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Chaparral in Southern and Central Coastal California in the Mid-1990s: Area, Ownership, Condition, and Change

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Cover Photos

Top left and bottom right: Dave Graber, Sequoia and Kings Canyon National Park.
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Abstract

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This report summarizes an inventory of chaparral-dominated lands in southern California conducted during the mid-1990s and provides a review of contemporary literature on the ecological dynamics of chaparral vegetation with emphases on stand development, species composition, and the role of fire. Detailed tables provide estimates of chaparral area by owner, type, size, and cover, and, for lands outside national forests, area by fire-hazard class and 10-year change in chaparral area.

Summary

In the mid-1990s, chaparral in California's south and central coast regions was estimated to occupy 4.6 million acres, 14 percent of total land area. About 2.1 million acres of the chaparral were privately owned, and 1.6 million acres were in national forests. The Bureau of Land Management, military reservations, and miscellaneous federal, state, and local agencies accounted for the rest. These estimates were among the results of a field-plot-based vegetation inventory with emphasis on woody species. Chaparral area decreased by 108,000 acres outside national forests between 1984 and 1994 owing to conversions to urban and agricultural use. At 42 percent of the total chaparral area, the chamise and red shank type was the most common type of chaparral, followed by mixed and montane (31 percent), scrub oak (12 percent) and coastal transition (15 percent). *Adenostoma fasciculatum* (chamise) was the most common shrub species, occurring on 71 percent of the area sampled, followed by *Quercus dumosa/john-tuckeri* (California scrub and Tucker oaks) at 39 percent, and *Heteromeles arbutifolia* (toyon) at 19 percent. Emergent trees, important to wildlife and scenery values, and thought by some to have been more prevalent in chaparral before Europeans settled here, were found on 11 percent of the area.

Outside national forests, 16 percent of the chaparral burned between 1984 and 1994; within national forests, 27 percent of the chaparral burned over that period. Remeasured plots that had burned between visits (all within 10 years) showed significantly less shrub and significantly more grass and forb cover. Notable was the loss of *Ceanothus* spp., obligate seeders that fix nitrogen in the soil. During this period, unburned chaparral outside national forests showed little evidence of degradation or loss of biodiversity. Shrub cover held steady or increased on 70 percent of the plots, and many shrub species increased in occurrence while very few decreased.

Outside national forests, application of a chaparral hazard class rating system based on ocular estimates of percentage of dead material in live shrubs and total shrub cover placed 38 percent of the chaparral area in the highest hazard class (greater than 25 percent cover of shrubs and greater than 25 percent dead material in more than half of those shrubs), and 42 percent in the moderate hazard class (greater than 25 percent cover of shrubs and some dead material in at least half of those shrubs). It appears that nearly all chaparral older than 10 years (i.e., since the last disturbance by fire) has moved out of the low-hazard category and would likely burn readily in a wildfire.

Keywords: Chaparral area, chaparral composition, fire hazard, ownership and change, southern California vegetation inventory.

Contents

Introduction and Objectives

Presented here is an analysis of data collected on more than 500 chaparral inventory plots spanning all ownership categories in southern and central coastal California in the mid-1990s. Some of the plots had originally been established in the mid-1980s as part of a statewide chaparral assessment and were revisited to assess change over the 10-year interval. A reassessment of chaparral throughout the entire state—estimated in 1984 to cover 7.4 million acres—was recommended by several people, but limited funds restricted the project to a 14-county area extending from Marin County south to San Diego County (fig. 1). This area contains an estimated 4.6 million acres of chaparral—62 percent of the total in the state–much of which is intermingled and juxtaposed with populous areas undergoing rapid land use change.

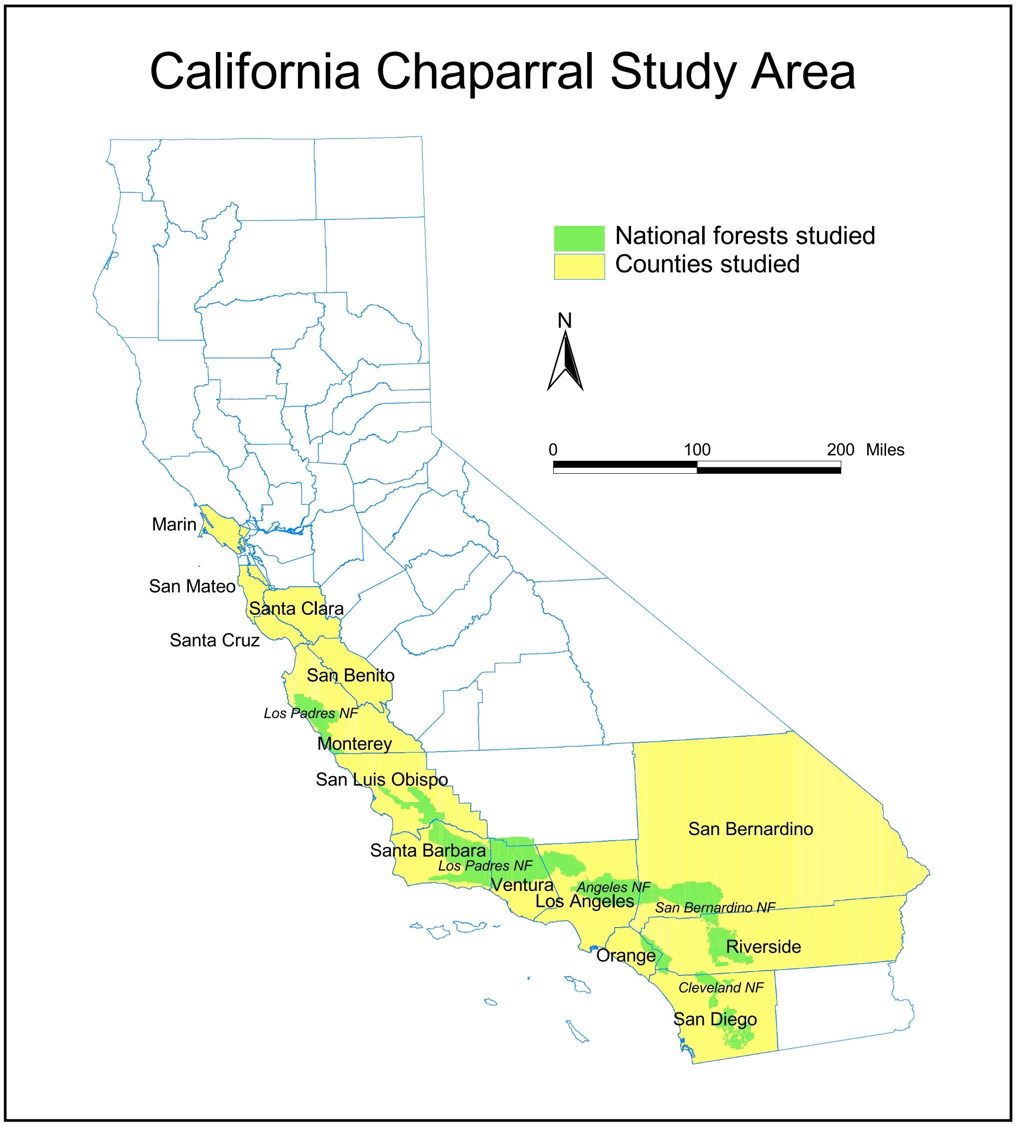

Figure 1—The central and southern coast forest survey units where chaparral was inventoried in the mid-1990s encompass 14 counties, 4 national forests, and considerable areas of reserved lands (e.g., state and federal parks).

Objectives of the inventory and of this study were to produce statistically reliable, replicable, and biologically sound estimates of the extent, ownership, condition, and dynamics of chaparral in the 14-county area, and to analyze this information as it relates to problems and opportunities that chaparral presents to land and resource managers, fire protection agencies, scientists, educators, and the general public. Special emphasis is given to flammability, loss of chaparral to development, characteristics of chaparral stands, and change in composition and density in burned and unburned stands. These objectives can be restated as questions as follows:

1. How much chaparral is there in southern and central coastal California? Who owns it? How much is in parks, preserves, and other kinds of public ownership where it is unlikely to be developed?
2. How much chaparral was lost to development between 1984 and 1994?
3. What are the major chaparral types and most abundant species?
4. How much chaparral burned between 1984 and 1994, and what fire-return interval is implied?
5. What is the postfire stocking condition of chaparral areas that burned since 1984?
6. How have chaparral stands in unburned areas changed? Are there signs of degradation or decline in species diversity?
7. What proportion of the chaparral seems to pose a medium-to-high fire hazard?
8. What proportion of the chaparral has emergent trees, and what tree species are present?

Three major sources of information were used in this study: (1) the rather voluminous and growing scientific literature on chaparral, (2) inventory data for national forest land gathered by the Pacific Southwest Region of the USDA Forest Service, Vallejo, California, and (3) inventory data for land outside national forests, gathered by the Pacific Northwest (PNW) Research Station of the USDA Forest Service, Portland, Oregon.

Data for national forest land were collected in 1993-96 by the Remote Sensing Lab of the Pacific Southwest Region, USDA Forest Service (the national forests in the 14-county study area are Angeles, Cleveland, Los Padres, and San Bernardino). Plots were distributed across these national forests on a systematic grid with an interval of 3.4 miles, and each plot nominally represented 7,400 acres. At each grid location in forest, woodland, or shrubland, a cluster of five, ¼-acre circular subplots was established over an area of about 2.5 acres. At each subplot, plants were recorded by life form (trees, shrubs, subshrubs, forbs, grasses, and grasslikes), species, height layer, and percentage of ground cover. Data quality was assured by specifications in the contract requiring check plots by registered professional foresters on the contractor staff as well as a check of 10 percent of the plots by Forest Service quality assurance staff. Plots in shrub types were not identified as chaparral by field crews; instead, computer models were used to screen the plant data for each plot in a shrub type to determine whether it was chaparral, and if it was, to identify its specific vegetation type (e.g., chamise, scrub oak) (table 1); then the results were scrutinized for reasonableness. A total of 340 national forest plots were classified by this process as chaparral (fig. 2).

Table 1—Area and percentage of total chaparral by type, for three chaparral classification systems, all ownerships

Classification system and type	Area	Percentage of chaparral
	Thousand acres	
PNW (1994):		
CH-Chamise and red shank	1,791.3	42
MIX-Mixed and montane	1,352.6	31
OAK-Scrub oak	500.9	12
CT-Coastal transition[a]	656.3	15
Total chaparral	4,301.1[b]	100
Nonchaparral[c]	55.9	NA
Total (513 plots)	4,357.0	NA
CALVEG:[d]		
BM—Curl-leaf mountain mahogany	7.2	0.2
BS—Basin sagebrush[e]	5.5	0.1
BX—High desert mixed chaparral	10.3	0.2
CA—Chamise	1,413.6	32.5
CC—Ceanothus chaparral	132.4	3.0
CD—Southern mixed chaparral	10.3	0.2
CG—Greenleaf manzanita	9.4	0.2
CQ—Lower montane mixed chaparral	1,479.5	34.0
CR—Red shank	131.4	3.0
CS—Scrub oak	328.1	7.5
CX—Montane-mixed chaparral	9.0	0.2
CZ—Semidesert mixed chaparral	82.7	1.9
DX—Mixed desert shrub[e]	10.8	0.3
JC—California juniper[e]	6.2	0.1
ML—Baccharis	15.7	0.4
NC—North coast chaparral	62.4	1.4
RS—Alluvial fan sage scrub[e]	57.0	1.3
SD—Manzanita chaparral	80.6	1.9
SH—Coastal bluff scrub	22.8	0.5
SM—Sumac	155.5	3.6
SQ—Mixed soft scrub chaparral[e]	25.0	0.6
SS—Coastal sage scrub[e]	240.8	5.5
WM—Birchleaf mountain mahogany	60.8	1.4
Total	4,357.0	100.0

continued next page

California Wildlife Habitat Relationships:		
CRC—Chamise-red shank	1,518.5	34.9
DSC—Desert scrub[e]	18.2	0.4
DSS—Desert succulent shrub[e]	1.7	T
JCW—Juniper[e]	13.2	0.3
MCH—Mixed chaparral	2,351.5	54.0
MCP—Montane chaparral	97.6	2.2
SCS—Coastal scrub[e]	343.6	7.9
SGB—Sagebrush[e]	12.7	0.3
Total	4,357.0	100.0

[a] Coastal transition includes hard chaparral that is geographically marginal to coastal scrub and early successional stages of hard chaparral in which coastal scrub species are temporarily abundant.
[b] 4,301.1 + 309.3 (untyped chaparral in reserved areas outside national forests) = 4,610.4 as shown in table 3.
[c] Classified as forest or as nonforest type other than chaparral by PNW's system.
[d] CALVEG = classification and assessment with Landsat of visible ecological groupings.
[e] Includes some nonchaparral by PNW.

Data for land outside national forests (except parks and other reserved areas) were collected by the Forest Inventory and Analysis Program (FIA) of the Pacific Northwest Research Station (PNW) of the USDA Forest Service in two inventories. In 1981-84, 72 plots were established in chaparral on a 6.8-mile grid, and each plot represented an average of about 29,600 acres. In 1993-94, these 72 plots were revisited, and an additional 109 plots were established on a new 6.8-mile grid offset so that the intersections fell in the interstices of the original grid (fig. 2). When used together, the plots in the two combined grids each represented an average of about 14,800 acres. Crews classified each plot in the field as chaparral or not chaparral (in contrast to procedure followed on national forest land). At plots classified as chaparral, crews established a 55-foot-radius circular plot on which they tallied plants by life form, species, height layer, and density in about the same manner as done on national forests. In addition, crews made ocular estimates of the amount of dead material for each shrub species by height layer; for remeasured plots in chaparral that had burned since the 1984-86 inventory, they determined the year of the fire—usually by contacting residents, landowners, or local agencies. As with all inventory data collected by PNW-FIA, a quality assurance system consisting of management quality objectives and spot checks of field measurements by quality assurance staff was relied on to ensure consistently precise measurements. By using decision rules implemented in computer models, we determined the chaparral type of each plot in the same manner used for national forest plots (except we did not have to determine which plots were chaparral, as that had already been done in the field). For parks and reserved areas, we obtained chaparral area by contacting the park managers or their agencies. In most cases, chaparral in these reserved areas was not classified by types consistent with our other data.

From these data we developed the summaries and analysis presented in this report. The literature reviewed in "A Chaparral Primer" of this report emphasizes the work completed since 1984 in the report, *Shrubs of California's Chaparral, Timberland, and Woodland* (Bolsinger 1989), in order to provide a foundation for the analysis results that follow. Following sections present and discuss the results of our analysis

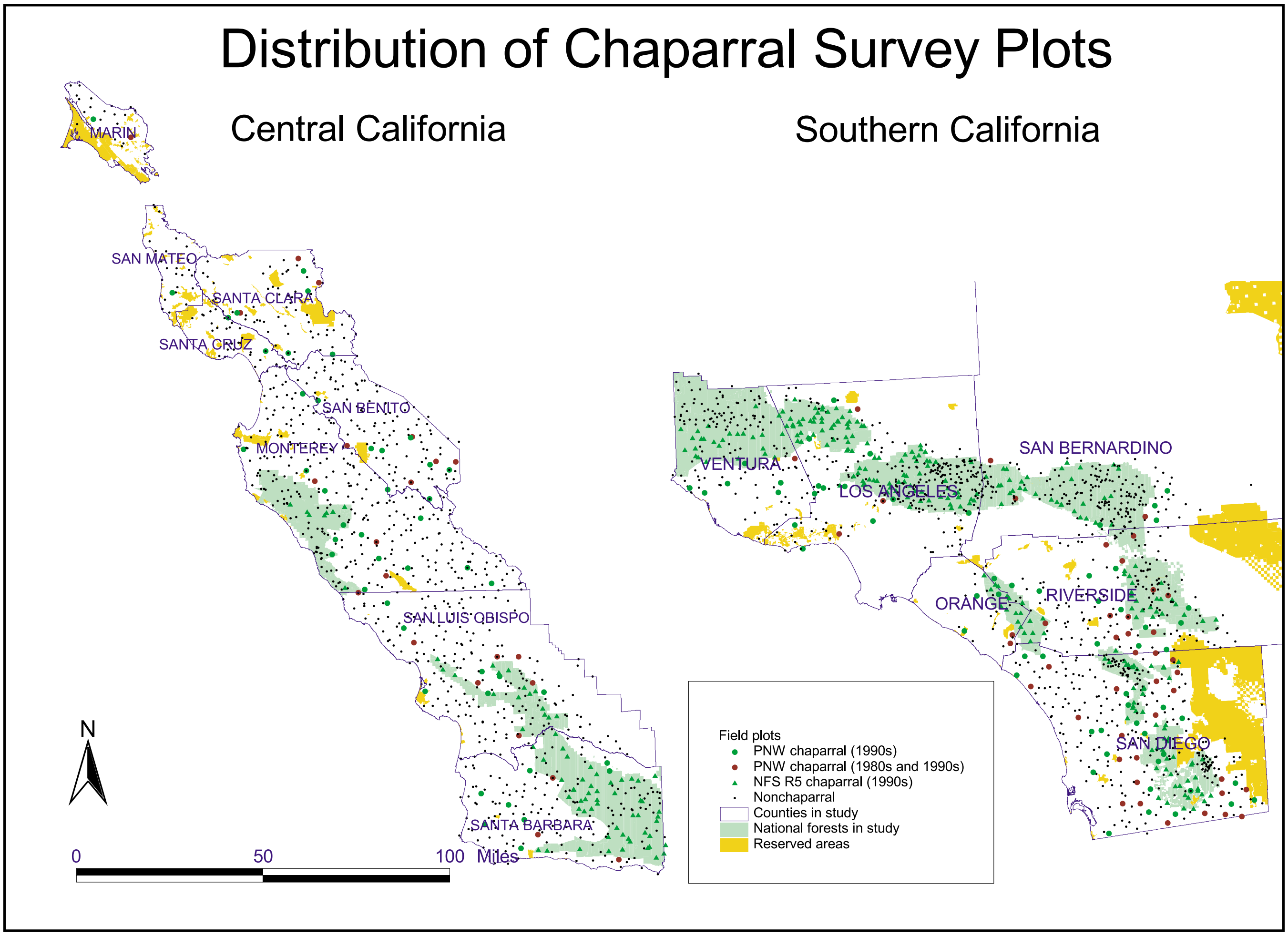

Figure 2— Forest Inventory and Analysis (FIA) field plots in the chaparral study area installed by PNW FIA and National Forest System (NFS) Region 5 as new or remeasured plots; nonchaparral plots also were visited in the field and classified as forest, oak woodland, or other (e.g., urban, agriculture) types. Plot locations are “fuzzed” by up to 8,200 feet (2500 meters) in X and Y dimensions to comply with federal statutes on plot confidentiality.

and relate them to information in the literature to enhance their context and meaning, and “The Next Steps” section outlines potential analytic extensions for which we believe these data may be suited along with plans for the next chaparral inventory.

A Chaparral Primer

Chaparral Defined

“Chaparral,” derived from the Spanish “chaparra” for scrub oak (McMinn 1939), refers to a group of biotic communities or vegetation types comprising several genera of shrubs, some of which exhibit treelike growth forms under optimal conditions. Chaparral is often referred to simply as “brush,” although in the past it was also called “elfin forest,” a poetic term apparently no longer in use. In California, chaparral occurs within the Mediterranean-type climate zone, which is characterized by hot, dry summers and mild, moist winters. Most plant growth occurs in late winter and spring when moisture is available; many chaparral plants are virtually dormant during lengthy periods of summer drought. Similar chaparral also grows in a non-Mediterranean-type climate in

Arizona and northeastern Mexico, where summer rains extend the period of plant growth (Rundel and Vankat 1986). The Mediterranean-type climate zone in California also supports grasslands, coastal scrub, oak woodland, oak savanna, and coniferous forests. Chaparral vegetation at a given place reflects the combined influences of disturbance, macroclimatic factors, and microenvironmental effects that vary by elevation, aspect, and distance from the ocean (Boorse et al. 1998, Keeley 1986, Riggan et al. 1988). Soil type and parent material influence growth and composition of chaparral much less than does climate, except on serpentine and peridotite formations, which are often dominated by specialized plants that tolerate low levels of calcium and the presence of toxic elements (Carrington and Keeley 1999, Keeley 1986).

Dominant shrubs in chaparral are often deeply rooted and usually evergreen and sclerophyllous. In California, major families include the Anacardiaceae, Compositae, Ericaceae, Fagaceae, Lamiaceae, Rhamnaceae, and Rosaceae. Among the genera of woody plants commonly found in California chaparral are *Adenostoma, Arctostaphylos, Artemisia, Baccharis, Ceanothus, Cercocarpus, Garrya, Heteromeles, Malosma, Prunus, Quercus, Rhamnus, Rhus, Salvia,* and *Toxicodendron* (see “Scientific and Common Plant Names” section). At lower elevations on dry sites, chaparral grades into the coastal scrub vegetation type, which includes many drought-deciduous plants (Mooney 1986). In general, chaparral species dominate where summer droughts last no longer than 100 days, and coastal scrub species dominate where summer droughts exceed 100 days (Field and Davis 1986). Within the growing season, photosynthesis of chaparral species is relatively temperature insensitive and differs little with change in elevation. However, differences can occur on a given site among species with contrasting or complementary morphologies and physiological dissimilarities such as different hydraulic properties, rooting depths (as much as 36 percent of chaparral biomass is below ground), and phenologies. This niche segregation or resource partitioning explains the coexistence of species that have different environmental responses, thus accounting for the botanical richness characteristic of many chaparral stands (Oechel and Reid 1984, Redtfeldt and Davis 1996, Vogl 1982). Among the plants that typify the coastal scrub are species of *Salvia, Lotus, Eriogonum, Artemisia,* and *Lupinus.* Chaparral grades into conifer forest or hardwood woodland on moister sites at higher elevations, or on north-facing slopes, and in canyons. Tree species include *Quercus agrifolia, Q. chrysolepis, Q. kelloggii* (on the very moist sites—McDonald 1990b), *Pinus coulteri, P. jeffreyi, P. ponderosa, Pseudotsuga macrocarpa, P. menziesii,* and *Sequoia sempervirens* (Monterey County and north). *Quercus douglasii* occurs in enclaves above, below, and within extensive areas of chaparral, on certain soil types, north of northern Los Angeles County (McDonald 1990a). The boundaries between chaparral and coastal sage scrub types are rarely sharp (fig. 3), with both mixtures of types and abundant type transitions, which appear to follow slight changes in slope, aspect, physiography, soil moisture, and air drainage. Fire effects tend to blur the already indistinct boundaries between chaparral and coastal sage scrub at low elevations and on xeric sites, and between chaparral and forest (including hardwood woodland) at higher elevations and on mesic sites, especially during the first few years following fire. With some exceptions, such as where serotinous conebearers are present (Ne’eman et al. 1999), species from both neighboring types are often present during the early successional period (Vogl 1982). At lower elevations on xeric sites, the presence of a few woody chaparral species, even as sprouts or seedlings, lends weight to a classification of chaparral rather than coastal scrub. At higher elevations and on mesic sites, snags, tree seedlings, and the presence of shrub species associated with the trees promote the conclusion that a forest preceded the fire, and that it will return given a sufficiently long period of fire exclusion. Among the shrubs found in forest and hardwood woodland more often than in chaparral on plots established by PNW in southern and coastal California in the 1980s (Bolsinger 1989) were *Arctostaphylos patula, A. pringlei* spp. *drupacea, Ceanothus integerrimus, C. cordulatus, C. thyrsiflorus* (often in canyons with *Quercus agrifolia, Q. chrysolepis, Pseudotsuga menziesii,* and *Sequoia sempervirens), C. sorediatus, Holodiscus discolor, Rhamnus californica, Rhus trilobata, Ribes* spp., *Rosa* spp., and *Symphoricarpos* spp. In several places in southern California, the chaparral zone is bounded in the east by desert shrub types, containing genera such as *Larrea, Prosopis, Baccharis, Ephedra, Encelia, Frasera, Atriplex, Coleogyne, Yucca,* and *Opuntia* (McMinn 1939).

Figure 3—California sagebrush, a common species in coastal sage scrub, also occurs in chaparral, as shown here in this association of scrub oak and other shrub species. (Photo by Br. Alfred Brousseau, St. Mary's College)

What We Think We Know About Chaparral

In the past four decades there has been a tremendous increase in the volume of scientific literature on chaparral. As in many fields, newer studies in chaparral have debunked earlier theories and cast doubt on what were thought to be immutable truths of chaparral ecology. There is no reason to believe that ongoing or future investigations will not result in further revisions of chaparral "knowledge," or that all scientists and resource managers will ever be in complete agreement. In fact, many scientists have cautioned users to apply their findings with discretion, and have often been blunt about what is not known. H.A. Mooney (1986): "Recent knowledge creates new puzzles…" Jon Keeley (1986): "…we are far from thoroughly understanding its [chaparral's] mysteries." Numerous authors emphasize "… the need for continued monitoring and research…" (Beyers et al. 1998) or that "…the effort presented here is meant to be a cautionary note…" (Fairbanks et al. 1999), or "The long-term ecological effect…is a critical unknown" (Fenn and Poth 1992). The following points concerning chaparral's origins, adaptations, and relation to fire, which we accept as true until contradicted by compelling evidence, are contextual to this report. Our findings are not dependent on these points being true. The significance and relevance of our findings may, however, change as a result of new research.

Origin of chaparral—Chaparral vegetation did not develop in a Mediterranean climate as defined today. It began in the form of an understory layer of plants in forest and woodland that thrived in a less mountainous landscape with a milder climate than now exists, and with moist summers, or at least some rainfall sometime during the warmer part of the year. As the climate became more xeric and mountains formed, a fire-prone ecosystem evolved. The combination of drought and fire all but eliminated overstory trees, and high-intensity—often human-caused—fires of current times could accelerate disappearance of these trees. What was originally an understory shrub layer in forests in a maritime/continental climate has become the dominant vegetation now called chaparral in the Mediterranean-like climate (Axelrod 1986, Graumlich 1993, Rundel and Vankat 1986).

Adaptation to drought—Chaparral plants have many survival traits and adaptations to the long summer drought. Among these are deep roots and some species with dual root systems; drought-deciduous root hairs; osmotic adjustability; specialized stomatal structure and placement; leaf angle, surface (pubescent or sclerophyllous), dimorphism, and drought-deciduous response of foliage (fig. 4); shape of canopy (dissipates radiation by convection); height of shrubs (keeps leaves away from hot soil surface); and adaptive wood anatomy (i.e., vasicentric tracheids, grouping of vessels, helical vessel shape) that maintains water column integrity during environmental extremes (Carlquist 1986, Davis 1986, Ehleringer and Comstock 1986, Field and Davis 1986, Hanes 1974, Kummerow and Ellis 1986, Oechel and Reid 1984).

Figure 4—*Aesculus californica* (California buckeye), a drought-deciduous shrub or small tree. (Photo by Br. Alfred Brousseau, St. Mary's College)

Relation to fire—Recurrent fire and persistent drought are the primary environmental factors that determine chaparral community structure. Opinions among chaparral scientists on the degree to which chaparral is dependent on fire differ: “Fire is an ecosystem property rather than an exogenous force…” (Riggan et al. 1988). “…fire may be necessary for ecosystem perpetuation…” (Wohlgemuth et al. 1998). “Increasing site stability allows chaparral to be replaced by oak or pine woodland, savanna, or grassland…” (Vogl 1982). Davis et al. (1998) and Keeley (1995) suggest that chaparral might be characterized as fire tolerant rather than fire dependent. Many chaparral plants have fire-adaptive traits, such as postfire crown sprouting, seeds that usually require high temperature or high concentrations of soil carbon before they will germinate, or ability (e.g., *Ceanothus* spp.) to restore soil nitrogen levels to preburn levels via biological fixation within 2 to 4 years after a fire (Ellis and Kummerow 1986). Chaparral plant communities exhibit successional patterns that begin and end with fire: rapid recovery and growth after fire followed by a brief fire-resistant period, a period of increasing buildup of flammable material, and completing the cycle, the recurrence of fire that removes all vegetation, preparing sites for the establishment of new stands. Despite the many fire adaptations of chaparral, the existence of “vigorous shrub populations, not obviously senile or senescent” (Keeley 1992), in chaparral stands where no burning has occurred for more than a century, indicates that in certain conditions chaparral can get along without fire for relatively long periods (Keeley et al. 1986, Lloret et al. 1999).

Frequency, size, and intensity of fires—Frequency and size of chaparral fires before arrival of European settlers cannot be definitively assessed; however, there are indications of fire-return intervals on the order of 50 to 100 years (Keeley et al. 1986). Although indigenous people set fires and probably increased fire frequency over the natural rate even before European settlers arrived, human populations were very small and vast areas were totally uninhabited. Burcham (1974) conjectures that, except in local areas, fires set by indigenous people would have had little effect on chaparral. Gannet (1900) reported that the grazing of cattle, sheep, and goats numbering in the tens of thousands, and fires set by herdsmen to open up grazing areas, removed vegetation over vast areas in southern Oregon and California between 1850 and 1899, the same period when miners were burning the slopes to expose rock outcrops. This doesn’t mean the indigenous people did not set fires, but the dense vegetation in unburned areas described by Gannet suggests fire had been absent for a long time in many areas. Gannet’s report suggests that European herdsmen, along with miners, might have had a hand in creating the “parklike” forests (stands lacking understory vegetation) photographed in the early 1900s and credited to lightning and indigenous people. In southern California, there is evidence that before the arrival of Europeans, fires in chaparral burned less frequently, but were larger and more intense when they did occur (Axelrod 1986, Byrne 1978). Lightning was probably the major cause of ignition, occurring mostly at higher elevations in areas now mostly within national forests.

Over the past several decades, a tremendous investment has been made in fire suppression and controlled burning in chaparral (fig. 5) aimed at decreasing the number, size, and intensity of catastrophic wildfires. The success of this effort is open to debate. Minnich (1983), in a study based on analysis of Landsat imagery, concluded: “Fire control in chaparral reduces the number of fires, not burned hectarage; **fires consequently increase in size, spread rate, and intensity and**

become uncontrollable in severe weather conditions" (emphasis added). A somewhat different view is offered by Keeley et al. (1999): "…analysis of the California Statewide Fire History Database shows that, since 1910, fire frequency and area burned have not declined, and **fire size has not increased**. Fire rotation intervals have declined and fire season has not changed, implying that the **fire intensity has not increased**" (emphasis added). Based on their findings (which used total county area in calculating return interval), Keeley et al. (1999) suggested that fire suppression does "…play a critical role in offsetting potential impacts of increased ignitions." Also, because "large fires were not dependent on old age classes of fuels…it is unlikely that age class manipulation can prevent large fires. Expansion of the urban-wildland interface is a key factor in wildland fire destruction."

Figure 5—Controlled burn in chaparral. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Response to fire—Fires usually occur in chaparral in late summer or fall. The following spring, herbaceous vegetation appears. Almost immediately, preburn shrubby species emerge—sprouters such as *Adenostoma fasciculatum* (fig. 6) and many *Arctostaphylos* species, and obligate seeders such as certain species of *Ceanothus* (Carrington and Keeley 1999, Lloret et al. 1999, Sparks and Oechel 1993, Stohlgren et al. 1986). A very hot fire in chaparral on a harsh site, though, may cause "shock stagnation," resulting in a semipermanent coastal sage scrub community, or even a depauperate grassland. On some sites, "flash-fuel species," such as *Lotus scoparius* and *Eriogonum fasciculatum,* are among the first woody or semiwoody plants to appear after a fire (Vogl 1982). These species have finely dissected foliage, and like annual grasses, become easily ignitable and highly flammable in late summer, increasing the chance of reburning before stand recovery. Chaparral that burns a second time within a few years often undergoes a dramatic change in vegetation, with the loss of obligate seeders and weakening of some sprouters (Keeley 1995, Riggan et al. 1988). The practice of seeding burned areas to annual grasses, such as *Lolium perenne* ssp. *multiflorum* (Italian ryegrass), can lead to early reburning, as well as

Figure 6—Sprouting chamise after fire killed the aboveground growth. (Photo by USDA Forest Service, Pacific Southwest Research Station)

delayed or failed regeneration of woody plants owing to grass root competition (Vila and Sardans 1999, Wohlgemuth et al. 1998).

Importance of chaparral—Chaparral's inherent flammability generates a lot of attention from land managers who are indirectly charged with protecting the property and lives of millions of people placed at risk from uncontrolled fires. Ongoing encroachment of development into chaparral ecosystems is placing more people in jeopardy and increasing the costs and complexity of management. Human encroachment also threatens the health, function, and even the existence of chaparral in four ways: (1) outright replacement of natural communities by urban and commercial development, putting many species of plants and animals in peril (e.g., San Diego County "…is home to more endangered species than any other county in the Continental United States" [Nickens 2001]); (2) fragmentation of habitat into pieces too small or too narrow to be self-sustaining or useful to wildlife (Bolger et al. 1997); (3) increased frequency of human-caused wildfires, resulting in degradation of chaparral communities (Keeley 1995); and (4) damage and degradation of stands by various human activities. Chaparral managers also are faced with trying to control or minimize erosion and mass movement of steep slopes—which, like fire, can lead to property damage and loss of life–and maintaining air and water quality, viewsheds, and open space. Soils under chaparral have been found to have relatively high concentrations of organic carbon and nitrogen, an important consideration locally, but also important at the global scale because soils store about twice the amount of carbon stored in living biomass or the atmosphere (Quideau et al. 1998).

Chaparral is important habitat for many species of birds, reptiles, and mammals—year-round residents as well as seasonal transients. Some deep-habitat dwellers rely almost entirely on chaparral for food, shelter, and reproduction sites, whereas others occupy the ecotonal zones between chaparral and woodland or chaparral and grassland, and use chaparral and nonchaparral habitats to satisfy their various needs (Bolger et al. 1997, Mayer and Laudenslayer 1988, Quinn 1990, Wirtz 1991). Chaparral management activities intended to protect or enhance one set of values may be at cross-purposes with other values and objectives. For example, prescribed fire is an important tool for maintaining healthy chaparral and minimizing the risk of catastrophic wildfire (Biswell 1989), but smoke emissions from controlled burns negatively affect air quality (Hardy et al. 1996), a critical factor in southern California where chaparral is juxtaposed and intermingled with built-up areas.

Chaparral Area, Ownership, and Classification

Chaparral Area

As defined in this study, chaparral covers about 4.6 million acres—approximately 7,200 square miles—in the southern and central coastal region of California. This is 14 percent of the total land in the 14-county study area (tables 2 and 3). Area of chaparral in central coastal and southern California by type and Bailey's ecosection (Bailey et al. 1994) is shown in tables 4, 5 and 6, and the distribution of chaparral plots by ecosection is shown in figure 7. Chaparral tends to be concentrated in counties that abut the ocean from Monterey south to San Diego. Excluded from the study are the Bay Area counties of Alameda, Contra Costa, and San Francisco, which are heavily urbanized, and contain relatively little chaparral; and Solano County, which consists mostly of agricultural and urban areas. Chaparral amounts to only 10.9 percent of the land area in Riverside County and 2.2 percent in San Bernardino, but these percentages are somewhat misleading (fig. 8). These counties collectively contain nearly 800,000 acres of chaparral. The percentages are small only because of the enormous size of the counties.

Table 2—Chaparral[a] area by county, owner class, and reserved status

County	Unreserved			Reserved			Total
	National forest	Other public[b]	Private	National forest	Other public[c]	Private[c]	
				Acres			
Los Angeles	300,582	21,420	175,730	18,406	36,981	670	553,789
Marin		21,462	9,124		6,580	400	37,566
Monterey	12,954	72,970	238,170	33,832	11,400	20	369,345
Orange	45,997		56,932		5,220	3,400	111,550
Riverside	79,357	78,708	231,185	79,202	30,208	500	499,160
San Benito		95,204	138,919		12,500		246,623
San Bernardino	163,681	10,782	91,117		10,430		276,010
San Diego	195,028	240,259	454,138	12,271	101,230	515	1,003,441
San Luis Obispo	72,508	85,846	209,269	30,635	19,460		417,718
San Mateo			18,249		17,843	60	36,152
Santa Barbara	167,420	38,631	117,431	115,263	1,900		440,645
Santa Clara			170,307		18,120		188,427
Santa Cruz			25,913		6,415		32,328
Ventura	79,315	21,462	114,420	85,825	25,425		326,447
Total	1,116,842	686,743	2,050,906	375,434	303,712	5,565	4,539,201

[a] PNW chaparral determined in field. National forest chaparral determined by <10 percent cover, and CALVEG type considered to be hard chaparral.
[b] Includes federal, state, county, and municipal agencies.
[c] Reserved other public and reserved private data are from reports by those owners, i.e., not sampled.

Table 3—Chaparral area, by county

County	Total land area	Chaparral area[a]	Percentage of county in chaparral	Study area chaparral in county
	----------- *Acres* -----------		----------- *Percent* -----------	
Los Angeles	2,514,560	588,896	23.4	12.8
Marin	332,800	37,566	11.3	.8
Monterey	2,126,080	369,345	17.3	8.0
Orange	505,600	111,550	22.1	2.4
Riverside	4,613,120	502,725	10.9	10.9
San Benito	888,960	246,623	27.7	5.3
San Bernardino	12,839,040	279,574	2.2	6.1
San Diego	2,691,200	1,003,441	37.3	21.8
San Luis Obispo	2,114,560	417,718	19.7	9.1
San Mateo	287,360	36,152	12.6	.8
Santa Barbara	1,628,800	462,344	28.4	10.0
Santa Clara	826,240	188,427	22.8	4.1
Santa Cruz	285,440	32,328	11.3	.7
Ventura	1,181,440	333,680	28.2	7.2
All	32,835,200	4,610,368	14.0	100.0

[a] County acreages differ from those in table 2 because National Forest System classifications of chaparral used in some counties differ from PNW classifications.

Table 4—Area by Bailey's ecosection, owner group, and PNW chaparral classification system

Bailey's ecosection	Owner group	Chamise	Coastal transition	Mixed chaparral	Scrub oak	Non-chaparral	Total
		Acres					
Bay area/delta	NF,[a] unreserved						0
	NF, reserved						0
	Other public	21,462					21,462
	Private	114,055	50,184	22,811	10,630		197,681
Colorado Desert	NF, unreserved	4,133					4,133
	NF, reserved				10,233		10,233
	Other public	32,346		17,970	6,829		57,145
	Private	58,912		47,129	15,710		121,751
Mojave	NF, unreserved						0
	NF, reserved						0
	Other public		10,782				10,782
	Private	15,710		15,710	40,845		72,265
San Joaquin Valley	NF, unreserved						0
	NF, reserved						0
	Other public			21,462			21,462
	Private				22,811		22,811
South-central coast	NF, unreserved	52,727	28,932	211,584	35,606	42,858	371,707
	NF, reserved	70,066	36,165	155,960	25,063		287,253
	Other public	107,308	30,046	103,016	30,819		271,189
	Private	440,755	53,743	105,273	107,121		706,892
South coast	NF, unreserved	259,546	85,313	395,609	92,862	13,061	846,390
	NF, reserved	30,367	10,233	50,510	8,536		99,646
	Other public	122,196	140,063	42,445			304,704
	Private	461,679	210,858	163,119	93,850		929,506
Total		1,791,263	656,319	1,352,596	500,914	55,919	4,357,011

Note: Other public includes federal, state, county, and municipal agencies.
[a] NF = national forest.

Table 5—Area by Bailey's ecosection, owner group, and CALVEG classification system

Bailey's ecosection	Owner group	Curl-leaf mountain mahogany	Basin sagebrush	High desert mixed chaparral	Chamise	Ceanothus chaparral	Southern mixed chaparral	Greenleaf manzanita	Lower montane mixed chaparral
		Acres							
Bay area/delta	NF, unreserved								
	NF, reserved								
	Other public								21,462
	Private				68,433				68,433
Colorado Desert	NF, unreserved				4,133				
	NF, reserved								10,233
	Other public				32,346				17,970
	Private				31,294	15,710			15,710
Mojave	NF, unreserved								
	NF, reserved								
	Other public								
	Private				15,710				15,710
San Joaquin Valley	NF, unreserved								
	NF, reserved								
	Other public								21,462
	Private								
South-central coast	NF, unreserved				42,384				255,283
	NF, reserved				58,245				182,805
	Other public				85,846	17,169		9,357	42,923
	Private				395,133				91,586
South coast	NF, unreserved	7,208	5,517	10,264	210,795	27,617	10,347		371,397
	NF, reserved				10,279				41,604
	Other public				104,226				63,907
	Private				354,821	71,857			258,974
Total		7,208	5,517	10,264	1,413,646	132,353	10,347	9,357	1,479,458

Note: Other public includes federal, state, county, and municipal agencies.

Table 5—Area by Bailey's ecosection, owner group, and CALVEG classification system (continued)

Bailey's ecosection	Owner group	Red shank	Scrub oak	Baccharis	Montane-mixed chaparral	Semidesert mixed chaparral	Mixed desert shrub	California juniper	North coast chaparral
		Acres							
Bay area/delta	NF, unreserved								
	NF, reserved								
	Other public								
	Private		10,630						27,373
Colorado Desert	NF, unreserved								
	NF, reserved								
	Other public		6,829						
	Private	27,618							
Mojave	NF, unreserved								
	NF, reserved								
	Other public						10,782		
	Private		40,845						
San Joaquin Valley	NF, unreserved								
	NF, reserved								
	Other public								
	Private		22,811						
South-central coast	NF, unreserved		6,675			13,389		6,156	
	NF, reserved		10,597			7,233			
	Other public		21,462			21,462			
	Private		84,310			22,811			25,913
South coast	NF, unreserved	19,860	53,759			17,817			
	NF, reserved	28,948	4,652		9,024				
	Other public	17,970							
	Private	36,981	65,573	15,710					9,124
Total		131,377	328,141	15,710	9,024	82,711	10,782	6,156	62,411

Note: Other public includes federal, state, county, and municipal agencies.

Table 5—Area by Bailey's ecosection, owner group, and CALVEG classification system (continued)

Bailey's ecosection	Owner group	Alluvial fan sage scrub	Manzanita chaparral	Coastal bluff scrub	Sumac	Mixed soft shrub chaparral	Coastal sage scrub	Birchleaf mountain mahogany	Total
		Acres							
Bay area/delta	NF, unreserved								0
	NF, reserved								0
	Other public								21,642
	Private						22,811		197,681
Colorado Desert	NF, unreserved								4,133
	NF, reserved								10,233
	Other public								57,145
	Private				31,420				121,751
Mojave	NF, unreserved								0
	NF, reserved								0
	Other public								10,782
	Private								72,265
San Joaquin Valley	NF, unreserved								0
	NF, reserved								0
	Other public								21,462
	Private								22,811
South-central coast	NF, unreserved	32,493					11,441	3,885	371,707
	NF, reserved	7,233					14,466	6,675	287,253
	Other public		42,923			21,462	8,585		271,189
	Private		13,687	22,811			50,641		706,892
South coast	NF, unreserved	17,253	18,847		10,933	3,564	28,963	32,249	846,390
	NF, reserved		5,140						99,646
	Other public				50,316		50,316	17,970	304,704
	Private				62,839		53,628		929,506
Total		56,979	80,596	22,811	155,508	25,026	240,850	60,779	4,357,011

Note: Other public includes federal, state, county, and municipal agencies.

Table 6—Area by Bailey's ecosection, owner group, and California Wildlife Habitat Relationships classification system

Bailey's ecosection	Owner group	Chamise-red shank	Mixed chaparral	Montane chaparral	Coastal scrub	Juniper	Desert succulent	Desert scrub	Sagebrush	Total
		Acres								
Bay area/delta	NF, unreserved									0
	NF, reserved									0
	Other public		21,462							21,462
	Private	68,433	79,063		50,184					197,681
Colorado Desert	NF, unreserved	4,133								4,133
	NF, reserved		10,233							10,233
	Other public	32,346	24,799							57,145
	Private	43,202	78,549							121,751
Mojave	NF, unreserved									0
	NF, reserved									0
	Other public									0
	Private	15,710	56,555					10,782		83,047
San Joaquin Valley	NF, unreserved									0
	NF, reserved									0
	Other public		21,462							21,462
	Private		22,811							22,811
South-central coast	NF, unreserved	42,384	294,693	10,041	11,441	13,147				371,707
	NF, reserved	58,245	200,635	13,908	14,466					287,253
	Other public	85,846	145,939	9,357	30,046					271,189
	Private	395,133	212,394		99,365					706,892
South coast	NF, unreserved	230,048	528,153	41,224	25,078		1,713	7,449	12,725	846,390
	NF, reserved	28,994	65,513	5,140						99,646
	Other public	122,196	114,223	17,970	50,316					304,704
	Private	391,802	474,952		62,752					929,506
Total		1,518,473	2,351,434	97,639	343,649	13,147	1,713	18,231	12,725	4,357,011

Note: Other public includes federal, state, county, and municipal agencies.

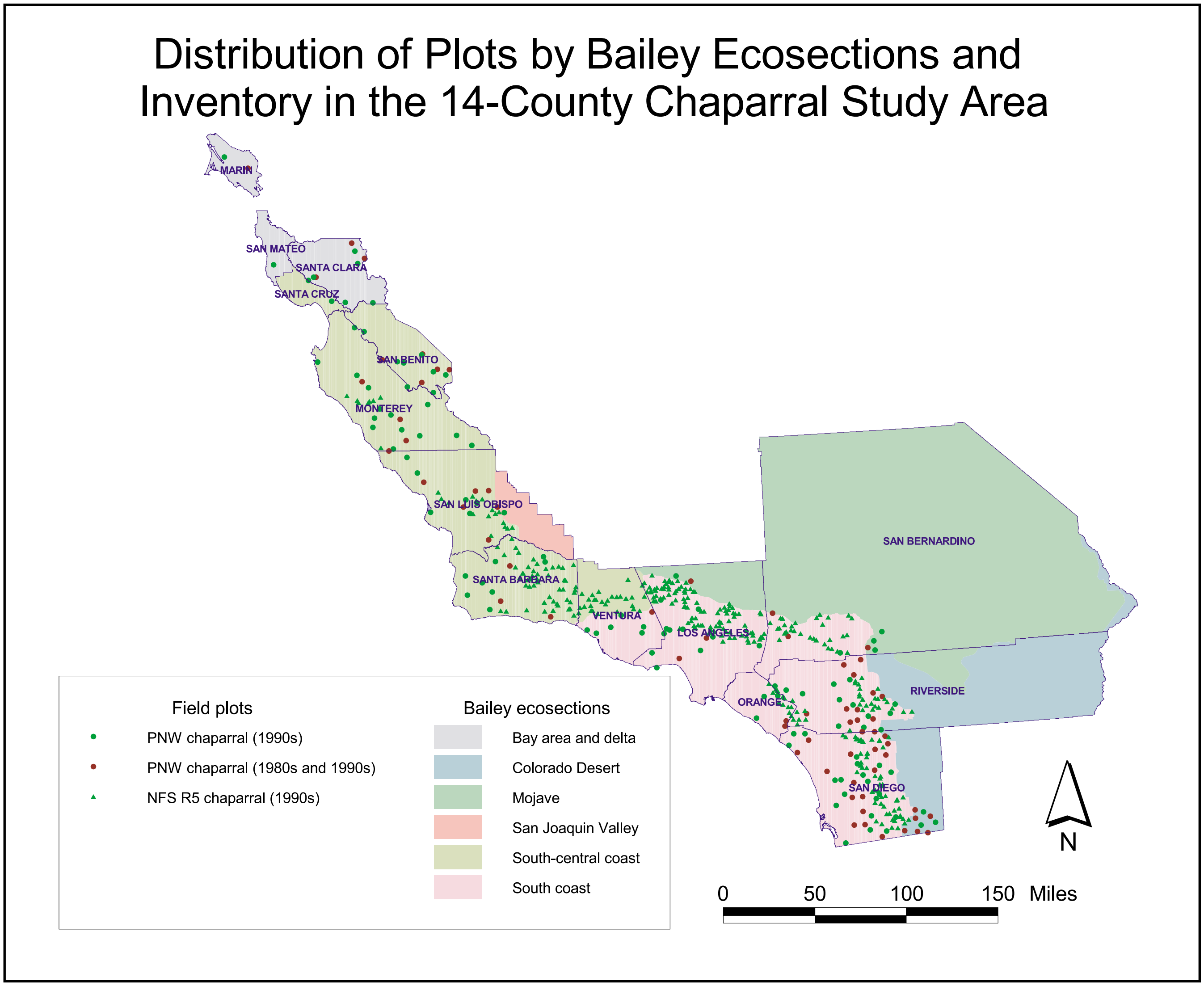

Figure 7—Distribution of chaparral plots by Bailey's ecosection.

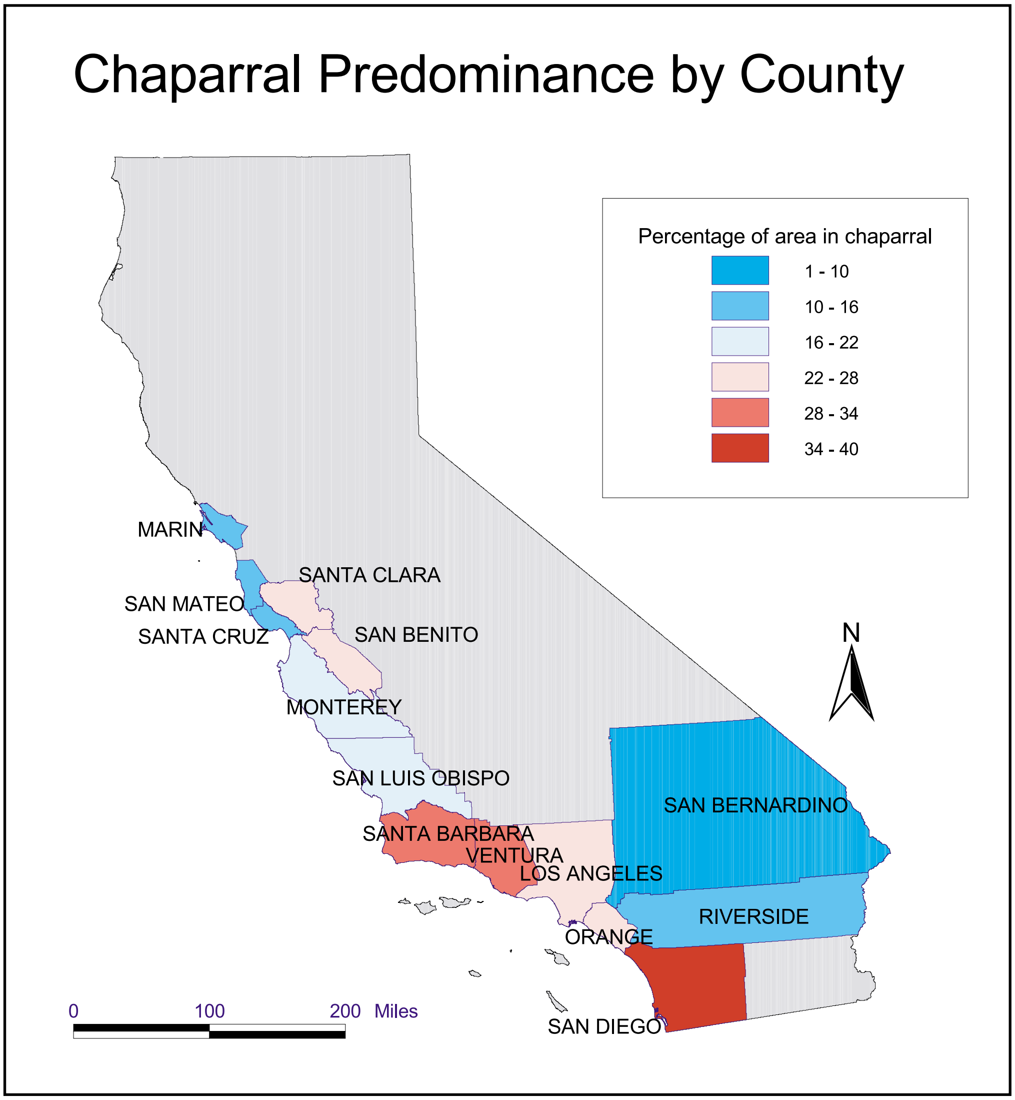

Figure 8—Chaparral predominance by county.

Ownership

A little more than 2 million acres (45 percent of chaparral area) of chaparral in southern and central coastal California is in private ownership, including 132,000 acres of tribal lands. About 1.2 million acres (34 percent) of chaparral are administered by the USDA Forest Service in the Angeles, Cleveland, Los Padres, and San Bernardino National Forests. The USDI Bureau of Land Management administers 392,000 acres (9 percent). The balance is fairly evenly divided among other federal, state, and county/municipal agencies, with roughly 200,000 acres (4 percent) in each ownership. About 15 percent of the chaparral is in parks, wilderness, and other reserved areas, as shown in table 7.

Table 7—Chaparral area by owner group

Ownership	Unreserved	Reserved	Total area	
	------------------------ *Acres*	------------------------		*Percent*
Private	2,050,905	5,565	2,056,470	44.6
National forest	1,166,311	397,132	1,563,443	33.9
Bureau of Land Management	392,095	41,030	433,125	9.4
Other federal[a]	177,195	22,910	200,105	4.4
State	0	171,506	171,506	3.7
County/municipal	117,453	68,266	185,719	4.0
Total	3,903,959	706,409	4,610,368	100.0

[a] Includes Department of Defense.

Change in Chaparral Area

Estimates of change in area of chaparral for land outside national forests are based on the classification of plots at two points in time. For example, the area represented by a plot classified as chaparral in the previous inventory (nominally 1984) and classified as nonforest urban in the next inventory (nominally 1994), would be counted as a decrease in chaparral area. Comparable change estimates cannot be made for national forests because plots have been visited only once. The primary causes of change in area of chaparral are urban, industrial, and agricultural developments, which are rare to nonexistent on national forest land. It is possible that land exchanges could have resulted in the development of land formerly under national forest control, but these areas would then be sampled by PNW plots, and theoretically accounted for in the resulting figures. Any change in area of chaparral in national forests caused by construction or removal of, for example, roads, reservoirs, and powerlines, cannot be accounted for by this analysis. The chaparral plots in national forests used in this study have been monumented for relocation, and will, if revisited in the future, provide a basis for monitoring change.

Based on the sample plots, the net decrease in chaparral outside national forests over the nominal 10-year period 1984-94 was 179,400 acres. This change comprises 108,400 acres in conversions to urban and agricultural/range uses; 84,000 acres dedicated to parks and other reserves (which are still chaparral, physically, but fell out of the inventory as defined in 1994); and, 13,000 acres of rangeland that became chaparral (fig. 9). This 13,000-acre conversion from rangeland to chaparral is a real change according to the definitions, but the land could possibly have been chaparral at some time prior to the 1984 inventory. All plots that changed land class were scrutinized closely to ensure that change was genuine and not simply the result of differences in the interpretation of definitions. For example, a plot classified as chaparral in the 1984 inventory was classified as oak woodland in 1994. On closer inspection the crews decided the plot really had been oak woodland all along, despite the abundance of chaparral species. That plot is not included in these change estimates. The net physical loss of chaparral is 95,400 acres—108,400 acres lost to development offset by 13,000 acres gained from grassland—and amounts to about 3.3 percent of the

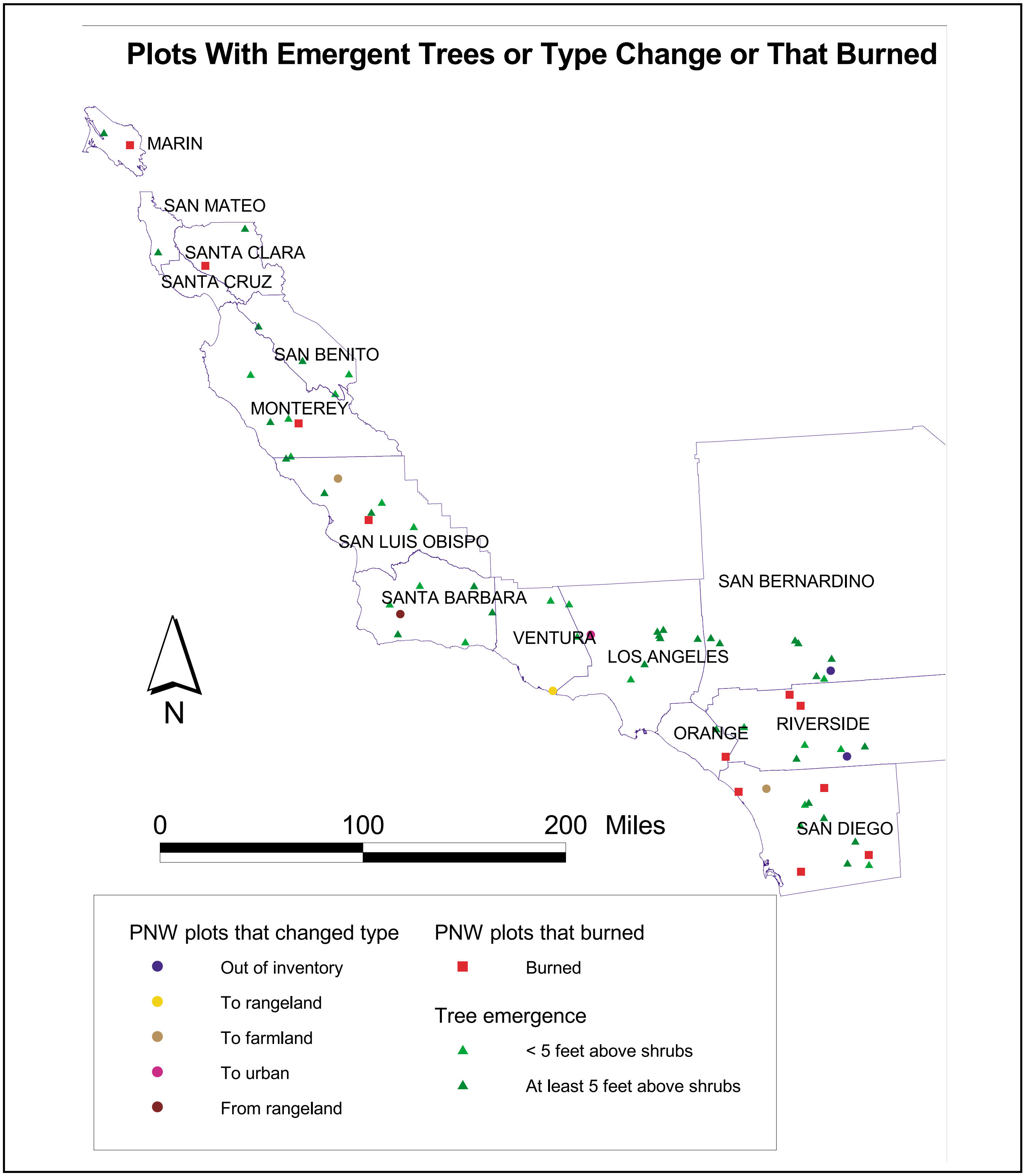

Figure 9—Plots outside national forest with type change or fire incidence between measurements and all plots with emergent or pre-emergent trees in the 1990s.

Table 8—Area by PNW chaparral type

PNW chaparral type	Area	Percentage of chaparral
	Thousand acres	
Chamise and red shank	3,822	51
Mixed and montane	1,520	20
Scrub oak	952	13
Mountain mahogany	309	4
Coastal transition	578	8
Untyped (in parks)[a]	267	4
Total	7,448	100

[a] Primarily where no systematic inventory has been undertaken and areas are estimated by park managers.

area of chaparral in 1984. This comes out to 9,540 acres—about 15 square miles per year. In the statewide chaparral inventory conducted in the 1980s (Bolsinger 1989), five broad types were recognized (table 8). The PNW chaparral types were classified by using the following protocol:

Chaparral Types in the 1980s

Chamise and red shank—Crown cover of *Adenostoma fasciculatum* or *A. sparsifolium* or both is 40 percent or more and exceeds that of all *Quercus* spp. combined, or *Cercocarpus* spp. combined, or other individual species; or, *Adenostoma* spp. have simple plurality if no species has 40 percent crown cover (fig. 10). In this report, plots that would have been classified as red shank in 1984 are usually lumped with the chamise type because red shank is so lightly represented in the study area covered by this report (five plots outside national forests and eight plots on national forests); however, results for red shank are listed separately from chamise in the burned area analysis and constancy tables because of possible differences between these two types.

Scrub oak—Crown cover of shrubby *Quercus* spp. is 40 percent or more and exceeds that of *Adenostoma* spp. combined, or *Cercocarpus* spp. combined, or other individual species; or, *Quercus* spp. have simple plurality if no species or type group has 40 percent crown cover.

Mountain mahogany—Crown cover of *Cercocarpus* spp. is 40 percent or more and exceeds that of *Adenostoma* spp. combined, or *Quercus* spp. combined, or other individual species; or, *Cercocarpus* spp. have simple plurality if no species or type group has 40 percent crown cover.

Coastal transition—Soft (pliable-stemmed) chaparral species (Paysen et al. 1980) make up 25 percent or more of the shrub cover, but hard (woody-stemmed) chaparral species are dominant, or when present but not dominant in immature stands are expected to dominate at maturity. Major hard chaparral species in this type are

Figure 10—Chamise stand with emergent trees in background. (Photo by Charles Webber, California Academy of Sciences)

Baccharis pilularis, Heteromeles arbutifolia, Rhus integrifolia, R. ovata, and *Malosma laurina,* but many others often occur. Common soft chaparral species are *Salvia* spp. (fig. 11), *Artemisia californica, Eriogonum* spp., *Lotus scoparius, Encelia* spp., and *Croton* spp. Stands classified as coastal transition were either in a zone of gradation from the more mesic hard chaparral to xeric scrub at lower elevation (geographic transition), or had been disturbed in the recent past and were temporarily (as judged by field crews) dominated by coastal scrub species (successional transition), although hard chaparral species were present.

Mixed and montane—Hard chaparral species dominate, and none of the above categories apply. In this broad type are species of *Adenostoma, Arctostaphylos, Ceanothus, Prunus, Rhus, Quercus, Garrya, Cercocarpus,* and many others (fig. 12).

Chaparral Types in the Current Study

In this study, the same broad types and definitions used in the 1980s chaparral inventory by PNW were used to develop basic statistics for comparative purposes with this exception: all species of *Cercocarpus* (mountain mahogany) were combined with mixed and montane chaparral because two-thirds of the area in mountain mahogany types is outside the central coast and southern California study area. Also, many of the stands with *Cercocarpus* species present were borderline, such that a difference in cover of 1 or 2 percent by any number of species could change the classification.[1] All plots in this study were classified according to the PNW

[1] The two most prevalent species of *Cercocarpus* in California—*C. ledifolius* and *C. betuloides*—occur in somewhat different environments and properly belong in different types, as they have been placed in the CALVEG and CWHR systems (see following section). There was only one plot with *C. ledifolius* in the current study area, so the matter is rather academic.

Figure 11—*Salvia mellifera* (black sage), a common species in coastal sage scrub, is seasonally dimorphic, with large, broad leaves during moist seasons, and small, narrow leaves during drought. (Photo by Todd Keeler-Wolf, California Department of Fish and Game)

chaparral types described above, and two other systems:[2] (1) Classification and assessment with Landsat of visible ecological groupings–CALVEG (USDA FS, 1981, 2000a, 2000b) and California wildlife habitat relationships (CWHR) (California Department of Fish and Game 1999, Mayer and Laudenslayer 1988). The CALVEG system is a constantly evolving mapping and hierarchical classification system that combines life form estimates derived from remotely sensed data with quite specific field observations of cover type, species, size, and other attributes of vegetation for broad-scale planning and analysis. The CWHR system, also hierarchical and evolving, incorporates information on vegetation life form, stand structure, and cultural and

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[2] A system of vegetation classification developed by a group of distinguished scientists and published by the California Native Plant Society (CNPS) (Sawyer and Keeler-Wolf 1995) has much to offer, and we expect to test its use for future assessments. We didn't use it in this assessment for these reasons: (1) timing; (2) the large number of shrub series in the CNPS system would stretch the limitations of our plot sample; (3) the CNPS system uses qualitative (vs. quantitative) criteria, which we feel (perhaps unjustifiably) would make it difficult to get consistent results in repeat measurements by field crews with various levels of experience.

aquatic elements, at scales needed for wildlife habitat management and planning. Applying these three classification systems to the 513 chaparral plots resulted in three distributions of area by type and some differences in total chaparral area (because a plot could fit a chaparral type in one classification system, but not in another). Included in table 1 are areas for plant associations that qualify as chaparral by at least one classification system, even though they may not qualify by all systems. A complete summary of acres by type and owner can be found in tables 4, 5, and 6. Maps of plot locations symbolized by chaparral type under each classification system strongly suggest spatial clustering (figs. 13-15).

Figure 12—Mixed chaparral consisting primarily of *Arctostaphylos glandulosa,* (Eastwood's manzanita) with minor amounts of *Ceanothus* spp., *Prunus* spp., and *Quercus* spp. (Photo courtesy of Todd Keeler-Wolf, California Department of Fish and Game)

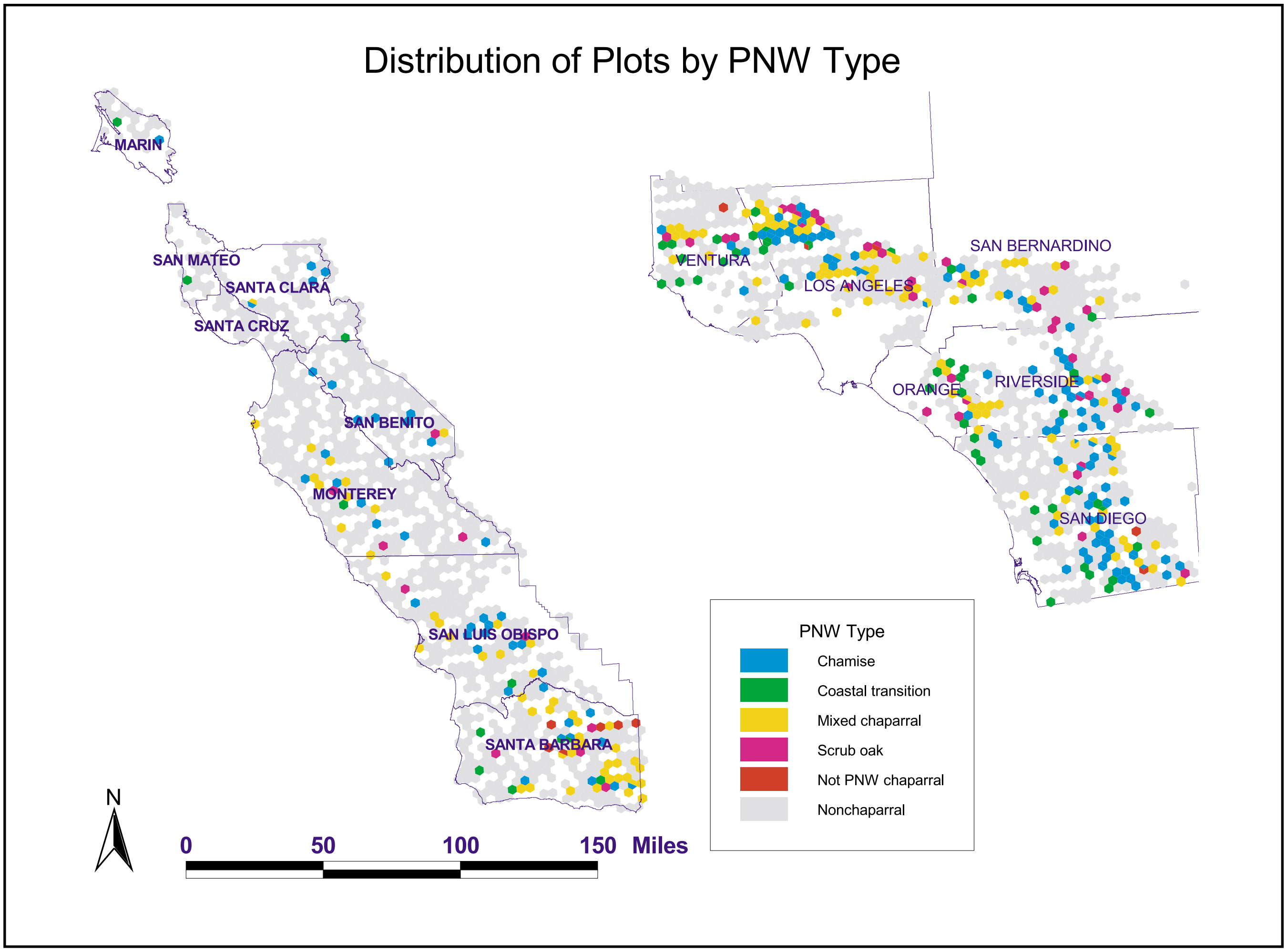

Figure 13—Distribution of chaparral plots by PNW type; to comply with federal statutes on plot confidentiality, 6,000-acre hexagons are attributed according to the plot or plots contained therein; where there are multiple plots in a hex with different attribute values, hexes are arbitrarily subdivided to ensure that all types are displayed.

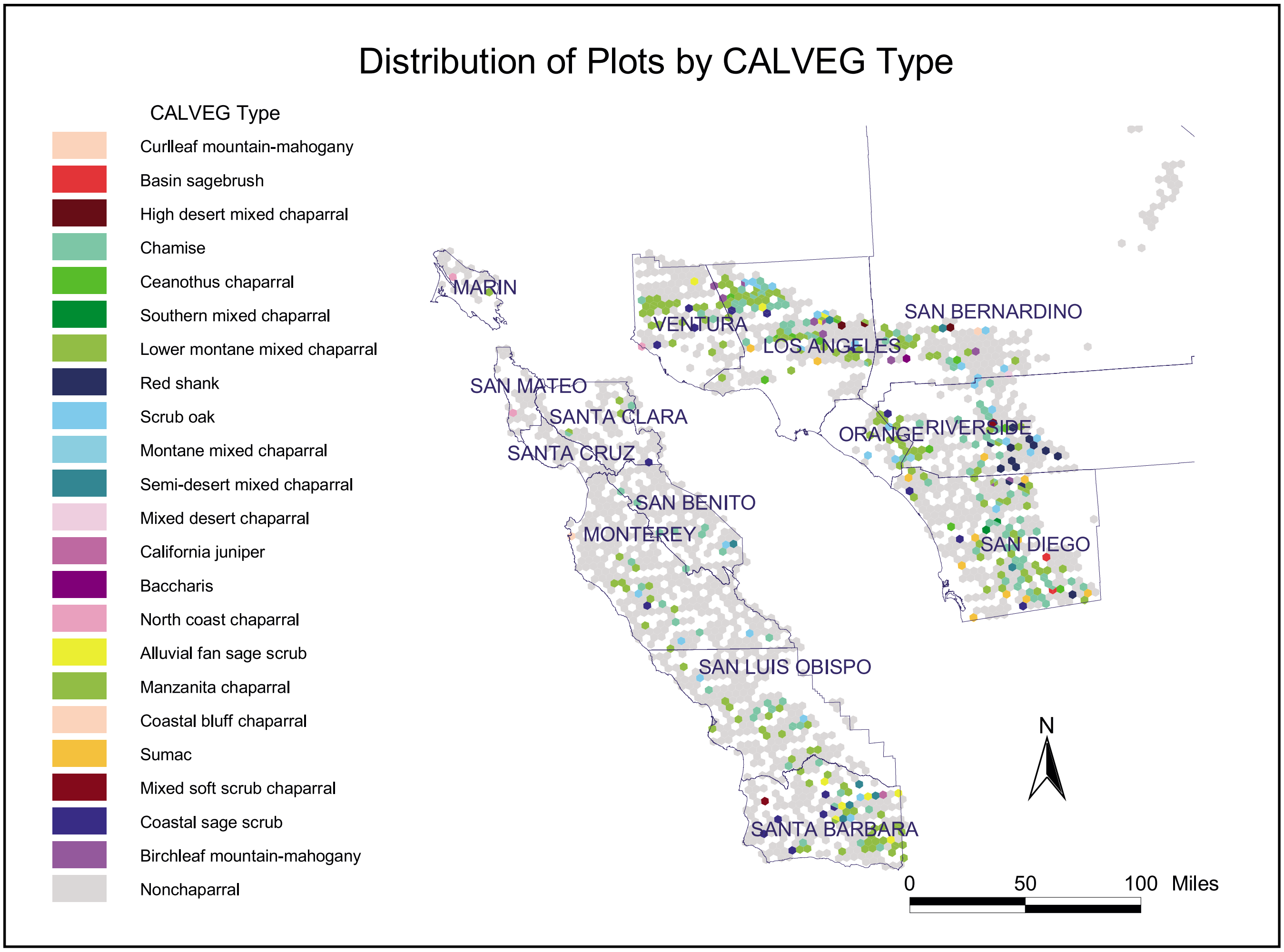

Figure 14—Distribution of plot locations coded by CALVEG type; to comply with federal statutes on plot confidentiality, 6,000-acre hexagons are attributed according to the plot or plots contained therein; where there are multiple plots in a hex with different attribute values, hexes are arbitrarily subdivided to ensure that all types are displayed. CALVEG = classification and assessment with Landsat of visible ecological groupings.

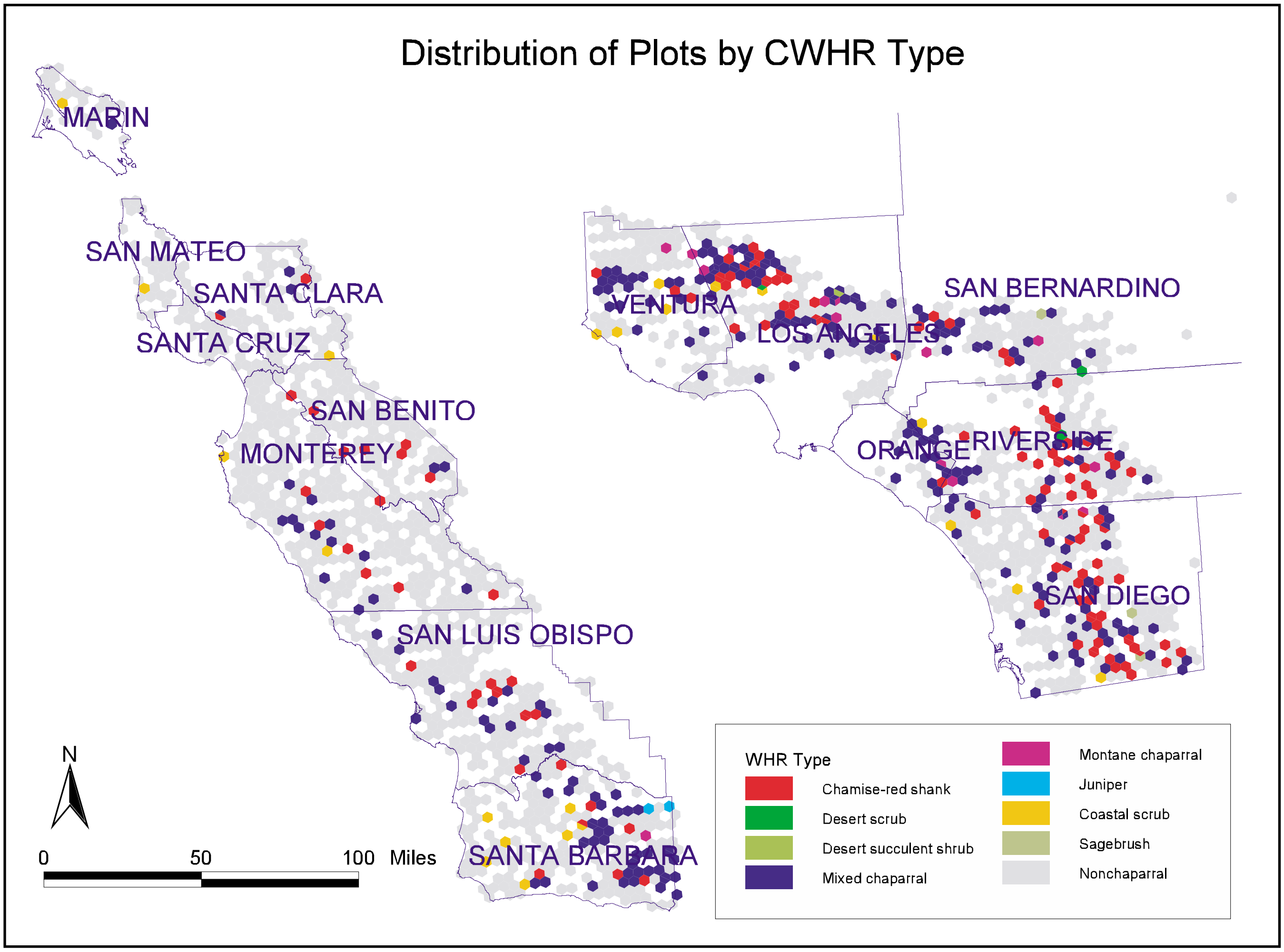

Figure 15—Distribution of plot locations coded by CWHR type; to comply with federal statutes on plot confidentiality, 6,000-acre hexagons are attributed according to the plot or plots contained therein; where there are multiple plots in a hex with different attribute values, hexes are arbitrarily subdivided to ensure that all types are displayed. CWHR = California wildlife habitat relationships.

Major Chaparral Types

Chamise (includes red shank)—This type occupies 1.5 or 1.8 million acres, depending on the classification system, or 32 to 42 percent of the chaparral in the study area. This type, dominated by *Adenostoma fasciculatum* or *A. sparsifolium* (fig. 16) or both, is more prevalent outside national forests (generally at lower elevation), where it makes up 52 percent of the chaparral area (PNW system). It accounts for 26 percent of the chaparral in national forests.

Figure 16—Chamise and red shank. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Mixed and montane chaparral—This type, as a single type (PNW), or a group (CALVEG and CWHR), is the second most extensive type by PNW's system (fig. 17), and the most extensive type by the CALVEG and CWHR systems. This type, actually a collection of many different plant associations (see "Characteristics of Chaparral Stands" section), occupies 1.4 million acres by PNW's system, 1.5 million acres by CALVEG (lower montane plus montane mixed), and 2.4 million acres by CWHR (mixed plus montane). More common at high elevations, it accounts for 50 percent of national forest chaparral, but only 19 percent of other ownerships.

Scrub oak—This type occupies about 500,000 acres by PNW's system, 328,000 acres by CALVEG, and is included in mixed chaparral in CWHR. Like mixed and montane, scrub oak type is made up of several plant associations, the common factor being that a species of shrub-size *Quercus* is dominant. Among the oaks in this type are *Q. dumosa* (some of which has recently been renamed *Q. berberifolia*), *Q. john-tuckeri* (called *Q. dumosa* in the 1980s), *Q. palmeri, Q. wislizeni* var. *frutescens, Q. agrifolia, Q. engelmannii, Q. chrysolepis,* and *Q. durata,* which typically grow on serpentine-peridotite soils (fig. 18). Scrub oak type makes up 11 percent of the chaparral both inside and outside national forests, although the predominant oak species in these two broad ownerships differ (see "Characteristics of Chaparral Stands" section).

Figure 17—Mixed chaparral. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Figure 18—*Quercus durata* (leather oak) on a serpentine ridge. (Photo courtesy of Todd Keeler-Wolf, California Department of Fish and Game)

Coastal transition—This type occupies about 656,000 acres and is more prevalent at lower elevations, amounting to 18 percent of the chaparral outside national forests, and 10 percent within national forests. Common hard chaparral species in this type are *Baccharis* spp., *Ceanothus greggii* var. *perplexans, Heteromeles arbutifolia, Rhus ovata* (fig. 19), and *Malosma laurina.* Many soft chaparral species are also present, among them *Artemisia californica, Lotus scoparius, Eriogonum* spp., *Croton* spp., and *Salvia* spp. (figs. 3 and 11).

Figure 19—*Rhus ovata* (sugar sumac) in bloom. (Photo by USDA Forest Service, Pacific Southwest Researech Station)

Coastal transition type is a PNW classification with no exact counterpart in CALVEG or CWHR. The PNW plots were classified in the field, and the types were assigned based on the plants present as well as other indicators on and in the general vicinity of the plot. The CALVEG and CWHR types were classified in the office and are based strictly on vegetation information collected by the field crews. A rough equivalent to coastal transition type in the CALVEG system would be a combination of coastal sage, scrub, mixed soft scrub chaparral, coastal bluff scrub, and sumac (totaling 444,000 acres); and in the CWHR system, coastal scrub (344,000 acres). We believe the PNW system provides a reasonable estimate of the total **potential** area of chaparral in undeveloped areas, whereas CALVEG and CWHR provide reasonable estimates of the area of plant communities as they **currently exist.** In this resource bulletin, any reference to chaparral type refers to PNW type, unless otherwise stated.

Characteristics of Chaparral Stands

Factors Affecting Composition and Structure

Chaparral ranges from nearly pure stands of chamise, manzanita, or scrub oak of uniform height and density, to ragged-looking stands of mixed chaparral in which every shrub seems to be of a different species, height, and form. The makeup of the overstory is greatly influenced by water availability. On drier chaparral sites, hard chaparral species—mainly *Adenostoma fasciculatum*—intermingle with soft chaparral or coastal sage-scrub species such as *Artemisia californica, Salvia apiana* (fig. 20), and *Eriogonum fasciculatum.* Moving along a gradient of increasing moisture, soft chaparral species give way to increasingly moisture-dependent associations of hard chaparral species. In a given geographic area the change is somewhat predictable, as shown in a conceptual chart of three-species associations (fig. 21), for the Forest Service Laguna Morena Demonstration Area (White 1981).

The assemblages of species that occur along the moisture gradient differ from one area to another, those on mesic sites more than those on xeric. The greatest departure occurs on serpentine sites, which support several species that occur

Figure 20—*Salvia apiana* (white sage), a soft chaparral or coastal sage species. (Photo by Todd Keeler-Wolf, California Department of Fish and Game)

Association											
ARCA	ERFA	ADFA	ADFA	ADFA	AFDA	CEGR	CEGR	QUDU	QUDU	CEBE	QUKE
SAAP	ADFA	ERFA	ERFA	CEGR	CEGR	ADFA	ADFA	ADFA	CEBE	QUDU	CEPA
ERFA	SAAP	SAAP	CEGR	YU	ARGL	ARGL	QUDU	CEGR	ADFA	ADFA	GR

Increasing moisture →

Code	Species, genus, or life form
ARCA	*Artemisia californica*
ADFA	*Adenostoma fasciculatum*
ARGL	*Arctostaphylos glandulosa*
CEBE	*Cercocarpus betuloides*
CEGR	*Ceanothus greggii* var. *perplexans*
CEPA	*Ceanothus palmeri*
ERFA	*Eriogonum fasciculatum*
GR	Grass
QUDU	*Quercus dumosa*
QUKE	*Quercus kelloggii*
SAAP	*Salvia apiana*
YU	*Yucca* spp.

Figure 21—Progression of species composition along a moisture gradient. Within each of the 12 associations, relative abundance of the species decreases moving down the column.

rarely or not at all on nonserpentine sites. Among these are *Quercus durata, Arctostaphylos bakeri, A. hispidula, A. hookeri* spp. *montana* (fig. 22), *A. viscida* ssp. *pulchella, Ceanothus ferrisiae, Ceanothus jepsonii,* and *Rhamnus californica* spp. *occidentalis.*

Composition of chaparral stands changes rapidly during the first 1 to 3 years of recovery after a fire (fig. 23). Annual forbs and grasses in great abundance and variety become established the first spring after a fire, and this lush growth attracts plant-eating animals and insects that, in turn, attract predators (Force 1982, Quinn 1982, Wirtz 1982). The herbaceous growth by the second or third year is usually replaced by shrubs, both sprouters and seeders. Dense stands often undergo self-thinning within a few years, then enter a period of apparent stability in terms of structure, density, and composition, although biomass continues to accumulate. In unusually long fire-free periods, chaparral stands will undergo changes in composition and structure.

Chaparral has been called a paradoxical vegetation type: it seems that its long-term existence depends on periodic disturbance, usually fire; otherwise it will give way to forest, oak savanna, or grass. However, extreme disturbance, especially one that soon follows a previous disturbance, will sometimes cause "shock stagnation"—a semipermanent degradation of the vegetation, often to exotic grasses such as *Avena fatua* (Vogl 1982). Just how long chaparral can exist without disturbance is not known. It would seem likely that it depends on type, site, and many other factors, as indicated by the existence of both healthy stands past the century mark and much younger stands that appear senescent (Keeley 1992, Stohlgren et al. 1986, Vila and Sardans 1999, Zedler and Zammit 1986). Although in many cases the primary determinants of stand composition are the species that occurred in the previous stand and elapsed time since fire, many other variables can come into play, including:

1. Mix of species with respect to their behavior after fire or in the long-term absence of fire. Chaparral species have been classified according to their postfire reproduction mode into obligate resprouters, facultative resprouters, and obligate seeders. Among the obligate resprouters are most species of *Quercus, Heteromeles arbutifolia, Rhamnus crocea, Prunus ilicifolia,* and *Cercocarpus betuloides.* Facultative resprouters (sprouters that also can regenerate from seed after a fire) include *Adenostoma* spp., *Arctostaphylos glandulosa, Ceanothus spinosus, Rhus ovata* (fig. 24), and *Salvia mellifera.* Obligate seeders include *Arctostaphylos glauca, A. viscida, A. manzanita* spp. *elegans, Ceanothus crassifolius* (fig. 25), *C. cuneatus, C. megacarpus,* and many others (Keeley 1986, Moreno and Oechel 1993). Chaparral species also have been classified into “fire recruiters” and “fire persisters,” according to their behavior in the long-term absence of fire, and their adaptation to different site conditions. In mesic, closed communities where fire has been absent for long periods, fire persisters such as species of *Quercus, Rhamnus, Prunus, Cercocarpus,* and *Heteromeles* often dominate, and in certain conditions may reproduce by seed. On arid, open sites, fire recruiters such as *Adenostoma, Arctostaphylos,* and *Ceanothus* generally prevail. On some sites, both categories of shrubs may coexist for periods of time, as different species capture moisture and nutrients from different environmental niches. This “niche segregation” or “resource partitioning” in chaparral is thought to occur at the initial regeneration phase after a fire (Davis et al. 1998). Certain species of obligate resprouters can regenerate from seed when stands have escaped fire for prolonged

Figure 22—*Arctostaphylos hookeri* (Hooker's manzanita) on serpentine outcrop. (Photo by David Graber, Sequoia and Kings Canyon National Park)

Figure 23—Annual forbs (Brassicaceae family) appear with shrub sprouts the first spring following a fire in chaparral. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Figure 24—*Rhus ovata* (sugar sumac), a facultative resprouter, resprouting following fire. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Figure 25—*Ceanothus crassifolius* (hoaryleaf ceanothus), an obligate seeder, in bloom. (Photo by USDA Forest Service, Pacific Southwest Research Station)

periods and litter has built up under shady canopies. These species may also produce sprouts of different ages from roots as well as burls, creating mixed-age stands, in contrast to obligate seeders, which always date back to the last fire (Keeley 1986, Zedler 1982, Zedler and Zammit 1986).

2. Age of previous stand. Older sprouters generally have larger lignotubers (burls), which promote copious sprouting after a fire. In the case of chamise, the primary function of burls may be to protect the latent buds from fire, rather than storage of carbohydrates, as has been generally assumed in the past (Sparks and

Oechel 1993). If stands burn at a very young age, obligate seeders, such as certain species of *Arctostaphylos* and *Ceanothus,* are killed before they can bear seed, and are thus eliminated from the site (Keeley 1986).

3. Age of present stand. Obligate seeders–many species of *Ceanothus* for example–are relatively short-lived, although their seeds may stay viable in the soil for a long time. In older stands, these short-lived species start dropping out, allowing existing, longer lived shrubs to expand their dominance, or for the recruitment of new species or both. The seeds of short-lived species may be present in the soil, but they generally won't germinate until there is a fire. Although it might appear that obligate seeders are somewhat at risk, some believe they actually have a genetic advantage over sprouters. After each fire cycle, a new genetic pool is produced, creating an ever-changing mix of genotypes of which some, theoretically, will be more adapted to changing environmental conditions. And as it turns out, most obligate seeders are more tolerant of environmental extremes than co-occurring sprouters (Davis et al. 1998, Zedler and Zammit 1986).

4. Amount of dead material in previous stand. Although older stands are often assumed to have more dead material than younger stands, factors other than age, such as disease, insects, herbivory, frost, drought, and atmospheric pollutants can also result in dead material (Paysen and Cohen 1990). Fire burning through large amounts of dead materials may generate intense hot spots in which lignotubers are damaged or killed. This results in few postfire sprouts and clumpy regeneration, which could lead to a change in species composition and even chaparral type. For example, seedlings of certain species of *Arctostaphylos* and *Ceanothus* are more likely to survive and thrive if nearby *Adenostoma* burls fail to sprout (Odion and Davis 2000).

5. Season and weather conditions when the last fire burned. These relate to maximum soil temperature and duration of high temperatures, and whether bud primordia were present at the time of the fire (Keeley 1986).

6. Presence of herbivores in the previous and present stand. Herbivory that targets certain species can alter the composition of stands. Although often negative, herbivory can have a positive effect: at certain times of the year rabbit browsing promotes the formation of bud primordia on certain shrub species. Harvester ants also can play a positive role by collecting seeds of *Ceanothus* and other shrub species and caching them in the soil below the lethal-heating zone (Ne'eman et al. 1999, Odion and Davis 2000). Mammals and birds as well as insects also may bring seeds of herbaceous plants from nearby coastal sage scrub into chaparral areas, either before a chaparral fire or immediately afterward. The herbaceous layer is generally very short-lived in chaparral, with many species disappearing within 2 to 3 years. In coastal sage scrub, however, many of these same herbaceous species exist in the understory for several years to decades. The flush of herbaceous vegetation the first spring following a fire is extremely important to erosion reduction, recovery of the chaparral, and animals that feed on the herbs, or animals that feed on those animals. To some extent, chaparral is dependent on, or at least benefits from, juxtaposition with coastal sage scrub as a source of seeds of herbaceous plants essential during the postfire recovery

period and on fauna that move between these two vegetation types as vectors (Westman 1979).

7. Site variations. Specifically, the focus is on site variations caused by interrelated factors such as elevation, distance from the ocean, slope, aspect, precipitation, physiography, and in some cases parent material and soil type (in general, climate overrides the influence of soils, with the exception of serpentine sites and extremely harsh sites on rocky ridgetops) (Carrington and Keeley 1999). In the case of sumacs, frost seems to be a critical factor. *Rhus ovata* is more cold hardy than *Malosma laurina* (previously *Rhus laurina),* tolerating temperatures as low as –4 degrees Fahrenheit. Pioneer citrus growers in southern California used *M. laurina* as an indicator of sites suitable for planting orchards (Boorse et al. 1998).

8. Human factors. Much attention has been given to the results of fire-prevention and fire-management efforts over the past several decades in terms of area burned, frequency of fires, nature of the resulting vegetation types, and patterns of vegetation across the landscape (Agee 1993, Biswell 1989, Conrad and Oechel 1982, Minnich 1983, Minnich and Chou 1997). With growing human presence in chaparral areas, ignition probability has increased, posing the threat of a drastically altered fire cycle (Keeley 1995), which, there is reason to believe, could produce wholesale changes in species composition and chaparral structure. Vegetation types that are inferior in the qualities people value might take the place of chaparral (Vogl 1982). Urbanization in some places has carved up the chaparral in sizes and configurations that put native plants and animals in jeopardy (Bolger et al. 1997). Various activities of humans in these areas—such as dumping trash, letting pets roam, riding motorbikes through the chaparral, planting invasive exotic plants, and plinking—have made things worse. The effect of smog, especially the phytotoxicity of ozone, has long been recognized, but more recently a different but related problem has been getting attention—nitrogen deposition in excess of what plants can use (referred to as "N saturation," or "chronic N inputs," or "elevated N deposition"). How serious this is in California has not yet been determined, but in other areas of the world nitrogen saturation has been associated with nutrient deficiencies, soil acidification, decreased mychorrhizal symbiosis, and increased susceptibility of plants to environmental stresses (Bytnerowicz and Fenn 1996, Fenn and Poth 1992, Riggan et al. 1985).

Shrub Species Tallied in the Inventory

In the statewide chaparral inventory conducted in the mid-1980s (Bolsinger 1989), about 60 species and varieties of shrubs were identified in the southern and coastal regions on land outside national forests. In the study reported here, about 70 species and varieties of shrubs were identified in the southern and coastal areas outside national forests. The greater number of species tallied in the more recent inventory is thought to be a function of the larger number of plots (about twice as many), the recent division of some species into two or more taxa, natural change, and possibly better plant identification.

In the mid-1980s inventory, plant species information was not available for national forests. In the current study, though, plants were identified on field plots in national forests. Because of the greater range of environmental conditions within national forests, as well as the greater number of plots, more shrub species were found in national forests than outside, 100 vs. 70. Table 9 lists shrub and subshrub species

Table 9—Constancy by PNW chaparral classification system, life form, and species in national forests (NF) and outside national forest (ONF) lands

Life form	Chamise		Red shank		Scrub oak		Mixed chaparral		Coastal transition	
	NF	ONF	NF	ONF	NF	ONF	NF	ONF	NF	ONF
	Constancy value[a] (percentage of plots on which species occurred)									
Shrubs:										
Adenostoma fasciculatum	100	96	63	40	48	24	73	71	75	16
Adenostoma sparsifolium	4	4	88	100			3	9	3	3
Arctostaphylos canescens	11	9			9	0	19	17	19	0
Arctostaphylos glandulosa	10	4	0	20	7	14	6	9	6	0
Arctostaphylos hookeri							0	3		
Arctostaphylos patula					2	10				
Arctostaphylos pringlei ssp. *drupacea*							1	3		
Arctostaphylos pungens	5	3			0	5	1	3		
Arctostaphylos spp.	53	1	38	0	48	5	43	3	22	0
Artemisia californica			13	0	2	5	12	3	28	50
Artemisia tridentata			25	20	2	10	3	3	3	0
Baccharis pilularis							3	0	6	0
Baccharis salicifolia									0	6
Baccharis spp.	1	3							0	29
Ceanothus cordulatus					5	0			3	0
Ceanothus crassifolius	8	5			2	5	17	11	16	0
Ceanothus cuneatus					2	10	4	17		
Ceanothus greggii var. *perplexans*	51	9	75	40	16	10	31	14	28	0
Ceanothus griseus									6	0
Ceanothus integerrimus					7	0	3	0	3	0
Ceanothus leucodermis	26	1			30	5	29	9	3	3
Ceanothus megacarpus	3	0					6	3	6	0
Ceanothus oliganthus							4	3	0	3
Ceanothus papillosus							6	3		
Ceanothus spinosus							1	11	6	0
Ceanothus thyrsiflorus							3	0	3	3
Ceanothus spp.					24	5	17	6	6	3
Cercocarpus betuloides	22	3	50	20	52	10	62	29	44	0
Cercocarpus ledifolius					2	5				
Chrysothamnus spp.	4	1	13	0	11	0	8	0	13	0
Cneoridium dumosum							1	3		
Comarostaphylis diversifolia							0	6		
Dendromecon rigida	5	0			5	0	11	0	6	0
Diplacus aurantiacus							0	3	0	3
Encelia farinosa									9	0
Encelia spp.									0	3
Ephedra viridis									3	0
Ephedra spp.							5	0	0	3

Ericameria ericoides							0	3		
Ericameria spp.							4	0	3	3
Eriodictyon californicum					0	5				
Eriodictyon capitatum									3	0
Eriodictyon crassifolium	26	0	13	0	5	0	15	3	22	0
Eriodictyon tomentosum	0	4								
Eriodictyon traskiae	7	0	13	0	5	0	19	0	16	0
Eriodictyon spp.							1	6		
Escobaria vivipara			13	0						
Fraxinus dipetala					0	5				
Fremontodendron californicum					5	0	6	0	3	0
Garrya fremontii					16	0	7	0	30	0
Garrya veatchii			13	0	18	0	13	0	3	0
Garrya spp.	4	1								
Hazardia squarrosa	7	3								
Heteromeles arbutifolia	7	10			30	14	42	23	31	16
Isomeris arborea									6	0
Juniperus californica	3	3			7	10	2	3	0	3
Keckiella antirrhinoides							0	3		
Keckiella ternata					9	0	11	0		
Keckiella spp.									6	0
Leptodactylon californicum					0	5				
Lonicera interrupta									3	0
Lonicera spp.					13	0	13	3	19	5
Lupinus spp.									3	0
Malacothamnus spp.							2	3	3	5
Malosma laurina	5	6			2	5	6	17	25	45
Philadelphus microphyllus					0	5				
Penstemon spp.							4	0		
Prunus ilicifolia	10	7	13	0	11	0	38	3	50	3
Prunus spp.							0	3		
Purshia glandulosa							5	0	6	0
Purshia tridentata var. *glandulosa*					5	0				
Quercus agrifolia var. *oxyadenia*							0	3		
Quercus chrysolepis					27	5	10	3		
Quercus dumosa/john-tuckeri	41	20	88	20	87	76	56	51	37	5
Quercus durata					0	10	0	3		
Quercus engelmannii					0	5				
Quercus wislizeni					23	0	18	0	3	0
Quercus spp.	9	0	0	20	2	5			0	3
Rhamnus californica							11	0	3	5
Rhamnus crocea	14	0	38	0			37	3	41	3
Rhamnus crocea var. *licifolia*					27	10	3	9	0	8
Ribes spp.			13	0	7	5	12	0	3	3
Rhus integrifolia									0	5

Rhus ovata	14	5	63	0	5	5	21	23	31	11
Rhus trilobata					7	0	6	0		
Rosa spp.							3	0		
Rubus ursinus					0	5			0	8
Rubus spp.							4	0		
Salix spp.							6	0	9	0
Salvia clevelandii	5	0								
Salvia leucophylla	3	0							9	0
Salvia mellifera	25	15			7	5	30	14	72	26
Salvia spp.			13	20			5	0	3	0
Sambucus spp.					2	5				
Symphoricarpos spp.	4	0	13	0	32	5			13	0
Toxicodendron diversilobum	7	0	13	0	36	10	27	11	16	24
Umbellularia californica							6	0		
Xylococcus bicolor	4	0	13	0						
Yucca schidigera									3	0
Yucca whipplei			63	0			58	0	75	0
Yucca spp.	67	4			38	5				
Subshrubs:										
Eriogonum fasciculatum	49	28	75	20	32	19	59	27	84	21
Eriogonum spp.									0	8
Gutierrezia sarothrae									0	3
Lotus scoparius	32	14	25	20	16	5	25	3	56	24
Lotus spp.									6	3
Opuntia acanthocarpa							0	3		
Opuntia basilaris									9	0
Opuntia occidentalis									0	3
Opuntia spp.			25	0	5	0			3	3
Salvia apiana	11	5	0	20			14	0	41	5
Salvia spp.					7	5	0	3	0	16
Solanum xanti			13	0					3	0
Sphaeralcea ambigua			13	0						

[a] Constancy values for national forests and other ownerships are not combined because of the different intensities and methodologies of the two inventories.

Continued (Part b)

Continued From Part a

tallied on plots, by chaparral type and by constancy value (percentage of plots on which a plant occurred; e.g., a plant that occurred on 10 percent of the plots would have a constancy of 10), in national forests and outside national forests. Species are included in this table only if they have a constancy value of 3 or greater, in one owner group or the other.[3] For a complete list of all species tallied, see "Scientific and Common Plant Names" section.

Species by Type, as Found on Inventory Plots

Despite the variable conditions that exist in southern and central coastal California, one could randomly select locations throughout the chaparral ecosystem and find chamise 7 times out of 10. Excluding plots with no shrub tally, chamise was present on 77 percent of the plots in national forests and 67 percent of the plots outside national forests. On the mesic sites where chamise was absent, *Arctostaphylos, Cercocarpus, Prunus,* and *Quercus* species often dominated. Scrub oak type had the lowest constancy of chamise in national forests, and second-lowest outside national forests. Coastal transition type outside national forests had the lowest constancy of chamise of all types. No single species, or genus for that matter, dominated coastal transition outside national forests. In this type, which is a collection of several associations, the major plants were *Artemisia californica, Baccharis* spp., *Ericameria* spp., *Heteromeles arbutifolia, Malosma laurina, Rhus ovata, Toxicodendron diversilobum, Eriogonum fasciculatum, Lotus scoparius,* and *Salvia* spp., with a smattering of *Ceanothus* spp., *Rhamnus* spp., *Ephedra* spp., *Encelia* spp., and others.

In chamise type, 35 species of shrubs were tallied. Common shrubs with high constancy value in this type in national forests were *Adenostoma fasciculatum, Yucc*a spp., *Ceanothus greggii* var. *perplexans, Quercus dumosa/john-tuckeri,*[4] and *Eriodictyon crassifolium;* outside national forests, shrubs in chamise with high constancy value included *Adenostoma fasciculatum, Ceanothus greggii* var. *perplexans, Quercus dumosa/john-tuckeri, Heteromeles arbutifolia,* and *Salvia mellifera.* On both ownerships, these and other species present show that chamise, as classified here, occurs over a rather broad range of moisture conditions. *Salvia* and *Yucca* would be expected on the more xeric sites, *Quercus dumosa/john-tuckeri* on more mesic sites, and *Ceanothus greggii* var. *perplexans* on intermediate sites. Four species of *Ceanothus* and three species of *Arctostaphylos* were tallied on plots in chamise type. A plant found only on plots in chamise type, both inside and outside national forests, is *Hazardia squarrosa* (sawtooth goldenbush), classified as a subshrub by McMinn (1939) but as a shrub in the *Jepson Manual* (Hickman 1993). *Salvia clevelandii* (fragrant sage), whose range barely reaches into San Diego County from Baja California, was found only in chamise type, in the Cleveland National Forest.

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[3] The list of herbaceous plants is longer and the constancy values are often greater for national forests because all plants were tallied down to a trace; outside national forests, herbaceous plants covering less than 3 percent of the plot area were not tallied.

[4] *Quercus dumosa* and *Q. tucker* were at one time identified as the same plant. *Quercus tucker* is now recognized as a separate species. In the PNW data, however, all *Q. dumosa* and *Q. tucker* are listed as *Q. dumosa. Quercus dumosa/john-tuckeri* in this bulletin may be in reference to *Q. dumosa* or *Q. tucker.*

In red shank type, which is usually grouped with chamise, 24 shrub species were tallied. A pattern of mesic and xeric shrubs similar to that in chamise occurred in both ownerships, with xeric-site plants such as *Artemisia tridentata,* mesic-site plants such as *Quercus dumosa/john-tuckeri,* and midsite plants such as *Ceanothus greggii* var. *perplexans.* The greater constancy of *Cercocarpus betuloides* on national forests suggests more mesic conditions there. One species of *Ceanothus* and two species of *Arctostaphylos* were tallied in red shank type. *Escobaria vivipara* (spiny-star), a rare plant threatened by collecting according to the *Jepson Manual* (Hickman 1993), was found only in red shank type on national forest land.

Fifty-two shrub species were tallied in scrub oak type, 44 in national forests, and 35 outside national forests. Only 2 species outside national forests had constancy values of 20 or higher—*Adenostoma fasciculatum* and *Quercus dumosa/john-tuckeri*—whereas in scrub oak type in national forests there were 14 species. Outside national forests only one oak species had a constancy value higher than 20–*Q. dumosa/john-tuckeri.* In national forests there were three oak species—*Q. dumosa/john-tuckeri, Q. chrysolepis,* and *Q. wislizeni.* This suggests that in national forests there may be more mesic scrub oak sites or older chaparral stands, or both, in which oak species have germinated in accumulated duff. One species of oak that occurred only outside national forests (in scrub oak type and mixed and montane type) was *Q. durata,* which typically grows on serpentine sites. Seven species of *Ceanothus* and five species of *Arctostaphylos* were tallied in scrub oak type. Three shrubs tallied only on plots in this type were: *Fraxinus dipetala* (foothill ash), a widespread shrub or small tree that favors moist sites; *Leptodactylon californicum* (prickly phlox), a short-lived, showy shrub that occurs in a variety of vegetation types; and *Philadelphus microphyllus* (littleleaf mock orange) found on rocky sites from southern California east to Texas.

Sixty-nine shrub species were tallied on plots in mixed and montane type, which makes it floristically the richest type (one more species than coastal transition). This is not surprising given that, as its name implies, the type is actually a mixture of several types that occur on sites ranging from xeric to mesic, although mesic sites seem to be more common, as indicated by the greater number of mesic species tallied. However, *Adenostoma fasciculatum*—a xeric-site to midsite species—had the highest constancy value on both ownerships. Eleven species of *Ceanothus* were tallied in mixed and montane type (fig. 26), which ties coastal transition for number of species of this nitrogen-fixing genus. Six species of *Arctostaphylos* were tallied in this type (fig. 27), more than in any other type. *Malosma laurina* (fig. 28) in mixed and montane type in national forests had a constancy value of 6, compared with 17 outside national forests, possibly indicating more frost-prone sites in this type in national forests. National forests tend to be farther from the moderating influence of the ocean and at higher elevations where frost would seem more likely. Two shrubs tallied only in mixed and montane type were *Arctostaphylos hookeri* (fig. 22), a sprawling shrub of sandy flats, pine woods, and serpentine outcrops; and *Cneoridium dumosum* (bush rue), a strong-scented shrub occurring in San Diego County and south into Baja California (also on San Clemente Island and in Arizona).

Coastal transition type, with 68 species of shrubs, is almost as rich as mixed and montane. In many places, coastal transition interfaces or grades into coastal sage scrub, which explains the occurrence of shrubs such as *Artemisia californica, Salvia*

Figure 26—*Ceanothus spinosus* (redheart) in mixed chaparral. Note dead terminal branches. (Photo by Br. Alfred Brousseau, St. Mary's College)

Figure 27—*Arctostaphylos glandulosa* (Eastwood's manzanita), one of several species of manzanita, in mixed chaparral. (Photo by Br. Alfred Brousseau, St. Mary's College)

spp., and *Baccharis* spp. Eleven species of *Ceanothus* were tallied in coastal transition type, and three species of *Arctostaphylos. Heteromeles arbutifolia* (fig. 29), *Prunus ilicifolia* (fig. 30), and *Rhamnus crocea* (fig. 31) were much more abundant outside national forests in this type. Shrubs tallied only on plots in coastal transition type include *Baccharis salicifolia* (mule's fat), a coastal sage scrub riparian shrub; *Ceanothus griseus* (Carmel ceanothus), a sprawling shrub of the central coast, associated with serotinous-cone conifers and coastal sage scrub; *Eriodictyon capitatum* (Lompoc yerba santa), found only in Santa Barbara County in low-elevation chaparral (Hickman 1993); *Isomeris arborea* (bladderpod), common on ocean-facing

Figure 28—*Malosma laurina* (laurel sumac), a frost-sensitive shrub. (Photo by Br. Alfred Brousseau, St. Mary's College)

Figure 29—*Heteromeles arbutifolia* (toyon—Christmas berry—California holly), said to be the namesake of Hollywood. (Photo by J.E. (Jed) and Bonnie McClellan, California Academy of Sciences)

bluffs, but occasionally found inland; *Purshia glandulosa* (desert bitterbrush), found in canyons bordering the Colorado Desert, but extending westward to Ventura County; *Rhus integrifolia* (lemonade sumac), found at low elevations along the coast in southern California; and *Yucca schidigera* (Mohave yucca), common in the Mojave Desert, but found as far west as coastal San Diego County.

Development of Chaparral Stands

On most sites, regrowth of chaparral is rapid following fire, and within a very few years most stands are similar in composition and structure to prefire stands (Lloret et al. 1999). Fires generally occur in late summer or fall, but plant growth doesn't begin until

Figure 30—*Prunus ilicifolia* (hollyleaf cherry) (Photo by Br. Alfred Brousseau, St. Mary's College)

Figure 31—*Rhamnus crocea* (redberry buckthorn). (Photo by Beatrice F. Howitt, California Academy of Sciences)

late winter or spring (Carrington and Keeley 1999). For a few to several months after a fire, denuded slopes are vulnerable to widespread topsoil movement in a process of dry erosion called "ravel." Winter rains accelerate the movement of material, sometimes causing floods, mudslides, and debris flows, often exacerbated by increased runoff from a crustlike layer of water-repellent soil created by the intense heat of burning chaparral plants (Beyers et al. 1998). Forbs and grasses appear in great abundance the first spring after a fire, including many species absent in the prefire stand. As shrubs gain dominance, most of the herbaceous plants, which originated from seed stored in the soil or brought in by wind, water, birds, mammals, and insects from adjacent areas (Westman 1979), disappear (generally within 1 to 3 years), or may persist in greatly reduced numbers but without blooming or producing seed. Allelopathy, or toxic effect of chemicals generated by dominant shrubs, once thought to explain the impoverishment and sterility of the herbaceous layer under developed chaparral canopies, is not believed to be so important now. More in favor is the idea that fire-induced seed germination brings on the herbaceous growth that flourishes in the sunlight until the developing shrub layer shades it out and captures the moisture and nutrients (Keeley and Keeley 1986).

For several decades–beginning in the 1940s–Italian ryegrass *(Lolium perenne* ssp. *multiflorum),* a native of Eurasia, had been seeded on burned chaparral areas for the purpose of reducing erosion during the initial recovery period. A study showed that rye-grass did reduce erosion by a small amount, but not until other vegetation had become established and erosion had returned to baseline levels (Beyers et al. 1998). Ryegrass, like many pioneer herbaceous plants, tends to dry out early in the growing season, thus increasing the possibility of another fire before a new stand is established. Fires at this early stage of chaparral stand development can result in local extinction of obligate seeders, which have germinated and begun to grow, but have not yet produced seed (Zedler and Zammit 1986). Ryegrass also can compete with native herbaceous plants, and may even in some cases affect the regrowth of shrubs (Wohlgemuth et al. 1998).

Most shrubs, both seedlings and sprouts, emerge during the first year after a fire. By the second year they begin to dominate over the herbaceous plants, which are ultimately relegated to open spaces between shrubs. Dense chaparral is typically devoid of herbaceous plants, and the lack of herbaceous vegetation can extend 2 to 6 feet beyond shrub crowns at interfaces of chaparral with other vegetation types (Keeley and Keeley 1986, Odion and Davis 2000). Chaparral stands often reach maximum density in a few years, and then become somewhat less dense as self-thinning sets in, although in general as chaparral stands age, both height and density increase (Guo and Rundel 1998). Data collected in this study show a definite trend of increasing height with increasing density for all chaparral types, although variations in site, drought, and unknown disturbances other than fire (diseases, herbivory, air pollution, frost, etc.) are confounding factors. For example, across all ownerships, of the stands that averaged taller than 6.6 feet, 66 percent had at least 60 percent shrub cover, and of the stands that averaged less than 3.4 feet tall, 53 percent had less than 40 percent cover (table 10).

Height of Chaparral Stands

Chaparral, by definition, consists of woody shrubs or short trees. Dominant shrubs rarely top 6 feet. In this study, scrub oak stands averaged the tallest—7.8 feet in national forests and 7.4 feet outside national forests (weighted average height of the tallest shrub layer) (table 11). Stands over 9.9 feet tall amounted to 16 percent of scrub oak types in national forests and 31 percent of those outside national forests. Coastal transition and chamise were about tied for shortest, with stands in national forests averaging 5.0 and 5.1 feet, respectively, and stands outside national forest averaging 5.6 and 5.7 feet, respectively.

Density of Chaparral Stands

Most chaparral stands are very dense at maturity with shrub cover often exceeding 60 percent. On the more xeric sites, however, shrub cover in mature chaparral stands can be considerably less. Also, because of frequent fires in chaparral, many stands are young and haven't yet attained maximum density. Across all ownerships, 58 percent of the chaparral in this study had at least 60 percent shrub cover and only 1 percent had no shrub cover at all, as shown in table 12. Complete summaries of acres by PNW chaparral type, canopy cover class, owner class, and height class are tabulated in table 10.

Emergent Trees in Chaparral

There is evidence that many chaparral areas had previously been forest or woodland, although most of the present-day chaparral was in place when Europeans first saw it. Some believe chaparral is still expanding (offset by losses to human development) in response to changes in climate, and "aided by man's interference with the environment" (Axelrod 1986). Trees still occur in many chaparral areas (fig. 32). In some cases, as with pinyon, juniper, and foothill pine, the distribution of trees in chaparral seems random. Often, however, trees occur near chaparral-forest ecotones, or on moist sites on north and east slopes, along canyon bottoms and washes, or around springs and seeps. In some areas, islands of trees in chaparral occupy inclusions of soil and parent material different from the surrounding landscape, or occur on rocky, "fire-proof" sites, suggesting that in the long-term absence of fire in these areas, forest or woodland could eventually dominate. Seemingly in contradiction with the view that chaparral is replacing forest, or possibly concordant with the idea that longer intervals between fires would result in more emergent trees, Callaway and Davis (1998) found vigorous *Quercus agrifolia* (coast live oak) saplings in chaparral communities. Plot data gathered in a statewide oak woodland inventory in the 1980s showed that seedlings and saplings of *Quercus douglasii* (blue oak) and *Q. lobata* (California white oak) were often associated with patches of chaparral shrubs, whereas blue oak and California white oak woodlands and savannas without shrubs were usually without seedlings and saplings (Bolsinger 1988). In these cases, it is unclear how shrubs abet tree regeneration, if indeed they do at all. Perhaps the shrubs suppress grass competition, favorably modify soil pH and temperature, attract acorn-caching birds and small mammals, protect emerging seedlings from browsing animals, or merely indicate higher soil moisture.

Whether on their way out because of natural processes (fig. 33) and "man's interference with the environment," or increasing through recruitment under the protective cover of shrubs, trees in chaparral make a difference: several species of birds are attracted to trees in chaparral for nesting and roosting; raptors and flycatchers use trees for staging areas; large birds and mammals use the mast or catch animals that eat the mast; deer use the thermal cover of trees for resting and fawning; and unlike chaparral shrubs, trees usually have an understory of herbaceous plants that serve as food, cover, and bedding for many animals (Heske et al. 1997). In summer, reptiles and small mammals sometimes climb trees to get as far above the intolerably hot surface of the soil as possible. Arboreal species such as the western gray squirrel (*Sciurus griseus*) venture into chaparral only when trees are present (Quinn 1990,

Table 10—Area of chaparral in southern and central coastal California, in national forest (NF) and outside national forest (ONF) lands by PNW classification type, height, and shrub canopy cover

		Percentage of canopy cover											
		1-39			40-59			60+			Total		
Type	Height	NF	ONF	Total	NF	ONF	Total	NF	ONF	Total	NF	ONF	Total
	Feet	*Thousand acres*											
Chamise	<3.4	35	55	90	9	16	25	8	46	54	52	117	169
	3.4-6.5	13	102	115	44	194	238	257	548	805	314	844	1,158
	6.6-9.8	7	103	110	9	50	59	31	231	262	47	384	431
	9.9+	0	0	0	0	0	0	4	0	4	4	0	4
	Total	55	260	315	62	260	322	300	825	1,125	417	1,345	1,762
Scrub oak	<3.4												
	3.4-6.5	9	38	47	4	23	27	24	64	88	37	125	162
	6.6-9.8	2	16	18	0	0	0	106	57	163	108	73	181
	9.9+	5	42	47	0	0	0	22	48	70	27	90	117
	Total	16	96	112	4	23	27	152	169	321	172	288	460
Mixed	<3.4	16	0	16	24	0	24	7	23	30	47	23	70
	3.4-6.5	43	16	59	102	65	167	295	108	403	440	189	629
	6.6-9.8	46	55	101	45	31	76	220	163	383	311	249	560
	9.9+	0	21	21	0	0	0	14	16	30	14	37	51
	Total	105	92	197	171	96	267	536	310	846	812	498	1,310
Coastal transition	<3.4	8	28	36	3	2	5	0	0	0	11	30	41
	3.4-6.5	22	82	104	39	78	117	80	161	241	141	321	462
	6.6-9.8	0	49	49	0	6	6	9	50	59	9	105	114
	9.9+												
	Total	30	159	189	42	86	128	89	211	300	161	456	617
Grand total[a]		206	607	813	279	465	744	1,077	1,515	2,592	1,562	2,587	4,149

[a] Excludes acres of chaparral represented by plots with no shrubs on which to base classification.

Table 11—Average height and percentage of chaparral taller than 2 height thresholds in national forest (NF) and outside national forest (ONF) lands for each PNW chaparral type

PNW Type	Average height		6.6 foot +		9.9 foot +	
	NF	ONF	NF	ONF	NF	ONF
	----- Feet -----		*----------------- Percent -----------------*			
Chamise	5.1	5.7	12	29	1	0
Scrub oak	7.8	7.4	78	57	16	31
Mixed and montane	6.2	6.2	40	58	2	7
Coastal transition	5.0	5.6	6	23	6	0

Table 12—Chaparral plots by shrub cover class[a]

Shrub cover	Percentage of chaparral plots
Percent	
0	1
1–39	23
40–60	18
61+	58

[a] Cover is additive for all species-level estimates on a plot and thus sometimes exceeds 100 percent.

Wirtz 1991). Trees give depth and scale to chaparral vistas, although whether they improve the scenery or not is a matter of personal preference. Certain spring flowers, *Cynoglossum grande* for example, are often found under trees in chaparral, but are absent under shrubs (author's observation).

In the chaparral inventory, emergent trees at least 5 feet taller than the tallest shrub layer were found on plots representing 11 percent of the total chaparral area, or 455,000 acres (fig. 9). The chaparral plots, scattered across 4.3 million acres, and monumented for future relocation, could, if revisited periodically, provide an objective measure of the changing presence of trees in chaparral. Table 13 illustrates that trees were most common in scrub oak type and least common in mixed and montane chaparral. Sixteen species of emergent trees were tallied on plots in this study. The two tree species most common were coast live oak and foothill pine (table 14).

Figure 32—Emergent foothill pine tree, *Pinus sabiniana* (California foothill pine), in mixed chaparral; *Ceanothus leucodermis* (chaparral whitethorn) in foreground. (Photo by Br. Alfred Brousseau, St. Mary's College)

Figure 33—Conifer trees killed by a fire in chaparral. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Table 13—Area and percentage of PNW chaparral type with emergent trees

Chaparral type	Area with emergent trees	Percentage of type
	Thousand acres	
Chamise	202	11
Scrub oak	84	17
Mixed and montane	105	8
Coastal transition	64	10
All types	455	11

Table 14—Chaparral with emergent trees by tree species

Emergent tree species	Percentage of occurrence
Quercus agrifolia (coast live oak)	25.9
Pinus sabiniana (California foothill pine)	14.9
Pinus monophylla (singleleaf pinyon)	10.8
Umbellularia californica (California laurel)	9.5
Aesculus californica (California buckeye)	7.8
Quercus chrysolepis (canyon live oak)	7.4
Quercus douglasii (blue oak)	4.0
Platanus racemosa (California sycamore)	4.0
Juniperus californica (California juniper)	3.8
Pseudotsuga menziesii (Douglas-fir)	3.2
Juniperus occidentalis (western juniper)	2.3
Quercus engelmannii (Engelmann oak)	1.6
Pinus coulteri (Coulter pine)	1.5
Populus fremontii (Fremont cottonwood)	1.5
Salix spp. (willow)	1.5
Pinus jeffreyi (Jeffrey pine)	.3
	100.0

A Look At Burned and Unburned Areas

Changes on Burned Plots

In the 1990s, on lands outside national forests, PNW inventory crews visited plots that had been established in the 1980s, including 11 plots in chaparral that had burned between the two occasions (fig. 9). In addition to gathering data on vegetation by species, density, height, etc., for each burned plot, crews determined the year of the fire from public records or by talking with knowledgeable people. For national forests where plots had not previously been established in chaparral, agency fire records were used along with vegetation maps to determine the acreage burned by chaparral types. The nominal period between inventories for lands outside national forests was 10 years—1984-94; the records for burned area on national forest land covered the 20-year period 1975-95. Outside national forests, the estimated area burned over 10 years was 435,000 acres, or 16 percent of the chaparral area. Within national forests 849,000 acres burned over 20 years, or 54 percent of chaparral area, which comes out to 27 percent over 10 years, not counting the unknown acreage that burned twice. Fire occurred in all of the major type groups, although none of the plots in the small area of red shank outside national forests burned.

Fires in chamise type (fig. 34) accounted for the greatest area burned outside national forests (41 percent of the chaparral burned); mixed and montane type accounted for the greatest area burned (53 percent of the chaparral burned) inside national forests (table 15). Coastal transition type had the highest burn rate outside national forests, where 26 percent of that type burned. These burn rates translate to fire-return intervals ranging from 83 years for scrub oak outside national forests to 38 years for coastal transition in national forests, and averaging 50 years across all types and ownerships. This estimate differs from some that can be found in the literature for both presuppression- and postsuppression-era fire rotation periods (Byrne 1978, Minnich and Chou 1997, Zedler and Zammit 1986), but is very close to the post-1950 interval reported by Keeley et al. (1999) for nine counties in central coastal and southern California, based on the California Statewide Fire History Database.

Keeley et al. (1999) reported county-level fire intervals ranging from 29 years in Orange County to 81 years in Santa Barbara County. These intervals bracket ours and, when averaged over the nine-county area (weighted by mean fire size), come out to 51.7 years, fairly close to our 50 years.

The changes in vegetation on the plots that burned were generally predictable, although postburn shrub cover had not attained preburn density on any of the plots, even those burned shortly after they had been established in the mid-1980s. For the

Figure 34—Fire in chamise type. (Photo by USDA Forest Service, Pacific Southwest Research Station)

Table 15—PNW chaparral type burned in and outside national forest lands

PNW Type	National forest		Outside national forest	
	Percentage of type burned	Percentage of all chaparral burned	Percentage of type burned	Percentage of all chaparral burned
Chamise	24	22	14	41
Red shank	22	2	0	0
Scrub oak	18	11	12	9
Mixed and montane	20	53	20	25
Coastal transition	26	12	21	25
Total	NA	100	NA	100

NA = Not applicable.

burned plots as a group, shrub cover and number of shrub species decreased; cover and number of species of subshrubs increased (cover only slightly); and herbaceous cover increased (table 16). There were 19 shrub species present on all 11 plots before they burned, and 11 shrub species afterward (table 17).

Of the nine shrub species that were present before burning but absent afterward, four are obligate seeders *(Arctostaphylos canscens, A. viscida, Baccharis* spp., *Ceanothus crassifolius),* and four were on plots that had burned within 2 years of the field crew's visit *(Ceanothus leucodermis, Comarostaphylis diversifolia, Purshia tridentata,* and *Quercus wislizeni* var. *frutescens).* Notable is the loss of *Ceanothus* spp., important in soil nitrogen fixation, from three of the four plots on which they occurred before burning.

Of the 11 plots that burned, 3 were classified as different types when revisited. One plot changed from chamise to mixed chaparral, one from mixed chaparral to chamise, and one from mixed chaparral to coastal transition. The number of subshrub species increased from one before burning to four after burning, although subshrub cover hardly increased at all. Before burning, *Eriogonum fasciculatum* was the only subshrub tallied. After burning it was still present, along with *Lotus scoparius, Eriodictyon* spp., and *Chrysothamnus* spp. As expected, the data show generally, with a few exceptions, the longer the period since the plot had burned the denser the shrub cover (fig. 35).

Changes on Plots That Did Not Burn

Fifty-three of the plots established in the 1980s and revisited in the 1990s did not burn and had not been converted to nonchaparral. On 17 of these plots, or 32 percent, shrub cover did not change. Shrub cover increased on 20 plots and decreased on 16 plots (table 18).

Shrub cover changed by one or both of two ways: (1) cover of existing shrub species increased or decreased, (2) species dropped out or new ones appeared.

Table 16—Average cover before and after fire

Life form	Average cover Preburn	Postburn
	Percent	
Shrub	81	33
Subshrub	4	5
Grass	3	18
Forb	5	9

Table 17—Regeneration mode and presence of species before and after fire

Species	Present: Before burning	After burning	Regeneration mode[a]
Adenostoma fasciculatum	Yes	Yes	fr
Aesculus californica	Yes	Yes	fr
Arctostaphylos canescens	Yes	No	os
Arctostaphylos glandulosa	Yes	Yes	fr
Arctostaphylos viscida	Yes	No	os
Artemisia californica	Yes	Yes	fr
Baccharis spp.	Yes	No	os
Ceanothus crassifolius	Yes	No	os
Ceanothus greggii var. *perplexans*	Yes	Yes	os
Ceanothus leucodermis	Yes	No (1992)[b]	or
Cercocarpus betuloides	No	Yes	or
Comarostaphylis diversifolia	Yes	No (1990)[b]	or
Heteromeles arbutifolia	Yes	Yes	or
Malosma laurina	Yes	Yes	fr
Purshia tridentata	Yes	No (1993)[b]	fr[c]
Quercus dumosa	Yes	Yes	or
Quercus wislizeni var. *frutescens*	Yes	No (1993)[b]	or
Rhus ovata	Yes	Yes	fr
Salvia mellifera	Yes	Yes	fr
Toxicodendron diversilobum	Yes	No	fr

[a] Fr = facultative resprouter, or = obligate resprouter, os = obligate seeder.
[b] Year burned.
[c] Variable over its extensive range (from Baja California to Saskatchewan), but fr in the study area.

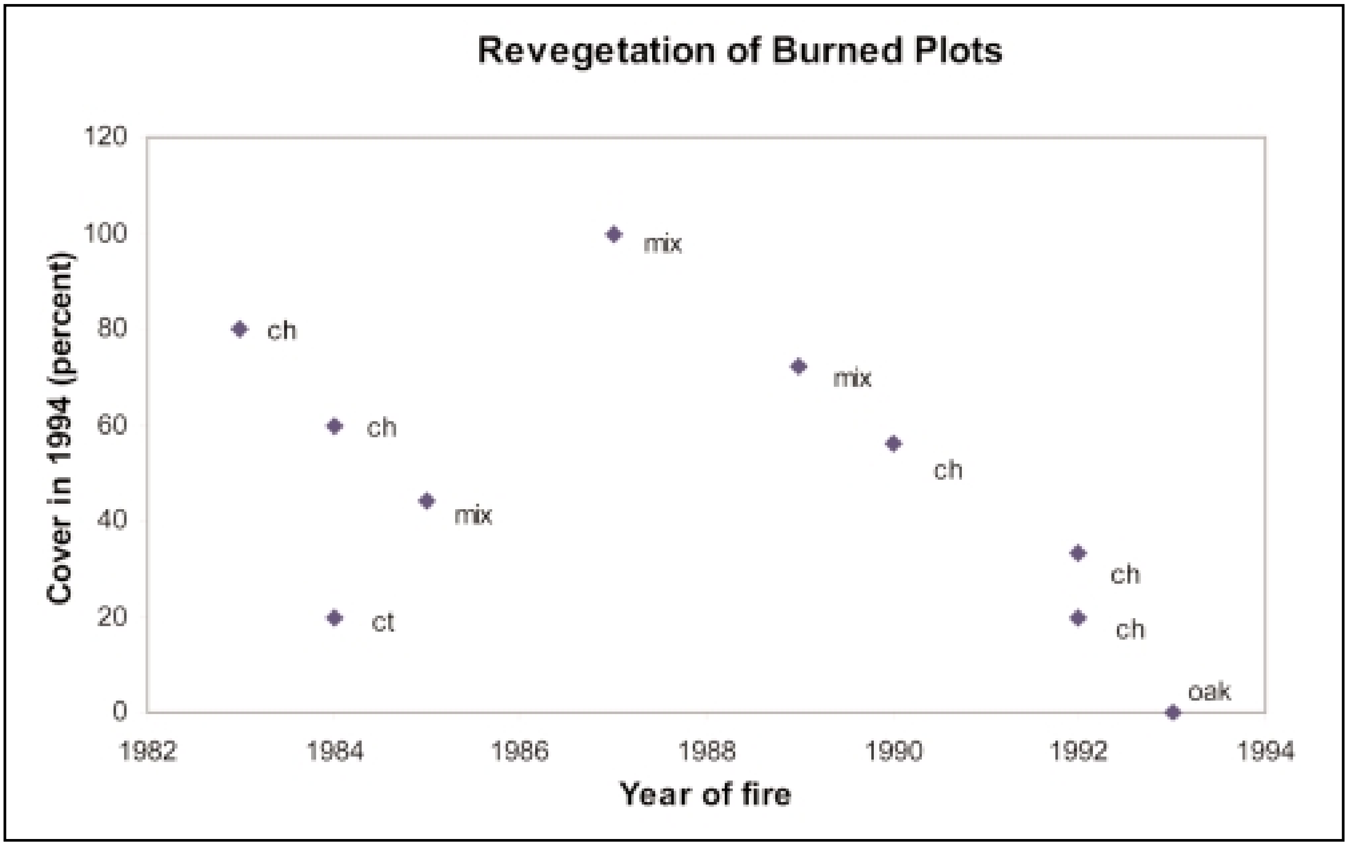

Figure 35—Revegetation of burned plots. Note: ch = chamise, mix = mixed chaparral, ct = coastal transition, oak = scrub oak.

Because of the difficulty of estimating shrub cover consistently within a few percentage points, estimated change of cover of species present at both occasions is probably reliable only at the 20-percent level. In other words, changes of less than 20 percent should probably be considered no change. This rule should not be followed, though, for percentage of cover in species that appeared or disappeared between inventories.

Forty-three percent of the plots neither gained nor lost shrub species, 46 percent gained shrub species, and only 11 percent lost species. Only two plots changed types between inventories (not counting burned plots). Both of these plots changed from scrub oak to other types, as shown in table 19. One plot changed from scrub oak to chamise; the other, from scrub oak to mixed and montane.

Although classification of chaparral, a complex ecosystem, into a few standard types provides a convenient communication tool, on some plots, even a minor change in species composition can change the classification. Such are the hazards of any classification system, and this needs to be taken into account when evaluating the significance of changes in area by type.

In general, plots that gained shrub species tended to be on mesic sites and were older stands, as evidenced by the height of the shrubs. Mixed and montane chaparral

Table 18—Change in shrub cover from 1984 to 1994 on unburned plots outside national forests

Change direction	Change in percentage of cover	Number of plots	Percentage of plots
No change	—	17	32
Increase	<20	10	19
	>20	10	19
Total increase		20	38
Decrease	<20	8	15
	>20	8	15
Total decrease		16	30
Grand total		53	100

Table 19—Shrub cover change on 2 plots outside national forests, 1984 to 1994

Plot change	Shrub species	Cover 1984	Cover 1994
		--------- *Percent* ----------	
Scrub oak	*Adenostoma fasciculatum*	25	25
to	*Artemisia tridentata*	15	0
chamise	*Arctostaphylos canescens*	10	25
	Quercus dumosa/john-tuckeri	50	10[a]
	Total cover	100	60
Scrub oak	*Adenostoma fasciculatum*	20	10
to	*Malosma laurina*	15	5
mixed and	*Salvia mellifera*	0	5
montane	*Comarostaphylis diversifolia*	0	15
	Quercus dumosa/john-tuckeri	50	0[a]
	Total cover	85	35

[a] Change of more than 20 percent.

was the major gainer—58 percent of the plots gained species. One plot in mixed and montane chaparral gained 6 shrub species, ending up with a total of 11. Shrubs up to 11 feet tall were tallied on the plot, indicating this was probably an older stand. Only 30 percent of the chamise plots gained species. Thirty-three percent of scrub oak plots, and 29 percent of coastal transition plots gained species. The “new” shrubs on these plots included 32 species, 5 of which were of the genus *Ceanothus* and 3 were *Arctostaphylos.*

In some cases, shrub cover and number of species changed in opposite directions. For example, on a plot in scrub oak type, shrub cover decreased from 75 to 60 percent, while the number of shrub species increased from five to six. On this plot, it appeared that some kind of partial dieback, or possibly herbivory, of *Arctostaphylos pungens* opened the stand to allow recruitment of another species.

Gainers and Losers in Unburned Chaparral

Over the 10-year period, 22 shrub species increased in occurrence, 6 decreased, and 2 balanced out with gainers equaling losers. The occurrence of some species increased on as many as seven plots, while none decreased on more than two plots. One plot represents about 2 percent of the unburned area. The net increase of some species (or genera) was as much as 10 percent, while the maximum net decrease was only 2 percent (table 20). One possible explanation is that perhaps chaparral has a natural tendency to become more complex with age, recruiting new species but retaining most of those already present until fire ends the process and it begins anew. Another is that the period 1984-94 was, in some way, anomalous, and a more likely outcome over most 10-year periods would have been gainers and losers balancing out.

Dead Material and Fire Hazard in Chaparral

For at least three decades, many fire and resource managers in southern California have considered dead vegetation to be the most important single characteristic related to chaparral flammability (Conrad and Oechel 1982, Countryman and Philpot 1970, Philpot 1974, Rothermel and Philpot 1973). It was assumed by most—and indeed it seems logical—that, barring abscission, the amount of dead vegetation in chaparral increased with stand age. Naturally, then, to keep fire danger low, a major goal of chaparral management was to maintain young stands (Conrad and Oechel 1982). Observations during prescribed burns and wildfires in southern California led researchers to question the assumed strong relationship between stand age and amount of dead material in chaparral, and prompted a study in chamise, the most extensive chaparral type in southern California, and the state. The study revealed a very weak relationship between amount of dead material and stand or shrub age (Paysen and Cohen 1990).

Although their study did not identify the specific agents responsible for the dead material, one can find many in the literature. Wagner et al. (1998) found that certain species of shrubs are more prone to breakage than others; sprouters generally have weaker stems than obligate seeders and would likely contribute more dead material at a given age. But even among sprouters, there may be differences. *Rhus ovata* and *Malosma laurina,* for example, are both sprouters, but *M. laurina* is much more susceptible to frost and on certain sites could become established and thrive until the first cold snap (Boorse et al. 1998). Natural longevity differs among chaparral shrubs. Most species of *Quercus, Cercocarpus,* and *Rhamnus,* for example, tend to be long lived, whereas some species of *Arctostaphylos* and *Ceanothus* are short lived and would contribute

Table 20—Shrub species occurrence on unburned plots

Species or genus	Increase	Decrease	Net change
		Number of plots	
Adenostoma fasciculatum	5	1	+4
Arctostaphylos spp.	3	1	+2
Artemisia californica	5	1	+4
Artemisia tridentae	1	2	-1
Ceanothus spp.	7	2	+5
Cercocarpus betuloides	1	1	0
Cercocarpus ledifolius	1	0	+1
Chrysothamnus spp.	1	0	+1
Cneoridium dumosum	1	0	+1
Comarostaphylis diversifolia	1	0	+1
Ericameria spp.	0	1	-1
Eriodictyon spp.	2	0	+2
Fraxinus dipetala	0	1	-1
Heteromeles arbutifolia	5	1	+4
Holodiscus spp.	1	0	+1
Juniperus californica	1	0	+1
Keckiella antirrhinoides	1	0	+1
Lonicera spp.	2	0	+2
Malosma laurina	1	0	+1
Prunus fremontii	0	1	-1
Quercus dumosa/john-tuckeri	4	1	+3
Quercus wislizeni	1	0	+1
Rhamnus crocea	2	1	+1
Rhamnus crocea var. *ilicifolia*	0	1	-1
Rhus ovata	1	1	0
Ribes spp.	0	1	-1
Salvia mellifera	6	1	+5
Sambucus spp.	1	0	+1
Toxicodendron diversilobum	4	0	+4

dead material at an earlier age, all else being equal (fig. 36). Chaparral stands that become very dense when young typically undergo self-thinning (Guo and Rundel 1998). Differential resistance to drought among species may cause dead material to build up more rapidly in one stand than in another of the same age. Characteristics of the stand that existed before the current one and the intensity and nature of the fire that destroyed it also may come into play: sprouts from weak lignotubers will be more likely to die than those from strong ones, and spotty, intense fires can damage some lignotubers more than others. Young shrubs generated from seed near vigorous sprouts often die from competition, and those in openings may outgrow the sprouts (Keeley 1986, Oechel and Reid 1984). Other factors include insects and disease, herbivory, air pollution, and inclusions of shallow soils or serpentine outcrops (Keeley 1986, Mills and Kummerow 1986, Moreno and Oechel 1993, Quinn 1990).

Figure 36—*Arctostaphylos glandulosa* (Eastwood's manzanita) with more than 25 percent dead branches. (Photo courtesy of Todd Keeler-Wolf, California Department of Fish and Game)

Paysen and Cohen (1990) state: "…fire behavior variations in chamise chaparral are more complex than can be described by a single fuel characteristic like the fraction of dead vegetation." This is not to say, however, that dead material is not important. It probably is a major factor in ignition and intensity of both small and large fires. The majority of the area burned is in the relatively small number of large fires that occur during hot, windy weather (Conard and Weise 1998, Keeley et al. 1999). Once these fires start raging across the landscape, stand characteristics—such as species, density, and amount of dead material—have little to do with whether a stand burns or not.

We assume there is some relationship or even possibly a synergistic function, between amount of dead material and shrub cover, or at least shrub cover above some threshold. We also assume that shrub species or type is an important factor in the flammability of a given stand, the effect of fire on the site, and the chemical composition of the smoke produced by a fire. And height and dead material may well influence fire behavior in ways that affect difficulty of suppression. It is also possible, we think, that the characteristics of postfire stands could be affected by the amount of dead material in stands before they burn.

These assumptions led to the development of what we call "hazard" classes for land outside national forests, based on amount of dead material by shrub layer and percentage of shrub cover (amount of dead material was not rated on national forest plots). Layers were recognized for a species that occurred in two distinct height classes. Field crews coded the amount of dead material (DM) for each species and layer combination as follows:

DM1—No dead material.
DM2—1 to 25 percent dead material.
DM3—More than 25 percent dead material.

Hazard classes (HC) were assigned as follows:

HC4—Shrub cover at least 25 percent; 50 percent or more of the cover coded DM3.
HC3—Shrub cover at least 25 percent; less than 50 percent coded DM3, but more than 50 percent DM3 + DM2.
HC2—Shrub cover at least 25 percent; 33 percent to 50 percent DM3 + DM2.
HC1—All other stands (shrub cover present).
HC0—Recently disturbed areas with no shrub cover.

As shown in (table 21), HC4 is the highest hazard class based on shrub density and amount of dead material and amounts to 38 percent of the chaparral outside national forests. When added to the next class, HC3, it can be seen that the total area with at least 25 percent shrub cover and a notable amount of dead material amounts to 2,190,000 acres, or 80 percent of the chaparral. That leaves 20 percent with very small amounts of dead material, which is fairly close to the 16 percent of chaparral outside national forests that burned between 1984 and 1994, according to the plot sample, and is therefore in young age classes. There appear to be no obvious spatial patterns in hazard class, in that every hazard class was represented throughout the study area (fig. 37).

Reliability of Data Used in This Report

Except for area of parks and other reserved areas outside national forests, the estimates of area by chaparral type and ownership in this report were obtained by sampling and are subject to sampling error. Tables 22, 23, and 24 report estimates of area, standard errors of area, and coefficients of variation to facilitate relative comparison of reliability among estimates. Smaller subsets of these estimates (e.g., chaparral with emergent trees, chaparral that burned) will have proportionately greater sampling errors.

Accuracy of Classification and Plant Identification

In the 1984 inventory, supervisory personnel and field crews from PNW were trained by local scientists and resource managers familiar with the plants and vegetation types, and many of the same people were involved in the 1994 inventory. National forest crews in the 1994 inventory were also trained by scientists familiar with the plants and vegetation types, and field crews included experienced botanists and a botanical illustrator. For PNW and national forest inventories, field crews had access to published and in-house plant guides and local herbaria, and they maintained their own collections, augmented by new plants when encountered. Plants that could not be identified with these resources were sent to experts at other locations. In addition to these measures taken to assure accurate plant identification and type classification, a formalized quality control/quality assurance system, based on a systematic remeasurement of a subsample of plots, was used to attain a high level of reliability of all measurements and classifications.

Discussion of Results

Chaparral occupies 4.6 million acres or 14 percent of the study area. Ironically, it covers a proportionately greater part of the landscape—22 to 37 percent—in the densely populated and/or high wildland urban interface counties of Los Angeles, Orange, Santa Barbara, Ventura, and San Diego. The mixed ownership of chaparral—45 percent in numerous private holdings and 55 percent in public ownership, including federal, state, county, and municipal agencies—adds to the complexity of managing

Table 21—Area of chaparral by type and hazard class outside national forests

Type	HC0	HC1	HC2	HC3	HC4	Total
			Thousand acres			
Chamise	NA	71	77	543	654	1,345
Scrub oak	NA	0	30	176	83	289
Mixed and montane	NA	52	52	235	159	498
Coastal transition	NA	53	64	202	138	457
Shrub cover zero	147	NA	NA	NA	NA	147
Total	147	176	223	1,156	1,034	2,736
Percent	5	7	8	42	38	100

HC0 = recently disturbed areas with no shrub cover.
HC1 = all other stands (shrub cover present).
HC2 = shrub cover at least 25 percent; 33 percent to 50 percent DM3 + DM2.
HC3 = shrub cover at least 25 percent; less than 50 percent coded DM3, but more than 50 percent DM3 + DM2.
HC4 = shrub cover at least 25 percent; 50 percent or more of the cover coded DM3.
NA = Not applicable.

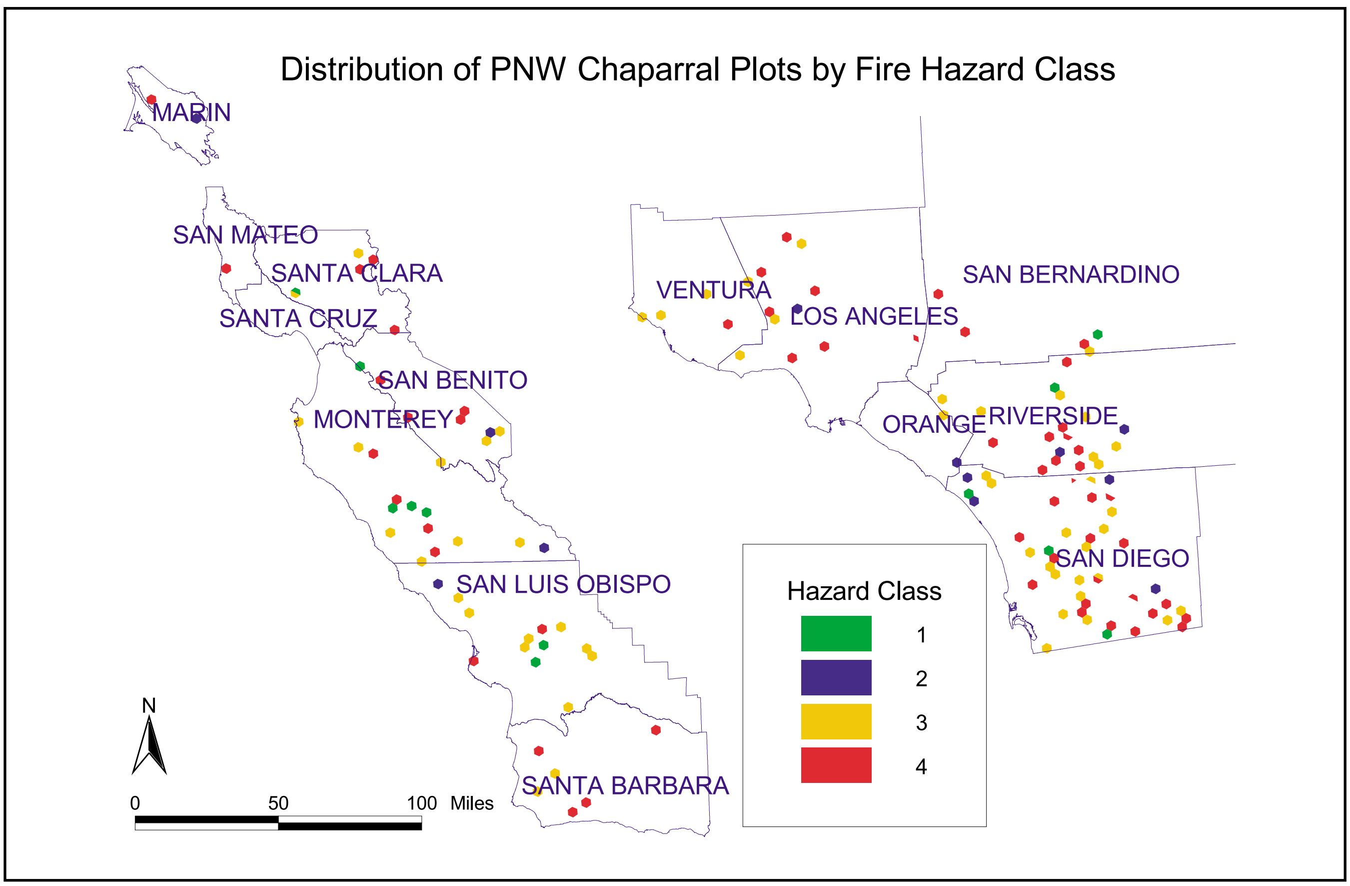

Figure 37—Fire hazard class, which was evaluated only for chaparral outside national forests, is mainly high or very high in nearly every part of the chaparral study area.

Table 22—Area estimates by chaparral classification system and owner class

Chaparral type	Private	Other public	National forest	National forest reserved
			Acres	
PNW:				
Chamise	1,091,111	283,312	316,406	100,434
Coastal transition	314,785	180,892	114,245	46,397
Mixed chaparral	354,042	184,892	607,192	206,469
Scrub oak	290,967	37,647	128,468	43,832
CALVEG:[a]				
BM—Curl-leaf mountain mahogany	0	0	7,208	0
BS—Basin sagebrush	0	0	5,517	0
BX—High desert mixed chaparral	0	0	10,264	0
CA—Chamise	865,391	222,418	257,313	68,524
CC—Ceanothus chaparral	0	17,169	27,617	0
CD—Southern mixed chaparral	87,567	0	10,347	0
CG—Greenleaf manzanita	0	9,357	0	0
CQ—Lower montane mixed chaparral	450,413	167,723	626,680	234,642
CR—Red shank	64,599	17,970	19,860	28,948
CS—Scrub oak	224,169	28,290	60,434	15,248
CX—Montane-mixed chaparral	0	0	0	9,024
CZ—Semidesert mixed chaparral	22,811	21,462	31,206	7,233
DX—Mixed desert shrub	0	10,782	0	0
JC—California juniper	0	0	6,156	0
ML—Baccharis	15,710	0	0	0
NC—North coast chaparral	62,411	0	0	0
RS—Alluvial fan sage scrub	0	0	49,746	7,233
SD—Manzanita chaparral	13,687	42,923	18,847	5,140
SH—Coastal bluff scrub	22,811	0	0	0
SM—Sumac	94,259	50,316	10,933	0
SQ—Mixed soft scrub chaparral	0	21,462	3,564	0
SS—Coastal sage scrub	127,079	58,901	40,405	14,466
WM—Birchleaf mountain mahogany	0	17,970	36,134	6,675
California Wildlife Habitat Relationships:				
CRC—Chamise-red shank	914,280	240,388	276,565	87,239
MCH—Mixed chaparral	924,324	327,883	822,846	276,380
MCP—Montane chaparral	0	27,327	51,265	19,047
SCS—Coastal scrub	212,301	80,362	36,520	14,466

Note: Other public includes federal, state, county, and municipal agencies.
[a] CALVEG = classification and assessment with Landsat of visible ecological groupings.

Table 23—Standard errors for acreage estimates[a] by chaparral type and owner class

Chaparral type	Private	Other public	National forest	National forest reserve
		Acres		
PNW:				
Chamise	112,720	70,727	36,377	23,996
Coastal transition	65,933	54,471	25,145	19,000
Mixed chaparral	73,352	58,474	47,803	34,790
Scrub oak	68,005	24,290	25,892	16,868
CALVEG:[b]				
BM—Curl-leaf mountain mahogany			7,208	
BS—Basin sagebrush			3,189	
BX—High desert mixed chaparral			6,375	
CA—Chamise	104,858	62,690	33,440	19,868
CC—Ceanothus chaparral		17,169	11,393	
CD—Southern mixed chaparral	37,525		7,306	
CG—Greenleaf manzanita		9,357		
CQ—Lower montane mixed chaparral	82,793	56,196	49,195	37,602
CR—Red shank	29,903	17,970	9,596	14,967
CS—Scrub oak	60,383	22,484	17,791	8,027
CX—Montane-mixed chaparral				6,433
CZ—Semidesert mixed chaparral	22,811	21,462	15,004	7,233
DX—Mixed desert shrub		10,782		
JC—California juniper			6,156	
ML—Baccharis	15,710			
NC—North coast chaparral	28,782			
RS—Alluvial fan sage scrub			16,463	7,233
SD—Manzanita chaparral	13,687	30,263	8,761	5,140
SH—Coastal bluff scrub	22,811			
SM—Sumac	36,038	29,030	6,359	
SQ—Mixed soft scrub chaparral		21,462	3,564	
SS—Coastal sage scrub	48,013	30,190	14,090	10,214
WM—Birchleaf mountain mahogany		17,970	13,887	6,675
California Wildlife Habitat Relationships:				
CRC—Chamise-red shank	105,639	64,857	34,254	22,530
MCH—Mixed chaparral	104,959	75,832	51,226	40,190
MCP—Montane chaparral		20,212	16,761	11,071
SCS—Coastal scrub	59,258	36,842	13,575	10,214

Note: Other public includes federal, state, county, and municipal agencies.
[a] Calculated as $N\sqrt{\text{var}(x)/N}$ where X is a vector of plot expansion factors for the chaparral inventory (PNW or NF) including zeros for plots containing no acres in the type, and N is the number of plots in the PNW or NF chaparral inventory.
[b] CALVEG = classification and assessment with Landsat of visible ecological groupings.

Table 24—Coefficient of variation for acreage estimates[a] by chaparral type and owner class

Chaparral type	Private	Other public	National forest	National forest reserve
PNW:				
Chamise	0.10	0.25	0.11	0.24
Coastal transition	0.21	0.30	0.22	0.41
Mixed chaparral	0.21	0.32	0.08	0.17
Scrub oak	0.23	0.65	0.20	0.38
CALVEG:[b]				
BM—Curl-leaf mountain mahogany			1.00	
BS—Basin sagebrush			0.58	
BX—High desert mixed chaparral			0.62	
CA—Chamise	0.12	0.28	0.13	0.29
CC—Ceanothus chaparral		1.00	0.41	
CD—Southern mixed chaparral	0.43		0.71	
CG—Greenleaf manzanita		1.00		
CQ—Lower montane mixed chaparral	0.18	0.34	0.08	0.16
CR—Red shank	0.46	1.00	0.48	0.52
CS—Scrub oak	0.27	0.79	0.29	0.53
CX—Montane-mixed chaparral				0.71
CZ—Semidesert mixed chaparral	1.00	1.00	0.48	1.00
DX—Mixed desert shrub		1.00		
JC—California juniper			1.00	
ML—Baccharis	1.00			
NC—North coast chaparral	0.46			
RS—Alluvial fan sage scrub			0.33	1.00
SD—Manzanita chaparral	1.00	0.71	0.46	1.00
SH—Coastal bluff scrub	1.00			
SM—Sumac	0.38	0.58	0.58	
SQ—Mixed soft scrub chaparral		1.00	1.00	
SS—Coastal sage scrub	0.38	0.51	0.35	0.71
WM—Birchleaf mountain mahogany		1.00	0.38	1.00
California Wildlife Habitat Relationships:				
CRC—Chamise-red shank	0.12	0.27	0.12	0.26
MCH—Mixed chaparral	0.11	0.23	0.06	0.15
MCP—Montane chaparral		0.74	0.33	0.58
SCS—Coastal scrub	0.28	0.46	0.37	0.71

Note: Other public includes federal, state, county, and municipal agencies.

[a] Calculated as $\frac{\sqrt{var(x)/N}}{mean(x)}$ where X is a vector of plot expansion factors for the chaparral inventory (PNW or NF) including zeros for plots containing no acres in the type and N is the number of plots in the PNW or NF chaparral inventory.

[b] CALVEG = classification and assessment with Landsat of visible ecological groupings.

chaparral and protecting lives and property when it burns. About 15 percent of the chaparral is in parks and other reserves.

Between 1984 and 1994, an estimated 179,400 acres of chaparral were lost to development, about 3.3 percent of the chaparral area in 1984. This comes out to roughly 15 square miles per year. This loss, which may seem innocuous to some, is not the whole story. While development decreases the chaparral area, it also creates islands and stringers of vegetation too small and narrow to be sustained, or useful to wildlife, and increases the chaparral-urban interface, a stress zone of rather continuous degradation by human activity. Spreading development also increases the probability of fire, thus further complicating protection, and raising the stakes and the costs.

The systematic samples on which this study was based confirm what has been determined by other methods—that chamise is the most widespread chaparral shrub species, occurring in 70 percent of stands. Chamise also is the most extensive single type (mixed chaparral exceeds chamise, but is actually a conglomerate of several species and types). The abundance of chamise, however, belies the complexity of the chaparral ecosystem, which is indicated by the large number of shrub species tallied on plots—more than 100—a considerably larger number of woody dominants than represented by trees in forests in the same area.

During the 10-year period 1984-94, fires outside national forests burned 16 percent of the chaparral area as estimated from the area-weighted proportion of plots on which evidence of fire was recorded. Fire records for national forests indicate that for the 20-year period 1975-95, fires there burned 54 percent of the chaparral, or 27 percent over 10 years, ignoring any differences by decade. These burn rates translate to an average fire-return interval of 50 years across all types and ownerships.

On none of the plots that burned between 1984 and 1994 had shrub cover attained the preburn density at time of data collection, although as expected, density was generally greater in plots that burned during the first few years of the decade. Fewer shrub species were present after burning; 44 percent of those that dropped out were obligate seeders. Subshrubs increased by 25 percent and grasses and forbs by over 300 percent. Chaparral type changed on 27 percent of the burned plots between the 1984 and 1994 inventories.

During the period 1984-94 unburned chaparral outside national forests showed little evidence of degradation or loss of biodiversity. Shrub cover held steady or increased on 70 percent of the plots, and many shrub species increased in occurrence while very few decreased. We wonder if this trend toward richer, more complex chaparral follows a natural tendency in the ecosystem, or if the period 1984-94 was in some way anomalous. Would gainers and losers tend to balance out over most 10-year periods? Future remeasurement of the chaparral plots on which this study was based could answer that question and provide many other useful facts about chaparral dynamics. An estimated 38 percent of the chaparral is in a high hazard status, and another 42 percent can be classified as moderate hazard or on the threshold of high hazard. This leaves 20 percent in low-hazard categories, which is close to the percentage of chaparral that burns during an average 10-year period, according to the sample used here and the state's fire records.

Emergent trees, important to wildlife and scenery values, and thought by some to have been more prevalent in chaparral before Europeans settled here, were found on 11 percent of the area.

Sixteen tree species were tallied on plots in chaparral; the three most common were *Quercus agrifolia, Pinus sabiniana,* and *P. monophylla.* The plots on which this study was based could, if remeasured periodically, provide useful information on the changing presence of emergent trees in chaparral and structural data, which could provide a clearer picture of successional dynamics.

The Next Steps

In this report, we sought to provide a concise overview and summary of current status and one decade's change in chaparral composition and extent over the majority of its range in California and to address selected issues that have been raised concerning chaparral in the past (e.g., area burned annually, implied fire frequency, emergent trees, and hazard classes). We also believe that the data summarized here, if linked with other spatially referenced databases, hold considerable promise for exploring a range of basic ecological science and issue-driven, policy-relevant questions.

For example, the often-reported premise that chaparral distribution is overwhelmingly, if not exclusively, controlled by climate could be tested if these data were combined with spatially referenced weather observation series, digital elevation models, and other environmental components such as soil or parent material. Vulnerability to air pollution might be inferred by relating the chaparral data on patterns of species composition and proportion of dead material to data on distance and direction from pollution-generating population centers. Chaparral type occurrence and even woody species richness gradients could be evaluated relative to latitude, elevation, precipitation, and other climatological factors. Integration of spatially referenced data derived from the 1990 and 2000 censuses would facilitate assessments of changes in the extent of wildland urban interface and its character (e.g., level of risk posed to homes, nature of structure protection challenges likely to be faced by firefighters, and degree of chaparral use).

The data summarized here are available for anyone to use to address these or any other questions. We, and others affiliated with the PNW Forest Inventory and Analysis Program, welcome opportunities to collaborate with other researchers and clients to address basic and applied research questions whenever our inventory data are likely to contribute useful information. To obtain the data or to discuss ideas for possible collaboration, please contact the senior author.

This will not be the last inventory of chaparral in California. A new chaparral data collection protocol, identical for lands in and outside national forests, has been developed and reviewed. It retains PNW-FIA-specific variables like percentage of dead material and local knowledge of fire activity, but changes the plot footprint to be consistent with the four-point, national FIA design that is now implemented on all forested FIA plots. This change will facilitate assessing within-stand variation, and provide better temporal continuity on plots that “migrate” between forest and chaparral types over time. Other changes from the previously implemented one-point protocol include estimating average heights of each species independently, measuring trees greater than 5 inches diameter at breast height according to standard tree protocols (i.e., height, crown ratio, insect and disease damage) instead of mere cover by species, and obtaining global positioning system-accurate plot location data to enable fine-scale spatial overlay analysis in conjunction with other spatially referenced data. As of this writing, data collection has begun in California's national forests on a 5-year, annual inventory cycle under which 20 percent of all forest and chaparral plots in the state on 3.4-mile (or in some cases, 1.7-mile) grids are visited and measured each year. Current plans call for converting to a 10-year cycle (10 percent of plots visited each year) beginning in 2006. There is currently no funding or plan for conducting remeasurement of chaparral plots outside of national forests.

Scientific and Common Plant Names[a]

Life form[b]/genus	Species (citation)	Common name
Trees		
Adenostoma	*sparsifolium* Torr.	red shank
Aesculus[c]	*californica* (Spach) Nutt.	California buckeye
Arctostaphylos	*glauca* Lindl.	bigberry manzanita
Arctostaphylos	*pringlei* Parry var. *drupacea* (Parry) P.V. Wells	pinkbracted manzanita
Arctostaphylos	*viscida* Parry	sticky whiteleaf manzanita
Arctostaphylos	*viscida* Parry spp. *pulchella* (T.J. Howell) P.V. Wells	sticky whiteleaf manzanita
Artemisia	*tridentae* Nutt.	big sagebrush
Ceanothus	*spinosus* Nutt.	redheart
Ceanothus	*thyrsiflorus* Eschsch.	blueblossom ceanothus
Cercocarpus Kunth	spp.	mountain mahogany
Cercocarpus	*betuloides* Nutt.	birchleaf mountain mahogany
Cercocarpus	*ledifolius* Nutt.	curl-leaf mountain mahogany
Fraxinus	*dipetala* Hook. & Arn.	California ash
Heteromeles M. Roemer	spp.	toyon
Heteromeles	*arbutifolia* (Lindl.) M. Roemer	toyon
Juniperus[c]	*californica* Carr.	California juniper
Juniperus[c]	*occidentalis* Hook.	western juniper
Malosma Nutt. ex Abrams	spp.	laurel sumac
Malosma	*laurina* (Nutt.) Nutt. ex Abrams	laurel sumac
Olea[c]	*europaea* L.	olive
Pinus L.	spp.	pine
Pinus[c]	*attenuata* Lemmon	knobcone pine
Pinus[c]	*coulteri* D. Don	Coulter pine
Pinus[c]	*jeffreyi* Grev. & Balf.	Jeffrey pine
Pinus[c]	*monophylla* Torr. & Frem.	singleleaf pinyon
Pinus	*ponderosa* P. & C. Lawson	ponderosa pine
Pinus[c]	*sabiniana* Dougl. ex Dougl.	California foothill pine

Platanus[c]	*racemosa* Nutt.	California sycamore
Populus[c]	*fremontii* S. Wats.	Fremont cottonwood
Prunus L.	spp.	plum
Prunus	*fremontii* S. Wats.	desert apricot
Pseudotsuga	*macrocarpa* (Vasey) Mayr	bigcone Douglas-fir
Pseudotsuga[c]	*menziesii* (Mirbel) Franco	Douglas-fir
Quercus[c]	*agrifolia* Lee	California live oak/coast live oak
Quercus	*berberidifolia* Liebm.	scrub oak
Quercus[c]	*chrysolepis* Liebm. var. nana (Jepson) Jepson	canyon live oak
Quercus[c]	*douglasii* Hook. & Arn.	blue oak
Quercus	*dumosa* Nutt.	coastal sage scrub oak
Quercus	*dumosa/john-tuckeri* Nutt./ Nixon & C.H. Muller	California scrub/Tucker oak
Quercus	*durata* Jepson	leather oak
Quercus[c]	*engelmannii* Greene	Engelmann oak
Quercus	*john-tuckeri* Nixon & C.H. Muller	Tucker oak
Quercus	*kelloggii* Newberry	California black oak
Quercus	*lobata* Nee	California white oak
Quercus	*palmeri* Engelm.	Palmer oak
Quercus[c]	*wislizeni* A.DC. var. *frutescens* Engelm.	interior live oak
Rhus	*integrifolia* (Nutt.) Benth. & Hook. f. ex Brewer & S. Wats.	lemonade sumac
Rhus	*ovata* S. Wats.	sugar sumac
Salix[c] *L.*	spp.	willow
Sambucus L.	spp.	elderberry
Sequoia	*sempervirens* (Lamb. ex D. Don) Endl.	redwood
Umbellularia[c]	*californica* (Hook. & Arn.) Nutt.	California laurel
Yucca[c] L.	spp.	yucca
Yucca	*schidigera* Roezl ex Ortgies	Mojave yucca

Shrubs

Adenostoma Hook. & Arn.	spp.	chamise
Adenostoma[c]	*fasciculatum* Hook. & Arn.	common chamise
Adenostoma[c]	*sparsifolium* Torr.	red shank
Amelanchier[c]	*utahensis* Koehne	Utah serviceberry
Amorpha[c]	*californic*a Nutt.	California false indigo
Arctostaphylos Adans.	spp.	manzanita
Arctostaphylos	*bakeri* Eastw.	Baker's manzanita
Arctostaphylos[c]	*canscens* Eastw.	hoary manzanita
Arctostaphylos[c]	*glandulosa* Eastw.	Eastwood's manzanita
Arctostaphylos[c]	*glauca* Lindl.	bigberry manzanita

Arctostaphylos	*hispidula* T.J. Howell	Gasquet manzanita
Arctostaphylos[c]	*hookeri* G. Don	Hooker's manzanita
Arctostaphylos	*hookeri* spp. *montana* (Eastw.) P.V. Wells	Mt. Tamalpais manzanita
Arctostaphylos	*manzanita* Parry spp. *elegans* (Eastw.) P.V. Wells	Konocti manzanita
Arctostaphylos[c]	*parryana* Lemmon	Parry manzanita
Arctostaphylos[c]	*patula* Greene	greenleaf manzanita
Arctostaphylos[c]	*pringlei* spp. *drupacea* (Parry) P.V. Well	pinkbracted manzanita
Arctostaphylos[c]	*pungens* Kunth	pointleaf manzanita
Arctostaphylos[c]	*viscida* Parry	sticky whiteleaf manzanita
Artemisia L.	spp.	sagebrush
Artemisia[c]	*californica* Less.	coastal sagebrush
Artemisia[c]	*tridentata* Nutt.	big sagebrush
Atriplex[c]	*canescens* (Pursh) Nutt.	fourwing saltbush
Baccharis L.	spp.	baccharis
Baccharis[c]	*pilularis* DC.	coyote brush
Baccharis[c]	*salicifolia* (Ruiz & Pavon) Pers.	mule's fat
Bidens[c]	*pilosa* L.	hairy beggarticks
Ceanothus L.	spp.	ceanothus
Ceanothus[c]	*cordulatus* Kellogg	whitethorn ceanothus
Ceanothus[c]	*crassifolius* Torr.	hoaryleaf ceanothus
Ceanothus[c]	*cuneatus* (Hook.) Nutt.	buckbrush
Ceanothus	*ferrisiae* McMinn	coyote ceanothus
Ceanothus[c]	*greggii* Gray	desert ceanothus
Ceanothus[c]	*greggii* var. *perplexans* (Trel.) Jepson	desert ceanothus
Ceanothus[c]	*griseus* (Trel. ex B.L. Robins.) McMinn	Carmel ceanothus
Ceanothus[c]	*integerrimus* Hook. & Arn.	deerbrush
Ceanothus	*jepsonii* Greene	Jepson ceanothus
Ceanothus[c]	*lemmonii* Parry	Lemmon's ceanothus
Ceanothus[c]	*leucodermis* Greene	chaparral whitethorn
Ceanothus[c]	*megacarpus* Nutt.	bigpod ceanothus
Ceanothus[c]	*oliganthus* Nutt.	hairy ceanothus
Ceanothus[c]	*palmeri* Trel.	Palmer ceanothus
Ceanothus[c]	*papillosus* Torr. & Gray	wartleaf ceanothus
Ceanothus	*sorediatus* Hook. & Arn.	jimbrush
Ceanothus[c]	*spinosus* Nutt.	redheart
Ceanothus[c]	*thyrsiflorus* Eschsch.	blueblossom ceanothus
Ceanothus[c]	*tomentosus* Parry	woolyleaf ceanothus
Cercocarpus[c]	*ledifolius* Nutt.	curl-leaf mountain mahogany
Cercocarpus[c]	*montanus* Raf. var. *glaber* (S. Wats.) F.L. Martin	birchleaf mountain mahogany
Chrysothamnus Nutt.	spp.	rabbitbrush
Chrysothamnus[c]	*nauseosus* Nutt. (now *Ericameria*)	rubber rabbitbrush

Clematis[c]	*pauciflora* Nutt.	ropevine clematis
Cleome[c] Greene	spp.	spiderflower
Cneoridium[c]	*dumosum* (Nutt.) Hook. f. ex Baill.	bush rue
Coleogyne Torr.	spp.	coleogyne
Comarostaphylis[c]	*diversifolia* (Parry) Greene	summer holly
Croton[c] L.	spp.	croton
Dendromecon[c]	*rigida* Benth.	tree poppy
Diplacus[c]	*aurantiacus* (W. Curtis) Jepson	orange bush monkeyflower
Encelia Adans.	spp.	brittlebush
Encelia[c]	*farinosa* var. *farinosa* Gray ex Torr.	goldenhills
Ephedra[c] L.	spp.	jointfir
Ephedra[c]	*viridis* Coville	mormon tea
Ericameria Nutt.	spp.	goldenbush
Ericameria[c]	*ericoides* (Less.) Jepson	California goldenbush
Eriodictyon Benth.	spp.	yerba santa
Eriodictyon[c]	*californicum* (Hook. & Arn.) Torr.	California yerba santa
Eriodictyon[c]	*capitatum* Eastw.	Lompoc yerba santa
Eriodictyon[c]	*crassifolium* Benth.	thickleaf yerba santa
Eriodictyon[c]	*tomentosum* Benth.	woolly yerba santa
Eriodictyon[c]	*trichocalyx* Heller	hairy yerba santa
Eriogonum[c] Michx.	spp.	buckwheat
Eriogonum	*fasciculatum* Benth.	Eastern Mojave buckwheat
Eriophyllum[c]	*confertiflorum* (DC.) Gray	golden-yarrow
Escobaria[c]	*vivipara* (Nutt.) Buxbaum	spinystar
Frangula[c]	*californica* (Eschsch.) Gray	California buckthorn
Fraxinus[c]	*dipetala* Hook. & Arn.	California ash
Fremontodendron[c]	*californicum* (Torr.) Coville	California flannelbush
Garrya Dougl. ex Lindl.	spp.	silktassel
Garrya[c]	*elliptica* Dougl. ex Lindl.	wavyleaf silktassel
Garrya[c]	*fremontii* Torr.	bearbrush
Garrya[c]	*veatchii* Kellogg	canyon silktassel
Hazardia[c]	*squarrosa* (Hook. & Arn.) Greene	sawtooth goldenbush
Heteromeles[c]	*arbutifolia* (Lindl.) M. Roemer	toyon
Holodiscus (K. Koch) Maxim.	spp.	oceanspray
Holodiscus	*discolor* (Pursh) Maxim.	oceanspray
Isocoma[c]	*acradenia* (Greene) Greene	alkali goldenbush
Isomeris	*arborea* Nutt.	bladderpod
Juniperus[c]	*californica* Carr.	California juniper
Keckiella[c]	*antirrhinoides* (Benth.) Straw	snapdragon penstemon
Keckiella[c]	*cordifolia* (Benth.) Straw	heartleaf keckiella
Keckiella[c]	*ternata* (Torr. ex Gray) Straw	Scarlet keckiella
Larrea Cav.	spp.	creosote bush
Leptodactylon[c]	*californicum* Hook. & Arn.	California prickly phlox
Lonicera L.	spp.	honeysuckle

Lonicera[c]	*interrupta* Benth.	chaparral honeysuckle
Lotus[c]	*scoparius* (Nutt.) Ottley	common deerweed
Lupinus L.	spp.	lupine
Mahonia Nutt.	spp.	barberry
Malacothamnus[c]	*fasciculatus* (Nutt. ex Torr. & Gray) Greene	Mendocino bushmallow
Malosma[c]	*laurina* (Nutt.) Nutt. ex Abrams	laurel sumac
Nicotiana[c]	*glauca* Graham	tree tobacco
Opuntia[c] P. Mill.	spp.	pricklypear
Penstemon[c] Schmidel	spp.	penstemon
Philadelphus[c]	*microphyllus* Gray	littleleaf mock orange
Prosopis L.	spp.	mesquite
Prunus[c]	*fremontii* S. Wats.	desert apricot
Prunus[c]	*ilicifolia* (Nutt. ex Hook. & Arn.) D. Dietr. spp. *lyonii* (Eastw.) Raven	hollyleaf cherry
Purshia DC. ex Poir.	spp.	bitterbrush
Purshia[c]	*glandulosa* Curran	desert bitterbrush
Purshia[c]	*tridentata* (Pursh) DC.	antelope bitterbrush
Quercus[c]	*agrifolia* Nee var. *oxyadenia* (Torr.) J.T. Howell	coast live oak (shrub form)
Quercus[c]	*chrysolepis* Liebm. var. *nana* (Jepson) Jepson	canyon live oak
Quercus[c]	*dumosa* Nutt.	coastal sage scrub oak
Quercus[c]	*dunnii* Kellogg	Palmer oak
Quercus[c]	*durata* Jepson	leather oak
Quercus[c]	*engelmannii* Greene	Engelmann oak
Quercus[c]	*john-tuckeri* Nixon & C.H. Muller	Tucker oak
Quercus[c]	*turbinella* Greene	Sonoran scrub oak
Quercus[c]	*wislizeni* A.DC.	interior live oak
Quercus[c]	*wislizeni* A.DC. var. *frutescens* Engelm	interior live oak
Rhamnus L.	spp.	buckthorn
Rhamnus	*californica* Eschsch.	California buckthorn
Rhamnus	*californica* spp. *occidentalis* (T.J. Howell) C.B. Wolf	California buckthorn
Rhamnus[c]	*crocea* Nutt.	redberry buckthorn
Rhamnus	*crocea* var. *ilicifolia*	holyleaf redberry
Rhamnus[c]	*ilicifolia* Kellogg	hollyleaf redberry
Rhus L.	spp.	sumac
Rhus[c]	*integrifolia* (Nutt.) Benth. & Hook. f. ex Brewer & S. Wats.	lemonade sumac
Rhus[c]	*ovata* S. Wats.	sugar sumac
Rhus[c]	*trilobata* Nutt.	skunkbush sumac
Ribes L.	spp.	currant
Ribes[c]	*roezlii* Regel	Sierra gooseberry
Rosa[c] L.	spp.	rose
Rosa[c]	*californica* Cham. & Schlecht.	California wildrose

Rubus[c]	*ursinus* Cham. & Schlecht.	California blackberry
Salix[c] L.	spp.	willow
Salix[c]	*exigua* Nutt.	narrowleaf willow
Salvia L.	spp.	sage
Salvia[c]	*apiana* Jepson	white sage
Salvia[c]	*clevelandii* (Gray) Greene	fragrant sage
Salvia[c]	*leucophylla* Greene	San Luis purple sage
Salvia[c]	*mellifera* Greene	black sage
Sambucus L.	spp.	elderberry
Sambucus[c]	*nigra* L. spp. *cerulea* (Raf) R. Bolli	blue elderberry
Senecio[c]	*flaccidus* Less var. *douglasii* (DC.) B.L. Turner & T.M. Barkl.	Douglas ragwort
Symphoricarpos[c] Duham.	spp.	snowberry
Symphoricarpos[c]	*mollis* Nutt.	creeping snowberry
Toxicodendron P. Mill.	spp.	poison oak
Toxicodendron[c]	*diversilobum* (Torr. & Gray) Greene	Pacific poison oak
Trichostema[c]	*lanatum* Benth.	woolly bluecurls
Trichostema[c]	*parishii* Vasey	Parish's bluecurls
Umbellularia[c]	*californica* (Hook. & Arn.) Nutt.	California laurel
Vitis[c] L.	spp.	grape
Xylococcus[c]	*bicolor* Nutt.	mission manzanita
Yucca[c]	*schidigera* Roezl ex Ortgies	Mojave yucca
Yucca[c]	*whipplei* Torr.	chaparral yucca

Forbs

Achillea[c]	*millefolium* L.	common yarrow
Agave[c]	*deserti* Engelm.	desert agave
Allium[c] L.	spp.	wild onion
Amaranthus[c]	*albus* L.	prostrate pigweed
Antennaria[c]	*rosea* Greene	rosy pussytoes
Arabis[c] L.	spp.	rockcress
Artemisia[c]	*douglasiana* Bess.	Douglas' sagewort
Artemisia[c]	*palmeri* Gray	San Diego sagewort
Astragalus[c] L.	spp.	milkvetch
Brassica[c]	*nigra* (L.) W.D.J. Koch	black mustard
Brassica[c]	*rapa* L.	field mustard
Brickellia[c]	*californica* (Torr. & Gray) Gray	California brickellbush
Brodiaea[c]	*jolonensis* Eastw.	chaparral brodiaea
Calystegia[c] R.Br.	spp.	false bindweed
Castilleja[c] Mutis ex L.F.	spp.	Indian paintbrush
Castilleja[c]	*minor* (Gray) Gray spp. *spiralis* (Jepson) Chuang & Heckard	lesser Indian paintbrush

Centaurea[c]	*solstitialis* L.	yellow star-thistle
Cheilanthes[c] Sw.	spp.	lipfern
Chloris[c] Sw.	spp.	windmill grass
Chlorogalum[c] Kunth	spp.	soap plant
Chlorogalum[c]	*pomeridianum* (DC.) Kunth	wavyleaf soap plant
Chrysothamnus[c] Nutt.	spp.	rabbitbrush
Cirsium[c] P. Mill.	spp.	thistle
Cirsium[c]	*vulgare* (Savi) Ten.	bull thistle
Claytonia[c]	*perfoliata* Donn ex Willd.	miner's lettuce
Clematis[c] L.	spp.	leather flower
Clinopodium[c]	*douglasii* (Benth.) Kuntze	yerba buena
Collinsia[c] Nutt.	spp.	blue eyed Mary
Cordylanthus[c]	*rigidus* (Benth.) Jepson	stiffbranch bird's beak
Croton[c]	*setigerus* Hook.	turkey mullein/dove weed
Cuscuta[c]	*californica* Hook. & Arn.	chaparral dodder
Cynoglossum	*grande* Dougl. ex Lehm.	Pacific hound's tongue
Delphinium[c] L.	spp.	larkspur
Descurainia[c]	*incana* (Bernh. ex Fisch. & C.A. Mey.) Dorn	mountain tansymustard
Dichelostemma[c]	*congestum* (Sm.) Kunth	ookow
Dodecatheon[c]	*clevelandii* Greene	padre's shootingstar
Dryopteris[c]	*arguta* (Kaulfuss) Watt	coastal woodfern
Dudleya[c]	*edulis* (Nutt.) Moran	fingertips
Epilobium[c]	*canum* (Greene) Raven	hummingbird trumpet
Equisetum[c] L.	spp.	horsetail
Eriastrum[c] Woot. & Standl.	spp.	woollystar
Ericameria[c] Nutt.	spp.	goldenbrush
Eriogonum[c] Michx.	spp.	buckwheat
Eriogonum[c]	*fasciculatum* Benth.	Eastern Mojave buckwheat
Eriophyllum[c]	*lanatum* (Pursh) Forbes	common woolly sunflower
Erodium[c]	*botrys* (Cav.) Bertol.	longbeak stork's bill
Erysimum[c]	*capitatum* (Dougl. ex Hook) Greene	sanddune wallflower
Eschscholzia[c] Cham.	spp.	California poppy
Eschscholzia[c]	*californica* Cham.	California poppy
Eucrypta[c]	*chrysanthemifolia* (Benth.) Greene	spotted hideseed
Frasera Walt.	spp.	green gentian
Galinsoga[c] Ruiz & Pavon	spp.	gallant-soldier
Galium[c] L.	spp.	bedstraw
Galium[c]	*angustifolium* Nutt. ex Gray	narrowleaf bedstraw
Galium[c]	*nuttallii* Gray	climbing bedstraw
Gayophytum[c] A. Juss.	spp.	groundsmoke
Gnaphalium[c] L.	spp.	cudweed

Gutierrezia[c]	*sarothrae* (Pursh) Britt. & Rusby	broom snakeweed
Hemizonia[c] DC.	spp.	tarweed
Horkelia[c] Cham. & Schlecht.	spp.	horkelia
Lepidium[c] L.	spp.	pepperweed
Linaria[c] P. Mill.	spp.	toadflax
Lotus[c]	*scoparius* (Nutt.) Ottley	common deerweed
Lotus[c]	*scoparius* (Nutt.) var. *brevialatus* Ottley	western birdsfoot trefoil
Lotus[c]	*wrangelianus* Fisch.& C.A. Mey.	Chilean bird's-foot trefoil
Lupinus[c] L.	spp.	lupine
Madia[c] Molina	spp.	tarweed
Malva[c] L.	spp.	mallow
Marah[c]	*fabaceus* (Naud.) Naud. ex Greene	California manroot
Marah[c]	*macrocarpus* (Greene) Greene	Cucamonga manroot
Mentha[c] L.	spp.	mint
Mimulus[c] L.	spp.	monkeyflower
Mimulus[c]	*brevipes* Benth.	widethroat yellow monkeyflower
Mimulus[c]	*cardinalis* Dougl. ex Benth.	scarlet monkeyflower
Minuartia[c]	*douglasii* (Fenzl ex Torr. & Gray) Mattf.	Douglas’ stitchwort
Mirabilis[c] L.	spp.	four o’clock
Monardella[c]	*odoratissima* Benth.	mountain monardella
Montia[c] L.	spp.	minerslettuce
Navarretia[c] Ruiz & Pavon	spp.	navarretia/pincushionplant
Opuntia[c] P. Mill.	spp.	pricklypear
Opuntia[c]	*acanthocarpa* Engelm. & Bigelow	buckhorn cholla
Opuntia[c]	*basilaris* Engelm. & Bigelow	beavertail pricklypear
Opuntia[c]	*occidentalis* Engelm. & Bigelow (pro sp.)	pricklypear
Paeonia[c]	*californica* Nutt.	California peony
Papaver[c]	*californicum* Gray	western poppy
Pedicularis[c]	*densiflora* Benth. ex Hook.	Indian warrior
Pellaea[c]	*andromedifolia* (Kaulfuss) Fée	coffee cliffbrake
Pellaea[c]	*mucronata* (DC. Eat.) DC. Eat.	birdfoot cliffbrake
Penstemon[c] Mitch.	spp.	beardtongue
Pentagramma[c]	*triangularis* (Kaulfuss) Yakskievych Windham & Wollenwebber	goldback fern
Phacelia[c] Juss.	spp.	scorpionweed
Phacelia[c]	*cicutaria* (Greene)	caterpillar phacelia
Phacelia[c]	*distans* Benth.	distant phacelia
Phacelia[c]	*imbricata* Greene	imbricate phacelia

Phacelia[c]	*minor* (Harvey) Thellung ex F. Zimmerman	wild canterbury bells
Phacelia[c]	*parryi* Torr.	Parry's phacelia
Phlox[c] L.	spp.	phlox
Phlox[c]	*diffusa* Benth.	spreading phlox
Plagiobothrys[c] Fisch. & C.A. Mey.	spp.	popcornflower
Plagiobothrys[c]	*collinus* (Phil.) I.M. Johnston	Cooper's popcornflower
Polypodium[c]	*californicum* Kaulfuss	California polypody
Polystichum[c]	*munitum* (Kaulfuss) K. Presl.	western swordfern
Potentilla[c] L.	spp.	cinquefoil
Pteridium[c]	*aquilinum* (L.) Kuhn	western brackenfern
Pteridium[c]	*aquilinum* (L.) Kuhn var. *pubescens* Underwood	hairy brackenfern
Ranunculus[c] L.	spp.	buttercup
Salvia[c]	*apiana* Jepson	white sage
Salvia[c]	*columbariae* Benth.	chia
Scrophularia[c]	*californica* Cham. & Schlecht.	California figwort
Selaginella[c]	*bigelovii* Underwood	bushy spikemoss
Senecio[c] L.	spp.	ragwort
Solanum[c] L.	spp.	nightshade
Solanum[c]	*xanti* Gray	chaparral nightshade
Solidago[c]	*californica* Nutt.	California goldenrod
Sphaeralcea[c]	*ambigua* Gray	desert globemallow
Stachys[c]	*bullata* Benth.	California hedgenettle
Thalictrum[c]	*fendleri* Engelm. ex Gray var. *polycarpum* Torr.	Fendler's meadow-rue
Trifolium[c] L.	spp.	clover
Urtica[c]	*urens* L.	dwarf nettle
Verbascum[c]	*thapsus* L.	common mullein
Viola[c] L.	spp.	violet
NA	NA	forb (herbaceous, not grass)

Grasses

Achnatherum[c]	*coronatum* (Thurb.) Barkworth	giant ricegrass
Agropyron[c] Gaertn.	spp.	wheatgrass
Arundo[c]	*donax* L.	giant reed
Atriplex L.	spp.	saltbush
Avena[c]	*fatua* L.	wild oat
Bromus[c] L.	spp.	brome
Bromus[c]	*carinatus* Hook. & Arn.	California brome
Bromus[c]	*ciliatus* L.	fringed brome
Bromus[c]	*hordeaceus* L.	soft brome
Bromus[c]	*tectorum* L.	cheatgrass
Carex[c] L.	spp.	sedge
Elymus[c] L.	spp.	wildrye
Festuca[c]	*californica* Vasey	California fescue
Hesperostipa[c]	*comata* (Trin. & Rupr.) Barkworth	needle and thread grass

Lolium	*perenne* L. ssp. *multiflorum* (Lam.) Husnot	Italian ryegrass
Muhlenbergia[c]	*rigens* (Benth.) A.S. Hitchc.	deergrass
Phalaris[c]	*minor* Retz.	littleseed canarygrass
Poa[c] L.	spp.	bluegrass
Poa[c]	*secunda* J. Presl.	Sandberg bluegrass
NA	NA	graminoid (grass or grasslike)
NA	NA	grass, annual
NA	NA	grass, perennial

[a] Plants were named according to Jepson (Hickman 1993) and Munz and Keck (1970) when field data were collected, then checked with, or converted to, names shown in the PLANTS data base (USDA NRCS 2000), with the exception of species not in the PLANTS data base, and a few reclassified plants whose names in the PLANTS database could not be verified; in such cases, Munz and/or Jepson was the final authority.
[b] Primary growth habit as listed in PLANTS database—FIA often classifies plants as secondary growth habit according to definitions of trees and shrubs (i.e., *Arctostaphylos* spp. are sometimes tree size but are never tallied as a tree regardless of size and form).
[c] Identified on field plots.

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Metric Equivalents

When you know:	Multiply by:	To find:
Acres	0.405	Hectares
Fahrenheit	.5555(F- 32)	Celsius
Inches	2.54	Centimeters
Feet	.3048	Meters
Miles	1.609	Kilometers
Square miles	2.59	Square kilometers

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