and others] 1975, MOTRONI 1979, REMSEN and CARDIFF 1979, ROOT 1966, VERNER and RITTER 1985.
Reviews. GAINES 1977; GRAVES 1977a, b; VERNER 1980, VERNER and BOSS 1980.

7.2 Mammals
Browsing shoots
Cattle. DAYTON 1931, FRANCO 1976, MACKIE 1903, SAMPSON and JESPERSON 1963, SIEGMUND 1979, TALBOT and BISWELL 1942.
Deer. ASHCRAFT 1981, BISSELL and WEIR 1957; BISWELL 1959, 1961; BOWYER and BLEICH 1980, DAYTON 1931, DIXON 1934, GRIFFIN 1971, LAWRENCE and BISWELL 1972, LEACH and HIEHLE 1957, LEOPOLD [and others] 1951, LONGHURST [and others] 1979, MACKIE 1903, ROBINSON 1937, SAMPSON and JESPERSON 1963.
Goats and sheep. BISSELL and WEIR 1957, GREEN [and others] 1978; SIDAHMED [and others] 1981, 1982, 1983; SAMPSON and JESPERSON 1963, WILSON [and others] 1971.
Eating acorns
Bears
Black. GOLDSMITH [and others] 1981, GRABER 1981, GRENFELL and BRODY 1983, NOVICK and STEWARD 1982, PIEKIELEK and BURTON 1975.
Grizzly. STORER and TEVIS 1955.
Cattle. HART [and others] 1947, SAMPSON and JESPERSON 1963, SIEGMUND 1979; TALBOT and BISWELL 1942, VanDYNE and HEADY 1965; WAGNON 1946, 1960.
Deer. BOWYER and BLEICH 1980, DIXON 1934, HARLOW [and others] 1975, KERNS 1980, LAWRENCE and BISWELL 1972, LEACH and HIEHLE 1957, LINSDALE and TOMICH 1953, LONGHURST [and others] 1979, MENKE and FRY 1980, POTTER and JOHNSTON 1980, TABER and DASMANN 1958.
Deer mice. JAMESON 1952, MATSON 1974.
Hogs. BARRETT, R. 1978, 1982; HOFFMAN 1985.
Squirrels
Gray. ASSERSON 1974, INGLES 1947, STIENECKER 1977, STIENECKER and BROWNING 1970.
Ground. FITCH 1948, LINSDALE 1946a, SCHITOSKEY and WOODMANSEE 1978.
Pocket gophers. GRIFFIN 1980b.
Wood rats. HORTON and WRIGHT 1944, LINSDALE and TEVIS 1951.
Miscellaneous accounts and reviews. BARRETT 1980, BARRETT [and others] 1976; DUNCAN and CLAWSON 1980; GRAVES 1977a,b; HORN and FITCH 1942, KERNS 1980, KNUDSEN 1984, LAWRENCE 1966, STARK 1968, VERNER and BOSS 1980.

8. Species Distributions

8.1 Maps and Related Topics
California range of tree species. GRIFFIN and CRITCHFIELD 1972.
General ranges of tree species. LITTLE 1971, 1976.
Inventory and distribution record keeping. DAVIS 1985, PAYSEN 1978, 1980.
Q. chrysolepis map. MYATT 1975, TUCKER and HASKELL 1960.
Q. kelloggii map. McDONALD 1969.
Soil-vegetation maps. COLWELL 1974, MALLORY [and others] 1965, 1968, 1973.

8.2 Some Distributional Notes

Q. cornelius-mulleri. NIXON and STEELE 1981.

Q. chrysolepis. HAVLIK 1980, McCLINTOCK [and others] 1968; SMITH, G. 1984.

Q. douglasii. GRIFFIN 1966.

Q. dunnii. GRIFFIN and TUCKER 1976, TUCKER [and others] 1982.

Q. lobata. GRIGGS 1983a, TWISSELMANN 1967 (high elev.)

Q. parvula. FLETCHER 1983, NIXON, 1980.

Q. sadleriana. JEPSON 1907, KIMBROUGH 1975, MUTH 1980, SIEMENS 1972, WARING 1969.

Q. wislizenii. McCLINTOCK [and others] 1968.

8.3 Historical Geographic Notes

BELCHER 1843, BLAKE 1858, BOLANDER 1865, BRYANT 1848, DERBY 1932, JEPSON 1893, KELLOGG 1882, MALONEY 1945, NUGEN 1853 (map), VANCOUVER 1798.

9. Communities

9.1 Some Recent Classifications of Communities with Oaks

BROWN and LOWE 1980 (map), BROWN [and others] 1980, CHEATHAM and HALLER 1975, GRIFFIN 1977, KUCHLER 1977 (with map), PAYSEN [and others] 1980, THORNE 1976.

9.2 Riparian Forests and Adjacent Woodlands

Communities with *Q. lobata*

Central Valley. WARNER 1984.

Dry Creek, Sonoma Co. McBRIDE and STRAHAN 1984.

Feather River. KNUDSEN 1984, MOTRONI 1979.

Sacramento River. BELCHER 1843, JEPSON 1893; McGILL 1975, 1979; STRAHAN 1984.

Sacramento Valley. CONARD [and others] 1977, DUTZI 1979, GAINES 1977, GRINNELL [and others] 1930, MICHNY [and others] 1975, THOMPSON 1961.

San Joaquin Valley. GRIGGS 1983b, JEPSON 1910, MEDEIROS 1979.

Santa Clara Valley alluvial fans. COOPER 1926.

Communities with *Q. agrifolia*

BONTRAGER 1974a,b; BOWERMAN 1944, FERREN [and others] 1984, HORTON 1960, La ROSA 1984, ROWE 1963.

Communities with miscellaneous species.

Q. douglasii. WARNER 1984.

Q. dumosa (Baja Calif.). ROBERTS, N. 1984.

Desert oasis woodland. THORNE 1982, THORNE [and others] 1981.

Reviews. ROBERTS, W. [and others] 1977; ROBICHAUX 1977, THOMPSON 1961.

9.3 Valley and Foothill Woodlands

Locally dominated by:

Q. douglasii. ASHER 1980, BAKER [and others] 1981, BAUER 1930, BOWERMAN 1944; BROOKS 1973, 1981; CLARK 1937, CRITCHFIELD 1971; GRIFFIN 1973b, 1977; GRINNELL [and others] 1930, JEPSON 1910, KLYVER 1931; MALLORY [and others] 1965, 1968, 1973; McCLARAN 1985, MURPHY and CRAMPTON 1964, NAVEH 1967, NEAL 1980; THOMAS, J. 1961; TWISSELMANN 1956, 1967; VANKAT 1982, VANKAT and MAJOR 1978; WHITE, K. 1966.

Q. engelmannii. BENSON 1962, CRITCHFIELD 1971; LATHROP and THORNE 1968, 1978, LATHROP and ZUILL 1984, PEQUEGNAT 1951, SNOW 1972, WEISLANDER 1938, ZUILL 1967.

Q. garryana. ANDERSON and PASQUINELLI 1984, CLARK 1937; COOPER, P. 1972; GRIFFIN 1966, 1967; HEKTNER [and others] 1983, SAENZ 1983, SAUERWEIN 1983, SILENE 1958, STEIN 1980, SUGIHARA [and others] 1983, TUNISON 1973, WARING and MAJOR 1964.

Q. kelloggii. BAKER [and others] 1981, CRITCHFIELD 1971, MALLORY [and others] 1973, McDONALD 1980a; PARSONS, D. 1981; VANKAT and MAJOR 1978, VANKAT 1982.

Q. lobata. ASHER 1980; BAUER 1930, BLAKE 1858, CLARK 1937, COOPER, W. 1926; CRITCHFIELD 1971, DUTZI 1979, FIEBLEKORN 1972; GRIFFIN 1973b, 1976; JEPSON 1910, TWISSELMANN 1967, VANCOUVER 1798.

Miscellaneous. PAVLIK 1976.

Reviews. BARNHART 1978, GRIFFIN 1977.

Species diversity. NAVEH and WHITTAKER 1979.

9.4 Mixed-Evergreen Forests and Woodlands

Q. agrifolia locally dominant. BOWERMAN 1944, CAMPBELL 1980; COOPER, W. 1922; COLE 1980, CRITCHFIELD 1971; DAVIS, F. 1985; ENGELS and GENETTI 1984, FERREN [and others] 1984, FINCH and McCLEERY 1983, FLETCHER 1983, GORDON 1985; GRIFFIN 1973b, 1977; McBRIDE 1974, POLCYN 1983, TUNISON 1973, WAINWRIGHT and BARBOUR 1984, WELLS 1962.

Q. chrysolepis locally dominant. BORCHERT and HIBBERD 1984, BOWERMAN 1944, CAMPBELL 1980; COOPER, W. 1922; CRITCHFIELD 1971, GRAY 1978, HORTON 1960, MALLORY 1980, McDONALD and LITTRELL 1976, McDONALD [and others] 1983, MINNICH 1980; MYATT 1975, 1980; TALLEY 1974; THOMAS, J. 1961; WHITTAKER 1960.

Q. kelloggii locally dominant. TUNISON 1973, WAINWRIGHT and BARBOUR 1984.

Q. sadleriana present in understory. JEPSON 1907, KIMBROUGH 1975, MUTH 1980, SIEMENS 1972, WHITTAKER 1960.

Q. wislizenii locally dominant. BAKER [and others] 1981, BOWERMAN 1944, GRIFFIN 1977, KLY-

VER 1931, MALLORY [and others] 1965.
Reviews. COOPER 1922, SAWYER [and others] 1977.

9.5 Mixed-Conifer and Pine Forests

Q. kelloggii present. ASHER 1980, BAUER 1930, BISWELL [and others] 1966, BONNICKSON and STONE 1982, GRAY 1978, GRIFFIN 1967, HEADY and ZINKE 1978, HORTON 1960; MALLORY [and others] 1965, 1968, 1973; McDONALD [and others] 1983, MYATT 1980, PARSONS and DeBENEDETTI 1979, STARK 1965, TAPPEINER and McDONALD 1980, VASEK 1978 (with *Pinus jeffreyi*), VOGL and MILLER 1968 (with *P. jeffreyi*), WARING 1969.

9.6 Chaparral

Q. agrifolia. FERREN [and others] 1984, MOONEY [and others] 1974 (Baja Calif.).
Q. chrysolepis. BOWERMAN 1944, HORTON 1960.
Q. dumosa. ATWOOD 1977, BJORNDALEN 1978, GRINNELL [and others] 1930, HORTON 1960, PATRIC and HANES 1964, RIGGAN and DUNN 1982.
Q. durata. BOWERMAN 1944, GAINES 1975, GRAY 1978, GRIFFIN 1975, MALLORY [and others] 1968, WELLS 1962.
Q. garryana. ASHER 1980, CLARK 1937; MALLORY [and others] 1965, 1968, 1973; McMINN 1951, TWISSELMANN 1967.
Q. parvula. FLETCHER 1983.
Q. turbinella. BENSON [and others] 1967, GRIFFIN 1975, TWISSELMANN 1967.
Q. vaccinifolia. CLARK 1973, HOWALD 1981, WARING 1969 (serpentine), WHITTAKER 1960.
Q. wislizenii BAUER 1930, HORTON 1960, LAWRENCE 1966, MALLORY [and others] 1968, WELLS 1962, TWISSELMANN 1967.
Review. HANES 1977.

9.7 Desert Woodlands and Chaparral

Desert chaparral-Joshua tree woodland (*Q. turbinella* ssp. *californica*). MILLER and STEBBINS 1964, PHILLIPS [and others] 1980, THORNE 1982.
Pinyon-Juniper-Oak Woodland (*Q. chrysolepis*, *Q. turbinella* ssp. *turbinella*). HENDRICKSON and PRIGGE 1975, MILLER and STEBBINS 1964, REMSEN and CARDIFF 1979; THORNE, PRIGGE, and HENRICKSON 1981.

9.8 "Mediterranean" Comparisons

California (cf. Chile). MOONEY [and others] 1970, 1972.
California (cf. Israel). NAVEH 1967, NAVEH and WHITTAKER 1979.

10. Physiological Ecology

10.1 Crown-Soil Interactions

Allelopathy. GLIESSMAN 1978 (Costa Rica), McPHERSON and THOMPSON 1972 (Oklahoma).
Canopy effects.
Q. agrifolia. PARKER, V. 1977; PARKER, V. and MULLER 1979, 1982; POLCYN 1983.
Q. douglasii. DUNCAN 1967; HOLLAND, 1973, 1980; HOLLAND and MORTON 1980, JACKSON [and others] 1985, KAY and LEONARD 1980, MURPHY 1980, MURPHY and BERRY 1973, MURPHY and CRAMPTON 1964.
Q. garryana. SAENZ 1983.
Litter-soil misc. DUNN 1980, JENNY [and others] 1949.

10.2 Rooting, Soil Moisture, Water Table Interactions

ARKLEY 1981; CANNON 1914a,b; COOPER, P. 1972; COOPER, W. 1926; GRIFFIN 1967, HARRIS [and others] 1980 (Flood tolerance), HELLMERS [and others] 1955, HOLSTEIN 1984, KIMBALL 1950, KRAUSE and KUMMEROW 1977, KUMMEROW and MANGAN 1981, LEWIS 1968; LEWIS and BURGHY 1964, 1967; MEYER 1983, NG and MILLER 1980, PITT [and others] 1978, ROWE 1963, RUNDEL 1980; THOMAS, W. 1980, WARING and MAJOR 1964.

10.3 Water Stress, Transpiration

BAKER [and others] 1981; BOWMAN and ROBERTS, S. 1985; BURK 1978, GRIFFIN 1973b, HASTINGS and OECHEL 1982; HOLLINGER 1983a, b; MAUFFETTE and OECHEL 1983, MILLER, P.C. 1981, OECHEL [and others] 1985; PARKER, V. 1984; ROBERTS, S.W. 1982; ROBERTS and SMITH 1980; ROBERTS, S.W [and others] 1981; SNOW 1972, SYVERTSEN 1974, YOCUM 1935.

10.4 Fire Interactions

Changes in fire frequency. DODGE 1975, HEADY and ZINKE 1978, MINNICH 1980, PARSONS 1981, PARSONS and DeBENEDETTI 1979, WELLS 1962.
Fire tolerance. GRIFFIN 1980a, LAWRENCE 1966, PLUMB 1980, PLUMB and GOMEZ 1983, SNOW 1980.
Chaparral biomass. CHANDLER 1955, RIGGAN and DUNN 1982, RIGGAN and LOPEZ 1982, WAKIMOTO 1978.
Fuel management, prescribed burning. BISWELL [and others] 1966, BROWN, R. 1973; GREEN 1980, GREEN and SCHIMKE 1971, LATHROP and MARTIN 1982, MARTIN 1982.
Miscellaneous. PALMA-FLEMING and KEPNER 1983,

10.5 Nutritional Interactions

Carbohydrates, photosynthesis. BRYAN and WRIGHT 1976; HASTINGS and OECHEL1982; HOLLINGER 1983a,b; MAUFFETTE and OECHEL 1985, MILLER, P.C. 1981; MILLER and POOLE 1980; MOONEY and HAYS 1973, OECHEL and HASTINGS 1983,OECHEL [and others] 1981, RUNDEL 1980.
Chemical composition. McCOLL 1979, PALMER 1917; PARKER, J. 1977; WALLACE [and others] 1982.

Nitrogen and tannin levels. DUNN 1980, FEENEY 1970, FLEXNER 1978, GLYPHIS 1982, HOLLINGER 1983a, McCOLL 1979, RIGGEN and LOPEZ 1982; SAMPSON and SAMISH 1935, ZINKE 1969, 1982.

10.6 Chemical Contral

IKENBERRY [and others] 1938, JOHNSON, R. [and others] 1980, JOHNSON, W. [and others] 1959, LEONARD 1956, LEONARD and CARLSON 1959, LEONARD and HARVEY 1965, MURPHY and CRAMPTON 1964, OTTER 1960; PLUMB 1963, 1971; PLUMB and GOODWIN 1982; WARREN 1980a,b.

10.7 Air Quality and Climatic Problems

Heat damage. MIELKE and KIMMEY 1942.

Ozone damage

Oaks. GEMMILL 1980, McBRIDE 1978; MILLER [and others] 1980, STOLTE 1982

Lichens in oaks. ROSS and NASH 1981, WOOD 1984.

Salt (and "wind") damage. OGDEN 1975, 1980.

Sulphur dioxide. WINNER 1981, WINNER [and others] 1982.

10.8 Miscellaneous

FRASER-SMITH 1978 (ULF potentials), ISHAM and MORIARTY 1981 (dendrochronology, Calif.), JOHNSON and RISSER 1978 (ring width and climate, Oklahoma), WEAVER and JONES 1980 (leaf effect on rain).

11. Ethnobotany

11.1 Aboriginal Acorn Usage

BARRETT S. and GIFFORD 1933; BARROWS 1900, BAUMHOFF 1963, BEAN and SAUBEL 1972, CHESNUT 1902, DuBOIS 1940, GIFFORD 1971, JAEGER 1920, MERRIAM 1918; WHITE, R. 1963.

11.2 Modern Acorn Usage

BAINBRIDGE 1984, MERRIAM 1918.

11.3 General Reviews and Miscellaneous

BALLS 1972, HOOVER 1977, KROEBER 1971, LEE 1978, PERI 1985 (oak pruning), SWEET 1962; WHITE, R. 1963.

12. Landscape Management

12.1 Cultural Interactions

Aesthetic and recreational values. ALFANO 1980, JEPSON 1903; LEMMON, R. 1952; LITTON 1980, McCLARAN 1983, McCLINTOCK 1983; ROSSI 1979, 1980; SAC. CO. OFF. ED. 1976, TUCKER 1958.

Hazards to public. ALFANO 1980; ANONYMOUS 1970, 1974; KELLOGG 1882, WAGENER 1963.

Unusual oaks. ABRAMS 1923, FULLER 1970, PARDO 1978; STERN 1963, 1977; TUCKER 1983.

12.2 Urban Development Impacts

COATE 1983, DARNELL 1983, GIBBENS and HEADY 1964, HARDESTY 1982, IRVINE 1982; McBRIDE and JACOBS 1976, 1979; McCLARAN 1983, ROGERS 1980, SAC. CO. OFF. ED. 1976, SCHEIDLINGER and ZEDLER 1980.

13. Range Management

13.1 Oak Tree Removal to Promote Grass

Chemical. EMRICK and LEONARD 1954, GRAHAM 1958; JOHNSON, W. [and others] 1959; KAY and LEONARD 1980, LEONARD 1956, LEONARD and CARLSON 1959, LEONARD and HARVEY 1965, LEONARD and MURPHY 1965, MURPHY 1980, MURPHY and BERRY 1973, MURPHY and CRAMPTON 1964, OLSON [and others] 1983, RAGUSE [and others] 1984.

Mechanical. BROWN, R. 1973; DAL PORTO and CARLSON 1965.

13.2 Grazing Effects on Oaks (for oak effects on grazing see 10.1; for other livestock or wildlife effects see 7.2)

Cattle browing shoots. DAYTON 1931, FRANCO 1976, MACKIE 1903, SAMPSON and JESPERSON 1963, SIEGMUND 1979.

Cattle eating acorns. DUNCAN and CLAWSON 1980, HART [and others] 1947, SAMPSON and JESPERSON 1963, SIEGMUND 1979; WAGNON 1946, 1960.

13.3 Oak Brush Control

JOHNSON, R. [and others] 1980; PITT [and others] 1978; PLUMB 1963, 1971; PLUMB and GOODWIN 1982.

14. Tree Management and Wood Utilization

14.1 Growth and Yield

BOLSINGER 1980, ELLIOTT 1958, FINCH and McCLEERY 1983, GEMMILL 1980, HARRINGTON [and others] 1979, HORNIBROOK [and others] 1950; JOHNSON, F. and RISSER 1978; McDONALD 1980a,b; 1981, 1983; OSWALD 1979; OSWALD and HORNIBROOK 1966, PAYSEN 1980; PILLSBURY 1978, 1980; PILLSBURY and BROCKHOUS 1979, 1981; PILLSBURY and KIRKLEY 1982, 1984; PILLSBURY and STEPHENS 1978, PILLSBURY [and others] 1978, POWERS 1972, ROY 1955, SNELL 1979, SUNDAHL 1966, U.S. FOREST SERVICE 1954.

14.2 Stand Structure

BOLSINGER 1980; GRIFFIN 1971, 1977; McCLARAN 1985, PILLSBURY 1978, WARNER 1984, WHITE 1966.

14.3 Silvics and Thinning

KIMMEY 1950, LONGHURST 1956; McDONALD 1969, 1978, 1980b; McDONALD and others 1983.

14.4 Wood Products (other than fuelwood)

ASHER 1980, DICKINSON 1958; DOST 1984, DOST and GORVAD 1977, DOST and MAXEY 1964, DOST [and others] 1966, ECKLUND 1959; ELLWOOD 1958, 1959a,b; ELLWOOD and ECKLUND 1963a,b; ELLWOOD [and others] 1963, HALL and ALLEN 1980, HORNIBROOK [and others] 1950, MALCOLM 1962; MAY 1956, 1957, 1958; McLAIN and STERN 1978, MITCHELL 1958, PALMER 1917, PAUL 1962; PFEIFFER 1953a,b; RESCH 1964; SCHNIEWIND 1958, 1959, 1960, 1962; SCHNIEWIND and BRYAN 1959; SCHNIEWIND and KERSAVAGE 1961, 1962; SMITH 1949, 1950, 1952, 1956, 1961; STERN, G., 1978; USDA FOREST SERVICE 1955, WAHLGREN 1958, WARD and SHEDD 1979.

14.5 Fuelwood, Biomass

DAL PORTO and CARLSON 1965, GRONCKI 1980, MENKE and FREY 1980, PILLSBURY and WILLIAMSON 1980, RIGGAN and DUNN 1982 (review), RIGGAN and LOPEZ 1982, SPENSER and JOINER 1979.

14.6 Managment Plans

ANDERSON and PASQUINELLI 1984, ASHER 1980, EDWARDS 1957, MURRAY 1973, PLUMB and McDONALD 1981, ROY 1962, TAPPEINER and McDONALD 1980.

14.7 Policy and Economics

EDWARDS 1957, STINE 1980; USDA FOREST SERVICE 1954, 1965; VAUX 1961.

15. Research Planning and Coordination

CALIFORNIA BOARD OF FORESTRY 1985, MUICK and BARTOLOME 1985, PASSOF and BARTOLOME 1985.

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California Quercus species and named hybrids (X)	Bibliography reference numbers
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engelmannii	37, 44, 80, 112, 130, 138, 139, 280, 297, 319, 327, 328, 329, 330, 436, 498, 515, 528, 598, 630, 631, 637, 666, 671, 736, 738, 768.
X *eplingii*	4, 129, 209, 451, 496, 684.
X *ganderi*	496, 684, 754.
garryana	
var. *breweri* (and var. *semota*)	10, 93, 112, 159, 375, 374, 377, 416, 435, 462, 596, 692, 722.
var. *garryana*	4, 54, 61, 92, 93, 103, 138, 142, 161, 162, 209, 210 225, 242, 244, 265, 361, 376, 389, 390, 411, 415, 435, 438, 451, 457, 510, 519, 522, 528, 551, 583, 590, 595, 617, 624, 636, 649, 661, 666, 671, 689, 717, 722, 723, 724, 726, 735.
X *grandidentata*	164, 329, 684.
X *howellii*	272, 678, 684.

California Quercus species and named hybrids (X)	Bibliography reference numbers
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kelloggii	3, 4, 5, 8, 9, 10, 26, 27, 28, 31, 36, 38, 44, 49, 50, 55, 56, 63, 87, 92, 114, 115, 126, 127, 130, 132, 135, 137, 138, 142, 144, 145, 148, 149, 150, 151, 152, 153, 154, 155, 156, 179, 180, 187, 189, 192, 194, 196, 199, 201, 202, 206, 208, 209, 210, 214, 223, 224, 225, 228, 230, 240, 242, 261, 265, 266, 274, 275, 277, 280, 282, 283, 285, 296, 304, 308, 311, 313, 317, 327, 332, 339, 340, 343, 344, 349, 351, 352, 356, 359, 360, 365, 373, 376, 381, 389, 390, 391, 393, 394, 404, 405, 406, 407, 408, 409, 410, 411, 415, 416, 420, 424, 426, 428, 436, 437, 438, 457, 460, 464, 466, 473, 491, 492, 493, 498, 504, 505, 510, 512, 513, 519, 522, 525, 528, 533, 536, 537, 538, 539, 543, 544, 545, 547, 551, 555, 566, 584, 592, 596, 599, 601, 602, 603, 604, 606, 607, 622, 623, 624, 625, 626, 627, 629, 632, 634, 635, 641, 642, 650, 653, 671, 689, 695, 699, 702, 703, 708, 713, 715, 717, 721, 722, 724, 726, 727, 733, 735, 737, 748, 749, 751, 761.
X *kewensis*	490.
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X *macdonaldii*	207, 455, 684.
X *morehus*	5, 44, 54, 61, 114, 157, 160, 209, 260, 272, 273, 280, 305, 329, 342, 344, 496, 515, 589, 661, 671, 684, 692, 751.
X *munzii*	273, 681.

California Quercus species and named hybrids (X)	Bibliography reference numbers
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palmeri (see *dunnii*)	
parvula	174, 207, 455, 471, 684.
pricei (see *agrifolia*)	
sadleriana	66, 290, 299, 310, 461, 462, 615, 684, 722, 735, 745.
shrevei (see *wislizenii*)	
X *subconvexa*	147, 272, 278, 684.
X *townei* (see X *macdonaldii*)	
tomentella	128, 455, 463, 666, 684.
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var. *turbinella*	110, 121, 229, 246, 341, 553, 667, 668, 692.
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var. *wislizenii*	5, 10, 27, 28, 32, 34, 36, 37, 38, 44, 47, 55, 61, 67, 104, 112, 114, 115, 120, 138, 142, 157, 160, 173, 192, 198, 199, 201, 202, 214, 216, 224, 227, 235, 264, 266, 267, 268, 280, 296, 313, 328, 329, 331, 337, 338, 339, 340, 342, 343, 344, 356, 359, 360, 362, 364, 365, 366, 374, 376, 385, 400, 420, 437, 455, 457, 464, 473, 512, 513, 522, 523, 528, 530, 536, 537, 538, 539, 581, 589, 656, 658, 660, 664, 671, 692, 700, 703, 707, 747, 751.
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BIBLIOGRAPHY

1. Abrams, Leroy. Illustrated flora of the Pacific States. Stanford, CA: Stanford University Press; 1923: 538 [v. 1].
2. Adam, David P.; Sims, John D.; Throckmorton, Constance K. 130,000-yr continuous pollen record from Clear Lake, Lake County, California. Geology 9(8):373-377; 1981 Aug.
3. Alfano, Sam S. California oaks and outdoor recreation. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 180-183.
4. Anderson, Melanie V.; Pasquinelli, Renee L. Ecology and management of the northern oak woodland community, Sonoma County, California. Rohnert Park, CA: Sonoma State University; 1984. 125 p. Thesis.
5. Anon. New tree species found in Oregon, Oliver Matthews definitely fixes the oracle oak as a tree native to this state. The Forest Log [Salem, OR] 17(9):1,3; 1948 Apr.
6. Anon. Giant oak falls in Walnut Creek. Oakland [CA] Tribune. 1970 Oct. 23:17 9 (col. 5).
7. Anon. *Fomes annosus* as a factor in the management of recreational forests. In: Kuhlman, E.G., ed. Proceedings of the fourth international conference on *Fomes annosus*; 1974 Sep. 17-22, Athens, GA. Washington, DC: U.S. Department of Agriculture, Forest Service, 1974: 2-7.
8. Arkley, R.J. Soil moisture use by mixed conifer forest in a summer-dry climate, Sierra Nevada and San Bernardino Mountains of California. Journal of the Soil Science Society of America. 45(2):423-427; 1981 Mar.-Apr.

9. Ashcraft, Gordon C. Deer use under black oaks with and without mistletoe. California Fish and Game 67(7):257-260; 1981 Oct.
10. Asher, James E. Oak management harvest A: an experimental management and utilization project on southern California private ownership. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 117-118.
11. Asserson, W. C.,III. Western gray squirrel study in Kern County, California. Wildl. Manage. Rep. 74-1. Sacramento, CA: Calif. Dep. of Fish and Game. 1974. 32 p.
12. Atwood, Jonathan. Fortieth breeding bird census. 112: Insular scrub oak woodland. American Birds 31(1):69-70; 1977 Jan.
13. Axelrod, Daniel I. A Pliocene flora from the Mount Eden beds, southern California. Carnegie Institution of Washington Publication 476:125-183; 1937.
14. Axelrod, Daniel I. A Miocene flora from the western border of the Mohave Desert. Carnegie Institution of Washington Publication 516:1-129; 1939.
15. Axelrod, Daniel I. The Mint Canyon flora of southern California: a preliminary statement. American Journal of Science 238:577-585; 1940.
16. Axelrod, Daniel I. The Mulholland flora. Carnegie Institution of Washington Publication 553:103-145; 1944a.
17. Axelrod, Daniel I. The Oakdale flora. Carnegie Institution of Washington Publication 553:147-165; 1944b.
18. Axelrod, Daniel I. The Sonoma flora. Carnegie Institution of Washington Publication 553:167-206; 1944c.
19. Axelrod, Daniel I. A Sonoma florule from Napa, California. Carnegie Institution of Washington Publication 509:23-71; 1950.
20. Axelrod, Daniel I. The Pliocene Verdi flora of western Nevada. University of California Publications in Geological Sciences 34:91-160; 1958.
21. Axelrod, Daniel I. History of the Mediterranean ecosystems in California. In: di Castri, F.; Mooney, H.A., eds. Mediterranean type ecosytems. New York: Springer-Verlag; 1973: 225-277.
22. Axelrod, Daniel I. Evolution and biogeography of Madrean-Tethyan sclerophyll vegetation. Annals of the Missouri Botanical Garden 62:280-334; 1975.
23. Axelrod, Daniel I. Outline history of California vegetation. In: Barbour, Michael G.; Major, Jack, eds. Terrestrial vegetation of California. New York: Wiley Interscience; 1977: 137-187.
24. Axelrod, Daniel I. Biogeography of oaks in the Arcto-Tertiary province. Annals of the Missouri Botanical Garden 70(4):629-657; 1983.
25. Axlerod, D.I; Ting, W.S. Late Pliocene floras east of the Sierra Nevada. University of California Publications in Geological Science 39:1-118; 1960.
26. Bainbridge, David. Acorns: the grain that grows on trees. The Mother Earth News 89:80-83; 1984 Sep./Oct.
27. Baker, Frederick S. Reproduction of ponderosa pine at low elevations in the Sierra Nevada. Journal of Forestry 40(5):401-404; 1942 May.
28. Baker, Gail A.; Rundel Philip W.; Parsons, David J. Ecological relationships of *Quercus douglasii* (Fagaceae) in the foothill zone of Sequoia National Park, California. Madrono 28(1):1-12; 1981 Jan.
29. Balls, Edward K. Early uses of California plants. Berkeley and Los Angeles, CA: University of California Press; 1972. 103 p.
30. Barnhart, Stephen J. The ecology of the central coast woodlands of California. 1978. 32 p. Unpublished draft supplied by author.
31. Barr, Percy M. The research program of Blodgett Forest of the University of California. Journal of Forestry 44(10):738-741; 1946 Oct.
32. Barrett, Reginald H. The feral hog at the Dye Creek Ranch. Hilgardia 46:283-355; 1978.
33. Barrett, Reginald H. Mammals of California oak habitats—management implications. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks; 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 275-291.
34. Barrett, Reginald H. Habitat preferences of feral hogs, deer, and cattle on a Sierra Foothill range. Journal of Range Management 35(3):342- 346; 1982.
35. Barrett, Reginald H.; Menke, John W.; Fry, Michael E.; Mangold, Donald. A review of the value of hardwoods to wildlife in California with recommendations for research. Research for the Tahoe National Forest, Supplement 8A, Master Agreement 21-395, Final Report. Berkeley, CA: University of California, Department of Forestry and Conservation; 1976. 45 p.
36. Barrett, S.A.; Gifford, E.W. Miwok material culture. Bulletin of the Public Museum, City of Milwaukee. 2(4):117-326; 1933 Mar.
37. Barrows, D.P. The ethno-botany of the Cahuilla Indians of southern California. Chicago: University of Chicago Press; 1900. 82 p.
38. Bauer, H.L. Vegetation of the Tehachapi Mountains, California. Ecology 11(2):263-280; 1930 Apr.
39. Baumhoff, Martin A. Ecological determinants of aboriginal California populations. University of California Publications in American Archaeology and Ethnology 49(2):155-235; 1963.
40. Bean, Lowell John; Saubel, Katherine Siva. Temalpakh—Cahuilla Indian knowledge and usage of plants. Banning, CA: Malki Museum Press, Morongo Indian Reservation; 1972. 225 p.

41. Beckjord, P.R.; McIntosh, M.S. Growth and fungal retention by field planted Quercus rubra seedlings innoculated with several ectomycorrhizal fungi. Bulletin of the Torrey Botany Club 110(3):353-359. 1983 Jul.-Sep.

42. Belcher, Edward. Narrative of a voyage round the world performed in Her Majesty's Ship Sulphur, during the years 1836-1842. 2 v. London: Henry Colburn; 1843:120-123. [v. 1].

43. Benson, Lyman. Taxonomic contributions: VI. The habit of the Alvord oak. American Journal of Botany 27(3):186-190; 1940 Mar.

44. Benson, Lyman. Plant taxonomy, methods and principles. New York: Ronald Press; 1962. 494 p.

45. Benson, Lyman; Phillips, Edwin A.; Wilder, Patricia Ann [and others]. Evolutionary sorting of characters in a hybrid swarm. I: Direction of slope. American Journal of Botany 54(8):1017-1026; 1967 Sep.

46. Bent, Arthur Cleveland. Life histories of North American jays, crows, and titmice. Washington, DC.: U.S. National Museum;, Bull. 191. 1946. 495 p.

47. Bissell, H.D.; Weir, W.C. The digestibility of interior live oak and chamise by deer and sheep. Journal of Animal Science 16(2):476-480; 1957.

48. Biswell, H.H. Deer forage from common mistletoe. California Fish and Game 45(3):218-219. 1959 Jul.

49. Biswell, H.H. Deer damage to pine seedlings and transplants at Hoberg's in the North Coast Range. Forestry and Forest Products Laboratory Rep. 27. Berkeley, CA: University of California; 1961. 4 p.

50. Biswell, H.H.; Buchanan, H.; Gibbens, R.P. Ecology of the vegetation of a second growth *Sequoia* forest. Ecology 47(4):630-634; 1966 summer.

51. Bjorndalen, Jorn Erik. The chaparral vegetation of Santa Cruz Island. Norwegian Journal of Botany 25(4):255-270; 1978.

52. Blake, William P. Report of a geological reconnaissance in California: made in connection with the expedition to survey routes in California. New York: H. Baillere; 1858.

53. Bock, Carl E.; Bock, Jane A. Geographic ecology of the acorn woodpecker: diversity versus abundance of resources. American Naturalist 108(963): 694-698; 1974 Sep.-Oct.

54. Bolander, Henry N. Remarks on California trees. Proceedings California Academy of Natural Science, Ser. 1. 3:225-233; 1865.

55. Bolsinger, Charles L. Oaks in California's commercial forests—volume, stand structure, and defect characteristics. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 100-106.

56. Bonnickson, T.M.; Stone, E.C. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology 63(4):1134-1148; 1982 Aug.

57. Bontrager, David R. Twenty-seventh winter bird population study. 46: Sycamore-coast live oak riparian woodland. American Birds 28(3):715- 716; 1974a Jun.

58. Bontrager, David R. Thirty-seventh breeding bird census. 110: Sycamore-coast live oak riparian woodland. American Birds 28(6):1035-1036; 1974b Dec.

59. Borchert, Mark; Hibberd, Mark. Gradient analysis of a north slope montane forest in the western Transverse Ranges of southern California. Madrono 31(3):129-139; 1984 Jul.

60. Bossema, I. Jays and oaks, an eco-ethological study of a symbiosis. Behavior 70:1-117; 1979.

61. Bowerman, Mary L. The flowering plants and ferns of Mount Diablo. Berkeley, CA: Gillick Press; 1944. 290 p.

62. Bowman, William D.; Roberts, Stephen W. Seasonal and diurnal water relations adjustments in three evergreen chaparral shrubs. Ecology 66(3):738-742; 1985 Jun.

63. Bowyer, R. Terry; Bleich, Vernon C. Ecological relationships between southern mule deer and California black oak. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 292-296.

64. Brooks, William H. The characterization of blue oak dominated savanna in grazed and protected stands in central California. Journal of the Arizona Academy of Science 8 [suppl.]:9; 1973 [abstract].

65. Brooks, William H. Phytosociological comparisons of oak savanna in central California. Assoc. Arid Lands Stud., Proc. 4:6; 1981.

66. Brophy, William. Oak flowers. Fremontia 4(1):9-11; 1976 Apr.

67. Brophy, William B.; Parnell, Dennis R. Hybridization between Quercus agrifolia and Q. wislizenii (Fagaceae). Madrono 22(6):290-302; 1974 Apr.

68. Brown, David E.; Lowe, Charles H. Biotic communities of the Southwest. Gen. Tech. Rep. RM-78. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980. 1 p. [map].

69. Brown, David E.; Lowe, Charles, H.; Pase, Charles P. A digitized systematic classification for ecosystems with an illustrated summary of the natural vegetation of North America. Gen. Tech. Rep. RM-73. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980. 93 p.

70. Brown, L.R.; Davis, C.S.; Koehler, C.S.; [and others]. Oaks on home grounds. Leafl. 2783. Berkeley, CA; University of California, Agricultural Experiment Station; 1975. 8 p.

71. Brown, Leland R. Insects feeding on California Oak Tres. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28; Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 184-194.

72. Brown, Leland R.; Eads, Clark O. A technical study of insects affecting the oak tree in southern California. Berkeley, CA: University of California Agricultural Experiment Station; 1965. 105 p. Bull. 810; 1965. 105 p.

73. Brown, R.D. Pre-burn treatment of oaks with the ball and chain. Range Improvement Studies 21. Sacramento, CA: Calif. Div. of For.; 1973. 6 p.

74. Bryan, W.; Wright, R. The effect of enhanced carbon dioxide levels and variable light intensities on net photosynthesis in competing mountain trees. The American Midland Naturalist 95(2):446-450; 1976 Apr.

75. Bryant, Edwin. What I saw in California. 2d ed. New York: Appleton and Co.; 1848. 445 p.

76. Burger, William C. The species concept in *Quercus*. Taxon 24(1):45-50; 1975 Feb.

77. Burgess, J. Wesley; Roulston, Diane; Shaw, Evelyn. Territorial aggregation: an ecological spacing strategy in acorn woodpeckers. Ecology 63(2):575-578; 1982 Apr.

78. Burk, J.H. Seasonal and diurnal water potentials in selected chaparral shrubs. The American Midland Naturalist 99(1):244-248; 1978 Jan.

79. Burnett, John A. A new cynipid wasp from California. Pan-Pacific Entomologist 50(3):298-302; 1974 Jul.

80. California Board of Forestry. Report of the hardwood task force. Sacramento, CA: Calif. Board of Forestry; 1985. 67 p.

81. Callizo, Joe. Where are Napa Valley's valley oaks? Fremontia 11(3):30; 1983 Oct.

82. Campbell, Bruce. Some mixed hardwood forest communities of the coastal ranges of southern California. Phytocoenologia. 8(3/4):297-320; 1980 Dec.

83. Camus, A. Les chenes: monographie du genre *Quercus*. In: [no editor] Encyclopedie economique de silviculture, 7 v [v. 1, atlas and explanatory text]. Paris: Lechevalier and Fils; 1934-.

84. Cannon, W.A. Tree distribution in central California. The Popular Science Monthly 85:417-424; 1914a Nov.

85. Cannon, W. A. Specialization in vegetation and environment in California. The Plant World 17:(8)223-237; 1914b.

86. Carpenter, I.W.; Guard, A.T. Anatomy and morphology of the seedling roots of four species of the genus Quercus. Journal of Forestry 52(4):269-274; 1954 Apr.

87. Carson, Hampton L. Breeding sites of *Drosophila pseudoobscura* and *Drosophila persimilis* in the transition zone of the Sierra Nevada. Evolution 5(2):91-96; 1951 Mar.

88. Cavagnaro, D. Circus of *Quercus*. Pacific Discovery 27(3):1-11; 1974 Jun.

89. Chandler, Craig Clayton. The classification of forest fuels for wildland fire control purposes. Berkeley, CA: University of California; 1955. 91 p. Thesis.

90. Chaney, R.W.; Axelrod, D.I. Miocene floras of the Columbia Plateau. II. Systematic considerations. Carnegie Institution of Washington Publication 617:135-237; 1959.

91. Cheatham, Norden H.; Haller, J. Robert. An annotated list of California habitat types. Berkeley, CA: University of California, Natural Land and Water Reserve System. 1975. 15 p. [66 tables]. Unpublished draft supplied by authors.

92. Chesnut, V.K. Plants used by the Indians of Mendocino County, California. Contribution of the U.S. National Herbarium 7(3):295-408; 1902.

93. Clark, Harold W. Association types in the north coast ranges of California. Ecology 18(2):214-230; 1937 Apr.

94. Coate, Barrie D. Planting under old oaks. Fremontia 11(3):26-28; 1983 Oct.

95. Cogswell, H.L. Thirtieth breeding bird census. 40: Broadleaf evergreen forest with shrub-filled openings. Audubon Field Notes 20(6):633-634, 642-643; 1966 Dec.

96. Cole, Kenneth. Geologic control of vegetation in the Purisima Hills, California. Madrono 27(2):79-89; 1980 Apr.

97. Cole, Kenneth. Late Pleistocene vegetation of Kings Canyon, Sierra Nevada, California. Quaternary Research 19:117-129; 1983.

98. Colwell, Wilmer L., Jr. Soil-Vegetation maps of California. Resource Bull. PSW-13. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1974. 6 p.

99. Conard, Susan G.; MacDonald, Rod L.; Holland, Robert F. Riparian vegetation and flora of the Sacramento Valley. In: Sands, Anne, ed. Symposium on riparian forests in California, their ecology and conservation, 1977 May 14, Davis, CA. Inst. Ecol. Publ. 15. Davis, CA: University of California; 1977: 47-55.

100. Condit, C. The Remington Hill flora. Carnegie Institution of Washington Publication 553:21-55;1944a.

101. Condit, C. The Table Mountain flora. Carnegie Institution of Washington Publication 553:57-90; 1944b.

102. Conrad, Abram H. A contribution to the life history of *Quercus*. Botanical Gazette 29(6):408-418; 1900 Jun.

103. Cooper, Peter V. Soil moisture relations of selected soils in the mixed evergreen type, northern Califoria. Arcata, CA: Humboldt State Univ.; 1972. 48 p. Thesis.

104. Cooper, William S. The broad-sclerophyll vegetation of California—an ecological study of the chaparral and its related communities. Carnegie Institution of Washington Publication 319:1-124; 1922.

105. Cooper, William S. Vegetational development upon alluvial fans in the vicinity of Palo Alto, California. Ecology 7(1):1-30; 1926 Jan.

106. Cornell, Howard V. The secondary chemistry and complex morphology of galls formed by the Cynipinae (Hymenoptera): why and how? The American Midland Naturalist 110(2):225-234; 1983 Oct.

107. Cornell, Howard V. Geographic texture of herbivore richness patterns on host plants. Bulletin of the Entomological Society of America 30(2): 6-15; 1984 summer.

108. Cornell, Howard V. Local and regional richness cynipine gall wasps on California oaks. Ecology 65(4):1247-1260; 1985 Jun.

109. Cornell, Howard V.; Washburn, Jan O. Evolution of the richness-area correlation for cynipid gall wasps on oak trees: a comparison of two geographic areas. Evolution 33(1):257-274; 1979.

110. Cottam, Walter, P.; Tucker, John M.; Drobnick, Rudy. Some clues to Great Basin postpluvial climates provided by oak distributions. Ecology 40(3):361-377; 1959 Jul.

111. Cottam, Walter P.; Tucker, John M.; Santamour, Frank S., Jr. Oak hybridization at the University of Utah. Salt Lake City, UT: Publ. 1. State Arboretum of Utah; 1982. 82 p.

112. Critchfield, William B. Profiles of California vegetation. Res. Pap. PSW-76. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1971. 54 p.

113. Cruzan, Mitch. Reproduction of coast live oak (*Quercus agrifolia*) in the Santa Ana Mountains. Crossosoma 7(2):1-4; 1981 Apr. [newsletter of Southern California Botanists].

114. Cummings, Michael P. Comparative leaf demography of evergreen and deciduous oaks and their hybrids. Bulletin of the Ecological Society of America 66(2):160; 1985 summer [abstract].

115. Dailey, D. Charles. Biosystematics of Pacific Slope gall-making cynipids on the oak subgenus *Erythrobalanus*. Davis, CA: University of California; 1969. 112 p. Thesis.

116. Dailey, D. Charles; Perry, T.; Sprenger, C.M. Biology of three *Callirhytis* gall wasps from Pacific slope Erythrobalanus oaks. Pan-Pacific Entomologist 50(1):60-67; 1974 Jan.

117. Dailey, D. Charles; Sprenger, C.M. Uni-sexual generation of Andricus- Atrimentus. Pan-Pacific Entomologist 49(2):171-173; 1973.

118. DalPorto, Norman J.; Carlson, Charles E. Blue oak cordwood from foothill rangeland. Range Improvement Studies No. 15. Sacramento, CA: California Division of Forestry; 1965. 4 p.

119. Darnell, David M. Southern California oak woodlands: a general report on the status of a sensitive ecosystem. Ecological Pap. No. 4. San Diego, CA: California Department of Transportation, Caltrans District 11; 1983. 18 p.

120. Davis, D.R. *Careospina quercivora*, a new genus and species of moth infesting live oaks in California (Lepidoptera: Incurvariidae). Proceedings of the Entomological Society of Washington. 74(1):121-128; 1972 Mar.

121. Davis, E.A. Propagation of shrub live oak cuttings. Botanical Gazette 131(1):55-61. 1970

122. Davis, F. Site relations of *Quercus agrifolia* Nee in southern California modelled using Thematic Mapper and terrain data. Bulletin of the Ecological Society of America 66(2):162; 1985 summer [abstract].

123. Dawson, K.J. Planting design inventory techniques for modeling the restoration of riparian landscapes. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on the California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19; Davis, CA. Berkeley, CA: University of California Press; 1984: 456-470.

124. Dayton, William Adams. Important western browse plants. Misc. Publ. 101. Washington, DC: U.S. Department of Agriculture; 1931. 213 p.

125. Derby, George, H. The topographic reports of Lieutenant George H. Derby [introduction by Farquhar, Frances P.]. California Historical Soc. Quaterly 11(2):99-123; 1932.

126. Dickinson, F.E. Factors contributing to the increased use of West Coast hardwoods. In: Proc. Soc. Am. For. 1957 Nov. 10-13, Syracuse, NY. Soc. Am. For. Washington, DC.:1958: 122-124.

127. Dixon, Joseph S. A study of the life history and food habits of mule deer in California. II: Food habits. California Fish and Game 20(4):315-354; 1934 Oct.

128. Dobbins, George C. Propagating oaks. Fremontia 4(1):12-13; 1976 Apr.

129. Dobzhansky, Theodosius. Genetics and the origin of species. New York: Columbia University Press; 1941: 259.

130. Dodge, John Marvin. Vegetational changes associated with land use and fire history in San Diego County. Riverside, CA: University of California; 1975. 216 p. Dissertation.

131. Dorsey, C.K. Experiments to control acorn weevils with systemic insecticides. Forest Science 13(4):390-396; 1967 Dec.

132. Dost, W.A. Black oak cordwood yields by log grade. Forestry and Forest Products 54. Berkeley, CA: University of California; 1984. 4 p.

133. Dost, W.A.; Dickinson, F.E.; Prestemon, D.R. California white oak log grades and lumber yield. Forestry and Forest Products 45. Berkeley, CA: University of California; 1966 6 p.

134. Dost, William A.; Gorvad, Michael. California oak tanks for California wine. California Agriculture 31(2):8-9; 1977 Feb.

135. Dost, William A.; Maxey, Carl. Gluing characteristics of some California hardwoods: black oak, chinkapin, madrone, and tanoak. Forestry and Forest Prod. 36. Berkeley, CA: University of California; 1964. 5 p.

136. Doutt, R.L. Heterogony in Dryocosmus (Hymenoptera, Cynipidae). Annals of the Entomological Society of America 52(1):69-74. 1959.

137. DuBois, Cora. Wintu ethnography. University of California Publications in American Archeology and Ethnology 36(1):1-148; 1940.

138. Duffield, John W. Chromosome counts in *Quercus*. American Journal of Botany 27(9):787-788; 1940 Nov.

139. Duncan, C.D. North American species of *Phylloxera* infesting oak and chestnut. Canadian Entomologist 54(11):267-276; 1922.

140. Duncan, D.A. Blue oak canopy effect on herbage yield on central California foothill rangeland. In: [no ed.] Abstracts, Papers Twentieth Annual Meeting, American Society Range Management, 1967 Feb. 14-17, Seattle, WA. p. 61-62. Journal of Range Management 1967 "Special Issue".

141. Duncan, D.A.; Clawson, W.J. Livestock utilization of California's oak woodlands. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 306-313.

142. Dunn, Paul H. Nutrient-microbial considerations in oak management. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service,Pacific Southwest Forest and Range Experiment Station; 1980: 149-160.

143. Dutzi, Elizabeth Jean. Valley oaks in the Sacramento Valley: past and present distribution. Davis, CA: University of California; 1979. 97 p. Thesis.

144. Dwinell, L.D. The relationship of the oak host to basidiospore cast of *Cronartium fusiforme*. Phytopathology 63(4):441; 1973 Apr.

145. Dwinell, L.D.; Powers, H.R., Jr. Potential for southern fusiform rust on western pines and oaks. Plant Disease Reporter 58(6):497-500; 1974.

146. Eastwood, Alice. A handbook of the trees of California. Occasional Paper California Academy of Sciences 9:1-86; 1905.

147. Eastwood. Alice. The prostrate oaks of Marin County, California. Leaflets of Western Botany 4(10):241-242; 1946.

148. Ecklund, Barton A. Drying behavior of wood with water replaced by non- aqueous liquids. Forest Products Laboratory Paper. Berkeley, CA: University of California; 1959. 14 p.

149. Edwards, M.B. California black oak—its management and economic possibilities. Journal of Forestry 53(7):506-510; 1957 Jul.

150. Elliott, Frank Lambert. Growth rate of four species of oaks. Stanford, CA: Stanford University; 1958. 83 p. Thesis.

151. Ellwood, E.L. Problems and prospects in drying California hardwoods for high quality use. Forestry and Forest Products 8. Berkeley, CA: University of California; 1958. 5 p.

152. Ellwood, E.L. Drying stress patterns in California black oak. Forestry and Forest Products 9. Berkeley, CA: University of California; 1959a. 6 p.

153. Ellwood, E.L. Kiln drying green 4/4 California black oak. Forestry and Forest Products 17. Berkeley, CA: University of California; 1959b. 8 p.

154. Ellwood, E.L.; Ecklund, B.A. The effect of organic liquids on collapse and shrinkage of wood. I: Effect of degrees of replacement. Forest Products Journal 13(7):291-298; 1963a.

155. Ellwood, E.L.; Ecklund, B.A. The effect of organic liquids on collapse and shrinkage of wood. II: Effect of drying temperature. Forest Products Journal 13(8):350-354; 1963b.

156. Ellwood, E.L.; Ecklund, B.A.; Zavarin, E. The effect of organic liquids on collapse and shrinkage of wood. III: Chemical influences. Forest Products Journal 13(9):401-404; 1963.

157. Emrick, Walter E.; Leonard, Oliver A. Delayed kill of interior live oak by fall treatment with 2,4-D and 2,4,5-T. Journal of Range Management 7(2):75-76; 1954 March.

158. Engelmann, George. About the oaks of the United States. Transactions of the St. Louis Academy of Science 3:372-400, 539-543; 1867-1877.

159. Engelmann, George. *Quercus breweri*. In: Watson, Sereno, ed. Geological survey of California: Botany. John Wilson and Son. Cambridge, MA: 1880:96 [v. 2].

160. Engles, Eric; Genetti, Katherine. Vegetation and flora. In: Engles, Eric, ed. The natural features of the Gamboa Point Properties, Monterey County, California. Environmental Field Program, Publ. 13, V. 1, pt. 4. Santa Cruz, CA: University of California, Santa Cruz; 1984: 43-174.

161. Evans, David. Life history and immature stages of *Pandemis cerasana* (Lepidoptera: Tortricidae). Canadian Entomologist 102(12):1597-1603; 1970.

162. Evans, David. Alternate generations of gall cynipids (Hymenoptera: Cynipidae) on garry oak. Canadian Entomologist 104:1805-1818; 1972.

163. Everett, Percy C. A summary of the culture of California plants at the Rancho Santa Ana Botanic Garden, 1927-1950. Claremont, CA: Rancho Santa Ana Botanic Garden; 1957. 223 p.

164. Ewan, Joseph. Annotations upon the California flora. I. Bulletin of the Torrey Botanical Club 64(8):509-521; 1937 Nov.

165. Faeth, Stanley H. An alternative hypothesis for early feeding by insects on oak. Bulletin of the Ecological Society of America 65(2):230; 1984 Jun. [abstract].

166. Feeney, Paul. Seasonal changes in oak leaf tannins and nutrients as a cause of spring feeding by winter moth caterpillars. Ecology 51(5): 565-581; 1970 summer.

167. Felt, E.P. Plant galls and gall makers. New York: Hafner; 1965. 364 p.

168. Feret, P.P.; Kreh, R.E.; Merkle, S.A.; Oderwald, R.G. Flower abundance, premature acorn abscission, and acorn production in *Quercus alba* L. Botanical Gazette

143(2):216-218; 1982.

169. Ferren, Wayne R.; Forbes, Holly C.; Roberts, Dar A.; Smith, Dale M. The botanical resources of La Purisima Mission State Historic Park, Santa Barbara County, California. Herbarium Publ. 3. Santa Barbara, CA: University of California, Department of Biological Sciences. 1984. 159 p.

170. Fieblekorn, Carl. Interim report of oak regeneration study. Fort Hunter Liggett, CA: Natural Resources Conservation Office; 1972. 23 p. Unpublished draft supplied by author.

171. Finch, Sherman J; McCleery, Dick. California coast live oak. In: Eyre, F.H., ed. Forest cover types of the United States and Canada. Washington, DC: Soc. Am. For. 1983: 127-128.

172. Fischer, Walter K. An acorn store-house of the California woodpecker. The Condor 8(5):107; 1906 Sep.-Oct. [photograph].

173. Fitch, Henry S. Ecology of the California ground squirrel on grazing lands. The American Midland Naturalist 39(3):513-596; 1948 May.

174. Fletcher, Martin. A flora of Hollister Ranch, Santa Barbara County, California. Herbarium Publ. 2. Santa Barbara, CA: University of California, Department of Biological Sciences; 1983. 77 p.

175. Flexner, C.W. Resource utilization and the role of oak tannins in the behavioral ecology of the acorn woodpecker *Melanerpes formicivorus*. Stanford, CA: Stanford University; 1978. 57 p. Thesis [undergraduate honors]

176. Forde, M.B.; Faris, D.G. Effect of introgression on the serpentine endemism of *Quercus durata*. Evolution 16(3):338-347; 1962 Sep.

177. Fraiser-Smith, A.C. ULF tree potentials and geomagnetic pulsations. Nature 271(5646):641-642; 1978.

178. Franco, Gera Maria Montanari. Grazing effects on oak distribution in Jasper Ridge and adjacent areas. Stanford, CA: Stanford University; 1976. 33 p. Thesis.

179. Fry, Michael E.; Vaughn, Charles E. Acorn selection by band-tailed pigeons. California Fish and Game 63(1):59-60; 1977 Jan.

180. Fuller, Warren. The Wood's mighty oak. American Forests 76(8):28-29; 1970 Aug.

181. Furniss, Robert L.; Carolin, Valentine M. Western forest insects. Misc. Publ. 1339. Washington, DC: U.S. Department of Agriculture; 1977. 654 p.

182. Gaines, David A. Thirty-ninth breeding bird census. 127: Serpentine chaparral. American Birds 29(6):1129-1130; 1975 Dec.

183. Gaines, David A. The valley riparian forests of California: their importance to bird populations. In: Sands, Anne, ed. Symposium on riparian forests in California, their ecology and conservation, 1977 May 14, Davis CA. Institute of Ecology Publ. 15. Davis, CA: University of California; 1977: 57-85.

184. Gardner, M.W.; Yarwood, C.E. Host list of powdery mildews of California. California Plant Pathology 42:1-9; 1978.

185. Gardner, M.W.; Yarwood, C.E.; Duafala, T. Oak mildews. Plant Disease Reporter 56(4):313-317; 1972.

186. Garrison, W.J.; Augspurger, C.K. Double- and single-seeded acorns of bur oak (*Quercus macrocarpa*) frequency and some ecological consequences. Bulletin of the Torrey Botanical Club 110(2):154-160; 1983 Apr.-Jun.

187. Gemmill, Barbara. Radial growth of California black oak in the San Bernardino Mountains. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June, 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 128-135.

188. Gerry, Eloise. Tyloses: their occurrence and practical significance in some American wood. Journal of Agricultural Research 1(6):445-470; 1914 Mar.

189. Gibbens, Robert P.; Heady, Harold F. The influence of modern man on the vegetation of Yosemite Valley. Calif. Agric. Exp. Stn. Manual 36. Berkeley, CA: University of California; 1964. 44 p.

190. Gibson, L.P. Biology and life history of acorn-infesting weevils of the genus *Conotrachelus* (Coleoptera:Curculionidae). Annals of the Entomological Society of America 57:521-526; 1964.

191. Gibson, L.P. Monograph of the genus *Curculio* in the New World (Coleoptera: Curculionidae). Part I: United States and Canada. Miscellanious Publications of the Entomological Society of America 6(5):241-285; 1969.

192. Gifford, E. W. California balanophagy. In: Heizer, R. F.; Whipple, M. A., eds. The California Indians, a source book (2d ed.). Berkeley, CA: University of California Press. 1971: 301-305.

193. Gliessman, Steve R. Allelopathy as a potential mechanism of dominance in the humid tropics. Tropical Ecology 19(2):200-208; 1978 winter.

194. Glyphis, J. P. Polyphenols, leaf nutritive quality and herbivory in five species of California oak. In: Leviton, A.E.; Aldrich, M.L.; Berson, M. eds. Proc. 63rd Annual Meet., Pac. Div. AAAS, 1982 Jun. 20-25, Santa Barbara, CA. San Francisco, CA: Pac. Div. AAAS; 1982: 39. [Abstract].

195. Goldsmith, Audrey; Walraven, Michael E.; Graber, David M.; White, Marshall. Ecology of the black bear in Sequoia National Park. Tech. Report 1. San Francisco, CA: U.S. Department of Interior, National Park Service, Western Region; 1981. 64 p.

196. Gordon, Burton L. Monterey Bay Area: natural history and cultural imprints. 2d ed. [with corrections]. Pacific Grove, CA: Boxwood Press; 1985. 321 p.

197. Graber, David Murray. Ecology and management of black bears in Yosemite National Park. Berkeley, CA: University of California; 1981. 206 p. Dissertation.

198. Graham, Charles A. Killing brush sprouts on open woodland range land in California. Res. Note 136. Berkeley, CA: U.S. Department of Agriculture, Forest Service,

Califoria Forest and Range Experiment Station; 1958. 5 p.

199. Graves, Walter C. The dependency of upland game on oak mast production. Progress Rep. Project W-47-R-24, Job IV-1.4. Sacramento, CA: California Dept. Fish Game; 1977a. 16 p.

200. Graves, Walter C. Diminishing habitat—oaks provide habitat for 86 species of birds, 11 mammals. Outdoor California 38(5):17-18,33; 1977b.

201. Graves, Walter C. Annual oak mast yields from visual estimates. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 270-274.

202. Gray, John T. The vegetation of two California mountain slopes. Madrono 25(4):177-185; 1978 Oct.

203. Green, Deborah Sue. Ecology and host-specificity of parasitoides of leaf- mining Lepidoptera on *Quercus agrifolia* (Fagaceae) in California. Berkeley, CA: University of California; 1979. 218 p. Dissertation.

204. Green, Lisle R. Prescribed burning in California oak management. In: Plumb, Timothy R., tech coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 24-26, Claremont. CA. Gen. Tech Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiement Station, Forest Service; 1980:136-142.

205. Green, Lisle R.; Hughes, Catherine L.; Graves, Walter L. Goat control of brush regrowth on southern California fuelbreaks. In: Hyder, L.R., ed. Proceedings of the 1st International Rangeland Congress, 1978 Aug. 14-18, Denver, CO. Denver,CO: Soc. for Range Manage.; 1978: 451-455.

206. Green, L.R.; Schimke, H.E. Guides for fuel breaks in the Sierra Nevada mixed conifer type. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1971. 14 p.

207. Greene, Edward L. Illustrations of West American oaks. San Francisco: Bosqui Engraving and Printing Co.; 1889-1890. 84 p.

208. Grenfell, William E., Jr.; Brody, Allan J. Seasonal foods of black bears in Tahoe National Forest, California. California Fish and Game 69(3): 132-150; 1983 Jul.

209. Griffin, James R. Notes on disjunct foothill species near Burney, California. Leaflets of Western Botany 10(15):296-298; 1966 Sep.

210. Griffin, James R. Soil moisture and vegetation patterns in northern California forests. Res. Paper PSW-46. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1967. 20 p.

211. Griffin, James R. Oak regeneration in the upper Carmel Valley, California. Ecology 52(5):862-868; 1971 late summer.

212. Griffin, James R. Valley oaks—the end of an era? Fremontia 1(1):5-9; 1973a Apr.

213. Griffin, James R. Xylem sap tension in three woodland oaks of central California. Ecology 54(1):152-159; 1973b winter.

214. Griffin, James R. Plants of the highest Santa Lucia and Diablo Range Peaks, California. Res. Paper PSW-110. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1975. 50 p.

215. Griffin, James R. Regeneration in *Quercus lobata* savannas, Santa Lucia Mountains, California. American Midland Naturalist 95(2):422-435; 1976 Apr.

216. Griffin, James R. Oak woodland. In: Barbour, Michael G.; Major, Jack, eds., Terrestrial vegetation of California. New York: Wiley-Interscience; 1977: 383-415.

217. Griffin, James R. Sprouting in fire-damaged valley oaks, Chews Ridge, California. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; 1980a 216-219.

218. Griffin, James R. Animal damage to valley oak acorns and seedlings, Carmel Valley, California. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980b: 242-245.

219. Griffin, James R.; Critchfield, William B. The distribution of forest trees in California. Res. Paper PSW-82. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1976 [revised] 118 p.

220. Griffin, J.R.; Tucker, J.M. Range extension for *Quercus dunnii* in California. Madrono 23(5):295; 1976 Jan.

221. Griggs, F. Thomas. Creighton Ranch Preserve—a relict of Tulare Lake. Fremontia 10(4):3-8; 1983a Jan.

222. Griggs F. Thomas. Kaweah oaks preserve. Fremontia 11(3):25; 1983b Oct.

223. Grinnell, Joseph. Up-hill planters. Condor 38(2):80-82; 1936 Mar.-Apr.

224. Grinnell, Joseph; Dixon, Joseph; Linsdale, Jean M. Vertebrate natural history of a section of northern California through the Lassen Peak region. Berkeley: University of California Press; 1930. 594 p.

225. Groncki, Al. Energy yield potential of California oaks and other wood biomass. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont CA. Gen. Tech. Rep. PSW-44.

Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 333-344.

226. Gutierrez, Ralph. J. Comparative ecology of the mountain quail and California quail in the Carmel Valley, California. Living Bird 18:71-93; 1980.

227. Gutierrez, R.J.; Koenig, Walter D. Characteristics of storage trees used by acorn woodpeckers in two California woodlands. Journal of Forestry 76(3):162-164; 1978 Mar.

228. Hall, Guy; Allen, Richard. Wood products from California oaks, Cal Oak Lumber Company style. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW- 44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 362-368.

229. Hanes, Ted L. Chaparral. In: Barbour, Michael G.; Major, Jack., eds. Terrestrial vegetation of California. New York: Wiley-Interscience; 1977: 417-469.

230. Hardesty, Nancy M. Landscape analysis and ecosystem management at Portola Valley Ranch. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the sympsoium on dynamics and management of Mediterranean- type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 601.

231. Hare, R.C. Rooting of cuttings from mature water oak. Southern Journal of Applied Forestry 1(2):24-25; 1977.

232. Harlow, Richard F.; Whelan, James B.; Crawford, Hewlette S.; Sheen, John E. Deer foods during years of oak mast abundance and scarcity. Journal of Wildland Management 39(2):330-336; 1975.

233. Harrington, Thomas J.; Pillsbury, Norman H.; Barrette, Brian. A gross volume table for California white oak in Monterey and San Luis Obispo counties. State Forest Note 77. Sacramento, CA: California Department of Forestry; 1979. 4 p.

234. Harris, R.W.; Leiser, A.T. Direct seeding woody plants in the landscape. Calif. Agri. Exp. Stn. Leaflet 2577. Berkeley, CA: University of California, Agricultural Experiment Station; 1979. 12 p.

235. Harris, Richard W; Leiser, Andrew T.; Fissell, Robert E. Tolerance of oaks to flooding. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agricuture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 238-241.

236. Hart, G.H.; Guilbert, H.R.; Wagnon, K.A.; Goss, H. "Acorn calves." A nonhereditary congenital deformity due to maternal nutritional deficiency. Calif. Agric. Exp. Stn. Bull. 699. Berkeley, CA: Unversity of California, Agricultural Experiment Station, 1947. 23 p.

237. Harville, J.P. Ecology and population dynamics of the California oak moth, *Phryganidia californica* Packard (Lepidoptera: Dioptidae). Microentomology 20(4):83-166; 1955 Nov.

238. Hastings, Steven J.; Oechel, Walter C. Photosynthesis and water relations of mature and resprout chaparral vegetation. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and mangement of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 602.

239. Havlik, Neil. New localities for two Bay Area trees. Four Seasons 6(2):21-22; 1980 Dec.

240. Heady, Harold F.; Zinke, Paul J. Vegetational changes in Yosemite Valley. Occas. Paper 5. Washington, DC: U.S. Department of Interior, National Park Service, U. S. Department of Interior; 1978. 25 p.

241. Hecht-Poinar, E.I.; Britton, J.C..; Parmeter, J.R., Jr. Dieback of oaks in California. Plant Disease Reporter 65(3):281; 1981 Mar.

242. Hedgecock, G.G.; Long, W.H. Heart-rot of oaks and poplars caused by Polyporus dryophilus. Journal of Agricultural Research 3(1):65-77; 1914.

243. Hejl, S.J. Foraging ecology of birds in relation to plant phenology in California pine-oak woodlands. Davis, CA: University of California; 1981. 73 p. Thesis.

244. Hektner, M.M.; Martin, R.W.; Davenport, D.R. The Bald Hills prairies of Redwood National Park. In: Van Riper, C., III; Whittig, L.D.; Murphy, M.L., eds. Proceedings of the first biennial conference of research in California's National Parks, 1982 Sep. 9-10, Davis, CA. Davis, CA: University of California Cooperative Park Studies Unit; 1983: 70-78 [map of grassland-woodland mosaic].

245. Hellmers, Henry; Horton, J.S.; Juhren G.; O'Keefe, J. Root systems of some chaparral plants in southern California. Ecology 36(4):667-678; 1955 Oct.

246. Henrickson, James; Prigge, Barry. White fir in the mountains of eastern Mojave desert in California. Madrono 23(3):164-168; 1975 Jul.

247. Hepting, George, H. Diseases of forest and shade trees of the United States. Agric. Handb. 386. Washington, DC: U.S. Department of Agriculture; 1971. 440 p.

248. Hertz, Paul E; Remsen, J.V. Jr.; Zones, Stacey I. Ecological complementarity of three sympatric parids in a California oak woodland. Condor 78(5):307-316; 1976 autumn.

249. Hildebrand, D.C.; Schroth, M.N. A new species of *Erwinia* causing drippy nut disease of live oaks. Phytopathology 57(3):250-253; 1967 Mar.

250. Hjelmquist, H. The embryo sac development of *Quercus robur* L. Phytomorphology 3(4):377-384; 1953.

251. Hoffman, Eric. Wild hog in the woods. Pacific Discovery 38(3):22. 1985 July-Sept.

252. Holdeman, Q.L. A review of professional information pertinent to the possible role oak firewood might play in the

introduction of oak wilt disease into California. Sacramento, CA: Calif. Dep. Food and Agric., Pest Exclusion Unit, Exterior Exclusion Program. 1983. [total no pages not known].

253. Holland, V.L. A study of soil and vegetation under *Quercus douglasii* H. & A. compared to open woodland. Berkeley, CA: University of California; 1973. 369 p. Dissertation.

254. Holland, V.L. In defense of blue oaks. Fremontia 4(1):3-8; 1976 Apr.

255. Holland, V.L. Effect of blue oak on rangeland forage production in central California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 314-318.

256. Holland, V.L.; Morton, Jimmy. Effect of blue oak on nutritional quality of rangland forage in central California. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service Pacific Southwest Forest and Range Experiment Station; 1980: 319-322.

257. Hollinger, David Y. Photosynthesis, water relations, and herbivory in co-occurring deciduous and evergreen California oaks. Stanford, CA: Stanford University; 1983a. 173 p. Dissertation.

258. Hollinger, David Y. Photosynthesis and water relations of the mistletoe *Phoradendron villosum* and its host the California valley oak *Quercus lobata*. Oecologia 60(3):396-400; 1983b.

259. Holstein, Glen. California riparian forests: deciduous islands in an evergreen sea. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19, Davis, CA. Berkeley, CA, University of California Press; 1984: 2-27.

260. Hoover, Robert F. The vascular plants of San Luis Obispo County, California. Berkeley, CA: University of California Press. 1970. 350 p.

261. Hoover, Robert L. California Indian uses of native plants. In: Walters, D.R. [and others], eds. Native plants, a viable option. Spec. Publ. 3. Berkeley, CA: California Native Plant Society; 1977: 131-162.

262. Horn, D.J. *Leptocoris rubrolineatus*, an occasional predator of the California oakworm, *Phryganidia californica*. Pan-Pacific Entomologist 49(3):196; 1973.

263. Horn, D.J. Observations on primary and secondary parasites of California oak-worm, *Phryganidia californcia* pupae (Lepidoptera:Dioptidae). Pan-Pacific Entomologist 50(1):53-59; 1974 Jan.

264. Horn, E.E.; Fitch, H.S. Interrelations of rodents and other wild-life of the range. In: [no editor] The San Joaquin Experimental Range. Bull. 663. Berkeley, CA: University of California, Agric. Exp. Stn.; 1942: 96-129.

265. Hornibrook, E.M.; Larson, R.W.; Van Akkeren,J. J.; Hasel, A.A. Boardfoot and cubic-foot volume tables for some California hardwoods. For. Res. Note 67. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1950. 31 p.

266. Horton, Jerome S. Vegetation types of the San Bernardino Mountains. Tech. Pap. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1960, 29 p.

267. Horton, J.S.; Krabel, C.J. Development of vegetation after fire in the chamise chaparral of southern California. Ecology 36(2):244-262; 1955 Apr.

268. Horton, Jerome S.; Wright, John T. The wood rat as an ecological factor in southern California watersheds. Ecology 25(3):341-351; 1944.

269. Hosner, J.F. Multiseeded acorns. Journal of Forestry 57(2):127; 1958.

270. Howald, Ann M. A flora of Valentine Eastern Sierra Reserve. Part 1: Valentine Camp. Herbarium Publication 1. Santa Barbara, CA: University of California, Department of Biological Sciences; 1981. 55 p.

271. Howell, John Thomas. A variant of the coast live oak. Madrono 2(4):38-39; 1931 Oct.

272. Howell, John Thomas. Marin flora. 2d ed. [with supplement]. Berkeley, CA: University of California Press; 1970. 366 p.

273. Howitt, Beatrice, F.; Howell, John Thomas. Supplement to the vascular flora of Monterey County, California. Pacific Grove, CA: Pacific Grove Museum of Natural History Assoc.; 1973. 60 p.

274. Hunt, R.S.; Wilcox, W.W.; Cobb, F.W. Resistance of stump tops to colonization by *Fomes annosus*. Canadian Journal of Forestry Research 4(1):140-142; 1974.

275. Hunter, Serena C.; Van Doren, Robert. Variation in acorn and seedling characteristics of two Califoria oaks. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 606.

276. Ikenberry, G.J.; Bruce, H.D.; Curry, J.R. Experiments with chemicals in killing vegetation on firebreaks. Journal of Forestry 36(5):507-515; 1938 May.

277. Ingles, Lloyd G. Ecology and life history of the California gray squirrel. California Fish and Game 33(3):139-158; 1947 Jul.

278. Irgens-Moller, H. Forest-tree genetics research: *Quercus* L. Economic Botany 9(1):53-71; 1955 Jan.-Mar.

279. Irvine, J.L. Native oaks and urban sprawl. Pacific Horticulture 43(1):13-17; 1982 spring.

280. Isham, Dana; Moriarty, James R., III. A dendrochronological evaluation of oak trees in San Diego County, Cal-

ifornia. San Diego, CA: University of San Diego; Unpublished report. 1981. 39 p.

281. Jackson, Louise.; Strauss, Robin B.; Firestone, Mary K.; Bartolome, James W. The effect of plant growth patterns on seasonal dynamics of nitrogen in a California oak savannah. Bulletin of the Ecological Society of American 66(2):199-200; 1985 summer [abstract].

282. Jaeger, Edmond C. The mountain trees of southern California. Pasadena, CA: Post Printing and Binding Co.; 1920. 116 p.

283. Jameson, E.W., Jr. Food of deer mice, *Peromyscus maniculatus* and *P. boylei* in the northern Sierra Nevada, California. Journal of Mammalogy 33(1):50-60; 1952 Feb.

284. Jehl, J.R. Jr. Pine cones as granaries for acorn woodpeckers *Melanerpes formicivorus*. Western Birds 10(4):219-220; 1979.

285. Jenny, H.; Gessel, S.P.; Bingham, F.T. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Science 68(6):419-432; 1949 Dec.

286. Jensen, Richard J.; Eshbaugh, W. Hardy. Numerical taxonomic studies of hybridization in *Quercus*. I: Populations of restricted areal distribution and low taxonomic diversity. Systematic Botany 1(1):1-9; 1976a spring.

287. Jensen, Richard J.; Eshbaugh, W. Hardy. Numerical taxonomic studies of hybridization in *Quercus*. II: Populations with wide areal distributions and high taxonomic diversity. Systematic Botany 1(1):10-19; 1976b spring.

288. Jepson, Willis Linn. The riparian botany of the lower Sacramento. Erythea 1:238-246; 1893.

289. Jepson, Willis Linn. The live oaks of the University of California campus. University Chronicles 6:179-185; 1903.

290. Jepson, Willis Linn. The deer oak. Muhlenbergia 3:130; 1907.

291. Jepson, Willis Linn. The Silva of California. Univ. Calif. Memoirs 2:1-480; 1910.

292. Johnson, A.M. Some abnormal inflorescences. Madrono 5(5):177-184; 1940 May.

293. Johnson, F.L.; Risser, P.G. Correlation of rainfall and annual ring index of central Oklahoma blackjack and post oak. American Journal of Botany 60(5):475-478; 1978 May-Jun.

294. Johnson, J.W. Another foodplant of *Erynnis tristis tristis* Bdv. (Lepidoptera:Hesperiidae). Atala 8(2):44; 1980a.

295. Johnson, J.W. A new foodplant for *Satyrium tetra* Edwards (Lepidoptera: Lycaenidae). Atala 8(2):45; 1980b.

296. Johnson, R.R.; Dunster, K.W.; Fosse, R.A. Control of California chaparral species with 2,4-D and dichlorprop. Proceedings Western Society of Weed Science 119-120; 1980.

297. Johnson, Sharon. California's oaks, herritage with an uncertain future. Pacific Discovery 38(3):4-13 1985 July-Sep. [photos by Cavagnaro, David].

298. Johnson, Walter C.; McKell, Cyrus, M.; Evans, Raymond A.; Berry, L.J. Yield and quality of annual range forage following 2,4-D application on blue oak trees. Journal of Range Management 12(1):18-20; 1959 Jan.

299. Kasapligil, Baki. Past and present oaks of Turkey. Part 1: Phytologia 49(21):95-146; 1981 Sep.

300. Kay, Burgess L.; Leonard, O.A. Effect of blue oak removal on herbaceous forage production in the north Sierra foothills. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Service; 1980: 323-328.

301. Keeley, Jon E. Reproductive cycles and fire regimes. In: Mooney, H.A. [and others], eds. Proceedings of the conference on fire regimes and ecosystem properties, Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 231-277.

302. Keeley, Jon E.; Keeley, Sterling C. Post-fire regeneration of southern California chaparral. American Journal of Botany 68(4):524-530; 1981 Apr.

303. Keeley, J.E.; Zedler, P.H. Reproduction of chaparral shrubs after fire: a comparison of sprouting and seedling strategies. The American Midland Naturalist 99(1):142-161; 1978.

304. Keen, F.P. Cone and seed insects of western forest trees. Tech. Bull. 1169. Washington DC: U.S. Department of Agriculture; 1958. 168 p.

305. Kellogg, Albert. Proceedings of the California Academy of Natural Sciences, Series 1. 2:36; 1863.

306. Kellogg, Albert. Forest trees of California [appendix to State Minerologists Report]. Sacramento, CA: State Printing Office; 1882. 148 p.

307. Kellogg, Albert. The Dunn oak. Pacific Rural Press 17(23):371; 1879.

308. Kerns, Steven J. Observations on wildlife abundance in several California black oak habitats in northern California. In: Plumb, Timothy R., tech. coord. Proceeding of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 354-359.

309. Kimball, Marston. Oak trees and rainfall in Los Angeles County. Berkeley, CA: University California, Agric. Extension Service; 1950. 8 p.

310. Kimbrough, David J. An ecological analysis of montane scrub in the Siskiyou Mountains, Trinity Alps, and Marble Mountains. Angwin, CA: Pacific Union College; 1975. 198 p. Thesis.

311. Kimmey, J.W. Cull factors for forest tree species in northwestern California. Forest Surv. Release 7. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1950. 30 p.

312. Kirn, T. The disappearing valley oak. Outdoor Calif. [unnumbered]: 7-8: 1982.

313. Klyver, F.D. Major plant communities in a transect of the Sierra Nevada mountains of California. Ecology 12(1):1-17; 1931 Jan.

314. Knudsen, Monty, D. Life history aspects of *Quercus lobata* Nee in a riparian community, Bobelaine Audubon Sanctuary, Sutter County, California. Sacramento, CA: Sacramento State University; 1984. 135 p. M.S. Thesis.

315. Koehler, C. Dripping acorns on live oak. University of California Extension Service, Growing Points [series title]. 1978: Jul. 1978: 2.

316. Koehler, Carlton, S. Oakworms and what to do about them. Fremontia 10(2):21-23; 1982 Jul.

317. Koenig, Walter D. Acorn storage by acorn woodpeckers in an oak woodland: an energetics analysis. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 265-269.

318. Korstian, Clarence Ferdinand. Factors controlling germination and early survival in oaks. New Haven, CT: Yale University, School of Forestry; Bulletin 19; 1927. 115 p.

319. Krause, D.; Kummerow, J. Xerophytic structure and soil moisture in the chaparral. Oecologia Plantarum 12(2):133-148; 1977.

320. Kroeber, A.L. The food problem in California. In: Heizer, R.F.; Whipple, M.A., eds. The California Indians, a source book. 2d ed. Berkeley, CA: University of California Press; 1971: 297-300.

321. Kuchler, A.W. The map of the natural vegetation of California. In: Barbour, Michael G.; Major, Jack, eds. Terrestrial vegetation of California. New York: Wiley Interscience; 1977: 909-938.

322. Kummerow, J.; Mangan, R. Root systems in *Quercus dumosa* Nutt. dominated chaparral in southern California. Acta Oecologia 2(2):177-188; 1981.

323. Kuntz, James E. Diseases of *Quercus* in the U.S.. In: Diseases of widely planted forest trees. Forest Protection, Sec. 24, FAO/IUFRO. Symposium on internationally dangerous forest diseases and insects. 1964: 184-213.

324. Landres, Peter B.; MacMahon, James A. Community organization of arboreal birds in some oak woodlands of western North America. Ecological Monographs 53(2):183-208; 1983 Jun.

325. Langdon, L.M. Ontogenetic and anatomical studies of the flower and fruit of the Fagaceae and Juglandaceae. Botanical Gazette 101(2):301-327; 1939 Dec.

326. La Rosa, R. Environmental resource conservation: riparian system enhancement through water reclamation. In: Warner, R.E.; Hendrix K.M.,. eds. Proceedings of the symposium on California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19; Davis, CA. Berkeley: University of California Press; 1984: 459-464.

327. Lathrop, Earl W.; Martin, Bradford D. Response of understory to prescribed burning in yellow pine forests of Cuyamaca Rancho State Park. Aliso 10(2):329-343; 1982.

328. Lathrop, Earl W.; Thorne, Robert F. Flora of the Santa Rosa Plateau of the Santa Ana Mountains, California. Aliso 6(4):17-40; 1968 Apr.

329. Lathrop, Earl W.; Thorne, Robert F. A flora of the Santa Ana mountains, California. Aliso 9(2):197-278; 1978.

330. Lathrop, Earl W.; Zuill, Henry A. Southern oak woodlands of the Santa Rosa Plateau, Riverside County, California. Aliso 10(4):603-611; 1984.

331. Lawrence, George E. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology 47(2):278-291; 1966 early spring.

332. Lawrence, George; Biswell, Harold. Effect of forest manipulation on deer habitat in giant sequoia. Journal of Wildlife Management 36(2):595- 605; 1972 Apr.

333. Leach, Howard R.; Hiehle, Jack L. Food habits of the Tehama deer herd. California Fish and Game 43(3):161-178; 1957 Jul.

334. Lee, Melicent Humason. Indians of the oaks. Ramona, CA: Acorn Books; 1978. 245 p. [reprint of 1931 edition; original title, The Indians and I, secrets of the trail].

335. Lemmon, Robert S. The best loved trees of America: intimate close-ups of their year-round traits. Garden City, NY: Doubleday; 1952; 128-131, 223-226.

336. Leonard, Oliver A. Effect on blue oak (*Quercus douglasii*) of 2,4-D and 2,4,5-T concentrates applied to cuts in trunks. Journal of Range Management 9(1):15-19; 1956 Jun.

337. Leonard, O.A.; Carlson, C.E. Aircraft spraying of blue oak. California Agriculture 13(4):3; 1959 Apr.

338. Leonard, O.A.; Harvey, W.A. Chemical control of woody plants. Bull. 812 Berkeley, CA: University of California, Agric. Exp. Stn. 1965. 26 p.

339. Leonard, O.A.; Murphy, A.H. Relationship between herbicide movement and stump sprouting. Weeds 13(1):26-30; 1965 Jan.

340. Leopold, A. Starker; Riney, T.; McCain, R.; Tevis, Lloyd, Jr. The Jawbone deer herd. Bull. 4. Sacramento: Calif. Div. Fish and Game; 1951. 139 p.

341. Leskinen, Paul H. Occurrence of oaks in late Pleistocene vegetation in the Mojave Desert of Nevada. Madrono 23(4):234-235; 1975 Oct.

342. Lewis, David C. Annual hydrologic response to watershed conversion from oak woodland to annual grassland. Water Resources Research 4(1):59-72; 1968 Feb.

343. Lewis, D.C.; Burgy, R.H. The relationship between oak tree roots and groundwater in fractured rock as determined by tritium tracing. Journal of Geophysical Research. 69(12):2579-2588; 1964.

344. Lewis, D.C. Water use by native vegetation and hydrologic studies. Ann. Rep. 7 (1965-66). Davis, CA: University of California, Dep. Water Sci. and Engineer.; 1967. 54 p.

345. Li, Hui-Lin; Hsiao, Ju-Ying. A preliminary study of the chemosystematics of American oaks: phenolic characters of leaves. Bartonia 42:5-13; 1973-1974.

346. Li, Hui-Lin; Hsiao, Ju-Ying. A preliminary study of the chemosystematics of American oaks: phenolic characters of staminate catkins. Bartonia 44:8-13; 1975-1976a.

347. Li, Hui-Lin; Hsiao, Ju-Ying. A preliminary study of the chemosystematics of American oaks: phenolic characters of young twigs. Bartonia 44:14-21; 1975-1976b.

348. Linsdale, Jean M. California quail feeding upon acorns. Condor 38(3):126; 1936 May-Jun.

349. Linsdale, Jean M. The California ground squirrel. Berkeley: University of California Press; 1946a. 475 p.

350. Linsdale, Jean M. Yellow-billed magpie. In: Bent, A.C., ed. Life histories of North American jays, crows, and titmice. Bull. 191. Washington, DC: U.S. National Museum; 1946b: 155-183.

351. Linsdale, Jean M.; Tevis, Lloyd P., Jr. The dusky-footed wood rat. Berkeley: University of California Press. 1951. 664 p.

352. Linsdale, Jean M.; Tomich, P. Quentin. A herd of mule deer. Berkeley: University of California Press. 1953. 567 p.

353. Little, Elbert L., Jr. Atlas of United States trees. V. 1: Conifers and important hardwoods. Misc. Publ. 1146. Washington, DC: U.S. Department of Agriculture; 1971. 219 p. [202 maps].

354. Little, Elbert L., Jr. Atlas of United States trees. V. 3: Minor western hardwoods. Misc. Publ. 1314. Washington, DC: U.S. Department of Agriculture; 1976. 213 p. [200 maps].

355. Little, Elbert L., Jr. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture; 1979. 375 p.

356. Litton, R. Burton, Jr. Oaks and the California landscape. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 161-166.

357. Lobel, D.C.; George, A.G. Plant your own tree. Leaflet 21334. Berkeley: University of California, Div. Agric. and Nat. Resour.; 1983. 3 p.

358. Long, W.H. Polyporus dryadeus, a root parasite on the oak. Journal of Agricultural Research 1(3):239-250; 1913 Dec.

359. Longhurst, William M. Stump sprouting in response to seasonal cutting. Journal of Range Management 9(4):194-196; 1956 Jul.

360. Longhurst, William M.; Connolly, Guy E.; Browning, Bruce M.; Garton, Edward O. Food interrelationships of deer and sheep in parts of Mendocino and Lake counties, California. Hilgardia 47(6):191-249; 1979 Dec.

361. Loveless, B.; Loveless, R. Fortieth breeding bird census. 113: Sycamore-coast live oak woodland. American Birds 31(1):70; 1977 Jan.

362. Lyon, R.J. An alternating, sexual generation in the gall wasp *Callirhytis pomiformis* (Ashm.) (Hymenoptera: Cynipidae). Bulletin of the Southern California Academy of Sciences 58(1):33-37; 1959.

363. Lyon, R.J. The alternate generation of *Heteroecus pacificus* (Ashmead) (Hymenoptera: Cynipidae). Proceedings of the Entomological Society of Washington. 65(3):250-254; 1963.

364. Lyon, R.J. The alternate generation of *Callirhytis agrifoliae* (Ashmead) (Hymenoptera: Cynipidae). Proceedings of the Entomological Society of Washington 66(3):193-196; 1964.

365. Lyon, R.J. The alternate generation of *Callirhytis quercussuttonii* (Bassett) (Hymenoptera: Cynipidea). Proceedings of the Entomological Society of Washington 71(1):61-65; 1969.

366. Lyon, R.J. Heterogony in *Callirhytis serricornis* (Kinsey) (Hymenoptera: Cynipidae). Proceedings of the Entomological Society of Washington 72(2):176-178; 1970.

367. MacGinitie, H.D. A middle Eocene flora from the central Sierra Nevada. Carnegie Institution of Washington Publication 534:1-178; 1941.

368. Mackie, W.W. The value of oak leaves for forage. Bull. 150. Berkeley, University of California, Agric. Exp. Stn; 1903. 21 p.

369. MacRoberts, Barbara R.; MacRoberts, Michael H. A most sociable bird. Natural History 81(10):44-51; 1972 Dec.

370. MacRoberts, Michael H. Notes on the food habits and food defense of the acorn woodpecker. The Condor 72(2):196-204; 1970 Apr.

371. MacRoberts, Michael H. Acorns, woodpeckers, grubs, and scientists. Pacific Discovery 27(5):9-15; 1974 Sep.-Oct.

372. MacRoberts, Michael H.; MacRoberts, Barbara R. Social organization and behavior of the acorn woodpecker in central coastal California. Ornithological Monographs 21; 1976. 115 p.

373. Malcolm, F.B. California black oak—a utilization study. Rep. 2237. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Lab.; 1962. 17 p.

374. Mallory, J.I.; Smith, B.F.; Alexander, E.B.; Gladish, E.N. Soils and vegetation of the Manton quadrangle. [no series number] Berkeley CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1965. 36 p. [2 maps].

375. Mallory, James I. Canyon live oak. In: Eyre, F.H. ed. Forest cover types of the United States and Canada. Washington, DC: Soc. Am. For.; 1980:125-126.

376. Mallory, James I.; Alexander, Earl B.; Colwell, Wilmer L., Jr.; Powell, W. Robert. Soils and vegetation of the Chanchellula Peak Quadrangle, Shasta and Trinity counties, California. [no series no.] Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1968. 48 p. [4 maps].

377. Mallory, James I.; Colwell, Wilmer L., Jr.; Powell, W. Robert. Soils and vegetation of the French Gulch quad-

rangle, Trinity and Shasta counties. Resour. Bull. PSW-12. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1973. 42 p. [4 maps].

378. Maloney, Alice B., ed. Fur brigade to the Bonaventura: John Work's California expedition, 1832-33, for the Hudson's Bay Company. San Francisco: California Historical Society; 1945. 112 p.

379. Mani, M.S. Ecology of plant galls. The Hague, Netherlands: W. Junk; 1964. 434 p.

380. Manolis, T. Thirty-fifth breeding bird census. Mixed oak-digger pine woodland. American Birds 26(6):981-983; 1972 Dec.

381. Martin, Bradford D. Vegetation responses to prescribed burning in Cuyamaca Rancho State Park, California. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on the dynamics and management of Mediterranean-type ecosystems, 1981 June 22- 26; San Diego, CA. Gen Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiement Station; 1982: 617.

382. Marx, D.H. The role of mycorrhyizae in forest production. In: McGrifkin, F.U., TAPPI Conf. Pap. Annual meeting, 1977 Feb. 14-16, Atlanta, GA. [publisher not known], 1977: 151-161.

383. Mason, Larry G. Mating selection in the California oak moth (Lepidoptera: Dioptidae). Evolution 23(1):55-58; 1969 Mar.

384. Matson, J.O. Notes on the arboreal activities of *Peromyscus boyleyi rowleyi* in Inyo County, California. Bulletin of the Southern California Academy of Sciences 73(1):51-52; 1974.

385. Matsuda, K.; McBride, J.R. Germination and initial seedling growth of five Californian oak species. In: Leviton, A.E.; Aldrich, M.L.; Berson, M. eds. Proc. 63rd Annual Meet. Pac. Div. AAAS, 1982 June 20-25, Santa Barbara, Ca. San Francisco, CA: Pac. Div. AAAS; 1982: 41 [abstract].

386. Mauffette, Yves; Oechel, Walter C. Herbivory on *Quercus agrifolia* in relation to carbon allocation. Bulletin of the Ecological Society of American 64(2):103; 1983 summer [abstract].

387. Mauffette, Yves; Oechel, Walter C. Seasonal carbon allocation patterns on an evergreen tree. Bulletin of the Ecological Society of America 66(2):225; 1985 summer [abstract].

388. Mauffette, Yves; Oechel, Walter C.; Hamner, Dyson L. Seasonal leaf chemistry of *Quercus agrifolia* in relation to herbivores. Bulletin of the Ecological Society of America 65(2):230; 1984 summer [abstract].

389. May, Richard H. Notes on the history of charcoal production and use in California. [no series number] Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1956. 12 p.

390. May, Richard H. Wood charcoal in Califoria. Forest Survey Rel. 28. Berkeley CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1957. 12 p.

391. May, Richard H. Development of the veneer and plywood industry in California. Forest Survey Rel. 34. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1958. 26 p.

392. McBride, Joe R. Plant succession in the Berkeley Hills, California. Madrono 22(7):317-329; 1974 Jul.

393. McBride, Joe, R. Predictions of changes in forest species composition associated with the effects of oxidant injury, pest complexes and fire. In; [no ed.] Workshop Proc.: simulation modeling of oxidant air pollution effects on mixed conifer forests. 1978 Mar. 20-21, Riverside, CA. Statewide Air Pollution Resour. Cent. Riverside, CA: University of California; 1978: 12.

394. McBride, J.; Jacobs, D. Urban forest development a case study Menlo Park, California. Urban Ecology 2(1):1-14; 1976.

395. McBride, J.; Jacobs, D. Urban forest structure: a key to urban forest planning. California Agriculture 33(5):24; 1979 May.

396. McBride, J.R.; Strahan, J. Influence of fluvial processes on patterns of woodland succession along Dry Creek, Sonoma County, California. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19; Davis, CA. Berkeley, CA: University of California Press; 1984: 110-119.

397. McClaran, Mitchel. Visalia and the valley oak. Fremontia 11(3):23-25; 1983 Oct.

398. McClaran, Mitchel. Regeneration of California blue oak as determined from age structures at multiple bole heights. Bulletin of the Ecological Society of America 66(2):226; 1985 summer [abstract].

399. McClintock, Elizabeth. Trees of Golden Gate Park. 26: Coast live oak. Pacific Horticulture 44(4):10-11; 1983 winter.

400. McClintock, Elizabeth; Knight, Walter; Fahy, Neil. A flora of the San Bruno Mountains, San Mateo County. Proceedings of the California Academy of Sciences (Series 4) 32(20):587-677; 1968.

401. McColl, J.G. Comparison of foliar composition of *Eucalyptus globulus* and *Quercus agrifolia* growing together. Journal of Plant Nutrition 1(1):65-71; 1979.

402. McComb, A.L. The relation between acorn weight and the development of one year chestnut oak seedlings. Journal of Forestry 32:479-484; 1934.

403. McCracken, I.; Egbert, D. California gall-making Cynipidae with descriptions of new species. Publ. Biol. Sci. III. Stanford, CA: Stanford University; 1922. 75 p.

404. McDonald, Philip M. Silvical characteristics of California black oak (*Quercus kelloggii* Newb.). Res. Pap. PSW-53. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Southwest Forest and Range Experiment

Station; 1969. 20 p.
405. McDonald, Philip M. Silviculture—ecology of three native California hardwoods on high sites in north-central California. Corvallis, OR: Oregon State University; 1978. 309 p. Dissertation.
406. McDonald, Philip M. California black oak. In: Eyre, F.H., ed. Forest cover types of the United States and Canada. Washington, DC.: Soc. Am. For.; 1980: 122a.
407. McDonald, Philip M. Growth of thinned and unthinned stands in the northern Sierra Nevada . . . preliminary findings. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Pacific Southwest Forest and Range Experiment Station; 1980: 119-127b.
408. McDonald, Philip M. Propagating tanoak and California black oak on a good site in northern California. In: Johnson, Paul S.; Garrett, H.E., comps. Workshop on seedling physiology and growth in oak planting, 1979 Nov. 6- 7, Gen. Tech. Rep. NC-62. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981: 25.
409. McDonald, Philip M. Local volume tables for Pacific madrone, tanoak, and California black oak in north-central California. Res. Note PSW-362. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1983. 6 p.
410. McDonald, Philip M.; Littrell, Edward E. The bigcone Douglas-fir— canyon live oak community in southern California. Madrono 23(6):310- 320; 1976 Apr.
411. McDonald, Philip M.; Minore, Don; Atzet, Tom. Southwestern Oregon— Northern California hardwoods. In: Burns, Russell M., tech. comp. Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture; 1983: 29-32.
412. McGill, R.R., Jr. Land use changes in the Sacramento River riparian zone, Redding to Colusa. North. Dist. Rep. Sacramento, CA: Calif. Dep. Water Resour.; 1975. 23 p.
413. McGill, R.R., Jr. Land use changes in the Sacramento River riparian zone, Redding to Colusa. An update 1972-1977. Sacramento, CA: Calif. Dep. Water Resour.; 1979. 34 p.
414. McKinnie, Ian R., Jr. Twenty-seventh winter bird population study. 50: Valley oak woodland. American Birds 28(3):717-718; 1974 Jun.
415. McLain, T.E.; Stern, G.E. Withdrawal resistance of pallet nails and staples in five western woods. Rep. 155. Blacksburg, VA: Virginia Polytechnic Inst. and State Univ. Wood Res. and Wood Construction Lab.; 1978. 12 p.
416. McMinn, H.E.; Babcock, E.B.; Righter, F.I.. The Chase oak, a new giant hybrid oak from Santa Clara County, California. Madrono 10(2):51-55; 1949 Apr.
417. McMinn, Howard E. An illustrated manual of California shrubs. Berkeley, CA: University of California Press; 1951. 663 p.
418. McPherson, James K.; Thompson, Gerald L. Competitive and allelopathic suppression of understory by Oklahoma oak forests. Bulletin of the Torrey Botanical Club 99(6):293-300; 1972 Nov.-Dec.
419. Medeiros, Joseph L. San Luis Island: the last of the Great Valley. Fremontia 7(1):3-9; 1979 Apr.
420. Menke, John W.; Fry Michael E. Trends in oak utilization—fuelwood, mast production, animal use. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 297-305.
421. Merkle, S.A.; Feret, P.P.; Croxdale, J.G.; Sharik, T.L. Development of floral primordia in white oak. Forest Science 26(2):238-250; 1980 Jun.
422. Merriam, C. Hart. The acorn, a possibly neglected source of food. The National Geographic Magazine 34(2):129-137; 1918 Aug.
423. Meyer, K.D. Soil drainage for trees. Journal of Arboriculture 9(8):214-216. 1983 Aug.
424. Michael, Charles W. Acorn storing methods of the California and Lewis woodpeckers. The Condor 28(2):68-69; 1926 Mar.-Apr.
425. Michny, F.J.; Boos, D.; Wernette, F. Riparian habitats and avian densities along the Sacramento River. Sacramento, CA: Admin. Rep. 75-1. Calif. Dep. Fish and Game; 1975. 42 p.
426. Mielke, J.L.; Kimmey, J.W. Heat injury to the leaves of California black oak and some other broadleaves. Plant Disease Reporter 26(5):116-119; 1942 Mar.
427. Miller, A.H.; Stebbins, R.C. The lives of desert animals in Joshua Tree National Monument. Berkeley, CA: University of California Press; 1964. 452 p.
428. Miller, Paul R.; Longbottom, Gail, J.; Van Doren, Robert E.; Thomas, Maureen A. Effect of chronic oxident air pollution exposure on California black oak in the San Bernardino Mountains. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of the California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 220-229.
429. Miller, P.C. Light and energy environments of chaparral and matorral in southern California and central Chile. In: Margaris, N.S.; Mooney, H.A., eds. Components of productivity of Mediterranean-climate regions. Basic and applied aspects. The Hague, Netherlands: W. Junk; 1981: 267- 276.
430. Miller, Philip C.; Poole, D.K. Partitioning of solar and net irradiance in mixed and chamise chaparral in southern California USA. Oecologia 47(3):328-332; 1980.

431. Milstead, J.E.; Kirby, M.; Pinnock, D.; Farmer, N. [et al.]. Evaluation of commercial formulations of *Bacillus thuringiensis* for the control of tent caterpillars affecting oaks. Plant Protection Bulletin 28(2):72-74; 1980a.

432. Milstead, J.E.; Odom, D.; Kirby, M. Control of early larval stages of the California oakworm by low concentrations of *Bacillus thuringiensis* applied to lower leaf surfaces. Journal of Economic Entomology 73(2):344-346; 1980b Apr.

433. Minnich, Richard A. Wildfire and the geographic relationship between canyon live oak, Coulter pine, and bigcone Douglas-fir. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 55-61.

434. Mircetich, S.M.; Campbell, R.N.; Matheron, M.E. Phytophthora trunk canker of coast live oak and cork oak trees in California. Plant Disease Reporter 61(2):66-70; 1977 Feb.

435. Mirov, N.T. Additional data on collecting and propagating the seeds of California wild plants. Res. Note 21. Berkeley, CA: U.S. Department of Agricuture, Forest Service, California Forest and Range Experiment Station, Forest Service; 1945. 17 p.

436. Mirov, N.T.; Cumming, C.J. Propagation of cork oak by grafting. Journal of Forestry 43(8):589-591; 1945 Aug.

437. Mirov, N.T.; Kraeble, Charles J. Collecting and handling seeds of California wild plants. For. Publ. 5. Washington, DC: Civilian Conservation Corps; 1939. 42 p.

438. Mitchell, Harry O. Pacific coast hardwoods and their uses. National Hardwood Magazine 32(11):110-114; 1958 Dec.

439. Mogensen, H.L. A contribution to the anatomical development of the acorn in *Quercus* L. Iowa State Journal of Science 40:221-255; 1966.

440. Mogensen, H.L. Ovule abortion in *Quercus* (Fagaceae). American Journal of Botany 62(2):160-165; 1975 Feb.

441. Mooney, H.A.; Dunn, E.L.; Shropshire, Frances; Song, Leo. Vegetation comparisons between the Mediterranean climatic areas of California and Chile. Flora 159:480-496; 1970.

442. Mooney, H.A.; Dunn, E.L.; Shropshire, Frances; Song, Leo. Land-use history of California and Chile as related to the structure of the sclerophyll scrub vegetations. Madrono 21(5):305-319; 1972 Jan.

443. Mooney, H.A.; Gulmon, S.L.; Parsons, D.J.; Harrison, A.T. Morphological changes within the chaparral vegetation type as related to elevational gradients. Madrono 22(6):281-285; 1974 Apr.

444. Mooney, H.A.; Hays, R.I. Carbohydrate storage cycles in two California mediterranean-climate trees. Flora 162(3):295-304; 1973.

445. Moran, R. Do oaks need apples? Environment Southwest 467:32-34; 1974 Oct.

446. Morgan, D.L.; McWilliams, E.L.; Parr, W.C. Maintaining juvenility in live oak. HortSci 15(4):493-494; 1980.

447. Morrison, Richard H. A species of *Clitocybe* associated with declining oak and sycamore in California. Plant Disease Reprorter 49(10):870-871; 1965 Oct.

448. Motroni, R.S. Avian density and composition of a riparian forest, Sacramento Valley, California. Sacramento, CA: California State University; 1979. 172 p. Thesis.

449. Muick, Pamela C. Restoring habitats in Sonoma County. Fremontia 8(2):17- 21; 1980 Jul.

450. Muick, Pamela C; Bartolome, James W. Research studies in California related to oaks. Rep. 7, Wildlands Resources Center; Berkeley, CA: University of California. 1985. 37 p.

451. Muller, C.H. Further studies in southwestern oaks. The American Midland Naturalist 19(3):582-588; 1938.

452. Muller, C.H. The problem of genera and subgenera in the oaks. Chron. Bot. 7:12-14; 1942.

453. Muller, C.H. The significance of vegetative reproduction in *Quercus*. Madrono 11(3):129-137; 1951.

454. Muller, C.H. Ecological control of hybridization in *Quercus*: a factor in the mechanism of evolution. Evolution 6(2):147-161; 1952 Jun.

455. Muller, C.H. Relictual origins of insular endemics in Quercus. In: Philbrick, Ralph N., ed. Proceedings of the symposium on the biology of the California Islands, Oct. 29-30, 1965, Santa Barbara, CA. Santa Barbara, CA: Santa Barbara Botanic Garden; 1967: 73-77.

456. Mumme, Ronald, L.; Koenig, Walter D.; Pitelka, Frank A. Are acorn woodpecker territories aggregated? Ecology 64(5):1305-1307; 1983 Oct.

457. Murphy, Alfred H. Oak trees and livestock—management options. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28 Claremont, CA. Gen. Tech Rep. PSW-44. U.S. Department of Agriculture, Forest Service Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; 1980: 329-332.

458. Murphy, A.H.; Berry, L.H. Range pasture benefits through tree removal. California Agriculture 27(1):8-10; 1973 Jan.

459. Murphy, A.H.; Crampton, Beecher. Quality and yield of forage as affected by chemical removal of blue oaks (*Quercus douglasii*). Journal of Range Management 17(3):142-144; 1964 May.

460. Murray, Lynn. Black oak management plan. Willows, CA: Mendocino National Forest; 1973 40 p.

461. Muth, Gilbert Jerome. The taxonomic and floristic relationships of *Quercus sadleriana* R. Br. Campst. to other chestnut oaks. Davis, CA: University of California; 1976. 302 p. Dissertation.

462. Muth Gilbert Jerome. *Quercus sadleriana* R. Br. Campst., its distribution, ecology, and relationships to other oaks. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA.

Gen. Tech. Rep. PSW-44. U.S. Department of Agriculture, Forest Service, Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; 1980: 75-80.

463. Myatt, Rodney G. Geographic and ecological variation in *Quercus chrysolepis* Liebm. Davis, CA: University of California; 1975. 220 p. Dissertation.

464. Myatt, Rodney G. Canyon live oak vegetation in the Sierra Nevada. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA: Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 86-91.

465. Nagata, J. Forty-fifth breeding bird census. 150: Coast live oak riparian woodland. American Birds 36(1):87; 1982 Jan.

466. Naveh, Zev. Mediterranean ecosystems and vegetation types in California and Israel. Ecology 48(3):445-459; 1967 late spring.

467. Naveh, Zev; Whittaker, R.H. Structure and floristic diversity of shrublands and woodlands in northern Israel and other Mediterranean areas. Vegetatio 41(3):171-190; 1979.

468. Neal, Donald L. Blue oak-Digger pine. In: Eyre, F.H., ed. Forest cover types of the United States and Canada. Washington, DC: Soc. Amer. For.; 1980: 126-127.

469. Neilson, R.P.; Wullstein, L.H. Catkin freezing and acorn production in Gambel oak in Utah, 1977. American Journal of Botany 67(3):426-428; 1980 Mar.

470. Ng, Edward; Miller, Philip C. Soil moisture relations in the southern California chaparral. Ecology 61(1):98-107; 1980 Feb.

471. Nixon, Kevin C. A systematic study of *Quercus parvula* Greene *parvula* on Santa Cruz Island and mainland California. Santa Barbara, CA: University of California; 1980. 92 p. Thesis.

472. Nixon, Kevin C.; Steele, Kelly P. A new species of *Quercus* (Fagaceae) from southern California. Madrono 28(4):210-219; 1981 Oct.

473. Novick, Harold J.; Steward, Glen R. Home range and habitat preferences of black bears in the San Bernardino Mountains of southern California. California Fish and Game 68(1):21-35; 1982.

474. Nugen, John A. Topographic sketch of Tulare Valley. 1853 [Washington DC. 1935 photograph of map, Div. Maps, Library of Congress].

475. Oechel, W.C.; Hastings, S.J. The effects of fire on photosynthesis in chaparral resprouts. Ecological studies: analysis and synthesis. Berlin: Springer-Verlag, 43:274-285; 1983.

476. Oechel, W.C.; Lawrence, W.T.; Mustafa, J.; Martinez, J. Energy and carbon acquisition. In: Miller, P.C., ed. Resource use by chaparral and matorral. New York: Springer-Verlag; 1981: 151-184.

477. Oechel, W.C.; Sproul, Fred; Roberts, Steve. Non-lethal water potentials in chaparral shrub seedlings. Bulletin of the Ecological Society of America 66(20):240; 1985 summer [abstract].

478. Ofcarcik, R.P.; Burns, E.E. Chemical and physical properties of selected acorns. Journal of Food Science 36(4):576-578; 1971.

479. Ogden, Gary L. Differential response of two oak species to far inland advection of sea-salt spray aerosol. Santa Barbara, CA: University of California; 1975. 230 p. Dissertation.

480. Odgen, Gary L. Sea-salt aerosol damage to *Quercus agrifolia* and *Quercus lobata* in the Santa Ynez Valley, California. In: Plumb, Timothy, R., tech coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 230-237.

481. Okiwelu, S.N. Studies on a pit-making scale, Asterolecanium minus, on Quercus lobata. Annals of the Entomological Society of America 70(4):615-621; 1977.

482. Olson, David F., Jr. *Quercus* L. Oak. In: Schopmeyer, C.S., Jr., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington DC: U.S. Department of Agriculture; 1974: 692-703.

483. Olson, Jo Ann. Vegetative propagation of oaks. Davis, CA: University of California; 1969. 39 p. Thesis.

484. Olson, K.D.; Adams, T.E.; Murphy, A.H. Evaluating the profitability of brush management and oak tree thinning for range improvement. California Agriculture 37(9-10):6-7; 1983 Sep.-Oct.

485. Opler, Paul A. Seven new lepidopterous leaf-miners associated with Quercus agrifolia (Heliozeldiae: Gracilaridae). Lepidoterists Society Journal 25(3):194-211; 1971 Aug.

486. Opler, Paul A. Fossil lepidopterous leaf miners demonstrate the age of some insect-plant relationships. Science 179(4080):1321-1323; 1973 Mar.

487. Opler, Paul A. Biology, ecology, and host specificity of Microlepidoptera associated with *Quercus agrifolia* (Fagaceae). University of California Publications in Entomology 75; 1974a. 83 p.

488. Opler, Paul A. Oaks as evolutionary islands for leaf-mining insects. American Scientist 62(1):67-73; 1974b Jan.-Feb.

489. Opler, P.A.; Davis, D.R. The leafmining moths of the genus *Cameraria* associated with Fagaceae in California (Lepidoptera: Gracillaridae). Smithsonian Contributions in Zoology 333:1-53; 1981.

490. Osborn, A. *Quercus kewensis*. Gardeners Chronicle Ser. 3. 90:473; 1931.

491. Oswald, Daniel D. Forests and timber resources of California's central coast. Resource Bulletin PNW-83. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 56 p.

492. Oswald, Daniel D.; Hornibrook, E.M. Commercial forest area and timber volume in California, 1963. Resour. Bull. PSW-4. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1966. 16 p.

493. Otter, F.L. Timber stand improvement by poisoning black oak on Mountain Home State Forest. State Forest Note 2. Sacramento, Ca: Calif. Div. of Forestry; 1960. 4 p.

494. Palma-Fleming, H.A.; Kepner, R.E. Volatile components of California live oak, *Quercus agrifolia*. Phytochemistry 22(6):1503-1505; 1983.

495. Palmer, E.J. The red oak complex in the United States. The American Midland Naturalist 27(3):732-749; 1942 May.

496. Palmer, E. J. Hybrid oaks of North America. Journal of the Arnold Arboretum, Harvard University 29(1):1-48; 1948 Jan.

497. Palmer, R.C. Yields from the destructive distillation of certain hardwoods. Second progress report. Agric. Bull. 508. Washington, DC: U.S. Department of Agriculture; 1917. 8 p.

498. Pardo, Richard. National register of big trees. American Forests 84(4):17-47; 1978 Apr.

499. Parker, J. Phenolics in black oak bark and leaves. Journal of Chemical Ecology 3(5):489-496; 1977 Sep.

500. Parker, V.T. Dominance relationships of tree associated herbs in some California grasslands. Santa Barbara, CA: University of California; 1977. 149 p. Dissertation.

501. Parker, V.T. Correlation of physiological divergence with reproductive mode in chaparral shrubs. Madrono 31(4):231-242; 1984 Nov.

502. Parker, V.T.; Muller, C.H. Allelopathic dominance by a tree-associated herb in a California annual grassland. Oecologia 37(3):315-320; 1979.

503. Parker, V.T.; Muller, C.H. Vegetation and environmental changes beneath isolated live oak trees (*Quercus agrifolia*) in a California annual grassland. The American Midland Naturalist 107(1):69-81; 1982.

504. Parsons, David, J. The historic role of fire in the foothill communities of Sequoia National Park. Madrono 28(3):111-120; 1981 Jul.

505. Parsons, David, J.; DeBenedetti, Stephen H. Impact of fire suppression on a mixed conifer forest. Forest Ecology Management 2:21-33; 1979.

506. Parsons, J.J. Slicing up the open space: subdivisions without homes in northern California. Erdkunde 26(1):1-18; 1972.

507. Pase, C.P. Survival of *Quercus turbinella* and *Q. emoryi* seedlings in an Arizona chaparral community. The Southwestern Naturalist 14(2): 149-156; 1969 Oct.

508. Passof, Peter C.; Bartolome, James W. An integrated hardwood range management program. Berkeley, CA: University of California, Wildland Resources Center; 1985. 18 p.

509. Patric, James H.; Hanes, Ted L. Chaparral succession in a San Gabriel Mountain area of California. Ecology 45(2)353-360; 1964 spring.

510. Paul, Benson H. Choose the right wood. Properties and uses of some western hardwoods. Woodworkers Digest 64:47-49; 1962.

511. Pavlik, Bruce M. A natural history of southern California oaks. Van Nuys, CA: West Los Angeles County Resource Conservation District; 1976. 73 p.

512. Paysen, Timothy E. Sampling wildland vegetation. Riverside, CA: University of California; 1978. 185 p. Dissertation.

513. Paysen, Timothy E. Inventory and distribution records of oaks in California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 67-74.

514. Paysen, Timothy E.; Derby, Jeanine A.; Black, Hugh [and others]. A vegetation classification system applied to southern California. Gen. Tech. Rep. PSW-45. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 33 p.

515. Pequegnat, Willis E. The biota of the Santa Ana Mountains. Journal of Entomology and Zoology 42(3/4):1-84; 1951.

516. Peri, David W. Pomoan plant resource management. Ridge Review 4(4):5-9; 1985 winter.

517. Perrone, Michael, Jr. Thirty-fourth breeding bird census, 17: deciduous oak woodland. Audubon Field Notes 24(6):749-751; 1970 Dec.

518. Perrone, M.; Remsen, V. Twenty-third winter bird population study: deciduous oak woodland. Audubon Field Notes 24(3):554-555: 1970 Jun.

519. Pfeiffer, J.R. Western hardwoods—a promising industry. National Hardwood Magazine 27:43-45; 1953a Mar.

520. Pfeiffer, J.R. Basic data for Oregon hardwoods. Rep. G-2. Corvallis, OR: Oregon Forest Prod. Lab. 1953b. 40 p.

521. Phillips, Edwin A.; Page, Kaaren K.; Knapp, Sandra D. Vegetational characteristics of two stands of Joshua Tree woodland. Madrono 27(1):43-47; 1980 Jan.

522. Piekielek, William; Burton, Timothy S. A black bear population study in northern California. California Fish and Game 61(1):4-25; 1975 Jan.

523. Pillsbury, N.H. Hardwood stand density characteristics for central coast counties of California. Salinas, CA: U.S. Department of Agriculture, Soil Conservation Service, Cent. Coast Resource Conservation and Development Area; 1978. 32 p.

524. Pillsbury, N.H. Inventory and quantification of Coast Range hardwood resources in California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 92-100.

525. Pillsbury, Norman H.; Brockhaus, John A. Tree photo volume and weight tables for California's central coast. Central Coast Res. Conser. and Develop. Area, Salinas, CA. 1979. 46 p.

526. Pillsbury, Norman H.; Brockhaus, John A. Hardwood biomass inventory maps for California's central coast. Salinas, CA: U.S. Department of Agricuture, Soil Conservation Service, Central Coastal Resource Conservation and Development Project; 1981. 10 p. [5 maps].

527. Pillsbury, Norman H.; Kirkley, Michael L. Hardwood biomass inventories in California. In: Conrad, C. Eugene; and Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service,Pacific Southwest Forest and Range Experiment Station; 1982: 171-178.

528. Pillsbury, Norman H.; Kirkley, Michael L. Equations for total, wood, and saw-log volume for thirteen California hardwoods. Research Note PNW-414. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 52 p.

529. Pillsbury, Norman H.; Stephens, Jeffrey A. Hardwood volume and weight tables for California's central coast. Sacramento, CA: Calif. Department of Forestry; 1978. 54 p.

530. Pillsbury, N.H.; Stephens, J.A.; Jackman, R.; Barrette, B. Weight tables for hardwoods in central coast counties in California. State For. Note 70. Sacramento, CA: Calif. Department of Forestry; 1978. 4 p.

531. Pillsbury, N.H.; Williamson, D.P. The landowners guide to fuelwood marketing opportunities in the central coast. San Francisco, CA: U.S. Department of Agriculture, Forest Service, State and Private Forestry; 1980. 13 p.

532. Pinnock, Dudley E.; Milstead, James E. Biological control of California oakmoth with *Bacillus thuringiensis* on *Quercus agrifolia*. California Agriculture 25(10):3-5; 1971 Oct.

533. Pitt, M.D.; Burgy, R.H.; Heady, H.F. Influence of brush conversion and weather patterns on runoff from a northern California watershed. Journal of Range Management 31(1):23-27; 1978.

534. Plumb, Timothy R. Delayed sprouting of scrub oak after a fire. For. Serv. Res. Note PSW-1. Berkeley, CA: U.S., Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1963. 4 p.

535. Plumb, Timothy R. Broadcast applications of herbicides to control scrub oak regrowth. Res. Note PSW-261. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1971. 4 p.

536. Plumb, Timothy R. Response of oaks to fire. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 202-215.

537. Plumb, Timothy R. Collecting, storing, and germinating acorns of southwestern oaks. In: Johnson, Paul S.; Garrett, H.E., comp. Workshop on seedling physiology and growth in oak planting, 1979 Nov. 6-7, Gen. Tech. Rep. NC-62. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981: 10.

538. Plumb, Timothy R. Factors affecting germination of southern California oaks. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosytems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 625.

539. Plumb, Timothy R; Gomez, A.P. Five southern California oaks: identification and postfire management. Gen. Tech. Rep. PSW-71. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1983. 56 p.

540. Plumb, T.R.; Goodin, J.R. Control of California's scrub oak with soil- applied chemicals. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on the dynamics and management of Mediterranean-type ecosytems, 1981 June 22-26, San Diego, Ca. Gen Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 628.

541. Plumb, Timothy R.; McDonald, Philip M. Oak management in California. Gen. Tech. Rep. PSW-54. Berkley, CA: U.S. Department of Agricuture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1981. 11 p.

542. Polcyn, David M. Competition and spacing in a pure stand of *Quercus agrifolia*. Bulletin of the Ecological Society of America 64(2):192; 1983 summer [abstract].

543. Potter, Donald; Johnston, Barbara. An approach to managing California black oak and hardwoods on a deer winter range in central California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 112-116.

544. Powers, Robert F. Site index curves for unmanaged stands of California black oak. Res. Note PSW-262. Berkeley, CA: U.S, Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1972. 5 p.

545. Pritchard, A.E.; Beer, R.E. Biology and control of Asterolecanium scales on oaks in California. Journal of Economic Entomology 43(4):494-497; 1950 Aug.

546. Pugh, W.A. Twentieth breeding bird census. 34: Sycamore-live oak dry wash. Audubon Field Notes 10(6):433-434; 1956 Dec.

547. Pugh, W.A. Twenty-fifth breeding bird census. 10: Oak wooded canyon. Audubon Field Notes 15(6):505-506; 1961 Dec.

548. Puttick, G.M. A comparison of two California oak species as food for the California oak moth *Phryganidia californica*. In: Leviton, A.E.; Aldridge, M.L.; Berson, M. eds. Proc. 63rd Annual Meet. AAAS, 1982 Jun. 20-25 Santa Barbara, CA. San Francisco, CA: Pac. Div. AAAS. 1982; 43. [abstract].

549. Raabe, Robert D. Plants resistant or susceptible to *Armillaria* root rot. Agric. Sci. Leafl. 2591. Berkeley, CA: University of California; 1975. 11 p.

550. Raabe, Robert D. Diseases of oaks in California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 195-201.

551. Radtke, Leonard B. Notes on the mast trees of the Hoopa. 1939. 14 p. [unpublished manuscript].

552. Raguse, Charles, A.; Hull, John L.; Jones, Milton B. [and others]. Range fertilization in the Sierra Nevada foothills. California Agriculture 38(5/6):4-6; 1984 May-Jun.

553. Remsen, J.V., Jr.; Cardiff, Steven. First records of race *scottii* of the Rufous-crowned sparrow in California. Western Birds 10(1):45-46; 1979.

554. Renny, Kenneth Michael. The Miocene Temblor flora of west central California. Davis, CA: University of California; 1972. 106 p. Thesis.

555. Resch, Helmuth. Steam bending characteristics of five California hardwoods. California Forestry and Forest Products 37: Berkeley, CA: University of California; 1964. 5 p.

556. Riggan, Philip J.; Dunn, Paul H. Harvesting chaparral biomass for energy —an environmental assessment. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Depatment of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1982: 149-157.

557. Riggan, Philip J.; Lopez, Ernst. Nitrogen relations in a *Quercus dumosa* chaparral community. In: Conrad, C. Eugene; Oechel, Walter C., tech. coord. Proceedings of the symposium on the dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 1982: 631.

558. Rilla, E.; Smith, R.; Altair, Z.; Van Soelen, P. [and others]. Acorn to oak: the care, protection, and planting of our living heritage. Windsor, CA: Environmental Restoration Center; 1979. 24 p.

559. Ritter, William Emerson. The California woodpecker and I. Berkeley, CA: University of California Press; 1938. 340 p.

560. Roberts, N.C. Important riparian/wetland systems of peninsular Baja California: an overview. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19, Davis, CA. Berkeley, CA: University of California Press; 1984: 356-374.

561. Roberts, Robert C. Ecological relationships in the acorn woodpecker (*Melanerpes formicivorus*). Davis, CA: University of California; 1976. 100 p. Dissertation.

562. Roberts, Robert C. Habitat and resource relationships in acorn woodpeckers. The Condor 81(1):1-8; 1979 Feb.

563. Roberts, Stephen, W. Some recent aspects and problems of chaparral plant water relations. In: Conrad, C. Eugene; Oechel, Walter, C., tech. coords. Proceedings of the symposium on the dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen. Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Pacific Southwest Forest and Range Experiment Station; 1982: 351-357.

564. Roberts, Stephen W.; Smith, Robin L. Aspects of water relations in coast live oaks and valley oaks subjected to root damage from land development operations. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW- 44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 171-175.

565. Roberts, S.W.; Miller, P.C.; Valamanesh, A. Comparative field water relations of four co-occurring chaparral shrub species. Oecologia 483(3):360-363. 1981.

566. Roberts, T.A.; Smith, C.H. Growth and survival of black oak seedlings under different germination, watering, and planting regimes. Tree Planters Notes 33(4):10-12; 1982.

567. Roberts, Warren G. California's oaks in the University of California Arboretum, Davis. Fremontia 11(3):13-18; 1983 Oct.

568. Roberts, Warren G.; Howe, J. Gregg; Major, Jack. A survey of riparian forest flora and fauna in California. In: Sands, Anne, ed. Symposium on riparian forests in California, their ecology and conservation, 1977 May 14, Davis, CA. Inst. Ecol. Publ. 15. Davis, CA: University of California; 1977: 3-19.

569. Robertson, J.L. Toxicity of Zectran aerosol to the California oakworm, a primary parasite, and a hyperparasite. Environmental Entomolology 1(1):115-117; 1972.

570. Robichaux, Robert. Geologic history of the riparian forest of California. In: Sands, Anne, ed. Symposium on riparian forests, their ecology, and conservation, 1977 May 14, Davis, CA. Inst. Ecol. Publ. 15. Davis, CA: University of California; 1977: 21-34.
571. Robinson, C.S. Plants eaten by California mule deer on the Los Padres National Forest. Journal of Forestry 35(3):285-292; 1937 Mar.
572. Roeper, R.A.; French, J.R. Observations on *Monarthrum dentiger* (Coleoptera: Scolytidae) and its primary symbiotic fungus in California. Pan-Pacific Entomology 54(1):68-69; 1978.
573. Rogers, Paul A. Measures that can help offset the detrimental effects that urban development has on oak trees. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980:167-170.
574. Root, Richard B. The avian response to a population outbreak of the tent caterpillar, *Malacosoma constrictum* (Stretch). Pan-Pacific Entomologist 42(1):48-53; 1966 Jan.
575. Root, Richard B. The niche exploitation pattern of the blue-gray gnatcatcher. Ecologoical Monographs 37(4):317-350; 1967 fall.
576. Rosenthal, Sara S. Biology and host relations of some Cynipidae forming galls on Quercus. Berkeley, CA: University of California; 1968. 78 p. Dissertation.
577. Rosenthal, S.S.; Koehler, C.S. Intertree distributions of some Cynipid (Hymenoptera) galls on *Quercus lobata*. Annals of the Entomological Society of America 64(3):571-574; 1971 May.
578. Ross, Lisa J.; Nash, Thomas, H., 111. Urban impacts on a coastal lichen community. Bulletin of the Ecological Society of America 62(2):161-162; 1981 summer [abstract].
579. Rossi, Randall S. Land use and vegetation change in the oak woodland- savanna of northern San Luis Obispo County, California. Berkeley, CA: University of California; 1979. 337 p. Dissertation.
580. Rossi, Randall S. History of cultural influences on the distribution and reproduction of oaks in California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks. 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 7-18.
581. Rowe, P.B. Streamflow increases after removing woodland-riparian vegetation from a southern California watershed. Journal of Forestry 61(5):365-370; 1963 May.
582. Rowlee, W.W.; Nicols, Susie P. The taxonomic value of the staminate flowers of some oaks. Botanical Gazette 29(5):353-356; 1900 May.
583. Roy, Douglass F. Hardwood sprout measurements in northwestern California. Res. Note 95. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1955. 6 p.
584. Roy, Douglass F. California hardwoods: management practices and problems. Journal of Forestry 60(3):184-186; 1962 Mar.
585. Rundel, Philip W. Adaptations of Mediterranean-climate oaks to environmental stress. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; 1980: 43-54.
586. Russo, Ronald A. Gall wasp nurseries. Pacific Discovery 28(6):25-31; 1975 Nov.-Dec.
587. Russo, Ronald A. Plant galls of the California region. Pacific Grove, CA: Boxwood Press; 1979. 203 p.
588. Russo, Ronald A. Galls—surreal ornaments on blue oaks. Fremontia 11(3): 19-22; 1983 Oct.
589. Sacramento County, Office of Education. Native oaks our valley heritage, a guide to the botany, care, and planting of native oaks in the Sacramento Valley. Sacramento, CA: Sacramento County; 1976. 60 p.
590. Saenz, Loretta. *Quercus garryana* woodland/grassland mosaic dynamics in northern California. Arcata, CA: Humboldt State University; 1983. 71 Thesis.
591. Sampson, Arthur W.; Jespersen, Beryl S. California range brushlands and browse plants. Man. 33, Berkeley, CA: University of California, Agric. Exp. Stn.; 1963. 162 p.
592. Sampson, A.W.; Samisch, R. Growth and seasonal changes in composition of oak leaves. Plant Physiology 10(4):739-751; 1935 Oct.
593. Santamour, F.S., Jr. Cambial peroxidase patterns in *Quercus* related to taxonomic classifcation and graft compatibility. Bulletin of the Torrey Botanical Club 110:280-286; 1983 Jul.-Sep.
594. Sargent, C.S. Notes on North American trees. I: Quercus. Botanical Gazatte 65(5):423-459. 1918 May.
595. Sauerwein, William J. Oregon white oak. Woodland Series No. 14 [Technical note]. Washington, DC: U.S. Department of Agriculture. Soil Conservation Service; 1983. 6 p.
596. Sawyer, J.O.; Thornburgh, D.A.; Griffin, J.R. Mixed evergreen forest. In: Barbour, Michael G.; Major, Jack, eds. Terrestrial vegetation of California. New York: Wiley-Interscience; 1977: 359-381.
597. Sax, Hally Jolivette. Chromosome numbers in *Quercus*. Journal of the Arnold Arboretum 11(4):220-223; 1930.
598. Scheidlinger, Carla; Zedler, Paul H. Change in vegetative cover of oak stands in southern San Diego County: 1928-1970. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 81-85.
599. Schettler, Suzanne; Smith, Michael N. Nursery propaga-

tion of California oaks. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, managment, and utilization of California oaks, 1979 June 26-28, 1979, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 143-148.

600. Schitoskey, Frank, Jr.; Woodmansee, Sarah R. Energy requirements and diet of California ground squirrels. Journal of Wildlife Management 42(2):373-382; 1978.

601. Schniewind, A.P. The strength and related properties of California black oak. I: General description and strength properties in the green condition. California Forestry and Forest Products 6. Berkeley, CA: University of California; 1958. 4 p.

602. Schniewind, A.P. Transverse anisotropy of wood: a function of gross anatomic structure. Forest Products Journal 9(10):350-359; 1959 Oct.

603. Schniewind, A.P. The strength and related properties of California black oak. II: Shrinkage and strength properties in the air-dry condition. California Forestry and Forest Products 21. Berkeley, CA: University of California; 1960. 3 p.

604. Schniewind, A.P. Tensile strength perpendicular to grain as a function of moisture content in California black oak. Forest Products Journal 12(5):249-252; 1962 May.

605. Schniewind, A.P.; Bryan, E.L. Some strength and related properties of California white oak. California Forestry and Forest Products 13. Berkeley, CA: University of California; 1959. 6 p.

606. Schniewind, A.P.; Kersavage, P.C. A quantitative evaluation of second order drying stresses. Forest Products Journal 11(11):523-530; 1961 Nov.

607. Schniewind, A.P.; Kersavage, P.C. Influence of rate of drying and rewetting on the dimensional changes of California black oak. Forest Products Journal 12(1):29-33; 1962 Jan.

608. Schwarz, O. Entwurf zu einem naturlichen System der Cupuliferen und der Gattung *Quercus* L. Notizbl. Bot. Gart. Mus. Berlin-Dahl. 13:1-22; 1936.

609. Sharp, Ward M.; Chisman, Henry H. Flowering and fruiting in the white oaks. I: Staminate flowering through pollen dispersal. Ecology 42(2):365-372; 1961 Apr.

610. Sharp, Ward M.; Sprague, Vance G. Flowering and fruiting in the white oaks. Pistillate flowering, acorn development, weather, and yields. Ecology 48(2): 243-251; 1967 early spring.

611. Shields, Paul W.; Duncan, Don A. Fall and winter food of California quail in dry years. California Fish and Game 52(4):275-282; 1966 Oct.

612. Sidahmed, A.E.; Morris, J.G.; Radosevich, S.R. Summer diet of Spanish goats grazing chaparral. Journal of Range Management 34(1)33-35; 1981.

613. Sidahmed, Ahmed E.; Radosevich, Steven R.; Morris, James G.; Koong, Ling J. Nutritive value of chaparral for goats grazing in fuel breaks. California Agriculture 361(5-6):12-14; 1982 May-Jun.

614. Sidahmed, A.E.; Morris, J.G.; Radosevich, S.R.; Koong, L.J. Seasonal changes in composition and intake of chaparral by Spanish goats. Animal Feed Science Technology 8(1):47-62; 1983.

615. Siemens, Larry A. A survey of the montane forest of the Preston Peak study area, Siskiyou County, California. Angwin, CA: Pacific Union College; 1972. 196 p. Thesis.

616. Siegmund, Otto H., ed. The merck veterinary manual. Rathway, NJ: Merck and Co.; 1979. 1680 p.

617. Silene, Roy R. Silvical characteristics of Oregon white oak. Silvical Ser. 10. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1958. 13 p.

618. Skiles, D.D.; Hovore, F.T.; Giesbert, E.F. Biology of *Leptura pacifica* Linsley (Coleoptera: Cerambycidae). Coleopterists Bulletin 32(2):107-112; 1978.

619. Skinner, H.T. Vegetative propagation of oaks and suggested research techniques. Proceedings of the International Plant Propagators Society 2:81-88; 1952.

620. Smiley, C.J. The Ellensburg flora of Washington. University of California Publications in Geological Science 35:157-275; 1963.

621. Smith, Gladys L. Supplement to a flora of the Tahoe Basin and neighboring areas. Wasmann Journal of Biology 41(1-2):1-46; 1984 spring-fall.

622. Smith, Harvey H. Seasoning California black oak. Res. Note 62. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1949. 8 p.

623. Smith, Harvey H. Further experiments in seasoning California black oak. Res. Note 75. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1950. 8 p.

624. Smith, Harvey H. Utilization of western hardwoods. Journal of the Forest Products Society 2(3):52-54; 1952 Sep.

625. Smith, Harvey H. Improved utilization of western hardwoods by modern drying. Forest Products Journal 6(3):121-124; 1956 Mar.

626. Smith, Harvey H. Recommendations for drying California black oak. Tech. Pap. 62. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1961. 19 p.

627. Smith, Walton A. The band-tailed pigeon in California. California Fish and Game 54(1):4-16; 1968 Jan.

628. Smith, Walton A.; Browning, Bruce. Wild turkey food habits in San Luis Obispo County, California. California Fish and Game 53(4):246-253; 1967 Oct.

629. Snell, J.A.K. Preliminary crown weight estimates for tanoak, black oak, and Pacific madrone. Res. Note PNW-340. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1979. 4 p.

630. Snow, Gerald Eldon. Some factors controlling the establishment and distribution of *Quercus agrifolia* Nee and *Q. engelmannii* Greene in certain southern California oak woodlands. Corvallis, OR: Oregon State University;

1972. 150 p. Dissertation.
631. Snow, Gerald E. The fire resistance of Engelmann and coast live oak seedlings. In: Plumb, Timothy, R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station; 1980: 62-66.
632. Spenser, John V.; Joiner, Charles C. Commerical firewood harvesting study, Boggs Mountain State Forest. State Forest Notes No. 76. Sacramento, CA: California Department of Foresty; 1979. 4 p.
633. Stairs, G.R. Microsporogenesis and embryogenesis in *Quercus*. Botanical Gazette 125(2):115-121; 1964 Jun.
634. Stark, N. Natural regeneration of Sierra Nevada mixed conifers after logging. Journal of Forestry 63(6):456-461; 1965 Jun.
635. Stark, N. Seed ecology of *Sequoiadendron giganteum*. Madrono 19(7):267-276; 1968 Jul.
636. Stein, William I. Oregon white oak. In: Eyre, F.H., ed. Forest cover types of the United States and Canada. Washington, DC: Soc. Am. Foresters; 1980: 110-111.
637. Steinhart, Peter. As the old oaks fall. Audubon 80(5):30-40; 1978 Sep.
638. Stern, George E. Performance of warehouse and exchange pallets made of six western woods. Rep. 156. Blacksburg, VA: Virginia Polytechnic Institute and State University, Wood Research and Wood Construction Laboratory; 1978. 48 p.
639. Stern, Kingsley R. Note on damage to the Hooker oak. Madrono 17(4): 143-144; 1963 Oct.
640. Stern, Kingsley R. The passing of the Hooker Oak. Fremontia 5(3):12-13; 1977 Oct.
641. Stienecker, Walter E. Supplemental data on the food habits of the western gray squirrel. California Fish and Game 63(1):11-21; 1977 Jan.
642. Stienecker, W.; Browning, B.M. Food habits of the western gray squirrel. California Fish and Game 56(1):36-48; 1970 Jan.
643. Stine, Raymond. Economics of utilizing oak for energy. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilizataion of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Service; 1980: 345-353.
644. Stolte, Kenneth Warren. The effects of ozone on chaparral plants in the California south coast air basin. Riverside, CA: University of California; 1982. 99 p. Thesis.
645. Storer, Tracy I.; Tevis, Lloyd P., Jr. California grizzly. Berkeley, CA: University of California Press; 1955. 335 p.
646. Strahan, Jan. Regeneration of riparian forests of the Central Valley. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19; Davis, CA. Berkeley, CA: University of California Press; 1984: 58-67.
647. Sudworth, George B. A new California oak (*Quercus pricei*). Forestry and Irrigation. 13:157-158; 1907 Mar.
648. Sudworth, George B. Forest trees of the Pacific slope. Washington, DC., U.S. Department of Agriculture; 1908. 441 p.
649. Sugihara, N.G.; Hektner, M.M.; Reed, L.J.; Lenihan, J.M. Oregon white oak woodlands of Redwood National Park: description and management considerations. In: Van Riper, C., III; Whittig, L.D.; Murphy, M. L., eds. Proceedings of the first biennial conference of research in California's National Parks, Sep. 9-10, 1982, Davis, CA. Davis, CA: University of California, Cooperative Park Studies Unit; 1983: 177-182.
650. Sundahl, William E. Crown and tree weights of madrone, black oak, and tanoak. Res. Note PSW-101. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1966. 4 p.
651. Sutton, D.D.; Mogenson, H.L. Systematic implications of leaf primordia in the mature embryo of Quercus. Phytomorphology 20(1):88-91; 1970 Mar.
652. Syvertsen, James P. Relative stem water potentials of three woody perennials in a southern oak woodland community. Bulletin of the Southern California Academy of Sciences 73(2):108-113; 1974 Aug.
653. Sweet, Muriel. Common edible and useful plants of the West. Healdsburg, CA.: Naturegraph Co.; 1962. 64 p.
654. Swersky, Karen. Valley oaks: an ecological approach to habitat restoration. Long Beach, CA: California State University,. 1985. 73 p. Thesis.
655. Taber, R.D.; Dasmann, R.F. The black-tailed deer of the chaparral. Bull. 8, California Dept. Fish Game; 1958. 163 p.
656. Talbot, M.W.; Biswell, H.H. The forage crop and its management. Bull. 663. In: [no ed.] San Joaquin Experimental Range. Berkeley, CA: University of California, Agricultural Experiment Station, 1942: 13-49.
657. Talley, Steven Neal. The ecology of Santa Lucia fir (*Abies bracteata*), a narrow endemic of California. Durham, NC: Duke University; 1974. 209 p. Dissertation.
658. Tangren, Gerald. Thirty-fifth breeding bird census. 6: Riparian oak woodland. American Birds 25(6):967-969; 1971 Dec.
659. Tappeiner, John; McDonald, Philip. Preliminary recommendations for managing California black oak in the Sierra Nevada. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 107-111.
660. Thomas, Donald. Hybridization and interpopulation variation in the California live oaks, *Quercus agrifolia* and *Quercus wislizenii*. Santa Cruz, CA: University of Cal-

ifornia; 1970. 40 p. Senior thesis.

661. Thomas, John Hunter. Flora of the Santa Cruz Mountains of California, a manual of the vascular plants. Stanford, CA: Stanford Univ. Press; 1961. 434 p.

662. Thomas, W.D. Characterisitics of root systems: California oaks. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 178-179.

663. Thomas, W.D.; Boza, C.A. Pathogens associated with the oak decline complex. Phytopathology 73(6):963; 1983 Jun.

664. Thompson, Kenneth. Riparian forests of the Sacramento Valley, California. Annals of the Assocation of American Geographers 51(3):294-315; 1961 Sep.

665. Thomson, Vivian E.; Mahall, Bruce E. Host specificity by a mistletoe, *Phoradendron villosum* (Nutt.) Nutt. subsp. *villosum*, on three oak species in California. Botanical Gazette 144(1):124-131; 1983 Mar.

666. Thorne, Robert F. The vascular plant communities of California. In: Latting, June, ed. Plant communities of southern California. Spec. Publ. 2. Berkeley, CA: California Native Plant Society 1976: 1-32.

667. Thorne, Robert F. The desert and other transmontane plant communities of southern California. Aliso 10(2):219-257; 1982.

668. Thorne, Robert F.; Prigge, Barry A.; Henrickson, James. A flora of the higher ranges and the Kelso dunes of the eastern Mojave Desert in California. Aliso 10(1):71-186; 1981.

669. Tillson, A.H.; Muller, C.H. Anatomical and taxonomic approaches to subgeneric segregation in American *Quercus*. American Journal of Bot. 29(7):523-529; 1942 Jul.

670. Torrey, John. [untitled] In: Sitgreaves, Lorenzo, ed. Report of an expedition down the Zuni and Colorado Rivers. Washington, DC: U.S. Army Corps of Topographic Engineers; 1854; 172 p. [pl. 17].

671. Trelease, William. Naming American hybrid oaks. American Philosphical Society Proceedings 56(1):44-52; 1917.

672. Trelease, William. The ancient oaks of America. Brooklyn Botanical Garden Memoirs. v. 1; 1918.

673. Trelease, William. The American oaks. Memoirs of the National Academy of Science 20:1-255; 1924.

674. Tucker, John M. Interrelationships within the *Quercus dumosa* complex. Berkeley, CA: University of California; 1950. 129 p. Dissertation.

675. Tucker, John M. Taxonomic interrelationships in the *Quercus dumosa* complex. Madrono 11(6):234-251; 1952a Apr.

676. Tucker, John M. Evolution of the Californian oak *Quercus alvordiana*. Evolution 6(2):162-180; 1952b Jun.

677. Tucker, John M. The relationship between *Quercus dumosa* and *Quercus turbinella*. Madrono 12(2):49-60; 1953a Apr.

678. Tucker, John M. Two new oak hybrids from California. Madrono 12(4): 119-127; 1953b Oct.

679. Tucker, John M. Western oaks for western horticulture. University of Washington Arboretum Bulletin 21(21):74-79; 1958.

680. Tucker, John M. A review of hybridization in North American oaks. Proceedings of the Ninth International Botanical Congrress II: 404- 405. 1959.

681. Tucker, John M. Identity of the oak tree at Live Oak Tank, Joshua Tree National Monument, California. Madrono 19(7):256-266; 1968 Jul.

682. Tucker, John M. Hermaphroditic flowers in California oaks. Madrono 21(7): 482-486; 1972 Jul.

683. Tucker, John M. Patterns of parallel evolution of leaf form in new world oaks. Taxon 23(1):129-154; 1974.

684. Tucker, John M. Taxonomy of California oaks. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 19-29.

685. Tucker, John M. California's native oaks. Fremontia 11(3):3-12; 1983 Oct.

686. Tucker, J.M.; Haskell, H.S. *Quercus dunnii* and *Q. chrysolepis* in Arizona. Brittonia 12(3):196-219; 1960 Jul.

687. Tucker, J.M.; Holstein, G.L.; Stout, H. [and others]. Another range extension for *Quercus dunnii* in central California. Aliso 10(2): 321-328; 1982.

688. Tucker, J.M.; Neilson, R.P.; Wullstein, L.H. Hermaphroditic flowering in Gambel oak. American Journal of Botany 67(8):1265-1267; 1980.

689. Tunison, J.T. A synecological study of the oak-dominated communities of Bennett Mountain, Sonoma County, California. Rohnert Park, CA: Sonoma State College; 1973. 143 p. Thesis.

690. Turkel, H.S.; Rebuck, A.L.; Grove, A.R., Jr. Floral morphology of white oak. Bull. 593. University Park, PA: Penn. State Univ. Agric. Exp. Stn., Bul.; 1955 14 p.

691. Twisselmann, Ernest C. A flora of the Temblor Range and neighboring part of the San Joaquin Valley. The Wasmann Journal of Biology 14(2):161-300; 1956 fall.

692. Twisselmann, Ernest C. A flora of Kern County, California. The Wasmann Journal of Biology 25(1,2):1-395; 1967 spring and fall.

693. U.S. Department of Agriculture, Forest Service. Forest statistics for California. For. Surv. Rel. 25. Berkeley, CA: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1954. 66 p.

694. U.S. Department of Agriculture, Forest Service. Wood handbook. Handb. 72. Washington, DC: U.S. Department of Agriculture; 1955. 528 p.

695. U.S. Department of Agriculture, Forest Service. What's wrong with my trees? Oaks and laurels in California hard hit by leaf diseases. Misc. Pap. 26. Berkeley, CA: U.S.

Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1958. 2 p.

696. U.S. Department of Agrculture, Forest Service. Timber trends in the United States. For. Resour. Rep. 17. Washington DC: U.S. Department of Agriculture; 1965. 235 p.

697. Vancouver, George. A voyage of discovery to the north Pacific Ocean, and around the world; . . . performed in the years 1790-1795. 3 v. London: G.G. and J. Robinson and J. Edwards; 1798. v. 1.

698. Van Dyne, G.M.; Heady, H.F. Botanical composition of sheep and cattle diets on a mature annual range. Hilgardia 36(13):465-492; 1965.

699. Vankat, John L. A gradient perspective on the vegetation of Sequoia National Park, California. Madrono 29(3):200-214; 1982 Jul.

700. Vankat, John L.; Major, Jack. Vegetation changes in Sequoia National Park, California. Journal of Biogeography 5(4):377-402; 1978 Dec.

701. Van Valen, Leigh. Ecological species, multispecies, and oaks. Taxon 25(2/3):233-236; 1976 May.

702. Vasek, Frank C. Jeffrey pine and vegetation of the southern Modoc National Forest. Madrono 25(1):9-30; 1978 Jan.

703. Vasey, Michael C. Natural hybridization between two evergreen black oaks in the north central Coast Ranges of California. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, mangement, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 30-35.

704. Vaux, H.J. What's happening in California forestry. In [no ed.]: Ext. Forestry Conf. on Hardwoods. Berkeley, CA: University of California, Agric. Ext. Serv. 1961. 6 p.

705. Verner, Jared. Birds of California oak habitats—management implications. In: Plumb, Timothy R., tech. coord. Proceedings of the symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest, Service, Pacific Southwest Forest and Range Experiment Station; 1980: 246-264.

706. Verner, Jared; Boss, A.S. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980. 439 p.

707. Verner, Jared; Ritter, Lyman V. A comparison of transects and point counts in oak-pine woodlands of California. The Condor 87(1):47-68; 1985 Feb.

708. Vogl, Richard J.; Miller, Brian C. The vegetational composition of the south slope of Mt. Pinos, California. Madrono 19(7):225-234; 1968 Jul.

709. Volney, W. Jan A.; Koehler, Carlton S.; Browne, Lloyd E. [and others]. Sampling for California oakworm on landscape oaks. California Agriculture 37(9,10):8-9; 1983a Sep.-Oct.

710. Volney, W.J.A.; Milstead, J.E.; Lewis, V.R. Effect of food quality, larval density, and photoperiod on the feeding rate of the California oakworm *Phryganidia californica*. Environmental Entomology 12(3):792-798; 1983b.

711. Wagener, W.W. Judging hazard from native trees in Califoria recreational areas: a guide for professional foresters. Res. Paper PSW-1. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1963. 29 p.

712. Wagner, Judith L. Seasonal change in guild structure: oak woodland insectivorous birds. Ecology 62(4):973-981; 1981 Aug.

713. Wagnon, K.A. Acorns as feed for range cattle. Western Livestock Journal 25(6):92-94; 1946.

714. Wagnon, K.A. Cattle feeding trials with acorns and oak leaves indicate need for supplementing dry range forage. California Agriculture 14(11): 10-11; 1960.

715. Wahlgren, Harold E. Occurrence of tension wood and related seasoning defects in California black oak. For. Prod. Lab. Rep. 2106. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1958. 15 p.

716. Wainio, W.W.; Forbs, E.B. The chemical composition of forest fruits and nuts from Pennsylvania. Journal of Agricultural Research 62(10):627- 635; 1941.

717. Wainwright, Thomas C.; Barbour, Michael G. Characteristics of mixed evergreen forest in the Sonoma Mountains of California. Madrono 31(4):219-230; 1984 Oct.

718. Wakimoto, Ronald Haruto. Response of southern California brushland vegetation to fuel manipulation. Berkeley, CA: University of California; 1978. 265 p. Dissertation.

719. Wallace, A.; Jones, M.; Alexander, G.V. Mineral composition of native woody plants growing on a serpentine soil in California USA. Soil Science 134(1):42-44; 1982.

720. Walsh, J.G. Report on the distribution and status of Quercus lobata groves in California which may support an ecotype of *Satyrium californicum*. Atala 5(1):7-12; 1977.

721. Ward, James C.; Shedd, Dell. California black oak drying problems and the bacterial factor. Res. Pap. FPL-344. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1979. 14 p.

722. Waring, R.H. Forest plants of the eastern Siskiyous: their. environment and vegetational distribution. Northwest Science 43(1):1-17; 1969.

723. Waring, R.H.; Emmingham, W.H.; Gholz, H.L.; Grier, C.C. Variation in maximum leaf area of coniferous forests in Oregon and its ecological significance. Forest Science 24(1):131-140; 1978 Mar.

724. Waring, R.H.; Major, J. Some vegetation of the California coastal redwood region in relation to gradients of moisture, nutrients, and temperature. Ecological Monogrographs 34(2):167-215; 1964 spring.

725. Warner, R.E. Structural, floristic and condition inventory of Central Valley riparian systems. In: Warner, R.E.; Hendrix, K.M., eds. Proceedings of the symposium on

California riparian systems: ecology, conservation, and productive management, 1981 Sep. 17-19, Davis, CA. Berkeley, CA: University of California Press; 1984: 356-374.

726. Warren, L.E. Control of tanoak and associated species with cut surface treatments of GARLON 3A herbicide. Down to Earth 36(2):8-13; 1980a winter.

727. Warren, L.E. Control of sprouting hardwoods with basal applications of GARLON 4 herbicide. Down to Earth 37(1):22-27; 1980b fall.

728. Warter, Janet K. Late Pleistocene plant communities—evidence from the Rancho La Brea tar pits. In: Latting, June, ed. Symposium proceedings: Plant communities of southern California, 1974 May 4, Fullerton, CA. Spec. Publ. 2. Berkeley, CA: California Native Plant Society; 1976: 32-39.

729. Washburn, Jan O. Mutualism between a cynipid gall wasp and ants. Ecology 65(2):654-659. 1984 Apr.

730. Weaver, George T.; Jones, Jon D. Modifications of chemical contents of precipitation by passage through oak forests. In: Miller, Paul R., ed. Proceedings of the symposium on the effects of air pollutants on Mediterranean and temperate forest ecosystems, 1980 June 22-27, Riverside, CA. Gen. Tech. Rep. PSW-43. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 254-255.

731. Weld, Lewis H. Cynipid galls of the Pacific slope. Ann Arbor, MI: [privately printed]; 1957. 64 p. [illus].

732. Wells, Philip V. Vegetation in relation to geological substratum and fire in the San Luis Obispo quadrangle, California. Ecological Monographs 32(1):79-103; 1962 winter.

733. White, Keith L. Structure and composition of foothill woodland in central coastal California. Ecology 47(2):229-237; 1966 early spring.

734. White, Raymond C. Luiseno social organization. University of California Publications in American Archaeology and Ethnology 48(2):1-194; 1963.

735. Whittaker, R.H. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30(3):279-338; 1960 Jul.

736. Wickman, Boyd E. California oakworm. Forest Pest Leaflet 72. Washington, DC: U.S. Department of Agriculture; 1962. 4 p.

737. Wien, D. Revision of the acataphyllous species of Phoradendron. Brittonia 16(1):11-54; 1964 Jan.

738. Wieslander, A.E. Vegetation types of California, Elsinore quadrangle (176). San Francisco, CA: U.S. Department of Agriculture, Forest Service; 1938 [map].

739. Williams, Pamela L. Forty-third breeding bird census. 104: Deciduous oak woodland. American Birds 33(1):82-83; 1979a Jan.

740. Williams, Pamela L. Thirty-second winter bird population study. 30: Deciduous oak woodland. American Birds 34(1):33. 1979b Jan.

741. Williams, Pamela L. Thirty-second winter bird population study. 42: Mixed habitat: riparian woodland and adjacent oak savanna. American Birds 34:35-36; 1980a Jan.

742. Williams, Pamela L. Forty-fourth breeding bird census. 133: Riparian woodland and oak savanna. American Birds 34(1):77; 1980b Jan.

743. Williams, Simon. Secondary vascular tissues of the oaks indigenous to the United States. I: The importance of secondary xylem in delimiting *Erythrobalanus* and *Leucobalanus*. Bulletin of the Torrey Botanical Club 66(6):353-365; 1939 Jun.

744. Williams, Simon. Secondary vascular tissues of the oaks indigenous to the United States. II. Types of tyloses and their distribution in *Erythrobalanus* and *Leucobalanus*. Bulletin of the Torrey Botanical Club 69(1):1-10; 1942a Jan.

745. Williams, Simon. Secondary vascular tissues of the oaks indigenous to the United States. III. A comparative study of the wood of *Leucobalanus* and *Erythrobalanus*. Bulletin of the Torrey Botanical Club 69(2): 115-129; 1942b Feb.

746. Williamson, M.J. Premature abscissions and white oak acorn crops. Forest Science 12(1):19-21; 1966.

747. Wilson, A.D.; Weir, W.C.; Torell, D.T. Evaluation of chamise and interior live oak as feed for sheep. Journal of Animal Science 32(5):1042-1045; 1971 May.

748. Winner, W.E. The effect of SO2 on photosynthesis and stomatal behavior of mediterranean climate shrubs and trees. In: Margaris, N.S.; Mooney, H.A., eds. Components of productivity of Mediterranean-climate regions, basic and applied aspects. The Hague, Netherlands: W. Junk; 1981: 91-103.

749. Winner, W.E.; Kock, G.W.; Mooney, H. A. Ecology of sulphur dioxide resistance, 4: Predicting metabolic responses of fumigated shrubs and trees. Oecologia 52(1):16-21; 1982.

750. Winston, Paul W. The acorn microsere, with special reference to arthropods. Ecology 37:(1)120-132; 1956 Jan.

751. Wolf, Carl B. California plant notes. II: X Quercus morehus. Occas. Pap. 1(2), Santa Ana Canyon, CA: Rancho Santa Ana Botanic Garden; 1938. 47-52.

752. Wolf, Carl B. *Quercus agrifolia* Coast live oak. Leaflets of popular information 39. Santa Ana Canyon, CA: Rancho Santa Ana Botanic Garden; 1941a. 2 p.

753. Wolf, Carl B. *Quercus lobata* Roble or valley oak. Leaflets of popular information 42. Santa Ana Canyon, CA: Rancho Santa Ana Botanic Garden; 1941b. 2 p.

754. Wolf, Carl B. The Gander oak, a new hybrid oak from San Diego County, California. 4th series. Proceedings of the California Academy of Sciences 25(5):177-187; 1944 Jun.

755. Wolf, Carl B. California wild tree crops. Santa Ana Canyon, CA: Rancho Santa Ana Botanical Garden; 1945. 68 p.

756. Wolfe, Jack A. Neogene floristic and vegetational history of the Pacific Northwest. Madrono 20(3):1-83; 1969 Jul.

757. Wolfe, Jack A. Neogene history of the California oaks. In: Plumb, Timothy R., tech. coord. Proceedings of the

symposium on the ecology, management, and utilization of California oaks, 1979 June 26-28, Claremont, CA. Gen. Tech. Rep. PSW-44. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; 1980: 3-6.

758. Wolgast, Leonard J.; Stout, Benjamin B. The effects of relative humidity at the time of flowering on fruit set in bear oak (*Quercus ilicifolia*). American Journal of Botany 64(2):159-160; 1977 Feb.

759. Wood, Janet H. Lace lichen: an indicator of air pollution. Fremontia 12(2):21-22; 1984 Jul.

760. Wright, J. W. Summary of tree-breeding experiments by the Northeastern Forest Experiment Station 1947-1950. Station Paper 56. Upper Darby, Pa: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1953. 47 p.

761. Wright, Robert D. Lower elevational limits of montane trees. I. Vegetational and environmental survey in the San Bernardino Mountains of California. Botanical Gazette 127(4):184-193; 1966 Dec.

762. Yocum, L. Edwin. The stomata and transpiration of oaks. Plant Physiology 10(4):795-801; 1935 Oct.

763. Young, Lester C. Pupal parasites of the California oak moth *Phryganidia californica* Packard: a biological and ecological study. Berkeley, CA: University of California; 1977. 126 p. Dissertation.

764. Young, Lester C. Field estimation of the functional response of *Itoplectis californica* parasite of the California oakworm, *Phryganidia californica*. Environmental Entomology 9(5):496-500; 1980.

765. Young, Lester C. Key to the pupal parasites of California oakworm *Phryganidia californica* (Lepidoptera: Dioptidae) based on larval exuviae. Pan-Pacific Entomologist 58(1):42-47; 1982.

766. Zinke, Paul J. Nitrogen storage of several California forest soil- vegetation systems. In: Biology and ecology of nitrogen: proceedings a conference, 1967 Nov. 28 to Dec. 1, Davis, CA. Washington, DC: Natl. Acad. Sci.; 1969: 40-53.

767. Zinke, Paul J. Fertility element storage in chaparral vegetation, leaf litter, and soil. In: Conrad, C. Eugene; Oechel, Walter C., tech. coords. Proceedings of the symposium on dynamics and management of Mediterranean-type ecosystems, 1981 June 22-26, San Diego, CA. Gen Tech. Rep. PSW-58. Berkeley, CA: U.S. Department of Agriculture, Forest, Service, Pacific Southwest Forest and Range Experiment Station; 1982: 297-305.

768. Zuill, Henry. Structure of two cover types of southern oak woodland in California. Loma Linda, CA: Loma Linda Univ.; 1967. 43 p. Thesis.

Griffin, James R.; McDonald, Philip M.; Muick, Pamela C., compilers. **California oaks: a bibliography.** Gen. Tech. Rep. PSW-96. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987. 38 p.

Among natural resource professionals, California oaks continue to attract considerable attention. This report provides a comprehensive bibliography of the extensive but scattered oak literature. The 768 references are organized into two systems: (a) a topical outline, in which references are displayed under key word headings and subheadings, and author-date entries help to locate items by researcher or date; and (b) a *Quercus* species index, in which references contain serial numbers for all species and hybrids.

Retrieval Terms: oaks, bibliography, indexes, *Quercus,* California

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 non-Federal 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 Forest and Range Experiment Station

- Represents the research branch of the Forest Service in California, Hawaii, and the western Pacific.

United States
Department of
Agriculture

Forest Service

**Pacific Southwest
Forest and Range
Experiment Station**

General Technical
Report PSW-97

International Directory of Forestry and Forest Products Libraries

The Compilers:

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Rosa Boianovsky
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Marie van Baer
A. M. E. van der Walt
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It has been a rewarding experience to correspond with all of them, not only for their expertise but for their encouragement. Overall responsibility, however, remains with the compilers and any errors must be attributed to them.

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International Directory of Forestry and Forest Products Libraries

Peter A. Evans Mark A. Arizmendi *Compilers*

CONTENTS

INTRODUCTION

The first edition of this Directory was issued in 1983, in response to the need to manage the information explosion in agriculture and related areas of knowledge, including forestry. That first edition had 273 entries, and was issued by the Pacific Southwest Forest and Range Experiment Station as a non-serial release.[1] Work on that and the current edition was done under a cooperative agreement between the Station and the University of California.

This second edition contains 392 entries—119 more than the first. It was compiled with the assistance of 23 regional editors. We sent questionnaires to all entries listed in the first edition and to other sources suggested by the regional editors.

Most of the libraries listed in this directory fulfill two requirements. First, they are associated with one of the five types of institutions listed below:

1. An academic institution that offers a bachelor's degree (or equivalent) in forestry, wood technology, or a closely related field.
2. An industrial organization where 75 percent or more of the income is derived from forestry or forest products.
3. A government organization where the primary concern is forestry or forest products.
4. An international organization where a major concern is forestry or forest products.
5. Any institution, private or public, where the primary focus of activity (75 percent or more) is directed toward forestry or forest products.

Second, these libraries employ a professional librarian, information specialist, or person with an equivalent level of professional training, whose primary responsibility is the forestry/forest products collection. There are exceptions. In some cases, it has been difficult to tell whether a returned questionnaire identifies a forestry/forest products library that is a distinct entity or whether it refers only to a forestry collection that is a part—and not necessarily the major part—of a more general library. In these cases, we have erred on the side of inclusiveness, assuming that if a librarian responded to the questionnaire, a significant forestry/forest products collection exists at that address. Some well established forestry/forest products libraries are listed from which we have received no response. These were made known to us by regional editors or by reference to secondary sources. There are, unfortunately, no entries from the U.S.S.R. We regret these inconsistencies and shall seek to correct them in future editions.

Any directory is quickly out of date, and one that attempts to be international in scope is rarely, if ever, completely accurate or comprehensive in content. To compensate for these weaknesses, this directory will be updated periodically. Therefore, we will appreciate notification of errors, changes, and recommended additions. If you wish to have a library added to the directory, please supply the complete information necessary for the entry format. (See *Entry Format* section.) Please direct correspondence to:

Peter A. Evans—FORINDOC
Forestry Library
University of California
Berkeley, CA 94720
U.S.A.

[1]Bessenyei, Helvi M.; Evans, Peter A. International directory of forestry and forest products libraries. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1983. 90p.

ENTRY FORMAT

The entries are arranged geographically, first by region (African, Asian-Pacific, European, Latin American, North American), then by country within that region, in some cases by state or province within a country, and finally by city.

Examples:	Asian-Pacific Region	North American Region
	Indonesia	Canada
	Bogor	British Columbia
		Vancouver

In addition to this geographical arrangement, the entries are numbered consecutively from 1 to 392. These numbers are used in the two indexes — one for name of librarian, the other for country.

Each complete entry contains ten units of information:

loca — city or town in which the library is located
name — name of the library
addr — mailing address
tele — telephone number
libr — name and title of person responsible for maintaining the collection or for handling reference questions concerning it
salu — salutation preferred by the librarian
subj — subjects which receive major emphasis within the collection
user — categories of people who are authorized to use this library
serv — services supplied by the library
inst — the institution that supports the library

Not all entries are complete. Where information was absent or was unclear on the questionnaire, the compilers have noted "[n.g.]" to indicate "not given." Usually, the information in each entry is presented the way it was given on the returned questionnaire. However, some editing for clarification and uniformity was done. Users may notice that two units of information that appeared in the 1st edition have been dropped from the 2nd—size of the collection (SIZE) and a listing of document services used by the library (DOCS). Experience with the 1st edition led us to believe that SIZE statistics are not always as reliable as the other information requested. As for DOCS, this information would have required more time to update than its use would appear to justify. An asterisk (*) at the end of an entry means that this information has not been verified since publication of the 1st edition of the directory (1983).

CAMEROON

1 loca Dschang; name Centre University of Dschang Library; addr BP. 255, Dschang, Cameroon , West Africa; tele 45-12-67; libr Caryl McKellar; Michael N. Monjah Nditange; salu Mrs. McKellar; Mr. Monjah Nditange; subj forestry in general, tropical forests, forest ecology, forest management, forest genetics; user faculty, students, staff; serv circulating library, reference on site; inst Centre University of Dschang.

2 loca Yaounde; name Centre for Forestry Research; addr P.O. Box 2102, Yaounde, Cameroon; tele 23-26-44; libr C.F.R. Matike; salu [n.g.]; subj agroforestry, silviculture, forest genetics, pulp and paper, wood machining; user general public; serv on site use only; inst Institute of Agronomic Research.

CONGO

3 loca Brazzaville; name Service des Archives et de la Documentation; addr Secrétariat Général aux Eaux et Forêts, Service des Archives et de la Documentation, B.P. 98 Brazzaville, Congo; tele [n.g.]; libr Moussala Marcel, Chef de Service; salu Monsieur Marcel; subj forestry in general, forest products, pulp and paper, wildlife management,; user students, general public; serv reference on site; inst Ministere de l'Economie Forestiere.

4 loca Pointe Noire; name Bibliothèque du Centre Technique Forestier Tropical du Congo; addr BP 764 Pointe Noire, République Populaire du Congo; tele [n.g.]; libr J. C. Delwaulle, Directeur du C.T.F.T., Mlle. Alphonsine Mouzonso; salu Monsieur Delwaulle; subj forestry in general, pulp & paper, eucalyptus and tropical pine; user staff, foresters; serv reference on site; inst Centre Technique Forestier Tropical, Nogent sur Marne, France.

ETHIOPIA

5 loca Addis Ababa; name The National Herbarium Library; addr Addis Ababa University, P.O. Box 3434, Addis Ababa, Ethiopia; tele 113177, ext. 172; 11-33-36, ext. 172; 129110, ext. 172; libr Ato Eskinder Seyoum, Documentalist; salu Mr. Ato Eskinder; subj forestry in general, forest products, plant taxonomy; user faculty, students, several institutions focusing on plant products; serv reference on site; inst Biology Department, Faculty of Science, Addis Ababa University.

GABON

6 loca Libreville; name Institut de Recherches Agronomiques et Forestieres; addr B.P. 2246, Libreville, Gabon, Africa; tele 73-25-65; libr Nang Colette, Ingenieur des Techniques Forestieres; salu Monsieur Colette; subj forestry in general, forest products, pulp and paper, wood technology; user faculty, students, staff; serv reference on site; inst Ecole Nationale des Eaux et Forets.

GHANA

7 loca Kumasi; name F.P.R.I. Library; addr Forest Products Research Institute, University P.O. Box 63, Kumasi, Ghana; tele 5873 or 5851 ext. 400; libr F.W. Addo-Ashong, Director; salu Mr. Addo-Ashong; subj silviculture, forest genetics, pulp and paper, forest pathology, forest entomology, wood preservation; user staff of institution; serv on site use, interlibrary loan; inst Ghana Forestry Commission.

KENYA

8 loca Londiani; name Kenya Forestry College; addr P.O. Box 8, Londiani, Kenya; tele 28 Londiani; libr Charles Sakwa; salu Mr. Sakwa; subj forestry in general; user staff of institution, students; serv interlibrary loan, reference on site; inst Ministry of Environment and Natural Resources.

9 loca Nairobi; name Forest Department Library; addr P.O. Box 30513, Nairobi, Kenya, East Africa; tele 722620, ext. 24; libr Peter Daniel Mathénge, Librarian; salu Mr. Mathénge; subj forestry in general, forest products, pulp and paper, wildlife management; user students, staff; serv reference on site, interlibrary loan; inst Forest Department, Ministry of Environment and Natural Resources.

10 loca Nairobi; name INFODOC, International Council for Research in Agroforestry; addr P.O. Box 30677, Nairobi, Kenya; tele 29867; libr Richard Labelle, Information Officer; salu Mr. Labelle; subj agroforestry, silviculture; user staff members, students (univ.), others by introduction; serv on site reference and use, computer searches; inst International Council for Research in Agroforestry.

11 loca Nairobi; name Kenya Agricultural Research Institute, Library; addr P.O. Box 30148, Nairobi, Kenya; tele Kikuyu 2121, ext. 266; libr Daniel Lazarus Njoroge, Librarian / Documentalist; salu Mr. Njoroge; subj forestry in general, forest products, range management, wildlife management, agriculture; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan; inst Kenya Ministry of Agriculture, Livestock and Natural Resources.*

LIBERIA

12 loca Monrovia; name Documentation and Marketing Center; addr DOMAC, Forestry Development Authority, P.O. Box 3010, Monrovia, Liberia, West Africa; tele 262252/262253 CABLES FORDA; libr Sammakai M. Richards, Head of DOMAC; salu Mr. Richards; subj silviculuture, pulp and paper, forest products reports, FAO publications on forestry and information services; user forest companies, institutions of higher learning, faculty and students, and the general public; serv on site use, reference on site, by mail and by telephone; inst The center was established by a grant from the German Government but it is presently financed by the Government of Liberia.

MOROCCO

13 loca Rabat; name Division de Recherches et d'Experimentations Forestieres; addr Charia Omar Ibn El Khattab, B. P. 763, Rabat-Agdal, Maroc; tele (07) 729-28 or (07) 738-30; libr Mme. Drissi; salu Mme. Drissi; subj silviculture, forest genetics, mycology and forest pathology, soil science, plant physiology; user staff of institution, students, general public; serv compilation of bibliographies; inst Forest Research Division.

NIGER

14 loca Niamey; name Service Statistiques et Documentation; addr Eaux et Forêts B.P. 578, Niamey(Niger); tele 73.30.44, poste 3339; libr Yahaya Mahamadou, Controleur des Eaux et Forêts; salu Mr. Mahamadou; subj forestry in general, forest products, range management, wildlife management; user faculty, students, general public; serv consultation on site, interlibrary loan; inst Eaux et Forêts.*

NIGERIA

15 loca Ibadan; name Federal Dept. of Forestry Library; addr P.M.B. 50011, Jericho Reservation Area, Ibadan, Nigeria; tele 022-410291; libr ...Shyllon; salu Mrs. Shyllon; subj silviculture, forest economics, pulp and paper, wood processing, wildlife management, range management; user staff, students, researchers; serv on site use, reference on site, by mail or telephone; inst Federal Department of Forestry.

16 loca Ibadan; name Forest Research Institute of Nigeria, Library; addr P.M.B. 5054, Ibadan, Nigeria; tele 414441/414022/414073; libr Y.A. Adedigba, Assistant Chief Librarian; salu Mr. Adedigba; subj forestry in general, forest products research, utilization of forest products; user research staff, state and federal government forestry staff; serv reference on site, interlibrary loan, compilation of lists, etc.; inst Forestry Research Institute of Nigeria.

17 loca Ibadan; name Forest Resources Management Library; addr Department of Forest Resources Management, University of Ibadan, Ibadan, Nigeria; tele 022-400550, ext. 1433 and 1437; libr A. Oyemakinde; salu Mrs. Oyemakinde; subj agroforestry, silviculture, forest genetics, forest economics, pulp and paper; user staff and students; serv reference on site, by mail, by telephone, interlibrary loan, computer searches; inst University of Ibadan, Ibadan, Nigeria.

18 loca Lagos; name Federal Dept. of Forestry Library - Headquarters Branch; addr P.M.B. 12613 Obalente, Lagos, Nigeria; tele 01-683324; libr K. Aladejane; salu Mr. Aladejana; subj silviculture, forest economics, pulp and paper, wood processing, wildlife management, range management; user staff, students, researchers; serv on site use, reference on site, by mail or telephone; inst Federal Department of Forestry.

19 loca Samaru-Zaria; name Savanna Forestry Research Station, Library; addr P.M.B. 1039, Samaru - Zaria, Kaduna State, Nigeria; tele (069) 32591 and 32592 ext. 4; libr B. R. Adetunmbi, Higher Library Officer; salu Mr. Adetunmbi; subj forestry in general, savanna afforestation, forest products research, utilisation of forest products; user research staff, state forestry staff, university staff, students; serv reference on site, by telephone, by mail, interlibrary loan, compilation of current contents in journals to staff; inst Ahmadu Bello University.

SENEGAL

20 loca Dakar; name Bibliotheque de la Direction des Eaux et Forets; addr Parc de Hann, BP: 1831, Dakar, Senegal; tele 210628; libr Marie Therese Ndione; salu Madame Ndione; subj silviculture, forest economics, wildlife management; user staff, students, faculty, general public; serv on site only; inst Senegal Government.

21 loca Dakar; name Bibliotheque du Centre National de Recherches Forestieres, Parc Forestier de Hann, BP 2312, Dakar, Senegal; tele 213219; libr [n.g.]; salu [n.g.]; subj agroforestry, silviculture, forest genetics, forest economics; user [n.g.], students; serv [n.g.]; inst Institut Senegal de Recherches Agricoles.

SOUTH AFRICA

22 loca Cape Town; name National Botanic Gardens, Kirstenbosch; addr Private Bag X7, Claremont 7735, South Africa; tele 021-771166 ext 16; libr Frances Hanekom, Librarian; salu Mrs. Hanekom; subj botany, horticulture, conservation, environmental education; user staff, students, general public; serv reference on site and by telephone, interlibrary loan, compilation of bibliographies; inst National Botanic Gardens.

23 loca George; name Saasveld Library; addr Saasveld Forest Research Centre, Private Bag X6515, 6530 George, South Africa; tele 0441-2059/2065; libr Ilse Shearar, Librarian; salu Mrs. Shearar; subj silviculture, soils, wildlife management, fire, forest management; user college staff, research staff, college students; serv on site use, interlibrary loan, computer searches, compilation of bibliographies; inst Saasveld Forest Research Centre and Saasveld College (Department of Environmental Affairs, Pretoria).

24 loca Pietermaritzburg; name Institute for Commercial Forestry Research; addr P.O. Box 375, Pietermaritzburg 3200, South Africa; tele 0331 62314; libr H. Woolfrey, Librarian; salu Mrs. Woolfrey; subj agroforestry, silviculture, forest genetics, forest economics; user staff on institute, students of university; serv on site use, reference on site, by mail, compilation of bibliographies, interlibrary loan, computer searches; inst Institute for Commercial Forestry Research.

25 loca Pretoria; name Central Forestry Library; addr Dept. of Environment Affairs and Tourism, Private Bag X447, Pretoria, South Africa, 0001; tele 012-299 2538; libr S. Oelofse, Librarian; salu Mrs. Oelofse; subj forestry in general, forest products, range management, wildlife management, environmental conservation; user staff, foresters of private organizations; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Dept. of Environment Affairs and Tourism.

26 loca Pretoria; name Mary Gunn Library; addr Botanical Research Institute, Private Bag X101, 0001 Pretoria, South Africa; tele 012-86-1164/5/6/70/80; libr E. Potgieter; salu Mrs. Potgieter; subj taxonomy, ecology, morphology, anatomy, plant geography, history of botany, paleobotany, economic botany; user staff of institute, scientists; serv by mail, by telephone, interlibrary loan, reference on site, etc.; inst Department of Agriculture and Water Supplies.

27 loca Pretoria; name National Timber Research Institute, Library; addr CSIR, P.O. Box 395, Pretoria 0001, South Africa; tele 012-86-9211; libr C.M. Groeneveld; salu Mrs. Groeneveld; subj charcoal, adhesives, timber engineering, preservation, pulp and paper; user staff, students, general public; serv computer searches, interlibrary loan, document delivery, reference on site, by telephone, by mail; inst Council for Scientific and Industrial Research.

28 loca Pretoria; name Nature Conservation Library; addr Transvaal Nature Conservation, Private Bag X 209; 0001 Pretoria, R.S.A.; tele (012) 2012874; libr P. C. Compaan, Liaison Officer; salu Miss Compaan; subj wildlife management, botany, nature conservation; user staff; serv on site use, interlibrary loan; inst Transvaal Provincial Administration.

29 loca Pretoria; name S.A. Forestry Research Institute Library; addr P.O. Box 727, Pretoria 0001, Republic of South Africa ; tele 012-28-7120; libr C. van Eeden; salu Mr. van Eeden; subj forestry in general, forest genetics, forest botany, conservation forestry, wood anatomy, hydrological research as related to S.A Forestry; user staff; serv reference on site, by telephone, by mail, interlibrary, compilation of bibliographies; inst Forestry Research Institute.

TANZANIA

30 loca Dar-es-Salaam; name Tanzania Wood Industry Corporation Headquarters Library; addr P.O. Box 9160, Dar-es-Salaam, Tanzania; tele 28271; libr J. Holmes, Training Manager; salu Mr. Holmes; subj forestry in general, forest products (except pulp and paper), management, accounting, mechanical engineering, civil engineering; user students, staff; serv reference on site, by telephone, by mail; inst Tanzania Wood Industry Corporation.

31 loca Morogoro; name Faculty of Agriculture, Forestry and Veterinary Science, Library; addr University of Dar es Salaam, University Sub-post Office, Morogoro, Tanzania; tele 2511 Morogoro; libr S.S. Mbwana, Senior Librarian; salu Mr. Mbwana; subj forestry in general; user [n.g.]; serv [n.g.]; inst University of Dar es Salaam.*

UGANDA

32 loca Entebbe; name Forest Department, Library; addr P.O. Box 31, Entebbe, Uganda; tele 20381; libr W.M. Bwiruka, Senior Library Assistant; salu Mr. Bwiruka; subj forestry in general, forest products, pulp and paper, range management, wildlife management, silviculture; user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan; inst Uganda Forest Department.*

ZAIRE

33 loca Kisangani; name Bibliothèque Centrale; addr Université de Kisangani, B.P. 2012 Kisangani, Rép. du Zaire; tele 3007; libr Muzila Label Kakes, Chef de Division des Bibliothèques; salu Seno Muzila; subj forestry in general, forest products (except pulp and paper), wildlife management; user faculty, students, staff, general public, ; serv reference on site, interlibrary loan, compilation of bibliographies; inst Université de Kisangani.*

ZAMBIA

34 loca Kitwe; name Forest and Timber Research Library; addr Research Division, P.O. Box 22099, Kitwe, Zambia; tele 210288 or 210456; libr Hakalima Boyd Hatembo, Librarian; salu Mr. Hakalima; subj forestry in general; user students, staff; serv reference on site; inst Ministry of Lands and Natural Resources.

AUSTRALIA

AUSTRALIAN CAPITAL TERRITORY

35 loca Canberra; name Department of Forestry, Australian National University; addr GPO Box 4, Canberra, A.C.T. 2601, Australia; tele (062) 494313; libr Paula Reid, Librarian; salu Mrs. Reid; subj silviculture, forest management, fire, soils, forest products; user academic staff, general staff, post graduates, general public in special cases; serv interlibrary loans, telephone reference, reference by mail; inst Department of Forestry, Australian National University.

36 loca Canberra; name Library, Department of Primary Industry; addr Edmund Barton Building, Barton, A.C.T. 2600, Australia; tele (062) 725608 ; libr Charles Ironside, Librarian; salu Mr. Ironside; subj forestry in general, forest products, pulp and paper, other aspects of agriculture and related fields; user staff, agricultural institutions, occasionally students; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Department of Primary Industry.

37 loca Yarralumla; name CSIRO Division of Forest Research, Library; addr Banks St., Yarralumla, A.C.T. 2600, Australia; tele (062) 818-355; libr Margaret Saville, Librarian; salu Miss Saville; subj forestry in general, forest products, biometrics; user students of Australian National University Forestry Dept., staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Commonweath Scientific and Industrial Research Organization.*

NEW SOUTH WALES

38 loca Sydney; name Forestry Commission of New South Wales Library; addr P. O. Box 100, Beecroft, N. S. W. 2119, Australia; tele (02) 8713222, ext. 1; libr J.R. Koraca, Librarian; salu Mrs. Koraca; subj forestry in general, forest products (except pulp and paper), wildlife management, wood technology; user staff, general public, research foresters in country locations; serv reference on site, by mail, interlibrary loan; inst Forestry Commission of New South Wales.

QUEENSLAND

39 loca Brisbane; name Department of Forestry, Library; addr GPO Box 944, Brisbane, Queensland 4001, Australia; tele (07) 2248419; libr Marcia Tommerup, Librarian; salu Ms. Tommerup; subj forestry in general, forest products (except pulp and paper); user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Department of Forestry.

40 loca Gympie; name Forestry Library; addr M.S. 483, Fraser Rd., Gympie, Queensland 4570, Australia; tele (071) 822244; libr Catherine Hunt; salu Ms. Hunt; subj forest soils, forest nutrition, hydrology, silviculture, forest fires; also interests in rainforest and agroforestry; user staff of institution only; serv reference on site, by mail, or telephone (mainly with the Department's head office library in Brisbane), interlibrary loans, computer searches, compilation of bibliographies; inst Department of Forestry.

SOUTH AUSTRALIA

41 loca Adelaide; name Woods and Forests Department Library; addr G.P.O. Box 1604, Adelaide S.A. 5001, Australia; tele (08) 2167211; libr Meredith Isbell, Librarian; salu Ms. Isbell; subj forestry in general, forest products, wildlife management, range management; user staff; serv reference on site, by telephone, by mail, interlibrary loan; inst Woods and Forest Department, South Australia.

42 loca Mount Gambier; name Lou Kloeden Library; addr South East College of Tafe, 7 Wehl Street South, Mount Gambier, South Australia, 5290, Australia; tele (087) 255011; libr position vacant; subj general botany, plant physiology, dendrology of Australian trees; user faculty, students, local industry, general public; serv on-site use, reference on site, by mail, by telephone, interlibrary loans, compilation of bibliographies, computer searches; inst South East College of Tafe.

TASMANIA

43 loca Burnie; name APPM Technical Library; addr P. O. Box 201, Burnie, Tasmania 7320, Australia; tele (004)307440; libr Derek W. Brown, Librarian; salu Dr. Brown; subj forestry in general, forest products, pulp and paper; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Associated Pulp and Paper Mills (Group Research Unit).

44 loca Hobart; name Australian Newsprint Mills Ltd., Library; addr Boyer, Tasmania 7140, Australia; tele (002) 610247; libr Carol Eastley; salu Mrs. Eastley; subj pulp and paper, forest products, mechanical engineering, chemical engineering, forestry; user all employees; serv reference by telephone, mail, fax, computer searching, bibliography compilation, interlibrary loan; inst Australian Newsprint Mills Ltd.

45 loca Hobart; name Forestry Commission Library; addr G.P.O. Box 207B, Hobart 7001, Australia; tele (002)30-6042; libr Christina Anstie, Librarian; salu Ms. Anstie; subj silviculture, forest economics, forest products, forest fires, biomass-energy; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Forestry Commission of Tasmania.

VICTORIA

46 loca Clayton; name CSIRO Division of Chemical and Wood Technology, Library; addr Private Bag no. 10, Clayton, Victoria 3168, Australia; tele (03) 5422244; libr Moshe Dua, Librarian; salu Mr. Dua; subj forest products, pulp and paper, biotechnology, wood composites; user staff, general public; serv Most services are for staff. Some restricted use available to general public.; inst Commonwealth Scientific and Industrial Research Organization; note The collection is divided between two libraries i.e. (1) CSIRO, Division of Chemical and Wood Technology-- above, and (2) CSIRO, Division of Building Research, P.O. Box 56, Highett, Victoria 3190, Australia .

47 loca Creswick; name Victorian School of Forestry Library; addr Creswick, Victoria 3363, Australia; tele (053)452304; libr Jean Baker, Librarian; salu Mrs. Baker; subj forestry in general, forest products (except pulp and paper), ecology, land use planning, land management, wildlife management; user faculty, students; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Department of Conservation, Forests and Lands, Victoria.*

48 loca Melbourne; name Amcor Library; addr 17 Rex Avenue, Alphington, Victoria 3078, Australia; tele (03) 4903333; libr Janet E. McGahy, Superintendent of Information Services; salu Miss McGahy; subj pulp and paper; user company staff; serv reference on site, by mail, telephone, telex, fax, monograph loans, journal circulation, interlibrary loans, computer searches; inst Amcor Research & Technology Centre.

49 loca Melbourne; name Department of Conservation, Forests and Lands Library; addr GPO Box 4018 Melbourne Vic. 3001, Australia; tele (03) 6179279; libr Marie van Baer, Librarian; salu Ms. van Baer; subj forestry in general, ecology, fire protection, forest management, landscape, silviculture; user staff of institution, students, teachers, business organizations, general public; serv reference - on site, by mail, telephone, fax. Interlibrary loan, computer searches. Compilation of "Australian Forestry Index"; inst Department of Conservation, Forests and Lands, Victoria.

50 loca Parkville; name Agriculture and Forestry Branch Library; addr School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria, 3052, Australia; tele (03)3415017; libr Margaret Routley, Librarian; salu Ms. Routley; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University of Melbourne.*

WESTERN AUSTRALIA

51 loca Perth; name Department of Conservation and Land Management Library; addr Wildlife Research Centre, P. O. Box 51, Wanneroo, Western Australia 6065; tele (09) 4051555; libr Elisabeth Laczo, Librarian-in-Charge; salu Ms. Laczo; subj agroforestry, silviculture, forest pathology, wildlife, parks and recreation; user full service to staff of the department, reference service to the general public; serv reference services: direct, by mail or by telephone, interlibrary loans, on line searches, bibliographies, monograph and periodical circulation; inst Department of Conservation and Land Management.

52 loca Perth; name CSIRO Western Australian Laboratories, Library addr Private Bag P.O. Wembley, Western Australia 6014, Australia; tele (09) 3870210; libr Bernadette Waugh; salu Mrs. Waugh; subj range management, forest ecosystems, nutrient cycling, forest diseases, soil salinity, agroforestry; user staff, general public, state government forestry staff; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Commonwealth Scientific and Industrial Research Organization.

53 loca Perth; name Forest Products Association (WA), Library; addr P.O. Box 254, West Perth, Western Australia 6005; tele (09) 3222088; libr C.C. Kneen, Manager - Technical Services; salu Mr. Kneen ; subj forestry in general, forest products, timber construction; user students, staff, general public, timber industry employees; serv reference on site, by telephone, by mail, information retrieval; inst Forest Products Association (WA).

BANGLADESH

54 loca Chittagong; name Institute of Forestry, University of Chittagong; addr Chittagong, Bangladesh; tele Chittagong; libr Md. Kamaluddin, Director; salu Mr. Kamal; subj silviculture, forest genetics, forest ecology, forest inventory and biology - mostly text books; user staff and students of the Institute; serv limited number of text books can be borrowed, reference books on site use only; inst University of Chittagong.

CHINA

55 loca Beijing; name The Library of the Chinese Academy of Forestry; addr Wan Shou Shan, Beijing, The People's Republic of China; tele 281431; libr Liu Yong Long; salu Mr. Liu; subj silviculture, forest genetics, forest economics, wood machining, wildlife management; user staff of institution; serv computer searches, compilation of bibliographies; inst The Chinese Academy of Forestry.

56 loca Chengdu; name Sichuan Research Institute of Forestry, Library; addr Jinhua Jie, Chengdu, Sichuan Province, People's Republic of China; tele 31705 Chengdu; libr Li Yun-sen, Librarian; salu Mr. Li; subj forestry in general, forest products (except pulp and paper), wildlife management; user faculty, staff; serv reference on site, interlibrary loan, computer searches; inst Sichuan Research Institute of Forestry.

57 loca Guangzhou; name The Library, Forest Research Institute of Guangdong Province; addr Shahe, Guangzhou, Guangdong Province, China; tele 773051; libr Kong Fan Ran, Information Research Department, Head, Silvichemicals Engineer; salu Mr. Kong Fan Ran; subj silviculture, forest protection, silvichemicals, wood, forestry machinery; user staff of institution; serv on site use only, compilation of bibliographies; inst Forest Research Institute of Guangdong Province.

58 loca Harbin; name Library, Harbin Research Institute of Forestry Machinery; addr Xuefu Road, Harbin, Heilongjiang, P.R.C.; tele 61136, 61137; libr Luo Qihua, Librarian; salu Mrs. Luo; subj forestry and forestry machinery, agriculture, industrial technology, transportation; user staff of institution; serv interlibrary loan, compilation of bibliographies; inst The China Ministry of Forestry.

59 loca Harbin; name Library, North-Eastern Forestry University; addr Hexing Lu, Harbin, Heilongjiang Province, People's Republic of China; tele 63161 Harbin; libr Pei Ke, Librarian, salu Mr. Pei; subj silviculture, forest genetics, forest economics, wildlife, forest machinery, woodworking, forest roads; user faculty, students; serv reference on site, information service, interlibrary loan; inst North-Eastern Forestry University.

60 loca Jiangnin County; name Jiangsu Provincial Institute of Forestry; addr Jiangnin County, Jiangsu Province, China; tele 24515 or 25090 Nanjing; libr Tu Zug Yu; salu Mr. Tu; subj silviculture, windbreaks, pillow genetics, plant tissue culture, bamboo shoot-producing stands study; user staff of institution, general public, students; serv on site use only, interlibrary loan; inst Ministry of Agroforestry, Jiangsu Province.

61 loca Jilin City; name Jilin Forestry College Library; addr Taishan Road 32, Jilin City, Jilin Province, China; tele "The Library", c/o 22375; libr Yu Jian-bo; salu Mr. Yu; subj silviculture, forest ecology, forest economics, logging, wood machining; user faculty, students; serv on site use, reference on site, interlibrary loan; inst Jilin Forestry College.

62 loca Kunming; name The Library of Southwest Forestry College; addr Hot Springs, Kunming, Yunnan Province, China; tele 28606; libr Zhang Yi Zhong; salu Madam Zhang; subj forestry, forest ecology, forest protection, forest genetics; user faculty, students, foreign teachers, staff of institution, etc.; serv on site use only, reference on site, interlibrary loan, computer searches, compilation of bibliographies, etc.; inst Southwest Forestry College.

63 loca LanZhou City; name GanSu Provincial Institute Centre of Forestry; addr GanSu Provincial Institute of Forestry, Duan Jia Tan Road, LanZhou City, GanSu Province, The People's Republic of China; tele 25008; libr Meng Shang Xian, Engineer, Director of GanSu Provincial Information Centre of Forestry and the GanSu Provincial Institute of Forestry; salu Mr. Meng; subj silviculture, forest genetics, forest entomology and pathology, forest management, wood machining; user staff of GanSu Provincial Institute of Forestry; serv on site use only, reference on site; inst Forestry Department of GanSu Province.

64 loca Nanchang; name Information Library of Jianxi Forestry Research Institute; addr Nanchang, Jiangxi Province, China; tele 51663, 51672, 51682; libr Tang Goang Xu; salu Mr. Tang; subj silviculture, forest genetics, wildife management, range management, parks and recreation; user staff of institution, faculty, general public; serv reference on site, by mail, by telephone, interlibrary loan, compilation of bibliographies, etc.; inst Jiangxi Forestry Research Institute.

65 loca Nanjing; name Library of the Research Institute of Chemical Processing and Utilization of Forest Products, Chinese Academy of Forestry; addr Shao-Shan Road, Nanjing, People's Republic of China; tele 41445; libr [n.g.]; salu [n.g.]; subj forest products, pulp and paper; user faculty; serv [n.g.]; inst Chinese Academy of Forestry.*

66 loca Nanjing; name Nanjing Forestry University, The Library; addr Nanjing Forestry University, Nanjing, China; tele 43161; libr Ding Zhensen, Librarian; salu Mr. Ding; subj silviculture, forest genetics, forest economics, pulp and paper, wood machining; user staff of university, faculty, students; serv on site use only; reference on site, by mail, interlibrary loan; inst Nanjing Forestry University.

67 loca Shanghai; name Library & Information Department of Shanghai Wood Industry Research Institute; addr 667 Zhongshan Lu (West), Shanghai, China; tele 523125 Shanghai; libr Yu-Jie Chang, Vice Director; salu Mr. Chang; subj pulp and paper, wood machining, wood based panels manufacturing, etc.; user staff of institution, faculty, students, etc.; serv on site use, reference on site, by mail, interlibrary loan, etc.; inst Shanghai Wood Industry Research Institute.

68 loca Shenyang; name Library of the Institute of Forestry & Soil Science, Academia Sinica; addr P.O. Box 417, Shenyang, P.R. China; tele 483329-36; libr Qi Gixin, Head of Library; salu Mr. Qi; subj forest ecology, agroforestry, silvilculture, forest genetics, range management; user staff of institution, faculty, students; serv on site use and interlibrary loan; inst Institute of Forestry and Soil Science, Academia Sinica.

69 loca Wuhan; name The Library of Forestry Science Research Institute of Hubei Province of China; addr Jou Fong, Wuhan, Hubei Province, China; tele 70488 or 70435; libr Yan Da-shan, assistant researcher; salu Mr. Yan; subj forest genetics and breeding, forest economics, forest ecology, forest culture, forest pest control; user technicians of institution, mostly; serv compilation of bibliographies; inst Forest Bureau of Hubei Province of China.

70 loca Xianyang Shi; name Shaanxi Provincial Institute of Forestry, Library; addr Yang-ling Station, Shaanxi Province, People's Republic of China; tele [n.g.]; libr Wang Xiu-Qi, Assistant Researcher; Zhang Liang-long, Engineer; salu Mr. Wang; subj agroforestry, silviculture, forest genetics, forest economics, wood machining; user faculty; serv interlibrary loan, compilation of bibliographies; inst Shaanxi Provincial Institute of Forestry.

71 loca Xining; name The Library of Qinghai Academy of Agriculture & Forestry; addr Xining, Qinghai, People's Republic of China; tele 24339 or 24330; libr Wang Jinsheng, Vice-director; salu Mr. Wang; subj plateau forestry, silviculture in dry areas, wildlife management, plants in plateau and cold areas, forest entomology; user all of the staff working in the Academy, general public; serv compilation of bibliographies; inst Qinghai Academy of Agriculture and Forestry.

72 loca Yangling; name The Library of Northwestern College of Forestry; addr Northwestern College of Forestry, Yangling, Shaanxi Province, China; tele [n.g.]; libr Zhang Youlan, Director of the division of scientific and technological information; salu Mr. Zhang; subj silviculture, forest genetics, forest economics, forest ecology, forest management; user faculty, students, general public; serv on site use only, reference on site, interlibrary loan; inst The Financial Department of Northwestern College of Forestry.

INDIA

73 loca Bangalore; name Indian Plywood Industries Research Institute; addr Post Bag No. 2273, Tumkur Road, Bangalore - 560 022, India; tele 384231, 384232, 384233; libr C.N. Deshprabhu, Assistant Director; salu [n.g.]; subj plywood, particle board, fibreboard, adhesives, preservation, etc.; user staff of institution, industry, faculty; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Indian Plywood Industries Research Institute.

74 loca Coimbatore; name Tamilnadu Agricultural University Library; addr Coimbatore 641003, Tamilnadu, India; tele 35461, ext. 73; libr K. Balasubramanian, University Librarian; salu Mr. Balasubramanian; subj forestry in general, forest products, pulp and paper, wildlife management, environmental sciences: conservation, pollution, energy; user faculty, students of TNAU, various arts and science colleges at Coimbatore, staff, general public, farmers, forest officials; serv reference on site, by telephone, by mail, interlibrary loan, documentation service; inst Government of Tamilnadu, Indian Council of Agricultural Research.

75 loca Dehra Dun; name Forest Research Institute and Colleges Library; addr P.O. New Forest, Dehra Dun, India, Pin - 248006; tele 7021 to 7028, ext. 279; libr U.C. Dandriyal, Central Librarian; salu Mr. Dandriyal; subj forestry in general, forest products, pulp and paper, range management, wildlife management, allied sciences; user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Forest Research Institute and Colleges.

76 loca Hyderabad; name Library and Documentation Centre, Andhra Pradesh Agricultural University; addr Rajendranagar, Hyderabad - 500 030, India; tele 48161; libr D.B. Eswara Reddy, University Librarian; salu [n.g.]; subj forestry in general; user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan; inst Forest Research Institute, Dehra Dun, India, and the Chief Conservator of Forests, Government of Andhra Pradesh.*

77 loca Hyderabad; name State Silviculturist Library; addr Office of the Chief Conservator of Forests, Hyderabad 500004, Andhra Pradesh, India; tele 230561, ext. 41; libr L. Krishna Bhoopal Rao; salu Mr. Rao; subj forestry in general, forest products, pulp and paper, wildlife management; user staff; serv [n.g.]; inst Forest Department.

78 loca Lucknow; name Central Library - Forest Department; addr Additional Chief Conservator of Forests (R.&D.), 17 Ranapratapmarg, U.P. : Lucknow, India 226001; tele 42734; libr A. Gupta; salu [n.g.]; subj agroforestry, silviculture, forest genetics, forest economics, forest wildlife management; user foresters, tree scientists, students, research workers, environmentalists; serv on site use only; inst State Forest Department.

79 loca Trichur; name Kerala Forest Research Institute Library; addr Peechi 680 653, Trichur, Kerala, India; tele 22375 (Trichur); libr K. Ravindran, Librarian; salu Mr. Ravindran; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, staff, students; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Kerala Forest Research Institute.

INDONESIA

80 loca Bogor; name Bogor Agricultural University Library; addr Jl. Raya Pajajaran, P.O. Box 101 Bogor 16151, Indonesia; tele 23171; libr Fahidin ; salu Drs. Fahidin; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, staff; serv reference on site, by mail, interlibrary loan; inst Bogor Agricultural University.

81 loca Bogor; name Library of Forest Research and Development Centre; addr P.O. Box 66, Bogor, Indonesia; tele (0251)-24032, 25111; libr Rubardi; salu Ms. Rubardi; subj silviculture, botany, forest influences, forest protection, forest mensuration; user staff of the institute and students; serv reference on site, by telephone, by mail, interlibrary loan; inst Forest Research and Development Centre.

82 loca Bogor; name National Library for Agricultural Sciences; addr Jl. Ir. H. Juanda 20, Bogor, Indonesia; tele (0251) 21746; libr Dr. Surya Mansur; salu Mr. Mansur; subj agroforestry, silviculture, range management, pulp and paper, wildlife management; user staff of institution, faculty members, students; serv on site, reproduction and by mail; inst Ministry of Agriculture.

83 loca; Ujung Pandang; name Perpustakaan Pusat Universitas Hasanuddin (Hasanuddin University Central Library); addr Kampus UNHAS Baraya, Ujung Pandang, Indonesia; tele Ujung Pandang 3029; libr A. Rahman Rahim; salu Mr. Rahim; subj forestry in general, forest products, pulp and paper, range management, wildlife management, forest ecology and silviculture; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst University of Hasanuddin.*

84 loca Yogyakarta; name Perpustakaan Fakultas Kehutanan Universitas Gadjah Mada (Library of Forestry Faculty, Gadjah Mada University); addr Gadjah Mada University, Yogyakarta, Indonesia; tele 88688 Pes 652; libr Pardiyan; salu [n.g.]; subj forestry in general, forest products, pulp and paper, range managment, wildlife management, forest genetics and tree improvement; user faculty, students; serv [n.g.]; inst Gadjah Mada University.*

IRAN

85 loca Karadj; name Library, College of Natural Resources; addr University of Tehran, Karadj, Iran; tele 0211-23044 ext. 36; libr Mehdi Navidi; salu Mr. Navidi; subj silviculture, forestry (general), watershed management, range management, ecology; user [n.g.]; serv reference on site, interlibrary loan; inst College of Natural Resources, University of Tehran.

ISRAEL

86 loca Kiryat Chaim; name Forest Department, Land Development Authority; addr P.O.B. 45, Kiryat Chaim 26103, Israel; tele 04-729171; libr Rina Ya'acovy; salu Mrs. Ya'acovy; subj sivlivculture, agroforestry, land development, soil conservation, forest fires, multipurpose forestry, forestry research, etc.; user staff, general public; serv interlibrary loan; inst Forest Department, Land Development Authority.

JAPAN

87 loca Ibaraki; name Library Section, Forestry and Forest Products Research Institute; addr P.O. Box 16, Tsukuba Norin Kenkyu Danchi-nai, Ibaraki, 305 Japan; tele 0298-73-3211; libr Seiya Tamai, Chief, Library Section; salu Mr. Tamai; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user researchers of supporting institution; serv reference on site, by telephone, by mail, compilation of bibliographies; inst Forestry and Forest Products Research Institute (National)

88 loca Kyoto; name Library, Department of Forestry, Kyoto Prefectural University; addr Shimogamo, Sakyo-ku, Kyoto 606, Japan; tele 075-781-3131; libr Shozo Tokuoka, Lecturer; salu Mr. Tokuoka; subj agroforestry, silviculture, forest economy, wood and wood products, erosion control, etc.; user staff, faculty, students, general public; serv on site use, reference on site, by mail, interlibrary loan; inst Kyoto Prefecture.

89 loca Sapporo; name Library of Forestry and Forest Products Department, Faculty of Agriculture, Hokkaido University; addr Kita 9, Nishi 9, Kita-ku, Sapporo 060, Japan; tele (011) 716-2111, ext. 2533; libr Kazuko Ohashi, Shisyo (Librarian); salu Miss Ohashi; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, staff; serv reference on site, by telephone; inst Experiment Forests of Hokkaido University.*

90 loca Tokyo; name Library of Japan Forest Technical Association (Nippon Ringyo Gijutsu Kyokai); addr No. 7, Rokubancho Chiyoda-ku, Tokyo, 102, Japan; tele Tokyo, (03) 261 - 5281; libr Yoshie Suzuki, Special Librarian; salu Mr. Suzuki; subj forestry in general, forest products; user staff; serv reference on site, by telephone, by mail; inst Japan Forest Technical Association.*

KOREA

91 loca Seoul; name Forest Research Institute, Library; addr 207 Chongyangnidong, Dongdaemun-ku, Seoul, Korea; tele 82-02-966-8961; libr Lee, Chin-Kyu, Chief of Planning & Coordination Division (F.R.I.); salu [n.g.]; subj forestry in general, forest products, pulp and paper, wildlife management; user students, staff; serv reference on site, by telephone, by mail, compilation of bibliographies; inst. Forest Research Institute, Seoul.

92 loca Suwon; name The Library, Institute of Forest Genetics; addr P.O. Box 24, Suwon, Kyonggido 170, Republic of Korea; tele 0331-32-2121; libr Sang Yung Shim; salu [n.g.]; subj forest genetics, silviculture, tree improvement, tree breeding, tissue culture; user staff of institution; serv on site use only; inst Institute of Forest Genetics.

MALAYSIA

93 loca Kepong; name Forest Research Institute Malaysia, Library; addr Forest Research Institute, Kepong, Selangor, Semenanjung Malaysia; tele 662633; libr Kong How Koii, B.A. Dip. Lib. (Univ. of Wales), A.L.A.; salu Ms. Kong; subj forestry in general, forest products, pulp and paper; user students, staff, researchers; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Forest Research Institute Malaysia.

94 loca Sandakan; name Forest Research Centre Library; addr P.O. Box 1407, Sandakan, Sabah, Malaysia; tele 089-214179; libr Poon Ka Ling; salu Mdm. Poon; subj forest ecology, silviculture, forest genetics, pulp and paper, soil and soil science, forest protection (forest pests & diseases); user staff of institution; serv site use, reference on site as well as by mail; inst Forest Department, Sabah.

95 loca Serdang; name Universiti Pertanian Malaysia, Library; addr Serdang, Selangor, Malaysia; tele 03-586101; libr Syed Salim Agha, Chief Librarian; salu Mr. Agha; subj silviculture, forest economics, pulp and paper, wildlife management, wood technology; user faculty, students, staff of university, scientists from neighbouring institutions; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, SDI services using AGRIS data base, on-line access to DIALOG, etc.; inst Universiti Pertanian Malaysia.

NEW ZEALAND

96 loca Auckland; name Fletcher Challenge Information Service; addr Fletcher Challenge Ltd., Private Bag, Auckland, New Zealand; tele (09) 599979; libr D. Jarvis; salu Mr. Jarvis; subj timber marketing, wood panels, country information (for marketing), timber construction; user staff of Fletcher Challenge; serv on site reference, by phone, mail, interlibrary loan, computer searches, SDI statistics, journal circulation; inst Fletcher Challenge Ltd.

97 loca Auckland; name Head Office Library; addr N.Z. Forest Products Ltd., Private Bag, Auckland, New Zealand; tele (09) 592899; libr Stewart W. Payne, Head Office Librarian; salu Mr. Payne; subj pulp and paper, building and wood-based products, business management; user staff; serv reference on site, by telephone, interlibrary loan, computer searches; inst N.Z. Forest Products Ltd.

98 loca Christchurch; name Protection Forestry Division, Forest Research Institute; addr P.O. Box 31-011, Christchurch, New Zealand; tele (03) 517099; libr Trish Faulkner, Librarian; salu Mrs. Faulkner; subj ecology (animal, plant and forest), hydrology, revegetation; user staff of institute, limited (reference only) access to students and public institute situated on university campus; serv reference and loan, journal circulation, interlibrary loan, computer searches; inst New Zealand Forest Service.

99 loca Christchurch; name University of Canterbury, School of Engineering, Library; addr University of Canterbury, Private Bag, Christchurch, New Zealand; tele (03) 482009; libr H. McCarrigan, Engineering Librarian; salu Ms. McCarrigan; subj forestry in general, forest products, pulp & paper; user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University of Canterbury

100 loca Kawerau; name Tasman Pulp & Paper Technical Library; addr Private Bag, Kawerau, New Zealand; tele (763) 6999; libr Susan Dugdale; salu Miss Dugdale; subj pulp and paper, engineering, electronics, computer; user staff; serv interlibrary loan, reference, computer searches; inst Tasman Pulp & Paper Co. Ltd.

101 loca Kinleith; name Kinleith Technical Library; addr Private Bag, Tokoroa, New Zealand; tele (080) 61999; libr Edna Fish, Librarian; salu Mrs. Fish; subj silviculture, forest products, logging and lumber, pulp and paper technology, botany; user staff, students; serv reference on site, by mail, by telephone, interlibrary loan; inst N.Z. Forest Products Ltd.

102 loca Rotorua; name Forest Research Institute, Library; addr Private Bag, Rotorua, New Zealand; tele (073) 475899; libr Beryl Anderson; salu Ms. Anderson; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst New Zealand Forest Service.

103 loca Rotorua; name New Zealand Logging Industry Research Association (Inc.); addr P.O. Box 147, Rotorua, New Zealand; tele (073) 21080; libr Anna Cody, Librarian; salu Mrs. Cody; subj logging, log transport, forest roading, thinning, protection logging; user The LIRA library is open to all those with an interest in logging. (Borrowing is restricted to staff and members); serv accessions list, interloans, computer searches, reference inquiries by visits, by mail, by phone; inst New Zealand Logging Industry Research Association (Inc.).

104 loca Rotorua; name Tasman Forestry Library; addr Tasman Forestry Ltd., Private Bag, Rotorua, New Zealand; tele (073) 474810; libr A. Jackson; salu Ms. Jackson; subj silviculture, forest economics; user staff of the institution; serv journal circulation, reference on site, by mail, telephone, interlibrary loan, reference to other offices of Tasman Forestry geographically distant; inst Tasman Forestry Ltd.

105 loca Taupo; name Groome and Associates, Library; addr P.O. Box 169, Taupo, New Zealand; tele (074) 89240; libr K.D. Marten, Senior Forest Industry Consultant; salu Mr. Marten; subj forestry in general, forest products, pulp and paper; user staff; serv reference on site; inst Groome and Associates.

106 loca Wellington; name New Zealand Forest Service Library; addr Private Bag, Wellington. New Zealand; tele (04) 721569; libr Julia Risk, Librarian; salu Mrs. Risk; subj forestry in general, forest products, pulp and paper, wildlife management, recreation in forests, environmental problems; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst New Zealand Forest Service;

PAPUA NEW GUINEA

107 loca Boroko-Port Moresby; name Forest Products Research Centre; addr P. O. Box 1358, Boroko, Papua New Guinea; tele (675) 256555; libr A. O. Amoako, Assistant Director; salu Dr. Amoako; subj pulp and paper, wood preservation, wood machining, wood technology, forest products technology; user staff of the centre, public, government employees; serv on site use and reference, staff borrowing only; inst Department of Forests.

108 loca Boroko-Port Moresby; name Forestry Library; addr P.O. Box 5055, Boroko, Papua New Guinea; tele (675) 254022; libr Tinut Siprokau, Librarian; Mrs. Siprokau; subj forestry in general, forest products, reforestation, forest economics, timber trade; user forestry staff, staff of institution, faculty, students, researchers; serv reference on site, by mail, by telephone, interlibrary loan, compilation of bibliographies; inst Department of Forests.

109 loca Bulolo; name PNG Forestry College Library; addr P.O. Box 92, Bulolo, Papua New Guinea; tele 445226 or 445236; libr Siage Kalogo, Principal of the College; salu Mr. Kalogo; subj agroforestry, silviculture, forest genetics, pulp and paper, forest economics; user staff of institution, faculty, students; serv reference on site, by mail, by telephone, interlibrary loan; inst Papua New Guinea Forestry College.

110 loca Lae; name Division of Botany Library; addr P.O. Box 314, Lae, Papua New Guinea; tele (675) 423199; libr Jim Croft, Assistant Director; salu Mr. Croft; subj forestry in general, botany in particular; user staff, public, university; serv reference on site, by mail, by telephone, interlibrary loan; inst PNG Department of Forests.

111 loca Lae; name TITC Library; addr P.O. Box 2132, Lae, Papua New Guinea; tele (675) 423886; libr Miriam Baru, Librarian; salu Ms. Baru; subj logging, sawmilling, wood machining, wood preservation; user staff and students of the college; serv reference on site, by mail, by telephone, interlibrary loan; inst Timber Industry Training College.

PHILIPPINES

112 loca Laguna; name College of Forestry Library, University of the Philippines at Los Banos; addr College, Laguna 3720, Philippines; tele 34-40; libr Juanita C. Ranit, College Librarian; salu Mrs. Ranit; subj forestry in general, forest products, pulp and paper, range management, wildlife management, agroforestry, silviculture, forest genetics, forest economics, wood in general, parks and recreation; user faculty, students (graduate & undergraduate), staff, researchers of the institution and other government agencies; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst College of Forestry, University of the Philippines at Los Banos.

113 loca Laguna; name Forest Research Institute (FORI) Library; addr College, Laguna 3720, Philippines; tele 2509, 3221; libr Estrella B. Jamias; salu Mrs. Jamias; subj agroforestry, silviculture, forest genetics, forest economics, range management; user staff of institution, students, general public; serv reference on site, by mail, by telephone, interlibrary loan, compilation of bibliographies; inst Forest Research Institute.

114 loca Laguna; name Scientific Technical Library; addr College, Laguna 3720, Philippines; tele 2377, 2360, 2586; libr Olympia M. Molod, Scientific Documentation Officer II; salu Miss Molod; subj foresty in general, forest products, pulp and paper, particleboard, packaging; user staff, faculty, students, general public, etc.; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Forest Products Research and Development Institute.

115 loca Marawi City; name College of Forestry Unit Library and Mindanao State University; Marawi City, Philippines; tele none; libr Carlos B. Glori; salu Prof. Glori; subj anatomy/botany, soils, forest management, surveying and pathology/entomology; user faculty, staff, students and general public; serv on site use only; inst Mindanao State University.

116 loca Metro Manila; name Gregorio Araneta University Foundation Library; addr Victoneta Park, Malabon, Metro Manila, Philippines - 3104, tele 34-70-31-33 or 35-75-51-55; libr Felisa W. Dodor, Chief Librarian; salu Mrs. Dodor; subj parks and recreation, agroforestry, silviculture, forest economics, wildlife management; user staff of institution, faculty, students and general public, etc.; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Gregorio Araneta University Foundation.

117 loca Visca; name Visayas State College of Agriculture, Library; addr Visca, Leyte 7127-A, Philippines; tele 521-20-27 or 58-86-92; libr Pacita R. Escalante, Senior Librarian; salu Mrs. Escalante; subj agroforestry, silviculture, range management; user staff of institution, faculty, students, general public, etc.; serv on site use only, reference on site only; inst Visayas State College of Agriculture.

118 loca Quezon City; name Bureau of Forest Development Library; addr Visayas Ave., Diliman, Quezon City, Philippines; tele 96-51-76; libr Flordeliza D. Garcia, Senior Librarian; salu Mrs. Garcia; subj forestry in general, range management, wildlife management, watershed management, parks; user students, staff, general public; serv reference on site; interlibrary loan; inst Bureau of Forest Development.

119 loca Quezon City; name Ministry of Natural Resources, The Library; addr Visayas Avenue, Quezon City 3008, Philippines; tele 97-66-26, local 38; libr Rosita O. De Guzman; salu Mrs. De Guzman; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user students, staff, general public, technical staff of the Ministry; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst The Ministry of Natural Resources.

SRI LANKA

120 loca Colombo; name Forest Department, Library; addr P. O. Box 509, Colombo 2, Sri Lanka; tele 32251; libr K. Vivekanandan, Chief Research Officer; salu Dr. Vivekanandan; subj silviculture, wood machining, agroforestry, forest economics, forest genetics; user staff of institution, university students, general public; serv reference on site, interlibrary loan; inst Sri Lanka Forest Department.

TAIWAN, REPUBLIC OF CHINA

121 loca Taipei; name Taiwan Forestry Research Institute, Library; addr 53 Nan-Hai Road, Botanical Garden, Taipei, Taiwan, Republic of China; tele (02)3817107-09; libr Chen An-Chi, Assistant Researcher; salu Mr. Chen; subj forestry in general, forest products, pulp and paper, range management, forest biology, silviculture; user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Science and Technology Information Center, National Science Council, Agricultural Science Information Center.

THAILAND

122 loca Bangkok; name Documentary Service and Library Sub-Division; addr Documentary Service and Library Sub-Division, Office of the Secretary, Royal Forest Department, Bangkok 10900, Thailand; tele 5794301; libr Nuansiri Mungkorndin; salu Mrs. Mungkorndin; subj forest products and their utilization, forest management, watershed management, silviculture, national parks and recreation; user staff of Royal Forest Department, students, general public; serv interlibrary loans, copy machine service, book circulation, reference on site, by mail, by telephone; inst Royal Forest Department.

123 loca Bangkok; name Faculty of Forestry Library; addr Kasetsart University, Bangkok 10900, Thailand; tele 5790520; libr [n.g.]; salu [n.g.]; subj silviculture, pulp and paper, wildlife management, range management, remote sensing; user faculty, students, staff of institution, general public; serv reference on site, by mail, by telephone, interlibrary loan; inst Kasetsart University.

AUSTRIA

124 loca Vienna; name Bundesministerium für Land- und Forstwirtschaft, Amtsbibliothek; addr Stubenring 1, A-1011 Wien, Austria; tele (0222) 7500-66 13 - 15; libr Ob. Rat Dr. Christina Wolff; salu Mrs. Wolff; subj agroforestry, silviculture, forest genetics, wood machining, forest economics; user staff of institution, faculty, students; serv on site use, reference on site, by mail, interlibrary loan; inst Bundesministeriüm fur Land- und Forstwirtschaft.

125 loca Vienna; name Dokumentationsstelle des Österreichischen Holzforschungsinstitutes; addr Arsenal-Franz-Grill-Straße 7, A-1030 Wien, Austria; tele 0222/78-26-23; libr Reinhold Bayer, Dipl. Ing.; salu Mr. Bayer; subj forest products, pulp and paper; user students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan; inst Österreichische Gesellschaft für Holzforschung.

126 loca Vienna; name Forstliche Bundesversuchsanstalt, Bibliothek; addr A-1131 Wien, Austria; tele Austria/0222/82 36 38 / 225; libr Gudrun Schmidberger; salu Mrs. Schmidberger; subj forestry, forest protection, forest genetics, forest economics, forest inventory; user staff of institution; serv interlibrary loan; inst Bundesministerium für Land- und Forstwirtschaft.

127 loca Vienna; name Institut für Holzforschung; addr Gregor Mendelstrasse 33, A-1180 Wien, Austria; tele 0222/342500, ext. 290; libr Alfred Teischinger, Dipl. ing.; salu Mr. Teischinger; subj forest products; user faculty, students staff, general public (restricted); serv reference on site, by telephone, by mail, compilation of bibliographies; inst Bundesministerium für Wissenschaft und Forschung, Universität für Bodenkultur (Vienna).

BELGIUM

128 loca Genk; name V.Z.W. Lisec - Centre for Ecology and Forestry; addr Bokrijk, B-3600 Genk, Belgium; tele 011/362791; libr M. M. Buntinx; salu Mr. Buntinx; subj silviculture, pulp and paper, forest genetics, economics, etc.; user institution, faculty; serv on site use; inst LISEC - Studiecentrum voor Ecologie en Bosbouw V.Z.W.

129 loca Groenendaal-Hoeilaart; name Station de Recherches Forestieres et Hydrobiologiques; addr Duboislaan, 14, Groenendaal-Hoeilaart 1990, Belgium; tele 02/657.03.86; libr M. Burnotte, Librarian; salu Mrs. Burnotte; subj forest pedology, sylviculture, forest genetics, wildlife management, forest ecology; user staff of institution, students, general public; serv reference on site, by mail, by telephone, interlibrary loan; inst Station de Recherches Forestieres et Hydrobiologiques.

130 loca Louvain-la-Neuve; name Bibliothèque EFOR; addr Unite des Eaux et Forets de l' U.C.L., Place Croix du Sud 2 B.P. 4, B-1348 Louvain-la-Neuve, Belgique; tele 010/43.36.98, ext. 3698; libr Pierre Andre, Professeur; salu Prof. Andre; subj forestry in general, forest products; user faculty, students, staff; serv reference on site; inst Université de Louvain.

131 loca Melle-Gontrode; name Library of the Research Center of Silviculture, Forest Management and Forest Policy; addr Geraardsbergse steenweg 267, B-9231 Melle-Gontorde, Belgium; tele Melle-Gontrode : 091/52.21.13;; libr V.A.R. Dua; salu Ms. Dua; subj silviculture, tropical silviculture, forest ecology, forest recreation and amenities, forest protection; user staff, faculty, students, private organisations, other universities and institutions; serv on site use is preferred, reference by mail and interlibrary loan possible; inst Research Center of Silviculture, Forest Management and Forest Policy.

132 loca Tervuren; name Service d'Anatomie des Bois, Bibliothèque du Musée Royal de l'Afrique Centrale; addr Leuvense Steenweg 13, B-1980 Tervuren, Belgium; tele 02/767 5401; libr Roger Dechamps, Chef du Service; salu Mr. Dechamps; subj forest products (except pulp and paper), wood anatomy, identification of wood; user faculty, students, general public, professional foresters; serv reference on site, by telephone, by mail, interlibrary loan; inst Musée Royal de l'Afrique Centrale.

BULGARIA

133 loca Pasardjik; name Research Technical Library; addr Institut po darvoobrabotvane, ul. "Christo Botev" No. 1, 4400 Pasardjik, Bulgaria; tele 2 72 14; libr Rossitza Gigowa; salu Mrs. Gigowa; subj wood machining, silviculture, forest economics, pulp and paper; user staff of institution, students; serv reference on site, by mail, interlibrary loan, compilation of bibliographies, distribution of selected information; inst DSO "Stara Planina", MGGP.*

134 loca Sofia; name Vissh Lessotehniceski Institut (Higher Institute of Forestry); addr ul Kliment Ohridski N10, 1156-Sofia, Bulgaria; tele 63-01, ext. 343; libr Rayna Krincheva, Director of the Library; salu Mrs. Krincheva; subj forestry in general, forest products, pulp & paper, range management, wildlife management; user faculty, students, staff; serv reference by mail; inst Ministry of Forestry and Forest Products.*

CZECHOSLOVAKIA

135 loca Bratislava; name Library of Institute of Experimental Biology and Ecology of SAS; addr ul. Obrancov mieru 3, 814 34 Bratislava, Czechoslovakia; tele 335377; libr Catherina Kis-Csaji, the Chief of Scientific Information Department; salu Madam Kis-Csaji; subj botany, zoology, forest ecosystems, landscape planning; user staff of institution, students; serv reference on site, by mail, by telephone; inst Institute of Experimental Biology and Ecology of the Slovak Academy of Sciences.

136 loca Kostelec; name Knihovna ETU; addr Ústav aplikované ekologie a ekotechniky, 281 63 Kostelec n.Č.1, Czechoslovakia; tele [n.g.];libr Marie Kadlecová, Librarian; salu Mrs. Kadlecová; subj forestry in general,forest products (except pulp & paper), wildlife management, ecology; user faculty, students, staff; serv reference on site, by mail, inter-library loan; inst Vysoká škola zemědělská.*

137 loca Prague; name Library of the Czech Pulp and Paper Industry in IRAPA; addr Development and Rationalization Institute of the Paper and Pulp Industry, Přístavní 1, 170 04 Praha 7, Czechoslovakia; tele 805 241; libr Ing. Marie Kheilova CSc., Head of Library/ Documentation Centre; salu [n.g.]; subj pulp and paper; user students, staff, general public, staff of the Institute IRAPA, Czech Pulp and Paper Industry; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, copy services, translations; inst Czech Pulp and Paper Industry.

138 loca Vieska nad Žitavou; name Information Centre, "Arborétum Mlyňany"-Institute of Dendrobiology, Centre of Biologic-ecological Sciences of SAS; addr "Arborétum Mlyňany"-Institute of Dendrobiology of CBES SAS, Vieska nad Zitavou, 951 52 Slepčany, Czechoslovakia; tele Nitra 852 00, Zlaté Moravce 948 35; libr František Benčať, DrSc.; salu Professor Benčať; subj genetics of woody plants, plant physiology, systematics and ecology of the landscape (inclusive of horticulture); user staff of the institute and of the institutes in Czechoslovakia; serv on site use only; inst Slovak Academy of Sciences (SAS).

139 loca Zbraslav; name ODIS Knihovna VULHM; addr Jíloviště Strnady 255 01, Post Office Praha 5 Zbraslav, Czechoslovakia; tele 591-612; libr Ing. Josef Běle, CSc, Forest Engineer; salu Mr. Běle; subj forestry in general, wildlife management, forest tree breeding, forest protection, seed handling, silviculture, forest economics, forest machines, forest ecology, forestry and air pollution; user students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, publishing of guides and manuals, research reports; inst Ministry of Forestry and Water Conservation of the Czech Socialist Republic.

140 loca Zvolen; name Ústredná lesnícka a drevárska knižnica (SSR pri Vysokej škole lesníckej a drevárskej vo Zvolene); addr Marxova 20, 961 02 Zvolen, Czechoslovakia; tele 235 36; libr Jan Daniel, promovaný pedagóg; salu Mr. Daniel; subj forestry in general, forest products, pulp and paper, wildlife management, wood machining; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, classical searches; inst Vysoká škola lesnícka a drevárska vo Zvolene.

141 loca Zvolen; name Výskumný Ústav Lesného Hospodárstva - Knižnica; addr Marxova 2175, 96092 Zvolen, Czechoslovakia; tele 27311; libr J. Sobocká, Librarian; salu Mrs. Sobocká; subj forestry in general, forest products, wildlife management, environment; user staff; serv reference on site, interlibrary loan, compilation of bibliographies; inst Vyskumny Ustav Lesného Hospodarstva.

DENMARK

142 loca Copenhagen; name The Danish Veterinary and Agricultural Library; addr Bülowsvej 13, DK-1870 Copenhagen V., Denmark; tele 01/351788; libr Inge Berg Hansen, Chief Librarian; salu Ms. Hansen; subj forestry in general, forest products, range management, wildlife management, agriculture, veterinary medicine; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst The Royal Veterinary and Agricultural University.

FINLAND

143 loca Espoo; name Teknillisen Korkeakoulun Kirjasto (Helsinki University of Technology Library); addr Otaniementie 9, SF-02150 Espoo, Finland; tele 90/460-144; libr Elin Törnudd, Director of Libraries; salu Professor Tornudd; subj all fields of technology, including forest products, pulp and paper, wood machining; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, dial up use of online catalogs, online ordering; inst Helsinki University of Technology (Teknillinen Korkeakoulu).

144 loca Helsinki; name Finncell, Statistical Department; addr Eteläesplanadi 2, P.O.B. 60, 00101 Helsinki, Finland; tele 90/ 170721, ext.3458; libr Eila Muotinen, M.Pol.Sc.; salu Ms. Muotinen; subj pulp and paper; user staff; serv reference on site; inst Finncell.*

145 loca Helsinki; name Finnish Game and Fisheries Research Institute, Game Division Library; addr Pitkänsillanranta 3 A, SF-00530 Helsinki, Finland; tele 90/739133; libr Björn Ehrnsten, Librarian; salu Mr. Ehrnsten; subj wildlife management, zoology (Mammalia, Aves); user students, staff, scientists; serv reference on site, by telephone, by mail, interlibrary loan; inst Finnish Game and Fisheries Research Institute, Game Division.

146 loca Helsinki; name Helsinki University Library of Forestry (Metsäkirjasto); addr Unioninkatu 40 B, SF-00170 Helsinki, Finland; tele 90/19241; libr Annikki Karjalainen, Librarian; salu Ms. Karjalainen; subj forestry in general, forest products, range management; user faculty, students, staff, general public, wood industry; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searchs; inst Helsinki University.

147 loca Helsinki; name Metsäntutkimuslaitoksen kirjasto (Library of the Finnish Forest Research Institute); addr Unioninkatu 40 A, 00170 Helsinki, Finland; tele 358-0-831941; libr Liisa Ikävalko-Ahvonen, Librarian; salu Ms. Ikävalko-Ahvonen; subj forestry in general; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Metsäntutkimuslaitos (Finnish Forest Research Institute).

148 loca Helsinki; name Oy Keskuslaboratorio - Centrallaboratorium Ab. (The Finnish Pulp and Paper Research Institute) Technical Information Service; addr P.O. Box 136, SF-00101 Helsinki, Finland; tele 90/460 411; libr Birgitta Holm, M.Sc., Head of the Department; salu Ms. Holm; subj pulp and paper; user students, staff, general public; serv reference on site, by telephone, by mail, computer searches; inst Oy Keskuslaboratorio - Centrallaboratorium Ab.

149 loca Imatra; name Enso-Gutzeit Oy, Research Centre, Information Service Department; addr SF-55800 Imatra, Finland; tele 954/293241; libr Liisa Sihvo, Department Head; salu Ms. Sihvo; subj forestry in general, forest products, pulp and paper, chemistry; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Enso-Gutzeit Oy.

150 loca Kuusankoski; name Kymmene-Strömberg Corporation, Information Service; addr SF-45700 Kuusankoski, Finland; tele + 358 51 402 160; libr Tuija Löfgren, M.Sc.,CHEM.; salu Ms. Löfgren; subj pulp and paper; user staff of supporting institution; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Kymmene-Strömberg Corporation.

151 loca Lappeenranta; name Kaukas Oy Ab, Information Service; addr SF-53200 Lappeenranta, Finland; tele 358 53 5141; libr Marja-Liisa Pajari, M.Sc.; salu Ms. Pajari; subj pulp and paper; user staff; serv interlibrary loan, computer searches; inst Oy Kaukas Ab.

152 loca Oulu; name Tietopalvelu (Information Service); addr Oulu Oy, Pl 196, SF-90101 Oulu, Finland; tele 981-221411; libr Anja Mattinen, Librarian; salu Ms. Mattinen; subj forest products, pulp and paper; user faculty, students; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Oulu Oy.

153 loca Pietarsaari (Jakobstad); name Oy Wilh. Schauman Ab, Jakobstads Mills / Library; addr P.O. Box 42, 967/68601 Jakobstad, Finland; tele 10444/503; libr Rita Grahn, Chief of Information Department; salu Ms. Grahn; subj forestry in general, forest products, pulp and paper, converted paper products; user [n.g.]; serv [n.g.]; inst Oy Wilh. Schauman Ab.

154 loca Varkaus; name A. Ahlström Osakeyhtiö, Paper Mill Library; addr P.O. Box 169, SF-78201 Varkaus, Finland; tele 972/25445; libr Ann-Christine Eriksson, Information Scientist; salu Ms. Eriksson; subj forest products, pulp and paper; user staff; serv reference on site, by telephone, computer searches; inst Oy A. Ahlström Ab.

FRANCE

155 loca Champenoux; name Bibliothèque Sylviculture; addr I.N.R.A. Centre National de Recherches Forestières, Champenoux, F-54280 Seichamps, France; tele 83-32-09-21; libr J. Bouchon, Maître de Recherches; salu Mr. Bouchon; subj forestry in general; user faculty, students, general public, research workers; serv reference on site, by telephone, computer searches; inst I.N.R.A. Centre National de Recherches Forestières.

156 loca Grenoble; name Centre de Documentation pour les Industries Graphiques; addr Ecole Française de Papeterie, BP 65, Domaine universitaire 38402, St. Martin d'Heres Cedex, France; tele 76.42.01.27, poste 86; libr Elisabeth Grasset; salu Madame Grasset; subj pulp and paper, graphic arts industry; user staff, students, industrialists, faculty; serv reference on site, by mail, by telephone, interlibrary loan, bibliographic bulletin; inst Ecole Français de Papeterie.

157 loca Grenoble; name Centre Technique de l'industrie des papiers, cartous et cellulose, Service Documentation; addr Boîte postale 7110, F - 38020 Grenoble Cedex, France; tele 76.44.82.36; libr C. Roger, Ingénieur, Chef de Service; salu Mlle. Roger; subj pulp & paper; user students, staff of supporting institution, general public, French pulp and paper manufacturers; serv reference on site, by telephone, by mail, compilation of bibliographies; inst Centre Technique de l'Industrie des Papiers, Cartous et Cellulose.

158 loca Nancy; name Ecole Nationale du Génie Rural, des Eaux et des Forêts, Centre de Nancy, Bibliothèque; addr 14 rue Girardet, F-54042 Nancy Cedex, France; tele 83-35-10-20; libr Marie-Jeanne Lionnet; salu Melle. Lionnet; subj forestry in general, forest products, range management, wildlife management, ecology, botany, plant biology; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Ecole Nationale du Génie Rural, des Eaux et des Forêts, 19 avenue du Maine, F-75732 Paris Cedex 15, France

159 loca Nangis; name Association Forêt-Cellulose, Bibliothèque; addr Domaine de l'Etancon, F-77370 Nangis, France. tele 64-08-41-98, poste 31; libr D. Ricordeau; salu Mr. Ricordeau; subj forestry in general, forest products, pulp and paper, plant physiology; user students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Association Forêt - Cellulose (AFOCEL).

160 loca Nogent-Sur-Marne; name Centre Technique Forestier Tropical; addr 45 bis avenue de la Belle Gabrielle, 94736 Nogent-Sur-Marne Cedex, France; tele (1) 48.73.32.95; libr Michéle Nicolas; salu Melle. Nicolas; subj forestry, wood technology, breeding and forest genetics, chemistry, aquaculture; user staff, students, general public; serv reference on site, by mail; inst Centre Technique Forestier Tropical.

161 loca Nogent sur Vernisson; name Bibliothèque de l'Ecole Nationale des Ingénieurs des Travaux des Eaux et Forêts; addr Domaine des Barres, F-45290 Nogent sur Vernisson, France; tele 38-97-60-20, poste 417; libr Maryse Tripier, Bibliothécaire-Documentaliste; salu Mlle. Tripier; subj forestry in general, forest products, pulp and paper; user [n.g.]; serv reference by mail, by telephone, interlibrary loan; inst Ecole Nationale des Ingénieurs des Travaux des Eaux et Forêts.

162 loca Olivet; name Centre de recherches forestierès d'Orleans; addr Ardon 45160 Olivet, France; tele 38 63 0206; libr Audoux; salu Miss Audoux; subj silviculture, forest genetics, biomass, forest entomology; user [n.g.]; serv reference on site, interlibrary loan, computer searches; inst Ministere de l'Industrie et de la Recherche, Ministere de l'Agriculture, I.N.R.A.

163 loca Paris; name Centre Technique du Bois et de l'Ameublement, Section Documentation; addr 10 av. de Saint Mande, 75012 Paris, France; tele (1) 43 44 06 20; libr F. Vigier; salu Mme. Vigier; subj wood properties, wood technology, wood products, furniture, wood preservation; user all publics; serv on site use only, reference on site, by mail, by telephone, interlibrary loan, photocopying; inst Centre Technique du Bois et de l'Ameublement.

164 loca Paris; name Direction des Forêts Documentation; addr 1, Avenue de Lowendal, F-75700 Paris, France; tele (1) 45.55.95.50 poste 32.07; libr C. Pugin, Documentaliste; salu Melle. Pugin; subj forestry in general, forest products; user faculty, students, staff, general public; serv reference on site; inst Ministere de l'Agriculture.*

165 loca Paris; name Institut pour le developpement forestier; addr 23 avenue Bosquet, F-75007 Paris, France; tele (1) 45.55.23.49; libr A. M. Maillard; salu Mme. Maillard; subj silviculture, forest economics, parks and recreation, trees outside forests; user staff of institution, students, forest professionals when required; serv on site use only; inst Institut pour le developpement forestier.

166 loca Paris; name Office National des Forêts (O.N.F.), Service Documentation; addr 2 av. de Saint Mandé, 75012 Paris, France; tele (1) 43 46 11 68; libr M. Charlemagne; salu Mme. Charlemagne; subj forestry in general, state forest management, environment, wildlife; user staff of institution only, professionals when required; serv on site use, information by telephone; inst Ministère de l'Agriculture

167 loca Toulouse; name Bibliothèque du Laboratoire botanique et forestier; addr Université Paul Sabatier, 39, allees Jules Guesde, 31-Toulouse, (addresse postale) F-32062 Toulouse Cedex, France; tele (61) 53-02-35; libr Guy Durrieu, Professeur; salu Prof. Durrieu; subj forestry in general, systematic botany; user faculty, students, staff, professional nurserymen; serv reference on site, interlibrary loan; inst Université Paul Sabatier.

GERMANY, DEMOCRATIC REPUBLIC

168 loca Eberswalde; name Institut für Forstwissenschaften Eberswalde, Bibliothek; addr DDR - 13 Eberswalde - Finow 1, Alfred Möller Straße, German Democratic Republic; tele 650; libr Professor Dr. Manfred Schütze; salu Dr. Schutze; subj forestry in general, forest products, wildlife management, wood machining, parks and recreation, other; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Ministerium für Land-, Forst- und Nahrungsgüterwirtschaft der DDR.

169 loca Tharandt; name Technische Universitat Dresden, Sektion Forstwirtschaft; addr DDR 8223 Tharandt, Pienner Str. 8, German Democratic Republic; tele 6231; libr Prof. Dr. Kabil F. Paul; salu Prof. Dr. Paul; subj forestry in general, forest products, wildlife management, biology, zoology, soil science, ecology, tropical forestry, physical environment; user staff, faculty, students, general public; serv reference on site, by telephone, by mail, compilation of bibliographies; inst Technische Universitat Dresden.

GERMANY, FEDERAL REPUBLIC

170 loca Berlin; name Bibliothek der Biologischen Bundesanstalt für Land- und Forstwirtschaft; addr Königin-Luise-Straße 19, D-1000 Berlin 33, Fed. Rep. Germany; tele 030/8304216; libr W. Laux, Prof.; salu Prof. Laux; subj plant protection, phytopathology, forest protection; user students, staff, members of German plant protection service; serv reference by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Biologische Bundesanstalt für Land- und Forstwirtschaft.

171 loca Braunschwieg; name Library Braunschweig of the Federal Research Centre for Agriculture and Forestry; addr Messeweg 11/12, D-3300 Braunschweig, West Germany; tele (0537) 399 290 or 292; libr Wolfgang Koch; salu Dr. Koch; subj phytopathology and plant protection in agriculture and forestry; user staff of institution, plant protection service, faculties, students, general public; serv interlibrary loan; inst Federal German government, Ministry of Agriculture.

172 loca Darmstadt; name Bibliothek und Archiv Zellcheming; addr Alexanderstraße 24, D-6100 Darmstadt, Fed. Rep. Germany; tele 06151/162277; libr Th. Krause, Bibliothek Zellcheming; salu Prof. Dr. Krause; subj pulp and paper (chemistry); user faculty, students, staff of supporting institution, general public, industries; serv reference on site, by mail, compilation of bibliographies, quick reference service (on cards); inst Verein Zellcheming, Technische Hochschule Darmstadt.

173 loca Freiburg; name Fakultätsbibliothek / Forstwissenschaft; addr Bertoldstrasse 17, D-7800 Freiburg, Fed. Rep. Germany; tele 0761/203-3752; libr Jutta Giencke; salu Mrs. Giencke; subj forestry in general, forest products, pulp and paper, forest management; user faculty, students, staff, other libraries; serv reference on site, by telephone, by mail, interlibrary loan; inst Universität Frieburg i Br.

174 loca Göttingen; name Bibliothek der Forstlichen Fakultät; addr Büsgenweg 5, D-3400 Göttingen, Fed. Rep. Germany; tele 0551/303407; libr Christiane Kollmeyer, Diplom-Bibliothekarin; salu Frau Kollmeyer; subj forestry in general, forest products, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan; inst Universität Göttingen. Land Niedersachsen.

175 loca Göttingen; name Bibliothek der Niedersächsischen Forstlichen Versuchsanstalt; addr Grätzelstrasse 2, D-3400 Gottingen, Fed. Rep. Germany; tele 0551 - 6 40 36; libr Gerda Knoblich; salu Frau Knoblich; subj silviculture, growth and yield, mensuration; user staff only; serv on site use only; inst Niedersächsische Forstliche Versuchsanstalt.

176 loca Göttingen; name Bibliothek für Agrarentwicklung in den Tropen und Subtropen am Institut fur Rurale Entwicklung/ Library for Agricultural Development in the Tropics and Subtropics of the Institute for Rural Development; addr Büsgenweg 2, D-3400 Göttingen, Fed. Rep. Germany; tele 0551/393914; libr J. S. Koch, M.A., Librarian; salu Mrs. Koch; subj forestry in tropical and subtropical countries, agroforestry; user faculty, students, staff, general public; serv reference on site; inst Georg- August-Universität (University of Göttingen)

177 loca Gross Umstadt; name Forsttechnische Informationszentrale; addr Kuratorium für Waldarbeit und Forsttechnik, Sprembergerstrasse 1, D-6114 Gross Umstadt, Fed. Rep. Germany; tele 06078/2017; libr H.-Chr. Meyer, Forstrat; salu Mr. Meyer; subj forestry machinery, technical information on forestry machines; user students, staff, general public, manufacturers of forestry-machinery, forest-offices, forest-owners; serv reference by telephone, by mail, infos (technical information on forestry-machinery); inst Federal Ministry of Food, Agriculture and Forestry, and forest administrations of states.

178 loca Hamburg; name Bundesforschungsanstalt für Forst- und Holzwirtschaft, Wissenschaftliche Fachbibliothek; addr Postfach 800210 Leuschnerstr. 91, D-2050 Hamburg 80 / Fed. Rep. Germany; tele 040/73962-442; libr Ulrike Reupke, Diplombibliothekarin; salu Frau Reupke; subj forestry in general, forest products, pulp and paper, wildlife management, ecology; user faculty, students, staff, general public, other libraries; serv reference on site, by mail, by telephone, interlibrary loan; inst Bundesministerium für Ernährung, Landwirtschaft und Forsten, D-5300 Bonn, Fed. Rep. Germany.

179 loca Hann. Münden; name Hessische Forstliche Versuchsanstalt; addr Postfach 1308, D-3510 Hann. Münden 1, Fed. Rep. Germany; tele 05541 / 1032; libr Ettine Boden; salu Miss Boden; subj forest genetics, forest tree breeding, forest production, forest hydrology, forest protection, forest decline; user staff of institution and Hessian State Forest Service, visitors with special permission; serv on site use only; inst State of Hessian and Research Inst. for Fast Growing Tree Species.

180 loca Hannover; name Bücherei des Niedersächsischen Ministers für Ernährung, Landwirtschaft und Forsten; addr Calenberger Strasse 2, D-3000 Hannover 1, West Germany; tele 0511/120-2237; libr Stefan Goetz, Librarian; salu Herr Goetz; subj silviculture, agroforestry, forest economics, forest legislation; user staff of institution and general public; serv on site use only, interlibrary loan; inst Der Niedersächsische Minister für Ernährung, Landwirtschaft und Forsten.

181 loca Munich; name Bibliothek der Papiertechnischen Stiftung; addr Hessstrasse 130a, D-8000 München 40, Fed. Rep. Germany; tele 089/126001-41; libr Nina Schur; salu Mrs. Schur; subj pulp and paper; user faculty, students, staff; serv reference by mail, computer searches; inst Papiertechnische Stiftung.

182 loca Munich; name Forstwissenschaftliche Fakultät der Universität München, Bibliothek; addr Amalienstr. 52, D-8000 München 40, Fed. Rep. Germany; tele 089 21803122; libr Wolf-Dietrich Schulze, Bibliotheks Inspektor; salu Herr Schulze; subj forestry in general, forest products (except pulp & paper), wildlife management; user faculty, students, staff; serv reference on site; inst Bayerische Versuchs- u. Forschungsanstalt.

183 loca Munich; name Lehrstuhl für Forstpolitik und forstliche Betriebswirtschaftslehre; addr Amalienstr. 52, D-8000 München-40, Fed. Rep. Germany; tele 089/ 2180-3137; libr Luise Wolf; salu Mrs. Wolf; subj forestry and general economics, forest administration, timber and forest products marketing, forestry in general, forest products, pulp and paper; user staff, students; serv reference on site; inst Forstwissenschaftliche Fakultät der Universität München.

184 loca Rosenheim; name Lehrinstitut der Holzwirtschaft, Bibliothek; addr Kuepferlingstrasse 66, D-8200 Rosenheim, Fed. Rep. Germany; tele 08031/14075; libr Ulf Lohmann, Teacher / Technischer Holzkaufmann HTR; salu Mr. Lohmann; subj forest products, sawmilling, timber trade, furniture, plastics, tools, machinery; user students, staff; serv reference on site; inst Lehrinstitut der Holzwirtschaft.

185 loca Wiesbaden; name Der Hessische Minister für Landwirtschaft, Forsten und Naturschutz, Bibliothek; addr Hölderlinstr. 1-3, Postfach 3127, D-6200 Wiesbaden, Fed. Rep. Germany; tele 06121 / 817-2243; libr Christiane Böckler-Wentlandt, Dipl. Bibl.; salu Frau Böckler; subj parks and recreation, environmental protection; user staff of institution; serv on site use only, reference on site, by mail and by telephone, monthly compilation of new books; inst Der Hessische Minister für Landwirtschaft, Forsten und Naturschutz.

GREECE

186 loca Athens; name Forest Research Institute of Athens; addr Terma Alkmanos, Ilissia, 115 28, Athens, Hellas [Greece]; tele / 77 84 850; libr M. Pavlopoulou; salu Mrs. Pavlopoulou; subj silviculture, forest genetics, forest economics, wood machining, parks and recreation; user staff of institution, students; serv on site use, reference by mail, by telephone, interlibrary loan, compilation of bibliographies; inst Greek Ministry of Agriculture.

187 loca Thessaloniki; name Forest Research Institute of Thessaloniki; addr Vassilika - Thessaloniki, Greece; tele 461-171; libr Eleni Hertura; salu [n.g.]; subj forestry in general, forest products, range management; user staff; serv reference by mail; inst [n.g.].

HUNGARY

188 loca Budapest; name Erdészeti Tudomanyos Intézet Könyvtara (Library of the Forest Research Institute); addr Frankel Leo u. 42-44, H-1023 Budapest, Hungary; tele 150-624; libr Balintne Luka Barcza; salu [n.g.]; subj forestry in general, silviculture, forest protection, environmental protection, technical development; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Erdészeti Tudomanyos Intézet (Forest Research Institute).

189 loca Budapest; name Muszaki Konyvtar (Technical Library); addr Faipari Kutatointezet Muszaki Konyvtara, Budapest, Pesterzsebet 1, Pf. 64, 1725 Hungary; tele Telex: 227902; libr Emese Juszka, librarian; salu Mrs. Juszka; subj wood machining, production of particle board, production of fibre board, wood preservation, wood anatomy; user staff of institution, students; serv reference on site, by mail, interlibrary loan, compilation of bibliographies; inst Faipari Kutatointezet (Research Institute for the Wood Industry).

190 loca Sopron; name University of Forestry and Wood Science, Central Library; addr 9400 Sopron, Bajcsy Zs. u. 4, Hungary; tele 11-100; libr Istvan Hiller, Director-General of Library; salu Dr. Hiller; subj forestry in general, forest products, pulp & paper, range management, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst University of Forestry and Wood Science.

IRELAND

191 loca Bray; name Forest and Wildlife Service Library; addr 1-3 Sidmonton Place, Bray, Co. Wicklow, Ireland; tele 01-867751; libr Mary Moore, Librarian; salu Ms. Moore; subj forestry in general, forest products (except pulp and paper), soils, plant and animal ecology; user students, staff, general public, foresters; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Dept. of Fisheries and Forestry.

192 loca Dublin; name Dept. of Fisheries and Forestry - Library; addr Leeson Lane, Dublin 2 Ireland; tele 01-600444; libr Mary Moore; salu Ms. Moore; subj silviculture, forest genetics, forest economics, wildlife management, parks and recreation; user staff of institution, general public; serv reference by telephone or mail, interlibrary loan, compilation of bibliographies; inst Dept. of Fisheries and Forestry.

193 loca Dublin; name The Library, Faculty of Agriculture, University College, Dublin; addr Belfield, Dublin 4, Ireland; tele 693244; libr Mary McErlean; salu Mrs. McErlean; subj forestry in general, wildlife management, general agriculture and horticulture; user faculty, students, external readers; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University College, Belfield, Dublin 4.

ITALY

194 loca Casale Monferrato; name Istituto di Sperimentazione per la Pioppicoltura; addr Casella Postale 116, I-15033 Casale Monferrato (Alessandria)-Italy; tele 5.46.54; libr Guiseppina Varese; salu Mrs. Varese; subj forestry in general, forest products, pulp and paper, poplar breeding and growing; user staff; serv reference on site; inst S.A.F. -Istituto di Sperimentazione per la Pioppicoltura.

195 loca Firenze; name Accademia Italiana de Scienze Forestali-Biblioteca; addr Piazza Edison, 11, I-50133 Firenze, Italy; tele 055/570348; libr Ezio Magini, M. Cristina Puccioni; salu Prof. Magini, Mrs. Puccioni; subj forestry in general; user students, staff, general public; serv reference on site, interlibrary loan; inst Ministero Beni Culturali.

196 loca Firenze; name Biblioteca dell'Istituto de Selvicoltura; addr Via S. Bonaventura 13, 50145 Firenze, Italy; tele 055/ 375147; libr Alessandra Zanzi Sulli; salu Prof. Sulli; subj silviculture, wildlife management, forest genetics; user staff of institution, faculty, students; serv on site use only; inst Universita degli Studi di Firenze.

197 loca Firenze; name Biblioteca dell'Istituto per la Ricerca sul Legno; addr Piazza Edison, 11 - Villa Favorita, I-50133 Firenze, Italy; tele 055/570210; telex 57 24 58 ILFI-I; libr Simonetta Del Monaco; salu Dr. Del Monaco; subj forest products, forestry in general; user students, staff; serv reference on site, by mail, compilation of bibligraphies; inst Consiglio Nazionale delle Richerche.

198 loca Firenze; name Biblioteca della Facolta' di Agraria e Forestale; addr Universita di Firenze, Piazzale delle Cascine,18, I-50144, Firenze, Italy; tele 055/352051; libr Piero Chelazzi, Library Manager; salu Mr. Chelazzi; subj forestry in general, forest products (except pulp & paper), range management, wildlife management; user faculty, students, staff; serv reference on site, by mail, interlibrary loan; inst Consiglio Nazionale delle Ricerche C.N.R., Ministero Pubblica Istruzione, Rome.

199 loca Firenze; name Istituto Assestamento e Tecnologia Forestale; addr Via San Bonaventura 13, 50145 Firenze, Italy; tele [0039] 055-37 24 37/37 25 12; libr Giovanni Bernetti; salu Prof. Bernetti; subj forest management, forest products; user staff, faculty members, students, external researchers/specialists; serv on site use only; inst University of Florence.

200 loca Grugliasco (Torino); name Istituto di Selvicoltura e Assestamento Forestale; addr Via Leonardo da Vinci, 44, 10095 Grugliasco (TO), Italia; tele 011/ 41.15.270; libr Mario Pividori; salu Dr. Pividori; subj silviculture, ecology; user faculty, students; serv by mail; inst University of Turin.

201 loca Padua; name Forest Department, Institute of Silviculture-Library; addr Via Gradenigo, 6, I-35100 Padova, Italy; tele 049/80.71.736; libr G. Tonello, Interpreter; salu Mr. Tonello; subj forestry in general, forest products, pulp and paper, range management, ecology (general), forest ecology, watershed management, soil protection, land planning, nature protection, pollution control; user faculty, students, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Universita degli Studi di Padova.

202 loca Roma; name Biblioteca, Centro di Sperimentazione Agricola e Forestale (S.A.F.-E.N.C.C. Group); addr P.O. Box 9079, 00100-Roma, Italia; tele + 39 6 6960241; libr Wanda Di Domenico; salu Dr. Di Domenico; subj fast growing forest species (poplars, eucalypts and some pines); all aspects; user staff use only; serv site use only; inst Societa' Agricola e Forestale per le Piante de Cellulosa e da Carta (S.A.F.).

203 loca San Michele all'Adige; name Istituto per la Tecnologia del Legno, Servizio Documentazione - Biblioteca; addr I-38010 San Michele all'Adige (Trento), Italy; tele 0461/650168; 650485, Telex 400453 ILSMA - I; libr Oscar Del Marco, (Emanuela Cristellotti, Librarian); salu Dr. Del Marco and Mrs. Cristelotti; subj forestry in general, forest products; user students, staff, general public, woodworking industries; serv reference on site, by mail, compilation of bibliographies, computer searches; inst Consiglio Nazionale delle Ricerche (National Research Council) and Istituto per la Tecnologia del Legno.

204 loca Torino; name Istituto per le Piante da Legno e l'Ambiente S.p.A.; addr Corso Casale, 476 - 10132 Torino, Italy; tele 011 - 89.89.33; libr Emma de Vecchi; salu Mrs. de Vecchi; subj silviculture, forest ecology, forest management, land use and cartography, waste recycling; user institute's staff, students; serv on site use only; inst Regione Piemonte.

205 loca Villazzano (Trento); name Library, Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura; addr Villa S. Carlo, I - 38050 Villazzano (Trento), Italy; tele 0461 - 924248; libr G. Tabacchi; salu Dr. Tabacchi; subj forest management, forest biometrics, range management; user staff of institution, students; serv on site use only; inst Istituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura.

NETHERLANDS

206 loca Delft; name Bibliotheek Houtinstituut TNU; addr Postbus 151, 2600 AD Delft, The Netherlands; tele 015 - 569330; libr J. van der Elburg; salu Miss van der Elburg; subj particleboard, wood anatomy, woodworking, preservation, wood chemistry; user general public; serv on site use, by mail, by telephone, interlibrary loan, computer searches, compilation of bibliographies; inst Houtinstituut TNO (TNO Timber Research Institute).

207 loca Utrecht; name State Forest Service, Bibliotheek addr Postbox 20020, 3502 LA Utrecht, Netherlands; tele 030/852410; libr J.G.L. Veerman; salu Mr. Veerman; subj forestry in general, wildlife management, nature conservation, landscape architecture, recreation; user students, staff of supporting institution, general public; serv reference by telephone, by mail, interlibrary loan; inst State Forest Service.

208 loca Wageningen; name Dorschkamp Research Institute for Forestry and Landscape Planning; addr Bosrandweg 20, Wageningen; (postal address: P.O. Box 23, 6700 AA Wageningen, Netherlands; tele 08370/95111; libr G.H. Jansen; salu Ms. Jansen; subj forest ecology, silviculture, forest soils, tree physiology, forest genetics, pests and diseases, forest techniques, forest economics and policy, urban forestry, landscape planning, tropical forestry; user staff of institution, students, general public; serv reference on site, by mail, by telephone, interlibrary loan, computer data base searches; inst Dorschkamp.

209 loca Wageningen; name Forestry Library of the Agricultural University; addr Postbus 342, 6700 AH Wageningen, Netherlands; tele 08370 - 82542; libr E. J. Waller-Wohlleben; salu Mrs. Waller; subj silviculture, forest technique and products, forest management, tropical forestry, forest economics; user staff of the Forestry Department of the Agricultural University, staff of the Agricultural University, students, general public; serv reference on site, interlibrary loan, computer searches; inst Agricultural University.

NORWAY

210 loca Ås; name The Library of the Agricultural University of Norway; addr P. O. Box 12, N-1432 Ås, Norway; tele (02) 949060; libr Jon Hjeltnes, Head Librarian; salu [n.g.]; subj silviculture, forest genetics, forest economics, wildlife management, parks and recreation; user open to all; serv reference on site, by mail, by telephone, computer searches, interlibrary loan; inst Agricultural University of Norway.

211 loca Ås-NLH; name Norsk Institutt for Skogforskning, Biblioteket; addr P.O. Box 61, 1432 Ås-NLH, Norway; tele (02)94 96 42; libr Mari Nordang, Librarian; salu [n.g.]; subj forestry in general; user staff of institution, students, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Norsk Institutt for Skogforskning (Department of Agriculture).

212 loca Oslo; name Norsk Treteknisk Institutt. Biblioteket; addr Box 337 Blindern, 0314 Oslo 3, Norway; tele 02/46 98 80, ext 763; libr Elise Furu, Librarian; salu [n.g.]; subj forest products (except pulp and paper); user staff of supporting institution, general public, industry; serv reference on site, by telephone, by mail, interlibrary loan; inst Norsk Treteknisk Institutt.

213 loca Trondheim; name Direktoratet for Naturforvaltning; addr Tungasletta 2, N-7000 Trohndeim, Norway; tele 075/37020; libr Anja Lydersen, Librarian; salu [n.g.]; subj range management, wildlife management; user staff of supporting institution; serv reference on site, interlibrary loan; inst [n.g.].

214 loca Vinderen; name Papirindustriens Forskningsinstitutts Bibliotek; addr POB 250, Vinderen, Oslo 3, Norway; tele 02/14 00 90; libr Bep Odegaard, Librarian; salu [n.g.]; subj pulp and paper; user staff of supporting institution, other; serv reference on site, by telephone, by mail, interlibrary loan; inst Papirindustriens Forskningsinstitutt.

POLAND

215 loca Poznan; name Zaklad Informacji Naukowo-Technicznej, Ekonomicznej i Patentowej (Department of Information and Documentation); addr Instytut Technologii Drewna, ul. Winiarska 1, 60-654 Poznan, Poland; tele 22-40-81; libr Maria Abramowicz-Wnuk; salu [n.g.]; subj forest products (except pulp and paper); user faculty, students, staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Ministerstwo Rolnictwa, Lesnictwa i Gospodarki Zywnosciowej (Ministry of Agriculture, Forestry and Food Economy).

216 loca Warsaw; name Zaklad Informacji Naukowo-Technicznej i Ekonomicznej Lesnictwa; addr ul. Wery Kostrzewy 3, 00-973 Warszawa, Poland; tele 22/32-01; libr Leopold Rossakiewicz, Doktor Inzynier; salu Dr. inz. Rossakiewicz; subj forestry in general, forest products (except pulp & paper), wildlife management; user students, staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Instytut Badawczy Lesnictwa.

PORTUGAL

217 loca Lisbon; name Centro de Documentaçao/Biblioteca do Instituto dos Produtos Florestais; addr Rua Braamcamp, 14, 1°., 1200 Lisboa, Portugal; tele 19/54 32 98; libr Dr. Fernando Jorge de Almeida Madeira; salu [n.g.]; subj forestry in general, forest products, pulp and paper, milling, wood, resins, forest industries, commerce, economics in general, international forest politics; user students, staff, silviculturists and economists; serv reference on site, by telephone, by mail, interlibrary loan; inst Instituto dos Produtos Florestais.*

RUMANIA

218 loca Brasov; name Biblioteca Centrala; addr B-dul Gh. Gheorghiu-Dej nr. 9, R-2200 Brasov, România; tele 21/44442; libr Conf.dr.ing. A. Negrutiu; salu Dr. Negrutiu; subj silviculture, wood machining, forest genetics, forest economics, wildlife management; user staff of institution, faculty, students; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Universitatea din Brasov; note Material on forestry and related subjects is only part of the collection of the library.

SPAIN

219 loca Madrid; name Biblioteca de la Escuela Técnica Superior de Ingenieros de Montes; addr Univ. Politecnica de Madrid, Ciudad Universitaria, 28040 Madrid, Espana; tele 243.70.06/07, 243.12.07; libr Rosario Martin-Montalvo y San Gil, Directora de la Biblioteca; salu [n.g.]; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students; serv reference on site, by telephone, by mail, interlibrary loan; inst Universidad Politécnica de Madrid.

220 loca Madrid; name Biblioteca de la Escuela Universitaria de Ingenieria Técnica Forestal; addr Escuela Universitaria de Ingenieria Técnica Forestal, Ciudad Universitaria, Madrid (3) Espana; tele 2-43-66-01; libr José Maria Gomez Rodriguez, Auxiliar de Archivos, Bibliotecas y Museos - Economista; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, staff , general public; serv reference on site; inst Escuela Universitaria de Ingenieria Técnica Forestal.*

SWEDEN

221 loca Garpenberg; name Sveriges Lantbruksuniversitet, Garpenbergsbiblioteket; addr S-770 73 Garpenberg, Sweden; tele 0225/221 00; libr Staffan Fridell, Librarian; salu [n.g.]; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students; serv reference on site, by mail, by telephone, interlibrary loan, computer searches; inst Sveriges Lantbruksuniversitet.

222 loca Jönköping; name Skogs- och Jordbruksbiblioteket ; addr S-551 83 Jönköping, Sweden; tele 36/169420; libr Inga Hedström, Librarian; salu [n.g.]; subj forestry in general, agriculture; user staff of supporting institution; serv reference on site, by telephone, by mail, interlibrary loan; inst National Board of Forestry, National Board of Agriculture, and National Agricultural Market Board.

223 loca Stockholm; name Forskningsstiftelsen Skogsarbetens Bibliotek; addr Box 1184, S-16313 Spånga, Sweden; tele 08/750 72 20; libr Helene Göransson, Librarian; salu Miss. Göransson; subj techniques and methods for different forest operations; user staff; serv reference on site; inst The Forestry Operations Institute ("Skogsarbeten").

224 loca Stockholm; name Kungl. Skogs- och Lantbruksakademiens bibliotek; addr Box 6808, S-113 86, Stockholm, Sweden; tele 08/ 30 07 08; libr Yvonne Orlog Hedvall, Chief Librarian; salu [n.g.]; subj forestry in general, range management, wildlife management; user students, staff, general public, members of the Academy; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst The Royal Swedish Academy of Agriculture and Forestry

225 loca Stockholm; name Träteknikcentrum, Bilioteket; addr Box 5609, S-114 86, Stockholm, Sweden; tele 08-145300; libr Laila Gunnare, Librarian; salu Mrs. Gunnare; subj Forest products (except pulp & paper); user students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Swedish Institute for Wood Technology Research.

226 loca Stockholm; name Troedssonbiblioteket; addr STFI, Troedssonbiblioteket, Box 5604, S-114 86 Stockholm, Sweden; tele 08/ 22 43 40; libr Sven Rasmusson, Librarian; salu [n.g.]; subj forest products, pulp and paper; user students, staff; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Swedish Forest Products Research Laboratory.

227 loca Uppsala; name Sveriges Lantbruksuniversitets Bibliotek, Ultunabiblioteket; addr S-750 07 Uppsala, Sweden; tele 018/17 10 00; libr H. Peter Hallberg, Deputy Librarian; salu [n.g.]; subj forestry in general, wildlife management, agriculture and veterinary medicine; user faculty, students, staff of supporting institutions; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, e.g. the yearly published Svensk lantbruksbibliografi (Bibliography of Swedish agriculture, forestry and veterinary medicine), computer searches, SDI-service, e.g. from the database LANTDOK (containing references to Swedish literature in agricultural sciences); inst Sveriges Lantbruksuniversitet; note The main holdings of the Ultuna library consist of agricultural and veterinary literature. The greater part of forestry literature is handled by two branch libraries: 1) Sveriges Lantbruksuniversitet, Skogsbiblioteket, Umea, Sweden, and 2) Sveriges Lantbruksuniversitet, Garpenbergsbiblioteket, Garpenberg, Sweden.

228 loca Umeå; name Sveriges Lantbruksuniversitet. Skogsbiblioteket (The Swedish University of Agriculture. Library of Forestry); addr 901 83 Umeå, Sweden; tele 90/16 58 02; libr Monica Danielsson, Librarian; salu [n.g.]; subj forestry in general and related subjects (environment, biology, botany, etc.); user faculty, students, staff of supporting institution, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Sveriges Lantbruksuniversitet. Skogsvetenskapliga Fakulteten (Swedish University of Agriculture. Department of Forestry).

SWITZERLAND

229 loca Birmensdorf; name Eidgenöessische Anstalt fuer das forstliche Versuchswesen, Bibliothek (Swiss Federal Institute of Forestry Research); addr CH-8903 Birmensdorf, Switzerland; tele (01) 739 22 07; libr Regina Schenker, Librarian; salu Ms. Schenker; subj forestry and forest products, silviculture, forest economics, dendrochronology; user staff, scientists; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Schweizerischer Schulrat (Board of the Swiss Federal Institute of Technology).

230 loca Zürich; name Forstbibliothek; addr Eidg. Technische Hochschule, Institut für Wald- und Holzforschung, CH-8092 Zürich, Switzerland; tele (01) 256 32 09; libr Rosmarie Louis, Librarian; salu Miss Louis; subj forestry in general, silviculture, wildlife management, botany, ecology; user faculty, students, staff of supporting institution, general public; serv reference on site, by telephone, by mail, interlibrary loan (restricted service only); inst Eidg. Technische Hochschule, Zürich.

TURKEY

231 loca Ankara; name Ormancilik Arastirma Enstitusu Kutuphane Mudurlugu; addr P.K. 24, Bahcelievler, Ankara, Turkey; tele 225390/2024; libr Nihat Yilmaz, Director of the Library; salu Mr. Yilmaz; subj silviculture, forest genetics, forest economics, wood machining, range management, forest management, forest products, mathematics-statistics; user staff of institution, faculty, students; serv site use, reference on site, by mail, by telephone, interlibrary loan (in Turkey only); inst Forest Research Institute (Ormancilik Arastirma Enstitusu).

232 loca Trabzon; name K.T.U. Orman Fakültesi Kütüphanesi; addr Karadeniz Universitesi, Orman Fakultesi, Trabzon, Turkey; tele 13920 (031); libr Harzemsah Hafizoglu, Asst. Prof.; salu Dr. Hafizoglu; subj silviculture, pulp and paper, wood machining, wildlife management, forest management; user faculty, students; serv reference on site, interlibrary loan; inst [n.g.].

UNITED KINGDOM

233 loca Aberdeen; name Forestry Department Library; addr University of Aberdeen, St. Machar Drive, Old Aberdeen, Scotland AB9 2UU; tele 40241, ext. 6510; libr Ian R. Brown; salu Dr. Brown; subj silviculture, forest genetics and physiology, management, forest products, arboriculture; user staff and students; serv on site use only; inst Aberdeen University.

234 loca Aylesbury; name Building Research Establishment, Princes Risborough Laboratory, Library; addr Princes Risborough, Aylesbury, Bucks, HP17 9PX, England; tele 084 44 3101, ext. 362; libr position vacant; salu [n.g.]; subj forestry in general, forest products (except pulp and paper), materials and components; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Building Research Establishment; note The library is scheduled to move during 1987 to: Department of the Environment, Building Research Establishment, Building Research Station, Garston, Watford, WD2 7JR; tele 0923 674040.

235 loca Bangor; name The Science Library; addr Deiniol Road, Bangor, Gwynedd LL57 2UW, United Kingdom; tele 0248-351151; libr Nigel Soane, Science Librarian; salu Mr. Soane; subj wood science, environmental forestry; user staff and students of the University of Wales; members of the general public upon application; serv on site use and loan, interlibrary loan, computer searches; inst University College of North Wales.

236 loca Edinburgh; name Darwin Library; addr Edinburgh University, Kings Buildings, Edinburgh EH9 3JU Scotland; tele 031-667-1081, ext. 2716; libr Alison M. N. Wood; salu Ms. Wood; subj agroforestry, silviculture, forest entomology, wildlife management; user university staff, students; serv on site use, person loans, interlibrary loans, information by mail or telephone; inst University of Edinburgh.

237 loca Edinburgh; name Institute of Terrestrial Ecology; addr Edinburgh Research Station, Bush Estate, Penicuik, Midlothian, EH26 OQB; tele Edinburgh 031-445-4343; libr [n.g.]; salu The Librarian; subj Physiology and ecology of trees, both as individuals and in forests and plantations. Research on air pollution, in particular its effect on trees, and bryophytes.; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst The Natural Environment Research Council.

238 loca Edinburgh; name Planning and Surveys Library; addr Forestry Commission, 231 Corstorphine Road EH12 7AT; tele 031-334-0303; libr Muriel Stickle; salu Mrs. Stickle; subj forest economics, economics; user staff; serv on site reference; inst Forestry Commission.

239 loca Farnham; name Forestry Commission Library; addr Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, England, GU10, 4LH; tele Bentley (0420) 22255; libr E. M. Harland; salu Mrs. Harland; subj forestry in general (concentrating on temperate climate), arboriculture; user staff, general public, personnel involved in private forestry; serv reference on site, by telephone, by mail, interlibrary loan (within UK only), compilation of bibliographies, computer searches (for F.C. staff only), current awareness and SDI services (within UK only); inst Forestry Commission of Great Britain.

240 loca Grange-over-Sands; name Institute of Terrestrial Ecology; addr Merlewood Research Station, Grange-over-Sands, Cumbria, England; tele 044-84-2264; libr J. Beckett, Chief Librarian; salu Mr. Beckett; subj forestry in general, ecological processes and management effects; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Natural Environment Research Council; note ITE has libraries at six sites - Monks Wood, Bush Estate, Bangor, Banchory, Furzebrook, and the Cultural Centre of Algae and Protozoa in Cambridge. Contact address for all is via Merlewood Research Station, as shown above.

241 loca High Wycombe; name Bucks. College of Higher Education; addr Queen Alexandra Rd., High Wycombe, Bucks. HP11 2JZ, United Kingdom; tele High Wycombe (0494) 22141; libr Alain S. Larche, BA, ALA; salu Mr. Larche; subj timber properties, wood products, wood preservation, wood working and joinery, furniture industry; user staff and students of Timber Technology, general public; serv main reference library, interlibrary loan, computer searches, bibliographies; inst Library and Learning Resources, Bucks. College of Higher Education.

242 loca High Wycombe; name Timber Research and Development Association, Library; addr Stocking Lane, Hughenden Valley, High Wycombe, Bucks., HP14 4ND, England; tele 0240-24 3091; libr Anne Peters, Librarian; salu Mrs. Peters; subj forest products (except pulp and paper); user students, staff, general public; serv reference on site, reference by telephone, reference by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Timber Research and Development Association.

243 loca Kew; name Royal Botanic Gardens; addr Library, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AE, England; tele 01-960-1171, TELEX: 296694; libr S. M. D. Fitzgerald, Chief Librarian & Archivist; salu Miss Fitzgerald; subj forest botany, anatomy of woods; user staff, bona-fide researchers only, by written appointment in advance; serv reference only, photocopying; inst Royal Botanic Gardens.

244 loca London; name Land Resources Development Centre Library; addr Tolworth Tower, Surbiton, Surrey KT6 7DY England; tele 01-399 5281, Librarian ext. 117, enquiries ext. 21 or 25; libr Philip Reilly; salu Mr. Reilly; subj land resource appraisal; user staff of the Centre plus other research workers - normally postgraduate; serv subject enquiry using our computerized library database (TRADIS), loans available to other libraries; inst Land Resources Development Centre.

245 loca London; name Overseas Development Administration Library; addr Eland House, Stag Place, London SW1E 5DH United Kingdom; tele 01-213 5417/5848/5407 (National code 01-213); libr Peter Griffiths; salu Mr. Griffiths; subj forest economics, economic development; user no restrictions on categories of user; serv reference use on site only (except for staff), special collection of FAO publications, enquiries, interlibrary loans, searches, copies, bibliographies; inst Foreign and Commonwealth Office, Overseas Development Administration.

246 loca Oxford; name Commonwealth Forestry Bureau; addr South Parks Road, Oxford OX1 3RD, England; tele Oxford 57185; libr [n.g.]; salu Dr.; subj forestry in general, forest products(except pulp and paper); user [n.g.]; serv preparation of Forestry Abstracts and Forest Products Abstracts; inst Commonwealth Agricultural Bureaux; note CFB is a documentation service. It uses the library of the Oxford Forestry Institute. Officer-in-charge of CFB is Kenneth M. Becker.

247 loca Oxford; name Oxford Forestry Institute, University of Oxford, Department of Plant Sciences; addr South Parks Road, Oxford OX1 3RB, UK; tele Oxford 511431, ext. 254; libr Roger A. Mills, Librarian; salu Mr. Mills; subj forestry in general, forest products (except pulp and paper); user faculty, students, staff, general public, many visiting forest researchers; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, microfilm service; inst University of Oxford.

248 loca Peterborough; name Nature Conservancy Council Library; addr Northminister House, Peterborough, PE1 1UA, United Kingdom; tele 0733-40345; libr Shirley M. Penny, Chief Librarian; salu Miss Penny; subj nature conservation, ecology, woodland management; user staff of Nature Conservancy Council, other bona fide users by appointment, loans through BLLD; serv interlibrary loans, literature searches, enquiries, publication in microfiche of NCC research reports; inst Nature Conservancy Council.

YUGOSLAVIA

249 loca Belgrade; name Faculty of Forestry - Library; addr 11030 Beograd, Kneza Višeslava 1 - Yugoslavia; tele 011/553 - 122/17; libr Milorad Šijak, dipl. ing.; salu Mr. Sijak; subj silviculture, wood machining, wildlife management, parks and recreation, forest protection; user staff of faculty, students; serv reference on site, by mail, interlibrary loan; inst The Faculty itself and the Republic Community for Science in Serbia.

250 loca Belgrade; name Library of Forestry and Wood Industry; addr Kneza Višeslava 3, Belgrade 11000, Yugoslavia; tele [n.g.]; libr Svetlana Stanišić; salu Mrs. Stanišić; subj agroforestry, silviculture, forest genetics, forest economics, wood machining; user [n.g.]; serv interlibrary loan; inst Institute for Forestry and Wood Research, Belgrade.

251 loca Ljubljana; name Gozdarska Knjižnica; addr Inštitut Za Gozdno In Lesno Gospodarstvo Pri Biotehniški Fakulteti in Vtozd Za Gozdarstvo Biotehniske Fakultete, Gozdarska Knjižnica, Večna Pot, 61 000 Ljubljana, Yugoslavia; tele 061 268 963 / 63 or 64; libr Marja Zorn, dipl. ing.; salu Ms. Zorn; subj factors of the environment, silviculture, forest injuries and protection, logging and transport, land use, forest management; user staff of forest institution, faculty, students and others; serv tenders of library and document service, but not computer searches; inst Ištitut Za Gozdno In Lesno Gospodarstvo Pri Biotehniški Fak. and Vtozd Za Gozdarestvo Biotehniske Fakultete.

252 loca Sarajevo; name Biblioteka Šumarskog Fakulteta; addr 71000 Sarajevo, Zagrebačka 20, Jugoslavija; tele 071/611-033; libr Čukac, Neda, dipl. ing.; salu Mrs. Čukac; subj silviculture, forest genetics, forest economics, forest management, forest products and their utilization; user faculty and students; serv by mail, by telephone, interlibrary loan; inst Šumarski Fakultet (Faculty of Forestry).

253 loca Sarajevo; name Ro "ŠIPAD-IRC" Šumaprojekt, biblioteka; addr 71000 Sarajevo, Omladinsko šetalište lo Yugoslavia; tele (071) 615-149; libr Milojka Drakulić; salu Ms. Drakulić; subj wood machining, forest economics; user staff of institution; serv on site use and reference on site; inst Ro "ŠIPAD-IRC" Šumaprojekt.

254 loca Zagreb; name Odjel za dokumentaciju Instituta za drvo; addr Ul. 8. maja 82/I, 41000 Zagreb, Yugoslavia; tele 041/448-611; libr Dinko Tusun, Librarian; salu Prof. Tusun; subj forest products (except pulp and paper); user faculty, students, staff, specialists from other institutions and enterprises; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Institut za Drvo, Zagreb.

255 loca Zagreb; name Šumarska Knjižnica (Faculty of Forestry, University of Zagreb; addr Sumarski fakultet - Zagreb, Šumarska knjižnica, Šimunska 25, 41000 Zagreb, Yugoslavia; tele 041/218-288/61; libr Katarina Piljac, Graduate Engineer; salu Mrs. Piljak; subj forestry in general, forest products, pulp & paper, range management, forest genetics, forest economics, wood machining, wildlife management; user faculty, students, staff; serv reference on site, by telephone; inst University of Zagreb.

ARGENTINA

256 loca Buenos Aires; name Instituto Forestal Nacional, Biblioteca; addr Av. Pueyrredon 2446, 1119 Buenos Aires, Argentina; tele 83-3728; libr Nilda Elvira Fernández, Bibliotecaria Auxiliar; salu Sra. Fernández; subj forestry in general , forest products, pulp and paper, range management, wildlife management; user students, staff, general public; serv reference on site, by telephone, by mail; inst Instituto Forestal Nacional.

257 loca La Plata; name Biblioteca de la Escuela Superior de Bosques; addr Escuela Superior de Bosques, Diag. 113 No. 469 (61 y 118), 1900 La Plata, Argentina; tele 33-467; libr Lelia Renée Marco; Bibliotecaria; salu Sra. Marco; subj silviculture, pulp and paper, forest economics, forest products; user faculty, students, professors, staff of the institution; serv reference on site, by mail; inst Facultad de Agronomía de la Universidad Nacional de La Plata.

258 loca Resistencia; name Biblioteca del CIBAGRO (Centro de Informacion Bioagropecuaria y Forestal) addr Universidad del Nordeste, Av. Las Heras 727, 3500 - Resistencia - Chaco, Argentina; tele 23893; libr Julio E. Encinas, Director; salu Mr. Encinas; subj forestry in general; user faculty, students; serv reference on site, by mail; inst Universidad del Nordeste.

259 loca San Martín; name Biblioteca del CICELPA (Centro de Investigacion de Celulosa y Papel); addr C.C. 157, 1650 San Martín, Pcia. de Buenos Aires, República Argentina; tele 755-6161; 752-4901, interno 553/559, telex: 021859 INTIAR; libr Delfina A. Silva de Buonamico; salu Ms. Silva de Buonamico; subj pulp and paper, silviculture, microscopy, wood chemistry; user staff of institutions, faculty, students, investigators, general public; serv reference on site, by mail, by telephone, interlibrary loan, computer searches, compilation of bibliographies, photocopy; inst Instituto Nacional de Tecnología Industrial (INTI).

BOLIVIA

260 loca Tarija; name Biblioteca de Ciencias Agricolas, Forestales de Ciencias y Tecnologia; addr Departamento de Bibliotecas, Universidad Boliviana Juan Misael Saracho, Casilla 1107, Campero 0887, Tarija, Bolivia; tele 5898; libr Juan Baldiviezo Valdes, Jefe del Departamento de Bibliotecas; salu [n.g.]; subj forestry in general, forest products, wildlife management; user faculty, students, general public; serv reference on site, by telephone; inst Universidad Boliviana Juan Misael Saracho.*

BRAZIL

261 loca Belém; name Biblioteca Lourenço José Tavares Vieira da Silva; addr Faculdade de Ciências Agrárias do Pará, Serviço de Documentação e Informação, Biblioteca - C.P. 917 - 66.000, Belém - PA-Brasil; tele 2261110; libr Sandra Bordallo Robilotta, Chefe do Serviço de Documentação e Informação; salu Ms. Robilotta; subj silviculture, forest genetics, forest economics, agro-forestry; user faculty, students, staff of institution; serv reference, interlibrary loan, compilation of bibliographies; inst Faculdade de Ciências Agrárias do Pará.

262 loca Belo Horizonte; name Biblioteca do Instituto Estadual de Florestas; addr Rua Caetes, 753, 22o andar - sala 2215, 30.000 - Belo Horizonte - MG, Brasil; tele (031) 201-8055 - Ramal 46; libr Silvana de Almeida - Bibliotecária; salu Ms. Almeida; subj silviculture, forest management, park administration, reforestation, environmental protection; user the library may be used by anyone with interest in its publications collection; serv on site use, by mail; inst Instituto Estadual de Florestas.

263 loca Belo Horizonte; name Central de Informações Técnicas; addr Av. Amazonas, 491 - '7o andar, Central de Informações Técnicas, 30.000 - Belo Horizonte-Minas Gerais; tele 201.68.00 R:124; libr Celia Maria de Oliveira Fulgêncio, Bibliotecária; salu Ms. Fulgencio; subj forestry in general; pulp and paper; user staff; serv reference on site, by telephone, by mail, compilation of bibliographies, publication of Boletim Bibliografico; inst Celulose Nipo Brasileira S/A - CENIBRA.

264 loca Brasília; name Instituto Brasileiro de Desenvolvimento Florestal - Biblioteca Central; addr Setor de Areas Isoladas - L4 Norte, 70,800 Brasília, Brasil; tele (061) 223-5966 Ramal 255; libr Rosa Boianovsky, Bibliotecária; salu Ms. Boianovsky; subj forestry in general, forest products, wildlife management, ecology, botany; user students, staff, general public; serv reference on site, by mail, by telephone, interlibrary loan, computer searches, compilation of bibliographies, etc.; inst Instituto Brasileiro de Desenvolvimento Florestal - IBDF.

265 loca Curitiba; name Biblioteca do Centro Nacional de Pequisa de Florestas (EMBRAPA); addr Estrada da Ribeira, km. 111, Caixa Postal, 3319, 80.000 Curitiba, PR, Brasil; tele (041) 256-2233; libr Carment Cassilha Stival; salu Miss Stival; subj forestry in general; user general public, students; serv on site, by mail, by telephone, interlibrary loan, compilation of bibliographies; inst EMBRAPA.

266 loca Curitiba; name Biblioteca do Setor de Ciências Agrarias da Universidade Federal do Paraná; addr Rua dos Funcionarios s/n; Caixa Postal 672, 80.000 - Curitiba, Parana, Brasil; tele (041) 252-3422; libr Léa Terezinha Belczak, Bibliotecária Documentalista; salu Ms. Belczak; subj forestry in general, forest products, pulp and paper; user faculty, students, general public; serv reference on site, by telephone, by mail, compilation of bibliographies, editorial services; inst Ministério de Educação e Cultura, Universidade Federal do Paraná.

267 loca Manaus; name Divisão de Biblioteca; addr Instituto Nacional de Pesquisas da Amazônia - INPA, Alameda Cosme Ferreira, KM 3, 5, no. 1756, Caixa Postal 478, 69.000 Manaus, Amazonas, Brasil; tele 236 - 9400 Remal 116 e 117; libr Algenir Ferraz Suano da Silva, Técnico da Informaçao; salu Mr. Silva; subj forestry in general, forest products, pulp and paper; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, compilation of bibliographies; inst Instituto Nacional de Pesquisas da Amazônia - INPA.

268 loca São Paulo; name Instituto de Pesquisas e Estudos Florestais, Biblioteca; addr ESALQ-USP, Caixa Postal 9, 13,400 Piracicaba, São Paulo, Brasil; tele 33-2080; libr Marialice Metzker Poggiani, Bibliotecária e Documentalista; salu Ms. Poggiani; subj forestry in general, forest products, pulp & paper, range management, wildlife management; user staff of institution, faculty, students; serv compilation of bibliographies, reference on site, by mail, by telephone, interlibrary loan; inst Instituto de Pesquisas e Estudos Florestais.

269 loca São Paulo; name Instituto Florestal - Biblioteca; addr Rua do Horto, 1197 - Caixa Postal, 1322 - 01000 São Paulo - SP - Brasil; tele 203-0122 - R. 48 e 53; libr Eleni Beck Escobar Gava, Bibliotecária; salu Ms. Gava; subj forestry in general, forest products, wildlife management; user students, staff, general public; serv reference on site, by telephone, by mail, compilation of bibliographies, alert service (Boletim Informativo Biblioteca IF); inst Secretaria de Agricultura e Abastecimento - Coordenadoria da Pesquisa de Recursos Naturais.

270 loca São Paulo; name Seção de Informação e Documentação do Centro Técnico em Celulose e Papel; addr Caixa Postal 7141 - CEP 01000, São Paulo, SP - Brasil; tele 268-2211 - Ramal 402; libr Maria Luiza de Azevedo Poli, Bibliotecária Chefe; salu Ms. Poli; subj pulp & paper; user students, staff, general public, industries; serv reference on site, by telephone, interlibrary loan, compilation of bibliographies; inst Instituto de Pesquisas Tecnológicas do Estado de São Paulo.

271 loca Viçosa; name Biblioteca Central da Universidade Federal de Viçosa; addr Avenida P. H. Rolfs, S/N, 36.570 - Viçosa - MG, Brasil; tele DDD (031) - 891-1825; libr Dirce Maria Soares Penido, MSLS - Diretora; salu Ms. Penido; subj agroforestry, silviculture, forest genetics, forest economics, pulp and paper, forest ecology; user students, faculty, general public, staff of institution, etc.; serv reference on site, compilation of bibliographies, loans of publications, library user orientation, etc.; inst Universidade Federal de Viçosa.

CHILE

272 loca Chillán; name Biblioteca, Facultad de Ciencias Agropecuarias y Forestales; addr Universidad de Concepción, Casilla 537, Chillán, Chile; tele 22645 - Anexo No. 265; Libr Norma Valderrama de Ramírez, Bibliotecaria Jefe; salu Mrs. Ramírez; subj agroforestry, forest products, range management, wildlife managment; user staff, faculty, students, general public; serv reference on site, by mail, compilation of bibliographies; inst Universidad de Concepcion.

273 loca Concepción; name Biblioteca "Luis David Cruz Ocampo"; addr Barrio Universitario, Universidad de Concepción, Casilla 1807, Concepción, Chile; tele 24985 anexo 2403; libr Sr. Juan de Luigi Lemus, Director de Servicios Bibliotecarios; salu Mr. de Luigi; subj pulp and paper, agroforestry, silviculture, forest economics, forest products; user faculty, students; serv reference on site, by telephone, by mail, interlibrary loan, computer searches, compilation of bibliographies; inst Universidad de Concepción.

274 loca Concepción; name Depto. de Ind. Forest., Univ. del Bio Bio; addr Casilla 5-C; tele 29984 an:311; libr Gerhard Stohr von Holleben, Ing. For., Dr.; salu Dr. Stohr; subj Wood technology; user faculty, students; subj reference on site, interlibrary loan; inst Universidad del Bio Bio.

275 loca Concepción; name Laboratorio Productos Forestales; addr Casilla 53-C, Concepcion, Chile; tele 34985/2137; libr Roberto Melo; salu Professor Melo; subj pulp and paper; user staff, students, technical people from industry; serv on site, interlibrary loan, compilation, by mail; inst Universidad de Concepción, Facultad de Ingeniería.

276 loca Santiago; name Biblioteca Rector Ruy Barbosa; addr Casilla 9206, Escuela de Ciencias Forestales, Santiago, Chile; tele 587042 Anexo 230; libr Rosa Prieto Roman - Head Librarian; salu Sra. Prieto Roman; subj agroforestry, silviculture, forest genetics, forest economics, pulp & paper, wildlife management, parks and recreation; user faculty, students, staff of institution; serv on site use only, reference on site, by mail, by telephone, interlibrary loan, computer searches, compilation of bibliographies, etc. domicilia loan; inst Escuela de Ciencias Forestales.

277 loca Santiago; name Biblioteca Técnica, Corporación Nacional Forestal; addr Avenida Bulnes 285 Oficina 703, Gerencia Técnica, Santiago, Chile; tele 722569; libr Ricardo Romero Alpe; salu Mr. Romero Alpe; subj national projects carried out by the institution, Chilean forestry, seasonal fire control and evaluation; user staff of the institution and public in general; serv reference on site, interlibrary loan; inst Corporación Nacional Forestal.

278 loca Santiago; name Documentation Section, Communication Secretariat; addr Av. Bulnes 197, Piso 2, Santiago, Chile; tele 6966724; libr Carlos Sierra Silva; salu Mr. Sierra Silva; subj wildlife, forest statistics, forest legislation; user general public; serv reference by telephone, on site, interlibrary loan, compilation of bibliographies; inst National Forestry Corporation (Corporacion Nacional Forestal).

279 loca Santiago; name Instituto Forestal, Biblioteca; addr Huérfanos 554, Casilla 3085, Santiago, Chile; tele 396189; libr Teresa Muñoz P., Jefe Biblioteca; salu Ms. Muñoz; subj forestry in general, forest products, pulp and paper, wildlife management; user faculty, students, staff , general public; serv reference on site, by telephone, by mail; inst Instituto Forestal.

280 loca Talca; name Departamento de Biblioteca, Pontifica Universidad Católica de Chile; addr Sede del Maule (Avda. San Miguel S/N), Casilla 617, Talca, Chile; tele 34222; libr Francisco Frias Alarcón, Bibliotecario; salu Mr. Frias Alarcón; subj silviculture, forest industries; user professors, students, general public; serv on site, interlibrary loan; inst Pontifica Universidad Católica de Chile, Sede del Maule.

281 loca Valdivia; name Biblioteca Central, Universidad Austral de Chile; addr Casilla 39-A, Valdivia, Chile; tele 3911-3915, Anexo 290; libr [n.g.]; salu [n.g.]; subj forestry in general, Chilean forestry; user students, professors, investigators; serv on site, reference on site, by mail, interlibrary loan, photocopy; inst Universidad Austral de Chile.

COLOMBIA

282 loca Bogotá; name Centro de Documentación Forestal - CEDOF; addr Carrera 8 40 - 78, o Apartado aéreo 8668, Bogotá, Colombia; tele 42 47 06; libr Gloria Inez Rincón Gomez, Licenciada; salu Lic. Rincon; subj forestry in general, forest products, wood, silviculture, forests, ecology, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail; inst Universidad Distrital "Francisco José de Caldas", Facultad de Ingeniería Forestal.*

283 loca Bogotá; name Oficina de Documentacion; addr Carrera 30 #47A-57 Bogotá, D.E. Colombia; tele 2684249; libr Liliana Osorio de Cardenas, Licenciada; salu Lic. Osorio; subj remote sensing applications in forestry; user investigating scientists, faculty, students, general public; serv reference on site, by telephone, interlibrary loan, compilation of bibliographies; inst Centro Interamericano de Fotointerpretacion (CIAF).

284 loca Bucaramanga; name Centro Investigaciones de Celulosa y Papel; addr Universidad Industrial de Santander, Apartado Aéreo 678, Bucaramanga, Colombia; tele 56141, ex. 220; 461; libr Hernán Cáceres-Rojas; salu Lic. Cáceres; subj pulp and paper; user staff of university, students; serv reference on site, compilation of bibliographies; inst OEA, Colciencias, U.I.S.

285 loca Ibague; name Biblioteca de la Universidad del Tolima; addr Apartado Aéreo 546, Ibague-Tolima, Colombia; tele 32544/32733; libr Cielo Urueña Lozano, Jefe de Biblioteca; salu Licenciada Uruena; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, general public; serv reference on site, by telephone, by mail, compilation of bibliographies; inst Universidad del Tolima.

COSTA RICA

286 loca San José; name Biblioteca - Organization for Tropical Studies (OTS); addr Universidad de Costa Rica, San Pedro de Montes de Oca, Costa Rica; tele 25-22-18, 25-75-07 or 25-50-64; libr Fernando Solís Prado, Bibliotecario; salu Mr. Solís; subj agroforestry, silviculture, tropical biology (flora, fauna), ecology, national parks, wildlife management; user staff of institution, students of the universities of the United States and University of Costa Rica and Universidad Nacional of Costa Rica; serv reference on site; inst [n.g.].

287 loca San José; name Ministerio de Agricultura y Ganadería, Biblioteca; addr Apartado 10.094, San José, Costa Rica. A.C.; tele 31 23 41, ext. 274; libr Bach. Carmen Chacón Saborío; salu [n.g.]; subj forestry in general, forest products, range management; user students, staff, general public; serv information on site, by telephone, interlibrary loan, compilation of bibliographies; inst Ministerio de Agricultura y Ganadería.

288 loca Turrialba; name Biblioteca Conmemorativa Orton; addr IICA-CIDIA, Turrialba, Costa Rica; tele 56-64-31 or 56-01-69; libr Ana María Arias, Lic. Bibliotecología; salu Lic. Arias; subj forestry in general; user faculty, students, staff; serv reference on site, by telephone, interlibrary loan, compilation of bibliographies; inst Interamerican Institute for Cooperation on Agriculture - Tropical Agricultural Research and Training Center.

289 loca Turrialba; name INFORAT: Informacion y Documentación Forestal para América Tropical; addr INFORAT, CATIE, 7170 Turrialba, Costa Rica; tele 56-01-21 or 56-64-31; libr Mario Gutiérrez, Ing. Agron.; salu Ing. Gutiérrez; subj tropical agroforestry, fuelwood and other alternative sources of energy, neotropical wildlife with emphasis on Central America and the Caribbean; serv faculty, students, general public; serv reference on site, by mail; inst Centro Agronomico Tropical de Investigación y Enseñanza: CATIE.

HONDURAS

290 loca La Ceiba; name Biblioteca, Centro Universitario Regional del Litoral Atlantico (CURLA); addr Apartado Postal 89, La Ceiba, Atlántida, Honduras, C.A.; tele 42-26-70; libr Lic. Elsa Victoria Barrios, Manger CURLA's Library; salu [n.g.]; subj forestry in general, forest products, pulp and paper, wildlife management; user faculty, students, staff, general public; serv reference on site, interlibrary loan, compilation of bibliographies; inst Universidad Nacional Autónoma de Honduras (Sistema Bibliotecario), Tegucigalpa.

291 loca Siguatepeque; name Biblioteca "Marco A. Flores Rodas"; addr Escuela Nacional de Ciencias Forestales, Apartado Postal No. 2 Siguatepeque, Depto. de Comayagua, Honduras, C.A.; tele 73-20-11, 73-20-18, 73-20-23; libr Merary Villalta de Moncada, Bibliotecaria; salu Sra. de Moncada; subj forest management, forest products, pulp and paper, silviculture, agroforestry; user faculty, students, staff, general public; serv reference on site, by telephone, interlibrary loan and exchange; inst Corporacion Hondurena de Desarrollo Forestal (COHDEFOR).

JAMAICA

292 loca Kingston; name Forest Department Library; addr 173 Constant Spring Road, Kingston 8, Jamaica, W I; tele 93-42667-8; libr Forest Officer; salu [n.g.]; subj agroforestry, silviculture, genetics, wood machining, parks and recreation; user students, staff, general public; serv reference on site; inst Government of Jamaica, Ministry of Agriculture.*

NICARAGUA

293 loca Managua; name Centro de Documentacion del IRENA; addr Km. 12 1/2 Carretera Norte., Apartado Postal 51-23, Managua, Nicaragua, C.A.; tele 3-11-10 al 13, ext. 222 y 233; libr Ruth Escobar Tenorio, Documentalista; salu Señora Escobar; subj forestry in general, forest products, wildlife management, watersheds, soil, national parks; user students, staff, general public; serv reference on site, interlibrary loan; inst Instituto Nicaraguense de Recursos Naturales y del Ambiente (IRENA).

PERU

294 loca Lima; name Centro de Documentación e Información Forestal (CEDINFOR); addr Universidad Nacional Agraria, Facultad de Ciencias Forestales, Apartado 456, Lima, Perú; tele 352035 - 233; libr Dora Mori Herrera; salu [n.g.]; subj forest science, agroforestry, pulp and paper, wood chemistry, silviculture, forest management, forest economics; user professionals, students, general public; serv Bulletin - "Documentos Recien Ingresados al CEDINFOR", photocopies, short bibliographies, interlibrary loan; inst Proyecto UNA - Cooperación Técnica Suiza.

PUERTO RICO

295 loca Rio Piedras; name Library of the Institute of Tropical Forestry; addr Southern Forest Exp. Stn., Institute of Tropical Forestry, U.S. Forest Service, P.O. Box AQ, Rio Piedras, Puerto Rico 00928; tele FTS 753-4335, ext. 223 or (809) 763-3939, ext. 223; libr JoAnne Feheley, Technical Information Specialist; salu Ms. Feheley; subj tropical forestry, wildlife management; user staff, general public including P.R. Commonwealth departments, students and faculty of Puerto Rican Universities; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst U.S. Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry.*

URUGUAY

296 loca Montevideo; name Departamento de Documentación y Biblioteca, Garzón 780, Montevideo, Uruguay; tele 39 71 91/95; libr Raquel Schneider, Head Librarian; salu Sra. Schneider; subj national parks, forest ecology, pulp and paper, forest protection; user staff of institution, students, teachers; serv reference on site, interlibrary loan; inst Faculty of Agronomy, Universidad de la Republica.

VENEZUELA

297 loca Mérida; name Instituto Forestal Latinoamericano; addr Apartado 36, Mérida, Venezuela; tele (074) 440535; libr Julio César Centeno, Director; salu Director César; subj silviculture, forest products, forest economics, market analysis; user general, faculty, students, etc.; serv on site, by mail, compilation of bibliographies; inst Instituto Forestal Lationamericano.

ALBERTA

298 loca Edmonton; name Alberta Energy and Natural Resources Library; addr 9th floor, Petroleum Plaza, South Tower, 9915 108th St., Edmonton, Alberta T5K 2C9 Canada; tele 1-403-427-7425; libr Peter Mutchler, Chief Librarian; salu Mr. Mutchler; subj forestry in general, forest products, range management, wildlife management; user staff; serv reference, interlibrary loan, compilation of bibliographies, computer searches, acquisitions list, circulation of title pages; inst Department of Energy and Natural Resources, Government of Alberta.

299 loca Edmonton; name Northern Forestry Centre Library, Canadian Forestry Service; addr 5320 - 122nd Street, Edmonton, Alberta T6H 3S5 Canada; tele (403) 435-7323/7324; libr David Robinson, Librarian; subj forestry in general; salu Mr. Robinson; user students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches, loan of materials restricted to federal government employees, others through interlibrary loans; inst Government of Canada, Dept. of Agriculture.

300 loca Edmonton; name Science and Technology Library, University of Alberta; addr 2nd floor - Cameron Library, University of Alberta, Edmonton, Alberta, Canada T6G 2J8; tele (403) 432-2728; libr Margo Young, Head, Science Library; salu Ms. Young; subj forestry in general, range management, wildlife management; user faculty, students, general public; serv reference on site, by telephone, interlibrary loan, computer searches; inst University of Alberta.

BRITISH COLUMBIA

301 loca Nelson; name Ministry of Forests, Branch Library; addr 518 Lake Street, Nelson, BC V1L 4C6, Canada; tele (604) 354-6206; libr Jo White; salu Ms. White; subj forestry in general, forest products (except pulp and paper), range management, land management; user staff, students; serv on site use mainly, interlibrary loan with provincial government; inst British Columbia, Ministry of Forests.

302 loca Vancouver; name Council of Forest Industries of British Columbia, Library; addr 1500/1055 W. Hastings Street, Vancouver, B.C. V6E 2H1; tele (604) 684-0211, L 258; libr Sheila Foley, Librarian; salu Ms. Foley; subj forestry in general, forest products pulp and paper, range management, economics, energy, environment; user students, staff, member companies; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Council of Forest Industries of British Columbia.

303 loca Vancouver; name Forintek Canada Corp., Western Region Library; addr 6620 N.W. Marine Drive, Vancouver, B.C. V6T 1X2 Canada; tele (604) 224-3221; libr Marion E. Johnson, Librarian; salu Mrs. Johnson; subj treated wood, utilization of forest products, wood chemistry, wood identification, timber engineering, wood machining, pulping North American softwoods; user staff, member companies, government agencies, students on referral; serv reference on site, by telephone, reference by mail not encouraged, interlibrary loan, compilation of bibliographies (for staff), computer searches (for staff), SDI; inst Forintek Canada Corp.

304 loca Vancouver; name MacMillan Bloedel Research Information Services; addr 3350 E. Broadway, Vancouver, B.C. V5M 4E6; tele (604) 254-5151; libr Diana Wilimovsky, Supervisor, Information Services; salu Ms. Wilimovsky; subj forest products, pulp and paper, chemistry, business and finance; user research staff, others by arrangement; serv reference, interlibrary loan, computer searches; inst MacMillan Bloedel Ltd.

305 loca Vancouver; name MacMillan Forestry/Agriculture Library; addr 2357 Main Mall, University of British Columbia, Vancouver, B.C. V6T 2A2; tele (604) 228-3445; libr Lore Brongers, Head; salu Mrs. Brongers; subj basic agricultural sciences, forestry in general; user undergraduate and graduate students, faculty and some off-campus users; serv reference, interlibrary loan, computer searches; inst University of British Columbia.

306 loca Vancouver; name Sandwell and Co. Ltd. Library Information Centre; addr 601 - 1550 Alberni St., Vancouver, B.C. V6G 1A4 Canada; tele (604) 684-8151 ext. 257; libr [position vacant, April 1986]; salu [n.g.]; subj pulp, paper, forestry, forest products; user staff, general public (in library use); serv reference on site, by phone, by mail, interlibrary loan, computer services, supply SAILS programs; inst Sandwell and Company Ltd.

307 loca Vancouver; name Technical Library, H. A. Simons (International) Ltd.; addr 425 Carrall Street, Vancouver, B.C. V6B 2J6 Canada tele (604) 664-4311 or (604) 664-4305; libr David Pepper; salu Mr. Pepper; subj pulp and paper, automation; user staff, public on request; serv [n.g.]; inst H. A. Simons (International) Ltd.

308 loca Victoria; name Ministry of Forests, Information Resource Centre; addr 1450 Government St., Victoria, B.C. V8W 3E7 Canada; tele (604)387-3628; libr S. E. Barker, Manager; salu Ms. Barker; subj forestry in general, forest products, pulp & paper, range management, wildlife management, electronic data management, business management; user staff, students, general public, industry; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst British Columbia, Ministry of Forests

309 loca Victoria; name Pacific Forestry Centre, Canadian Forestry Service; addr 506 West Burnside Road, Victoria, BC V8Z 1M5; tele (604) 388-0600, ext. 637; libr Alice Solyma, Librarian; salu Ms. Solyma; subj forestry in general; user faculty, students, staff, consultants, government employees (provincial and federal); serv reference on site, by telephone, by mail, interlibrary loan, computer searches (for staff only), accessions list, translation requests; inst Pacific Forestry Centre.

NEW BRUNSWICK

310 loca Fredericton; name Maritimes Forest Research Centre, Library; addr Canadian Forestry Service, P.O. Box 4000, Fredericton, N.B. E3B 5P7 Canada; tele (506) 452-3541, telex 014-4615; libr Barry Barner, Librarian; salu Mr. Barner; subj forestry in the Maritime provinces; user staff, University of New Brunswick, general public; serv [n.g.]; inst Canadian Forestry Service.

311 loca Fredericton; name Science and Forestry Library, University of New Brunswick; addr P.O. Box 7500, Fredericton, N.B. E3B 5H5 Canada; tele (506) 453-4600/01/02; libr Eszter L.K. Schwenke, Head Librarian; salu Mrs. Schwenke; subj forestry, biology, chemistry, geology, and physics; user faculty, students, general public; serv reference on site, by telephone, interlibrary loan, computer searches; inst University of New Brunswick.

312 loca Fredericton; name Timber Management Branch Library; addr New Brunswick Dept. of Forest, Mines and Energy, P. O. Box 6000, Fredericton, New Brunswick, Canada E3B 5H1; tele (506) 453-2516; libr I. R. Long, Library Assistant; salu Mrs. Long; subj forest management, silviculture, entomology; user staff; serv on site; inst Government of New Brunswick.

NEWFOUNDLAND

313 loca Corner Brook; name Dept. of Forest Resources and Lands; addr P.O. Box 2006, Herald Bldg., Corner Brook, Newfoundland A2H 6J8 Canada; tele (709) 637-2307; libr Sylvia Keeping, Librarian; salu Mrs. Keeping; subj [n.g.]; user staff, forestry students; serv reference on site, by mail, by telephone, interlibrary loan; inst Dept. of Forest Resources and Lands.

314 loca St. John's; name Newfoundland Forest Research Centre - Library; addr Canadian Forestry Service, P.O. Box 6028, St. John's, N.F., A1C 5X8; tele (709) 772-4672; libr Catherine E. Philpott, Librarian; salu Mrs. Philpott; subj forestry in general; user students, staff; serv reference on site, by telephone, by mail, interlibrary loan, computer searches (to staff only); inst Agriculture Canada

ONTARIO

315 loca Chalk River; name Petawawa National Forestry Institute Library; addr Canadian Forestry Service, Chalk River, Ontario K0J 1J0; tele (613) 589-2880; libr Mary Mitchell, Librarian; salu Ms. Mitchell; subj forestry in general; user staff; serv reference on site, by telephone, interlibrary loan; inst Petawawa National Forestry Institute.

316 loca Hawkesbury; name CIP Research Ltd., Library; addr 179 Main Street West, Hawkesbury, Ontario K6A 2H4; tele (613) 632-4122, ext. 233; libr Margaret Higginson, Librarian; salu Mrs. Higginson; subj pulp and paper; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, current awareness services; inst CIP Research Ltd., a subsidiary of CIP Inc. (previously known as Canadian International Paper Co.).

317 loca Maple; name Natural Resources Research Library; addr Maple, Ontario L0J 1E0, Canada; tele (416) 832-2761; libr Janyce Addey; salu Miss Addey; subj forestry, fish, wildlife; user staff; serv [n.g.]; inst Ontario Ministry of Natural Resources.

318 loca Ottawa; name Forintek Canada Corp., Eastern Laboratory, Information Resource Unit; addr 800 Montreal Road, Ottawa, Ontario K1G 3Z5; tele (613) 744-0963; libr Marjorie Wickens, Librarian; salu Mrs. Wickens; subj forest products (except pulp and paper); user staff; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Forintek Canada Corp.

319 loca Toronto; name Faculty of Forestry, Library; addr University of Toronto, Toronto, Canada M5S 1A1; tele (416) 978-6016; libr Mary Husband, Library Technician; salu Mrs. Husband; subj forestry in general, forest products (except pulp and paper), wildlife management; user faculty, students, government and industry; serv reference on site, by telephone, interlibrary loan; inst University of Toronto.

320 loca Toronto; name Natural Resources Library; addr Whitney Block, Room 4540, Queen's Park, Toronto, Ontario M7A 1W3 Canada; tele (416) 965-6319; libr Sandra Louet, Manager; salu Mrs. Louet; subj parks and recreation, wildlife, fisheries, forestry, land use; user staff of institution, outsiders by appointment; serv outsiders: on site use, interlibrary loan; inst Ontario Ministry of Natural Resources.

321 loca Thorold; name Ontario Paper Company, Library; addr Allanburg Road, Thorold, Ontario L2V 3Z5 Canada; tele (416) 227-1121, ext. 306; libr Mrs. Isabelle Ridgway, Librarian; salu Mrs. Ridgway; subj forestry in general, pulp and paper; user staff, general public (by special arrangement); serv reference on site, by telephone, interlibrary loan, computer searches; inst The Ontario Paper Company Limited.

322 loca Sault Ste. Marie; name Great Lakes Forest Research Centre, Library; addr Canadian Forestry Service, P.O. Box 490, 1219 Queen St. E., Sault Ste. Marie, Ontario P6A 5M7 Canada; tele (705) 949-9461, ext. 2000; Interlibrary loan's ext. 2001; libr Sandra Burt; salu Mrs. Burt; subj forestry in general, entomology, forest pest management; user staff (full services to staff only; on-site library use by students and general public available by contacting the librarian); serv reference on site, by telephone, interlibrary loan, computer searches and compilation of bibliographies for staff only; inst Great Lakes Forest Research Centre.

QUEBEC

323 loca Pointe Claire; name Forest Engineering Research Institute of Canada, Library; addr 143 Place Frontenac, Pointe Claire, Quebec H9R 4Z7, Canada; tele (514) 694-1140; telex: 05-822652; libr Christel Mukhopadhyay, Librarian; salu Ms. Mukhopadhyay; subj forest engineering, mechanization of silviculture, transportation of wood, woodlot technology, forest biomass energy; user staff, member companies, others by appointment; serv reference on site and by mail, interlibrary loan, current awareness, computer searches, patent current awareness service; inst Forest Engineering Research Institute of Canada.

324 loca Pointe Claire; name Pulp and Paper Research Institute of Canada, Library; addr 570 St. John's Boulevard, Pointe Claire, Quebec H9R 3J9; tele (514) 630-4100; libr Hella Stahl, Manager, Technical Information Section; salu Mrs. Stahl; subj pulp and paper; user staff, maintaining industry members; serv reference on site, by mail, interlibrary loan, computer searches; inst Pulp and Paper Research Institute of Canada.

325 loca Québec; name Bibliothèque Scientifique; addr Secteur de Foresterie et de Géodésie, Université Laval, Québec G1K 7P4; tele (418) 656-3478; libr Philippe Lemay; salu Mr. Lemay; subj forestry in general, forest products, pulp and paper, range management, wildlife management, other; user students, faculty, government employees, general public; serv reference on site, by telephone, mail, interlibrary loan; inst Université Laval.

326 loca Québec; name Ministère de l'Energie et des Ressources; Centre de Documentation et des Renseignements - Secteur Terres et Forêts; addr 200B, chemin Ste-Foy, 7e étage; Québec, Québec G1S 4X7; tele (418) 643-6004; libr Johanne Belanger, Librarian; salu Ms. Belanger; subj forestry in general, forest products, pulp and paper; user staff of institution, students, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Ministère de l'Energie et des Ressources.

327 loca Senneville; name DOMTAR INC., Research Centre Library; addr C. P. 300, Senneville, Quebec H9X 3L7, Canada; tele (514) 457-6810, loc. 236; libr Barbara Bolton, Librarian; salu Ms. Bolton; subj pulp and paper; user staff; serv reference on site, interlibrary loan; inst DOMTAR Inc..

328 loca Ste-Foy; name Centre de Recherches Forestières des Laurentides, Bibliothèque; addr Canadian Forestry Service, C. P. 3800, Ste-Foy, PQ, G1V 4C7, Canada; tele (418) 694-4428; libr Claudine Lussier, Bibliothécaire; salu Ms. Lussier; subj forestry in general, forest entomology; user staff, scientific researchers; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Centre de Recherches Forestières des Laurentides.

329 loca Ste-Foy; name Service de documentation et de bibliothèque, Ministère de l'Energie et des Ressources; addr Complexe scientifique, C-1-1, 2700, rue Einstein, Sainte-Foy, Québec G1P 3W8; tele (418) 643-9730; libr Lucie Jobin, Library Technician; salu Mrs. Jobin; subj forestry in general, forest products (except pulp and paper); user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Ministère de l'Energie et des Ressources.

SASKATCHEWAN

330 loca Prince Albert; name Forestry Division Library, Department of Parks and Renewable Resources; addr Box 3003, Prince Albert, Saskatchewan S6V 6G1; tele (306) 953-2455; libr Janell D. Ernst, Clerk; salu Mrs. Ernst; subj forestry in general, forest products (except pulp and paper), range management; user staff, general public; serv reference on site, interlibrary loan; inst Department of Parks and Renewable Resources.

MEXICO

331 loca Guadalajara; name Biblioteca del Departamento de Pulpa y Papel; addr CeRETI - Guadalajara, Departamento de Pulpa y Papel, P.O. Box 6-725, Guadalajara, Jalisco 44620, México; tele 41-32-50, ext. 122; libr Roman Lamas and Patricia Godinez Diaz, Técnico en Manejo de Informatica; salu Doctor Lamas and Señorita Godinez; subj forestry in general, pulp and paper; user [n.g.]; serv [n.g.]; inst Departamento de Pulpa y Papel.

332 loca Guadalajara; name Departamento de Informacion y Documentacion; addr Apartado Postal 4-120, 44400, Guadalajara, Jalisco, México; tele 21-79-89, 13-76-59, 13-76-60, 13-76-61; libr Luz Elena Arce Castillo, Quimica; salu Señorita Arce; subj forestry in general, forest products, pulp and paper; user students, general pulbic, other; serv reference on site, by telephone, compilation of bibliographies, computer searches; inst Fideicomiso de la Universidad de Guadalajara.

333 loca México; name Biblioteca del Banco de México, S.A. (FIRA); addr Programa Forestal, Av. Insurgentes sur 2375, 01080 México, D.F.; tele 550 7011, ext. 214; libr Martha Benitez, Bibliotecario; salu Señora Benítez; subj forestry in general, forest products, pulp and paper; user staff; serv reference on site; inst Banco de Mexico, S.A.*

334 loca México; name Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias; addr Av. Progreso 5, 04110 Mexico, D.F.: tele 554-06-25; libr Maria de la Luz Vela Rosales, Jefe del Centro de Documentacion Cientifica y Tecnologica; salu Ms. Vela Rosales; subj forestry in general, silviculture, forest soils, botany, photogrammetry, forest products; user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies; inst Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias.

335 loca México/Chapingo; name Biblioteca Central; addr Universidad Autonoma Chapingo, 56230 Chapingo, Méx., D.F., México; tele 5-85-45-55, exts. 5741, 5791, 5010, and 5060; libr Rosa Maria Ojeda Trejo, Maestra en Biblioteconomia; salu Señora Ojeda; subj forestry in general, forest products (except pulp and paper), wildlife management; user faculty, students, staff, general public, other; serv reference on site, by telephone, by mail, interlibrary loan; inst Universidad Autonoma Chapingo.

ALABAMA

336 loca Auburn; name Ralph Brown Draughon Library, Science and Technology Department; addr Auburn University, Alabama 36849; tele (205)826-4500, ext. 21; libr John F. Vandermolen, Head, Science and Technology Dept.; salu Mr. Vandermolen; subj forestry in general, forest products, pulp and paper, range management, wildlife management, other; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Auburn University.

ALASKA

337 loca Juneau; name Forestry Sciences Laboratory, Library; addr P.O. Box 909, Juneau, Alaska 99802; tele (907) 586-8811; libr Carol A. Ayer, Librarian; salu Ms. Ayer; subj forestry in general, forest products, parks and recreation, wildlife management, fisheries; user U.S. Forest Service personnel, general public; serv U.S.F.S. personnel: online literature searches, interlibrary loan, quarterly accessions list, reference on site, by mail, by telephone. Non-U.S.F.S. users: circulation of library materials, basic reference services.; inst USDA Forest Service.

ARIZONA

338 loca Flagstaff; name Northern Arizona University, Library - Forestry Collection; addr C.U. Box 6022, Flagstaff, Arizona 86011; tele (602)523-2171; libr Cindy White, Reference Librarian; salu Ms. White; subj forestry in general, range management, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Northern Arizona University.

CALIFORNIA

339 loca Berkeley; name U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station; addr P.O. Box 245, Berkeley, California 94701; tele (415)486-3685; libr Dennis Galvin; salu Mr. Galvin subj forestry in general, range management, wildlife management, forest fire research; user faculty, students, staff, general public, National Forest Personnel; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, WESTFORNET Monthly Alert; inst USDA Forest Service - PSW Station and USDA Forest Service Region 5, National Forest System.

340 loca Berkeley; name University of California, Forestry Library; addr 260 Mulford Hall, University of California, Berkeley, California 94720; tele (415) 642-2936; libr Peter A. Evans, Librarian; salu Mr. Evans; subj forestry in general, range management, wildlife management, agroforestry; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University of California, Berkeley.

341 loca Richmond; name University of California, Forest Products Library; addr 1301 S. 46th Street, Richmond, California 94804; tele (415) 231-9549; libr Peter A. Evans, Librarian; salu Mr. Evans; subj wood machining, wood preservation, paint, adhesives, biomass energy, pulp and paper; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University of California, Berkeley.

342 loca San Francisco; name Crown Zellerbach Corporate Information Center; addr 1 Bush St., San Francisco, California 94104; tele(415) 951-5403; libr Gloria Capel, Administrator; salu Ms. Capel subj pulp & paper, marketing of forest products; user staff; serv reference on site, compilation of bibliographies, computer searches; inst Crown Zellerbach Corporation.

343 loca San Francisco; name Sierra Club William E. Colby Memorial Library; addr 730 Polk Street, San Francisco, California 94109; tele (415) 776-2211 ext. 6666; libr Barbara Lekisch, Resource Librarian; salu Ms. Lekisch; subj [n.g]; user staff, members, general public; serv reference, quick searches by telephone, interlibrary loan; inst Sierra Club.

344 loca Stockton; name California Cedar Products Co., Research Department Library; addr P.O. Box 8449, Stockton, California 95208; tele (209) 931-2448; libr Keiko Nakata, Librarian; salu Mrs. Nakata subj wood machining, wood structure & properties, wood waste utilization, wood drying, noise control; user staff; serv reference on site, by telephone, by mail; inst California Cedar Products Company.

COLORADO

345 loca Denver name U.S. Bureau of Land Management Library; addr Bldg. 50, P.O. Box 25047, D-553A, Denver Federal Center, Denver, Colorado 80225; tele FTS 776-6649 Comm. (303) 236-6649; libr Sandra L. Bowers, Librarian; salu Ms. Bowers subj forestry in general, range management, wildlife management, minerals; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, Monthly Alert; inst U.S. Bureau of Land Management.

346 loca Fort Collins; name Colorado State University Libraries; addr Colorado State University, Fort Collins, Colorado 80523; tele (303) 491-5911; libr Curtis Gifford, Forestry and Agricultural Sciences Librarian; salu Mr. Gifford; subj forestry in general, forest products, pulp and paper, range management, wildlife management; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, other; inst Colorado State University.

CONNECTICUT

347 loca New Haven; name Yale Forestry Library; addr 205 Prospect St., P. O. Box 6666, New Haven, Connecticut 06511; tele (203)432-5130; libr Joseph Miller, Librarian; salu Dr. Miller; subj forestry in general, forest products, pulp & paper, range management, wildlife management, environmental studies generally; user faculty, students; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Yale School of Forestry and Environmental Studies.

348 loca Stamford; name Champion International Corporate Library; addr 1 Champion Plaza, Stamford, Connecticut 06921; tele (203) 358-7692; libr [n.g.]; salu [n.g.]; subj pulp & paper, business; user staff; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches; inst Champion International Corporation.

DISTRICT OF COLUMBIA

349 loca Washington, D.C.; name Richard McArdle Memorial Library; addr American Forestry Association, 1319 18th Street, N.W., Washington, D.C. 20036; tele (202) 467-5810; libr Deborah Gangloff; salu Ms. Gangloff; subj forest history, forest economics, silviculture, wildlife, recreation; user staff, membership, conservation organizations; serv on site use only; inst American Forestry Association.

350 loca Washington; name U.S. Forest Service, Historical Photo Collection; addr Special Collections, National Agricultural Library, Beltsville, Maryland 20705; tele (301) 344-3876; libr William G. Hauser, Head, Still Photography; salu Mr. Hauser; subj forestry in general, forest products, pulp and paper, range management, wildlife management, public land management, recreation; user general public, Forest Service and other government agencies; serv reference on site, by telephone, by mail, Permanent Image Collection (PIC) data base; inst USDA Forest Service.*

351 loca Washington, D.C.; name National Forest Products Association, Information Center; addr 1619 Massachusetts Avenue, N.W., Washington, D.C. 20036; tele (202) 797-5836; libr Susan W. Wool, Manager; salu Ms. Wool subj forestry in general, forest products (except pulp and paper); user staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches (for staff only); inst National Forest Products Association; note There is a $50 per hour fee for research, literature searches, and other special services for users not affiliated with the National Forest Products Association.

352 loca Washington, D.C.; name Pulp & Paper Machinery Manufacturers Association; addr 5313 38th St., N.W., Washington, D.C. 20015; tele (202) 362-6034; libr Frank McManus, Executive Director; salu Mr. McManus; subj pulp & paper machinery, trade publications, government reports; user [n.g.]; serv reference on site, by mail, by telephone; inst Pulp & Paper Machinery Manufacturers Association.

FLORIDA

353 loca Gainesville; name Hume Library; addr McCarty Hall, University of Florida, IFAS, Gainesville, Florida 32611; tele (904)392-1934; libr William B. Weaver, Librarian; salu Mr. Weaver; subj forestry in general, range management, wildlife management, recreation; user faculty, students, staff, general public, industry; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Institute of Food & Agricultural Science, University of Florida.

GEORGIA

354 loca Athens; name SOUTHFORNET (Southern Forestry Information Network); addr Science Library, University of Georgia, Athens, Georgia 30602; tele (404)546-2477; libr Virginia L. Rutherford, SOUTHFORNET Coordinator; salu Ms. Rutherford subj forestry in general, forest products, pulp & paper, range management, wildlife management; user U.S. Forest Service - Region 8, Southeastern Forest Experiment Station and Southern Forest Experiment Station, subscribers (including state forestry agencies); serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies, computer searches, Monthly Alert (a current awareness publication which includes delivery of documents listed therein); inst USDA Forest Service; note SOUTHFORNET is an information service housed within the University of Georgia Science Library. It does not have a separate collection but uses the collection of the University.

355 loca Atlanta; name Georgia-Pacific Corporation; addr P.O. Box 105605, Atlanta, Georgia 30348; tele (404) 521-4644; libr Deanna Morrow Hall; salu Mrs. Hall; subj pulp and paper; user staff; serv full complement of services; inst Georgia-Pacific Corporation.

356 loca Atlanta; name TAPPI Information Resource Center; addr P.O. Box 105113, Atlanta, Georgia 30348; tele (404) 446-1400; libr Elizabeth A. Bibby, Information Resources Administrator; salu Ms. Bibby subj pulp & paper, packaging; user staff, members, general public; serv reference on site, by telephone, by mail, computer searches, photocopy service (TAPPI publications only); inst Technical Association of the Pulp & Paper Industry.

IDAHO

357 loca Boise; name Boise Cascade Corporation, Corporate Library Services; addr One Jefferson Square, Boise, Idaho 83728; tele (208) 384-6694; libr Patricia Metcalf, Librarian; salu Ms. Metcalf subj forestry in general, forest products, pulp and paper; user corporate employees and occasionally neighboring companies and community members; serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst Boise Cascade Corporation.

358 loca Moscow; name Science and Technology Library; addr University of Idaho, Moscow, Idaho 83843; tele (208) 885-6235; libr Donna M. Hanson, Science Librarian; salu Ms. Hanson; subj forestry in general, agroforestry, international forestry, forest products, pulp and paper, range management, wildlife management, fisheries; user faculty, students, staff, general public (limited services), other (USDA Document Retrieval Agreement, Wash. State Univ., reciprocal); serv reference on site, by telephone, by mail, interlibrary loan, computer searches; inst University of Idaho.

ILLINOIS

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391 loca Madison; name Forest Products Laboratory, Library; addr One Gifford Pinchot Drive, Madison, Wisconsin 53705; tele (608) 264-5713; libr Roger Scharmer, Supervisory Librarian; salu Mr. Scharmer; subj forest products, pulp and paper; user faculty, students, staff, general public; serv reference on site, by telephone, by mail, interlibrary loan, compilation of bibliographies (staff only); inst USDA Forest Service.

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Evans, Peter A.; Arizmendi, Mark A.; **International directory of forestry and forest products libraries**. Gen. Tech. Rep. PSW-97. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987. 106 p.

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Ecological Type Classification for California: The Forest Service Approach

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INTRODUCTION

Classification systems of vegetation, soil, habitats, and ecosystems are used by resource managers to group information by some unit. The units are labelled and described so that managers can use them to measure land area, plan treatments, conduct inventories, and aggregate information. Classification units can be broad or site specific, oriented to a single resource or to multiple resources, used widely or locally, or be based on multiple factors or on a single factor.

All classifications are artificial. The units are initially identified and described to meet a specific need and are distinguished from each other by specific criteria. Natural classification units such as habitat types or ecological types, as a subset of artificial classification, are generally regarded as those based on natural relationships and serving a larger number of purposes (Pfister and Arno 1980).

Why Classify Ecosystems?

Legislation such as the National Environmental Policy Act (1970), Federal Land Policy and Management Act (1976), and National Forest Management Act (1976) mandates the development and use of a structured ecological data base to improve resource decision making (Barnes 1982). The legislation has resulted in a 10-year effort in National Forest land management planning, and a requirement for site-specific productivity estimates and predictions of expected site response to management for FORPLAN modeling (Johnson and others 1986). These numbers mostly are unavailable for California ecosystems, or are available for only a part of the ecosystem (for example, the tree component) so that true interactions cannot be assessed.

At the same time, current national emphasis on increasing efficiency, eliminating duplicate data collection, and standardizing resource terminology have had these outcomes: new Forest Service policy on classification and inventory (USDA Forest Service 1986a); increased interest and cooperation between State and federal agencies in producing compatible, interchangeable resource assessments (USDA Forest Service 1984); and reactivation in California in 1983 of the Interagency Vegetation Classification Committee (1986) which is charged with meeting many of these national goals.

At State and Federal levels, agencies and functional specialists within agencies continue to collect resource data on uncommon units, which results in duplicate information and data gaps. In general, vegetation inventories—whether timber inventory, range analysis, or wildlife habitat surveys—have not included soil interpretations, so that maps of soil and vegetation produce a fragmented landscape when the information is combined on overlays. Resource managers have a difficult time interpreting the meaning of one inventory in terms of another because of different scales of resolution, different objectives, and different definitions for the same term or factor. In existing inventories a timber manager refers to a piece of ground by a different name than does the range manager, who refers to it differently than does the wildlife biologist, and so on.

Finally there is a lack of on-the-ground ecological data regarding the location and extent of forests and rangelands that will respond favorably to management. Most existing inventories and surveys are not multifunctional but are designed for specific functional purposes, or are not detailed enough to adequately address potentials, hazards, constraints, interactions and environmental effects for intensive management.

Alternative Classification Models

Classification models that use soil, vegetation, and physiographic variables are not new. Ecologically based, natural classification systems, such as habitat types (Daubenmire 1952) and plant community types (Hall 1973) have been used in Forest Service Regions (Northern, Rocky Mountain, Southwestern, and Pacific Northwest). The systems organize resource information, and provide information on productivity and expected response to treatment for National Forest planning, PROGNOSIS (Mouer 1985, Stage 1973) modeling, and project prescription writing. In addition, the classifications serve as a common labeling system to integrate functional resource inventories, reduce data gaps, and improve communication between functional resource specialists. Development of this type of classification tool by the Forest Service in California began in 1983.

Development of these habitat type, plant community, and forest site classification systems have required intensive, long-term data collection and analysis, and long-term on-site experience of an ecologist. Late seral, potential, or climax vegetation is the focus of the habitat type and plant community type classifications. The weak link in these systems has been the lack of integration of soil data and the existing soil data base. In all these classification models, once the classification framework is established, the next step is to develop successional classifications by habitat type, plant community type, or ecological type.

Broader classification systems focusing on ecoregions (Bailey 1976, 1978), component classification for the United States (Driscoll and others 1984), or land cover types (Witmer 1978) are also widely used especially for broad level planning. Other systems widely used in California focus on describing existing vegetation (Barbour and Major 1977, Cheatham and Haller 1975, Eyre 1980, Munz and Keck 1975, Paysen and others 1980, USDA Forest Service 1981), combine soil and vegetation through mapping (Jensen 1947, State of California 1969, USDA Soil Conservation Service 1976, Weislander 1935) or describe and map broad units of existing (Matyas and Parker 1980) or potential (Kuchler 1977) vegetation.

Each of these systems has value and uses in its own right, but none contains the site-specific productivity or expected response to management information specific to California ecosystems. *Table 1* summarizes the differences between many of the common California classification systems, and their primary uses. Habitat types and plant community types are also included in the table, as much of the methodology used to develop those systems are incorporated in Forest Service policy (USDA Forest Service 1986a) and the Pacific Southwest Region's classification model.

This report describes an ecosystem-type classification system for California, which was begun by the Forest Service's Pacific Southwest Region in 1983. It presents the first two phases of the classification effort, reconnaissance and intensive sampling, and includes a sample ecological type description.

ECOLOGICAL TYPE CLASSIFICATION MODEL

The Ecological Type is the basic unit in the Pacific Southwest Region's (R5) classification model. This unit is defined as a classified category of land with a unique plant association and physical site characteristics, differing from other categories of land in its ability to produce vegetation and respond to management (RISC 1983, USDA Forest Service 1986a). Vegetation, soils, and physiographic data are classified into individually distinct ecological types using late seral, undisturbed, self-reproducing (stable) plant communities.

Table 1—*Major vegetation/ecologically based classification systems in California*

Classification[1]	Unit scale	Vegetation	Soils	Other descriptors
SAF Forest cover types	Broad	Existing	No	Mappable, applies to forest types
SCS Range sites	Broad to narrow	Potential	Compared	Productivity applies to rangeland, mapped
Habitat types	Narrow	Potential	No	Widely used in Forest Service Regions, some methods used in ecological type approach
Plant community types	Site specific	Potential	Not most	R6, methods used in ecological type development
WHR Wildlife habitat types	Broad	Existing and potential	No	Ecological types will aggregate soils in descriptions
CALVEG	Hierarchical	Both	No	Lowest level not described, series groups mapped
Kuchler (1977)	Broad	Potential	No	Worldscale mapped
Munz and Keck (1975)	Broad	Existing	No	With book
Barbour and Major (1977)	Broad	Existing	No	With book
Jensen (1947)	Broad	Existing	No	With map, emphasis on commercial timber
California soil–vegetation survey	Broad to narrow	Existing	Yes	Map system, soil, main vegetation

[1]SAF = Society of American Foresters.
SCS = Soil Conservation Service.
WHR = Wildlife Habitat Relationships Program.
CALVEG = California Vegetation (Matyas and Parker 1980).

A classification system such as this holds time constant by focussing on a stable, predictable, self-reproducing vegetative state (Hall 1973, Pfister and Arno 1980, RISC 1983). This allows for the labeling and description of units around which seral plant community classification and predictive models can be developed. Such an ecologically based classification expresses the interrelationships between all vegetation and landforms, landforms and soils, and vegetation and soils (Barnes and others 1982). An ecological classification system based on the potential natural plant community provides the framework around which multiple-use resource management can be applied.

This framework does not mean that resource managers must manage land for potential vegetation, which they may never want to do. However, knowing the site potential and being able to recognize it in any state of seral development will allow predictions of productivity and site response to management through a stable classification system.

The identification of ecological and management information for each ecological type will be accessed through the use of a dichotomous key carried in pocket-sized booklets ready for field use. Maps will be prepared only on a case-by-case basis in support of specific project level work. Eventually much of the Region may be mapped, but—most likely—aggregates of ecological types will be the mapping unit.

Eight Forest Service ecologists are leading the ecological type classification effort on and around 16 of the 18 National Forests in California *(fig. 1)*. Classification methodology is standardized and coordinated by the Regional Ecologist and Ecology Advisory Committee out of the Regional Office in San Francisco. The Regional Ecologist has these responsibilities for program direction: standardization of terminology and methodology, monitoring of classification development, and coordination between other Regions and other classification efforts to avoid duplication of types with different names.

The forest classification team leaders, who actually develop the ecological type classification systems, are skilled in plant ecology, soils, and management. They have the ability to interpret ecosystem processes through testing of hypotheses developed during several years of field data collection. The approach and methodology are spelled out (USDA Forest Service 1986b), but each team leader must interpret the directive using his or her own understanding and experience. Standardization and communication within the Region is maintained through yearly field training courses and yearly field monitoring by the Regional Ecologist.

CLASSIFICATION METHODS

Field methodology as described in FSH 2090.11 (USDA Forest Service 1986b) is drawn heavily from Franklin and others

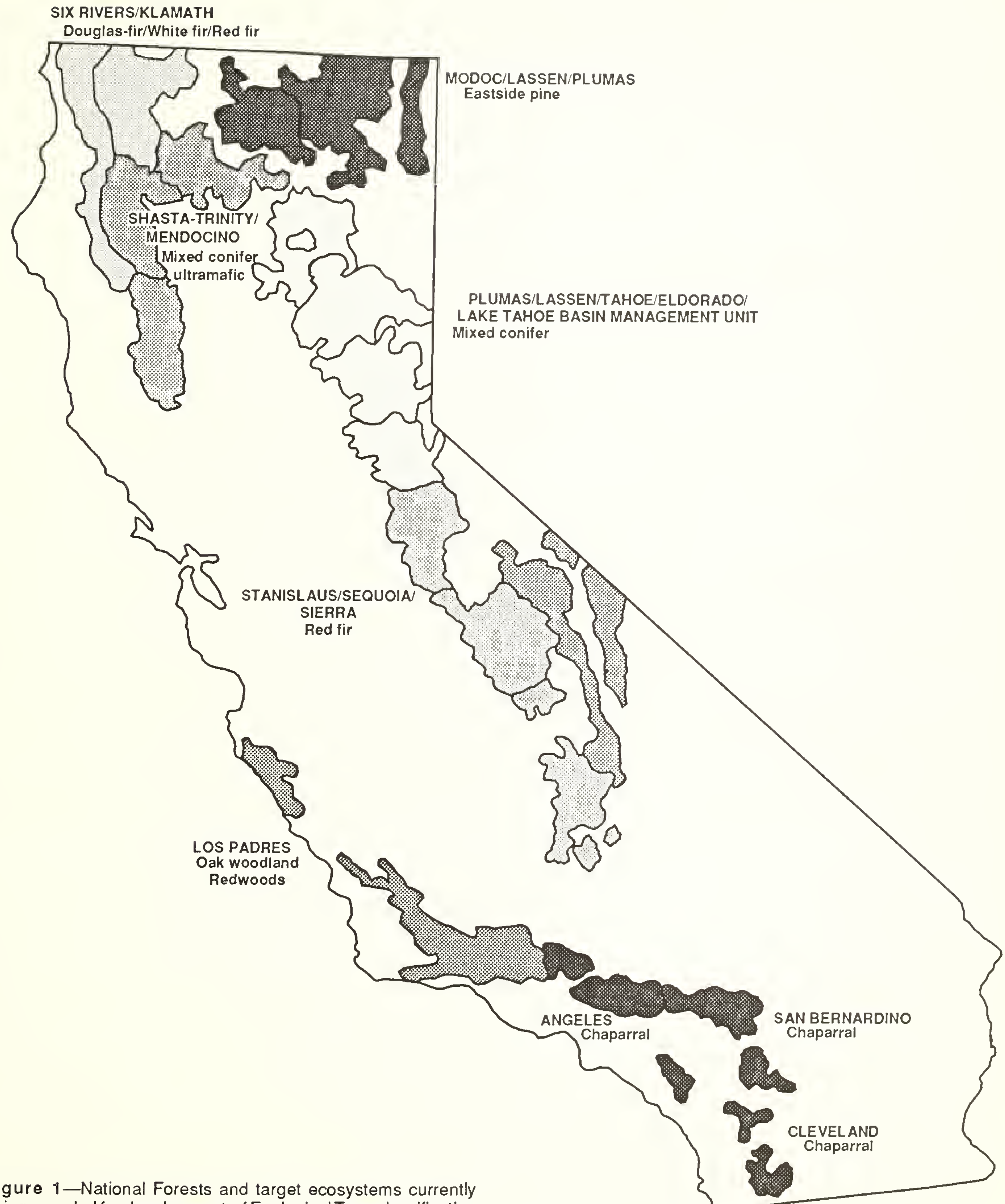

Figure 1—National Forests and target ecosystems currently being sampled for development of Ecological Type classification correspond to major areas of forest activity in California. Shading indicates individual team leader responsibility for that particular group of forests.

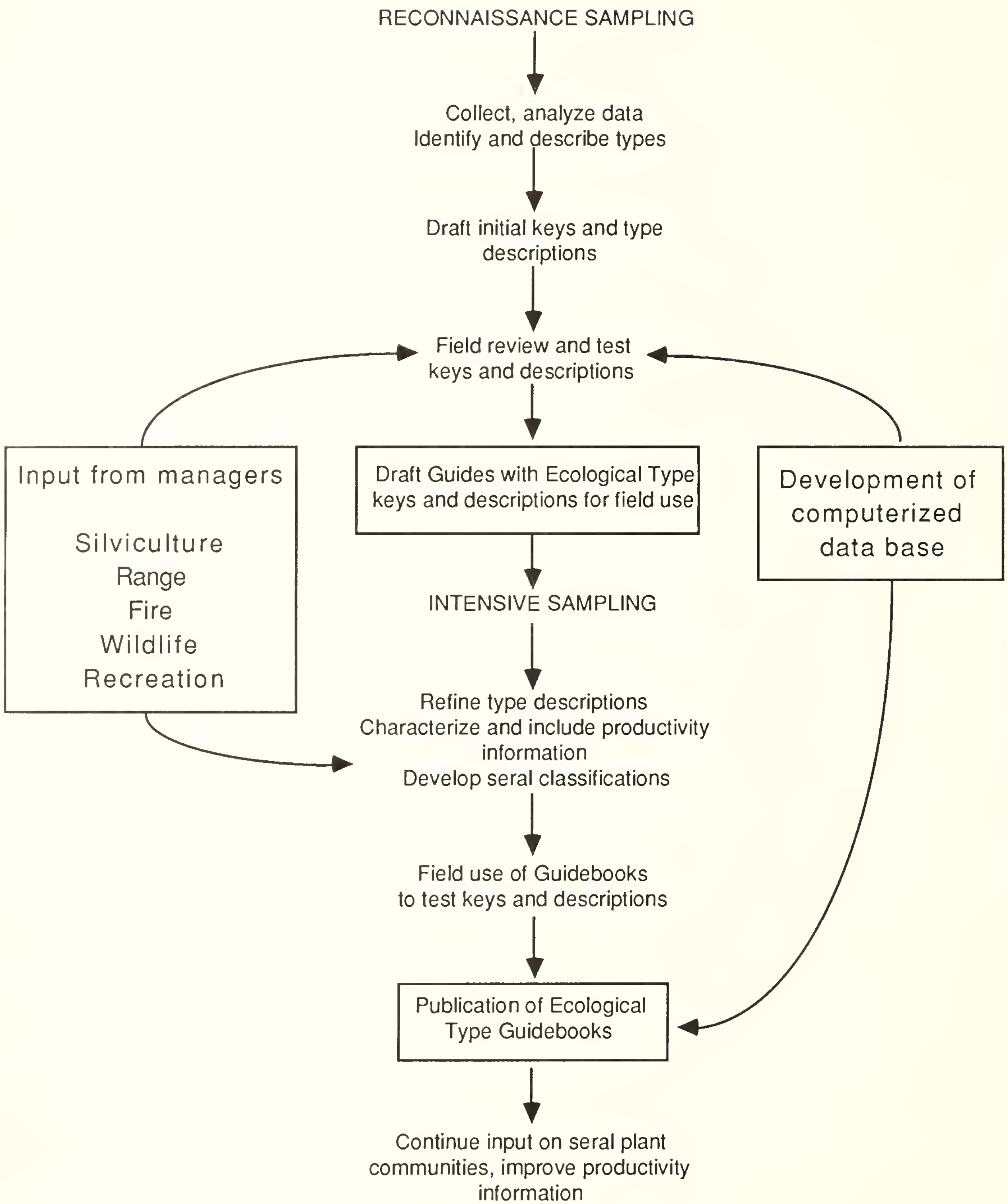

Figure 2— The six major steps in the development of an Ecological Type classification system are carried out by a team of ecologists, botanists, and soil scientists.

(1970), Hall (1973) and Pfister and Arno (1980). Intensive sampling methodology has been borrowed and modified from Arno and others (1985), Atzet and Wheeler (1984), Hall (1983), Pfister and Arno (1980) and Steele (1984). *Figure 2* schematically describes the overall classification process.

Reconnaissance Sampling

The first phase, which takes 2 to 5 years in the identification of ecological types is accomplished through reconnaissance sampling. Measurements from late seral stage plots are taken to encompass the total variability of vegetation, soils, and landforms within the target ecosystem or geographic area. Once plot data have been analyzed and classified into ecological types and field checked, each type is described and its distinguishing attributes incorporated into a dichotomous key for field use.

Reconnaissance plots are 1/10th acre (0.04 ha) and are selected "systematically without preconceived bias" (Mueller-Dombois and Ellenberg 1974). On every plot, detailed environmental and location data are recorded. Plots are marked on the ground and on aerial photographs so that they can be located again.

The percent cover of all plant species is recorded, since initially the ecologist doesn't know which plant species will be most helpful in identifying the type. Tree basal diameters, age, and average height are recorded to characterize stand structure and provide gross estimates of volume. Shrub height by species is recorded in addition to cover, allowing the team leader to examine shrub structure and calculate crude volumes. Unknown species are collected for later identification.

A soil pit is dug to 40 inches (102 cm), and thickness, texture, and color of the surface and subsurface horizons are recorded. Parent material, total depth, available waterholding capacity (AWC), and pH are recorded or calculated to aid in the classification of the soil to series.

Intensive Sampling

The second sampling phase, intensive sampling, takes 3 to 10 years and makes the ecological type the focal point of data collection. The objectives are twofold: First, to describe the seral stages and successional pathways of the type following natural and management related perturbations; and second, to characterize the potential of the type, such as the capability to produce vegetation (forage, timber) or to provide wildlife habitat.

All species of vegetation are recorded on a 1/10th acre (0.04 ha) plot (USDA Forest Service 1986b). A complete soil pit is dug using standard soil inventory procedures (USDA Soil Conservation Service 1981), and the soil profile is described and classified. On forest sites, specific stands are sampled for timber productivity with standard forest inventory techniques (USDA Forest Service 1976). Age, known management history, and environmental and location parameters are recorded for every plot. Shrub and herbaceous production for key forage species are also taken on both forest and chaparral communities.

At the end of the field season, the data are analyzed using statistical and multivariate analyses. The primary analysis packages include Computer Analyses of Ecological Data (Volland and Connelly 1978), DECORANA (Hill 1979a), and TWINSPAN (Hill 1979b). Consistency of data analysis is maintained through training sessions and year-round coordination.

PRODUCTS FOR USERS

Two usable products will result from reconnaissance sampling: draft field keys to the ecological types,[1] and eight General Technical Reports describing the types for the major areas of forestry activities in California.[2] Draft keys and ecological type descriptions are available for chaparral, southcoast redwoods, Klamath mountain red fir and westside mixed conifer, at this writing.

In the appendix is an example of a Chamise-White Sage—Cieneba (SC-CH-51) Ecological Type developed on the Cleveland National Forest (White 1985). The description is based on reconnaissance sampling and input from field managers. Information on fire ecology and behavior, range productivity, and suitability for type conversion comes from the team leader's field experience and observations, other managers' input, and research.

The information in the sample description and corresponding key is currently being field tested by Regional and Forest resource specialists. The key is applied to a variety of plant communities to see if it leads the user to the correct type description. Information in the description is tested through field observation of the plant community and analysis of the accuracy of the predictions of plant community response to treatment. Intensive sampling and field input through the use of the keys and descriptions will lead to the refinement of information on management treatment response. Information, such as that on wildlife, will be refined as additional information is obtained.

APPLICATIONS OF THE CLASSIFICATION SYSTEM

Classification models meeting specific user needs are numerous. The proposed ecological type classification being developed in R5 will provide common labels and common site descriptions for use by all types of resource managers. Site-specific productivity data will be available because this classification system includes the entire vegetation/soil/physiographic unit.

The ecological type classification system is only a tool, a framework within which to organize information. It is ecologically based, not use-oriented, allowing users to make their own interpretations. It is a tool that can be used to improve communication between functional resource specialists.

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[1] The keys are available on request from the Supervisor's Offices of the 16 National Forests shown in *figure 1*.

[2] For information on availability and for copies of the General Technical Reports, write to: Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, CA 94701, Attention: Publications Distribution.

As others have so appropriately stated (Barnes and others 1982, Hall 1983), resource managers need to know six attributes of a site to manage it effectively:

1. Productive potential and expected response to management treatments.
2. Existing vegetation.
3. Land situation, such as geomorphic classification, steepness of slope, aspect.
4. Juxtaposition to other land types and ownerships.
5. Current use.
6. Soil situation (taxonomy).

The ecological type classification and information addresses only the first item. However, an ecological type classification system, based on years of site specific data collection and evaluation, can be used in many ways by resource managers including these:

- It can guide foresters in deciding which species to plant on a given site, and which site treatment to use under differing circumstances. Once completed the classification can be applied to determine potential stand productivity, potential site productivity, optimum expected growth, fertilization requirements, tree species, and the best season for harvesting.
- For wildlife and range managers, ecological type classification can be used to determine above-ground biomass production, stocking rates, carrying capacities, and habitat critical to wildlife survival.
- In conservation, it can guide the selection of ecological reserves and research natural areas by identifying unique or threatened ecosystems.
- In watershed management, potential soil erosion, water interception and use, and soil fertility can be determined.
- To recreation, it offers guidelines for land use assessment and development of interpretive programs.
- In planning, the information in the classification system can be used to weigh land-use allocation alternatives.
- In research it can focus efforts on areas where research is needed as well as provide the common site labeling system for application of research results.
- In engineering the classification can provide critical site and soil information.

FUTURE OF THE CLASSIFICATION EFFORT

The Pacific Southwest Region of the Forest Service is committed to completing an ecological type classification system for the lands it manages in California. However, its commitment and support to the ecological type approach extends beyond lands managed by National Forests. The Forest Service is part of the State of California Interagency Vegetation Classification Working Group, whose charge is to keep lines of communication open between State and Federal agencies and to standardize terminology and methodology. The Forest Service is also working closely with the Soil Conservation Service, U.S. Department of Agriculture, in evaluating range site descriptions—which are widely used in California—for modification and incorporation into an ecological type concept. The National Range Handbook (USDA Soil Conservation Service 1976) already incorporates many of the concepts described here for ecosystem classification.

Further, cooperation between the California Department of Forestry, the Pacific Northwest Forest and Range Experiment Station Forest Survey and research is evidenced by open communication and evaluation of proposed R5 classification methodologies. This cooperation will continue to promote the development and completion of a standardized, ecological type classification for the State of California.

APPENDIX

Sample Type Description

CHAMISE-WHITE SAGE—CIENEBA ECOLOGICAL TYPE (SC-CH-51) (ADFA-SAAP1-CIENEBA)

Description

The Chamise-White Sage—Cieneba Ecological Type is characteristic of the most xeric low elevation sites. It is often transitional to the coastal sage type especially on south slopes at the lower end of the elevational range. A characteristic stand is dominated by chamise *(Adenostoma fasciculatum)* with either white sage (*Salvia apiana)* or California buckwheat *(Eriogonum fasciculatum*) present in the understory, usually making up 5-10 percent cover in combination. Scrub oak is absent from the stand or occurs with very low cover.

Cieneba soils have coarse to moderately coarse textures and are somewhat excessively drained. They are derived mostly from granitic parent materials. The underlying bed rock is softly weathered and occurs within 50 centimeters of the surface. Plant roots are capable of penetrating deeply into the substratum, and typically have low fertility and organic matter content. The thin soil mantles have low water holding capacities and plant roots obtain needed moisture from the substratum.

CONSTANCY TABLE (N = 13 plots)

Dominant Species	Constancy	Range	Average cover
		Percent	
Chamise	100	22-89	44
White sage	83	1-12	5
California	50	1-20	7
Nolina	59	1-3	1
Mission manzanita	27	1-15	9
Cieneba Soil Series	100		

Site characteristics	Average	Minimum	Maximum
Elevation (m)	625	390	950
Slope (pct)	26	8	60
Solar insulation (PASI)	295	282	305
Vegetation cover (pct)	62	50	90
Bare ground (pct)	15	1	74
Gravel (pct)	11	1	30
Rock (pct)	9	0	50
Litter (pct)	54	15	98
Litter depth (mm)	16	12	28
Soil depth (cm)	4	2	7
A Horizon depth (cm)	4	2	7
AWC (mm)	35	4	59

Management Interpretations

Fire Ecology

Average fire frequencies range from 20 to 30 years (Countryman and Philpot 1970). On the Cleveland National Forest the historical average fire frequency for this type was 32 years (White 1982). Due to the proximity of the coastal sage type in most areas a higher fire frequency can be expected in transitional areas especially on sites with a high ignition frequency in the coastal sage (Hanes 1971). A high portion of 1-hour fuels due to the white sage and buckwheat understory make this type more flammable at an early age than pure chamise stands found at higher elevations. Fires in 15-year-old stands are common. Frequent fires could lead to an increase in the sage and buckwheat component, which in turn would lead to higher fire frequencies. White sage inhibits establishment of chamise seedlings in mature stands (Went, Juhren and Juhren 1952). All associated shrub species are strong post-fire sprouters. The lack of seeding species may be due to the relatively high fire frequency or simply the xeric site conditions (Minnich and Howard 1984).

Fire Behavior

A high percentage of fine fuel (1 to 10 h) is characteristic of this type. The buckwheat and white sage understory mentioned above, in addition to chamise, makes these sites extremely flammable at a relatively young age. Flammability is locally reduced on sites that are very sparse with a low percent cover of sage and buckwheat, but this is the exception rather than the rule. With little to no litter fires have to carry in the crowns, which makes crown continuity especially important in predicting fire behavior in this type. Fires burn out quickly due to the high percentage of fine fuel and little large diameter dead material. Humidity recovery control of prescribed fires is effective unless a continuous cover of sage or buckwheat is present to carry fire under high humidity conditions. Spotting is a problem due to the high percentage of fine dead fuel in most areas.

Range Productivity

Shallow coarse textured soils and low rainfall make this a poor range site. Average annual forage production on recently burned areas is estimated to be less than 96 kilograms per hectare.

Wildlife

WHR Cover Type = Chamise-Redshank Chaparral

Chamise and associated shrubs in this type are of low palatability when mature. Chamise is utilized for 2 to 3 years following burns (based on field observations, high use by rabbits, no wood rats, open stand structure, and poor cover for deer).

Suitability for Type Conversion

Physical limitations	None
Water yield potential	Low
Range production	Low
Fuelbreak	High

REFERENCES

Amo, Stephen F.; Simmerman, Dennis G.; Keane, Robert E. 1985. **Forest succession on four habitat types in western Montana.** Gen. Tech. Rep. INT-77. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 74 p.

Atzet, Thomas; Wheeler, David L. 1984. **Preliminary plant association of the Siskiyou mountain province.** Portland, OR: Pacific Northwest Region, Forest Service, U.S. Department of Agriculture; 315 p.

Bailey, Robert G. 1976. **Ecoregions of the United States (map).** Ogden, UT: Intermountain Region, Forest Service, U.S. Department of Agriculture.

Bailey, Robert G. 1978. **Description of ecoregions of the United States.** Ogden, UT: Intermountain Region, Forest Service, U.S. Department of Agriculture; 77 p.

Barbour, Michael G.; Major, Jack, eds. 1977. **Terrestrial vegetation of California.** New York: John Wiley & Sons; 1002 p.

Barnes, Burton V. 1982. **Ecosystem classification—number 1 priority.** In: Proceedings, Artificial regeneration of conifers in the Upper Great Lakes Region; 1982 October 26-28; Green Bay, WI. Houghton: Michigan Technical University; 8-30.

Barnes, Burton V.; Pregitzer, Kurt S.; Spies, Thomas A.; Spooner, Vera N. 1982. **Ecological forest site classification.** Journal of Forestry 80(8): 493-498.

Cheatham, Norden H.; Haller, J. Robert. 1975. **An annotated list of California habitat types.** Unpublished draft supplied by author.

Countryman, C.M.; Philpot, C.W. 1970. **Physical characteristics of chamise as wildland fuel.** Res. Paper PSW-66. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 16 p.

Daubenmire, R. 1952. **Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification.** Ecological Monographs 22(3): 301-330.

Driscoll, Richard; Merkel, Daniel L.; Radloff, D.L.; and others. 1984. **An ecological land classification framework for the United States.** Misc. Publ. 1439. Washington, DC: Forest Service, U.S. Department of Agriculture; 56 p.

Eyre, F.H., ed. 1980. **Forest cover types of the United States and Canada.** Washington, DC: Society of American Foresters; 148 p.

Franklin, Jerry F.; Dyrness, C.T.; Moir, W.H. 1970. **A reconnaissance method for forest site classification.** Tokyo, Japan: Shirin Richi XI(1):1-14.

Hall, Frederick C. 1973. **Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington.** R6 Area Guide 3-1. Portland, OR: Pacific Northwest Region, Forest Service, U.S. Department of Agriculture; 52 p.

Hall, Frederick C. 1983. **Applications and interpretation of forest ecosystems classification.** In: Proceedings, Forestland Grazing Symposium; 1983 February 23-25; Spokane, WA. Pullman: Cooperative Extension, Washington State University; 7-14.

Hanes, T.L. 1971. **Succession after fire in the chaparral of southern California.** Ecological Monographs 41: 27-52.

Hill, M.O. 1979a. **DECORANA, a FORTRAN program for detrended correspondence analysis and reciprocal averaging.** Available from Cornell University, Ithaca, NY.

Hill, M.O. 1979b. **TWINSPAN, a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes.** Available from Cornell University, Ithaca, NY.

Interagency Vegetation Classification Committee. 1986. **Memorandum of agreement among the federal, state, and county agencies and private organization relating to wildland resource assessments in California.** Berkeley: Wildland Resources Center, University of California; 4 p.

Jensen, Herbert A. 1947. **A system for classifying vegetation in California.** California Fish and Game 33(4): 199-266.

Johnson, K. N.; Stuart, T.; Crim, S. 1986. **FORPLAN (Version II)—an overview.** Fort Collins, CO: Land Management Planning Staff, Fort Collins Computer Center, U.S. Department of Agriculture; (mimeo).

Kuchler, A.W. 1977. **The map of natural vegetation of California.** In: Barbour, M.G.; Major, Jack, eds. Terrestrial vegetation of California. New York: John Wiley & Sons; map.

Matyas, Wendy J.; Parker, Ike. 1980. **CALVEG—Mosaic of existing vegetation of California.** Regional Ecology Group Report. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 27 p.

Minnich, R.; Howard, L. 1984. **Biogeography and prehistory of shrublands.** In: DeVries, Johannes J., ed. Shrublands in California: literature review and research needed for management. Report 60. Davis: Water Resources Center, University of California: 1-2.

Mouer, Melinda. 1985. **COVER: a user's guide to CANOPY and SHRUBS extension of the stand PROGNOSIS Model.** Gen. Tech. Rep. INT-190. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 49 p.

Mueller-Dombois, Dieter; Ellenberg, Heinz. 1974. **Aims and methods of vegetation ecology.** New York: John Wiley & Sons; 547 p.

Munz, Philip A.; Keck, David D. 1975. **A California flora.** Berkeley: University of California Press; 1681 p.

Paysen, Timothy E.; Derby, Jeanine A.; Black, Hugh, Jr.; Bleich, Vernon C.; Mincks, John W. 1980. **A vegetation classification system applied to southern California.** Gen. Tech. Rep. PSW-45. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 33 p.

Pfister, Robert D.; Arno, Stephen F. 1980. **Classifying forest habitat types based on potential climax vegetation.** Forest Science 26: 52-70.

RISC: Range Inventory Standardization Committee. 1983. **Guidelines and terminology for range inventories and monitoring.** Report to Board of Directors of Society for Range Management. Albuquerque, NM; 13 p.

Stage, Albert R. 1973. **PROGNOSIS model for stand development.** Res. Paper INT-137. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 32 p.

State of California. 1969. **Soil-vegetation surveys in California.** Sacramento: California Department of Forestry; 31 p.

Steele, Robert. 1984. **An approach to classifying seral vegetation within habitat types.** Northwest Science 58(1): 29-39.

U.S. Department of Agriculture, Forest Service. 1976. Pacific Southwest Region. **Forest Service Handb. 2409d, Timber inventory handbook.** San Francisco, CA.

U.S. Department of Agriculture, Forest Service. 1981. **CALVEG—A classification of vegetation of California.** San Francisco, CA: Regional Ecology Group, Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 168 p.

U.S. Department of Agriculture, Forest Service. 1984. **Proceedings of the Inventory Integration Workshop; 1984 October 15-19; Portland, OR.** Washington, DC: Range and Timber Management Staff; 165 p.

U.S. Department of Agriculture, Forest Service. 1986a. Forest Service Manual. **Chapter 2060, Ecosystem classification, interpretation and application.** Washington, DC.

U.S. Department of Agriculture, Forest Service. 1986b. **Ecosystem classification, application, and interpretation.** San Francisco, CA: Pacific Southwest Region. Forest Service Handb. 2090.11, Ecosystem classification handbook. San Francisco, CA..

U.S. Department of Agriculture, Soil Conservation Service. 1976. **National Range Handbook.** NRH, July 13. Washington, DC. 150 p.

U.S. Department of Agriculture, Soil Conservation Service. 1981. **Soil Survey Manual, 430-V Issue 1.** Washington, DC. 294 p.

Volland, Leonard A.; Connelly, Margaret. 1978. **Computer analysis of ecological data: methods and programs.** R6 ECOL-79-003. Portland, OR: Pacific Northwest Region, Forest Service, U.S. Department of Agriculture; 352 p.

Weislander, A.E. 1935. **A vegetation type map of California.** Madrono 3: 140-144.

Went, F.W.; Juhren, G.; Juhren, M.C. 1952. **Fire and biotic factors affecting germination.** Ecology 33: 351-364.

White, Thomas. 1982. **Use of prescribed fire on the Laguna Morena Demonstration Area.** In: Proceedings, 34th Annual California Weed Conference; 1982 January 18-21; San Diego, CA. Sacramento: California Weed Conference: 156-161.

White, Thomas. 1985. **The chamise-white sage—cieneba ecological type.** Unpublished draft supplied by author.

Witmer, Richard E. 1978. **U.S. Geological Survey land-use and land-cover classification system.** Journal of Forestry 76(10): 661-666.

Allen, Barbara H. **Ecological type classification for California: the Forest Service approach.** Gen. Tech. Rep. PSW-98. Berkeley CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1987. 8 p.

National legislation has mandated the development and use of an ecological data base to improve resource decision making, while State and Federal agencies have agreed to cooperate in standardizing resource classification and inventory data. In the Pacific Southwest Region, which includes nearly 20 million acres (8.3 million ha) in California, the Forest Service, U.S. Department of Agriculture, has begun a long term project to develop an ecosystem type classification system. It will identify and describe vegetation/soil/ physiographic units called ecological types, which are site-specific units distinguished from each other by significant differences in species composition, soils, productivity, and expected response to management; and which are identifiable in the field in any seral stage. The classification will provide resource managers a useful tool for organizing complex arrays of resource information, a common labeling system and site-specific ecological information to improve predictions of site productivity and expected response to management. Methodology described for classification development includes reconnaissance and intensive sampling. An ecological type description developed on the Cleveland National Forest is an example of the products that will be available to users.

Retrieval Terms: classification, ecological type, ecosystem, Forest Service, California

United States
Department of
Agriculture

Forest Service

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General Technical
Report PSW-99

Common Shrubs of Chaparral and Associated Ecosystems of Southern California

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C. Eugene Conrad

CONTENTS

INTRODUCTION

California is especially rich in plant species, subspecies, and varieties. Stebbins and Major (1965) reported more than 4000 species in California, one-third of these endemic. Such richness is largely attributable to the extreme diversity of habitats and conditions created by the climate and geology of California. It is not uncommon to find habitats that contain isolated or disjunct populations that are geographically separated from the main population center for that species.

Plant species and habitat diversity figures importantly in the implementation of sound land management practices. The best decisions of the land manager are those which account for the vegetation of an area; that is, species identification, habitat distribution, responses to fire, and value as food for wildlife or livestock grazing. But not all land managers are botanists. This guide is therefore directed to the land manager who has some biology training but not a strong background in technical plant identification. Moreover, it is designed as a field identification manual of 132 of the most important and/or most common shrubs in the southern California chaparral area. However, this guide is not intended to replace standard taxonomy manuals such as McMinn (1939) or Munz (1974), nor is it a source document for all southern California shrubs.

Vegetative and woody parts of plants have been used in building the keys to the species. Those familiar with plant keys know that many species are distinguished by their flowering and fruiting characteristics. Often, the only consistent difference between two species is floral. Users of this guide are encouraged to treat any identification as tentative until a specimen is identified by a qualified botanist who will often use standard taxonomic references such as McMinn (1939), Munz and Keck (1959), or Munz (1974). When necessary, the collected specimen should be verified against herbarium specimens.

The plant key is most reliably applied to that area of southern California outlined on the map *(fig. 1)*. The following foothills and ranges are included: the southern part of the south coastal ranges and the Santa Ynez, Santa Monica, and San Gabriel Mountains of Santa Barbara, Ventura, Los Angeles, and Orange Counties; the San Bernardino and San Jacinto Mountains of San Bernardino and Riverside Counties; and the Santa Rosa, Santa Ana, Palomar, Cuyamaca, and Laguna Mountains of Riverside, San Diego, and Orange Counties.

Appendix A contains a list of plant families and genera, including woody or semi-woody plant species recognized by Munz (1974). Appendix A also includes a synopsis of features that partially characterize the environment of the species in each genus.

Figure 1—Topographic map of southern California.

PLANTS INCLUDED IN THE GUIDE

This guide emphasizes shrub species on the coastal drainage side of the mountains (cismontane) as opposed to the desert side (transmontane). The transition between coastal drainage species and desert species is gradual.

Shrubs or subshrubs fitting the following conditions are included:

- Plants with main stems that are woody at least at the base, usually living several years or more;
- Plants with several main branches from or near the ground. If these conditions do not apply, then the plant is probably not in the guide, with the following exceptions:
- Yucca species which commonly have short woody stems but are prominent members of the chaparral community;
- Several species of vines that climb over and through other shrubs but have mostly woody stems;
- A few species normally considered trees but often existing in multiple-stem shrub form.

HOW TO USE THE VEGETATIVE KEYS

The vegetative keys identify shrubs based solely on vegetative characters. Thus, it is important to study the leaves and stems carefully. Choose a leaf whose size and shape looks like at least two-thirds of the leaves on the shrub. In other words, look at several leaves. Avoid young or immature leaves which often differ from mature leaves. Major leaf features are illustrated *(fig. 2)*. Determine whether the leaves on your specimen are scale-like or not scale-like. Are the leaves alternate or opposite? Are the leaf veins in a pinnate or palmate pattern? Are the leaves simple or compound? If they are compound are they palmate or pinnate?

Begin with the first page of the vegetative key and find the correct group, subgroup, and leaf type; then in the section directed to compare statement a with statement b at the same level of indentation. The number sequence is only important relative to statements a and b, the comparison statements must have the same number. Also the further along in the key, the higher the number. If your specimen best fits statement b, go directly down one line under b and one indentation to the right to the next statement a, and compare this statement a and statement b with your specimen. Continue making these dichotomous comparisons until the comparison ends with the

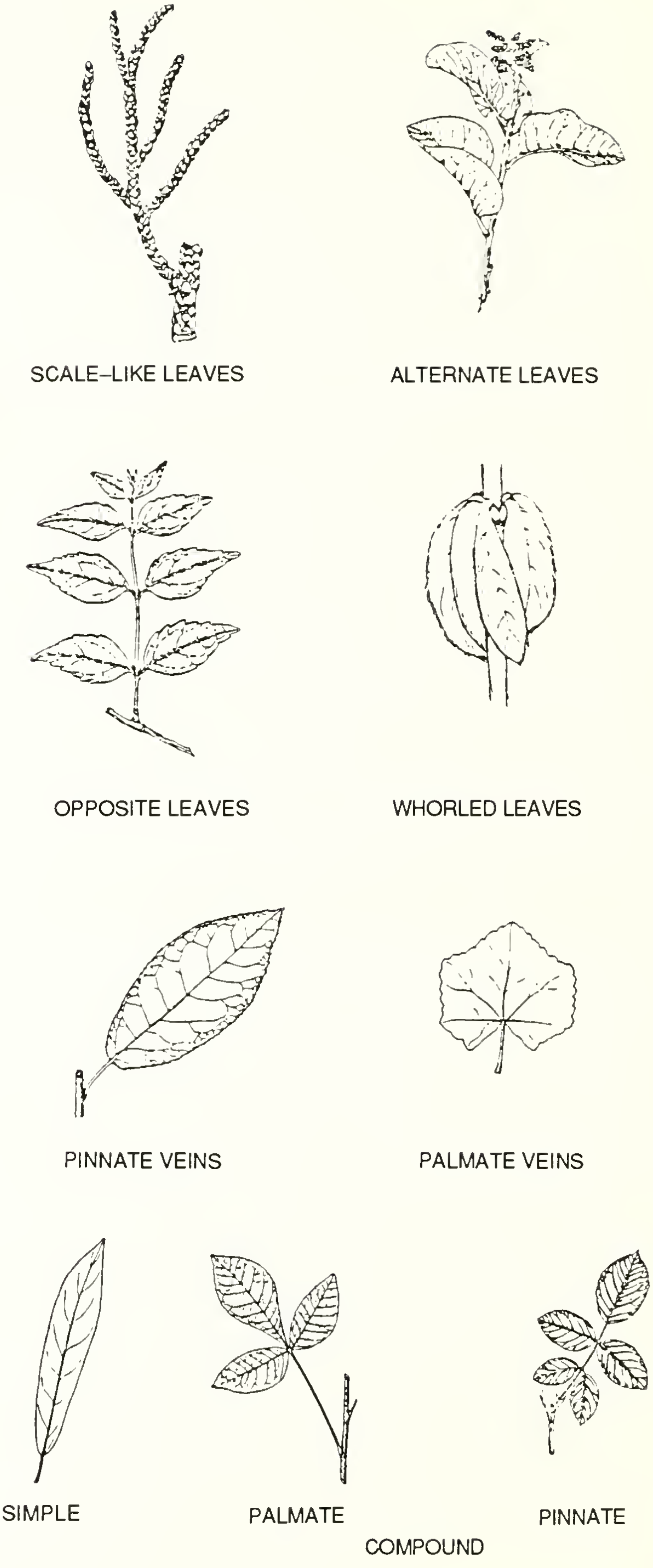
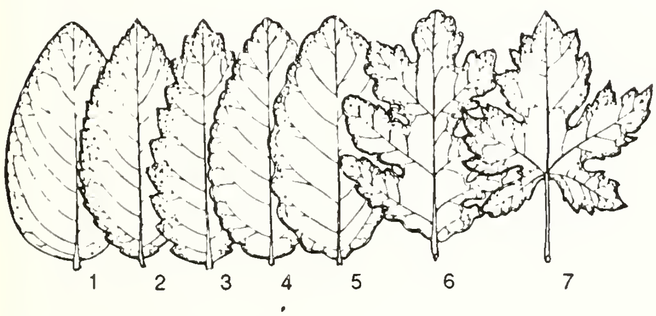


Figure 2—Illustrated use of the southern California shrub key.

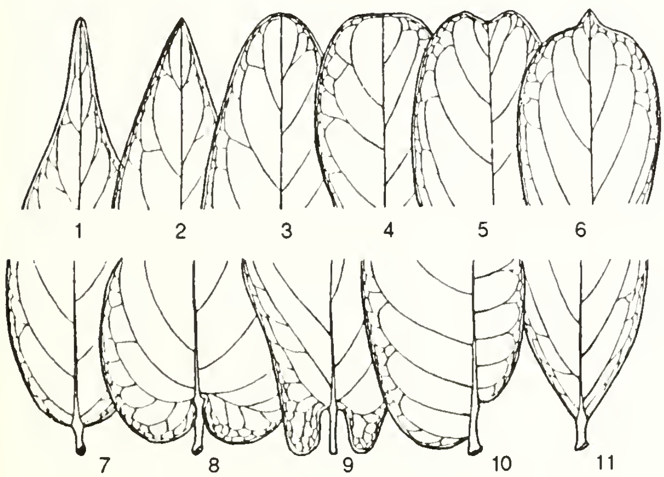
name of a shrub species or genus. Go to the page indicated and you will find either a genus or species description. If you are at the genus level, you will either go through another dichotomous key to get to the species or you will need to select the description which most closely fits your specimen. If you are directed to a species compare your specimen with the description and illustration.

A common error in judging a simple versus compound leaf is to mistake a leaflet for a leaf. Simple leaves usually have buds or growing points at their base; leaflets of compound leaves do not *(fig. 2)*. Compound leaves usually end in a leaflet, never with a growing tip; whereas, on plants with simple leaves, the twigs end in a bud or growing point, almost never with a leaf. Always check several leaves.

Another critical decision in keying a plant involves leaf margin and leaf shape. These features are especially critical in this key. Common leaf margins and shapes of leaf tips and bases are shown in *figure 3*. Common leaf shapes are shown in *figure 4*. Compare these illustrations with glossary definitions to better understand how various definitions relate to physical features.



Margins of leaves 1. Entire 2. Serrate 3. Denate 4. Crenate 5. Sinuate. 6. Pinnately lobed. 7. Palmately lobed *(From Pacific Coast Trees, Univ. Calif. Press.)*



Tips and bases of leaves 1. Acuminate. 2. Acute. 3. Obtuse. 4. Truncate. 5. Emarginate. 6. Mucronate. 7. Rounded. 8. Cordate or heart–shaped. 9. Auriculate. 10. Oblique or unequal. 11. Cuneate or wedgeshaped. *(From Pacific Coast Trees, Univ. of Calif. Press.)*

Figure 3—Leaf margin, tip, and base types.

GLOSSARY OF TERMS

Abrupt: Terminates suddenly without taper.

Acuminate: Leaf tapers to a point which may be sharp *(fig. 3B)*.

Acute: Less taper than acuminate but with a sharp point *(fig. 3B)*.

Akene: A small fruit which does not break open when it matures but does become dry and hard.

Alternate: Generally indicates one leaf per node, can also be applied to other parts *(fig. 2)*.

Appressed: Pressed against another part or organ.

Aromatic: Fragrant with spicy, pungent, pleasant, or ill-smelling odor.

Auricle: An appendage like an ear (lobe) especially at the base of an organ *(fig. 3)*.

Auriculate: Having an auricle *(fig. 3)*.

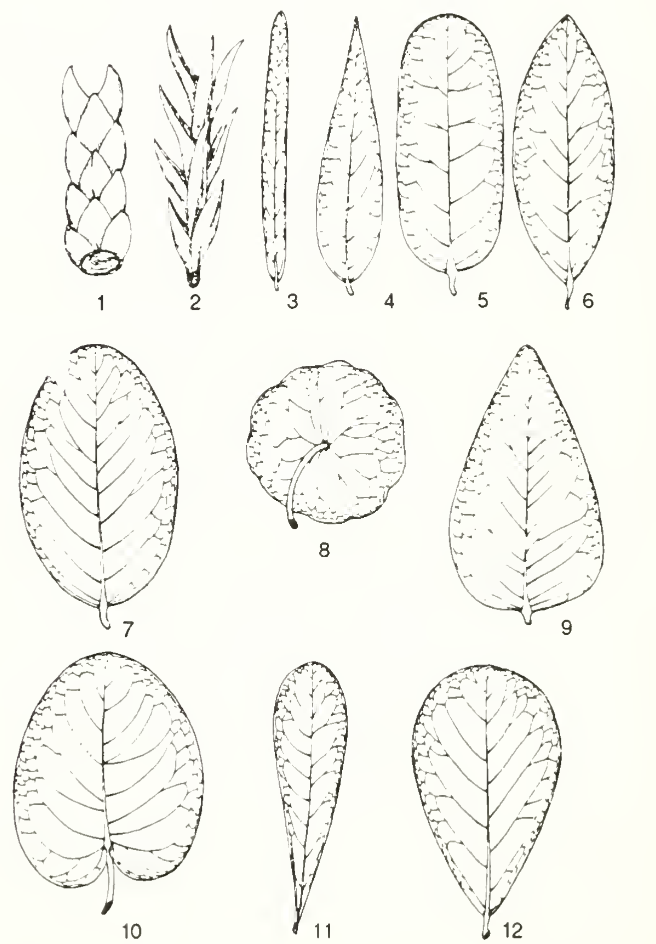
Awl-shaped: Narrow, may be nearly round and tapering to a point *(fig. 4)*.

Bark: External covering or rind of a woody stem or root usually fibrous or cork-like and often with outer scales.

Basal: Relative to or at the base.

Bipinnate: Doubly or twice pinnate.

Bluff: Geographic feature rising steeply to a flat or rounded front; for example, at a coast line.



Shapes of leaves 1. Scale–like. 2. Awl–shaped. 3. Linear. 4. Lanceolate 5. Oblong. 6. Elliptic. 7. Oval. 8. Orbicular. 9. Ovate. 10. Cordate. 11. Oblanceolate. 12. Obovate. *(From Pacific Coast Trees Univ. of Calif. Press.)*

Figure 4—Leaf shapes.

Bract: Appendage(s) below flowers formed by a reduced leaf usually at the base of a flower pedicel.

Bractlet: A bract borne on a pedicel rather than at the base; for example, below the sepals of roses.

Branch: A shoot or secondary stem growing from a larger stem.

Branchlet: Generally the ultimate or final and smallest branch.

Broom-like: Resembling the household implement for sweeping; branches end with several slender branchlets with small leaves.

Burl: A lump at the base of the stem and at the root crown which has many buds from which sprouts may arise.

Bush: A shrub, especially one with thick, dense branching.

Canescent: Covered with whitish or grayish fine hairs.

Capsule: Fruit with two or more seeds, splits open when mature and dry.

Catkin: An open or tight cluster of small scale-like or bearded unisexual flowers in a string resembling a cat's tail; also called an "ament."

Chaparral: Shrub formation generally composed of dense shrubs (sometimes nearly impenetrable) with small, hard leaves (sclerophylls).

Coastal: Geographic location near the seashore with climate influenced by proximity to the ocean.

Compound: An organ having two or more similar parts (fig. 2).

Conifers: Cone-bearing plants; trees or shrubs with needle or scale-like leaves.

Convolute: Rolled upwards longitudinally.

Cordate: Heart-shaped, with the notch at the base and ovate in general outline (figs. 3 and 4).

Coriaceous: Tough like leather, especially in texture and feel.

Crenate: Leaf margin has rounded projections and scalloped look (fig. 3).

Crisped: Irregularly curled or wavy, ripples.

Cuneate: Wedge shaped, tapered toward the base (fig. 3).

Cupped: In the form of a cup or with edges more or less turned up to form a bowl.

Cyme: A flowering cluster which is more or less flat-topped; blooms mature from the center out, and the central axis ends with a flower.

Cymose: Bearing one or more cyme.

Deciduous: Denotes to leaves that fall or are shed at a particular season.

Decumbent: Lying down on the ground with the tips turning up.

Deltoid: Delta shaped, an equal sided triangle.

Dentate: Margin is cut with sharp teeth not pointed forward.

Denticulate: Margin is finely toothed.

Dermatitis: A skin rash.

Desert: Region of low rainfall with sparse vegetation except where supplemental moisture is provided as along streams and seeps.

Dioecious: Plant species that have male and female flowers on different plants.

Divergent: Extending away at a steep angle; divaricate divergence is especially wide.

Divided: Separated to base.

Drought-deciduous: Referring to woody plants that shed leaves in response to inadequate moisture supply.

Drupe: Fleshy fruit enclosing a single hard stone containing a seed, e.g., a stone fruit such as a peach.

Elliptic: Leaf shaped like an ellipse - more than twice as long as broad and widest at the center.

Emarginate: A leaf or petal with a small notch at the tip (fig. 3).

Entire: An unbroken margin, not toothed or serrated.

Epidermis: The outer layer of cells form the skin of plant parts.

Erect: Generally upright with respect to the ground but also implies an organ which is perpendicular to a stem or leaf surface.

Evergreen: Retains green leaves year-round.

Fascicle: Close cluster or bundle of flowers, leaves, stems, or roots.

Feather-veined: Veins arise from the sides of the midrib.

Forest: Dense growth of trees and shrubs covering the landscape; implies tree cover greater than woodland.

Genus: Taxonomic classification category between family and species; the first word in the Latin name of a species and is capitalized.

Glabrous: Refers only to the lack of hairyness, bald.

Gland: An organ represented by a depression or protuberance for secreting fluids (sometimes in very small amounts).

Glandular: Bearing gland or gland-like structures.

Glaucous: More or less covered with a white or gray powder that can be rubbed off.

Globose: Spherical or roundish.

Glutinous: Waxy or gluey appearing surface formed by an exudate.

Half-shrub: Used as a synonym for subshrub; between a shrub and a herbaceous plant, having herbaceous stems that are shed with leaves or flowers.

Herbaceous: Plants or plant parts having the texture and color of leaves; plants that die to the ground after completing annual growth cycles.

Hirsute: Covered more or less densely with coarse distinctive hairs.

Hispid: Rough with stiff or bristly hairs.

Hoary: Covered with white down.

Inflorescence: Characteristic arrangement and disposition of flowers on a plant.

Interior: Inland, here meaning removed from the coast far enough to reduce influence from the ocean.

Internode: That portion of stem between two nodes.

Lanceolate: Lance-shaped leaf; much longer than broad (usually more than 3 times) tapering from below the middle to the tip *(fig. 4)*.

Lateral: On the side or coming from the sides.

Leaf: Outgrowth from a plant stem; in several forms, but most frequently flat *(figs. 2, 3, and 4)*.

Leaflet: Subunit or segment of a compound leaf (fig. 2).

Leathery: Resembles leather in appearance and feel, may be associated with the stiff and or thick characteristics of sclerophylls (harsh-leaved).

Linear: Leaf sides parallel like a blade of grass; linear leaves tend to be long and narrow *(fig. 4)*.

Lobe: Division or segment of an organ, usually rounded or obtuse; cut less than halfway to the leaf midrib.

Margin: Border or edge of a structure.

Midrib: Central rib or vein of a leaf.

Midvein: Variant of midrib; the central rib of an organ such as a leaf.

Monoecious: Plant species that have male and female flowers on the same plant.

Montane: Pertaining to mountains.

Mucronate: With a short sharp pointed tip at the end of a leaf *(fig. 3)*.

Node: Joint of a stem; the point where lateral buds and leaves arise on a stem.

Oblanceolate: Broadest part of the leaf between mid-leaf and the outer end; tapers gradually toward the petiole, usually rounded abruptly at the end, similar to spatulate *(fig. 4)*.

Oblique: Sides of unequal length *(fig. 3B)*.

Oblong: Leaf much longer than broad, sides nearly parallel *(fig. 4)*.

Obovate: Reverse of ovate, with the wide end toward the leaf tip *(fig. 4)*.

Obtuse: Blunt or rounded at the end *(fig. 3)*.

Opposite: Set against, as with two leaves at a node *(fig. 2)*.

Orbicular: Circular and flat *(fig. 4)*.

Oval: Broad, elliptic leaf with rounded ends *(fig. 4)*.

Ovate: Leaf shaped like the outline of a hen's egg with the big end near the base *(fig. 4)*.

Palmate: Hand-shaped with the fingers spread; in a leaf, lobes or veins radiate from a common point *(figs. 2 and 3)*.

Peduncle: Stalk of an inflorescence; the stalk between a flower and the plant stem.

Perfect flower: Flowers with both male and female parts (stamens and pistils).

Pericarp: Ripe walls of the ovary; often in several layers, as in a peach which includes a hard endocarp next to the seed, the mesocarp or flesh of the fruit, and the epicarp or skin of the fruit.

Petiole: Leafstalk which supports the leaf blade and connects to the plant stem.

Pinnate: Having the leaflets or veins arranged on each side of a common petiole, midrib or central vein; leather-like *(fig. 2)*.

Prickle: Sharp outgrowth of the bark or epidermis.

Prickly: Covered with prickles.

Prostrate: Lying flat upon the ground.

Prussic acid: Hydrocyanic acid is a weak acid, hence an acrid but not unpleasant peach blossom odor.

Puberulent: Minutely hairy, finely pubescent.

Pubescent: Any plant part more or less covered with short, soft hair.

Raceme: Inflorescence with flowers on stalks (pedicels) along a main axis in a dense or open, upright or drooping arrangement.

Resin: Amorphous yellow to brown to transparent covering or exudate.

Resinous: Having the characteristics of resin, as in leaves with resinous surfaces.

Revolute: Leaf rolled downward from both margins; that is, toward the underside.

Rhizome: Rootlike stem usually growing underground, mostly parallel with the soil surface and giving rise to roots from the lower side and shoots from the upper side.

Rib: (midrib) Primary vein of a leaf, or a ridge on a fruit.

Riperian: Along a stream, lake, or spring.

Rush-like: Resembling a rush; more or less straight greenish stems with few or no leaves.

Sage: Group of aromatic shrub or subshrub species belonging to the Salvia genus in the mint family.

Sage: scrub A subshrub formation generally found near the coast to about 1000 m (3300 ft).

Scarious: Thin and membranous in texture as a scarious bract.

Scale-like: Any thin scarious bract, usually a vestigial leaf *(figs. 2 and 4).*

Sclerophyllous: Refers to the leaves; meaning hard, indurate. The common shrubs of chaparral have hard leathery leaves.

Scurfy: Covered with small flaky scales, branlike.

Sepal: A leaf or segment of a flower's calyx.

Serrate: Sawtoothed leaf margin; teeth pointing forward *(fig. 3).*

Sessile: Stalkless, attached directly at the base; sessile leaves lack a petiole.

Shreddy: Coming off in narrow strips; shreddy bark.

Shrub: A woody plant, smaller than a tree and generally with multiple branching near the ground.

Simple: Not branched or compound *(fig. 2).*

Sinuate: Leaf with a wavy indented margin similar to crenate *(fig. 3).*

Smooth: Not rough to touch; without hairs or other rough material.

Spatulate: Spatula shaped, similar to oblanceolate; a long blade rounded at both ends, but tapers toward the base from above the middle.

Species: Latin or "scientific" taxonomic name for a group of plants that have characteristics more specific than genus but less than sub species or variety; abbreviated sp. for singular and spp. for plural.

Spine: Sharp-pointed, stiff, woody body, arising from below the epidermis, usually a modified leaf.

Sprawling: Spreading irregularly along the ground or in and over other plants.

Stem: Any stalk or structure which supports a more distant part of a plant as a leaf, flower, or plant canopy.

Stipule: Appendage (usually two) at the base of a leaf petiole, a modified or undeveloped leaf often reminiscent of an ear.

Stolon: A stem usually growing along the ground surface (sometimes just below the surface) that gives rise to roots and shoots.

Strigose: Clothed with sharp appressed hairs.

Subshrub: Synonym for half-shrub; that is, between a shrub and a herbaceous plant, having herbaceous stems that are shed with leaves or flowers.

Subspecies: Taxonomic division of species; that is, more specific than species and with consistent minor differences between subspecies; abbreviated ssp.

Suffrutescent: Somewhat or obscurely woody, but not necessarily low stature.

Suffruticose: Somewhat woody with low stature.

Ternate: Arranged in groups of three, as a leaf consisting of three leaflets.

Taxon: A taxonomic unit such as variety, species, family, etc.

Taxa: Plural of taxon.

Thorn: Stiff and sharp-pointed like a spine but a thorn is a modified branch.

Tomentose: Covered with a mat (tomentum) of short dense hairs appearing wool-like.

Tomentulose: Minutely tomentose.

Tooth: Small, usually pointed lobe on a leaf margin.

Tree: Perennial woody plant generally limited to one or a few stems at the base, with a mature height greater than 3 m (10 ft) tall.

Truncate: Ending abruptly as if cut off, not tapering *(fig. 3).*

Twig: A small diameter branch; diameter of less than 0.6 cm (.25 in) is implied in this guide.

Undulate: Wavy.

Utricle: Indehiscent (does not split at maturity) fruit composed of a pouch-like, membranous pericarp enclosing the seed.

Variety: A taxonomic division of species; approximately the same meaning as subspecies; abbreviated var.

Vein: Vascular conductive bundle of a leaf or other flat organ.

Venation: Arrangement of the veins of a leaf.

Vestigial: Adjective implying evovled to a trace of a part once more perfectly developed.

Villous: Covered with shaggy hair not especially matted.

Vine: A plant whose stems depend on objects or other plants for support.

Viscid: Sticky or glutinous.

Whorl: Ring of similar organs radiating from a node as several leaves arising from a stem node.

Woodland: Land covered with trees and shrubs. Woodland implies land with tree cover less than a forest.

Woody: Stems and twigs are ligneous (wood) rather than herbaceous and do not die back to the ground after completing annual growth.

Woolly: Having long, soft hairs; usually more or less matted.

VEGETATIVE KEY TO COMMON SOUTHERN CALIFORNIA SHRUBS

Group I. Plants vine-like with woody stems that climb through and over other shrubs and trees. ---------- go to 1a

Group II. Plants not vine-like; leaves stiff, sharp-pointed, spine-tipped, often more than 30 cm long. ---------- YUCCA (*Yucca* spp.), page 75

Group III. Plants not vine-like, leaves not stiff and sharp-pointed; stems mostly woody.

Subgroup I. Leaves scale-like (fig. 2), less than 6 mm long. ---------- go to 7a

Subgroup II. Leaves usually more than 3 mm long, not scale-like.

Leaf type I. Leaves opposite (fig. 2); that is, paired with one on each side of the stem. ---------- go to 9a

Leaf type II. Leaves simple and alternate *(fig. 2)*, lanceolate or oblanceolate or segments nearly linear *(fig. 4)*; leaves mostly less than 11 mm wide, up to 22 mm wide if leaves approach 15 cm long (secondary and terminal stems of *Spartium junceum* are green, vaguely rush-like; leaves tend to be drought deciduous by May or June). ---------- go to 27a

Leaf type III. Leaves simple, alternate *(fig. 2)*, mostly more than 10 mm wide; leaf may have several veins arising from near the base, and/or with leaves that are palmately lobed *(fig. 3)*. ---------- go to 49a

Leaf type IV. Leaves simple, alternate *(fig. 2)*, mostly more than 10 mm wide, pinnately veined with one main vein from the base or with several veins arising from the base with sparse branching; mature leaves tough and/or stiff and thick and/or leathery. ---------- go to 62a

Leaf type V. Leaves simple, alternate *(fig. 2)*, mostly more than 10 mm wide, pinnately veined or with several veins with sparse branching arising from the base of long, narrow lance or linear shaped leaves *(fig. 2)*; mature leaves more or less of thin and flexible feel. ---------- go to 82a

Leaf type VI. Leaves alternate, mostly more than 10 mm wide, and compound *(fig. 2)*; that is, leaves are divided into leaflets in a palmate or pinnate arrangement. ---------- go to 99a

Leaf type VII. Leaves whorled, three at a node on the stems *(fig. 2)*; subshrub on dry slopes in pine and oak woodlands and in manzanita chaparral. ---------- WHORL-LEAF PENSTEMON (*Keckiella ternata*), page 46

Group I. Plants vine-like with woody stems that climb through and over other shrubs and trees.

1a. Stems prickly; widespread shrubs in woodlands and chaparral. ---------- BLACKBERRY (*Rubus* spp.), page 64

1b. Stems not prickly.

2a. Leaves alternate.

3a. Leaves divided into three leaflets; widespread shrub on shaded slopes. ---------- POISON-OAK (*Toxicodendron diversilobum*), page 72

3b. Leaves not divided, with five main veins from the base; occasional shrub along shaded streams. ---------- WILD GRAPE *(Vitis girdiana)*, page 74

2b. Leaves opposite, arranged in definite pairs along the stems.

4a. Leaves compound, usually divided into more than three leaflets; occasional shrub on shaded, mesic slopes and along streams, in many plant communities. ---------- WESTERN CLEMATIS (*Clematis* spp.), page 33

4b. Leaves simple, not divided into leaflets.

5a. Leaves shiny and dark green above, thin and/or flexible, none are united.

6a. Leaves cordate to ovate with serrate margins; widespread shrub in dry chaparral to oak woodlands. ---------- STRAGGLY PENSTEMON *(Keckiella cordifolius)*, page 46

6b. Leaves round to ovate not cordate, entire margins; common shrub on shaded woodland and chaparral slopes. ---------- SNOWBERRY (*Symphoricarpos* spp.), page 71

5b. Leaves usually dark green, not especially shiny, but thick, leathery, and not flexible; leaves near the end of stems and below the inflorescence may be united around the stem; dry chaparral to conifer forests. ---------- HONEYSUCKLE (*Lonicera* spp.), page 47

Group III. Plants not vine-like, leaves not stiff and sharp-pointed; stems mostly woody.

Subgroup I. Leaves scale-like *(fig. 2)* and less than 6 mm long.

7a. Leaves completely covering the branchlets and closely adhering; branches crooked; dry coastal washes and desert slopes. ---------- JUNIPER (*Juniperus* spp.), page 44

7b. Leaves scattered along the branchlets.

8a. Leaves located singly on the stems; stems straight and broom-like; coastal washes and desert slopes. -- SCALEBROOM *(Lepidospartum squamatum)*, page 47

8b. Leaves in twos and threes appearing as brown or blackish rings at the joints of the branches; subshrub, desert slopes. -- MORMON-TEA (*Ephedra* spp.), page 36

Subgroup II. Leaves usually more than 3 mm long and not scale-like.

Leaf type I. Leaves opposite *(fig. 2)*; that is, paired with one on each side of the stem.

9a. Leaves compound, pinnately divided into 3 to 9 glaucous to pubescent leaflets.

10a. Young stems feel round when rolled between the fingers; widespread shrub in canyons and valleys. -- ELDERBERRY (*Sambucus* spp.), page 68

10b. Young stems feel square; fuzzy with fine hairs; shrub, chaparral and riparian communities. -- FLOWERING ASH (FOOTHILL ASH) *(Fraxinus dipetala)*, page 40

9b. Leaves simple, not compound as above.

11a. Leaves aromatic, with a strong smell when crushed.

12a. Leaves 1 to 3 mm wide, flat; stems more or less round throughout the plant; shrub, coastal sage scrub to chamise chaparral on coastal bluffs and desert slopes. ---------------- BUSHRUE *(Cneoridium dumosum)*, page 33

12b. Leaves more than 3 mm wide and/or rolled under at edges, stems usually squarish, subshrubs.

13a. Leaves nearly linear to narrowly lanceolate, up to 6 mm wide, becoming strongly rolled under at edges; widespread on dry coastal mountain slopes. -- WOOLLY BLUE CURLS (*Trichostema lanatum*), page 72

13b. Leaves more than 6 mm wide and elliptic to lanceolate.

14a. Leaf veins noticeably prominent and leaves usually more than 2 cm wide; open chaparral and woodlands on dry slopes. ------------------ PITCHER SAGE *(Lepechinia calycina)*, page 46

14b. Leaf veins not especially prominent and leaves mostly narrower; widespread in chamise chaparral to coastal and desert sage scrub. ------------------------ SAGES (*Salvia* spp.), page 67

11b. Leaves not aromatic, lacking a strong smell when crushed.

15a. Plants with warty projections on the stems at the base of the leaves; leaves often notched at the tips or cupped upwards; widespread shrubs. ------------------------ CALIFORNIA-LILACS (*Ceanothus* spp.), page 24

15b. Plants without warty projections; leaves not as above.

16a. Leaves mostly flat, feel thin and/or flexible.

17a. Plant thorny with many sharp-tipped twigs in opposite branching from the main stems; leaves small and falling early; shrub, dry flats and canyons, San Diego County and south. -- ADOLPHIA (*Adolphia californica*), page 16

17b. Plant not thorny, leaves not falling early.

18a. Leaves up to 12 cm long and 6 cm wide, large shrubs or small trees up to 6 m tall.

19a. Leaves lanceolate to elliptic or oblanceolate, leaf tips pointed with obvious lateral veins that curve toward the tip.

20a. Young twigs may be reddish with a few stiff short hairs; if not reddish, then twigs covered with short hairs; leaves glabrous or nearly so, not glandular; robust montane shrub 2 to 5 m tall, moist woodlands. ---- DOGWOOD (*Cornus* spp.), page 34

20b. Young stems yellowish green becoming light brown, leaves glandular and often somewhat sticky; subshrub 0.3 to 1.2 m tall, dry slopes, coastal sage scrub to chaparral. -------------- MONKEYFLOWER *(Mimulus longiflorus)*, page 50

19b. Leaves elliptic to ovate, leaf tip more or less rounded without especially obvious veins, veins do not curve toward leaf tip, twigs whitish to grayish; occasional in moist montane canyon bottoms. ---------- BURNING BUSH *(Euonymus occidentalis* ssp. *parishii)*, page 39

18b. Leaves all less than 5 cm long and up to 4 cm wide.

21a. Leaves grayish green to light green, round to ovate with blunted end, pubescent above and below, rarely only on the margins; shrub, woodland and shaded chaparral slopes. ------------------------------ SNOWBERRY (*Symphoricarpos* spp.), page 71

21b. Leaves green, lance-ovate to roundish, usually with more or less pointed end, glabrous to minutely pubescent.

22a. Leaves entire, linear to ovate-elliptic, up to 2 cm long, 0.7 cm wide; spreading and much-branched shrub, common on dry rocky sage scrub and chaparral slopes. -------------------- BUSH PENSTEMON *(Keckiella antirrhinoides)*, page 45

22b. Leaves with coarse or fine serrated margins, ovate to roundish leaves, usually with heart-shaped base, 1.5 to 5 cm long, 1 to 3 cm wide; sprawling, vine-like shrub, dry oak woodland and chaparral slopes.
------ STRAGGLY PENSTEMON (*Keckiella cordifolius*), page 46

16b. Leaves rolled under along margins; feel thick, tough and leathery.

23a. Some leaves long and narrow, up to five times longer than broad; subshrub 0.3 to 1.2 m tall, dry coastal sage scrub to chaparral slopes. --- MONKEYFLOWER (*Mimulus longiflorus*), page 50

23b. Leaves wider, usually less than five times longer than broad.

24a. Erect, more or less rigid shrubs.

25a. Young stems usually more or less white, woolly, not especially stiff; scattered shrub on dry chaparral slopes. ------------------ SILKTASSEL (*Garrya veatchii*), page 40

25b. Young stems considerably pubescent but not woolly; rigid shrub on dry barren slopes near and in desert. ---------JOJOBA (GOATNUT) (*Simmondsia chinensis*), page 70

24b. Plant not especially woody, often not erect throughout, either decumbent and straggly, vine-like or with more or less brittle stems, mainly woody below.

26a. Branches straggly or twining, often climbing through other shrubs; dry chaparral to conifer forests. ---------- HONEYSUCKLE (*Lonicera* spp.), page 47

26b. Branches not as above, erect and rounded subshrub with harsh more or less resinous surfaces; dry chaparral and coastal sage scrub in southwestern San Diego County.
-----------------------SAN DIEGO SUNFLOWER (*Viguiera laciniata*), page 74

Leaf type II. Leaves are simple and alternate, lanceolate or oblanceolate or segments nearly linear (*fig. 4*); leaves mostly less than 11 mm wide, up to 22 mm wide if leaves approach 15 cm long (secondary and terminal stems of *Spartium junceum* are green, vaguely rush-like; leaves tend to be drought deciduous by May or June).

27a. Leaves usually present and definitely linear, or narrowly lance-shaped or narrow spatulate.

28a. Leaves deeply divided into linear lobes but not compound.

29a. Leaves and stems green and resinous; bark reddish gray, shredded, peeling; dry chaparral, often in well-defined plant communities. ---------- RED SHANK (RIBBON BUSH) (*Adenostoma sparsifolium*), page 15

29b. Leaves gray green; bark not as above.

30a. Leaves aromatic, with a strong sage-like smell; upper leaves may be linear and fascicled; subshrub, common on dry exposed coastal sage scrub slopes. --- COAST SAGEBRUSH (*Artemisia californica*), page 20

30b. Leaves lacking a strong smell; at least some leaves divided, not fascicled; subshrub in dry washes and slopes, coastal sage scrub to scrub oak chaparral. ------ BUSH GROUNDSEL (*Senecio douglasii*), page 69

28b. Leaves not divided into linear lobes.

31a. Branches rather straight and broom-like.

32a. Stems and leaves whitish green; subshrub, dry open montane conifer slopes.
------------------ RUBBER RABBITBRUSH (*Chrysothamnus nauseosus*), page 32

32b. Stems and leaves green, resinous; may be nearly leafless except near end of stems; shrub, sandy washes, San Diego County and south. ------------ BROOM BACCHARIS (*Baccharis sarothroides*), page 23

31b. Branches not as above.

33a. Branches thorny, more or less sharp-tipped; leaves may be in fascicles, almost linear to spatulate (oblanceolate).

34a. Leaves single or in groups of three; numerous spine-tipped short branchlets; intricately-branched shrub; coastal shrub, mostly below 110 m elevation.
---------------------------------------BOXTHORN (*Lycium californicum*), page 49

34b. Leaves generally in fascicles (bundles) with short and long leaves together; branches somewhat spine tipped; shrub, desert slopes. ---------- DESERT ALMOND (*Prunus fasciculata*), page 52

33b. Branches not thorny or sharp-tipped; short, needle-like leaves in fascicles, 4 to 10 mm long; most common chaparral shrub. ---- CHAMISE (GREASEWOOD) (*Adenostoma fasciculatum*), page 15

27b. Leaves wider than above, up to 10 mm wide (up to 22 mm if leaves approach 15 cm long); leaves sometimes nearly missing but then leaving small green twigs.

35a. Leaves usually present and strongly aromatic.

36a. Leaves whitish, not resin dotted.

37a. Leaves with three or more short teeth at tips, widest point may exceed 10 mm; shrub, desert interface scrub communities, dry conifer woodlands. - BASIN (BIG) SAGEBRUSH (*Artemisia tridentata*), page 20

37b. Leaves usually deeply divided into linear (1 mm wide) segment; common subshrub, dry coastal sage scrub, chaparral washes and slopes. ------------------ COAST SAGEBRUSH *(Artemisia californica)*, page 20

36b. Leaves green, more or less resin-dotted, sticky, lemon or pine smell; some or most leaves less than 2 mm wide; shrub, dry coastal sage scrub; chaparral washes and slopes.
--- GOLDENBUSH (*Haplopappus pinifolius*), page 42

35b. Leaves, if present, not strongly aromatic.

38a. Leaves usually present, most lance shaped; mature leaves usually more than 4 cm long.

39a. Leaves dark green on both surfaces, somewhat sticky, often appearing three-veined with the lowest laterals continuing to near leaf tip; common willow-like evergreen shrub, streamsides and other wet places.
-- MULEFAT *(Baccharis glutinosa)*, page 22

39b. Leaves somewhat tomentose to silky, white hairs, midvein with several laterals throughout its length; common deciduous shrub, wet places. ---------------- SANDBAR WILLOW *(Salix hindsiana)*, page 66

38b. Leaves, if present, mostly less than 6 cm long; not lance-shaped.

40a. Leaves usually present; at least some in fascicles.

41a. Leaves more or less revolute or at least rolled under at the edge.

42a. Leaves tend to be wedge-shaped or rounded to heart-shaped with point at end.

43a. Leaves generally have three broad, blunt teeth at end; glabrous or nearly so, more or less glandular; shrub, desert and chaparral-desert interface.
------------------------------------ BITTERBRUSH (*Purshia glandulosa*), page 54

43b. Leaves round or heart-shaped; subshrub, coastal bluffs.
------------------------- SEACLIFF BUCKWHEAT *(Eriogonum parvifolium)*, page 39

42b. Leaves longer, not wedge-shaped, tapering to a point, pubescent, not glandular; low, spreading shrub, dry slopes. ------------ CALIFORNIA BUCKWHEAT *(Eriogonum fasciculatum)*, page 38

41b. Leaves normally flat or at least not rolled under at the edges.

44a. Leaves tend to be more or less round or oval on a petiole at least 2 mm long; evergreen shrub, dry coastal sage scrub slopes. ---------------- REDBERRY *(Rhamnus crocea)*, page 59

44b. Leaves more or less long and narrow, normally sessile.

45a. Leaves and at least some twigs are pubescent to densely tomentose; leaves not resinous and sticky.

46a. Leaves almost all less than 3 mm wide, rigid and spine-tipped with age; branchlets and leaves light gray to white with tomentum, darkening with scale patches during aging; shrub, dry slopes. -- HAIRY HORSEBRUSH *(Tetradymia comosa)*, page 71

46b. Leaves 2 to 8 mm wide, becoming neither spine-tipped or very rigid with age; branchlets covered with white or rusty star shaped hairs, mixed with straight hairs, becoming grayish with age but without scale spots; small shrub, dry montane flats and desert. ------------ WINTER FAT *(Eurotia lanata)*, page 39

45b. Leaves and twigs glabrous or nearly so, resinous and sticky; erect shrubs, dry exposed south slopes and washes. -------- GOLDENBUSH *(Haplopappus parishii)*, page 41

40b. Leaves, if present, are not in fascicles.

47a. Leaves, if present, are green and glabrous.

48a. Leaves present, often appear to be three-veined; leaves and young stems more or less glandular; shrub may have broom-like appearance; shrubs and subshrubs, many environments.
-------------------------------- BACCHARIS (*Baccharis* spp.), page 22

48b. Leaves, if present, nearly flat, green and neither glandular or pubescent; both secondary and terminal branches are green becoming gray at base; plant, more or less delicate with vague rush-like appearance; naturalized exotic shrub, roadsides.
----------------------------------- SPANISH BROOM (*Spartium junceum*), page 70

47b. Leaves mostly grayish and scurfy, not glandular, definite single midvein; shrub, dry hills and washes, desert and chaparral-desert interface.
---------------------- WINGSCALE SALTBUSH (*Atriplex canescens*), page 21

Leaf type III. Leaves simple, *(fig. 2)* alternate, mostly more than 10 mm wide, several veins arising near the base and or with leaves palmately lobed *(fig. 3)*.

49a. Leaves with three or more veins coming from the base, not palmately lobed.

50a. Several veins arising from the base of the leaf.

51a. Leaves rounded, mostly with six, seven, or more main veins from base; shrub or small tree; Palomar, Laguna, and Cugamaca Mountains. -------------------- REDBUD *(Cercis occidentalis)*, page 30

51b. Leaves usually longer than broad, with three veins arising from the base; common shrub, many communities. —— CALIFORNIA-LILACS (*Ceanothus* spp.), page 24

50b. Leaves with three to five veins arising from near the base of single central vein.

52a. Leaves triangular to lance-shaped; leaves and stems harsh and roughly hairy; subshrub, dry chaparral and coastal sage scrub, southwestern San Diego County. —— SAN DIEGO SUNFLOWER (*Viguiera laciniata*), page 74

52b. Leaves and stems not as above.

53a. Leaves notched or somewhat heart-shaped at base.

54a. Leaves 1.2 to 4 cm long; plant aromatic with many thin stems from a woody base; subshrub, dry coastal sage scrub to chamise chaparral washes and slopes. —— BRICKELLBUSH (*Brickellia californica*), page 24

54b. Leaves 3 to 15 cm long; plant not aromatic, sparingly branched; subshrub, shaded canyon sides, coastal sage scrub to scrub oak chaparral. —— CANYON-SUNFLOWER (*Venegasia carpesioides*), page 74

53b. Leaves not as above, rounded or tapering at base.

55a. Leaves yellowish green and pubescent; bark light brown; subshrub, coastal bluffs, coastal sage scrub to dry chaparral. —— CALIFORNIA ENCELIA (*Encelia californica*), page 35

55b. Leaves covered with dense hairyness; leaf feels of felt; subshrub, interior species, dry chaparral to deserts. —— BRITTLEBUSH (INCIENSO) (*Encelia farinosa*), page 35

49b. Leaves with single vein at the base, may branch later, at least obscurely palmately lobed to deltoid to nearly round, but with three or more rounded or pointed lobes in outline.

56a. Stems with spines where the leaves are attached; widely distributed shrub. —— GOOSEBERRIES (*Ribes* spp.), page 59

56b. Stems lacking spines.

57a. Leaves with three to five pinnate lobes, pinnate venation, olive colored; stems exude clear bitter juice; subshrub, dry coastal sage scrub and chaparral washes and canyons. —— MATILIJA POPPY (*Romneya* spp.), page 63

57b. Leaves may be variously lobed but not generally in pinnate form, green; stems lack bitter juice.

58a. Leaves dark green above, rusty, fuzzy below, on branchlets; usually with well-developed thick trunk at base; large shrub or small tree, chaparral to conifer slopes. —— FLANNEL BUSH (*Fremontodendron californicum*), page 40

58b. Leaves and stems not as above; basal branches usually less than 2 cm thick; not trunk-like, but may be up to 5 cm in *Malacothamnus*.

59a. Leaves grayish green, densely fuzzy on both surfaces; shrub, dry coastal sage scrub canyon sides. —— BUSH MALLOW (*Malacothamnus fasciculatus*), page 50

59b. Leaves not as above; lacking fuzz; if fuzzy, then green above and paler below.

60a. Leaves less than 10 cm wide, lobes rounded in outline; widely distributed shrub. —— CURRANTS (*Ribes* spp.), page 59

60b. Leaves more than 10 cm wide with three or more lobes.

61a. Leaves 10 to 16 cm wide, 3 to 5 blunt lobes; stems not armed; bark grayish, peeling; young branchlets may be pubescent; shrub, open woods, shaded canyons. —— THIMBLEBERRY (*Rubus parviflorus*), page 65

61b. Leaves large, 10 cm up to 40 cm, more than five lobes; stems glabrous, often red and herbaceous; exotic subshrub, washes and waste places. —— CASTOR-BEAN (*Ricinus communis*), page 62

Leaf type IV. Leaves simple, alternate (*fig. 2*), mostly more than 10 mm wide, pinnately veined with one main vein from the base or with several veins arising from the base with sparse branching; mature leaves tough and/or stiff and thick and/or leathery.

62a. Leaves stiff, mostly spiny or at least with sharply serrated margins.

63a. Leaves clasping the stems at base, lacking petiole; low subshrub, open hills, coastal sage scrub to chamise chaparral. —— SAWTOOTH GOLDENBUSH (*Haplopappus squarrosus*), page 42

63b. Leaves petioled, at least not clasping stems.

64a. Mature leaves of various lengths up to 13 cm long.

65a. Leaves green, lighter below and usually hairless but sometimes pubescent; leaves usually flat, sometimes convex, bark becoming gray but not shreddy; large shrub or tree, shaded chaparral to oak woodland slopes. —— TOYON (CHRISTMASBERRY) (*Heteromeles arbutifolia*), page 42

65b. Leaves green, white fuzz below and hairless above; leaves usually strongly revolute, sometimes flat; bark becoming gray and shreddy; shrub, dry chaparral slopes below 550 m near coast.
---------- SUMMER-HOLLY *(Comarostaphylis diversifolia)*, page 34

64b. Leaves mostly less than 6 cm long.

66a. Mature leaves commonly dark green above, with or without pubescence, shiny but not glossy; major veins may be yellowish green; on same plant, some leaves with spiny margins, some margins smooth; shrub oaks, widespread on dry slopes and canyons. ---------- SHRUB OAKS (*Quercus* spp.), page 54

66b. Leaves not as above in all ways; leaves tend to be glossy, glabrous at least above, always with more or less spiny margins.

67a. Leaves rounded or notched at tips, normally flat; scraped bark not noticeably aromatic; shrub, chaparral and pine forests. ---------- HOLLYLEAF REDBERRY *(Rhamnus ilicifolia)*, page 56

67b. Leaves usually tapering to a point, sometimes abruptly, rarely rounded outline; leaf normally wavy (crisped); scraped bark aromatic with prussic acid odor; shrub or small tree, chaparral to oak woodlands. ---------- HOLLYLEAF CHERRY *(Prunus ilicifolia)*, page 53

62b. Leaves not as above, margins lacking serration or serration not spiny, may be dentate (toothed); some leaves on a particular plant may have rather sharp serrations (e.g. *Rhus integrifolia*).

68a. Mature trunks and branches with smooth red epidermis or somewhat furrowed, dark red brown to gray brown bark, bark often shredding; leaf margins lack serrations.

69a. Mature leaves flat, base usually tapering abruptly to petiole, tip tapering gradually or abruptly to a point; widespread shrub. ---------- MANZANITA (*Arctostaphylos* spp.), page 17

69b. Mature leaves almost always somewhat cupped downward to nearly revolute, tapering gradually at both ends; shrub, chamise chaparral in western San Diego County and Baja California.
---------- MISSION-MANZANITA *(Xylococcus bicolor)*, page 75

68b. Trunks and branches not as above; most leaves entire, some leaves serrate or dentate.

70a. Leaves folded or curled upwards along midvein; rarely, leaves serrated.

71a. Leaves green or green with reddish tint, thick and usually folded upward forming a narrow, shallow U or almost a V from the midvein; species found below 1800 m.

72a. Twigs usually dark red; leaves sometimes with dark reddish tint, may be thin and flexible, somewhat aromatic when crushed; shrub, coastal sage scrub hills and washes below 600 m elevation.
---------- LAUREL SUMAC *(Rhus laurina)*, page 57

72b. Twigs tinted light reddish leaves mostly without reddish veins or margins, thick and leathery, not aromatic when crushed; shrub, dry chaparral between 300 and 1700 m.
---------- SUGAR BUSH (*Rhus ovata*), page 58

71b. Leaves yellowish green, rust colored fuzz below; leaves thick, almost flat to slightly cupped upwards; shrub, mostly high montane shrub above 1600 m in thickets on rocky ridges, conifer woodlands.
---------- CHINQUAPIN (Chrysolepis *sempervirens*), page 32

70b. Leaves usually flat; sometimes cupped upward; rolled under, or crumpled; almost never folded upwards from the midvein as above; leaves may be dentate; some leaves entire, some serrated on same plant.

73a. Leaves nearly same color on both surfaces, usually flat, at least not cupped upward.

74a. Leaves dark green to yellowish green, not fuzzy or pubescent, may be dentate.

75a. Leaves entire, lance-shaped to oblong or elliptical, dull yellowish green; shrub, dry chaparral slopes.
----------BUSH POPPY (TREE POPPY) *(Dendromecon rigida)*, page 35

75b. Leaves dentate, dark green, not lance shaped; shrub, coastal hills, inland to 900 m elevation.
----------CHAPARRAL BROOM *(Baccharis pilularis* ssp. *consanguinea)*, page 22

74b. Leaves densely grayish, fuzzy on both surfaces; leaf margins crenate to coarsely dentate; mostly woody subshrub, dry gravelly and rocky places in chaparral to dry conifer and oak woodlands.
---------- THICKLEAF YERBA SANTA *(Eriodictyon crassifolium)*, page 37

73b. Leaves more or less bicolored, green or dark green above, paler below.

76a. Leaves mostly more than 3 cm long.

77a. Leaves flat to cupped upward in a U shape and smooth on both surfaces, though veins below sometimes prominent; most leaves entire, sometimes both entire and serrate on the same plant.

78a. Leaves commonly elliptic, margins irregularly toothed, somewhat aromatic when crushed, prominent midvein; shrub, ocean bluffs below 600 m.
---------- LEMONADEBERRY *(Rhus intergrifolia)*, page 57

78b. Leaves lance-shaped or oblong, margins entire, aromatic with strong odor of Bayleaf when crushed, midvein not especially prominent; tree or robust shrub, shaded slopes.
----------CALIFORNIA BAY (LAUREL) *(Umbellularia californica)*, page 73

77b. Leaves not as above, midveins may be prominent, especially below.

79a. Mature leaves sticky or resinous, crumpled and uneven surface with prominent midvein; shrub, dry chaparral and conifer woodlands to the high desert. ---------- YERBA SANTA (*Eriodictyon trichocalyx*), page 38

79b. Leaves not sticky or resinous, veins curving to somewhat parallel with margin, prominent feather-veining below; shrub, shaded hills and riparian areas, chaparral, oak and conifer forests. ---------- COFFEEBERRY (*Rhamnus californica*), page 55

76b. Leaves mostly less than 3 cm long, shade leaves sometimes longer (to 7 cm).

80a. Leaves serrate at tips, smooth, more or less wedge-shaped at base; large gray barked shrub, dry chaparral and oak woodland slopes. ---------- WESTERN MOUNTAIN-MAHOGANY (*Cercocarpus betuloides*), page 31

80b. Leaves, serrations (if present) usually involve most of leaf margins.

81a. Leaves similar in color on both surfaces; base of leaf has stipules (wart-like projections), usually prominent; leaves may be strongly revolute; widespread shrub. ---------- CALIFORNIA-LILACS (*Ceanothus* spp.), page 24

81b. Leaves grayish green or whitish below, margins not serrated, stipules not prominent, leaves almost always strongly revolute; shrub or small tree, dry and rocky sage brush and conifer slopes above 1200 m. ---------- CURLLEAF MOUNTAIN-MAHOGANY (*Cercocarpus ledifolius*), page 31

Leaf type V. Leaves simple, alternate *(fig. 2)*, mostly more than 10 mm wide, pinnately veined or with several veins with sparse branching arising from the base of long, narrow lance or linear-shaped leaves *(fig. 2)*; mature leaves have more or less thin and flexible feel.

82a. Leaves whitish, pale green on both surfaces.

83a. Leaves glaucous (covered with white film), often more than 5 cm long; common shrub or small tree, naturalized exotic, waste places and along roads. ---------- TREE TOBACCO *(Nicotiana glauca)*, page 51

83b. Leaves scurfy, less than 5 cm long; shrub, near the coast, saline desert places, coastal sage scrub, and saltbrush communities. ---------- LENSCALE SALTBUSH *(Atriplex lentiformis)*, page 22

82b. Leaves not pale on both surfaces; green or dark green on upper or both surfaces, sometimes paler to yellowish or brownish below.

84a. Leaves green, densely fuzzy on both surfaces, may be sticky, cause dermatitis in some people; subshrub, occasionally on dry disturbed places in chaparral and pine woodlands. ---------- POODLE-DOG BUSH *(Turricula parryi)*, page 72

84b. Leaves not as above.

85a. Leaves round in outline, without serration, with rusty fuzz below and on new growth; shrub, chaparral and oak woodland slopes. ---------- STORAX *(Styrax officinalis)*, page 71

85b. Leaves lanceolate to ovate or elliptical to approximately linear, sometimes margins serrate or dentate, normally rusty fuzz below is absent.

86a. Leaves commonly approximately lance-shaped or oval to linear, few to several shallow dentations, same color on both surfaces.

87a. Leaves usually much longer than broad, lanceolate or oblanceolate to almost linear, usually serrated or with shallow dentations, may be glutinous or hairy; small stems not spine-tipped.

88a. Evergreen leaves, often with few to several shallow dentations above lower third of leaf; commonly, leaves and young stems glabrous, more or less glutinous, color about equal above and below; shrubs and subshrub, widely distributed. ---------- BACCHARIS (*Baccharis* spp.), page 22

88b. Deciduous leaves, entire or with small serrations (edges may be rolled downward), usually somewhat darker above, leaves usually pubescent to hairy, not glutinous; shrub or small tree, common in wet places. ---------- WILLOW (*Salix* spp.), page 65

87b. Leaves mostly glabrous, usually somewhat longer than broad, lance shaped to ovate, mostly entire, sometimes with notch at tip; leaves and stems not glutinous; small stems spine-tipped; large shrub, coastal sage scrub and chaparral slopes below 900 m elevation. ---------- GREENBARK CEANOTHUS (*Ceanothus spinosus*), page 29

86b. Leaves elliptic or ovate to lance-shaped, lower surface paler to somewhat more yellowish green than upper surface.

89a. Leaves prominently feather-veined below, midvein and lateral veins easily felt.

90a. Leaf margins generally dentate or with coarse serrations on outer half of leaf.

91a. Leaf margins dentate, surfaces generally pubescent to villous; shrub, moist wooded slopes. ---------------------------------- CREAMBUSH *(Holodiscus discolor)*, page 43

91b. Leaf margins with relatively coarse serrations on outer half of leaf; leaves commonly glabrous above and pubescent below or pubescent on both sides; shrub or small tree, dry chaparral to oak woodlands.
------------WESTERN MOUNTAIN-MAHOGANY *(Cercocarpus betuloides)*, page 31

90b. Leaf margins entire; serrations, if present, on entire leaf margin.

92a. Bark of young branchlets reddish; shrub, chaparral to conifer hillsides and ravines between 1200 and 2100 m. ------------- COFFEEBERRY *(Rhamnus californica)*, page 55

92b. Bark of most branchlets whitish or yellowish to green or olive; widespread shrub.
----------------------------CALIFORNIA-LILACS (*Ceanothus* spp.), page 24

89b. Leaves smooth on lower surface; except for midvein, lacking prominent easily felt veins.

93a. Leaves commonly roundish at least in outline to ovate or elliptical but may also approach lanceolate to oblong.

94a. Leaves with serrations or dentations, if present, confined to tips; flat, up to 4 cm long, 3 cm wide; shrub, dry conifer slopes.
------------------------------SERVICE BERRY *(Amelanchier utahensis)*, page 16

94b. Leaves mostly with entire margins, folded upward from the midvein, usually greater than 5 cm long and 2-to 5-cm wide; shrub, dry chaparral and coastal sage slopes below 600 m.
---------------------------------- LAUREL SUMAC *(Rhus laurina)*, page 57

93b. Leaves lance-shaped, often tapering at both ends, usually more than 4 cm long.

95a. Leaves deciduous, light green and glabrous above and below.

96a. Young twigs pubescent to densely tomentose, becoming gray and furrowed, limited to wet places like stream banks; shrub or small tree, common in wet places.
-- WILLOW (*Salix* spp.), page 65

96b. Young twigs not pubescent or tomentose, reddish to brown becoming dark brown or gray with smooth bark to gray and shreddy; not limited to wet places, but some species in moist woods.

97a. Young twigs brown, becoming gray with shreddy bark; leaves, obvious yellowish red midvein; shrub, moist woods or near streams.
------------ WESTERN AZALEA *(Rhododendron occidentale)*, page 56

97b. Young twigs red brown to brown, becoming brown or gray with smooth bark; leaves without obvious midvein (likely to have taste of bitter almond); widespread, along moist stream to desert slopes.
------------------------------ STONE FRUITS *(Prunus* spp.), page 51

95b. Leaves evergreen, glossy to dark green above, paler to almost equal below, pubescent to hairy on leaf margins and/or veins, sometimes glaucous.

98a. Leaves entire, strong odor of bay when crushed; tree or robust shrub, shaded canyons and slopes, many communities.
---------------------CALIFORNIA BAY *(Umbellularia californica)*, page 73

98b. Leaves entire to slightly serrate, without strong odor of bay when crushed; large shrub, moist places in coastal sage scrub, chaparral, woodlands below 50 m.
------------------------- WAX- MYRTLE *(Myrica californica)*, page 50

Leaf type VI. Leaves alternate, mostly more than 10 mm wide, compound *(fig. 2)*: that is, leaves divided into leaflets in a palmate or pinnate arrangement.

99a. Leaves with three or more leaflets; in a palmate pattern if four or more leaflets.

100a. Leaves with more than four leaflets in a palmate pattern, originating from same point and leaflets of same form; rounded subshrub, common after fire and occasional later below 1600 m, many plant communities.
-- LUPINE (*Lupinus* spp.), page 49

100b. Leaves normally with three leaflets (sometimes with four or five) in various patterns with variously serrated margins.

101a. Leaflets with variously serrated margins.

102a. Stems with prickles; widespread shrub in woodlands and chaparral.
-----------------------------------BLACKBERRY (RASPBERRY) (*Rubus* spp.), page 64

102b. Stems without prickles.

103a. Leaflets joined at base; occasional sprawling shrub found in patches. ---------- SQUAW BUSH (BASKET SUMAC) (*Rhus trilobata*), page 58

103b. Leaflets separate at base; common sprawling shrub often in dense thickets, shaded chaparral and oak hillsides; causes dermititis in most people. ---------- POISON-OAK (*Toxicodendron diversiloba*), page 72

101b. Leaflets with entire margins.

104a. Branchlets ending in stiff thorn; infrequent shrub, dry manzanita chaparral to live oak woodland slopes. ---------- CHAPARRAL-PEA (*Pickeringia montana*), page 51

104b. Branchlets not ending in a stiff thorn.

105a. Leaves strongly ill-scented; shrub, coastal bluffs and deserts, coastal sage scrub to creosote bush communities. ---------- BLADDERPOD (*Isomeris arborea*), page 43

105b. Leaves lacking strong smell.

106a. Low subshrub, most upper stems green and rounded with strong tendency to be drought deciduous; dry coastal sage scrub and chaparral slopes. ------- DEERWEED (*Lotus scoparius*), page 48

106b. Erect shrub with green, angled branchlets; more or less drought deciduous leaves, pubescent at least below; exotic shrub, along highways and near the coast in waste places. ---------- FRENCH BROOM (*Cytisus monspessulanus*), page 34

99b. Leaves with five or more leaflets in a pinnate pattern, rarely three and then with sharp-toothed margins.

107a. Leaflets holly-like, with sharp-toothed margins; shrub, shaded chaparral and dry oak to conifer slopes. ---------- BARBERRY (*Berberis* spp.), page 24

107b. Leaflets not holly-like, without sharp-toothed margins.

108a. Leaves or stems with thorns or prickles.

109a. Leaflets 11 to 27; shrub, chaparral to dry conifer slopes. ---------- FALSE-INDIGO (*Amorpha californica*), page 17

109b. Leaflets 5 to 9; sprawling shrubs, common in moist to shaded woodlands

108b. Leaves and stems lacking thorns and prickles.

110a. Leaflets 11 to 27, ranging from 3.5 to 7.5 cm long, edges serrated; tree or large shrub, locally common in oak woodlands. ---------- WALNUT (*Juglans californica*), page 44

110b. Leaflets finely subdivided at least once into oval segments or lobes; leaves ranging from 3.5 to 8 cm long; small ill-smelling shrub, San Diego County in chaparral and coastal sage scrub. ---------- SAN DIEGO MOUNTAIN MISERY (*Chamaebatia australis*), page 31

SPECIES DESCRIPTIONS

The common names for the plants described herein are those in general usage. The latin names are consistent with Munz (1974). Plant descriptions are arranged in alphabetic order by genus. The brief descriptions emphasize vegetative features (rather than flower and fruiting characters) which are based on field observations: specimens filed at the Forest Fire laboratory, USDA Forest Service, Riverside; Botanic Garden, Rancho Santa Ana; Botanic Garden, Santa Barbara; and the Herbarium, University of California, Riverside. Several manuals are available to help identify shrubs; *A Flora of Southern California* by Munz (1974) is the primary resource manual; Raven (1966) authored *Native Shrubs of Southern California;* and McMinn's (1939) text *An Illustrated Manual of California Shrubs,* remains a major reference work. Other references include Abrams (1960), Collins (1974a,b), and Munz and Keck (1970). Smith (1976) authored a text on the flora of the Santa Barbara area.

Wildlife values follow Martin et al. (1951), Van Dersal (1938), or USDA Forest Service (1969), and are defined for utilization of browse or fruits as preferred, staple, or low value. Cultural values are largely based upon information contained in literature discussing uses by Native Americans, especially the Cahuilla Indians of southern California (Balls 1972, Clarke 1977, Medsger 1966, Sweet 1962).

The unit titled *Fire Response Mechanism* provides information about the sprouting characteristics for each species, if known. Collectively, chaparral shrubs are well adapted to fire and have developed diverse methods of regeneration. Many species readily stump-sprout from trunks, main branches, enlarged basal burls, roots, or rhizomes. Species that do not sprout as so defined but are dependent solely upon seeds for regeneration are termed *obligate seeders.* Some dominant shrubs combine sprouting strategies; for example, chamise sprouts vigorously from basal burls and has a seedling response to fire as well.

Adenostoma fasciculatum H. & A. Rose Family *(Rosaceae)*
CHAMISE (GREASEWOOD) *(fig. 5).* Diffusely branched, evergreen shrub, 0.5 to 3.5 m tall, reddish bark becoming shreddy with age; leaves green, mostly 4 to 14 leaf, alternate bundles crowded on stems, rarely single, linear, 4 to 10 (> 20) mm long, sharp-pointed, usually channeled on one side; seedling leaves divided one, two, or three times into two to several linear lobes; flowers, February through June, small, white, compact clusters 4 to 12 cm long; fruit, akene enclosed by hardened floral tube.
Distribution: Common dominant on dry slopes below 1500 m (5000 ft); chaparral merging into coastal sage scrub (soft chaparral) and desert chaparral; Channel Islands, coast ranges, Mendocino County to Baja California, Sierra Nevada foothills. Var. *obtusifolium* Wats., broader leaves, almost obtuse; shorter (3-7 mm long, 1+ mm wide); San Diego County.

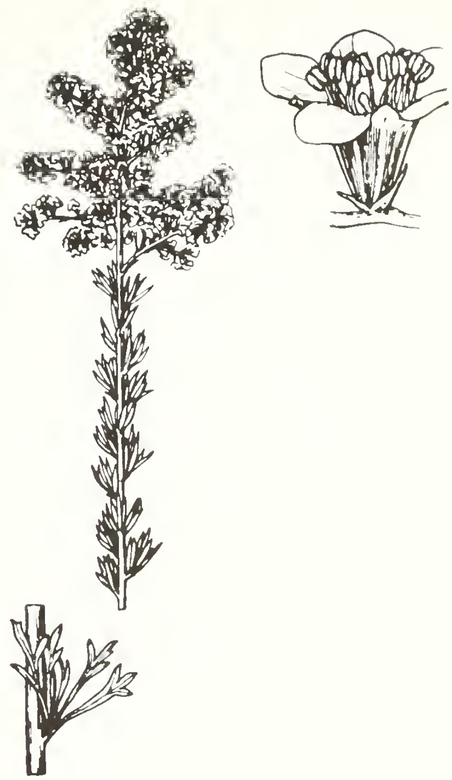


Figure 5—Chamise (greasewood), *Adenostoma fasciculatum* (McMinn 1939).

Fire Response Mechanism: Stump-sprouts from basal burls and lateral shoots after fire; many seeds germinate after some fires, only few survive.
Wildlife Value: Readily browsed few years after fire; cover for deer.
Cultural Value: Native Americans used infusion of bark and leaves as cure for syphilis, and oil of plant to cure skin infections (Sweet 1962); scale insect on plant used to bind arrows, baskets, etc.

A. sparsifolium Torr.
RED SHANK (RIBBON BUSH) *(fig. 6).* Evergreen shrub or small tree, 2 to 6 m tall, red brown bark; peels in thin sheets and strips; twigs yellowish green, resinous, sticky; leaves linear, alternate, 4 to 10 (< 15) mm long, leaves not in bundles, often crowded on young twigs; shoots arise from leaf axil buds with leaf persisting; flowers, July and August, white or pinkish, fragrant, loose clusters 2 to 6 cm long; fruit, akene enclosed by hardened floral tube.
Distribution: Discrete, disjunct populations, dry slopes, mesas below 1800 m (6000 ft); chaparral, often dominant in Baja California, Mexico; red shank-dominated communities common in southern Riverside and northern San Diego Counties; small enclave on Los Angeles-Ventura County border; disjunct communities in northern Santa Barbara County into San Luis Obispo County (Hanes 1965).
Fire Response Mechanism: Stump-sprouts from basal burls; seed response to fire.

Figure 6—Red shank (ribbon bush), *Adenostoma sparsifolium* (McMinn 1939).

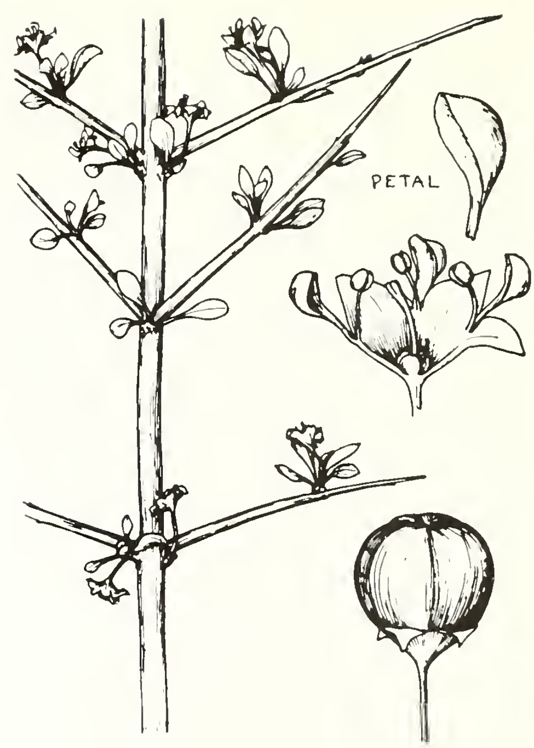


Figure 7—Adolphia, *Adolphia californica*.

Wildlife Value: Low value; cover for deer.
Cultural Value: Leaves, same as *A. fasciculatum;* ground into powder, mixed with grease for salve.

Adolphia californica Wats. Buckthorn Family *(Rhamnaceae)*
ADOLPHIA *(fig. 7).* Shrub, thorny, stiff, many-branched, drought deciduous; to 1 m tall; branches green; leaves round to oval, opposite, 2 to 5 mm long; 2 to 3 mm wide, fall early, pale green, about 5 mm long or more; flowers, December through April, inconspicuous, greenish white, five petals; fruit, 3-lobed capsule 4 to 5 mm wide.
Distribution: Dry flats and canyons; southwest San Diego County to Baja California.
Fire Response Mechanism: Obligate seeder.
Wildlife Value: Low value.
Cultural Value: Unknown.

Amelanchier utahensis Koehne. Rose Family *(Rosaceae)*
SERVICE-BERRY *(fig. 8).* Deciduous shrub, much-branched, 1 to 5 m tall; youngest twigs reddish, mature with ash-gray bark, rigid twigs, white pubescence on young growth; mature leaves gray green, color nearly equal above and to somewhat lighter below, alternate, roundish to oval or elliptic, usually flat, 1 to 4 cm long, 0.5 to 3 cm wide, usually tomentose to some degree to near base on both sides, toothed or serrate especially on outer two-thirds of leaf margin, sometimes serrations restricted to end of leaf, rarely entire; leaves on petioles 5 to 15 mm long, rather delicate midvein most

Figure 8—Service-berry, *Amelanchier utahensis*.

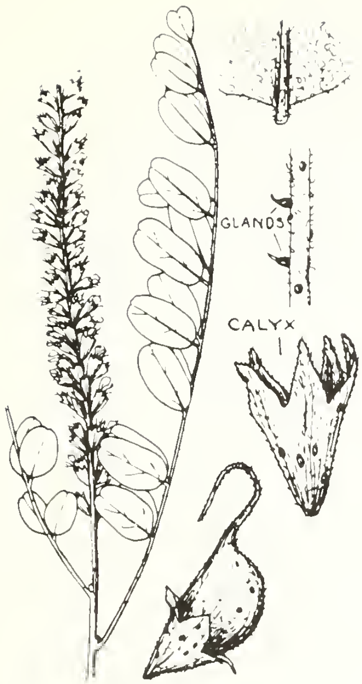


Figure 9—False indigo, *Amorpha californica* (McMinn 1939).

prominent near base, 11 to 13 pairs of lateral veins, tend to thin and flex; flowers, April through May, white, 3- to 6-flower clusters, five petals, deciduous; fruit 6 to 10 mm diameter, purplish black, juicy to dry.
Distribution: Dry slopes 900 to 2100 m (3000-7000 ft); ponderosa pine, Jeffrey pine, pinyon-juniper, western juniper; San Bernardino, San Gabriel Mountains, south to San Diego County, north to Montana and Oregon.
Fire Response Mechanism: Stump-sprouter after fire.
Wildlife Value: Staple browse for deer, livestock; fruits preferred by birds and many mammals.
Cultural Value: Native American, berries eaten fresh or dried; pounded, stored for later use as 4.5 to 7 kg (10-15) loaves; green inner bark, boiled for eyewash (Clarke 1977).

Amorpha californica Nutt. Pea Family *(Fabaceae)*
FALSE-INDIGO *(fig. 9)*. Slender, deciduous shrub, 1.5 to 3 m tall, somewhat hairy twigs; young stems green, soon become brownish then dark gray; prickly-like glands on branchlets and leaf midveins; leaves darker green above; gland dotted below; mature leaves 0.8 to 2 cm long, 11 to 27 leaflets, usually oblong-elliptic with entire margins, mature leaflets 1 to 3 cm long, 0.5 to 2 cm wide; leaflets opposite or nearly so, give appearance of 7 to 13 pairs along leaf petiole, on short (1-2 mm) leaflet petiole; flowers, April to July, crowded spike; fruit, purplish pods, 6 to 8 mm long. If lacking prickly glands, probably desert false indigo (*A. fruticosa* L. var. *occidentalus* (Abrams) Kearn. and Peeb.).
Distribution: Dry wooded or brushy slopes, below 2300 m (7500 ft); ponderosa/Jeffrey pine communities and chaparral; Santa Rosa, Santa Ana Mountains to Santa Lucia Mountains, San Gabriel, San Bernardino, San Jacinto Mountains.
Fire Response Mechanism: Stump-sprouts readily after fire.
Wildlife Value: Deer and sheep browse leaves.
Cultural Value: Unknown.

Arctostaphylos spp. Heather Family (Ericaceae)
MANZANITAS. Manzanitas (Spanish for "little apples"), evergreen shrubs or small trees with stiff branches and dark reddish-brown bark. Leaves alternate and simple; flowers urn- or bell-shaped. Munz and Keck (1970) list 43 species in California flora, 10 of which occur in area covered by this guide plus Channel Islands. Species differ in fire response mechanisms. Eastwood manzanita is only mainland species in this guide that has a basal burl, therefore, can vigorously resprout after fire. One Channel Island species (Woollyleaf Manzanita, *A. tomentosa* [Pursh] Lindl.) also forms a burl. Other species depend primarily in seedlings for post-fire recovery.
Wildlife Value: Low value browse, new growth eaten by deer; if heavily used, indicate range problems; berries, staple of many animals including fox, raccoon, skunk, coyote, quail, bear.
Cultural Value: Native American, very valuable for food, medicine, shelter, pleasure (Sweet 1962). Pulp of berries soaked in water for tart beverage; seeds ground into meal; leaves mixed with tobacco or steeped in water for tea to relieve diarrhea or wash poison oak rash (Clarke 1977).

1a. Root crown burl present, (detected as swollen collar near ground surface in zone between above-ground stems and roots); leaves oblong, somewhat mucronate, dull green, hairy; sometimes sticky; in chaparral, conifer woodlands, or forests.
EASTWOOD MANZANITA *A. glandulosa*
1b. Root crown burl not present.
- 2a. Leaves usually oblong to oval, sometimes obovate; tip usually mucronate.
  - 3a. Leaves usually glaucous or waxy in appearance; locally common shrub; on dry chaparral slopes.
  BIGBERRY MANZANITA, *A. glauca*
  - 3b. Leaves not glaucous or waxy appearing.
  - 4a. Majority of petioles have appearance of being at right angle with stem; young stems, dense glandular pubescence or villous (do not appear shiny green); dry chaparral, pine woodland slopes, San Bernardino Mountains to Baja California.
  PINK-BRACTED MANZANITA, *A. pringlei* var. *drupacea*
  - 4b. Petioles not commonly appear at right angles with stem, young stems glabrous to finely glandular pubescent or pubescent (usually appear shiny green); dry chaparral to conifer woodland slopes, Santa Rosa, San Gabriel Mountains, north to Tehachapi Mountains.
  PARRY MANZANITA, *A. parryana*

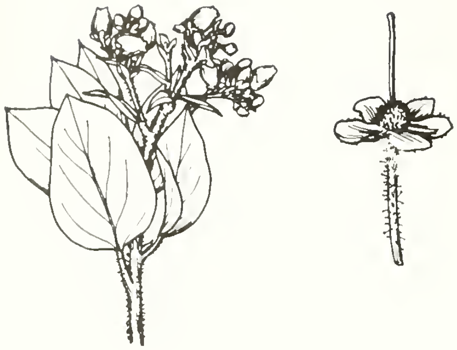


Figure 10—Eastwood manzanita, *Arctostaphylos glandulosa* (McMinn 1939).

Figure 11—Bigberry manzanita, *Arctostaphylos glauca* (McMinn 1939).

2b. Leaves mostly elliptic; commonly, tips gradually narrow to a point; rarely mucronate.
   - 5a. Leaves green, more or less shiny, usually hairless; leaf venation usually impressive to eye; dry, transmontane slopes in chaparral, oak, and conifer communities. . MEXICAN MANZANITA, *A. pungens*
   - 5b. Leaves green to yellowish green, not particularly shiny, usually more or less pubescent; venation less impressive than above; dry chaparral, San Diego County. OTAY MANZANITA, *A. otayensis*

A. glandulosa Eastw.

EASTWOOD MANZANITA (CROWN MANZANITA) *(fig. 10)*. Evergreen spreading shrub with basal burl, 1.5 to 2.5 m tall; smooth reddish stems, coarse hairy, greenish, glandular branchlets; glandular sheath shed with maturity leaving red bark-covered stems (only ssp. *glandulosa* has glandular branchlets); mature leaves stiff and leathery, elliptic-ovate or lanceolate, margins entire; leaves dull green or yellowish, pointed at tips, more or less glandular-pubescent on leaf margins and both surfaces, becoming glabrate with age but retains somewhat rough feel, 3 to 6 cm long, 1 to 4 cm wide, mature leaves nearly flat, petiole 5 to 12 mm long, seedling leaves same shape but dentate margin; flowers, February to May, white bloom subtended by sticky, lance-shaped, persistent pubescent bracts; fruit, berry-like, about 8 mm across, green glandular and sticky when immature, eventually reddish brown and less sticky, glandular (only ssp. *glandulosa*, glandular fruit).

Distribution: Common shrub, 300 to 1800 m (1000-6000 ft); chaparral, mixed conifer to ponderosa and Jeffrey pines; coast ranges, to Cuyamaca Mountains, San Diego County, north to Oregon.

Fire Response Mechanism: Stump sprouts from enlarged burls after fire or cutting.

Wildlife Value: Poor browse, berries desired.

Cultural Value: See genus.

A. glauca Lindl.

BIGBERRY MANZANITA *(fig. 11)*. Evergreen, erect shrub or small tree without basal burl, 2 to 4 (to 6 m) tall, smooth red-brown mature bark and/or waxy appearing green to pale green, hairless to finely pubescent young twigs; old bark more or less continually shed; somewhat glaucous gray green leaves, stiff, leathery, flat, ovate to oblong, rounded to tapering at apex, 2.5 to 4.5 cm long, 1 to 3 cm wide, petioles 6 to 12 mm long; flowers, December to March, white to pinkish, urn-shaped, about 8 to 9 mm long; young fruit, sticky glandular berry, 12 to 15 mm diameter.

Distribution: Common on dry slopes below 1400 m (4500 ft); chaparral; mountains, southern California northward to Mt. Hamilton, Mt. Diablo, south to Baja California.

Fire Response Mechanism: Nonsprouter, obligate seeder after fire.

Wildlife Value: See genus.

Cultural Value: See above for genus. Native American, especially desired for large fruit.

Figure 12—Otay manzanita, *Arctostaphylos otayensis* (McMinn 1939).

Figure 13—Parry manzanita, *Arctostaphylos parryana* (McMinn 1939).

A. otayensis Wies. & Schreib.

BIGBERRY MANZANITA, OTAY MANZANITA *(fig. 12).* Erect evergreen shrub, to 2.5 m tall, without basal burl, reddish to red-brown mature stems; young stems hairy, sometimes with few glandular hairs; mature leaves stiff and leathery, elliptical to ovate, rarely with mucronate tip, 1 to 4.5 cm long, 0.6 to 2.5 cm wide; petioles, 2 to 10 mm long, pubescent, leaves slightly to densely pubescent or glandular pubescent, grayish green to green both sides, sometimes darker above; flowers, February to April, white to rose, urn-shaped, 3 to 6 mm long, subtended by leafy bracts, in open panicles or racemes; fruit, round berry becoming pale brown or red, 3 to 5 mm across, contains solid nut.

Distribution: Dry slopes, 550 to 1500 m (1800-5000 ft); chaparral; San Diego Mountains, especially Laguna Mountains.

Fire Response Mechanism: Nonsprouter; apparently obligated to regenerate by seedlings after fire.

Wildlife Value: See genus.

Cultural Value: See genus.

A. parryana Lemmon

PARRY MANZANITA *(fig. 13).* Evergreen, diffusely spreading shrub without basal burl, 1 to 2 m tall, without enlarged root-crown, bark on main stems reddish brown; lateral branches lie on ground, sometimes root on contact; branchlets and petioles canescent to glabrous, not glandular; stiff, leathery leaves, bright green, somewhat shiny, darker above, hairless, ovate, elliptic or broadly oval, entire margins, flat, rounded or acute to a point at apex, 2 to 4.5 cm long, 1 to 3 cm wide, on petioles 5 to 10 mm long; flowers, February to April, white, urn-shaped, 6 to 7 mm long, few-flowered clusters; fruit, dark red berry, 5 to 12 mm, hairless, nutlets usually separable, sometimes fused.

Distribution: Dry slopes, 1200 to 2300 m (4000-7500 ft); chaparral, ponderosa and Jeffrey pine to mixed conifer; Santa Rosa Mountains to San Gabriel Mountains, Mt. Pinos area to Tehachapi Mountains. Similar sp. *Arctostaphylos patula* var. *platyphylla* (Grey) Wells, glandular-pubescent branchlets, petioles, infloresence; dry slopes, 1500 to 2700 m (5000-9000 ft); in ponderosa and Jeffrey pine to mixed conifers, Santa Rosa Mountains to San Gabriel Mountains.

Fire Response Mechanism: Nonsprouter after fire, cutting; roots from lateral branches on ground; obligate seeder after fire.

Wildlife Value: See genus.

Cultural Value: See genus.

A. pringlei Parry var. *drupaceae* Parry

PINK-BRACTED MANZANITA *(fig. 14).* Evergreen, erect shrub, without basal burl, 2 to 4 m tall, smooth reddish brown shedding bark, young stems greenish becoming red, densely hairy glandular branchlets; leaves stiff and leathery, 2.5 to 5.5 cm long, 1.5 to 3 cm wide, ovate-roundish, gray green, fine hairs, rough to touch on both sides; petioles 5 to 7 mm long; flowers, February to June, rose colored, urn-shaped, 7 to 8 mm long, subtended by lance-shaped deciduous pink bracts,

Figure 14—Pink-bracted manzanita, *Arctostaphylos pringlei* var. *drupaceae* (McMinn 1939).

Figure 15—Mexican manzanita, *Arctostaphylos pungens* (McMinn 1939).

5 to 6 mm long; fruit, round berry 6 to 10 mm across, glandular, hairy, becoming red.
Distribution: Dry slopes, 1400 to 2300 m (4500-7500 ft); chaparral, ponderosa and Jeffrey pine; San Bernardino San Jacinto Mountains to Baja California.
Fire Response Mechanism: Nonsprouter; obligate seeder after fire.
Wildlife Value: See genus.
Cultural Value: See genus.

A. pungens H.B.K.
MEXICAN MANZANITA *(fig. 15).* Erect evergreen shrub without basal burl, 2 to 3 m tall, smooth red brown bark, grayish with age, finely hairy twigs; leaves bright green, shinier above, hairless, elliptic or obovate, 1.5 to 4 cm long, 1 to 2 cm wide, petioles 3 to 10 mm long; flowers, January to March, white, urn-shaped, 6 mm long; fruit, brown hairless berries, separate or irregularly united nutlets ridged at back.
Distribution: Dry transmontane slopes 900 to 2100 m (3000-7000 ft); chaparral, ponderosa and Jeffrey pine to canyon live oak woodlands and forests; common in San Diego County to Los Angeles and San Bernardino Counties, San Gabriel, San Bernardino, San Jacinto Mountains, to Mexico, Texas.
Fire Response Mechanism: Nonsprouter, without basal burl; roots from branches; obligate seeder after fire.
Wildlife Value: See genus.
Cultural Value: See genus.

Artemisia californica Less. Sunflower Family (Asteraceae)
COAST SAGEBRUSH *(fig. 16).* Grayish, mostly woody subshrub, 0.5 to 1.5 m tall, evergreen, sage-like odor; young stems, white to yellowish, gray with age; old bark, shreddy; leaves and young stems, woolly; leaves alternate, numerous, dense short leafy branches, divided mostly once or twice into segments, at least upper ones commonly linear and borne in fascicles, 1 to 6.5 cm long, mostly 1 mm or less wide; seedling leaves with shorter and broader segments, 1 to 2 cm long, to 2 mm wide; flowers, August to December, clusters with many nodding heads, 3 to 5 mm wide; fruit, akene.
Distribution: Common, exposed slopes, hills, below 900 m (3000 ft); Marin and Napa Counties south to Baja California.
Fire Response Mechanism: Nonsprouter, exhibits vigorous seedling response after fire.
Wildlife Value: Low value browse.
Cultural Value: Cahuilla Indians, products used to prepare young girls for womanhood; important medicinal plant (Clarke 1977); may have been dried and smoked with tobacco.

A. tridentata Nutt.
BASIN (BIG) SAGEBRUSH *(fig. 17).* Evergreen shrub, 0.5 to 3 m tall, short trunk; young stems tend to be yellowish to yellowish green, become gray and shreddy with age; simple leaves, opposite and clustered, grayish, spatulate, canescent or pubescent, 1 to 4 cm long, to 8 mm wide, 3-toothed (rarely 4 to 9) at apex, strong sagebrush smell; flowers, July to

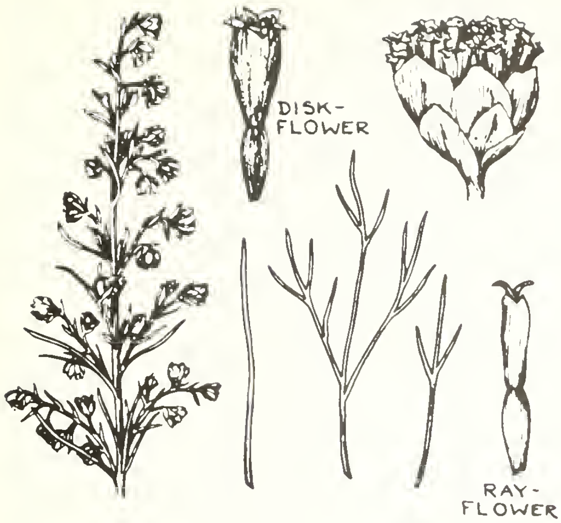


Figure 16—Coast sagebrush, *Artemisia californica* (McMinn 1939).

Figure 18—Wingscale saltbush, *Atriplex canescens* (McMinn 1939).

Figure 17—Basin sagebrush, *Artemisia tridentata* (McMinn 1939).

November, narrow clusters, spike or panicle of many small heads persisting after fruiting; fruit, akene.
Distribution: Dry slopes and plains, 450 to 3200 m (1500-10,600 ft); sagebrush, ponderosa pine, Jeffrey pine, western juniper, and pinyon-juniper; Laguna Mountains, San Diego County, western edge of deserts to Sierra Nevada, Rocky Mountains to Canada, to Baja California.
Fire Response Mechanism: Fibrous root system, occasionally root-sprouting after fire, cutting; indicator of deep soils.
Wildlife Value: Staple when eaten with other forage, decreases amount of essential oils in sagebrush which act as rumen flora inhibitors.
Cultural Value: Cahuilla Indians, source of medicine and food (Clarke 1977).

Atriplex canescens (Pursh) Nutt.
Goosefoot Family *(Chenopodiaceae)*
WINGSCALE SALTBUSH (SHADSCALE) *(fig. 18).* Evergreen, erect, stiff-branched dioecious shrub, 0.4 to 2 m tall, gray scaly or scurfy branches, young branchlets, yellowish green, become yellow gray with age; leaves alternate, often crowded in bunches, not fasicled, linear-spatulate or narrowly oblong, margins entire, 1 to 5 cm long, 2 to 8 mm wide, often somewhat rolled under (not revolute), gray to olive colored, slightly darker above with dense scurf (scales) on both sides, curled under at edges. Male and female flowers, July to August, separate plants, clusters arise from leaf axils, floral

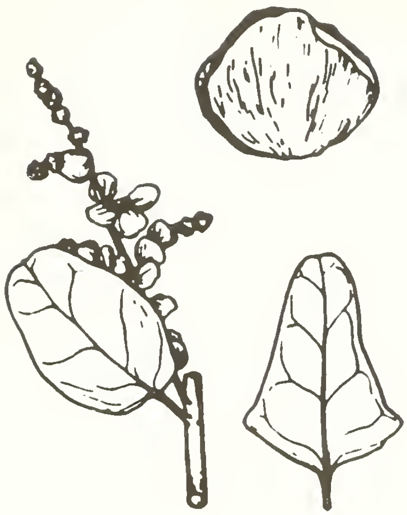


Figure 19—Lenscale saltbush, *Atriplex lentiformis* (McMinn 1939).

racemes become more leafy toward base; fruits, 4-winged utricles, single seed, wings entire or dentate.
Distribution: Dry slopes, flats, washes, below 2200 m (7000 ft); saltbush, creosote, pinyon-juniper and subsaline sinks; deserts, San Diego and Los Angeles Counties, east to Kansas and Texas, south to Baja California.
Fire Response Mechanism: Fire resistant; nonsprouter, taproot deep as 9 to 12 m (30-40 ft).
Wildlife Value: Fruits, preferred food by birds, rodents; staple browse for wildlife and livestock, concentrated feeding may cause scours in livestock.
Cultural Value: Native Americans, ground seed for meal and emetic; saliva moistened, ground roots or flowers to sooth ant bites; ashes stirred into water bread, changed color of meal to greenish blue (Sweet 1962).

A. lentiformis (Torr.) Wats.
LENSCALE SALTBUSH *(fig. 19).* Widespreading leafy dioecious shrub, 1 to 3 m tall, often wider than tall; young twigs yellowish brown becoming grayish brown; leaves alternate, triangular or ovate, truncate to wedge-shaped at base, blunt point, deciduous in desert forms, tend to be evergreen elsewhere, 1.0 to 5 cm long, 0.5 to 4 cm wide, 1-veined from base, sessile or on short petiole, grayish, fine-scaly surface; tiny flowers, August to October, long clusters; fruit, bracts flattish or convex, 3 to 7 mm long. Ssp. *lentiformis,* most common in desert; most common southern California chaparral ssp. *breweri* (Wats.) H. & C., usually with larger leaves, often monecious (Munz 1974).

Distribution: Along coast, in desert, saline places mostly from 500 m (1600 ft) and below; in coastal sage scrub (soft chaparral) and saltbush; Santa Barbara County to Santa Monica foothills, Orange County.
Fire Response Mechanism: Somewhat fire resistant foliage; profuse seeder.
Wildlife Value: Preferred browse of mule deer, livestock; seeds important to many animals.
Cultural Value: Probably same as for wingscale saltbush *(A. canescens).*

Baccharis spp. Sunflower Family *(Asteraceae)*

1a. Leaves lance shaped to linear.
  2a. Leaves linear, up to 2 cm long, not glutinous or slightly so; branches somewhat resinous, often nearly leafless; shrub on sandy washes usually near water courses, coastal sage, and creosote bush scrub. BROOM BACCHARIS, *B. sarothroides*
  2b. Leaves lance shaped, mature leaves more than 2 cm long, usually somewhat glutinous, stems leafy and not resinous; shrub, common along streams and other moist ground below 900 m, associated with coastal sage scrub and chaparral. MULEFAT (STICKY BACCHARIS), *B. glutinosa*
1b. Leaves somewhat wedge shaped in outline; shrub, common on coastal strand, coastal sage scrub, below 900 m elevation. CHAPARRAL BROOM, *B. pilularis* ssp. *consanguinea*

B. glutinosa Pers.
MULEFAT (STICKY BACCHARIS or SEEP-WILLOW) *(fig. 20).* Willow-like evergreen shrub, 1 to 3 m tall; slender, straight, relatively unbranched stems; young stems somewhat herbaceous and greenish to reddish, may be pubescent, become yellowish to brown with age; light green shiny leaves, color equal above and below, commonly glutinous, small pits on underside of leaves, alternate leaves lance-shaped, willow-like, 5 to 15 cm long, 7 to 22 mm wide, sessile or on short petiole (to 2 mm), tapering at both ends with some serration above middle or entire, single midvein or with long lateral veins arising from near base of midvein, soon becoming parallel; flowers, most of year, terminal clusters, numerous, bracts on flower heads, 4 mm long, 3 to 4 series of straw-colored bracts; fruit, small ribbed akene.
Distribution: Along streams, moist ground, to 900 m (3000 ft); throughout southern California, north to Owens Valley, Inyo County, to Texas, Mexico, Chile.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Low-value browse plant.
Cultural Value: Unknown.

B. pilularis DC. ssp. *consanguinea* (DC.) Ktze.
CHAPARRAL BROOM *(fig. 21).* Erect, much-branched evergreen shrub, straight green branchlets become brown with age, 1 to 4 m tall; alternate leaves numerous, somewhat wedge-shaped, dark green, may be darker above, 1.0 to 4 cm long, 5 to 15 mm wide, or 1- or somewhat 3-veined from the

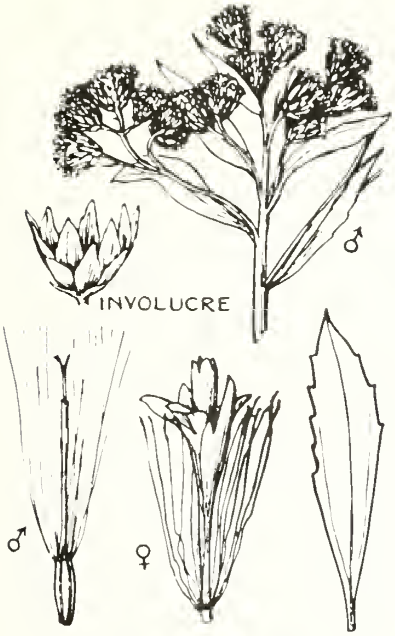


Figure 20—Mulefat, *Baccharis glutinosa* (McMinn 1939).

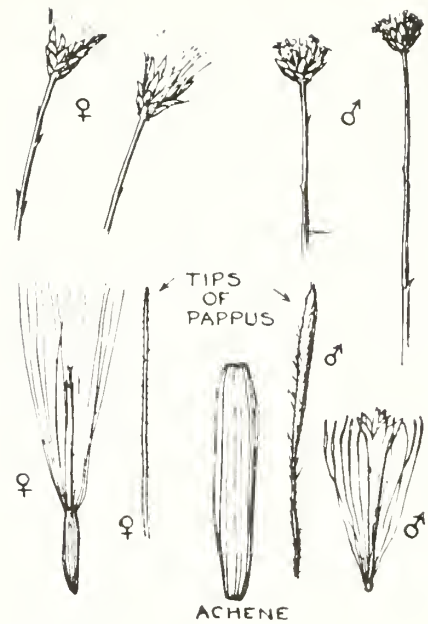


Figure 22—Broom baccharis, *Baccharis sarothroides* (McMinn 1939).

Figure 21—Chaparral broom, *Baccharis pilularis* ssp. *consanguinea* (McMinn 1939).

base, irregularly toothed (dentate) margins above lower one-third, teeth few to 6 or 7 points or sometimes entire; flowers, August to December, numerous heads on branchlets, brownish white, may make plant appear woolly; fruit, small ribbed akene. Similar species, with hairy-sticky leaves, is Plummer Baccharis (*B. plummerae* Gray); Los Angeles to Santa Barbara Counties.

Distribution: Common along coastal hills and inland, to 900 m (3000 ft); coastal strand, coastal sage scrub (soft chaparral), chamise chaparral; north San Diego County to Oregon.

Fire Response Mechanism: Colony forming, recommended for dune fixation; presumably root-sprouter after fire.

Wildlife Value: Staple browse for mule deer; seeds eaten by quail, etc.

Cultural Value: None known.

B. sarothroides Gray.

BROOM BACCHARIS *(fig. 22).* Erect shrub, 2 to 4 m tall, with grooved broom-like, green, somewhat resinous stems, branchlets becoming reddish with gray-textured bark, stems nearly leafless below; leaves alternate, approximately linear, rigid, entire, 0.6 to 2 cm long, 1 to 2 mm wide; flowers, June to October, heads 5 to 8 mm long, cream colored or brownish; fruit, ribbed akene.

Distribution: Sandy washes or soils, mostly below 300 m (1000 ft); coastal sage scrub (soft chaparral) to creosotebush;

Figure 23—Barberry, *Berberis dictyota* (McMinn 1939); renamed *Mahonia dictyota.*

Figure 24—Brickellbush, *Brickellia californica* (McMinn 1939).

San Diego County to Baja California, Colorado Desert.
Fire Response Mechanism: Unknown.
Wildlife Value: Unknown.
Cultural Value: Unknown.

Berberis dictyota Jeps. Barberry Family *(Berberidaceae)*
BARBERRY *(fig. 23).* Species renamed *Mahonia dictyota* Fedde. and listed as a synonym (Munz 1974). *Berberis dictyota* retained to be consistent with Munz. Evergreen shrub with erect stems, few branched, to 1.8 m tall; leaves alternate, compound, divided into five (rarely 3 or 7) holly-like leaflets, 3 to 5 cm long and 1.5 to 3 cm wide, green above, paler and white-filmy below, with prominent midvein, margins wavy with stiff spines; leaves on petiole to 1 cm long; flowers, February through May, yellow in drooping racemes; fruit, berry 6 to 7 mm long, blue black or filmy. If leaves are large oval shaped, glossy-green on both surfaces or somewhat darker above with up to nine leaflets, terminal leaflet to 8 cm long, 5 cm wide, it is shiny-leaf Barberry (*B. pinnata* Lag.); if leaflets lance-shaped, terminal leaflets mostly less than 4 cm long, 1 cm wide, all less than 2 cm wide, it is the rare *B. nevinnii* Gray, and location should be reported to a local land management agency or university botanist.
Distribution: Local, dry rocky foothills, 600 to 1800 m (2000-6000 ft); chaparral and oak to ponderosa and Jeffrey pine communities.
Fire Response Mechanism: Suckers, root-sprouts after fire.
Wildlife Value: Low value browse and fruits.
Cultural Value: Important medicinal source for ulcers, served as tonic and flavoring for soup, etc. (Sweet 1962).

Brickellia californica (T. & G.) Gray
Sunflower Family *(Asteraceae)*
BRICKELLBUSH *(fig. 24).* Rounded, aromatic subshrub, with many stems from woody base young stems pubescent, light brown, becoming darker; leaves alternate, pubescent, deltoid to ovate, sometimes taper to blunt point, with rounded serrations, rarely heart-shaped at base, 1 to 4 cm long, petiole 1 to 5 mm long; flowers, June to November, cream-colored heads on pedicels, arise from leaf axils and in small, terminal clusters, somewhat leafy; fruit, ribbed akene.
Distribution: Washes, dry slopes, below 2100 m (7000 ft); coastal sage scrub (soft chaparral), chamise; Sierra Nevada foothills, Humboldt County, south to southern California, Mexico.
Fire Response Mechanism: Believed to be nonsprouter or poor sprouter after fire.
Wildlife Value: Low value or staple browse.
Cultural Value: Unknown.

Ceanothus spp. Buckbrush Family *(Rhamnaceae)*
CALIFORNIA-LILACS. Shrubs or small trees, mostly evergreen, in southern California. Leaves simple, alternate or opposite, deciduous or evergreen. Flowers, small, five-parted, spoon-shaped petals, glandular disk. Fruit, 3-lobed capsule; when viewed from top, bears mark similar to Mercedes Benz

insignia. Of 60 species in the genus, 40 native to California, 17 to southern California.

Wildlife Value: Most species preferred for browse by deer, bighorn sheep.

Cultural Value: Southern California species seem not to have been heavily used; available information suggesting its use difficult to find. Flowers of several species can be used as substitute for soap.

1a. Leaves opposite.
  2a. Leaves usually flat, spatulate to obovate, sometimes notched at apex, smooth margins; common on dry chaparral and conifer woodland slopes below 1800 m. BUCKBRUSH, C. *cuneatus*
  2b. Leaves mostly cupped upwards or rolled downward at edges.
    3a. Leaves commonly rolled downward, never cupped upward, dull green above, distinctly white-tomentose below, vaguely oak appearing leaf; common in chaparral below 1100 m. HOARYLEAF CEANOTHUS, *C. crassifolius*
    3b. Leaves commonly cupped upwards, usually pubescent below, sometimes tomentose on both sides, rarely rolled downward, grayish green to yellowish green above, gray below; locally common in chaparral, sagebrush, and pine woodlands. CUPLEAF CEANOTHUS, *C. greggii*
1b. Leaves alternate.
  4a. Plants with spine-tipped twigs.
    5a. Leaves with three veins from base, sometimes laterals less significant; leaves dull green with whitish film above and below or grayish without film below.
      6a. Leaves with whitish film on both surfaces, lateral veins sometimes obscure; dry chaparral slopes below 1800 m. CHAPARRAL WHITETHORN, *C. leucodermis*
      6b. Leaves with whitish film above, gray below; dry, open conifer slopes above 1500 m. MOUNTAIN WHITETHORN, *C. cordulatus*
    5b. Leaves with one main vein, hairless and shiny on both surfaces; dry coastal sage scrub and chaparral slopes below 900 m. GREENBARK CEANOTHUS, *C. spinosus*
  4b. Plants without spine-tipped twigs.
    7a. Leaves mostly 3-veined from base, more or less hairy.
      8a. Leaves serrated, young branchlets reddish brown to olive and hairy or warty on a more villous petiole; western Riverside County and northward; dry slopes below 1400 m. HAIRY CEANOTHUS, *C. oliganthus*
      8b. Leaves entire or serrated, young branchlets green to yellowish and glabrous (sometimes strigose) or reddish and tomentose, petioles not much more or less pubescent than leaves.
        9a. Leaves with dark serrations at margins, young branchlets reddish and hairy; Redlands area to Santa Ana Mountains and south, in chamise and mixed chaparral below 1100 m. WOOLLYLEAF CEANOTHUS, *C. tomentosus* var. *olivaceous*
        9b. Leaf margins usually entire to somewhat fine-toothed near tip, greenish branchlets usually glabrous or somewhat pubescent; woodlands on dry slopes and ridges between 300 and 1800 m. DEER BRUSH, *C. integerrimus*
    7b. Leaves mostly 1-veined.
      10a. Leaves usually more than 2 cm long, more than 10 mm wide; woodlands on dry slopes and ridges between 300 and 1800 m. DEER BRUSH, *C. integerrimus*
      10b. Leaves usually less than 2 cm long, less than 15 mm wide.
        11a. Leaves dull green, smooth above with grayish white fine hairs below; near coast, below 600 m in chaparral. BIGPOD CEANOTHUS, *C. megacarpus*
        11b. Leaves dark green, smooth above, very fine hairs below; coastal hills in coastal sage scrub and chamise chaparral. WARTYSTEM CEANOTHUS, *C. verrucosus*

C. cordulatus Kell.

MOUNTAIN WHITETHORN (SNOW BRUSH) *(fig. 25).* Much branched, spiny shrub, 1 to 2 m tall, smooth whitish or grayish bark; leaves alternate, more or less clustered bundles, evergreen, ovate or elliptic, tapering to a point at apex, rounded at base, mostly entire, 1 to 3 cm long, 0.5 to 2 cm wide, 3-veined, dull green, pubescent, filmy coating above, lighter green to grayish below; flowers, May to July, 2 to 6 cm long, dense white clusters; fruit, capsule with slight crests (horns) 4 to 6 mm across, somewhat sticky before maturity.

Distribution: Dry open slopes, flats; 1500 to 2900 m (5000-9500 ft); in mixed conifer, yellow pine, mostly above yellow pine; San Jacinto Mountains, north to Sierra Nevada; Oregon, Nevada, and Baja California.

Fire Response Mechanism: Stump-sprouts after fire; seed-sprouter.

Wildlife Value: Provides staple or preferred browse for deer and bighorn sheep; fruit eaten by birds, small mammals. Poor for livestock, except sheep and goats.

Cultural Value: None known.

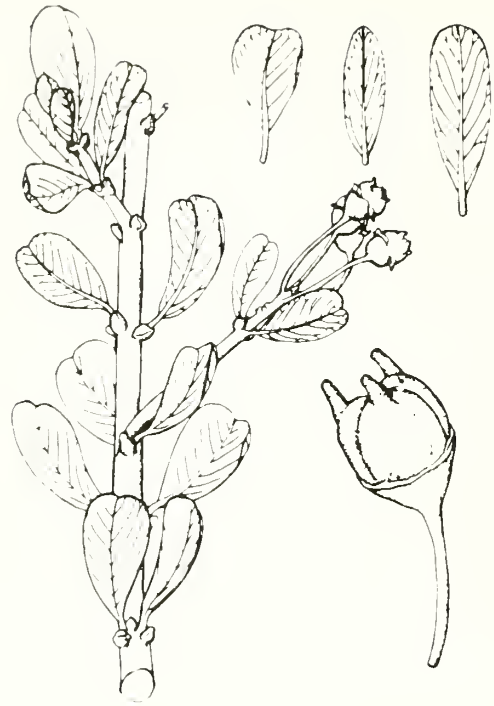


Figure 25—Mountain whitethorn, *Ceanothus cordulatus* (McMinn 1939).

Figure 27—Buckbrush, *Ceanothus cuneatus* (McMinn 1939).

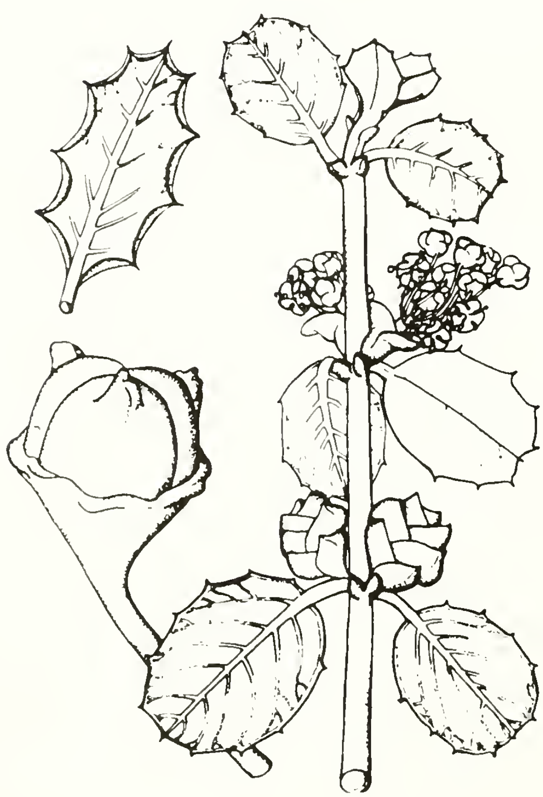


Figure 26—Hoary leaf ceanothus, *Ceanothus crassifolius* (McMinn 1939).

C. crassifolius Torr.

HOARY LEAF CEANOTHUS *(fig. 26).* Much-branched shrub, 2 to 3.5 m tall; grayish, brown, or white branches with wart-like protrusions at nodes; leaves, evergreen, opposite, thick, leathery, rounded to spatulate, elliptic, or ovate 1.5 to 3.5 cm long, 0.8 to 2.5 cm wide, commonly revolute (edges curled under), olive green above, white-fuzzy below, coarsely dentate or sometimes entire leaf petiole less than 5 mm long; flowers, January to April, white clusters, inflorescences 1.5 to 3 cm long; fruit, roundish, sticky capsule, 6 to 8 mm diameter. Var. *planus* Abrams. with flat leaves occurs in Santa Barbara and Ventura Counties.

Distribution: Common below 1100 m (3500 ft); chaparral; Santa Barbara County to Baja California.

Fire Response Mechanism: Rarely stump-sprouts from exposed roots, otherwise nonsprouter after fire, obligate seeder.

Wildlife Value: Provides staple browse for deer; fruit preferred by birds, small mammals, insects.

Cultural Value: Unknown.

C. cuneatus (Hook) Nutt.

BUCKBRUSH *(fig. 27).* Rigid shrub 1 to 3.5 m tall, bark soon becomes grayish; leaves, evergreen on spur-like divergent, rigid branchlets, sometimes several at a node, opposite, sometimes notched at apex or almost entire and spatulate to ovate, gray green, hairless or pubescent above, firm, 0.5 to 1.5 cm long, 3 to 10 mm wide, flat or sometimes rolled downward at margins; flowers, white, March to May; fruit, capsule 5 to 6 mm with short erect horns. Primary seedling leaves serrated and spatulate, larger (2+ cm long, 1+ cm wide), less stiff than on mature plants, cotyledons entire and nearly oval.

Figure 28—Cup-leaf ceanothus, *Ceanothus greggii* var. *perplexans* (McMinn 1939).

Figure 29—Deerbrush, *Ceanothus integerrimus* (McMinn 1939).

Distribution: Common on dry slopes and fans below 1800 m (6000 ft); chaparral, pinyon-juniper, Jeffrey pine and ponderosa pine communities; Oregon to Baja California.
Fire Response Mechanism: Obligate seeder, seedlings usually prolific after fire. Can regenerate from exposed roots.
Wildlife Value: Important browse and cover. Seeds preferred by small animals, insects, birds.
Cultural Value: Unknown.

C. greggii Gray var. *perplexans* (Trel.) Jeps.
CUPLEAF CEANOTHUS *(fig. 28).* Plant erect, rigidly and intricately branched, 1 to 2 m tall, young branchlets with greenish bark soon become gray; leaves, evergreen, opposite, roundish to broadly elliptical or ovate, commonly cupped upward, 1 to 3 cm long, 8 to 20 mm wide, petiole 1 to 4 mm long, mostly conspicuously toothed, yellowish green, hairless to pubescent or rarely tomentose above, usually tomentose below; flowers, March to May, cream-colored clusters; fruit, rounded capsule 4 to 5 mm across, small horns on sides of capsule.
Distribution: Dry slopes below 2100 m (7000 ft); in chaparral, sagebrush, pinyon-juniper, Jeffrey or ponderosa pine, south face of San Bernardino Mountains to Lower California. Var. *vestitus* (Greene) McMinn, grayish green on both leaf surfaces, margins entire or dentate, cupped, 7 to 15 mm long, occurs on San Jacinto Ranger District and in Lake Hughes-Sawmill Mountain area of eastern Los Padres National Forest (Los Angeles County).

Fire Response Mechanism: Nonsprouter after fire, cutting; obligate seeder.
Wildlife Value: Staple browse for wildlife and livestock, especially goats, in winter and early spring. Seeds preferred by small mammals, birds, insects.
Cultural Value: None known.

C. integerrimus H. & A.
DEERBRUSH *(fig. 29).* Loosely branched, 1 to 4 m tall, glabrous (sometimes strigose) green or yellowish branches, some young twigs, green turning reddish, somewhat pubescent, twigs flexible, not spinose; semideciduous to deciduous; leaves flexible, alternate, either pinnate (1-veined) or 3-veined from base, broadly ovate to elliptic, rounded at base, tapering or somewhat rounded at apex, 2.5 to 7 cm long, 1 to 4 cm wide, olive to light green, puberulent to almost bald above, slightly paler and commonly with some hairs on veins below, edges entire to somewhat toothed near the tip, on petioles 6 to 12 mm long; flowers, May to July, white to dark blue, rarely pink, on branched flower clusters 4 to 15 cm long; fruit, somewhat rounded capsule 4 to 5 mm wide, usually with small horns. *Ceanothus integerrimus* var. *puberulus* (Green) Abrams, also in southern California chaparral and distinctly 3-veined from base.
Distribution: Dry slopes and ridges, 300 to 1800 m (1000-6000 ft); ponderosa and Jeffrey pine, mixed conifer; Riverside County or northern San Diego County, Cuyamaca Moun-

Figure 30—Chaparral whitethorn, *Ceanothus leucodermis* (McMinn 1939).

Figure 31—Bigpod ceanothus, *Ceanothus megacarpus* (McMinn 1939).

tains to Santa Rosa and San Gabriel Mountains, Ventura County north to Santa Cruz.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Preferred browse of deer and bighorn sheep. Important forage plant for livestock; valuable honey plant.
Cultural Value: None known.

C. leucodermis Greene.
CHAPARRAL WHITETHORN *(fig. 30).* Evergreen shrub, 2 to 4 m tall, rigid spine-tipped branchlets, gray or whitish, bark on young twigs green becoming olive green; leaves alternate, with three somewhat obscure veins, midvein more prominent, 0.5 to 2.5 cm long, 5 to 12 mm wide, petioles 2 to 3 mm long, oval to lanceolate, rounded or tapering to a point at apex, rounded at base, minutely serrate or entire edges, usually hairless, darker above, filmy-white on both surfaces, sometimes hairs on veins below; flowers, February to June, white or blue clusters 3 to 8 mm long; fruit, capsule 4.5 to 6 mm wide, sticky, without horns, depression in top center. Seedling leaves serrate, oval to lanceolate; cotyledons entire.
Distribution: Dry slopes below 1800 m (6000 ft); chaparral; mountains of southern California, north along Coast Ranges, Santa Cruz to Humboldt and Siskiyou Counties.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Preferred browse and cover for deer; also bighorn, if stands are open. Fruit staple for small animals, birds, insects.
Cultural Value: None known.

C. megacarpus Nutt.
BIGPOD CEANOTHUS *(fig. 31).* Large shrub, 1 to 4 m tall, grayish brown or reddish branches, young branchlets commonly with fine, stiff hairs, soon becoming gray, older bark rough; leaves alternate, spatulate to obovate with smooth margins, sometimes notched at tip, wedge-shaped at base, 0.5 to 2.5 cm long, 6 to 12 mm wide, petiole 2 to 3 mm, 1-veined, thick and leathery, sometimes rolled under at edges, dull green and smooth above, grayish white fine hairs below; flowers, January to April, white; fruit, capsule 8 to 12 mm broad.
Distribution: Near coast, below 600 m (2000 ft); chaparral; Santa Barbara to Orange County to San Diego County.
Fire Response Mechanism: Probably obligate seeder after fire.
Wildlife Value: Provides browse and cover for deer. Flowers used by insects; seeds used by small mammals, birds, insects.
Cultural Value: None known.

C. oliganthus Nutt.
HAIRY CEANOTHUS *(fig. 32).* Shrub, 1 to 4 m tall, younger branches round, reddish to olive, hairy or warty; leaves alternate, evergreen, 1.0 to 4 cm long, 5 to 20 mm wide, villous, petioles 3 to 8 mm long, oval or ovate to lanceolate with fine serrate margins, dark green above, paler below, scattered long hairs to hirsute pubescent especially on veins below, often with two long veins curving upward to parallel midveins, flowers, February to May, blue or purplish clusters; fruit, capsule 4 mm broad, usually somewhat sticky. Deer-

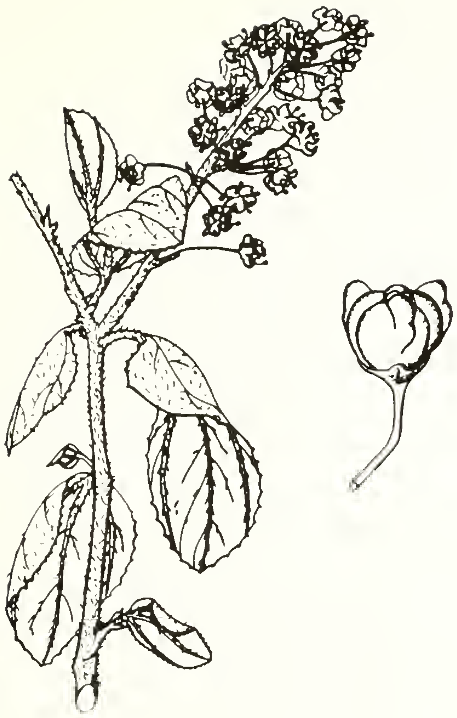


Figure 32—Hairy ceanothus, *Ceanothus oliganthus* (McMinn 1939).

Figure 33—Greenbark ceanothus, *Ceanothus spinosus* (McMinn 1939).

brush *(C. integerrimus)* may also key out to this species but differs from hairy ceanothus; leaves thin, less hairy, usually without serrations, with greenish yellow bark and branches—not reddish.
Distribution: Dry slopes below 1400 m (4500 ft); Los Angeles, west Riverside Counties, north to San Luis Obispo.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Provides browse and cover for deer. Seeds used by birds, small mammals, insects. Insects (especially bees) use flowers.
Cultural Value: None known.

C. spinosus Nutt.
GREENBARK CEANOTHUS *(fig. 33).* Large shrub, 2 to 6 m tall, usually with smooth olive-green bark, main branches flexible, commonly with short, stiff, spine-tipped branchlets angled away from main stems; leaves evergreen, oval to lanceolate to nearly linear or oblanceolate, alternate, thick and leathery, hairless and shiny on both surfaces, margins commonly entire, occasionally denticulate or sometimes with notch at tip (emarginate), lateral veins curve toward tip, 1.2 to 4 cm long, 5 to 15 mm wide, petiole 1 to 6 mm long; flowers, February to May, pale blue or white; fruit, globose, viscid capsule 4 to 5 mm broad, with small horns.
Distribution: Dry slopes below 900 m (3000 ft) coastal sage scrub (soft chaparral) and chaparral; Baja California to San Luis Obispo County.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Provides browse and cover for deer. Flowers and seeds used by birds, insects, seeds by small mammals, insects.
Cultural Value: None known.

C. tomentosus Parry var. *olivaceous* (Jeps.) Munz
WOOLLYLEAF CEANOTHUS *(fig. 34).* Evergreen shrub, 1 to 3 m tall, young branchlets, reddish bark with matted hairy surface becoming gray with age; leaves alternate, ovate to elliptic, commonly several at a node, 0.5 to 2.5 cm long, 5 to 15 mm wide, petiole 1 to 5 mm long, dark green with some hairs above, grayish green and pubescent to almost woolly below, 3- or 1-veined from base, dark gland tipped serrations along margins; flowers, January to May, pale blue to white, clusters branched, 2 to 5 cm long; fruit, roundish, sticky capsule about 4 mm across, usually with small horns.
Distribution: Below 1100 m (3500 ft), chamise chaparral, mixed chaparral; Redlands area to Santa Ana Mountains, south to San Diego County, Baja California, merging with hairy ceanothus in Trabuco-Bedford Canyon area.
Fire Response Mechanism: Stump-sprouts vigorously after fire, cutting.
Wildlife Value: Provides browse and cover for deer. Seeds used by small animals, birds, insects. Birds and insects use flowers.
Cultural Value: None known.

C. verrucosus Nutt.
WARTYSTEM CEANOTHUS *(fig. 35).* Erect evergreen shrub, to 4 m tall; leaves 0.8 to 2 cm long, 6 to 15 mm wide,

Figure 34—Woolyleaf ceanothus, *Ceanothus tomentosus* var. *olivaceous* (Munz 1974).

Figure 36—Western redbud, *Cercis occidentalis* (McMinn 1939).

Figure 35—Wartystem ceanothus, *Ceanothus verrucosus*.

petiole less than 4 mm long, alternate, round-to deltoid-obovate, sometimes notched at tip, 1-veined from base, dark green and mostly hairless above, paler below with fine stiff hairs especially on midvein, entire or rarely dentate margins, thick and leathery; flowers, January to April, white clusters 1 to 2 cm long; fruit, round-horned capsule 5 mm across.
Distribution: Coastal hills and mesas; chamise to coastal sage scrub (soft chaparral); San Diego County to Baja California.
Fire Response Mechanism: Unknown.
Wildlife Value: Unknown.
Cultural Value: None known.

Cercis occidentalis Torr. Pea Family *(Fabaceae)*
WESTERN REDBUD *(fig. 36).* Deciduous, rounded shrub or small tree, to 5 m tall; mature leaves rounded, often wider than long, 4 to 6 cm long, 4 to 8 cm wide, entire margins, immature leaves commonly reddish, becoming green with maturity, more glossy and darker above, heart-shaped (cordate) at base, 5 to 9 main veins in palmate pattern, leaf smooth, somewhat leathery; flowers, February to April, mostly before leaf development, reddish purple to pink, 5 to 12 mm long; fruit, flat pod, 4 to 9 cm long.
Distribution: Slopes of Palomar, Laguna, Cuyamaca Mountains 900 to 1400 m (300-4500 ft), becoming more abundant to Shasta and Humboldt Counties.
Fire Response Mechanism: Not known.
Wildlife Value: Browsed by deer.

Figure 37—Western mountain-mahogany, *Cercocarpus betuloides* (Munz 1974).

Figure 38—Curlleaf mountain-mahogany, *Cercocarpus ledifolius* (McMinn 1939).

Cultural Value: Bark from young shoots used for baskets, and as mild astringent to treat diarrhea and dysentery (Sweet 1962).

Cercocarpus betuloides Nutt. Rose Family *(Rosaceae)*
WESTERN MOUNTAINMAHOGANY *(fig. 37).* Erect open evergreen shrub or small tree, 2 to 7 m tall, young twigs reddish becoming reddish brown, mature bark smooth gray; leaves simple, alternate, 1 to 4.5 cm long, 1 to 2.5 cm wide, petiole 3 to 10 mm long, leaf obovate or oval to elliptic, sometimes tapering wedge shape and usually entire below middle, serrate towards apex with short protrusions of veins, more or less pubescent or puberulent on both surfaces, dark green above, paler with evident feather veining below, flowers, March to May, clusters of 2 to 5 blooms, with cylindrical floral tube, first hairy, becoming reddish brown with age; fruit, akene with long, silky, twisting tail.
Distribution: Dry slopes and washes below 1800 m (6000 ft); chaparral, canyon live oak, interior live oak woodlands; Baja California, north to Oregon, east to Nevada.
Fire Response Mechanism: Crown-sprouts after fire, cutting, very palatable at this stage for wildlife.
Wildlife Value: Usually preferred browse for cattle, sheep, goats, deer, bighorn sheep.
Cultural Value: Wood used for fish spears, arrow shafts, digging sticks. Inner bark made purple dye, bark used in tea for treating colds, dried inner bark boiled for lung trouble. Young plant powdered and stirred into water for use as laxative (Sweet 1962).

C. ledifolius Nutt.
CURLLEAF MOUNTAINMAHOGANY *(fig. 38).* Evergreen shrub or small tree, 2 to 9 m tall, bark gray or reddish, furrowed with age; leaves simple, alternate, green above, grayish below, somewhat pubescent and more so below, nearly linear to lanceolate or elliptic, 1 to 3 cm long, 0.3 to 1 cm wide, pointed at apex, thick and leathery, rolled under at edges; flowers, April or May, one to three attached directly to stems, 4 to 5 mm wide, cylindrical tube 4 to 6 mm long; fruit, 6 to 10 mm long, hairy tail 4 to 7 cm long.
Distribution: Dry rocky slopes 1200 to 3200 m (4000-10500 ft); if fire absent or rare, can be found at lower elevation; one collection made near Mormon Rocks in San Bernardino County at 975 m (3200 ft); sagebrush, pinyon-juniper, limber pine, western juniper, yellow pine, and subalpine communities; Santa Rosa, San Jacinto Mountains, north to Washington, Montana, Colorado, Arizona.
Fire Response Mechanism: Nonsprouter, rare in chaparral. Usually not found in areas of frequent fire over large areas.
Wildlife Value: Preferred browse of deer, goats.
Cultural Value: Apparently same as *C. betuloides.*

Chamaebatia australis (Bdg.) Abrams.
Rose Family *(Rosaceae)*
SAN DIEGO MOUNTAIN MISERY *(fig. 39).* Evergreen shrub 0.6 to 2 m tall, smooth stems with light gray to nearly black bark, sometimes covered with whitish film; leaves compound, alternate, aromatic sticky fern-like foliage, leaves pubescent 3 to 8 cm long, pinnately divided into tiny oval

Figure 39—San Diego mountain misery, *Chamaebatia australis.*

Figure 40—Bush chinquapin, *Chrysolepis sempervirens* (McMinn 1939).

segments or lobes; flowers, November to May, white, five petals, 4 to 5 cm long; fruit, small rounded leathery akene.
Distribution: Chaparral and sage scrub (soft chaparral) below 600 m (2000 ft); southern San Diego County to Baja California.
Fire Response Mechanism: Rootsprouts after fire, cutting.
Wildlife Value: Low value browse.
Cultural Value: Native Americans probably used this species like a closely related Sierra Nevada species, Sierra mountain misery (*C. foliolosa* Benth.), for treating ailments such as rheumatism, skin eruptions, colds, cough, and occasionally, venereal diseases (Sweet 1962).

Chrysolepis sempervirens (Kell.) Hjelmquist.
Beech Family *(Fagaceae)*
BUSH CHINQUAPIN *(fig. 40).* Evergreen monoecious shrub less than 2.5 m tall with spreading, round-topped growth form, smooth brown gray bark; leaves simple, alternate, 3 to 7.5 cm long, 1 to 2 cm wide, petiole 5 to 15 mm long, mostly obtuse and oblong or oblong-lanceolate to spatulate, margins entire, yellowish or gray green above, golden or pale below, with rusty fuzz; flowers, July through September, ill-smelling male flowers on densely flowered erect catkins, 2.5 to 7 cm long, one to three female flowers at base of male catkin; fruit, matures in two seasons, burr covered with dense coat of long spines, 2 to 3 cm thick, clusters of 2 to 7.
Distribution: Thickets on rocky slopes, ridges 1500 to 3400 m (5000-11,000 ft); in mixed conifer, limber pine, lodgepole, etc.; San Jacinto and San Bernardino Mountains, north to Oregon.
Fire Response Mechanism: Readily stump-sprouts after fire, cutting.
Wildlife Value: Fruits provide staple food source for birds, rodents. Low value browse for bighorn sheep.
Cultural Value: Spiny burrs contain edible nuts.

Chrysothamnus nauseosus (Pall.) Britton ssp. *bernardinus* (Hall) Hall & Clem.
Sunflower Family *(Asteraceae)*
RUBBER RABBITBRUSH *(fig. 41).* Evergreen mostly wood subshrub 0.5 to 2 m tall, several fibrous-barked main stems from base, gray to whitish, felty branches, leafy, ill-smelling; leaves simple, alternate, with very fine short hair (canescent) especially on young leaves, linear, or divided into linear divisions, 2 to 7 cm long, 0.5 to 4 mm wide; flowers, August to September, yellowish tomentose heads, terminal clusters, 10 to 13 mm long, ray-flowers lacking; fruit, akene.
Distribution: Dry benches 1200 to 2900 m (4000-9500 ft); ponderosa and Jeffrey pine, pinyon communities; San Gabriel, San Bernardino, and San Jacinto Mountains.
Fire Response Mechanism: Variable stump-sprouter after cutting.
Wildlife Value: Low value.
Cultural Value: Tea from twigs relieved chest pain, toothache.

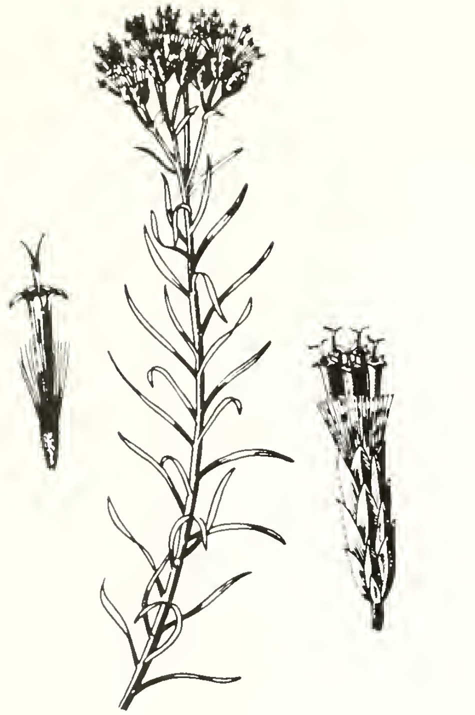


Figure 41—Rubber rabbitbrush, *Chrysothamnus nauseosus* ssp. *bernardinus* (McMinn 1939).

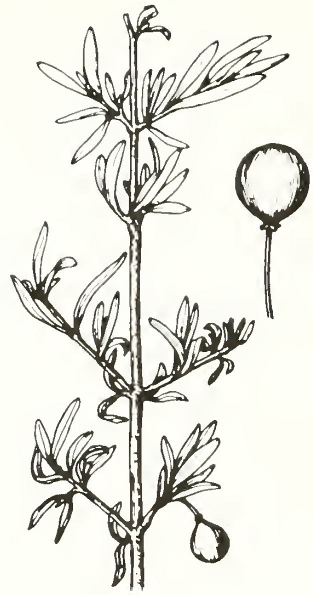


Figure 43—Bushrue, *Cneoridium dumosum* (McMinn 1939).

Figure 42—Western clematis, *Clematis ligusticifolia* (McMinn 1939).

Clematis ligusticifolia Nutt.

Buttercup Family *(Ranunculaceae)*

WESTERN CLEMATIS *(fig. 42).* Woody vine, climbing over shrubs and trees, to 12 m tall; leaves compound, opposite, glabrous, divided into 5 to 7 leaflets, leaflets lance shaped or ovate to palmate, leaf sometimes not divided or otherwise leaflets may be subdivided, nearly entire or 3-lobed, 2 to 11 cm long, 2 to 9 cm long; flowers, June through August, small, in dense clusters; fruit, numerous, hairy-tailed akene, forming fluffy powderpuff-like ball, very noticeable in fall. If leaves are divided into threes, it is pipestem clematis, *C. lasiantha* Nutt.
Distribution: Along streams, moist places, below 2100 m (7000 ft), in many plant communities; coast ranges and Sierra Nevada to mountains of southern California.
Fire Response Mechanism: Probably nonsprouter or poor sprouter from rootstock, but prolific seeder.
Wildlife Value: Low value, mule deer browse.
Cultural Value: Infusions used by early settlers for sores and cuts on horses, by Native Americans for sore throat, colds (Munz and Keck 1959).

Cneoridium dumosum (Nutt.) Hook.

Rue Family *(Rutaceae)*

BUSHRUE *(fig. 43).* Low evergreen shrub, to 2 m tall, densely branched, becoming grayish, branchlets slender; leaves simple, more or less oblong, opposite, may be crowded at tips of branchlets, 1 to 2.5 cm long, 1 to 3 mm wide, somewhat resin-dotted foliage strong scented; flowers, November to

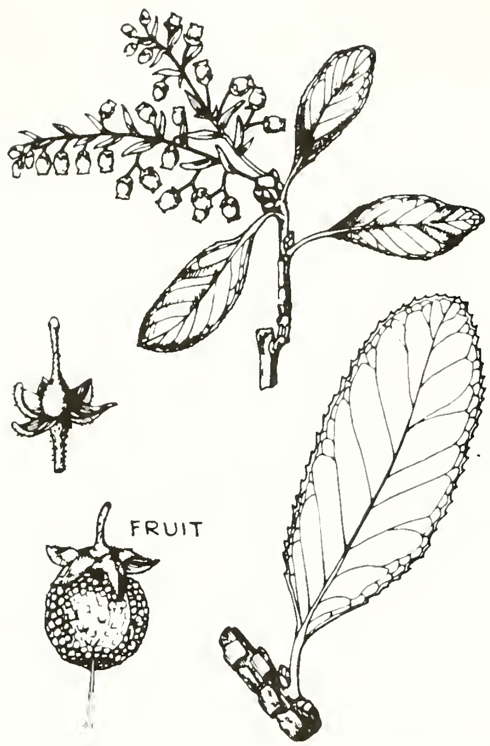


Figure 44—Summer-holly, *Comarostaphylis diversifolia* (McMinn 1939).

Figure 45—American dogwood, *Cornus stolonifera.*

March, white, four petals; fruit, fleshy, 1- to 2-seeded capsule, 5 to 6 mm long.
Distribution: Below 800 m (2500 ft); frequent on coastal bluffs, on desert slopes of Cuyamaca Mountains; coastal sage scrub (soft chaparral), chamise communities, Orange County, south to Baja California.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Low value browse and fruit.
Cultural Value: None known.

Comarostaphylis diversifolia (Parry) Greene. Heather Family *(Ericaceae)*
SUMMER-HOLLY *(fig. 44).* Erect, evergreen shrub, 2 to 5 m tall, young branchlets olive and hairy becoming gray with fibrous and shredded bark; leaves simple, alternate, 3.5 to 9.5 cm long, 1 to 3 cm wide, normally leaf somewhat revolute, petioles 2 to 5 mm long, thick and leathery, oblanceolate to ovate, dark green, glabrous above, whitish-fuzzy beneath with prominent midvein, sharp pointed, finely serrated margins sometimes entire; flowers, April to June, white, bell shaped; fruit, warty-skinned red berry containing solid stone.
Distribution: Dry slopes, mostly well below 550 m (1800 ft) along coast; manzanita and chamise chaparral; Santa Barbara County (Nojoqui Park) to Santa Monica Mountains, to San Diego County, Baja California.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Low value.
Cultural Value: Unknown.

Cornus stolonifera Michx. Dogwood Family *(Cornaceae)*
AMERICAN DOGWOOD *(fig. 45).* Spreading shrub, 2 to 5 m tall, brownish or reddish twigs with some short stiff hairs; leaves simple, opposite, lance shaped or elliptic, tapering to a point at tips, 4 to 9 cm long, 1.5 to 5 cm wide, petiole 5 to 10 mm long, nearly glabrous and darker above, covered with short stiff hairs below, obvious lateral veins curving upward; flowers, April to November, small white blossoms, clusters; fruit, smooth, white or bluish berry. If leaves are little longer (10 cm), dark green above and definitely elliptic with considerable soft hairs on underside of leaf and on young twigs, species probably western dogwood (*C. occidentalis* (T.& G.) Cov.). Munz (1974) considers western dogwood more common than American dogwood in southern California.
Distribution: Moist places, below 2700 m (9000 ft); willow and mixed conifer communities; Alaska to Mexico, occasionally in San Gabriel and San Bernardino Mountains (near Pine Knot Station, Big Bear, Lake Arrowhead).
Fire Response Mechanism: Sprouts readily from underground shoots.
Wildlife Value: Low value browse for mule deer, beaver. Not used by livestock. Fruit eaten by birds.
Cultural Value: Berries probably eaten (Clarke 1977); inner green cambium layers peeled, dried, and smoked in ceremony.

Cytisus monspessulanus L. Pea Family *(Fabaceae)*
FRENCH BROOM *(fig. 46).* Shrub to 3 m tall, more or less

Figure 46—French broom, *Cytisus monspessulanus.*

Figure 47—Bush poppy (tree poppy), *Dendromecon rigida* (McMinn 1939).

drought deciduous, angled branches, young branches covered with mat of soft hairs; leaves compound, alternate, tend to be drought deciduous, 3-parted, crowded on stems, leaflets 0.8 to 2 cm long, 2 to 7 mm wide, petioles very short, leaflets tend to be obovate and nearly bald above and pubescent below; flowers, March to June, bright yellow, 1 to 2 cm long, more or less dense racemes; fruit, hairy pod to 2.5 cm long.
Distribution: Exotic from Canary Islands; planted along highways, naturalized near coast, mostly below 150 m (500 ft); Ventura and Los Angeles Counties, north to Washington.
Fire Response Mechanism: Unknown, probably resprouts.
Wildlife Value: Unknown.
Cultural Value: Introduced species.

Dendromecon rigida Benth. Poppy Family *(Papaveraceae)*
BUSH POPPY (TREE POPPY) *(fig. 47).* Rounded evergreen shrub, 1 to 3 m, sometimes 6 m tall, young branchlets with whitish shredding bark becoming dark gray; leaves, somewhat rough, coriacious feel, leaves alternate, thick and leathery, lanceolate, 2.5 to 10 cm long, 7 to 25 mm wide, minutely serrate to entire, vertical to axis of stems, somewhat glaucous gray to yellowish green and darker above; flowers, April to July, 2 to 5 cm across, yellow, showy with rounded petals, 2 to 3 cm long; fruit, linear pod 5 to 10 cm long.
Distribution: Dry chaparral slopes below 1500 m (5000 ft); coast ranges, Sonoma County to Baja California, west base of Sierra Nevada.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Staple browse; seeds preferred by small birds, animals.
Cultural Value: Fruits, numb gums of teething babies.

Encelia californica Nutt. Sunflower Family *(Asteraceae)*
CALIFORNIA ENCELIA *(fig. 48).* Rounded subshrub, more or less drought deciduous, 0.6 to 1.2 m tall, young stems densely pubescent to tomentose; leaves alternate, yellowish green darker above, ovate to lanceolate, some leaves may have irregular serrations on margins, surfaces with short hairs, tend to be 3-veined at or near base, veins becoming parallel with leaf margins, 2 to 7 cm long, 1.5 to 3.5 cm wide, petiole 5 to 20 mm long; flowers, February to July, solitary heads, yellow rays 1.5 to 3 cm long, purple center; fruit, akene.
Distribution: Coastal bluffs, low hills below 600 m (2000 ft); coastal sage scrub (soft chaparral), chamise, etc.; Santa Barbara County to Baja California, inland to west Riverside and San Bernardino Counties.
Fire Response Mechanism: Variable root-sprouters after fire, cutting.
Wildlife Value: Low value.
Cultural Value: None known.

E. farinosa Gray.
BRITTLEBUSH (INCIENSO) *(fig. 49).* Roundish subshrub, 0.3 to 1.5 m tall, more or less drought deciduous, brittle stems arising from brown to gray linear furrowed, woody trunk,

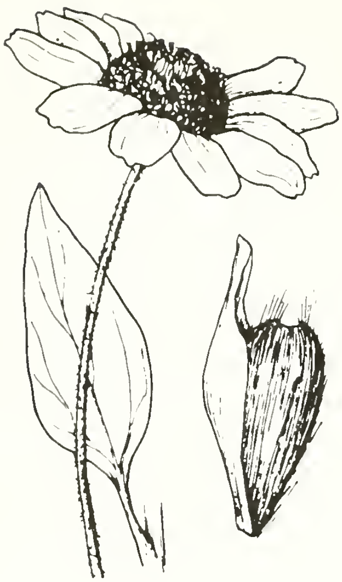


Figure 48—California encelia, *Encelia californica* (McMinn 1939).

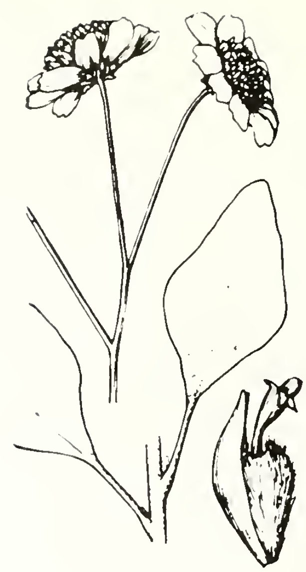


Figure 49—Brittlebush (incienso), *Encelia farinosa* (McMinn 1939).

branches very leafy at ends, young stems may be tomentose; leaves broadly ovate to lanceolate, rounded or obtuse at apex, tapering to petiole at base, leaf entire or wavy margined, 3-veined from base, silvery-white and felty, 2 to 8 cm long, 1 to 4 cm wide, petiole very short, to 2 cm long; flowers, March to May, on yellowish green stalks protruding much beyond leaves, stalks branched, bear several sunflowers; heads 1 to 1.5 cm across (excluding rays), 4 to 7 mm high, rays showy, 8 to 12 mm long, yellow or orange, 8 to 18 in number falling early; fruit, akene.

Distribution: Inland counterpart of California encelia *(E. californica)* below about 1200 m (4000 ft), common in deserts and arid parts of western San Bernardino, Riverside, and San Diego Counties to Mexico.

Fire Response Mechanism: Poor root-sprouter. Seeds into available burned over areas.

Wildlife Value: Seeds eaten by birds, rodents.

Cultural Value: Exudate used as incense in churches in Baja California (McMinn 1939).

Ephedra spp. *Ephedra* Family *(Ephedraceae)*

1a. Leaf scales in twos; stems bright yellow green; shrub, western edge of deserts in pinyon-juniper and creosote bush between 900 and 2300 m.
GREEN EPHEDRA, *E. viridis*

1b. Leaf scales in threes; stems green brown; desert shrub on dry slopes in creosote bush, sage scrub and grassland below 1100 m. MORMON-TEA, *E. californica*

E. californica Wats.

MORMON-TEA *(fig. 50).* Low, spreading or suberect shrub, 0.3 to 1 m tall, jointed semiflexible to rigid, straight branches, 3 to 4 mm thick, 3 to 6 cm long between green brown joints, branching at joints into several smaller branchlets 2 to 4 mm thick; leaf scales in threes at joints, mostly less than 6 mm long, about 2 mm wide at base narrowing to point, leaves overlapping to encompass stem; most leaves are on vegetative branchlets that arise from branches also with floral and fruiting branchlets, vegetative branchlets smaller (approximately one-half) than main branches, and elongated from overlapping leaves to several centimeters between leaves; flowers, February to May, dioecious; fruit, small cone, 6 to 10 mm long, 3 to 6 mm thick, somewhat 4-angled, abruptly pointed at apex, 1 to several at node. McMinn (1939) considered flowering and fruiting bodies to be in catkins; Munz (1974) calls them cones. They certainly appear to be more like small cones.

Distribution: Dry slopes and fans below 1100 m (3600 ft); creosotebush, sage scrub (soft chaparral), grassland; both deserts, San Diego County to Merced County, Baja California.

Fire Response Mechanism: Nonsprouter.

Wildlife Value: Used in emergency, not preferred by wildlife.

Cultural Value: Tea used by Native Americans and early settlers; tonic for kidney problems, purify blood, and for colds and stomach disorders. Dried stems ground or

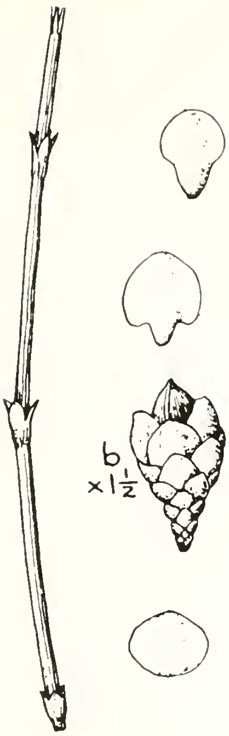


Figure 50—Mormon-tea, *Ephedra californica* (McMinn 1939).

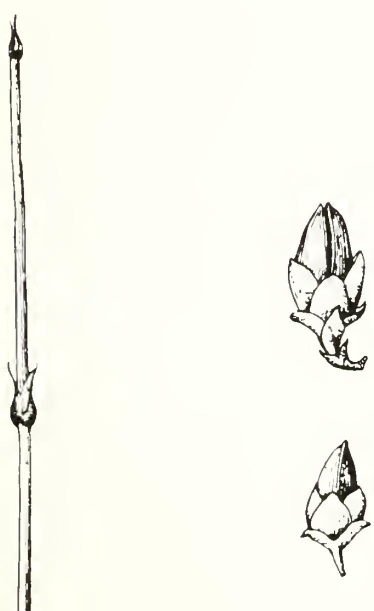


Figure 51—Green ephedra, *Ephedra viridis* (McMinn 1939).

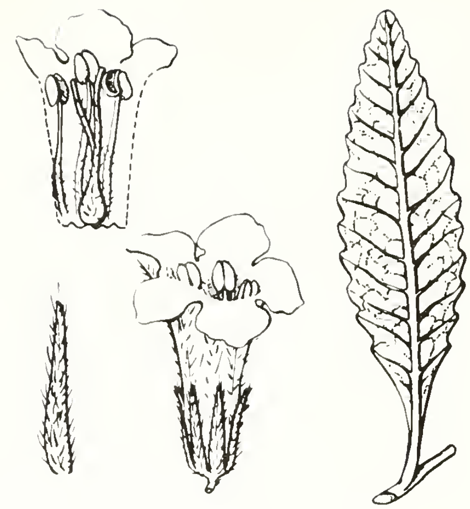


Figure 52—Thickleaf yerba santa, *Eriodictyon crassifolium* (McMinn 1939).

mixed with pinyon pine resin and used on open sores. Powder made into a poultice for burns (Balls 1972).

E. viridis Cov.
GREEN EPHEDRA *(fig. 51).* Erect shrub, 0.5 to 1.5 m tall, numerous broom-like yellow green branchlets 1 to 2 mm thick becoming thicker with gray shreddy bark, several branchlets arising from swollen nodes at 2 to 5 cm intervals; leaves on vegetative branchlets, opposite in twos, tips falling away from brown bases, leaves may be inverted at base, 3 to 10 mm long; flowers, March to May, dioecious; fruiting cones sometimes 1 or 3, usually 2 at a node, 5 to 8 mm long.
Distribution: Frequent on dry rocky slopes, canyons, 900 to 2300 m (3000-7500 ft); creosote to pinyon-juniper; western edge of both deserts, western slope of Sierra Nevada to Mono and Lassen Counties, to Colorado, Utah, Arizona.
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Seasonally important for bighorn sheep. New growth eaten in May, June, July. Used by livestock.
Cultural Value: Same as Mormon-tea *(E. californica).*

Eriodictyon crassifolium Benth.
(Hydrophyllaceae) Waterleaf Family
THICKLEAF YERBA SANTA *(fig. 52).* Evergreen shrub, 1 to 3 m tall, twigs leafy toward upper ends, young stems grayish green becoming brown; leaves and twigs densely woolly; alternate clusters, leaves of several sizes

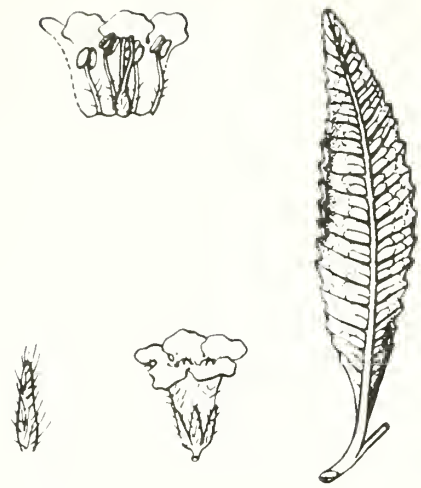


Figure 53—Yerba santa, *Eriodictyon trichocalyx* (McMinn 1939).

Figure 54—California buckwheat, *Eriogonum fasciculatum* (McMinn 1939).

in many clusters lance-ovate to elliptic, 3 to 10 cm long, 1 to 3.5 cm wide, gray green, darker above, rounded serration on edges, short petioled; flowers, April to August, pale lavender, in scorpioid woolly raceme, funnel-shaped, 10 to 15 mm long; fruit, hairy capsule, 2 to 3 mm long. Var. *denudatum* Abrams. appears much like *E. trichocalyx*, but occurs in Santa Barbara and Ventura Counties. Trask Yerba Santa (*E. traskiae* Eastw.), common woolly species in Santa Ynez Range and north to San Luis Obispo County.

Distribution: Gravelly, rocky places, below 1800 m (6000 ft); manzanita, ceanothus, pinyon-juniper, communities; Santa Monica, San Gabriel Mountains to western edge of Colorado Desert, San Jacinto, and Santa Rosa Mountains.

Fire Response Mechanism: Root-sprouts from lateral shoots after fire, cutting.

Wildlife Value: Low value.

Cultural Value: Leaves boiled into tea for cough, colds, sore throat, tuberculosis, rheumatism; liniment to reduce fever. Poultice of pounded fresh leaves bound to sores on people and animals (Balls 1972).

E. trichocalyx Heller.

YERBA SANTA *(fig. 53).* More or less aromatic, evergreen shrub, 0.5 to 2 m tall, very glutinous, resinous branchlets, some young stems may be hairy to woolly, angular, green becoming greenish brown then dark brown; leaves alternate with smaller leaves in leaf axils, lanceolate, tapering to both ends, 5 to 15 cm long, 1 to 3.5 cm wide, hairless, glutinous, darker above, grayish or gray green below prominently veined, margins dentate, sometimes slightly curled under at edges; flowers, May to August, dense, pale purple to white clusters, coiled like fiddle neck, 5 to 8 mm long, coils hairy-bristly; fruit, bristly capsule, 2 to 3 mm long.

Distribution: Dry slopes, fans, disturbed places, roadsides, below 2400 m (8000 ft); chaparral, yellow pine, pinyon-juniper, Joshua tree communities; Ventura County through San Gabriel, San Bernardino Mountains, east of Santa Rosa Mountains.

Fire Response Mechanism: Sprouts from lateral roots after fire, cutting.

Wildlife Value: Low value.

Cultural Value: Same as thick leaf Yerba Santa *(E. crassifolium).*

Eriogonum fasciculatum Benth.

Buckwheat Family *(Polygonaceae)*

CALIFORNIA BUCKWHEAT *(fig. 54).* Low spreading evergreen shrub to 1 m tall, branches flexible, bark reddish brown, thin and shredding; leaves simple, oblong-linear to lanceolate or oblanceolate, revolute, evergreen, alternate bundles (fascicles), 6 to 20 mm long, 2 to 5 mm wide, margins entire, green above, whitish below, somewhat pubescent above to nearly villous below; flowers, May to October, dense white or pinkish clusters, turn red brown with age; fruit, shiny akene about 2 mm long.

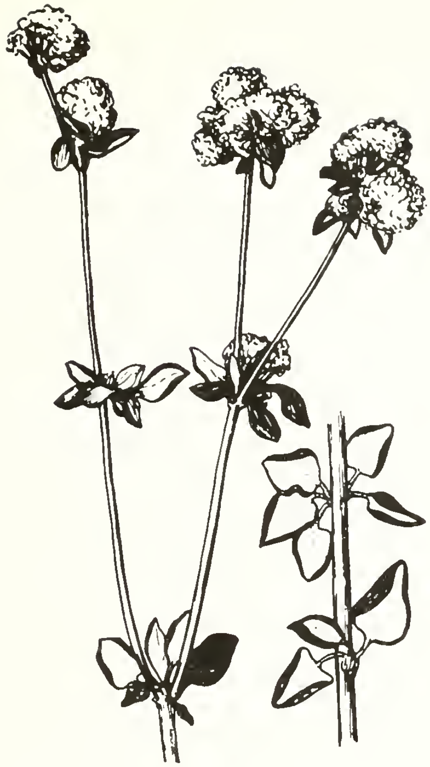


Figure 55—Seacliff buckwheat, *Eriogonum parvifolium* (McMinn 1939).

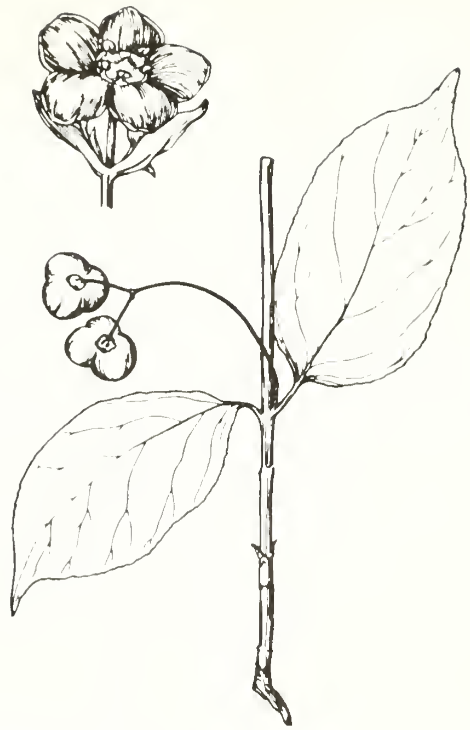


Figure 56—Burning bush, *Euonymous occidentalis* ssp. *parishii* (McMinn 1939).

Distribution: Common on slopes, mesas; Santa Clara County south to Baja California; in many plant communities. Munz (1974) recognizes four subspecies in different plant communities from immediate coast to 2100 m (7000 ft).
Fire Response Mechanism: Seedling response to fire; nonsprouter or rarely from underground shoots.
Wildlife Value: Low value browse and seed.
Cultural Value: Green young shoots edible. Leaves boiled to make potion for headache and stomach ailments. White flowers steeped for use as eyewash (Sweet 1962).

E. parvifolium Smith
SEACLIFF BUCKWHEAT *(fig. 55).* Evergreen spreading shrub or branches lying on ground, 10 to 12 cm tall, bark becomes shreddy with age; leaves simple in alternate bundles, somewhat deltoid to orbicular or nearly obovate in outline, 5 to 15 mm long, 3 to 12 mm wide, petiole 2 to 4 mm long, green and hairless above, white and fuzzy below, margins rolled under at edges; flowers, May to December, tiny white dense clusters; fruit, akene to 2.5 mm long.
Distribution: Coastal bluffs below 150 m (500 ft); coastal scrub (soft chaparral); Monterey to San Diego County.
Fire Response Mechanism: Deep taproot and lateral roots spread to three times area of aboveground parts.
Wildlife Value: Low value except flowers for insects (bees); seeds for insects, birds, small animals.
Cultural Value: None known, probably same as California buckwheat *(E. fasciculatum).*

Euonymus occidentalis Nutt. ssp. *parishii* (Trel.) Jeps.
Staff-tree Family *(Celastraceae)*

BURNING BUSH *(fig. 56).* Deciduous shrub or tree-like, 2 to 6 cm tall, straggling branches, bark gray or whitish; leaves thin and flexible, opposite, elliptic or ovate, rounded at apex, minutely serrate, darker above, 3 to 12.5 cm long, 2 to 6 cm wide, petiole 5 to 15 mm long; flowers, May to July, brownish purple with tiny dots, five petals, 1 to 7 clusters; fruit, capsule 4 to 7 mm across.
Distribution: Infrequent, moist canyon bottoms, 300 to 2000 m (1000-6500 ft); ponderosa and Jeffrey pine communities; San Jacinto Mountains, south to Palomar, Cuyamaca Mountains.
Fire Response Mechanism: Information not available.
Wildlife Value: Not significant.
Cultural Value: Unknown.

Eurotia lanata (Pursh) Moq.
Goosefoot Family *(Chenopodiaceae)*
WINTER FAT *(fig. 57).* This species recently renamed *Ceratoides lanata* (Pursh) Howell, *Eurotia* retained here to be in accord with Munz (1974). Erect or spreading, usually monoecious shrub, 0.3 to 0.8 m tall, hairy (lanate) on young stems and leaves, white or rusty star-shaped hairs intermingled with unbranched straight hairs; young twigs light brown to reddish brown become grayish with age; leaves alternate, sessile, commonly in fasciles (bundled) or often borne singly, linear

Figure 57—Winter fat, *Eurotia lanata* (McMinn 1939); renamed *Ceratoides lanata*.

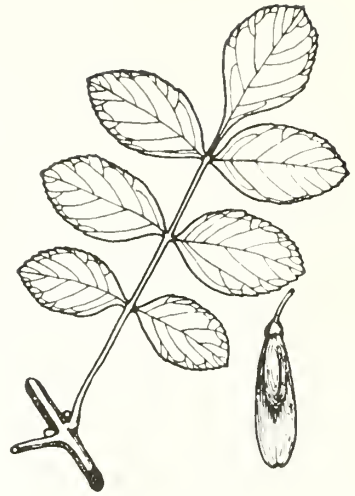


Figure 58—Flowering ash (foothill ash), *Fraxinus dipetala* (McMinn 1939).

or oblong, 1.5 to 5 cm long, 2 to 8 mm wide, fascicled leaves shorter, leaves mostly rust colored to most often dull green and more or less darker above; flowers, March to August, unisexual, female flowers have pair of bracts from which the two styles emerge; fruit, bladder-like sacs enclose seeds, two short horns above, strikingly dense spreading tufts of long silky rust-colored hairs.
Distribution: Flats and rocky mesas above 600 m (2000 ft); creosotebush to pinyon-juniper woodlands; Lassen and Inyo Counties, Mojave Desert, eastern slope of inner Coast Range, San Bernardino Mountains, south to Mexico, east to Nebraska.
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Staple browse for livestock, burros, etc.
Cultural Value: None known.

Fraxinus dipetala H. & A. Olive Family *(Oleaceae)*
FLOWERING ASH (FOOTHILL ASH) *(fig. 58).* Deciduous shrub or small tree, 2 to 7 m tall, erect, 4-angled branchlets with reddish brown to gray bark, young stems usually pubescent; leaves 4 to 12 cm long, divided into 3 to 9 leaflets, glabrous to somewhat pubescent, darker green above, oblong-ovate, serrate, 2 to 4 cm long, 0.5 to 2.5 cm wide; flowers, March and April, numerous blossoms with two white petals, 5 mm long in compound clusters; fruit, samara, 2 to 3 cm long, 7 to 9 mm wide, winged along sides, crowded clusters.
Distribution: Dry slopes and creek bottoms, below 1100 m (3500 ft); chaparral and riparian communities; Siskiyou County south, Sierra Nevada foothills from Shasta County, south to Los Angeles County, rare in San Diego County.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Staple browse for deer.
Cultural Value: None known.

Fremontodendron californicum A. Davids.
Cacao Family *(Sterculiaceae)*
FLANNEL BUSH *(fig. 59).* Loosely branched shrub or small tree, 1.5 to 4 m, evergreen but somewhat drought deciduous; leaves usually palmate or round in outline to elliptic, elliptic-ovate, more or less 3-lobed, dark green above, pubescent above to densely pubescent yellowish below, leaves 1 to 2 cm long, 1 to 2 cm wide, petioles 1 to 5 cm long; flowers, April to July, bright yellow, showy, 2.5 to 4 cm broad; fruit, round bristly capsule 2.5 to 3.5 cm long.
Distribution: Granitic slopes, 900 to 1800 m (3000-6000 ft); ceanothus and manzanita to scrub oak chaparral, yellow pine, pinyon-juniper communities; San Diego County north to Shasta and Kern Counties.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Staple browse for deer, livestock, goats.
Cultural Value: Inner bark used as demulcent for poultices to raw membranes (Sweet 1962).

Garrya veatchii Kell. Silktassel Family *(Garryaceae)*
SILKTASSEL *(fig. 60).* Erect evergreen dioecious shrub, 1 to 2 m tall, usually with white-woolly twigs, young stems green-

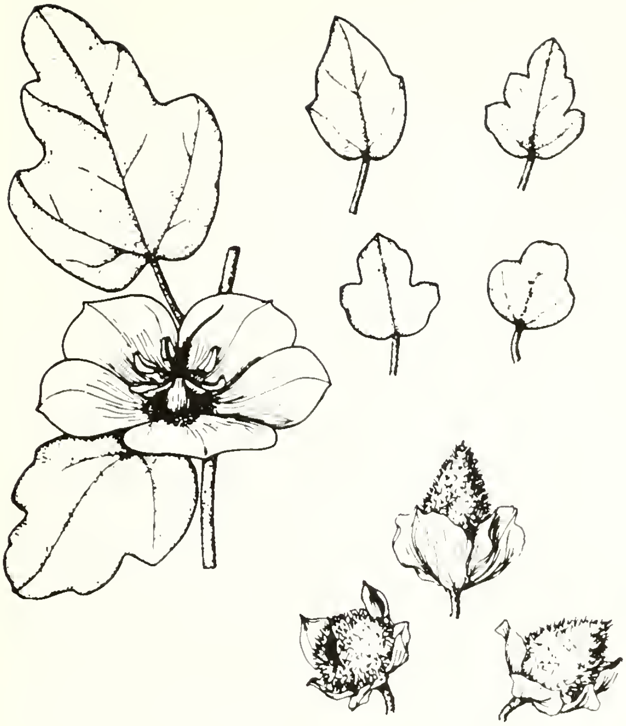


Figure 59—Flannel bush, *Fremontodendron californicum* (McMinn 1939).

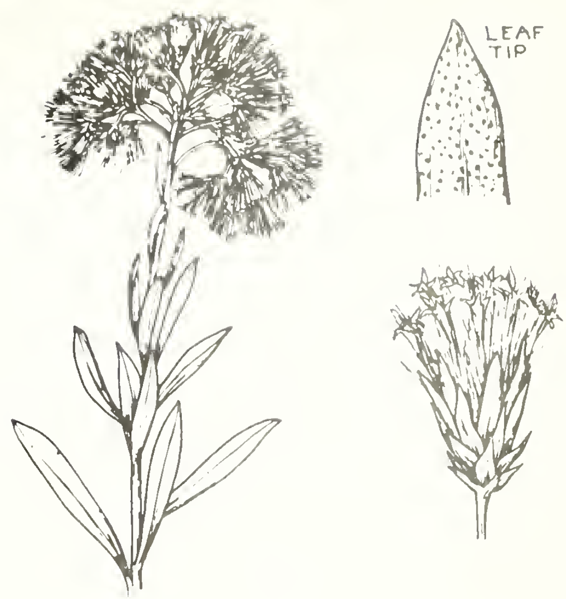


Figure 61—Goldenbush, *Haplopappus parishii* (McMinn 1939).

Figure 60—Silktassel, *Garrya veatchii* (McMinn 1939).

ish becoming dark brown; leaves simple, opposite, leathery, lanceolate to ovate, 2.5 to 6.5 cm long, 1.0 to 3.3 cm wide, petioles 4 to 10 mm long, leaves green and hairless to pubescent above, dense hairs give felty feeling beneath, plane or slightly wavy margined tending to roll downward; flowers, March through May, 2 to 4 dangling strings or "catkins" per cluster, staminate (male) clusters 5 to 10 cm long and pistillate (female) clusters 2.5 to 6 cm long; fruit, ovoid or rounded berry 7 to 8 mm across, buff to reddish brown and pubescent.
Distribution: Dry slopes below 2100 m (7000 ft); manzanita, redshank and other chaparral communities; San Luis Obispo County south to Baja California, San Jacinto, San Bernardino (Cajon Pass), and San Gabriel Mountains.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Staple browse plant.
Cultural Value: Bark, leaves, and fruit contain the alkaloid garryine, used as tonic whose bitter taste gives rise to some species called quinine bush (McMinn 1939).

Haplopappus parishii (Greene) Blake.
Sunflower Family *(Asteraceae)*
GOLDENBUSH *(fig. 61).* Erect, branched shrub, 2 to 4 m tall, young stems green turning yellow at inflorescence to brown to gray below, branches hairless, resinous, with numerous glands; mature sessile leaves usually with shorter leaves in fascicle or bundle, alternate, simple, entire, more glandular than stems, linear to oblanceolate or elliptic, 2 to 6 cm long, 3 to 10 mm wide, flat, thick or leathery; flowers, July

Figure 62—Pine goldenbush, *Haplopappus pinifolius* (McMinn 1939).

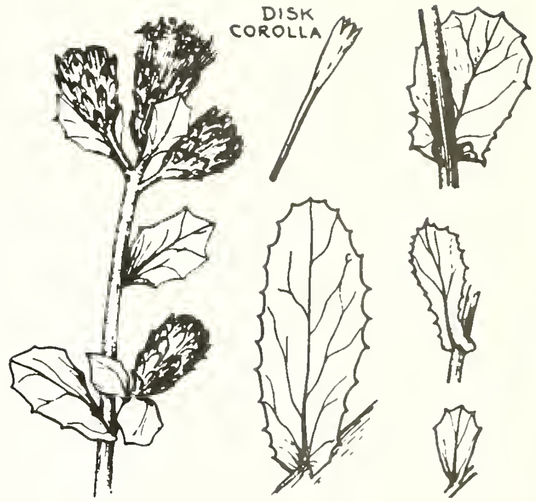


Figure 63—Sawtooth goldenbush, *Haplopappus squarrosus* (McMinn 1939).

through October, yellow, all tube flowers in compact clusters of several heads, each head 5+ mm high, subtended by four series of scale-like bracts; fruit, akene.
Distribution: Locally frequent on dry, south-facing slopes or outwash fans and other disturbance areas at 500 to 2100 m (1500-7000 ft); chaparral; San Gabriel, San Bernardino, San Jacinto, Santa Ana Mountains, through San Diego County to Baja California.
Fire Response Mechanism: Fire resistant foliage; nonsprouting, may set seed in first or second year following fire.
Wildlife Value: Low value.
Cultural Value: Unknown.

H. pinifolius Gray
PINE GOLDENBUSH *(fig. 62).* Shrub 0.5 to 2.5 m tall, main stem trunk-like; parallel erect branches, young stems yellowish green, resinous, often glandular-punctate, older branches becoming brown. Stems densely leafy, short and long leaves in a fascicle (bundle); leaves glandular pitted, linear to filiform, 1 to 4 cm long, about 1 mm wide, resinous, sticky, lemony smell; flowers, May through November, heads in dense or few-headed clusters, 5 to 10 or more yellow rays and many tube flowers; fruit, akene.
Distribution: Washes, dry slopes, 200 to 1600 m (500-5400 ft); sage scrub (soft chaparral), scrub oak, chamise chaparral; San Gabriel, San Bernardino, San Jacinto, and Laguna Mountains.
Fire Response Mechanism: Seedling response after fire.
Wildlife Value: Low value.
Cultural Value: Unknown.

H. squarrosus H. & A.
SAWTOOTH GOLDENBUSH *(fig. 63).* Low, erect subshrub, to 1 m tall, young stems light brown with persistent leaves, brown with age, bark becomes flaky; leaves, green, somewhat darker above, sharply serrated margins, somewhat rounded at tips, bases clasp slightly roughish pubescent stems, resinous, somewhat glandular oblanceolate to obovate, 1.5 to 4 cm long, 1 to 2 cm wide; flowers, September through October, yellow tube-flower heads with brownish-red hairs in spike-like raceme; fruit, akene. Subspecies *grindelioides* (DC.) Keck. most common representative in southern California.
Distribution: Common subshrub, open hills below 1400 m (4500 ft); coastal sage scrub (soft chaparral) chamise chaparral; Monterey and Santa Barbara Counties south to Baja California, and west San Bernardino County.
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Low value.
Cultural Value: Unknown.

Heteromeles arbutifolia M. Roem. Rose Family *(Rosaceae)*
TOYON (CHRISTMASBERRY) *(fig. 64).* Evergreen shrub or small tree, 2 to 10 m tall, freely branched, reddish to gray bark, young branchlets reddish green to green, sometimes pubescent; leaves elliptic-oblong, 3 to 11 cm long, 2 to 5 cm wide, petiole 1 to 2.5 cm long, leaves may have ligules, taper-

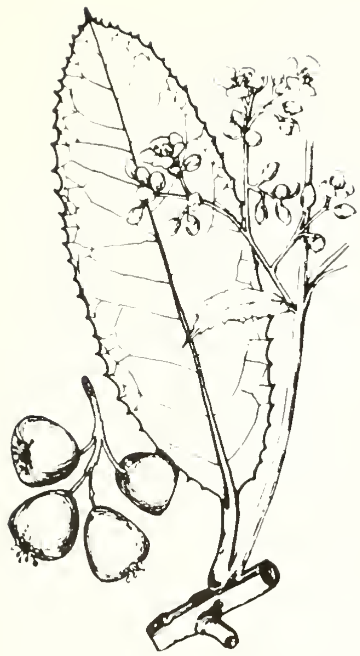


Figure 64—Toyon (Christmasberry) *Heteromeles arbutifolia* (McMinn 1939).

Figure 65—Creambush, *Holodiscus discolor.*

ing at both ends, rather sharply toothed margins, midvein prominent especially below, leathery, flat to somewhat convex, dark green above, lighter below, leaf surfaces sometimes pubescent; flowers, May through August, small white blooms, terminal clusters with five petals, 4 mm long; fruit, dry red berry 5 to 6 mm long, most prominent in December, present September through January.
Distribution: Brushy slopes, mostly below 1200 m (4000 ft); chaparral to live oak woodland; mountains of southern California to Humboldt, Shasta Counties.
Fire Response Mechanism: Vigorous crown- or stump-sprouter after fire, cutting.
Wildlife Value: Low value or staple browse; fruits preferred food of birds, small mammals.
Cultural Value: Berries cooked slightly to remove bitterness and eaten. Some Native Americans made a tea to cure aches and pains (Balls 1972). Channel Island fishermen used bark for tanning fish nets (Sweet 1962).

Holodiscus discolor (Pursh.) Maxim.
Rose Family *(Rosaceae)*
CREAMBUSH *(fig. 65).* Deciduous spreading shrub, 1.0 to 6 m tall, young stems pubescent and brownish, become ashy gray with shreddy bark; leaves alternate, ovate in outline, dentate with 3 to 7 teeth each side, 4 to 9 cm long (rarely 2 to 3 cm long), 3 to 4 cm wide, petiole to 1 cm long, pubescent to villous above and villous-tomentose below, green, often with impressed veins on upper surface, lighter green to white-fuzzy, often with prominent veins below; flowers, June through August, creamy white, dense branched clusters, 5-petaled, 2 mm long; fruit, akene.
Distribution: Moist woody slopes below 1400 m (4500 ft); Los Angeles and Orange Counties, north to British Columbia, and Rocky Mountains.
Fire Response Mechanism: Early successional after fire.
Wildlife Value: Low value browse for livestock, deer.
Cultural Value: Fruits edible.

Isomeris arborea Nutt. Caper Family *(Capparidaceae)*
BLADDERPOD *(fig. 66).* This species renamed *Cleome isomeris* Greene. *Isomeris arborea* retained to be consistent with Munz 1974. Erect, rounded evergreen shrub, 0.5 to 1.5 m tall, young branchlets pubescent, greenish becoming light brown to gray; leaves sometimes pubescent above and below, gray green, 3-parted or simple below flowers; leaflets oblong or lance shaped, 1 to 4.5 cm long, 3 to 10 mm wide, ill-scented when crushed; flowers, February through May, yellow blossoms, two lower petals more spreading than two upper; fruit, inflated pod, 2.5 to 5 cm long, 1 to 1.5 cm thick.
Distribution: Desert and coastal bluffs and dunes, subsaline places 1200 m (4000 ft); coastal sage scrub (soft chaparral), creosotebush, etc.; near coast, San Diego to Santa Barbara Counties (Monterey), south to Mexico; species also found in Mojave and Colorado Deserts.
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Low value.
Cultural Value: Green pods edible and spicy.

Figure 66—Bladderpod, *Isomeris arborea* (McMinn 1939); renamed *Cleome isomeris.*

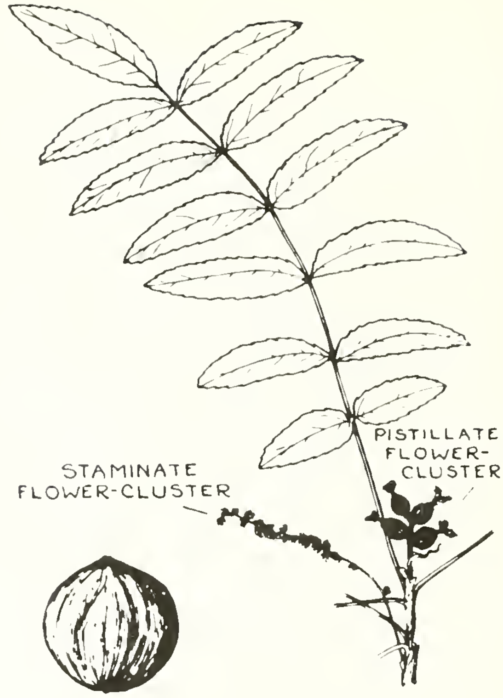


Figure 67—California black walnut, *Juglans californica* (McMinn 1939).

Juglans californica Wats. Walnut Family *(Juglandaceae)*
CALIFORNIA BLACK WALNUT *(fig. 67).* Small monoecious, deciduous tree or large shrub, usually with several trunks from or near the ground, 3 to 10 m tall, young stems brownish, pubescent becoming dark brown to gray; leaves alternate, pinnate-compound, 15 to 25 cm long, 9 to 19 elliptic to oblong or lanceolate leaflets, base of each somewhat wedge-shaped or rounded, serrated, 3.0 to 7.5 cm (sometimes 11 cm) long, 1 to 3 cm (sometimes 5.5 cm) wide; flowers, March through May, male flowers in catkins 5 to 8 cm long, arise from 1-year-old twigs, female flowers on peduncles arise from end of current year twigs; fruit, walnut enclosed in dark brown husk.
Distribution: Locally common in oak woodlands below 1400 m (4500 ft); Santa Barbara to Orange Counties, to west San Bernardino County.
Fire Response Mechanism: Stump sprouts after fire, cutting.
Wildlife Value: Staple browse for mule deer; fruits preferred by squirrels.
Cultural Value: Nuts edible. Clarke (1977) indicates Cahuilla Indians used hulls for dye in basket making.

Juniperus spp. Cypress Family *(Cupressaceae)*

1a. Leaves with glandular pits on the back; shrub or small tree in pinyon-juniper and Joshua tree communities below 1500 m on desert slopes.
CALIFORNIA JUNIPER, *J. californica*

1b. Leaves without glandular pits; shrub or small tree on dry desert mountains and flats, east Mojave Desert between 1500 and 2600 m. UTAH JUNIPER, *J. osteosperma*

J. californica Carr.
CALIFORNIA JUNIPER *(fig. 68).* Shrub or small tree, usually dioecious, much branched, several codominant main branches from base, 1 to 4 m tall, young stems green becoming brown as with Utah juniper *(J. osteosperma),* bark ashy grey or reddish, shreddy; leaves scale-like, usually in whorls of three around branchlet, sometimes in twos opposite, 2 to 4 mm long, bluntly pointed at apex, usually with conspicuous glandular-pitting on back; male cones minute in leaf axils; fruit, berry-like cone, bluish white, turn red brown, oblong-ovoid, 12 to 18 mm long.
Distribution: Dry slopes, flats below 1500 m (5000 ft); pinyon-juniper, Joshua tree communities; desert slopes, Colorado Desert north to Kern, Santa Barbara, and Los Angeles Counties.
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Low value browse, fruits.
Cultural Value: See Utah juniper *(J. osteosperma).*

J. osteosperma (Torr.) Little
UTAH JUNIPER, *(fig. 69).* Large evergreen shrub or small tree, usually dioeceous, 1 to 2 m tall, bushy habit; young stems with leaf scales become brown with age as leaf scales drop; bark grayish, flaky small barbs at branchlet scars; leaves mostly opposite in scale-like pairs, sometimes in whorls of

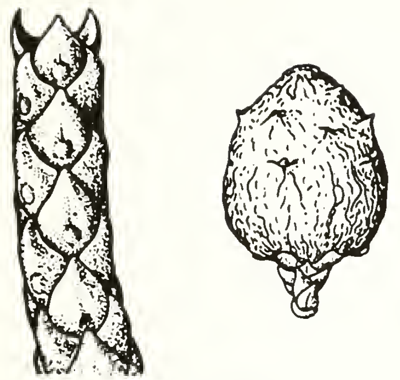


Figure 68—California juniper, *Juniperus californica*.

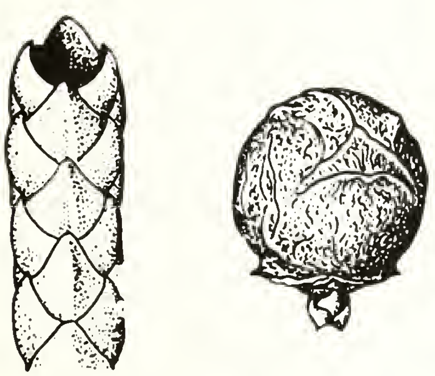


Figure 69—Utah juniper, *Juniperus osteosperma*.

Figure 70—Bush penstemon, *Keckiella antirrhinoides* (McMinn 1939).

three, 2 to 4 mm long, without glands; male cones, minute in leaf axils; fruit, round berry-like cone, 6 to 9 mm diameter, reddish brown under white film.

Distribution: Dry slopes, flats 1500 to 2600 m (4800-8500 ft); pinyon-juniper; mountains of east Mojave Desert, to Mono County, southwest Idaho. Also on east-facing desert slopes of San Bernardino Mountains.

Fire Response Mechanism: Nonsprouter.

Wildlife Value: Low value browse, fruit.

Cultural Value: Berries eaten fresh or sun-dried and ground into flour and made into beverage. Bark used as medicine and red dye made from ashes (Clarke 1977).

Keckiella antirrhinoides (Benth.) Straw
Figwort Family *(Scrophulariaceae)*

BUSH PENSTEMON *(fig. 70).* Evergreen shrub, 1 to 2.5 m tall, spreading, much-branched stems; leaves opposite, entire, linear- to ovate-elliptic, 0.5 to 2 cm long, 2 to 7 mm wide, firm, crowded, leaf surfaces glabrous to somewhat pubescent; flowers, April through June, yellow blooms tinged with brownish red, 16 to 20 mm long, irregularly lobed, snapdragon-like; fruit, capsule containing many seeds.

Distribution: Dry rocky slopes, below 1400 m (4500 ft); coastal sage scrub (soft chaparral); San Bernardino, Santa Barbara Counties, south Baja California.

Fire Response Mechanism: Information not available.

Wildlife Value: Low value.

Figure 71—Straggly penstemon, *Keckiella cordifolius* (McMinn 1939).

Figure 72—Whorl-leaf penstemon, *Keckiella ternata* (McMinn 1939).

Cultural Value: Bush penstemon (*Keckiella* spp.) probably used like penstemon (*Penstemon* spp.) as wash and poultice for running sores and burns and for floral decorations and ceremonies (Sweet 1962).

K. cordifolius (Benth.) Straw
STRAGGLY PENSTEMON *(fig. 71)*. Sprawling shrub, 1 to 3 m tall, commonly with scrambling, long, straggly brown stems, or bushy; leaves opposite, at least some leaves with serrated margins dark green, shiny, glabrous to pubescent, lighter below, ovate or roundish, cordate (heart-shaped base) with prominent veins below, 1.5 to 5 cm long, 1 to 3 cm wide; flowers, May through July, red or scarlet, 30 to 40 mm long, tubular, terminal racemes; fruit, many-seeded capsule.
Distribution: Dry slopes, below 1200 m (4000 ft) in live oak woodlands, manzanita and chamise chaparral; San Luis Obispo County, south to San Gabriel, San Bernardino, San Jacinto Mountains, to Baja California.
Fire Response Mechanism: Stump-sprouts.
Wildlife Value: Low value.
Cultural Value: See bush penstemon *(K. antirrhinoides)*.

K. ternata (Torr.) Straw
WHORL-LEAF PENSTEMON *(fig. 72)*. Straggly evergreen subshrub, 0.5 to 1.5 m tall, rather straight wand-like stems from woody base, white-filmy; bluntly serrated leaves in whorls of three, occasionally two, lance-shaped or somewhat linear, often folded upwards along midvein, 2 to 5 cm long, 2 to 11 mm wide; flowers, June to September, scarlet blooms, 23 to 30 mm long, tubular; fruit, many-seeded capsule.
Distribution: Dry slopes below 1800 m (6000 ft); ponderosa and Jeffrey pine woodlands, black oak woodlands, manzanita chaparral; San Gabriel, San Bernardino Mountains, to San Diego County.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Low value browse.
Cultural Value: See bush penstemon *(K. antirrhinoides)*.

Lepechinia calycina (Benth.) Epl. Mint Family *(Lamiaceae)*
PITCHER-SAGE *(fig. 73)*. Erect, small subshrub, to 12 cm tall, considerable stem pubescense (sometimes woolly), at least young stems square; leaves simple, opposite, aromatic, more or less prominent veins, 4 to 12 cm long, 2 to 3 cm wide, petioles 5 to 20 mm long, leaves usually approximately lanceolate to obtuse or oblong, glabrous or scattered pubescense above, more or less hairy or pubescent below; flowers, April through August, 2.5 to 3 cm long, white to pink with purple spots, somewhat prominent veins; fruit, ellipsoid nutlet about 3.5 mm long.
Distribution: Chaparral and woodlands on exposed slopes, below 900 m (3000 ft); Lake County south to Ventura County, *L. fragrans* (Greene) Epl. (leaves tomentose) occasional in Santa Monica, San Gabriel Mountains, Los Angeles County, *L. ganderi* Epl. occurs in San Diego County and looks much like *L. calycina*.
Fire Response Mechanism: Root-sprouts after fire, cutting.

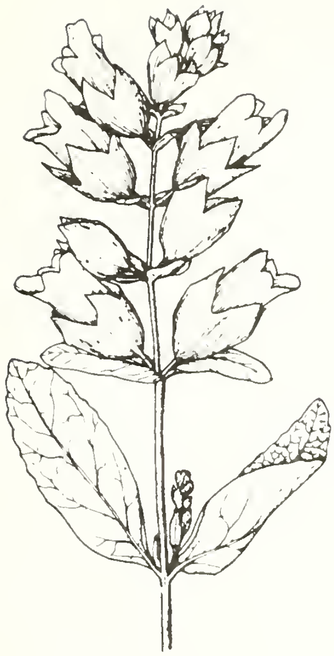


Figure 73—Pitcher-sage, *Lepechinia calycina* (McMinn 1939).

Figure 74—Scalebroom, *Lepidospartum squamatum*.

Wildlife Value: Low value.
Cultural Value: None known.

Lepidospartum squamatum (Gray) Gray
Sunflower Family *(Asteraceae)*

SCALEBROOM *(fig. 74).* Broom-like shrub, 1 to 2 m tall; except for spring shoots, stems and branches usually hairless, green becoming light brown to gray with age; leaves acute, ovate, alternate scales 1 to 2 mm long, sometimes a small tomentose appendage in leaf axils, spring growth may be quite different, including larger leaves (7 to 15 mm long, 2 to 8 mm wide) with fuzzy to tomentose leaf surfaces; flowers, June through December, heads numerous, terminating short lateral branches, bracts of heads papery, overlapping like shingles, flower heads dull white to yellow; fruit, akene.
Distribution: Common in washes, gravelly places, below 1200 m (4000 ft); coastal sage scrub (soft chaparral), chaparral, Joshua tree woodland; Santa Clara, Tulare Counties, south to deserts, and Baja California.
Fire Response Mechanism: Unknown.
Wildlife Value: Low value.
Cultural Value: None known.

Lonicera spp. Honeysuckle Family *(Caprifoliaceae)*

1a. Leaves often joined together in a whorl near branch tips, especially just below flowers or fruits; vine-like shrub, dry slopes between 300 and 1800 m in chaparral, yellow pine. CHAPARRAL HONEYSUCKLE, *L. interrupta*
1b. Leaves all separate to branch tips; vine-like shrub in chaparral below 900 m in Santa Barbara region. SANTA BARBARA HONEYSUCKLE, *L. subspicata*

L. interrupta Benth.
CHAPARRAL HONEYSUCKLE *(fig. 75).* Evergreen bushy vine-like shrub with branches leaning on and growing over other vegetation; branchlets often purplish becoming brown with stringy bark, filmy covered, and hairless; leaves opposite, entire, roundish to elliptic, 1.5 to 7.0 cm long, 1.5 to 5.0 cm wide, green above, white-filmy below, thick and somewhat leathery, uppermost pair often joined at base, forming apparently single leaf through which stem passes; flowers, May to July, whorls of terminal clusters, 3 to 16 cm long, yellowish corolla, funnel-shaped, 10 to 14 mm long; fruit, red berry 5 mm diameter.
Distribution: Dry slopes 300 to 1800 m (1000-6000 ft); chaparral to yellow pine forests; north coast ranges to San Bernardino Mountains. California Honeysuckle (*L. hispidula* Dougl.) with pink purple flowers and glandular-hairy flower stalks also occur with this species.
Fire Response Mechanism: Probably nonsprouter or poor sprouter.
Wildlife Value: Low to moderate value for deer and birds, some use by bees.

Figure 75—Chaparral honeysuckle, *Lonicera interrupta* (McMinn 1939).

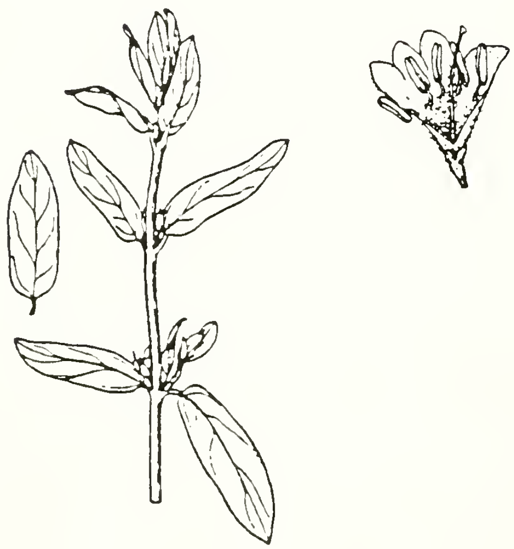


Figure 76—Santa Barbara honeysuckle, *Lonicera subspicata* (McMinn 1939).

Figure 77—Deerweed, *Lotus scoparius* (McMinn 1939).

Cultural Value: Medsger (1966) reported twinberry *(L. involucrata* [Richards.] Banks) berries eaten by Native Americans, no mention made of chaparral honeysuckle or Santa Barbara honeysuckle.

L. subspicata H. & A.
SANTA BARBARA HONEYSUCKLE *(fig. 76).* Clambering, evergreen, vine-like shrub, 1 to 2.5 m tall, thin shredded brown gray bark on older branches; leaves, 1 to 3.5 cm long, 0.5 to 2.5 cm wide; petiole 3 to 4 mm long, narrowly elliptical or linear to oblanceolate, leathery, darker green and hairless above, lighter below and usually pubescent white, fuzzy below; leaf margins may be rolled downward and somewhat serrate; flowers, June to July, pale yellow; fruit, yellowish or red ellipsoid berry, 5 to 7 mm long.
Distribution: In chaparral, mostly below 900 m (3000 ft); Santa Barbara region. Var. *johnstonii* Keck. with somewhat broader leaves grows at higher elevation, to 1500 m (5000 ft).
Fire Response Mechanism: Early postfire successional; nonsprouter.
Wildlife Value: Preferred browse for deer, livestock, goats; especially after burns.
Cultural Value: See chaparral honeysuckle *(L. interrupta).*

Lotus scoparius (Nutt.) Ottley Pea Family *(Fabaceae)*
DEERWEED *(fig. 77).* Spreading, more or less drought deciduous subshrub 0.5 to 1.2 m tall, long slender green branches become brown with age; leaves 3-foliate with gland

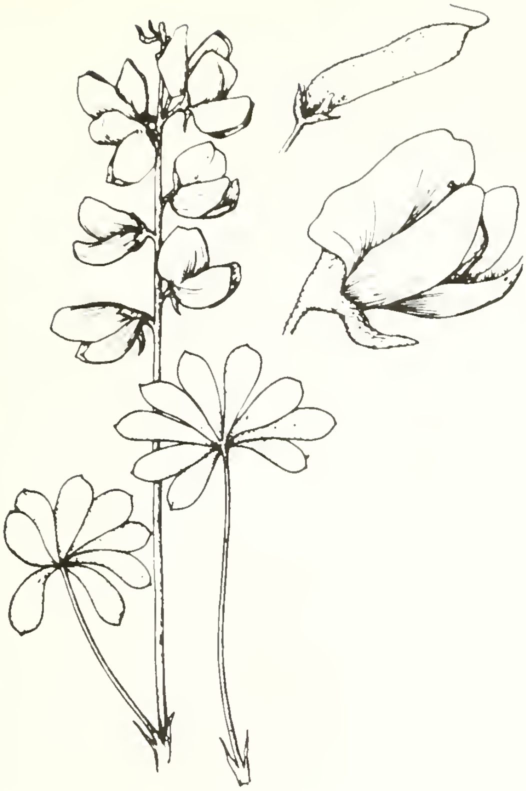


Figure 78—Silver lupine, *Lupinus albifrons* (McMinn 1939).

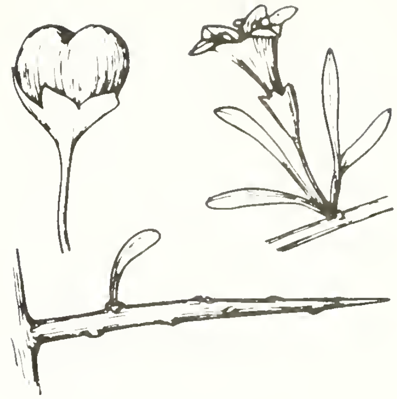


Figure 79—Box-thorn, *Lycium californicum* (McMinn 1939).

like stipules at base of leaf, leaflets entire, lance- to oblanceolate-shaped, 3 to 10 mm (sometimes to 15 mm) long, 1 to 4 mm wide; flowers, January through May, 1- to 5-flowered clusters in leaf axils, 7 to 10 mm long, yellow or tinged with red; fruit, slightly curved pod.
Distribution: Common on dry slopes, below 1500 m (5000 ft); coastal sage scrub (soft chaparral) and chaparral; Baja California to northern California.
Fire Response Mechanism: Seedling response to fire; nonsprouter.
Wildlife Value: Staple to low value browse for deer, livestock.
Cultural Value: None known.

Lupinus albifrons Esch. Pea Family *(Fabaceae)*
SILVER LUPINE *(fig. 78).* Rounded shrub, to 1.5 m tall, yellowish green pubescent stems becoming brownish to gray with flaky bark and silky-silver foliage; leaves compound, alternate, olive green divided into 7 to 10 palmate leaflets, silky on both surfaces, leaflets 1 to 3 cm long, 3 to 10 mm wide, petioles 2 to 4 cm long; flowers, March to July, blue or purple, upper petal with light center; fruit, pubescent pod 3 to 5 cm long.
Distribution: Common on dry hillsides, sandy places below 1500 m (5000 ft); in many plant communities; Ventura County north to Humboldt County. Pauma lupine (*L. longifolius* [Wats.] Abrams.) similar species, has more herbaceous growth with somewhat longer petioles (4 to 7 cm long), leaflets (3 to 6 cm), confined to lower elevations inland from coast to Santa Ana Mountains. Inyo lupine (*L. excubitus* Jones var. *johnstonii* C.P. Sm.) found in pine woodlands, San Gabriel Mountains, 1700 to 2000 m (5500-6600 ft), longer petioles (4 to 10 cm), usually larger leaves (leaflets 2 to 4 cm long); stems woody at base. Along coastal strand in Santa Barbara County, look for tree lupine (*L. arboreus* Sims.) with yellow flowers. Dune lupine (*L. chamissonis* Eschs.) is another coastal species with silky leaves.
Fire Response Mechanism: Important early invader following fire, lasts 3 to 4 years, later only as an occasional plant, coastal species useful for dune reclamation; nonsprouter.
Wildlife Value: Low value except for insects, especially bees, small animals.
Cultural Value: Though seeds of some species contain poisonous alkaloids, Native Americans made medicinal tea from seeds especially to help urination (Sweet 1962).

Lycium californicum Nutt. Nightshade Family *(Solonaceae)*
BOX-THORN *(fig. 79).* Compact appearing, intricately branched and densely spiny shrub with numerous small twigs ending in spines, 1 to 2 m tall; leaves somewhat drought deciduous, grayish green above and below, 1 to 3 in a bundle, fleshy and succulent, hairless, spatulate to linear, 3 to 12 mm long, 1 to 3 mm wide; flowers, much of year, solitary, white or purplish, somewhat trumpet-shaped, 2 to 4 lobes; fruit, firm, ovoid (2 mm across), reddish 2-seeded berry.
Distribution: Near coast mostly below 110 m (360 ft); coastal sagebrush in coastal sage scrub (soft chaparral); Los Angeles County, south to Baja California.

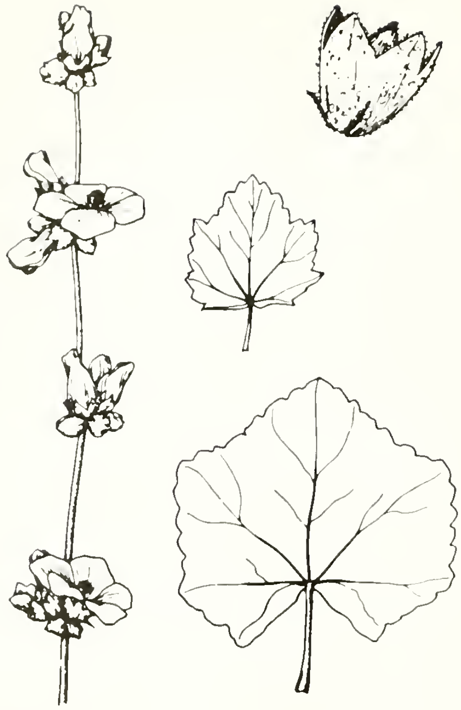


Figure 80—Bush mallow, *Malacothamnus fasciculatus* (McMinn 1939).

Figure 81—Monkeyflower, *Mimulus longiflorus* (inset, McMinn 1939); renamed *Diplacus longiflorus*.

Fire Response Mechanism: Unknown.
Wildlife Value: Staple fruit for doves, quail, small mammals.
Cultural Value: Edible fruits.

Malacothamnus fasciculatus (Nutt.) Greene
Mallow Family *(Malvaceae)*

BUSH MALLOW *(fig. 80).* Tall, somewhat drought deciduous shrub, 1 to 5 m, long slender wand-like branches covered with short, soft yellowish fuzz, young stems cream-colored becoming gray brown; leaves with yellowish fuzz, round-ovate to deltoid in outline, often presenting an upside-down heart shape, barely to deeply 3- to 5-lobed, with rounded serrations, 2 to 5 cm wide, petioles 0.5 to 1 cm long; flowers, April through December, pink clustered blooms attached directly to stems; flowers on branched stalks indicate *M. fasciculatus* var. *laxiflorus* (Gray) Kearn.; petals 12 to 18 mm long.
Distribution: Dry canyon sides, slopes, below 800 m (2500 ft) or up to 1700 m (5500 ft) for variety in coastal sage scrub (soft chaparral); Santa Barbara, Orange, north Riverside Counties to San Bernardino County, Cajon Pass.
Fire Response Mechanism: Early successional; seedling response to fire.
Wildlife Value: Low value or staple browse for livestock, deer.
Cultural Value: None known.

Mimulus longiflorus Nutt.
Figwort Family *(Scrophulariaceae)*

MONKEYFLOWER *(fig. 81).* This species renamed ***Diplacus** longiflorus* Nutt. *Mimulus longiflorus* retained to be consistent with Munz 1974. Diffusely branched, largely wood subshrub 0.3 to 1.2 m tall. Upper stems and branches, under side of leaves, and pedicels hairy. Yellowish green leaves, upper side with impressed veins, leaves lighter below, lanceolate to oblong, may be serrate, 2.5 to 8 cm long, 5 to 20 mm wide; flowers, February through August, orange to buff, 5 to 6 cm long; fruit, capsule.
Distribution: Common on dry rocky slopes to 1500 m (5000 ft); coastal sage scrub (soft chaparral); chaparral, San Diego to San Luis Obispo Counties, inland to San Jacinto Mountains and Kern River area.
Fire Response Mechanism: Probably poor sprouter or nonsprouter.
Wildlife Value: Low to moderate value.
Cultural Value: Sweet (1962) reports leaves and young stems of some species used by Native Americans for food and as poultice for sores.

Myrica californica C. & S.
Wax-Myrtle Family *(Myricaceae)*

PACIFIC WAX-MYRTLE *(fig. 82).* Large monoecious, evergreen shrub, 2 to 4 m tall, smooth gray or light brown bark; leaves simple, alternate, elliptic to approximately oblanceolate, glossy and dark green above, paler below, hair-

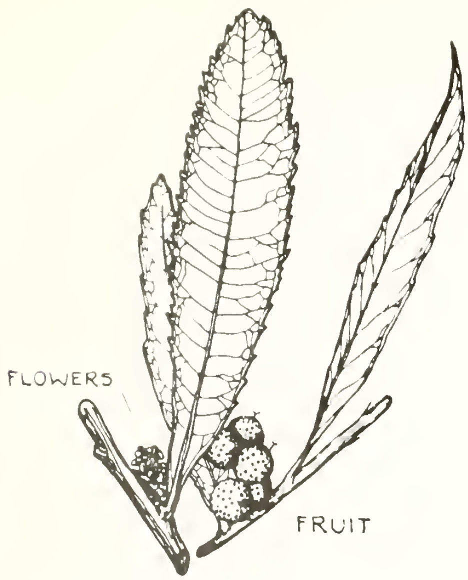


Figure 82—Pacific wax-myrtle, *Myrica californica* (McMinn 1939).

Figure 83—Tree tobacco, *Nicotiana glauca* (McMinn 1939).

less, 5 to 11 cm long, 1.2 to 2 cm wide, petiole short or missing, slightly serrate or with smooth margins; flowers, March to May, male catkins in leaf axils below female catkins; fruit, round brownish-purple nut covered with whitish wax, 3 to 8 mm diameter, borne at base of leaves.
Distribution: Moist places; coastal sage scrub (soft chaparral); chaparral, woodlands, below 150 m (500 ft); Santa Monica Mountains, north along coast to Washington.
Fire Response Mechanism: Sprouts from root shoots, suckers after fire, cutting.
Wildlife Value: Low value browse; fruits used by California quail.
Cultural Value: None known.

Nicotiana glauca Grah. Nightshade Family *(Solanaceae)*
TREE TOBACCO *(fig. 83).* More or less drought deciduous, tall, loosely branched shrub or small tree, 2 to 8 m tall, white filmy glaucous, green stems and glaucous leaves, easily brush green at touch; leaves ovate or elliptic to almost lanceolate, entire, 3 to 17 cm long, 1.5 to 3.5 cm wide, petiole 3 to 5 cm long; flowers much of year, especially April through September, 3 to 4 cm long, yellow and tubular; fruit, 4-valved ovoid capsule, 10 to 12 mm long.
Distribution: Common, naturalized from South America in waste places, below 900 m (3000 ft).
Fire Response Mechanism: Nonsprouter.
Wildlife Value: Toxic to livestock, rarely browsed.
Cultural Value: According to legend, tobacco was one of first plants created by the god Mukat. Leaves used for smoking. Leaves, stems and seeds used for medicinal purposes (Sweet 1962).

Pickeringia montana Nutt. Pea Family *(Fabaceae)*
CHAPARRAL-PEA *(fig. 84).* Evergreen shrub, 0.5 to 2 mm tall, densely branched, spine-tipped branchlets, greenish or grayish becoming reddish to gray; leaves alternate, compound, 3-parted or some solitary, green, mostly glabrous or pubescent, leaflets entire, obovate, firm 4 to 12 mm long, 3 to 5 m wide, attached directly to stems; flowers, May to June, rose to purple, five irregular petals with yellowish spot near base of upper petal; fruit, pod 3 to 5 cm long, constricted between seeds. San Bernardino and eastern San Diego Counties variant have pubescent to canescent leaves and young twigs (Munz 1974).
Distribution: Dry slopes, ridges below 1500 m (5000 ft); manzanita to live woodlands; Sierra Nevadas, Butte County, south to San Diego County.
Fire Response Mechanism: Sprouts from exposed roots, root shoots.
Wildlife Value: Low value.
Cultural Value: None known.

Prunus spp. Rose Family *(Rosaceae)*
1a. Plants evergreen; leathery, holly-like leaves; shrub or small tree on dry foothills in chaparral to live oak wood-

Figure 84—Chaparral-pea, *Pickeringia montana* (McMinn 1939).

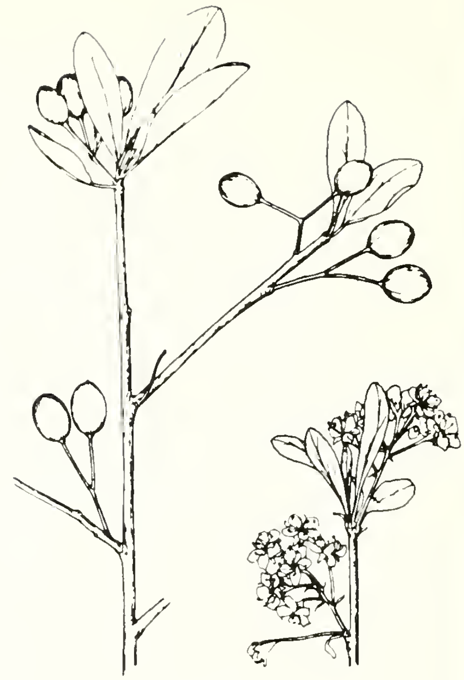


Figure 85—Bitter cherry, *Prunus emarginata* (McMinn 1939).

lands below 1500 m.

HOLLYLEAF CHERRY, *P. ilicifolia*

1b. Plants deciduous; not with leathery leaves.

2a. Shrubby, with spine-tipped branchlets; shrub on desert slopes in creosote bush, Joshua tree, pinyon-juniper between 970 and 1800 m.

DESERT ALMOND, *P. fasciculata*

2b. Shrubby or small trees, not spiny.

3a. Leaves 1 to 2.5 cm wide; petioles short, 5 mm long; shrub or tree on moist chaparral to pine woodland slopes below 2700 m.

BITTER CHERRY, *P. emarginata*

3b. Leaves 2 to 5 cm wide; petioles 1 to 2 cm long; shrub or tree on moist slopes in chaparral to oak and pine woodlands below 2500 m.

WESTERN CHOKE CHERRY
P. virginiana ssp. *demissa*

P. emarginata (Dougl.) Walp.
BITTER CHERRY *(fig. 85)*. Deciduous shrub or tree, 1 to 6 m tall, hairless red twigs, older bark smooth; leaves simple, alternate, grouped or somewhat bundled, spatulate to ovate, rounded at apex, 2 to 5 cm long, 1 to 2 cm wide, petiole less than 1 cm long, light green both sides, smooth surface, possible slightly pubescent especially below, minutely serrate; flowers, April and May, 1.5 to 4 cm long, five white petals, 5 to 7 mm long, clusters of 3 to 10; fruit, red bitter drupe 6 to 8 mm diameter, turning black at maturity, stone pointed at ends.

Distribution: Moist slopes, stream banks, below 2700 m (9000 ft); yellow pine woodlands, manzanita and other chaparral communities; southern California, coast ranges, Sierra Nevada, to British Columbia, Nevada, Arizona.

Fire Response Mechanism: Stump-sprouts after fire, cutting.

Wildlife Value: Preferred browse of deer; fruits staple for birds.

Cultural Value: Fruits used, but bitter.

P. fasciculata (Torr.) Gray
DESERT ALMOND *(fig. 86)*. Rigidly much-branched deciduous shrub, 1 to 3 m tall, with short, stiff, thorn-like twigs, brownish branchlets becoming gray; leaves simple, alternate, bundles of 3 to 7 or more, spatulate to oblance-spatulate usually widest near end, 5 to 15 mm long, 2 to 4 mm wide, pale green above and below, slightly pubescent to glabrous; flowers, April and May, single or few-flowered clusters, five white petals, 2 to 3 mm long; fruit, dry ovoid drupe 8 to 12 mm long, pubescent with light brown hairs and smooth stone.

Distribution: Desert slopes, mostly 970 to 1800 m (3200-6000 ft); creosote bush, Joshua tree to pinyon-juniper woodlands; Mojave and Colorado Deserts, Arizona, Utah.

Fire Response Mechanism: Root-sprouts after fire, cutting.

Wildlife Value: Low value browse.

Cultural Value: Fruits eaten, not preferred.

Figure 86—Desert almond, *Prunus fasciculata* (McMinn 1939).

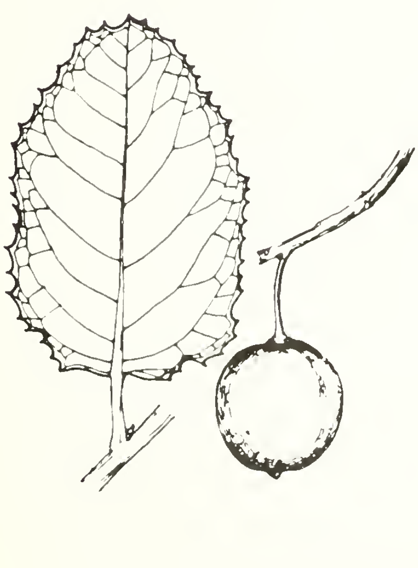


Figure 87—Hollyleaf cherry, *Prunus ilicifolia* (McMinn 1939).

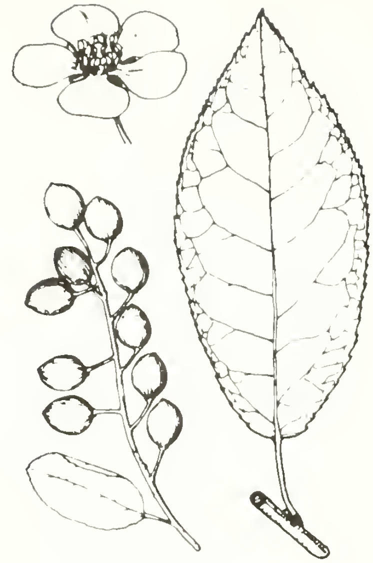


Figure 88—Western choke cherry, *Prunus virginiana* var. *demissa* (McMinn 1939).

P. ilicifolia (Nutt.) Walp.
HOLLYLEAF CHERRY *(fig. 87).* Evergreen shrub or small tree, 1 to 8 m tall, twigs gray or reddish brown; leaves simple, alternate, thick, leathery, 2 to 7 cm long, 2 to 4 cm wide, petiole 0.5 to 1.5 cm long, mature leaves generally with coarse spiny-toothed margins, ovate to oval, dark green, shiny above, paler below; flowers, April and May, 3 to 10 cm long cylindrical clusters of white 5-petaled blossoms; fruit, purplish drupe 2 to 3 cm across, pulp, thin and sweetish.
Distribution: Dry foothills, below 1500 m (5000 ft); chaparral, scrub oak, live oak woodlands; coast ranges, Napa County south to Baja California.
Fire Response Mechanism: Stump-sprouts vigorously after fire.
Wildlife Value: Preferred browse of deer and bighorn sheep. Fruits preferred food of birds, animals.
Cultural Value: Fruits sweet, eaten raw or peeled, dried, and stored. Pit ground for flour.

P. virginiana L. ssp. *demissa* (Nutt.) Sarg.
WESTERN CHOKE CHERRY *(fig. 88).* Large shrub or small tree, 1 to 5 m tall, deciduous with smooth gray brown bark, minutely hairy twigs; leaves simple, alternate, light green, lighter below, glabrous above, finely pubescent below, ovate, or broadly elliptic, finely toothed edges, abruptly pointed at apex, rounded or slightly indented at base, 5 to 10 cm long, 1.5 to 2.5 (rarely up to 5) cm wide; flowers, May through July, white petals 5 to 6 mm broad, many-flowered

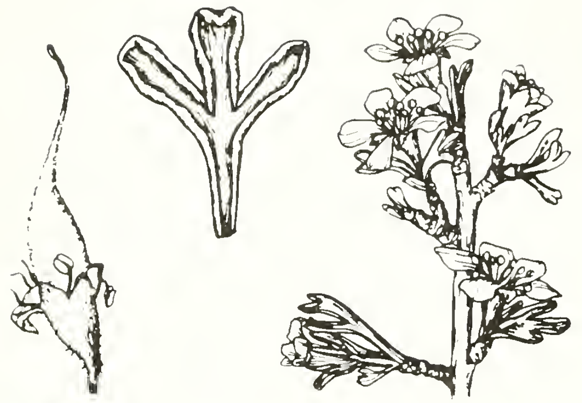


Figure 89—Bitterbrush, *Purshia glandulosa* (McMinn 1939).

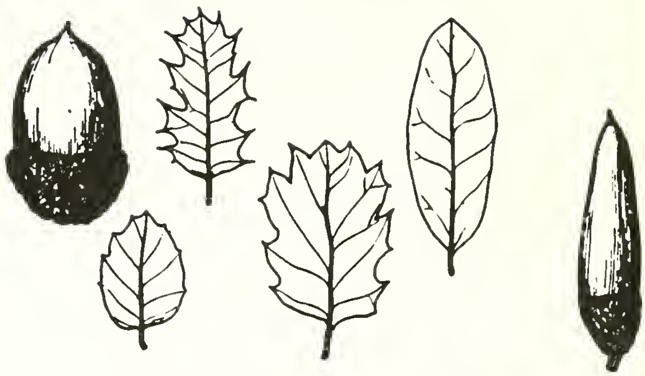


Figure 90—California scrub oak, *Quercus dumosa* (McMinn 1939).

clusters 5 to 11 cm long; fruit, dark red cherry 5 to 6 mm thick, bitter, with smooth round stone.
Distribution: Moist, brushy slopes, below 2500 m (8200 ft); yellow pine, live oak, black oak forests or woodlands, ceanothus chaparral; San Diego County north along Sierra Nevada, coast ranges, British Columbia.
Fire Response Mechanism: Shallow-rooted; spreads by rhizomes; sprouts from rhizomes after fire.
Wildlife Value: Staple browse, toxic if overgrazed by livestock; fruits preferred by birds, small mammals, black or brown bear.
Cultural Value: Fruit can be eaten raw, but slightly astringent.

Purshia glandulosa Curran. Rose Family *(Rosaceae)*
BITTERBRUSH *(fig. 89).* Erect evergreen shrub, 1 to 2.5 m tall, gray or brown bark, not very shreddy, young twigs glabrous and glandular; simple leaves and short vegetative stems alternate, 0.5 to 1 cm long, 3-cleft, tend to be rolled under at edges, in crowded fascicle-like clusters, somewhat darker green with glandular pits above, slightly fuzzy below; flowers, April to June, solitary, terminal blossoms with five pale yellow or white petals, 6 to 8 mm long; fruit, hairy akene.
Distribution: Transmontane dry slopes 900 to 2700 m (2800-9000 ft); chaparral to Joshua tree, pinyon-juniper, or juniper woodlands; western Colorado Desert, Cajon Pass, Mojave Desert to Mono County, Nevada, Arizona.
Fire Response Mechanism: Variable stump-sprouter.
Wildlife Value: Staple browse for livestock, deer.
Cultural Value: None known.

Quercus spp. Beech Family *(Fagaceae)*
SHRUB OAKS. Fifteen species native to California. Usually tree-like, the two taxa described here are shrubs found in exposed environmental conditions and subject to frequent fire.
Wildlife Value: Young shoots and leaves preferred browse of deer, bighorn sheep, cattle, goats. Acorns important food for many birds, small mammals.
Cultural Value: Acorns provided staple food for Native Americans. Nuts hulled, ground, leached to remove water soluble tannins, and used as flour for baking or in soups. Bark and some insect galls used for various medicinal purposes, making dye, curing hides (Balls 1972).

1a. Leaves green on both surfaces, slightly paler below, lacking fuzz of any kind; shrub or small tree in chaparral up to 1500 m elevation.
INTERIOR LIVE OAK, *Q. wislizenii* var. *frutescens*
1b. Leaves dark green above, pale and minutely fuzzy below, 1.2 to 4 cm long; thin-walled acorn cup encloses about half the nut; common shrub or small tree on dry chaparral slopes below 1500 m. SCRUB OAK, *Q. dumosa*

Q. dumosa Nutt.
CALIFORNIA SCRUB OAK *(fig. 90).* Evergreen, monoecious shrub or small tree, 1 to 3 m tall, young stems reddish brown becoming dark brown to grayish brown; leaves simple and alternate, shape and size variable, oblong or roundish to spatulate, 1.2 to 4.0 cm long, 6 to 20 mm broad, petiole 3 to 5 mm long, brittle to leathery and thick, plane or undulate,

Figure 91—Interior live oak, *Quercus wislizenii* var. *frutescens* (McMinn 1939).

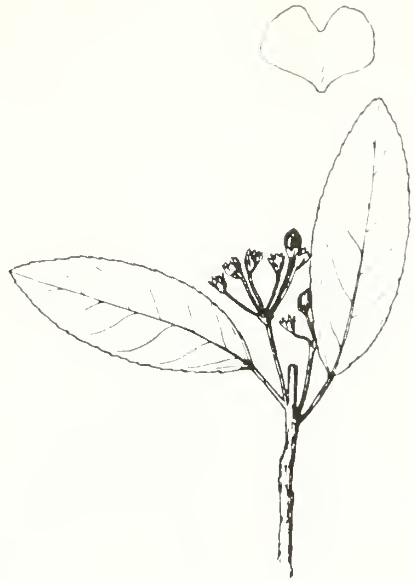


Figure 92—Coffeeberry, *Rhamnus californica* (McMinn 1939).

sometimes dentate, green, shiny, hairless above, may be concave, paler and pubescent below; flowers, March to May, male flowers in catkins 2.5 to 5 cm long, female flowers in clusters of 2 to 3 in axils of upper leaves; acorn, ovoid and rounded or acute at apex, matures in one season, with cup enclosing up to one-half of the acorn, cup scales ovate or united at least near base. Palmer oak (*Q. dunnii* Dell) is similar species with wavy-margined, spiny leaves; acorn cup flares out and away from nut around rim; localized in San Jacinto, San Bernardino Mountains at Coxey Meadow.
Distribution: Common on dry slopes below 1500 m (5000 ft); southern California, west base of Sierra Nevada to northern California.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: See genus.
Cultural Value: See genus.

Q. wislizenii A. DC var. *frutescens* Engelm.
INTERIOR LIVE OAK *(fig. 91).* Small evergreen monoecious tree or sometimes shrubby (1 to 5 m tall), young twigs green to reddish becoming gray; leaves usually convex, ovate or oblong to lanceolate, plane or slightly wavy, margin entire to dentate, dark green above, green and somewhat paler and hairless below, 2 to 6 cm long (mostly 3 to 4 cm), 1 to 2.5 cm wide, petiole 2 to 5 mm long; flowers, March to May, male flowers in catkins 2 to 5 cm long, female flowers in clusters of 2 to 4 in upper leaf axils; acorns oblong-ovate and abruptly pointed, maturing second season, cup, 8 to 12 mm wide, 12 to 18 mm long.

Distribution: Chaparral, valleys, slopes, below 1500 m (5000 ft); lower slopes of Sierral Nevada, Shasta County, south to mountains of southern California.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: See genus.
Cultural Value: See genus.

Rhamnus californica Esch.
Buckthorn Family *(Rhamnaceae)*
COFFEEBERRY *(fig. 92).* Shrub, 1 to 4 m tall, persistent leaves, bark on young twigs reddish; leaves alternate, flat to somewhat revolute, oval or elliptic, taper to a point or obtuse, 2.5 to 8 (up to 10) cm long, 1 to 3 cm wide, usually glabrous, dark green above, glabrous or with few hairs, paler below with prominent midvein below, sometimes rusty or pale green, sometimes minutely serrate; flowers, April through June, small and greenish, usually without petals, less than 3 mm long, 6- to 50-flower clusters; fruit, green, black, or red, juicy berry with two "coffeebean" seeds, 7 to 9 mm long.
Distribution: Hillsides and ravine riparian areas, 1200 to 2100 m (4000-7000 ft); mixed conifer to redwood forests, chaparral; east and west slopes of Sierras, Mono and Madera Counties, south to Riverside, Los Angeles Counties.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Staple browse; fruits, preferred food of birds, bears.
Cultural Value: Berries edible and sweet, laxative effect.

Figure 93—Redberry, *Rhamnus crocea.*

Figure 94—Hollyleaf redberry, *Rhamnus ilicifolia* (McMinn 1939).

R. crocea Nutt.
REDBERRY *(fig. 93).* Densely branched evergreen shrub, to 2 m tall, stiff, relatively divaricate gray branchlets often ending with a sharp point; leaves often in bundles and dark green above (sometimes lighter), yellowish green below, leaves usually feel leathery, ovate or nearly round, 5 to 15 mm long, 3 to 6 mm wide, usually glabrous or slightly pubescent below with smooth margins or often serrated; flowers, February to April, greenish, tiny, small clusters from the leaf axils; fruit, red berry 5 to 6 mm long with two seeds.
Distribution: Dry slopes, below 900 m (3000 ft); coastal sage scrub (soft chaparral); Lake County south to San Diego County, Baja California.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Preferred browse of deer, livestock.
Cultural Value: Berries edible, bark was peeled, ground, dried, and used as laxative.

R. ilicifolia Kell.
HOLLYLEAF REDBERRY *(fig. 94).* Erect evergreen shrub, similar to redberry *(R. crocea),* but taller, to 4 m tall, young stems slightly pubescent, reddish with bark becoming gray; leaves 1 to 4 cm long, 1 to 4 cm wide, spine-toothed margins or rarely entire, leaf darker above, somewhat pubescent above and below; flowers, March to May, clusters of tiny greenish flowers, almost always without petals; fruits, red berry 3 to 5 mm across, much like redberry *(R. crocea).* Redberry and hollyleaf redberry often occur together.
Distribution: Up to 2000 m (6600 ft); chaparral to yellow pi[ne] forests or woodlands; Humboldt County, south to San Die[go] County, Baja California.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Probably same as redberry *(R. crocea).*
Cultural Value: Probably same as redberry *(R. crocea).*

Rhododendron occidentale (T. & G.) Gray
Heath Family *(Ericace[ae])*
WESTERN AZALEA *(fig. 95).* Loosely branched deciduous shrub, 1 to 3 m tall, often branching 4 to 6 times [i]n umbrella-like pattern, brown bark on young stems becomi[ng] gray and shreddy; leaves simple, alternate, thin, light gre[en], sometimes pubescent, midvein yellowish red and obvio[us], elliptic or obovate to oblanceolate, 3 to 9 cm long, 1.5 to [3] cm wide, stiff hairs along margins, lacking serration; flowe[rs], May to July, showy, large, white or tinged pink; fruit, caps[ule] 1 to 2 cm long.
Distribution: Along streams, moist places, below 2300 [m] (7500 ft); mixed conifer, ponderosa or Jeffrey pine, willo[w]; Humboldt, Shasta Counties, south to San Jacinto, Palom[ar], and Cuyamaca Mountains.
Fire Response Mechanism: Thicket-forming by late[ral] shoots.
Wildlife Value: Toxic to cattle, sheep, much used by beav[er].
Cultural Value: None known.

Figure 95—Western azalea, *Rhododendron occidentale* (T. & G.) Gray (McMinn 1939).

Figure 97—Laurel sumac, *Rhus laurina* (McMinn 1939); renamed *Malosma laurina*.

Figure 96—Lemonadeberry, *Rhus integrifolia* (McMinn 1939).

Rhus integrifolia (Nutt.) Benth. & Hook.

Sumac Family *(Anacardiaceae)*

LEMONADEBERRY *(fig. 96).* Rounded evergreen shrub, 1 to 3 m tall, fine fuzzy twigs and leaves; leaves leathery, midvein prominent, flat, smooth margins or irregularly toothed, sometimes with curled down edges, 2.5 to 6 cm long, 1 to 4 cm wide, petiole 3 to 4 mm long, elliptic and rounded at both ends, glaucous to fuzzy with pubescence on veins at least, dark green above and paler below; flowers, January to March, white or pink oval clusters; fruit, reddish and somehat flattened, waxy drupe.

Distribution: Ocean bluffs, canyons below 600 m (2000 ft); inland to west Riverside County, Santa Barbara to Baja California.

Fire Response Mechanism: Roots from branches touching ground; stump sprouts after fire, cutting.

Wildlife Value: Low value browse; seed used by birds, including 8 to 9 percent of diet of roadrunners.

Cultural Value: Fruits quite tart, yield a lemony drink when added to water. Cahuillas made tea of leaves to treat coughs and colds (Clarke 1977).

R. laurina Nutt.

LAUREL SUMAC *(fig. 97).* This species renamed *Malosma laurina* Nutt. ex. Abrams. *Rhus l.* retained to be consistent with Munz (1974). Leafy, evergreen shrub, 2 to 5 m tall, reddish-brown bark; leaves oblong-lanceolate to ovate or elliptical, mature leaves 5 to 10 cm long, 2 to 5 cm wide,

Figure 98—Sugar bush, *Rhus ovata*.

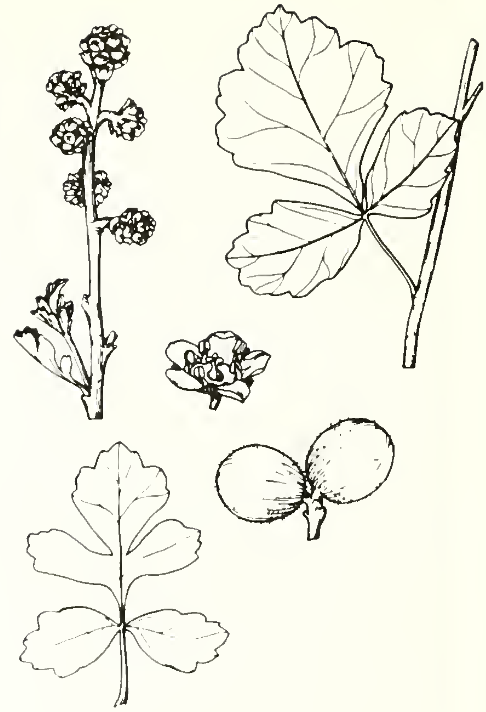


Figure 99—Squaw bush (basket sumac), *Rhus trilobata* (McMinn 1939).

petiole 1 to 3 cm long, somewhat aromatic, somewhat glaucous, green, lighter below, usually folded upwards along midvein, like sugar bush *(R. ovata)*, tapering to soft point; veins, leaf margins, petioles, new growth twigs, reddish; produces new growth before flowering in May and June, hence old inflorescences frequently on ends of branches and obvious; flowers numerous, small (1 to 2 mm), white, dense panicle 5 to 15 cm long; fruit, whitish or greenish to reddish glabrous drupe, 2 to 4 mm long, single smooth stone; frost sensitive, stands occasionally severely frosted with resultant large quantities of dead leaves and twigs.
Distribution: Dry slopes below 600 m (2000 ft); coastal sage scrub (soft chaparral), chamise chaparral; Santa Barbara County to Baja California.
Fire Response Mechanism: Stump sprouts vigorously after fire, seedlings common after fire but mortality very high.
Wildlife Value: Low value browse; flowers commonly visited by honey bees; seeds important for quail, wren tits, other birds.
Cultural Value: Unknown, probably like lemonadeberry *(R. integrifolia)*.

R. ovata Wats.
SUGAR BUSH *(fig. 98)*. Evergreen shrub, 1.5 to 3 m tall, stout reddish, hairless twigs; leaves shiny green, thick, leathery, smooth margins, midvein prominent, ovate to lanceolate, tapering to a point at apex, 4 to 8 cm long, 2 to 4 cm wide, petiole 1 to 1.5 cm long, cupped upwards at edges from midvein to form a trough, edges wavy; flowers, April and May before producing new growth, hence old inflorescences not on ends of branches, flower panicles often present long before flowers, 5-parted, pinkish white, dense panicle; fruit, reddish, pubescent, acid-tasting, sticky drupe, 7 to 8 mm diameter, single stone; relatively frost resistant.
Distribution: Dry chaparral slopes, mostly 300 to 1700 m (1000-5700 ft); coastal sage scrub (soft chaparral, chaparral) Santa Barbara County to northern Baja California.
Fire Response Mechanism: Stump-sprouts rapidly after fire cutting.
Wildlife Value: Low value browse; flowers attract bees, other insects; fruits important for birds, many animals.
Cultural Value: Berries dried, eaten fresh, or ground int flour; white sap on berries used as acid flavoring (Clark 1977).

R. trilobata Nutt.
SQUAW BUSH (BASKET SUMAC) *(fig. 99)*. Sprawling t erect normally deciduous shrub, stems to 1.5 m long, youn twig ends tend to be reddish becoming gray with age branches spreading and pubescent; leaves 3-foliate, minutel hairy, leaflets may be pubescent ovate to obovate or almos diamond-shaped in outline with rounded serrations at apex terminal 1 to 3 cm long, about as wide, terminal leaflet large than laterals, lower margin concave taper to petiole, lowe margin of lateral leaflets convex to petiole; flowers, March t May, yellowish clustered spikes; fruit, reddish sticky, hair drupe.

Distribution: Canyons and dry washes, below 1200 m (4000 ft); coastal sage scrub (soft chaparral), ceanothus chaparral, live oak and canyon live oak woodlands; southern California to Butte County.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Low value or staple browse for livestock, mule deer. Seeds eaten by quail, other birds.
Cultural Value: Native Americans used stems in basket making. Berries used in several forms, food and medicine. Hopis used berry juice in body paint. Navajos made black dye from roots (Clarke 1977).

Ribes spp. Saxifrage Family *(Saxifragaceae)*
CURRANTS and GOOSEBERRIES. Erect or trailing shrubs, drought or winter deciduous or evergreen, with simple, alternate, palmately lobed leaves and leaf venation; stems armed with spines at nodes where leaves join the stem or without spines; several species with both spines and internode prickles; flowers, 5-parted, produce many-seeded berries, may be covered with prickles, otherwise edible. Munz (1974) lists 17 species of *Ribes* in southern California; 11 of these have spines, 6 have pubescent to sticker covered fruits. Seven species included here.
Fire Response Mechanism: Most species stump-sprout after fire, cutting.
Wildlife Value: Most species provide fair to poor browse for deer, livestock, bighorn sheep. Most berries taken by birds, many mammals, insects.
Cultural Value: Berries edible. Most serious problem is coat of prickles that encase berries of some species. According to Clarke (1974), currants and gooseberries important ingredients in pemmican, an important part of diet of Native Americans.

1a. Stems with spines at nodes.
- 2a. Stems usually with bristles or prickles between nodes.
  - 3a. Leaves sticky; straggling shrub on dry pine woodland slopes above 2100 m elevation.
    MOUNTAIN GOOSEBERRY, *R. montigenum*
  - 3b. Leaves not sticky; spreading shrub in shaded moist coast sage and chaparral canyons below 450 m elevation.
    FUCHSIA-FLOWERED GOOSEBERRY, *R. speciosum*
- 2b. Stems without bristles or prickles between nodes.
  - 4a. Leaves more or less equally pubescent on both surfaces; erect shrub on shady, moist woodland slopes below 1800 m.
    BITTER GOOSEBERRY, *R. amarum*
  - 4b. Leaves darker green and less pubescent above; spreading shrub on dry chaparral to conifer slopes between 1100 and 2600 m.
    CHAPARRAL GOOSEBERRY, *R. roezlii*

1b. Stems without spines at nodes.
- 5a. Young stems covered with woolly and/or gland-tipped bristly hairs; multiple stemmed shrub common on dry chaparral and woodland slopes below 1500 m.
  CHAPARRAL CURRANT, *R. malvaceum*
- 5b. Young stems glabrous or with fine puberulence.
  - 6a. Leaves rather thin and flexible, somewhat paler and more pubescent below; slender stemmed shrub of moist places between 900 and 3000 m.
    SIERRA CURRANT, *R. nevadense*
  - 6b. Leaves somewhat stiff and leathery, color and pubescents nearly equal above and below; erect shrub in moist places in scrub oak chaparral and oak woodlands below 500 m.
    GOLDEN CURRANT, *R. aureum* var. *gracillimum*

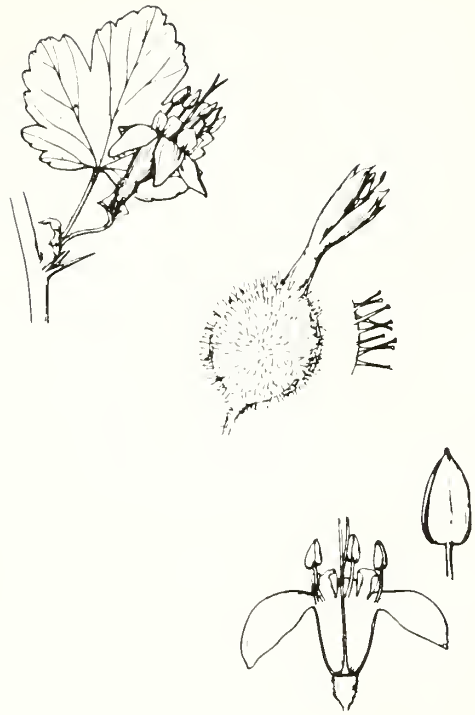


Figure 100—Bitter gooseberry, *Ribes amarum* (McMinn 1939).

R. amarum McCl.
BITTER GOOSEBERRY *(fig. 100).* Erect, drought deciduous shrub, 1 to 2 m tall, brown nodal spines, lacking prickles on rest of stems, young stems pubescent; leaves pubescent to somewhat glandular-puberulent on both surfaces roundish to palmate, heart-shaped at base, darker green above, 1.5 to 3 cm wide, petiole to 3 cm long, 3- to 5-lobed with rounded serrations, leaves develop in January and February; flowers, February to April, 1 to 3 on pubescent peduncles, blossoms purplish; fruit, berry, 1.5 to 2 cm diameter, densely covered with gland-tipped bristles.
Distribution: Shady, usually moist wooded slopes below 1800 m (6000 feet); San Diego to Monterey, El Dorado Counties.
Fire Response Mechanism: Resprouts after burning, cutting.

Figure 101—Golden currant, *Ribes aureum* (McMinn 1939).

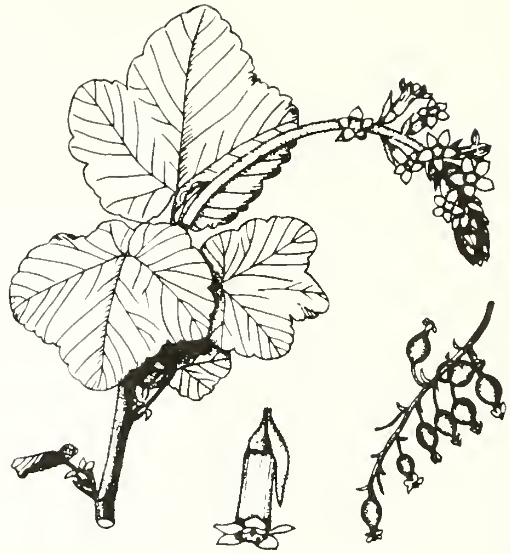


Figure 102—Chaparral currant, *Ribes malvaceum* (Munz 1974).

Wildlife Value: Low value browse, fruit eaten by many animals.
Cultural Value: Edible berries well armed (see Clarke 1974).

R. aureum Pursh var. *gracillimum* (cov. & Britt.) Jeps.
GOLDEN CURRANT *(fig. 101).* Erect, drought deciduous shrub, bark gray or brown, 1 to 2 m tall, stems without spines, young stems and leaves nearly glabrous; leaves fairly stiff, leathery, mostly 3-lobed, light green with palmate venation, lobes rounded or toothed, 2 to 5 cm long, 1.5 to 5 cm wide, petioles 1 to 4 cm long; flowers, January to June, 5 to 15 odorless yellow blossoms becoming red, 5-parted, 3- to 7-cm long raceme; fruit, berry 6 to 8 mm diameter without bristles, mostly orange to yellowish, color varies sometimes on same plant.
Distribution: Moist places on foothill areas below 500 m (1650 ft); scrub oak chaparral and oak woodland; Los Angeles and Riverside Counties, north to British Columbia, east to Rocky Mountains.
Fire Response Mechanism: Sprout after cutting, fire.
Wildlife Value: Low value browse; fruit eaten by numerous species.
Cultural Value: Tasty berry used fresh, in cooking; probably used by Native Americans in several ways, an ingredient of pemmican (Clarke 1977).

R. malvaceum Sm. Abrams.
CHAPARRAL CURRANT *(fig. 102).* Drought deciduous shrub, 1 to 2 m tall, 5 to 20 straight stout stems from base; young stems covered with woolly- and gland-tipped bristly hairs; leaves roundish in outline, 3- to 5-lobed, palmate venation, wrinkled surface, dull green above with stalked glands, margins serrate, paler green and pubescent below, 2 to 6 cm long and wide, petioles 1 to 5 cm long; flowers, December to April, 10 to 25 rose-colored blossoms in drooping terminal racemes, corolla tubular and abruptly flaring at apex, 8 to 12 mm long tube; fruit, purplish-black berry, 6 mm diameter, somewhat hairy and glandular. Subspecies *viridifolium* Abrams. has greener leaves and more coarse glandular pubescence. *R. indecorum* Eastw. similar with white flowers. *R. cereum* Dougl. has more finely toothed leaves, found in San Gabriel Mountains, on Mt. Pinos.
Distribution: Common foothill shrub of dry places, several chaparral communities, oak woodlands, closed cone pine communities, mostly below 1500 m (5000 ft); San Jacinto Mountains to Santa Ana, Santa Monica Mountains.
Fire Response Mechanism: Same as genus.
Wildlife Value: See *R. aureum* var. *gracillimum.*
Cultural Value: See *R. aureum* var. *gracillimum.*

R. montigenum McCl.
MOUNTAIN GOOSEBERRY *(fig. 103).* Low, straggling, much branched, drought deciduous shrub, 0.3 to 0.6 m tall, usually bristly all along stems (sometimes almost smooth); leaves glandular, sticky, appear round in outline, heart-shaped base, 1 to 4 cm long and wide, 5-cleft with much incised and toothed lobes, palmate venation, spines at base of

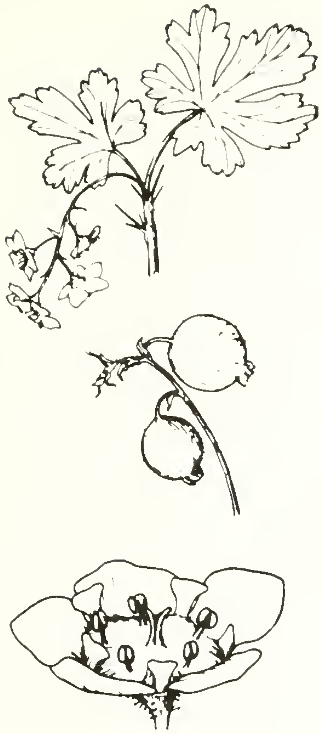


Figure 103—Mountain gooseberry, *Ribes montigenum* (McMinn 1939).

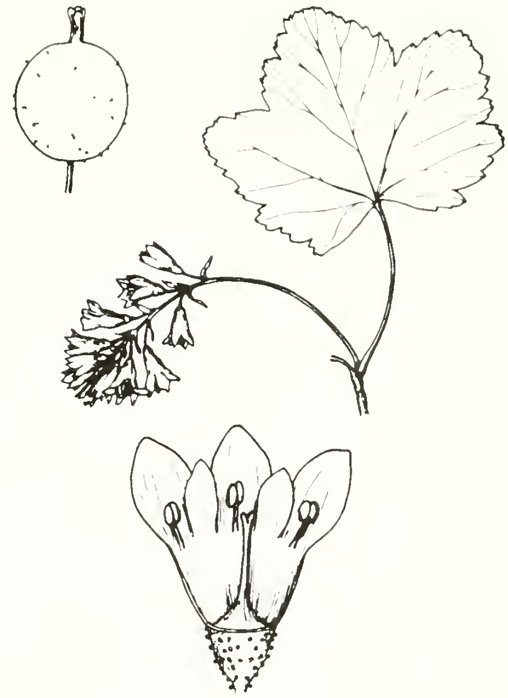


Figure 104—Sierra, currant, *Ribes nevadense* (McMinn 1939).

petioles; flowers, July and August, 3 to 7 saucer-shaped blooms, short purplish to greenish white raceme; fruit, bristly red berry about 6 mm diameter.
Distribution: Dry rocky places, 2100 to 3800 m (7000-12,500 ft); alpine and limber pine communities; San Jacinto, San Bernardino, San Gabriel Mountains to British Columbia, Rocky Mountains.
Fire Response Mechanism: Variable root-sprouter after fire, cutting.
Wildlife Value: Berries edible.
Cultural Value: Fresh berries good raw, mashed and strained through sieve to remove bristles (Clarke 1977).

R. nevadense Kell.
SIERRA CURRANT *(fig. 104).* Slender stemmed, drought deciduous shrub, 1 to 2 m tall, without spines or prickles, young growth glabrous or puberulent; leaves roundish, rather thin and flexible, palmately 3- to 5-lobed, lobes obtuse, bluntly toothed, resinous-dotted and glabrous above, somewhat pubescent and paler below, 3 to 9 cm long and wide, petioles 1 to 6 cm long; flowers, April to July, drooping 8- to 12-flowered racemes, blossoms tubular and abruptly flaring at ends, tube approximately 5 mm long, small white petals with erect pink rose to red sepals; fruit, blue black somewhat glandular, glaucous berry about 8 mm diameter.
Distribution: Moist places, stream sides; 900 to 3000 m (3000-10,000 ft); Palomar, San Gabriel, San Bernardino, and San Jacinto Mountains, north to Sierra Nevadas, Shasta and Modoc Counties.
Fire Response Mechanism: Resprouts when burned, cut.
Wildlife Value: Berries eaten, especially by birds.
Cultural Value: Berries edible (Clarke 1977).

R. roezlii Regel.
CHAPARRAL GOOSEBERRY *(fig. 105).* Drought deciduous shrub, 0.5 to 1.2 m tall, long spreading stems and short rigid branchlets, 1 to 3 straight or recurved spines at leaf nodes; leaves round in outline with palmate venation, 1.5 to 3.5 cm long and wide on 0.6 to 2 cm petiole, dark green with fine, short pubescence above, paler below, cleft into 3 to 5 lobes; flowers, April to July, 1 to 2 glandular, purplish red blooms with whitish petals, 3 to 5 mm long; fruit, purple or sometimes pinkish or yellowish berry, 1.4 to 1.6 cm diameter, covered with stout spines, usually with some gland-tipped bristles.
Distribution: Dry slopes 1100 to 2600 m (3500-8500 ft); ponderosa or Jeffrey pine, bigcone Douglas-fir woodlands or forests, manzanita chaparral; Tulare County south to mountains of southern California, San Diego County.
Fire Response Mechanism: Stump-sprouts after fire, cutting.
Wildlife Value: Staple browse for deer and bighorn sheep; fruit eaten by birds and small mammals.
Cultural Value: Berries dried and stored or eaten raw.

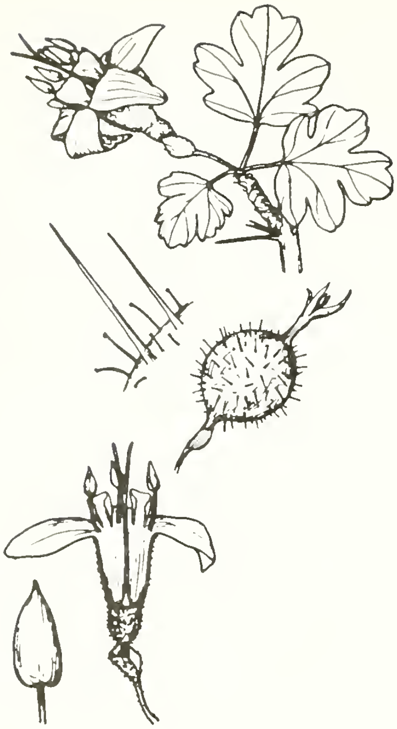


Figure 105—Chaparral gooseberry, *Ribes roezlii* (McMinn 1939).

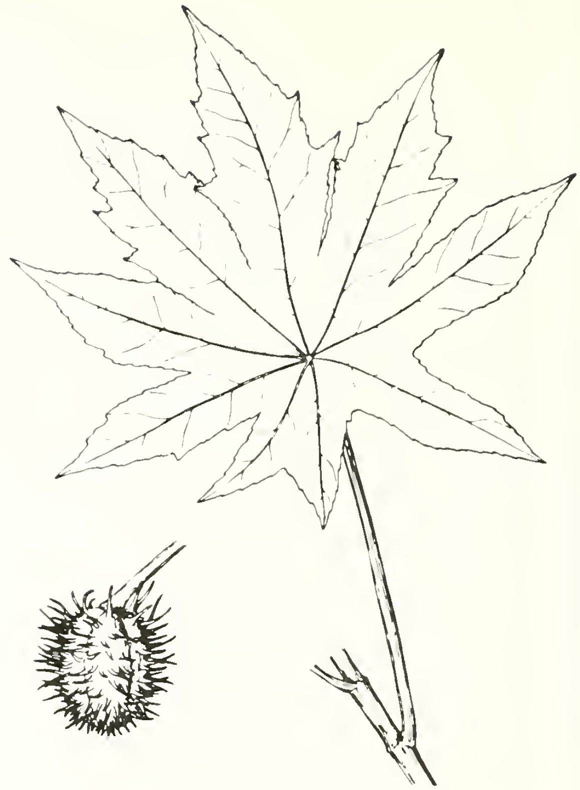


Figure 107—Castor-bean, *Ricinus communis* (McMinn 1939).

Figure 106—Fuchsia-flowered gooseberry, *Ribes speciosum*.

R. speciosum Pursh.
FUCHSIA-FLOWERED GOOSEBERRY *(fig. 106)*. Evergreen shrub, 1 to 2 m tall, spreading bristly branches, stems with three nodal spines 1 to 2 cm long; leaves roundish to obovate with palmate venation, 1 to 3.5 cm long and wide, petiole 6 to 25 mm long, glossy dark green above, paler below, 3- to 5-lobed; flowers, January to May, 1 to 4 drooping, crimson, peduncled blossoms with stamens extending three times the length of petals; fruit, bristly, glandular, oval-shaped berry about 1 cm long.
Distribution: Shaded, moist canyons below 500 m (1500 ft); coastal sage scrub (soft chaparral), chaparral; Santa Clara to San Diego Counties, to north Baja California.
Fire Response Mechanism: Same as genus.
Wildlife Value: Berries and flowers used by insects, birds, small animals.
Cultural Value: Edible berries armed with bristles; colorful shrub useful as an ornament (McMinn 1964).

Ricinus communis L. Spurge Family *(Euphorbiaceae)*
CASTOR-BEAN *(fig. 107)*. Monoecious subshrub, to 3 m tall; young stems green or reddish or becoming reddish then brown, older stems have a ring at each leaf scar, easily identified by its large leaves, 10 to 30 cm long, 10 to 40 cm broad, prominately palmate 5- to 11-veined and lobed, glossy, lighter green below; flowers most of year, inconspicuous clusters of blooms with female flowers higher on stem than male; fruit, spiny capsule.

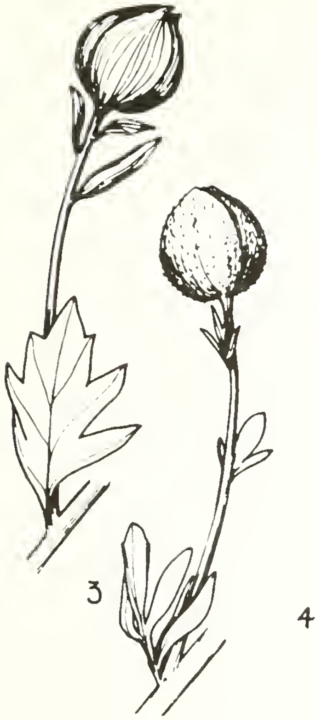


Figure 108—Matilija poppy, *Romneya coulteri* (A); *Romneya trichocalyx* (B) (McMinn 1939).

Figure 109—California wild rose, *Rosa californica* (McMinn 1939).

Distribution: Native of Old World, escaped from cultivation around arroyos, waste places up to 730 m (2000 ft).
Fire Response Mechanism: Rather flammable, nonsprouter.
Wildlife Value: Low value, toxic in large quantities.
Cultural Value: Seeds more poisonous than leaves. Seeds ground into salve for sores; source of castor oil. This species not available to Native Americans.

Romneya coulteri Harv. Poppy Family *(Papaveraceae)*
MATILIJA POPPY *(fig. 108).* Subshrub with numerous wand-like green stems becoming gray with age and with clear bitter juice, from woody base, to 2.5 m tall; leaves simple, sometimes sparsely toothed, alternate, olive-colored, lighter below, divided into 3 to 5 pinnate lobes, sometimes nearly separate, appear as leaflets, venation is pinnate, leaf 5 to 20 cm long, 5 to 15 cm wide, petiole 1 to 2 cm long; flowers, May to August, white and showy with crinkled petals 5 to 10 cm long; fruit, capsule 3 to 4 cm long. Hybridizes with *R. trichocalyx*.
Distribution: Dry washes, canyons, below 1200 m (4000 ft); coastal sage scrub (soft chaparral) and chaparral; Ventura or Santa Barbara to San Diego Counties, Baja California.
Fire Response Mechanism: Sprouts readily from underground roots.
Wildlife Value: Low value.
Cultural Value: Watery sap may have been used as a drink.

Rosa spp. Rose Family *(Rosaceae)*
ROSES. Erect or sprawling prickly shrubs. Leaves alternate, deciduous or almost evergreen, compound, with 5 to 7 leaflets arranged pinnately on leaf petiole. Ear-like appendices (stipules) at base of petioles are attached to stem along sides of petiole. Stem prickles in species discussed here may be straight or recurved. Flower, spring and summer, rose pink to red, may be borne singly or in cluster on floral stems. Munz (1974) lists three species in southern California; two included here, most common below 1800 m (6000 ft). Third species, *R. woodsii* Linde. with three high mountain, desert slope variations which are difficult to separate from *R. gymnocarpa*, since all have straight, slender prickles. *R. gymnocarpa* fruit easily identified because flower parts shed from rose hip fruit.
Distribution: Throughout region in moist and often more or less shaded areas.
Fire Response Mechanism: Most species resprout from basal organs.
Wildlife Value: Useful as food, cover.
Cultural Value: Most rose species used for numerous purposes, especially as source of minerals and vitamin C.

1a. Stem prickles usually stout and recurved; erect shrub in moist places associated with willows and other riparian communities below 1800 m.
CALIFORNIA WILD ROSE, *R. californica*
1b. Stem prickles mostly slender and straight; slender shrub in moist shaded woodlands below 1500 m.
WOOD ROSE, *R. gymnocarpa*

R. californica C. & S.
CALIFORNIA WILD ROSE *(fig. 109).* Erect, branched, 1 to 3 m tall, young stems greenish with short prickles, stems

Figure 110—Wood rose, *Rosa gymnocarpa* (McMinn 1939).

become reddish brown and armed with stout recurved thorns; leaves compound, divided into 5 to 7 leaflets; leaflets green, nearly oval, serrate, few scattered hairs to clearly pubescent, 1 to 5 cm long, wedge-shaped appendages (stipules) at base of leaf; flowers, April through August, rose-colored or pink, few to 30 in showy clusters, petals 1 to 2.5 cm long, ovary below sepals; fruit, bright orange rose hip, 8 to 16 mm long, 10 to 15 mm thick.

Distribution: Moist places, canyons, near streams, below 1800 m (6000 ft); willow and other riparian plant communities; Washington, Oregon, east to Rocky Mountains, south to Baja California.

Fire Response Mechanism: Roots from branchlets, suckers; stump-sprouts after fire, cutting.

Wildlife Value: Fruits staple for birds.

Cultural Value: Hips and flowers used in tea as source of vitamin C, calcium, phosphorus, iron (Clarke 1977).

R. gymnocarpa Nutt. in T. & G.

WOOD ROSE *(fig. 110).* Slender shrub mostly 1 m tall or less, reddish-brown stems armed with slender straight prickles, numerous bristles; leaves green, with stipules at base of petioles adherent to petiole stems, petiole up to 9 cm long including 5 to 7 leaflets nearly oval to roundish, leaflets 1 to 2.5 cm long, 0.6 to 1.2 cm wide with serrated margins commonly with glands on tips of teeth, glabrous and equal color on both surfaces; flowers, May to July, mostly solitary at ends of branchlets, red petals, ovary below sepals, ovary and sepals nearly glabrous; fruit, reddish rose hip; as hip matures, sepals and other flower parts dry and fall away, leaving naked rose hip.

Distribution: In more or less moist shaded woods below 1500 m (5000 ft); Palomar and San Gabriel Mountains, north to British Columbia, and Montana.

Fire Response Mechanism: Probably resprouts following fire, cutting.

Wildlife Value: Poor browse; flowers and hips important staple for birds, animals, insects.

Cultural Value: Rose hips an important source of vitamin C, calcium, phosphorus, and iron. Native Americans used roots, hips, and flowers (Clarke 1977).

Rubus spp. Rose Family *(Rosaceae)*

BLACKBERRIES. Trailing or erect shrubs with or without spines and bristles. Leaves alternate, simple, or compound; if compound, generally 3 to 5 parted. First year canes normally do not produce flowers; in second year, flowers appear and foliage may appear different. Stipules at base of petioles adnate (connected) to petioles. Flowers, 5-parted, usually white or pink or sometimes red solitary or in small clusters. Fruits, many druplets crowded on elevated receptical. Munz (1974) lists seven species in southern California, three of which are included here. Three other species which Munz lists have escaped from cultivation; the fourth, *R. glaucifolious* Kell. var. *ganderi* (Bailey), Munz identified with shaded woods and coniferous forests on Palomar and Cuyamaca Mountains in San Diego County at 1400 to 1650 m (4500-5500 ft). Of the following species, the above is most easily confused with western raspberry *(R. leucodermis* var. *bernardinus),* but stems of western raspberry more densely covered with prickles.

1a. Stems without prickles or spines, unarmed; common shrub in open conifer woodlands.
THIMBLEBERRY, *R. parviflorus*

1b. Stems with prickles.
- 2a. Leaves and petioles (stalk) with prickle-like pubescence; common shrub in many plant communities below 900 m.
CALIFORNIA BLACKBERRY, *R. ursinus*
- 2b. Leaves without prickles; leaf petioles (stalks) and stems with relatively few prickles; shrub in yellow pine woodlands. WESTERN RASPBERRY, *R. leucodermis* var. *bernardinus*

R. leucodermis Dougl. ex T. & G. var. *bernardinus* (Greene) Jeps.

WESTERN RASPBERRY *(fig. 111).* Straggly shrub with trailing, prickly stems, some recurved prickles, arched and branched, may root at tips, brambles 1 to 2 m high; leaves compound with 2 to 5 leaflets, whitish tomentum below, green above, prickly stalked, leaflets ovate to lanceolate, with terminal larger, 3 to 9 cm long, 1 to 5 cm wide, irregularly serrate; flowers, May to July, 3 to 10 blossoms in compact clusters, 5-petaled, white, 7 to 10 mm broad; fruit, dark red to black raspberry, sweet, sometimes dry and abortive.

Figure 111—Western raspberry, *Rubus leucodermis* (McMinn 1939).

Figure 112—Thimbleberry, *Rubus parviflorus.*

Distribution: Dry flats, slopes, 1400 to 2300 m (4700-7500 ft); yellow pine communities; mountains of southern California north to British Columbia.
Fire Response Mechanism: Root-sprouts after fire; spreads by rooting-branchlets.
Wildlife Value: Fruits staple for game, birds, and small mammals.
Cultural Value: Berries edible. Leaves can be dried, used for tea (Clarke 1977).

R. parviflorus Nutt.
THIMBLEBERRY *(fig. 112).* Low, scrambling deciduous shrub, 1 to 2 m tall, without prickles; leaves large, simple, palmately 5-lobed, 9 to 13 cm long, 10 to 16 cm broad, unequally serrate, green with soft pubescence to tomentose on both surfaces, more so below; flowers, March through August, blooms 2 to 5 cm broad, few-flowered clusters, white petals 1.5 to 2 cm long; fruit, dull red berry, somewhat like a blunt strawberry, 1 to 1.6 cm broad.
Distribution: Open woods and canyons, below 2400 m (8000 ft); yellow pine, mixed conifer, white fir woodlands or forests; San Diego County to Alaska.
Fire Response Mechanism: Sprouts from underground roots after fire, cutting.
Wildlife Value: Berries staple food of many birds and mammals; low value browse.
Cultural Value: Berries eaten raw or dried and stored, or used as ingredient in pemmican. Young shoots can be eaten fresh or boiled (Clarke 1977).

R. ursinus C. & S.
CALIFORNIA BLACKBERRY *(fig. 113).* Evergreen trailing or climbing shrub with many densely prickled stems, somewhat prickly leaves, young stems greenish becoming brown; leaves green, lighter below, pubescent above, nearly tomentose below, mostly 3-parted on bristly stalks, leaf sometimes not compound but palmate-shaped, leaflets mostly ovate to oval, 2.5 to 12 cm long, 2 to 7 cm wide; flowers, March through July, white blooms 2 to 3 cm across, few to several flowered clusters near end of leafy branchlets; fruit, sweet, black, somewhat bristly blackberry, to 2 cm long.
Distribution: Below 900 m (3000 ft); many plant communities; Oregon to Baja California.
Fire Response Mechanism: Sprouts from suckers after fire, cutting.
Wildlife Value: Fruits, important food of birds and animals.
Cultural Value: Fruits, edible. Roots boiled with water to relieve diarrhea. Half-ripe berries soaked in water to make a drink, leaves used for tea (Clarke 1977).

Salix spp. Willow-Family *(Salicaceae)*
WILLOWS. Erect, dioecious shrubs to large trees with simple, alternate, deciduous leaves commonly associated with moist places. Flowers are single sex; on separate plants and borne in compact clusters called catkins. Male and female flowers are on separate plants. Leaves often start growing after plants flowered and are usually long and relatively narrow. Leaves tend to end in gradually tapering tip or base.

Figure 113—California blackberry, *Rubus ursinus* (Munz 1974).

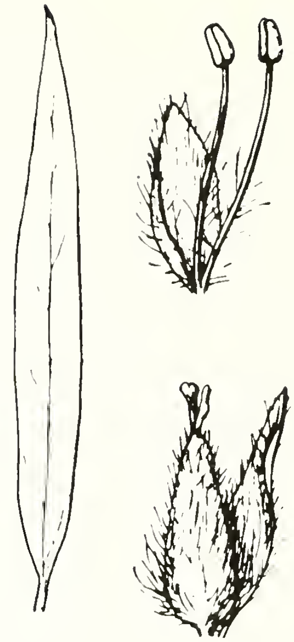


Figure 114—Sandbar willow, *Salix hindsiana* (McMinn 1939).

Often, one end of leaf is abrupt, the other tapered. Munz (1974) lists nine shrub willows; only two given here. Two species listed below commonly occur below 2100 m (7000 ft) while remaining species tend to be rare below 1800 m (6000 ft) or are desert species.

1a. Bark gray and furrowed, young stems with gray hair; shrub or small tree along streams and other wet places. SANDBAR WILLOW, *S. hindsiana*

1b. Bark smooth and dark brown to yellowish, twigs brownish to yellowish; shrub or small tree along streams and other wet places. ARROYO WILLOW, *S. lasiolepis*

S. hindsiana Benth.

SANDBAR WILLOW *(fig. 114).* Erect, deciduous shrub or small tree, to 7 m tall, with gray, furrowed bark; young stems with dense gray-woolly hair; leaves light green, simple, alternate, nearly linear, mostly 4 to 8 cm long, 0.2 to 1.6 cm wide, entire or with minute serrations or sometimes vaguely denticulate, mostly covered with gray, silky hairs, midvein with several laterals tending toward leaf tip; flowers, March to June, following leaf development in February and March; fruit, 2-valved, silky to nearly glabrous capsule, almost sessile. Similar shrubby species is narrowleaf willow, *S. exigua* Nutt., with leaves usually less hairy and greener above.

Distribution: Wet places, sandbars; common from Ventura to San Diego County, Baja California.

Fire Response Mechanism: Root-sprouts after fire, cuttings.

Wildlife Value: Staple browse for deer, preferred by livestock.

Cultural Value: Leaves and green bark probably ground and steeped in water for use as beverage to relieve colds, headaches, etc. Salicylic acid, an active ingredient of aspirin, first isolated in Europe from a *Salix*.

S. lasiolepis Benth.

ARROYO WILLOW *(fig. 115).* Erect, deciduous shrub or small tree, 2 to 10 m tall, smooth bark and yellowish to dark brown twigs; leaves simple, alternate, wider above the middle than below, oblanceolate or obovate, leaf size highly variable, 2 to 10 cm long, 0.6 to 3 cm wide, sometimes serrate, flat to rolled under at edges, green and hairless above, pubescent and white-filmy below; flowers, February to April (usually before, but sometimes coincidental with, leaf development) in slender, compact clusters (catkins), dark scales; fruit, 2-valved, glabrous or finely pubescent, pedicled capsule.

Distribution: Stream banks, sandbars, other wet places below 2100 m (7000 ft); many plant communities; throughout cismontane California, occasional on desert side, north to Washington, and Idaho.

Fire Response Mechanism: Stump-sprouts and root-sprouts after fire, cutting.

Wildlife Value: Staple or preferred browse of deer, bighorn sheep, and beaver.

Cultural Value: Leaves ground and steeped for several hours; beverage used to relieve colds, headaches, and other pains.

Figure 115—Arroyo willows, *Salix lasiolepis* (McMinn 1939).

Figure 116—White sage, *Salvia apiana* (McMinn 1939).

Salvia spp. Mint-Family *(Lamiaceae)*

1a. Leaves green to grayish green, at least above.
  2a. Leaves dark green and wrinkled above; shrub, foothills in coastal sage scrub to chamise chaparral. BLACK SAGE, *S. mellifera*
  2b. Leaves grayish green and wrinkled on both surfaces; occasional shrub in chamise chaparral and coastal sage scrub in San Diego County. CLEVELAND SAGE, *S. clevelandii*

1b. Leaves and stems whitish gray.
  2a. Plants generally coastal, below 600 m in coastal sage scrub. PURPLE SAGE, *S. leucophylla*
  2b. Plants more interior, up to 1500 m in woodlands and sage scrub. WHITE SAGE, *S. apiana*

S. apiana Jeps.

WHITE SAGE *(fig. 116)*. Subshrub, 1 to 2 m tall, very white on stems and leaves, long erect branches from base, young stems square; leaves simple, opposite, canescent, crowded at base of branches, lanceolate with some rounded teeth on leaf margins, 3 to 9 cm long, 1 to 3.5 cm wide, petioles variable, leaves appear white with fuzzy texture; flowers, March to July, white to pale lavender, blooms in whorls at leaf axils in terminal, few flowered racemes 50 to 150 cm long, pedicels 3 to 15 cm long on opposite sides of stems; fruit, 4 nutlets, 2.5 to 3 mm long, become separate at maturity.

Distribution: Widespread, mostly below 1500 m (5000 ft); yellow pine woodlands, sage scrub (soft chaparral), chamise chaparral; mountains of southern California to Colorado Desert, south to Baja California.

Fire Response Mechanism: Numerous root-sprouts and seedlings following fire.

Wildlife Value: Low value browse mostly by rodents. Seeds taken by birds and rodents. Flowers preferred by bees.

Cultural Value: Leaves used for tea, or in sweathouses to remove body odors before a hunt. Elongating stalks can be peeled and eaten.

S. clevelandii (Gray) Greene

CLEVELAND SAGE *(fig. 117)*. Sweetly fragrant low shrub, to 1 m tall, young stems square and tomentose; leaves grayish green covered with short hairs (canescent), somewhat wrinkled on both surfaces, dark green above, lighter below, elliptic-oblong with small rounded teeth on leaf margins, 1 to 5 cm long, 0.5 to 1.5 cm wide, petioles mostly 1 to 6 mm long; flowers, December through September, along elongated flowering stem in widely-spaced whorled clusters, blue violet to occasionally whitish; fruit, 4 nutlets, 1.5 to 2 mm long, becoming separate at maturity. Appears somewhat like S. mellifera, but with grayer foliage, and has characteristic sweet fragrance.

Figure 117—Cleveland sage, *Salvia clevelandii* (McMinn 1939).

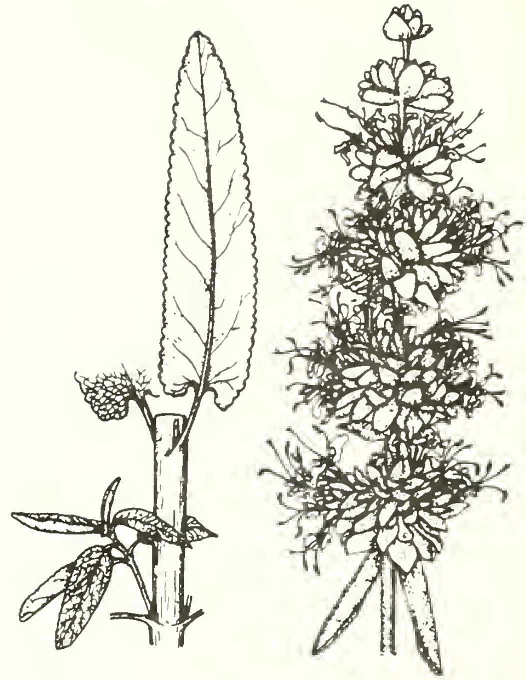


Figure 118—Purple sage, *Salvia leucophylla* (McMinn 1939).

Distribution: Below 1100 m (3000 ft); chamise chaparral to coastal sage scrub (soft chaparral); San Diego County to Baja California.
Fire Response Mechanism: Variable sprouter from roots and stems after cutting; rather flammable especially when flower stems mature and become dry.
Wildlife Value: Low value browse.
Cultural Value: Leaves excellent for tea or cooking.

S. leucophylla Greene
PURPLE SAGE *(fig. 118)*. Much-branched shrub, 1 to 1.5 m tall, whitish stems, young stems square, reddish becoming gray with age; leaves opposite with several secondary leaves at primary leaf node, primary leaves ovate to almost lance-shaped, 6 or 7 cm long, 0.5 to 2.5 cm wide, petioles (if present) 3 to 8 mm long, leaves with rounded teeth on margins, grayish green above with rough, wrinkled surface, paler and white, fuzzy below; flowers, April to June, lavender, 3 to 5 compact, whorled clusters on elongated flowering stems; fruit, 4 nutlets, 3 to 4 mm long, separates at maturity.
Distribution: Coastal mountains below 600 m (2000 ft); coastal sage scrub (soft chaparral); Orange County (Santiago Canyon), north to San Luis Obispo County.
Fire Response Mechanism: Root-sprouts after fire, cutting; rather flammable, especially when flower stems mature and become dry.
Wildlife Value: Low value browse; seeds eaten by birds.
Cultural Value: Can be used to make pleasant herb tea.

S. mellifera Greene
BLACK SAGE *(fig. 119)*. Shrub, 1 to 2 m tall, young stems square, hairy, sometimes purple, commonly greenish, become brownish gray with age; leaves simple, opposite, mostly elliptic to oblong, dark green with many small crenate (rounded teeth) margins, wrinkled above, lighter to ash-colored below and covered with short hairs (canescent), 2 to 6 cm long, less than 1.5 cm wide, petioles (if present) 10 to 12 mm long; flowers, March to June, pale blue to whitish, 2-lipped, compact whorls, spaced along elongated stem; fruit, 4 nutlets about 2 mm long, separates at maturity.
Distribution: Foothills below 900 m (3000 ft); coastal sage scrub (soft chaparral) to chamise chaparral; Contra Costa County, Mt. Diablo, south to Baja California.
Fire Response Mechanism: Rather flammable, especially when flower stems mature and become dry; many root-sprouts and seedlings after fire.
Wildlife Value: Browsed by rodents, low value; seeds staple of birds, small mammals; flowers preferred by honey bees.
Cultural Value: Seeds parched and ground into meal. Leaves and stalks used as condiment.

Sambucus mexicana Presl.
Honeysuckle Family *(Caprifoliaceae)*
MEXICAN ELDERBERRY *(fig. 120)*. Tall shrub or small tree, 2 to 8 m tall, young stems reddish becoming brown, old bark heavily ridged, thick and grayish; leaves opposite, compound, divided into 3 or more (commonly 5, sometimes 7)

Figure 119—Black sage, *Salvia mellifera* (inset, Munz 1974).

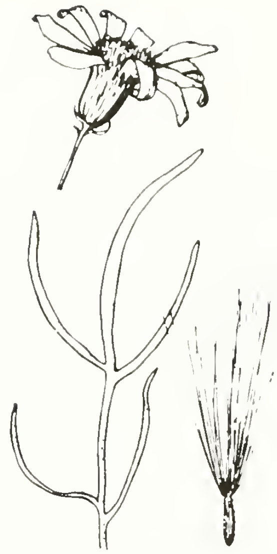


Figure 121—Bush groundsel, *Senecio douglasii* (McMinn 1939).

Figure 120—Mexican elderberry, *Sambucus mexicana* (Munz 1974).

leaflets, terminal leaflet 4 to 14 cm long, 2 to 5 cm wide, leaflets ovate to obovate, finely serrate and pubescent to glabrous; flowers, April through July, small blooms with five dull white petals in flat-topped spreading cluster, 4 to 10 cm across; fruit, bluish drupe about 5 mm across, white filmy covering. Blue elderberry (*S. coerulea* Raf.) occurs at higher elevations to 3000 m (10,000 ft), 5 to 9 leaflets, better flavored berries.

Distribution: Common in canyons and valleys, below 1700 m (5600 ft); many plant communities; Lake and Glenn Counties, south to Baja California, and Arizona.

Fire Response Mechanism: Stump-sprouts after fire.

Wildlife Value: Staple browse plant; fruits preferred by birds, small mammals, rodents.

Cultural Value: Flower clusters dried, preserved, and later cooked to make sweet sauce. Berries eaten fresh or stored, used to make purple black dye. Stems used to make yellow or orange dye. Native Americans made flutes from branches and arrow shafts from straight stems (Sweet 1962).

Senecio douglasii DC. Sunflower Family *(Asteraceae)*

BUSH GROUNDSEL *(fig. 121).* Straggly or straight branched subshrub, 1 to 1.6 m tall, leafy up to flowers, young stems light green and tomentose becoming less tomentose and brown with age, mature bark gray, stems marked with longitudinal lines or furrows; leaves 3 to 10 cm long, linear, filiform or divided into 5 to 9 linear lobes, upper leaves commonly 3-lobbed or entire, leaf divisions usually deep enough to make

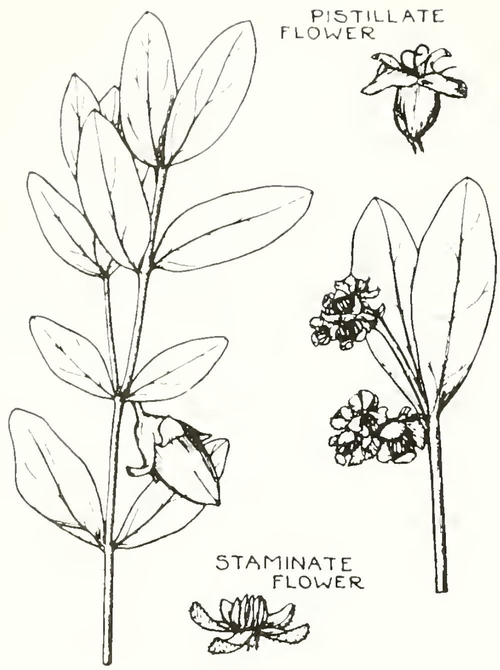


Figure 122—Jojoba (goatnut), *Simmondsia chinensis* (McMinn 1939).

Figure 123—Spanish broom, *Spartium junceum.*

leaf appear compound, divisions flattened and near filiform, gray green above, whitish fuzz below; flowers, April through November, several to many showy, yellow heads with 10 to 13 rays, 10 to 15 mm long; fruit, hairy akene about 4 mm long. Munz (1974) recognizes *S. spartiodes* T. & G. as species of higher elevation, 2400 to 3200 m (8000-10,500 ft). This species grows from a heavy woody base (caudex), stems leafy up to flowers. Leaves mostly linear, entire, and glabrous, 3 to 10 cm long, 1.5 to 5 mm wide; flowers approximately same as above, blooming more pronounced mid-summer.

Distribution: Common in washes, dry hillsides, below 1800 m (6000 ft); coastal sage scrub (soft chaparral) to scrub oak chaparral; coast ranges, Mendocino County to Baja California.

Fire Response Mechanism: Information not available.

Wildlife Value: Low value.

Cultural Value: None known.

Simmondsia chinensis (Link) Schneider.
Box Family (*Simmondsiaceae* formerly *Buxaceae* [Munz 1974])

JOJOBA (GOATNUT) *(fig. 122).* Rigid, spreading dioecious evergreen shrub, 1 to 2 m tall, young stems densely pubescent and green becoming gray; leaves leathery, simple, opposite, approximately ovate, 2 to 5 cm long, 1.0 to 2.5 cm wide, petiole very short or absent, leaf surfaces about equally covered with fine pubescence, pale green or yellowish, 1- to 3-veined from base; flowers, March to May, male and female flowers on separate plants, pale green or yellowish, 3 to 4 mm long with sepals only, female flowers become 10 to 20 mm long as fruit develops; fruit, smooth cylindrical capsule about 2 cm long, resembling an acorn.

Distribution: Dry barren slopes, below 1500 m (5000 ft); creosote bush, Joshua tree woodland; Little San Bernardino Mountains, west to Riverside, San Diego Counties to Baja California.

Fire Response Mechanism: Information not available.

Wildlife Value: Fruits staple for small mammals, birds. Leaves and twigs staple browse for livestock.

Cultural Value: Seeds eaten fresh or ground and mixed with water for coffee-like beverage (Clarke 1977). Oil from nut has considerable commercial value as whale oil substitute.

Spartium junceum L. Pea Family *(Fabaceae)*

SPANISH BROOM *(fig. 123).* Tall broom-like drought deciduous shrub, to 3 m tall, stems green becoming gray at base often nearly leafless; leaves (when present) green, simple, alternate, entire and glabrous, oblong-oblanceolate, 1 to 3 cm long, 2 to 6 mm wide; flowers, April to June, bright yellow, 2 to 2.5 cm long, fragrant, terminal clusters on straight green stems; fruit, pod 5 to 10 cm long.

Distribution: Frequent escapee from cultivation or planted along roadsides below 2100 m (7000 ft).

Fire Response Mechanism: Information not available.

Wildlife Value: Not used.

Cultural Value: Introduced.

Figure 124—Storax, *Styrax officinalis* var. *fulvescens* (Munz 1974).

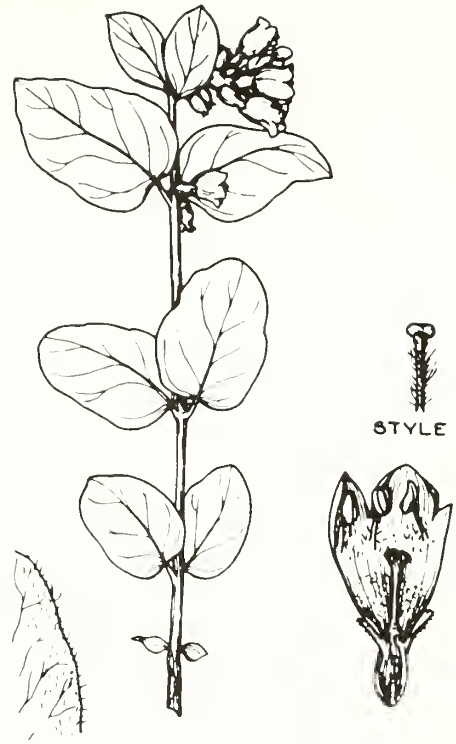


Figure 125—Spreading snowberry, *Symphoricarpos mollis* (McMinn 1939).

Styrax officinalis L. var. *fulvescens* (Eastw.) M. & J.
Storax Family *(Styracaceae)*

STORAX *(fig. 124)*. Erect, deciduous shrub to 4 m tall with grayish twigs, young stems pubescent; leaves 2 to 9 cm long, 1.5 to 7 cm wide, upper surface pubescent, rather short brownish matted hair below, roundish (round-ovate to obovate), obtuse or subcordate base, obtuse to rounded apex, petioles to 10 mm long; flowers, April to May, terminal clusters of white blossoms with 4- to 10-lobed corolla, 12 to 18 mm long, persistent, unequally toothed calyx on flowering branchlets, peduncles 6 to 12 mm long; fruit, globose-oval seed about 12 to 14 mm long.
Distribution: On slopes and in canyons to 1500 m (5000 ft); chaparral and southern oak woodlands from San Luis Obispo south to San Diego.
Fire Response Mechanism: Not known.
Wildlife Value: Unknown.
Cultural Value: None known.

Symphoricarpos mollis Nutt.
Honeysuckle Family *(Caprifoliaceae)*

SPREADING SNOWBERRY *(fig. 125)*. Low sprawling, deciduous shrub, stems to 90 cm long, twigs reddish, usually with dense short, curved hairs; leaves opposite, grayish green to light green, oval to nearly ovate, usually entire, rarely lobed, short pubescence above and densely pubescent with whitish appearance beneath, 1 to 4 cm long, 0.7 to 3 cm wide; flowers, March through August, short clusters or pairs, corolla lobes pink, bell shaped, 3 to 5 mm long, lobes 2 to 3 mm long; fruit, white berry-like drupe (hence the name snowberry).
Distribution: Shaded slopes, below 900 m (3000 ft), sometimes to 1500 m (5000 ft); oak woodland, conifer forest, chaparral, scrub oak chaparral; coast ranges, Mendocino County to Baja California. Similar species, MOUNTAIN SNOWBERRY, *S. parishii*, Rydb., funnel-shaped, white yellow to pink flower; leaves thicker than *S. mollis*, grayish green on both surfaces; occurs at higher elevations 1500 to 3400 m (5000-11,000 ft) throughout San Bernardino National Forest to Humboldt County.
Fire Response Mechanism: Sometimes roots at branchlet tips; stump sprouts after fire.
Wildlife Value: Staple or preferred browse for deer, preferred browse of cattle and sheep. Honey bees use flowers.
Cultural Value: Leaves contain saponin, possibly in poisonous amounts; Native Americans used portions of roots and fruits for medicinal purposes (Sweet 1962).

Tetradymia comosa Gray. Sunflower Family *(Asteraceae)*

HAIRY HORSEBRUSH *(fig. 126)*. Erect bush, 0.5 to 1.2 m tall, white fuzzy (tomentose) branchlets, light gray, darkening to dark gray with patches of fuzzy scales; tomentose leaves, simple, entire, alternate, whitish, linear, 2.5 to 5 cm long, to 2 mm wide, early leaves flexible, later become rigid and spine-tipped, sometimes short leaves in fascicle with principle leaves; flowers, June to September, heads of 6 to 10 tube flowers (no ray flowers) subtended by 5 to 6 woolly bracts; fruit, akene covered with long, woolly hairs.

Figure 126—Hairy horsebrush, *Tetradymia comosa* (McMinn 1939).

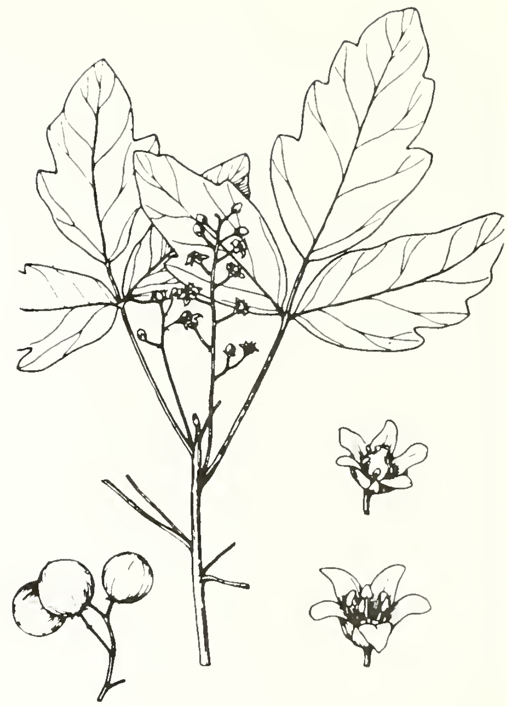


Figure 127—Poison-oak, *Toxicodendron diversilobum* (McMinn 1939).

Distribution: Dry places usually on interior mountain slopes, below 1500 m (5000 ft); coastal sage scrub (soft chaparral), chaparral and many other shrub plant communities; southern California, north to Newhall, occasional in Mojave Desert.
Fire Response Mechanism: Stump-sprouts after fire.
Wildlife Value: Low value.
Cultural Value: None known.

Toxicodendron diversilobum Greene.
Sumac Family *(Anacardiaceae)*
POISON-OAK *(fig. 127).* Erect or spreading deciduous shrub, 1 to 3 m tall, young stems olive green to reddish becoming dark brown and somewhat shreddy; leaves 3-foliate, divisions with rounded serration or lobed, ovate to round in outline, leaflets 2 to 7 cm long, 1 to 5 cm wide, leaves bright green and shiny above, paler below, leaflets glabrous to more or less pubescent on veins, new leaves usually red; flowers, March through June, small, greenish white blossoms in drooping clusters from leaf axils; fruit, white or brownish, berry-like drupe.
Distribution: Low places, thickets, stream banks, below 1500 m (5000 ft); many plant communities; Baja California north to Oregon and Washington.
Fire Response Mechanism: Root-sprouts.
Wildlife Value: Fair to poor browse for deer and livestock.
Cultural Value: Oils from this species cause most people to break out with minor to serious allergic skin rash and swelling, may be more serious if taken internally. Reputedly, Native Americans were not allergic to the plant and used sap for black dye in basketry.

Trichostema lanatum Benth. Mint Family *(Lamiaceae)*
WOOLLY BLUE CURLS *(fig. 128).* Small rounded evergreen largely woody subshrub, 0.5 to 1.5 m tall, young stems square, hairy and reddish becoming brown and less hairy, mature stems with shreddy bark; leaves lance-linear, 3.5 to 7.5 cm long, 1 to 6 mm wide, rolled under at edges, green above, white and fuzzy below, bundles of small leaves in axils of larger opposite pairs; flowers, April to August, short clusters from leaf axils along upper stems, blooms are irregular, blue and fuzzy with long stamens extending beyond corolla, blooms more or less covered with bluish pink to nearly white hairs; fruit, 4 nutlets, joined at base, roughened with prominent veins and short stiff hair.
Distribution: Dry slopes of coastal mountains, below 1400 m (4500 ft); San Diego to Monterey Counties.
Fire Response Mechanism: Sprouting ability unknown, numerous seedlings after fire.
Wildlife Value: Low value; honey bees use flowers.
Cultural Value: Leaves and flowers boiled for tea to relieve stomach ailments and for various uses (Sweet 1962).

Turricula parryi (Gray) Macbr.
Waterleaf Family *(Hydrophyllaceae)*
POODLE-DOG BUSH *(fig. 129).* Coarse evergreen subshrub 1 to 2.5 m tall, glandular-hairy purplish stems becom-

Figure 128—Woolly blue curls, *Trichostema lanatum* (McMinn 1939).

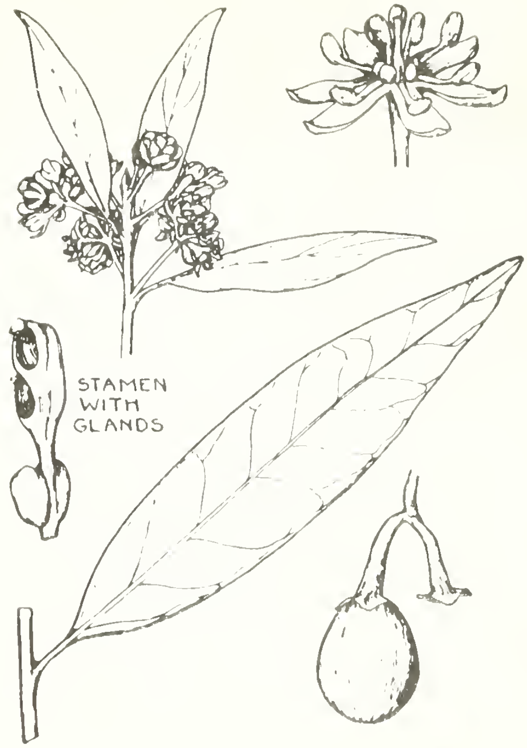


Figure 130—California bay (laurel), *Umbellularia californica* (McMinn 1939).

Figure 129—Poodle-dog bush, *Turricula parryi* (McMinn 1939).

ing brown at base, sticky, ill-smelling herbage, drooping and brown with age, appearing like shaggy poodle heads; leaves alternate, pubescent or hirsute, crowded, 5 to 20 cm long, 1 to 2.5 cm wide, toothed or entire, without petioles; flowers, June to August, numerous in a scorpiod raceme, coiled fiddle-neck cluster commonly more than 10 cm long, individual flowers purple, tubular and pubescent, 13 to 18 mm long; fruit, membranous capsule. Plants may be mostly herbaceous.

Distribution: Occasional in dry disturbed places, 300 to 2400 m (1000-8000 ft); chaparral to yellow pine communities; Fresno, Kern Counties, Sierra Nevada to Baja California.

Fire Response Mechanism: Nonsprouter, profuse seedlings on burns.

Wildlife Value: Low value, insects use flowers.

Cultural Value: None known; contact with this plant causes some people to have dermatitis.

Umbellularia californica (H. & A.) Nutt.

Laurel Family *(Lauraceae)*

CALIFORNIA BAY (LAUREL) *(fig. 130).* Normally an evergreen tree to 30 m tall or large erect shrub on exposed slopes and in chaparral, young stems with green bark turning brown with age; leaves entire, simple, alternate, shiny, lance-shaped or oblong, 3 to 10 cm long, 1.5 to 4 cm wide, pungent odor when crushed; flowers, January through June, small, greenish yellow, 4- to 10-flowered clusters; fruit greenish to dark purple round-ovoid drupe, 2 to 2.5 cm long containing hard stone.

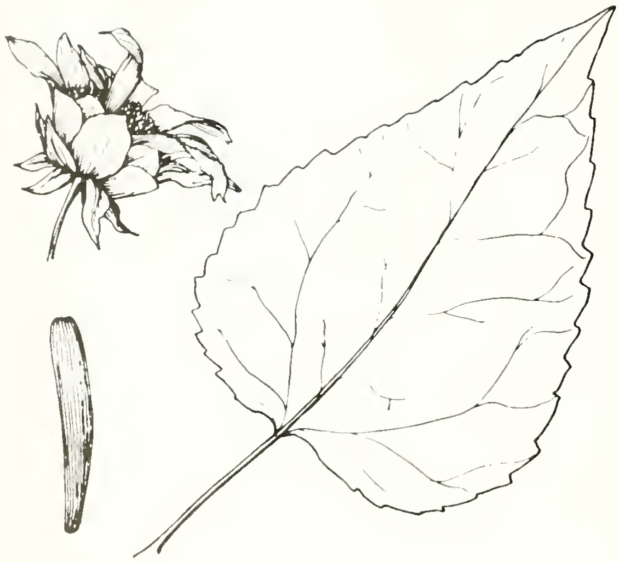


Figure 131—Canyon sunflower, *Venegasia carpesioides* (McMinn 1939).

Figure 132—San Diego sunflower, *Viguiera laciniata* (McMinn 1939).

Distribution: Common in canyons, shaded slopes; many plant communities from mesic chaparral to dense woodlands; mostly below 1500 m (5000 ft); San Diego County to southwest Oregon.
Fire Response Mechanism: Vigorous stump and crown sprouts after fire, cutting.
Wildlife Value: Low value browse. Fruits eaten by Steller's jays and similar birds.
Cultural Value: Leaves can be dried and used as condiment. Inhaling too much of aromatic leaves can cause headaches. Native Americans used leaves to cure headaches by placing piece of leaf in nostril and binding several leaves to forehead (Clarke 1977).

Venegasia carpesioides DC. Sunflower Family *(Asteraceae)*
CANYON SUNFLOWER *(fig. 131).* Erect perennial herbs from a woody base, to 2.5 m tall, young stems purplish to brown becoming more definitely brown with age, stem has pith center, stems and leaves sparingly pubescent; leaves, thin, alternate and simple, 3 to 15 cm long, 1.5 to 12 cm wide, large serrations, notched at base and somewhat heart-shaped, sometimes lobed, usually darker green above; flowers, March through August, blooms are large heads with 13 to 20 yellow female ray-flowers, 15 to 20 mm long, many male tube flowers; fruit, akene.
Distribution: Shaded canyon walls, coastal to 800 m (2700 ft); coastal sage scrub (soft chaparral), scrub oak chaparral; Monterey County, south to San Diego, and Baja California.

Fire Response Mechanism: Seedlings.
Wildlife Value: Birds like seeds.
Cultural Value: None known.

Viguiera laciniata Gray Sunflower Family *(Asteraceae)*
SAN DIEGO SUNFLOWER *(fig. 132).* Rounded subshrub, 1 to 2 m tall, more or less resinous with tough feeling surfaces, much-branched, slender rough pubescent and more or less brittle stems, young stems greenish, bark becoming brown with age; leaves simple, at least lower ones opposite, 2 to 5 cm long, to 1.5 cm wide, lance-shaped, often with an abrupt base, margins serrated, thick and leathery, darker green above with sparse short, sometimes recurved hairs especially on veins; flowers, February to June, blooms in heads with 8 to 13 rays, 10 to 15 mm long, many tube flowers; fruit, laterally compressed akene.
Distribution: Dry slopes, to 800 m (2500 ft); chamise chaparral, coastal sage scrub (soft chaparral); southwest San Diego County to Baja California.
Fire Response Mechanism: Unknown.
Wildlife Value: Low value browse.
Cultural Value: None known.

Vitis girdiana Munson. Grape Family *(Vitaceae)*
DESERT WILD GRAPE *(fig. 133).* Deciduous shrub with trailing tendril bearing stems climbing over and supported by other plants or may be bush-like, young stems with some hairyness becoming brown with age; leaves, simple, alternate,

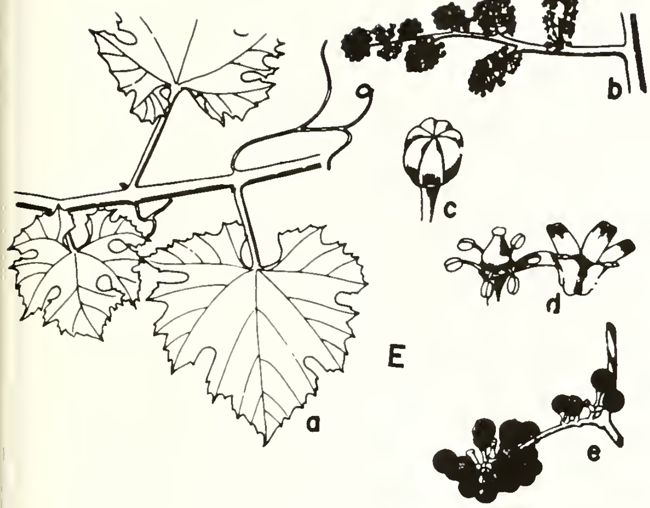


Figure 133—Desert wild grape, *Vitis girdiana:* (a) vegetative branch, (b) fruiting branch, (c) bud, (d) flower, (e) fruit (Munz 1974).

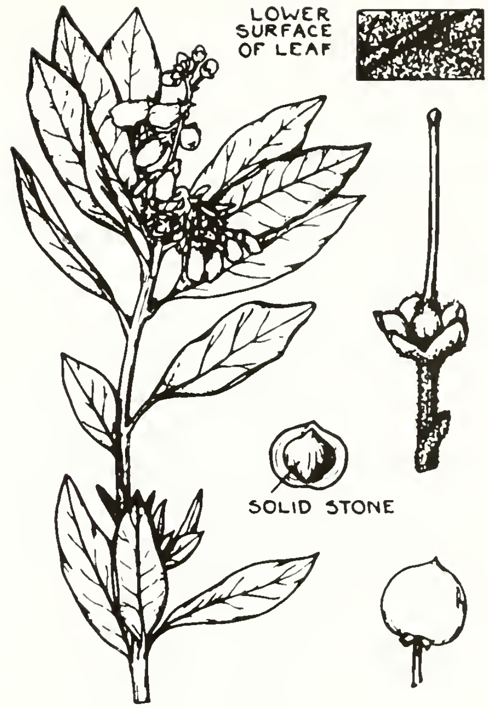


Figure 134—Mission-manzanita, *Xylococcus bicolor* (McMinn 1939).

green to light green, darker above, 3 or 5 veins from heart-shaped base, ovate in outline but tips tend to be triangular, lobed and coarsely serrate, with cobwebby hairs beneath, 5 to 10 cm long, 5 to 16 cm wide, petioles 3 to 5 cm long; flowers, May and June, small, fragrant, greenish blossoms in racemes to 12 cm long; fruit, smooth, blackish berry, 3 to 6 mm diameter.

Distribution: Along streams, canyon bottoms below 1200 m (4000 ft); scrub oak chaparral, live oak woodland, coastal sage scrub (soft chaparral); Inyo and Santa Barbara Counties, south to Baja California.

Fire Response Mechanism: Information not available, probably root sprouts if not too severely burned.

Wildlife Value: Berries staple for birds and animals.

Cultural Value: Native Americans ate berries raw or dried and stored them. Juice of grape leaves used to treat diarrhea and lust in women (Clarke 1977).

Xylococcus bicolor Nutt. Heath Family *(Ericaceae)*

MISSION MANZANITA *(fig. 134).* Erect evergreen shrub to 3 m tall, shredded reddish to graybrown bark; leaves lanceolate to ovate or obovate, alternate, dark green and shiny above, often with obvious vein indentations, whitish and pubescent to tomentose below, thick and leathery, involute or at least rolled under at margins, tapering at both ends, 3 to 6 cm long, 1 to 2 cm wide, petiole 0.5 to 1 cm long; flowers, December to March, white or pink urn-shaped blossoms, 8 to 9 mm long; fruit, black or reddish dry drupe, 5 to 8 mm diameter, containing hard stone.

Distribution: Below 600 m (2000 ft); chamise chaparral and ceanothus chaparral; west San Diego County to Baja California.

Fire Response Mechanism: Stump or crown sprouts after fire, cutting.

Wildlife Value: Low value browse and fruit.

Cultural Value: None known.

Yucca spp. Agave Family *(Agavaceae)*

1a. Leaves gray green, with sharp, black spine at the tips, never with stringy edges; common in dry coastal sage scrub, chaparral, creosote bush between 300 and 2400 m.
CHAPARRAL YUCCA, *Y. whipplei*

1b. Leaves with stringy edges; occasional on dry inland slopes on both sides of the mountains below 1500 m.
SPANISH BAYONET, *Y. schidigera*

Y. schidigera Roezl ex. Ortgies

SPANISH DAGGER *(fig. 135).* Stiff leaved, robust plant with short trunk; leaves concave or flattened, green to greenish yellow with brown tip, to 1 m long, 2 to 6 cm wide, sharp-pointed spine tip, stringy edges; flowers, March to June, on extended stalk to 30 cm long (short compared with *Y. whipplei*), blossoms whitish with purple tinge, bell-shaped,

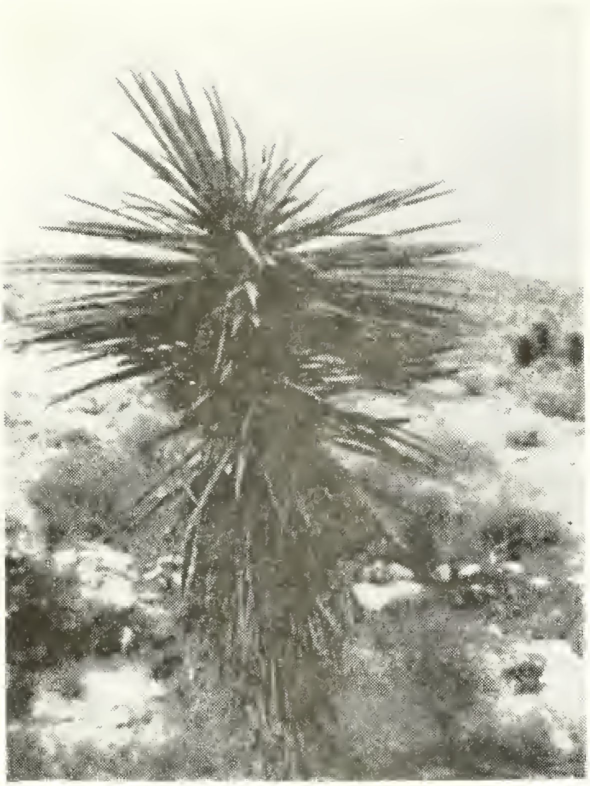


Figure 135—Spanish dagger, *Yucca schidigera.*

Figure 136—Chaparral yucca, *Yucca whipplei.*

to 4 cm long; fruit, capsule to 11 cm long, 4 cm wide. Pollination done only by yucca moth (*Pronuba* sp.).
Distribution: Dry rocky slopes, below 1500 m (5000 ft); both sides of southern California mountains, Mojave Desert, San Bernardino Valley, San Jacinto, Santa Rosa Mountains south to San Diego, and Baja California. On desert side, Joshua Tree, *Y. brevifolia* Engelm. in Wats., root-sprouts after fire and may appear shrubby at that time.
Fire Response Mechanism: Root-sprouts after fire, cutting.
Wildlife Value: Low value browse. Indicator of severe range problems if used by cattle.
Cultural Value: Fruits of chaparral yucca edible. Leaves used for cordage, leaf tips could be used as a needle.

Y. whipplei Torr.
CHAPARRAL YUCCA (OUR LORD'S CANDLE) *(fig. 136).* A stiff-leaved robust plant, apparently stemless, has tall flower stalk with massive fruiting panicle; leaves all basal, bright green to gray green with brown spine tip, 0.3 to 1 m long, 0.8 to 1.0 cm wide, more or less flattened or concave, rigid, slender terminal spine 1 to 2 cm long; flower stalk sprouting from base, to 2.5 m tall, flowers, April and May, cream white, or tinged purple, open bell-shaped, 2 to 4 cm long; fruit, capsule about 4 cm long and 3 cm across. After fruiting is complete, entire aerial part of plant dies and regeneration may occur from seed or short rhizomes or stolons. Pollination only by small yucca moth (*Pronuba* sp.).
Distribution: Dry slopes, 300 to 2400 m (1000 to 8000 ft); coastal sage scrub (soft chaparral), creosote bush, manzanita, to chamise chaparral; Monterey County, southern Sierra Nevadas to southern California.
Fire Response Mechanism: Basal resprouts if not too severely burned and a burned stand frequently produces a profusion of flowers in a year or two after fire.
Wildlife Value: Low value browse, fruits eaten by birds and insects.
Cultural Value: Fruits and flowers edible (Clarke 1977).

REFERENCES

Abrams, LeRoy. **Illustrated flora of the Pacific States.** 4 v. Palo Alto, CA: Stanford Univ. Press; 1960. 2791 p.

Balls, Edward K. **Early uses of California plants.** Berkeley: Univ. of California Press; 1972. 103 p.

Clarke, Charlotte Bringle. **Edible and useful plants of California.** Berkeley: Univ. of California Press; 1977. 280 p.

Collins, Barbara J. **Key to coastal and chaparral flowering plants of southern California.** Northridge, CA: California Lutheran College; 1974a. 249 p.

Collins, Barbara J. **Key to trees and wildflowers of the mountains of southern California.** Northridge, CA: California Lutheran College; 1974b. 277 p.

Hanes, Ted L. **Ecological studies on two closely related chaparral shrubs in southern California.** Ecological Monographs 35(2):213-235; 1965 Spring.

Martin, A. C.; Zim, H. S.; Nelson, A. L. **American wildlife and plants; a guide to wildlife food habits.** New York: Dover Publ., Inc.; 1951. 500 p.

McMinn, Howard E. **An illustrated manual of California shrubs.** Berkeley: Univ. of California Press; 1939. 663 p.

Medsger, Oliver Perry. **Edible wild plants.** New York: Collier MacMillan Publishers; 1966. 323 p.

Munz, Philip A. **A flora of southern California.** Berkeley: Univ. of California Press; 1974. 1086 p.

Munz, Philip A.; Keck, David. **A California flora and supplement.** Berkeley: Univ. of California Press; 1970. 1681 p.

Raven, Peter H. **Native shrubs of southern California.** Berkeley: Univ. of California Press; 1966. 132 p.

Smith, Clifton F. **A flora of the Santa Barbara region.** Santa Barbara: Santa Barbara Museum of Natural History; 1976. 331 p.

Stebbins, G. L.; Major, J. **Endemism and speciation flora.** Ecological Monographs 35(1):1-35; 1965 Winter.

Sweet, Muriel. **Common edible and useful plants of the west.** Healdsburg, CA: Naturegraph Co.; 1962. 64 p.

U.S. Department of Agriculture, Forest Service. **Range analysis.** FSH 2209.21. San Francisco: Div. Range and Wildlife Manage., California Region, Forest Service, U.S. Department of Agriculture; 1969 [Loose leaf, updated].

Van Dersal, William R. **Native woody plants of the United States.** Misc. Publ. No. 303. Washington, DC.; U.S. Department of Agriculture; 1938. 362 p.

APPENDIX A

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

Family/genus	Common name	Total: Genera	Total: Species	Chaparral: Shrubs	Chaparral: Sub-shrubs	Shrubs and subshrubs: Elevation ranges (meters)[3]	Shrubs and subshrubs: Major aspect[4]	Shrubs and subshrubs: Geographic zone[5]	Shrubs and subshrubs: Typical vegetation types[6]
Aceraceae	Maple family	1							
Acer	Maple		3	1	0	<2000-2700	MONT, TRANS	SJ, SB, HD	MCF, MCW
Agavaceae	Agave family	3							
Yucca	Yucca[2]		4	2	0	<2400	CIS, TRANS	FH, DC	C, CSS, CBS
Aizoaceae	Carpet-weed family	11							
Aptena			1	0	1	<150	CST	CST, I	INTRO
Carpobrotus	False-fig		2	0	2	<150	CST	CST	CS, CSS, INTRO
Drosanthemum			2	0	2	<500	CST	CST	INTRO
Anacardiaceae	Sumac family	3							
Rhus	Sumac[2]		4	4	0	<1700	CIS	CST-FH	C, CSS, OW
Toxicodendron	Poison-oak[2]		1	1	0	<1500	CIS	CST-FH	C, CSS, OW, WW
Asclepidaceae	Milkweed family	5							
Sarcostemma			2	0	1	<600	CST, TRANS	CST, D	CSS, C, CBS
Asteraceae	Sunflower family	149							
Ambrosia	Bursage		10	1	1	<300	CIS	CST	CSS, C
Artemisia	Sagebrush[2]		13	4	1	<900 (500-3200)	CIS, TRANS	CST, MTS, D	CSS, SGS, W, C, CF
Aster	Aster		15	0	2	<1100	CIS, TRANS	CST-LD AS,	CSS, CBS
Baccharis	Baccharis[2]		8	5	1	<1100	CIS, TRANS	CST-FH	CSS, WW, CBS, C, CS, CSM
Bebbia	Sweet Bush		1	0	1	<1200	CST, TRANS	CST, D	CBS, CSS
Brickellia	Brickellbush[2]		12	2	1	<2300	CIS, TRANS	CST-D	CBS, CSS, PJ, C, JTW
Chaenactis			10	0	1	1500-2100	CIS	SJ, SR	C, YPF
Chrysopsis	Golden-aster		2	0	1	UND	UND	SB-SN	RARE OR EXTINCT
Chrysothamnus	Rabbit-brush[2]		7	1	1	1200-3400	TRANS, CIS	SB, SJ, MP	CW, MC, SGS, PJ
Coreopsis	Coreopsis (Tickseed)		7	1	0	<100 CST	CST	CS, CSS	
Corethrogyne	Cudweed-Aster		1	0	1	150	CST	CST	CSS
Encelia	Encelia[2]		4	0	3	<1200	CIS, TRANS	CST-FH-D	CBS, CSS, C
Eriophyllum	Golden-yarrow		10	0	3	<150	CST	CST-FH, I	CSS, CS, C
Gutierrezia	Matchweed		3	0	1	<1100	CIS, TRANS	FH	C, VG, CSS
Haplopappus	Goldenbush[2]		25	11	2	<2100	CST, CIS, TRANS	FH, CST, I, MTS	CSS, C, CS, CBS,
Hemizonia	Tarweed		15	2	0	<200	CST	I, CST	C, CSS
Hymenoclea	Burrobrush		2	1	0	<550	CIS	FH, CW	C, CSS
Iva	Poverty weed		3	0	2	<2000 <300	CIS, TRANS	CST, D	AS, CSM
Lepidospartum	Scale-broom[2]		2	1	0	<1500	CST, TRANS	CST-FH-D	SS, C, JTW
Malacothrix	Cliff-aster		11	0	2	<600	CST, CIS	CST-FH	CSS, CS
Munzothamnus			1	1	0	<200	I	I	CSS
Pulchea	Arrowweed		2	1	0	<300	CST, TRANS	CST-FH	CSS, CBS, WW

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

Family, genus	Common name	Total		Chaparral		Shrubs and subshrubs			
		Genera	Species	Shrubs	Sub-shrubs	Elevation ranges (meters)[3]	Major aspect[4]	Geographic zone[5]	Typical vegetation types[6]
Porophyllum	Poreleaf		1	0	1	60-1500	CIS, TRANS	CST-FH-D	CBS, CSS
Santolina	Lavender-Cotton		1	1	0	<100	CST	CST	INTRO
Senecio	Senecio[2]		17	0	2	<1800	CIS	CST-FH, I	CSS, C, VG, FHW
Stephanomera	Tejon Milk-Aster		6	0	1	<1800	CIS	SB, SA	C, YPF
Tetradymia	Horsebrush[2]		7	1	0	<1500	CIS, TRANS	FH, SB, SG	CSS, C
Vengasia	Canyon-sunflower[2]		1	0	1	<800	CST	FH-CST	CSS, C, OW
Viguiera	Desert-sunflower[2]		4	0	2	<1500	D, CST	D-CST	CBS, C, CSS
Batidaceae	Batis family	1							
Batis	Saltwort		1	0	1	<150	CST	CST	CS, CSM
Berberidaceae	Barberry family	1							
Berberis	Barberry[2]		7	5	0	600-2000 (<600)	CIS	MTS, FH	C, CSS, PJ, CF, CW
Bignoniaceae	Bignonia family	1							
Chilopsis	Desert-willow		1	1	0	<1500	TRANS	FH-D	C, CBS, JTW
Brassicaceae	Mustard family	38							
Erysimum	Wallflower		5	0	2	<150	CST	CST, I	CS
Cactaceae	Cactus family	10							
Bergerocactus			1	0	1	<150	CST	CST, I	CSS
Echinocereus	Hedgehog cactus		2	0	1	1500-2100	MONT	SB, SJ, D	PJ, YPF
Ferocactus	Barrel cactus		2	1	0	<300	CIS	FH	CSS, VG
Opuntia	Prickly-Pear		21	8	0	<1800	CST, CIS	CST, FH	C, CSS, YPF, VG
Capparidaceae	Caper family	5							
Isomeris	Bladderpod[2]		1	1	0	<1200	CST, TRANS	I, CST, D	CBS, JTW, CSS
Caprifoliaceae	Honeysuckle family	3							
Lonicera	Honeysuckle[2]		5	5	0	<900 (<1800)	CST, MONT, CIS	G	C, W, YPF, WW, CS
Sambucus	Elderberry[2]		3	3	0	<1800 (3000)	CIS, MONT, TRANS	MTS, G	MC, CSS, C, OW, SF
Symphoricarpos	Snowberry[2]		3	3	0	1200-3300 (<1500)	CIS, MONT, TRANS	MTS	PJ, BCPF, C, OW, SF
Celastraceae	Staff-tree family	3							
Euonymus	Burning Bush[2]		1	1	0	300-2000	CIS, MONT	SJ-PM, CM	YPF
Chenopodiaceae	Goosefoot family	18							
Atriplex	Saltbush[2]		25	4	4	<500 (<2200)	CST, CIS, TRANS	CST, I, D	VG, CSS, CS, CSM, AS, PJ
Eurotia	Winter fat[2]		1	1	0	<600	TRANS	HD, SB, SN, SR	CBS, PJ
Salicornia	Pickleweed		5	0	1	<500	CST	CST, CSM, I	CSM
Suaeda	Seep-weed		4	0	3	<1500	CST, CIS, TRANS	CST, MTS, D	CSS, CBS, AS, CSM

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

		Total		Chaparral		Shrubs and subshrubs			
Family, genus	Common name	Genera	Species	Shrubs	Sub-shrubs	Elevation ranges (meters)[3]	Major aspect[4]	Geo-graphic zone[5]	Typical vegetation types[6]
Cistaceae	Rock-rose family	2							
Cistus	Rock-rose		1	1	0	UND	CIS	UND	INTRO
Helianthemum	Rush-rose		2	0	2	<1300	CIS, CST	CST, I, FH	C, CSS
Cornaceae	Dogwood family	1							
Cornus	Dogwood[2]		4	3	0	<2700	CIS, MONT	CST, I	WW, MCF
Crassulaceae	Stonecrop family	4							
Cotyledon			1	0	1	<150	CST	CST	INTRO
Crossosomataceae	Crossosoma family	1							
Crossosoma			2	1	0	<150	CST	I	CSS, C
Cupressaceae	Cypress family	3							
Juniperus	Juniper[2]		3	1	0	<1500		D-FH	PJ, JTW, C
						(1500-2600)	TRANS, CIS		
Ephedraceae	Ephedra family	1							
Ephedra	Ephedra[2]		7	1	0	900-2300 (<1100)	CIS, TRANS	CST, D	CBS, C, VG, JTW
Ericaceae	Heath family	11							
Arctostaphylos	Manzanita[2]		13	10	0	<2700	CIS, TRANS	G	C, YPF, MC, W
Chimaphila	Pipsissewa		2	2	0	1500-2900	MONT	MTS	MCF
Comarostaphylis	Summer-holly[2]		1	1	0	<550	CST	CST	C
Phyllodoce	Mountain-heather		1	1	0	2700-3500	MONT	SB	SF
Rhododendron	Azalea[2]		1	1	0	1400-2300	CIS, TRANS	SJ-CM	WW
Vaccinium	Blueberry		1	1	0	700	CIS	MTS, I	WW, C, W
Xylococcus	Mission-manzanita[2]		1	1	0	<600	CIS	CST, FH, I	C
Euphorbiaceae	Spurge family	10							
Acalypha	California copperleaf		1	1	0	200-1200	CIS	SR, BV	C, OW
Euphorbia	Spurge		30	1	0	<150	CST, TRANS	I, CST, D	CBS, CSS
Ricinus	Castor-bean[2]		1	1	0	<730	CIS	G	INTRO
Tetracoccus			3	1	0	<800	CIS	FH	C
Fabaceae	Pea family	32							
Acacia	Acacia		6	1	0	<1000	CIS	FH	C, INTRO
Amorpha	False Indigo[2]		2	2	0	<2300	CIS	SR, SA	CSS, C, YPF, WW
Cercis	Redbud[2]		1	1	0	100-1500	TRANS, CIS	LM, CM, FH	C, YPF
Cytisus	Broom[2]		2	2	0	<500	CST, CIS	I, CST	INTRO
Lotus	Birdsfoot trefoil[2]		22	0	2	<1500	CIS, TRANS	FH, D, I	CSS, CS, C, YPF, JTW
Lupinus	Lupine[2]		48	2	4	<2200	CST, CIS	MP, SG, SA, FH, CST	CS, CSS, C, OW, MCF
Pickeringia	Chaparral-pea[2]		1	1	0	<1500	CIS	SM, SB, I	C
Psoralea			8	0	1	<1500	CIS	SG	C
Spartium	Spanish-broom[2]		1	1	0	<2100	CST	UND	INTRO
Ulex	Gorse		1	1	0	UND	CST	CST	INTRO
Fagaceae	Beech family	3							
Chrysolepis	Chinquapin[2]		1	1	0	1600-3400	MONT	SJ, SG	MC, SF
Quercus	Oak[2]		12	4	0	<1500	CIS, TRANS	G	FHW, C, YPF, W

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

Family/genus	Common name	Total		Chaparral		Shrubs and subshrubs			
		Genera	Species	Shrubs	Sub-shrubs	Elevation ranges (meters)[3]	Major aspect[4]	Geographic zone[5]	Typical vegetation types[6]
Frankeniaceae	Frankenia family	1							
Frankenia	Frankenia		2	0	1	<100 (<1500)	CST, CIS	CST, AS	CSM, CS, AS
Garryaceae	Silktassel family	1							
Garrya	Silktassel bush[2]		4	4	0	<2500	CIS, TRANS, MONT	FH	C, YPF, PJ, FHW
Hippocastanaceae	Buckeye family	1							
Aesculus	Buckeye		1	1	0	1200	CIS	FH	FHW
Hydrophyllaceae	Waterleaf family	12							
Eriodictyon	Yerba Santa[2]		5	4	0	<2500	CIS, TRANS	I, SY-SB-SR	C, YPF, PJ
Turricula	Poodle-dog bush[2]		1	1	0	300-2400	CIS, TRANS	MTS, FH	C, YPF
Wigandia			1	0	1	UND	CST	CST	INTRO
Hypericaceae	St. John's Wort family	1							
Hypericum	St. John's Wort		4	1	0	UND	CIS	FH	INTRO
Juglandaceae	Walnut family	1							
Juglans	Walnut[2]		1	1	0	1400	CIS	FH	OW
Lamiaceae	Mint family	25							
Lepechinia	Pitcher Sage[2]		4	0	4	<1200	CST, CIS	SA, SG, SM, I	C, FHW
Monardella	Coyote-mint		12	0	6	900-3000 (<300)	CIS, MONT, TRANS	SG, SB, SJ, SA, FH	MC, C, YPF, CSS
Salvia	Sage[2]		20	6	1	1500 (<3000)	CIS, MONT, TRANS	SB, FH, I	CSS, C, YPF, PJ, MC
Satureja	Yerba Buena shrub		2	0	1	<800	CIS	FH	C
Trichostema	Bluecurls[2]		5	2	0	<1800	CIS, TRANS	FH	C, YPF, JTW
Lauraceae	Laurel family	1							
Umbellularia	California Bay[2]		1	0	0	1800	CIS	CST	C, FHW, MCF
Loganiaceae	Logania family	2							
Chilianthus			1	1	0	<700	CST	CST	INTRO
Malvaceae	Mallow family	12							
Lavatera	Tree-mallow		3	0	2	150	CST	I, CST	CSS, INTRO
Malacothamnus	Globemallow[2]		8	4	3	1500 (<2100)	CST, CIS	FH, SA-CM, I	CSS, C, YPF, FHW
Myoporaceae	Myoporum family	1							
Myoporum	Myoporum		1	1	0	<150	CST	CST	CSS, INTRO
Myricaceae	Wax-Myrtle family	1							
Myrica	Wax-Myrtle[2]		1	1	0	<150	CIS	SM	C, CSS
Myrtaceae	Myrtle family	1							
Eucalyptus	Gum tree		2	1	0	UND	CST	CST	INTRO
Nyctaginaceae	Four-O'Clock family	8							
Mirabilis	Four-O'Clock		5	0	1	<800	CIS	CST, FH, I	C, CSS, FHW
Oleaceae	Olive family	3							
Forestiera	Desert-olive		1	1	0	2000	CIS, TRANS	SR-CST	C, CBS, CSS, FHW
Fraxinus	Flowering Ash[2]		4	1	0	1100	CIS	SA-CST	C, FHW
Onagraceae	Evening-Primrose family	11							
Zauschneria	California-Fuchsia		3	0	2	600	CIS	FH, I	C, CSS

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

Family/genus	Common name	Total: Genera	Total: Species	Chaparral: Shrubs	Chaparral: Sub-shrubs	Shrubs and subshrubs: Elevation ranges (meters)[3]	Shrubs and subshrubs: Major aspect[4]	Shrubs and subshrubs: Geo-graphic zone[5]	Shrubs and subshrubs: Typical vegetation types[6]
Papaveraceae	Poppy family	13							
Dendromecon	Tree Poppy[2]		1	1	0	<1500	CIS	FH, I	C
Romneya	Matilija Poppy[2]		2	0	1	<1200	CIS	FH, CST	C, CSS
Pittosporaceae	Pittosporum family	2							
Pittosporum	Pittosporum		2	1	0	UND	UND	UND	INTRO
Sollya			1	0	1	UND	UND	UND	INTRO
Polemoniaceae	Phlox family	12							
Eriastrum	Mesa-phlox		8	0	1	1200-2400	MONT	MTS	MC
Ipomopsis	Jacumba-gilia		5	0	1	500-1100	CIS, TRANS	FH, D	CBS, PJ, C
Leptodactylon	Prickly-phlox		3	1	1	<1700 (2700)	CIS, MONT	FH, MTS	C, FHW, MCF
Linanthus	Bush-gilia		23	0	1	<2300	CIS, MONT	FH, MT	SC, YPF, OW
Phlox	Phlox		6	0	2	1500-3300	MONT, TRANS	MTS, D	PJ, YPF
Polygalaceae	Milkwort family	1							
Polygala	Milkwort		4	2	0	<900	CIS	I, SM, SA	C, OW
Polygonaceae	Buckwheat family	10							
Eriogonum	Wild Buckwheat[2]		67	5	4	300-3400 (150)	MONT, CST	CST, MTS, I	CSS, C, CS, YPF, PJ, SGS, JTW, MC
Ranunculaceae	Buttercup family	9							
Clematis	Clematis (Virgin's Bower)[2]		3	0	3	<2100	CIS, TRANS	G, FH	C, W, YPF, WW
Rhamnaceae	Buckthorn family	6							
Adolphia	California adolphia[2]		1	1	0	<1400	CIS	CW	C
Ceanothus	California-Lilac[2]		17	17	0	<1800 (2000)	CIS, TRANS, MONT	G	C, MC, CSS, PJ, YPF, OW, JTW
Rhamnus	Buckthorn[2]		5	5	0	<2100	CST, CIS, TRANS	I, CST, FH	CS, CSS, OW, YPF, CBS, PJ, C, WW
Rosaceae	Rose family	30							
Adenostema	Chamise[2]		2	2	0	<1800	CIS, TRANS	FH	C
Amelanchier	Service-berry[2]		3	2	0	1500-2100 (3400)	MONT, TRANS	MTS	PJ, MC, YPF
Cercocarpus	Mountain-Mahogany[2]		5	3	0	<1800 (1200-3000)	CIS, CST	I, G	C, PJ, SGS, MC
Chamaebatia	Fern bush[2]		1	1	0	<600	CIS	FH	C
Heteromeles	Toyon[2]		1	1	0	<1200 (1600-3300)	CIS	FH, MTS	C
Holodiscus	Spirea[2]		3	2	0	<1700	CIS, TRANS	I, FH, MTS	MC, PJ, C
Prunus	Stone-Fruits[2]		10	4	0	600-2700 (<1500)	CIS, TRANS	I, MTS	C, YPF, MC, W
Purshia	Bitterbrush[2]		1	1	0	800-2700	TRANS, MONT	MTS, D	PJ, JTW
Rosa	Rose[2]		3	3	0	<1800	CIS, TRANS	MTS	MC, WW

Southern California Shrub and Subshrub Vegetation Excluding Desert Genera[1]

Family/genus	Common name	Total		Chaparral		Shrubs and subshrubs			
		Genera	Species	Shrubs	Sub-shrubs	Elevation ranges (meters)[3]	Major aspect[4]	Geo-graphic zone[5]	Typical vegetation types[6]
Rubus	Blackberry[2]		7	7	0	1200-2400 (<1300)	CIS, TRANS	FH, MTS	MC, YPF, WW, INTRO
Rubiaceae	Madder family	3							
Galium	Bedstraw		26	1	3	<2500	CIS, MONT	I, SG, SR	CSS, C, OW, PJ
Rutaceae	Rue family	3							
Cneoridium	Bushrue[2]		1	1	0	<800	CST	I, CST	C, CSS
Salicaceae	Willow family	2							
Salix	Willow[2]		13	6	0	<2700	CIS	CW, I	MC, WW
Saxifragaceae	Saxifrage family	10							
Ribes	Currant/ Gooseberry[2]		18	18	0	<3800	CIS, MONT, TRANS, CST	MTS, I	C, CSS, MC, CF, SF, OW, FHW, WW
Schrophulariaceae	Figwort family	20							
Castilleja	Paint-Brush		19	0	3	<1500	CST, CIS	I, FH	CS, CSS, C
Galvezia	Galvezia		1	1	0	<100	I	I	INTRO
Keckiella	Kecks-penstemon[2]		5	5	0	<2500	CIS, TRANS	MTS, FH	C, YPF, RJ, MC, CBS
Mimulus	Monkey-Flower[2]		35	3	3	<1800 (<100)	CIS	FH, I	C, YPF, CSS
Penstemon	Penstemon		27	0	4	1400-3000 (<1500)	CIS, TRANS	MTS, FH	MC, C, FHW, YPF, PJ
Simmondsiaceae	Jojoba family	1							
Simmondsia	Jojoba (goatnut)[2]		1	1	0	<1500	CIS, TRANS	SB-D	CBS, C, JTW
Solanaceae	Nightshade family	10							
Lycium	Box-Thorn[2]		10	6	0	<1800	CST, CIS, TRANS	I, CST, FH	CBS, PJ, SGS, C, CSS, INTRO
Nicotiana	Tobacco[2]		5	1	0	<900	CIS	FH	INTRO
Solanum	Nightshade		15	1	7	<1400 (1500-2700)	CIS	I	CSS, C, CS, YPF, VG, FHW, OW, INTRO
Sterculiaceae	Cacao family	2							
Fremontodendron	Flannel Bush[2]		2	2	0	900-2100 (500)	CIS, TRANS	FH	C, OW, YPF, PJ
Styracaceae	Storax family	1							
Styrax	Storax[2]		1	1	0	<1500	CIS	FH	C, OW
Verbenaceae	Vervain family	3							
Lippia	Lippia		4	0	1	UND	CIS	I, FH	INTRO
Vitaceae	Grape family	1							
Vitis	Grape[2]		1	1	0	<1200	CIS, TRANS	I, CW	OW, CSS

[1] Based on Munz (1974) and McMinn (1939).

[2] Species from this genus are in the guide.

[3] *Elevation ranges* based on ranges of elevation given by Munz (1974) and McMinn (1939) for the various species in the genus. The indicated values should generally be the range of elevations in meters which includes the extent of the shrub and subshrub species. Where there are definable breaks between species or groups of species, the elevation range of the second grouping is shown in parentheses. In some cases there is no information identifying elevation ranges, shown as UND (undetermined).

[4] *Major aspect* codes broadly identify the major areas that include habitats of the majority of shrub or subshrub species in a genus. Usually, more than one code is entered for a genus. Multiple codes mean that the species are found on one or more aspects. The codes are:

CIS - On the ocean side of the mountains as opposed to the desert side
CST - Mostly in the coastal influence zone
D - Primarily desert species
I - Primarily island species
MONT - Mostly high mountain species
TRANS - On the desert side of the mountains as opposed to the ocean side
UND - Aspect not determined

[5] *Geographic zone* codes identify the geographic areas indicated for the shrub and subshrub species by Munz (1974) and McMinn (1939). The geographic code does not imply exclusive representation in the zones; it does imply that species in the genus should be found in the zone(s) indicated. The codes are:

AS - Alkali sink
BV - Borrego Valley (mostly San Diego and Imperial counties)
CW - Canyons and washes
CM - Cuyamaca Mountains (San Diego County)
CSM - Coastal salt marshes
CST - Coastal units
D - Deserts
FH - Foothills
C - Generally widespread, many geographical zones
HD - High desert (mostly San Bernardino and Los Angeles counties)
I - Islands
LD - Low desert (mostly San Bernardino, Riverside, and Imperial counties)
LM - Laguna Mountains (San Diego County)
MP - Mount Pinos (mostly Ventura County)
MTS - Mountains in general
PM - Palomar Mountains (mostly San Diego County)
SA - Santa Ana mountains (Orange and Riverside counties)
SG - San Gabriel Mountains (Los Angeles County)
SJ - San Jacinto Mountains (Riverside County)
SM - Santa Monica Mountains (Los Angeles and Ventura counties)
SN - Sierra Nevada
SR - Santa Rosa Mountains (San Diego and Imperial counties)
SSM - Santa Susanna Mountains (Ventura and Los Angeles counties)
SY - Santa Ynez Mountains (Santa Barbara to Ventura counties)
UND - Undefined

[6] *Typical vegetation* types codes are the vegetation types identified by Munz (1974) and McMinn (1939) as frequent habitats for shrub and subshrub species in the genus. The identified communities are not necessarily the only habitats of the species. The following codes are:

AS - Alkali sink
BCPF - Bristle-cone pine forest
C - Chaparral
CBS - Creosotebush scrub
CF - Conifer forest
CGS - Coastal sagebrush shrub
CS - Coastal strand
CSM - Coastal salt marsh
CSS - Coastal sage scrub
CW - Conifer woodland
FHW - Foothill woodland
INTRO - Introduced species with no community identified
JTW - Joshua tree woodland
MC - Montane conifers
MCF - Montane conifer forest
MCW - Montane conifer woodland
OW - Oak woodland (southern)
PJ - Pinyon-juniper
SF - Subalpine forest
SGS - Sagebrush scrub
VG - Valley grassland
W - Woodland
WW - Waterway areas (riparian)
YPF - Yellow pine forest

APPENDIX B

Index to species

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[1]Species described but only the genus name appears in the plant key.

[2]Species mentioned but not described; species name is not in the dichotomous key.

[3]Genus and or species has been renamed.

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This Guide presents taxonomic keys based on vegetative features of 132 southern California shrub and subshrub species found in an area bounded by the southern part of the coast ranges, the north and east sides of the transverse and peninsular ranges, and Mexico. The keys are supported with instructions and an extensive glossary. Species discussion includes a brief description and generalized distribution of each species. When known, the fire response mechanism, wildlife value, and cultural value are given. A line drawing or photograph of each species is included. All genera that include chaparral shrub and subshrub species recognized by *A Flora of Southern California* by Philip A. Munz are listed in an appendix. Typical plant communities that include species in the genera listed along with elevation range, aspects, and geographic zones of the species habitats are given.

Retrieval Terms: chaparral, fire, shrubs, southern California, taxonomy, wildlife