CHAPTER 1

Fire and California Vegetation

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> In California, vegetation is the meeting place of fire and ecosystems. The plants are the fuel and fire is the driver of vegetation change. Fire and vegetation are often so interactive that they can scarcely be considered separately from each other.
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During the last decades of the twentieth century and early years of the twenty-first century, fire ecology has emerged as a rapidly expanding area of study. Since the first article on fire ecology appeared in *Scientific American* in 1961 (Cooper 1961), several books have been published on the subject (Kozlowski and Ahlgren 1974, Wright and Bailey 1982, Agee 1993, Whalen 1995, Arno and Allison-Bunnel 2002). However, no book has been published that focuses specifically on the ecological role of fire in California. Wildland fire is a complex, dynamic, and often spectacular force that plays a richly complex role in California's diversity of ecosystems. Human interactions with fire have developed around our need to simultaneously protect ourselves from its harm and use it as a tool. As we get more effective at controlling wildfire, we are gaining an appreciation of the value that fire has to ecosystems and biological diversity. We are also recognizing that exclusion of fire from wildlands is not always the most effective way of protecting ourselves from fire or managing ecosystems. Managing wildland fire has developed into one of the largest ecosystem restoration efforts ever undertaken. Our need to understand fire and the consequences of its occurrence—or exclusion—have become great. This book is the first effort at a comprehensive synthesis of our knowledge of fire in California ecosystems.

Fire as an Ecological Process

Part I of this book is an introduction to the study of fire ecology and provides a basic framework and perspective on fire as an ecological process. Much of California has a mediterranean climate conducive to the occurrence of fire (Pyne et al. 1996), with long dry summers and periods of thunderstorms, low relative humidity, and strong winds. These patterns vary through an extremely wide range of climatic zones and complex topography.

Fire is a physical process as well as an ecological process. The heat it produces, the rate at which it spreads, and the effects it has on other ecosystem components are all part of the physical process. Watersheds, soils, air, plants, and animals are affected in one way or another by fire. Water quality and quantity, erosion, smoke, and plant and animal mortality are some of the more obvious effects. Other ecosystem effects are less obvious, but perhaps even more important. Dead biomass accumulates in mediterranean ecosystems because weather conditions are favorable for growth while decomposition is active for a relatively short part of the year. Fire complements decomposition in these systems by periodically removing debris through combustion. Fire has a differential effect on plant species mortality, allowing those that are best adapted to fire to be perpetuated.

Pyrogenic vegetation has evolved with recurring fire and includes species that tolerate or even require fire in order to complete their life cycles. There is a feedback loop between fire and vegetation. Fire feeds on vegetation as fuel and cannot reoccur without some minimum burnable, continuous biomass; and vegetation cannot maintain its occupation of a site without recurring fire. Fire and vegetation are often so interactive that they can scarcely be considered apart from one another. Indeed, the properties of any fire regime—its seasonality, fire return interval, fire size, spatial complexity, fireline intensity, fire severity, and fire type—require specific responses by the vegetation to persist.

Animal populations and communities have developed in habitats where fire has been the dynamic perturbation. The distribution of animal species on landscapes has been driven by the patterns of fire, controlled by climate, weather, and topography, over space and time. Perpetuation of California's biological diversity certainly requires fire to be present as a vital ecological process.

It is difficult to overstate the importance of fire in California ecosystems. A central theme of this book is that wildfire is a pervasive, natural, environmental factor throughout much of the state, and ignoring its role in ecosystems will seriously limit our ability to understand or manage wildlands in a sustainable, ecologically appropriate manner.

Bioregions and the California Landscape

The diversity of the California landscape is well known; from the mist-shrouded mountains of the north coast to the searing heat of the southeastern deserts, and from the sun-drenched beaches of the south coast to the high Sierra Nevada, the range of climate, geomorphology, and vegetation mirrors this diversity. Similarly, fire's role in each of these bioregions of the state is equally diverse.

If we add up the areas of vegetation types generally regarded as fire maintained, about 54% of California's 39,400,000 ha (985,000,000 ac) requires fire to persist (Barbour and Major 1988). Only desert scrub, alpine tundra, subalpine woodland, and a few other, less widespread, vegetation types are not fire dependent. Even some wetlands—such as tule marsh, riparian forest, and California fan palm *(Washingtonia filifera)* oases—have experienced fires set by both indigenous human populations and lightning strikes (Anderson 2005). Knowledge of how fire operates as an ecological process within the state's various bioregions is part of the foundation for wise management and conservation of California's natural heritage. In Part II of this book, we examine each bioregion in detail to see how that bioregion's physical features influence the interactions among fire, vegetation, and other ecosystem components. But first we take a statewide look at the bioregions and the vegetation within them.

California's Bioregions: Climate and Geography

Bailey (1996) and Bailey et al. (1994) developed an ecosystem classification based on climate, as affected by latitude, continental position, elevation, and landform. Located at the mid-latitudes, California receives a moderate amount of solar radiation, placing it in the temperate thermal zone with both a summer and a winter. California's position on the western edge of the North American continent provides the western portion of the state with a moderate marine climate. Bailey (1996) included this area in the Humid Temperate Domain. East of the crest of the Cascades, the Sierra Nevada, and the Peninsular ranges, where the influence of the ocean is much decreased, lies the Dry Domain.

In California, the Humid Temperate Domain comprises two divisions: the Mediterranean Division and the Mediterranean Regime Mountains Division with alternating wet winters and dry summers (Bailey 1996). In the mountains, the climatic regimes differ from the adjacent lowlands and results in climate zones that change with elevation. Two divisions make up the Dry Domain as well: the Tropical/Subtropical Division occurs in the southeastern desert portion of the state, whereas the Temperate Desert Division includes areas of the Great Basin.

Bailey (1996) further divided these divisions into provinces based on macro features of the vegetation. Ecological subregions of California including provinces, sections, and subsections were described by Miles and Goudey (1997). They divided the Mediterranean Division into the California Coastal Chaparral Forest and Shrub Province, the California Dry Steppe Province, and the California Coastal Steppe, Mixed Forest, and Redwood Forest Province. The Mediterranean Regime Mountains Division comprises the Sierran Steppe–Mixed Forest–Coniferous Province and the California Coastal Range Open Woodland–Shrub–Coniferous Forest–Meadow Province. In the Dry Domain in California, the Tropical/Subtropical Desert Division has only the American Semi-Desert Province. The Temperate Desert Division includes the Intermountain Semi-Desert and Desert Province and the Intermountain Semi-Desert Province.

The next level in Bailey's (1996) classification is the section. A section is defined by landform, the overall shape of the surface. For example, mountain ranges are differentiated as are coastal steppes, deserts, and the Central Valley. We have combined the 19 sections described by Miles and Goudey (1997) that comprise California into nine bioregions based on relatively consistent patterns of vegetation and fire regimes (Map 1.1). In the northeastern portion of the state, tall volcanoes and extensive lava flows characterize the Southern Cascade Range and Northeastern Plateaus bioregions. To the west of the Cascades lies the Klamath Mountains bioregion, a complex group of mountain ranges. Numerous valleys and steep coastal and interior mountains are typical of the North Coast, Central Coast, and South Coast bioregions. The Sacramento and San Joaquin Rivers flow through broad interior valleys with extensive, nearly flat alluvial floors. These valleys constitute the Central Valley bioregion. Immediately east of the valley is the Sierra Nevada bioregion, a high range of north-to-south trending mountains. Finally, the vast southeast corner of California constitutes the Southeastern Desert bioregion. Table 1.1 lists the sections from Miles and Goudey (1997) that are included in each bioregion.

Coastal California is characterized by a long chain of steep, geologically complex mountains known collectively as the Coast Ranges. In general, the climate (and vegetation) progress from mesic to dry on a gradual gradient from north to south and a much more abrupt transition from the coast to the interior. A montane gradient, with cooler and wetter conditions at high elevations, is also present. The Coast Ranges are composed of three bioregions: the North Coast, Central Coast, and South Coast.

The North Coast bioregion supports north coastal scrub and prairie, north coast pine forest, and Sitka spruce *(Picea sitchensis)* forest on the immediate coast. Upland forests and woodlands that are farther away from the marine influence include coast redwood *(Sequoia sempervirens)*, Oregon white oak *(Quercus garryana)*, and mixed evergreen. At the higher elevations, the vegetation is typically mixed conifer lower montane forest and Shasta red fir *(Abies magnifica* var. *shastensis)* upper montane forests.

MAP 1.1. Shaded relief map of California bioregions, as defined in this book.

TABLE 1.1
Sections from Miles and Goudey (1997) assigned to bioregions used in this book

North Coast Bioregion
Northern California Coast
Northern California Coast Ranges
Klamath Mountains Bioregion
Klamath Mountains
Southern Cascades Bioregion
Southern Cascades
Northeastern Plateaus Bioregion
Modoc Plateau
Northwestern Basin and Range
Sierra Nevada Bioregion
Sierra Nevada
Sierra Nevada Foothills
Central Valley Bioregion
Great Valley Section
Northern California Interior Coast Ranges
Central Coast Bioregion
Central California Coast
South Coast Bioregion
Southern California Coast
Southern California Mountains and Valleys
Southeastern Deserts Bioregion
Mojave Desert
Sonoran Desert
Colorado Desert
Mono
Southeastern Great Basin

The Central Coast bioregion is an area of transition between the bioregions to the north and south. Ridge tops are generally less than 1,200 m (3,800 ft) in elevation, but a few peaks rise up to 1,800 m (5,700 ft). The region supports a mixture of the vegetation types found to the north and south in a more complex mosaic including coastal prairie, north and south coastal scrub, redwood forest (in isolated locations), mixed evergreen forest, chaparral, oak woodland, and some mixed conifer forest in the lower montane belt of the Santa Lucia Range.

The South Coast bioregion contains the east–west-running Transverse Range and the north–south-oriented Peninsular Range. Except for the alpine zone, both ranges have a full complement of montane zones. Elevations extend from sea level to over 3,500 m (11,400 ft). In addition to montane vegetation types, low-elevation vegetation includes interior grassland, south coastal scrub, chaparral, foothill woodland, and mixed evergreen forest. Despite the fact that Coastal California is greatly urbanized, including the San Francisco Bay Area, Los Angeles, San Diego, and their adjacent urban centers, these bioregions do still have large areas of wildland with relatively low human population densities.

The Klamath Mountains bioregion lies between the North Coast bioregion on the west and the Southern Cascade Range bioregion on the east. These mountains are characterized by steep, complex topography dissected by a number of large river valleys. The area is noted for its exceptionally rich flora, which results from several factors. First, the Klamath area is a meeting ground for three regional bioclimates and floras—the Pacific Northwest, California, and the Great Basin—and this increases the number of species present. In addition, the area has served as a refugium for millions of years, hence the presence of many woody species near the edges of their ranges or even restricted to the region. Finally, the diversity of geologic substrates is impressive, ranging from acid granite, to basic marble, metamorphosed shale, and chemically unique ultramafic extrusions (Franklin and Dyrness 1973, Franklin and Halpern 2000). As a consequence, the mosaic of vegetation types does not fall neatly into broadly continuous zones or belts, as it does in the Coast Ranges or the Sierra Nevada (Whittaker 1960, Sawyer and Thornburgh 1988).

The Central Valley bioregion is a wide, flat, low-elevation trough of sediments bounded by the Coast Ranges to the west and Sierra Nevada to the east. The northern part is drained by the Sacramento River; and the southern part, by the San Joaquin and Kern Rivers and their tributaries. The valley floor and adjacent foothills have largely been converted to agriculture or urbanized but were once dominated by a combination of chaparral, foothill woodland, riparian forest, bunchgrass prairie, forb fields, tule marsh, and in the dry southern San Joaquin Valley, saltbush scrub. Recent research has questioned previous assumptions that bunchgrass prairie characterized most of the landscape (Holstein 2001).

The Sierra Nevada and Cascade Ranges form an axis of high mountains east of the Central Valley and Klamath Mountains. The Southern Cascade Range bioregion is the southern end of an extensive chain of volcanoes and volcanic flows extending northward from Oregon and Washington. Mount Shasta and Mount Lassen are the two largest and most well-known Cascade volcanoes in California. The Sierra Nevada bioregion extends south from the Cascade Range 600 km (373 mi) to the Tehachapi Mountains. Vegetation generally occurs in elevation bands with oak woodlands and chaparral in the extensive foothills on the west side of these mountains. The lower montane zone consisting of mixed conifers gives way to an upper montane fir forest and montane chaparral at higher elevations. The highest mountains and ridge tops support subalpine forests and alpine meadows and shrublands.

The western edge of the huge intermountain Great Basin extends into the northeastern corner of California forming the Northeastern Plateaus bioregion. This is a semi-arid region of mountain ranges separated by lower-elevation basins and includes the Modoc Plateau. Major vegetation types include western juniper *(Juniperus occidentalis* var. *occidentalis)* woodland, sagebrush scrub, mixed ponderosa pine *(Pinus ponderosa),* and Jeffrey pine *(Pinus jeffreyi)* forest, upper montane fir forest, and whitebark pine *(Pinus albicaulis)* subalpine woodland.

The southeastern portion of the state is extremely arid. Except for isolated desert mountains, rainfall is <25 cm (10 in). Portions of the Mojave and Sonoran warm deserts, and the southwestern tongue of the Great Basin cold desert comprise the Southeastern Deserts bioregion. Major vegetation types include various desert scrubs (creosote bush *[Larrea tridentata]*, blackbrush *[Coloegyne ramosissima]*, sagebrush *[Artemisia* spp.*]*), halophytic scrubs in alkaline sinks (greasewood *[Sarcobatus vermiculatus]*, saltbush *[Atriplex* spp.*])*, desert riparian woodland, pinyon *(Pinus monophylla)* woodland, montane conifer forest dominated by white fir *(Abies concolor)*, and, in the Panamint and White Mountains, a subalpine woodland with scattered western bristlecone pine *(Pinus longaeva)* and limber pine *(Pinus flexilis)*. Fire is typically limited by the lack of fuel continuity.

California's Floristic Provinces: Evolution of the Vegetation

Floristically, California is divided into three provinces (Hickman 1993). The California Floristic Province corresponds to the Humid Temperate Domain and comprises the portion of California west of the mountainous crest. Both the Great Basin Floristic Province and the Desert Floristic Province are in the area of the Dry Domain. The three provinces are further divided into 10 regions, 24 subregions, and 50 districts. The regions most closely correspond to our bioregions and various combinations of the subregions "or districts" approximate sections. The vegetation in the provinces evolved from different floras. Today, the Arcto-Tertiary Flora dominates in the Northwestern California, Sierra Nevada, Klamath Mountains, and Cascade Ranges regions. Species from the Madro-Tertiary Flora are most common in the Great Central Valley, Central Western California, Modoc Plateau, east of Sierra Nevada, Mojave Desert, and Sonoran Desert regions.

The modern array of bioregions is a product of millions of years of plant evolution, geologic upheavals, and climate change. For the purposes of this chapter, let's begin some 40–60 million years ago, in the Paleocene Epoch, when California was low lying. Large embayments of the sea covered much of what today are the Coast Ranges and the Central Valley. At that time, the highest mountains were only low hills. Judging from plant fossils deposited then, the climate was temperate, with wet summers and mild winters. Forests were composed of a much richer mix of tree types and species than now: an overstory of evergreen conifers, winter-deciduous conifers, evergreen broad-leaf trees, and winter-deciduous hardwoods; and an understory of winter-deciduous shrubs and summer-active perennial herbs. This collection of species has been called the Arcto-Tertiary Geoflora by Axelrod (1976, 1988), which is thought to have dominated the north-temperate region of the world. Today, no existing forest contains such diversity, but various elements and mixtures exist along the northern California coast, in mountains at middle and upper elevations, and along riparian corridors.

In the Miocene Epoch, about 25 million years ago, the North Coast Range, Diablo Range, and Transverse Range began to form. Water retreated from the Sacramento Valley, but remained in the San Joaquin Valley. From fossils dating to that time, we know that the climate had become warmer and drier, with precipitation more evenly distributed throughout the year. The Arcto-Tertiary Geoflora had begun to fragment and retreat, being slowly replaced by more drought-tolerant plants moving north from what is Mexico today—members of the Madro-Tertiary Geoflora such as chamise *(Adenostoma fasciculatum)*, *Ceanothus* spp., pinyons, junipers *(Juniperus* spp.*)*, manzanitas *(Arctostaphylos* spp.*)*, brittlebrush *(Encelia farinosa)*, *Agave* spp., and cactus *(Cactaceae)* (Axelrod 1958).

By 5–10 million years ago (Pliocene Epoch), a mediterranean-type semi-arid climate was in place at low elevations. This was a time of spread for grasslands, chaparral, mixed evergreen sclerophyllous forest, and oak woodlands. Elements of the Madro-Tertiary Geoflora became dominant throughout low elevations, whereas Arcto-Tertiary taxa and vegetation retreated to high elevations, riparian areas, or the coastal strip. The Sierra Nevada, Klamath Mountains, and Transverse Ranges were thrust up to ever higher elevations, creating rain shadows to the east that deepened and expanded over time to become today's hot and cold deserts, dominated by drought-tolerant shrubs, succulent cacti, and short-lived ephemeral herbs.

Periods of glacial advances in the last 2 million years (Quaternary Period) forced species and vegetation types to migrate downslope or southward. Because California's mountain chains are largely oriented north-to-south, montane taxa driven south were able to migrate back north during warmer interglacial periods, including the current period. The most recent glacial retreat was completed about 10,000 years ago, but abnormally cold and warm periods continued to alternate after that time. These relatively short-term climate fluctuations undoubtedly affected the location of ecotones between vegetation belts in the mountains and along the coast, and their location may still be slowly rebounding from those times. Tree-ring records for the past several hundred years (Michaelsen et al. 1987) show continuing fluctuations in temperature, precipitation, and interannual variation at the time scale of one-to-several decades; but there does not appear to have been any cumulative, directional change.

Californians and Fire

The third part of this book describes how the succession of dominant cultures that have lived in California viewed fire, used it, tried to suppress it, and finally incorporated it in complex policy issues concerning air quality, watershed resources, rare species, and the reduction of fires that threaten people and property. Relatively speaking, the landscapes of California have changed little in the 3,000 years prior to the arrival of European settlers. Few plant species have become extinct and the belts of vegetation in mountains have remained the same; the height of mountain peaks, the thickness of sediments beneath meadows and grasslands, the amount of snow falling in winter, the degree of summer aridity, the distribution of wetlands, the location of sea level, and the gradients of humidity and aridity from coastal west to interior east have not shifted. The most change has occurred just in the past two centuries, due to exotic and aggressive plants, agriculture, fire exclusion, domesticated livestock, and human populations that are approaching 100 times denser than those of precontact time.

It is not the occurrence of fire in an ecosystem that constitutes an ecological disturbance; rather it is our actions that have led to changes to the existing fire regimes. Fire regimes have probably never been static, but the pace and magnitude of changes to California fire regimes accelerated with the arrival of humans from Asia more than 12,000 years ago and again with the arrival of large numbers of settlers of European origin with the Gold Rush in the mid-1800s. Despite intensive efforts to suppress wildland fires over the past century, fires have continued. We can identify several historic periods of time during which fire regimes were altered, and each time the changes also profoundly altered the ecosystems. Changes to fire regimes are fundamental changes to ecosystems that have occurred while climate, landforms, and species compositions were also changing. It is the result of these processes that give us today's California vegetation.

The Era Prior to Human Settlement

We know that humans have occupied California for at least 11,000 years. Prior to that time, fire regimes were dependent upon the time required for continuous fuel to build up to the point at which it would support a spreading flame ignited by lightning. Fires were also started by much rarer events, such as volcanic eruptions or a spark initiated by rocks falling and striking each other. Only broad generalizations can be drawn from the evidence that has been documented regarding the history of fire in California prior to human settlement. Much of what is known is very general in nature and has been reconstructed from paleoecological evidence. For example, we do know that in the Southern California Coast Ranges, pulses of charcoal deposition in sediments indicate a fire regime dominated by infrequent, large fires (Byrne et al. 1977, Mensing 1998, Mensing et al.1999). Similarly, extensive charcoal deposits in the Sierra Nevada indicate that fire was prevalent at least 5,000 years ago (Smith and Anderson 1992).

The Native American Era

Once humans arrived in California, they changed fire patterns with additional ignitions that were focused on their resource needs (Stewart 2002). Using fire to manipulate vegetation was universal among Native Americans at the time of European contact. Studies show that vegetation changes occurred following the arrival of Native Americans (Keeter 1995) and again with their demise (Mensing 1998). At the time of European contact, California was already inhabited with large populations of indigenous people living and influencing broad landscapes throughout the state (Cook 1972). As detailed in Chapter 17, fire was the most significant, effective, efficient, and widely employed vegetation management tool utilized by California Indian tribes. The pattern of burning was often very specific and focused on particular ecosystem effects. Indigenous burning practices defined and maintained the physiognomy of many vegetation types, encouraging particular suites of understory plants. The area that burned during this time period was extensive: Martin and Sapsis (1992) estimate that between 2.2 and 5.2 million ha (5.6–13 million acres) burned annually from both lighting-caused and human-caused ignitions. However, given the diversity of ecosystems, uneven indigenous occupation patterns, and the complex fire characteristics of the vegetation types, the effect of burning by indigenous people was neither uniform nor equally applied across landscapes. These effects formed a continuum encompassing a range of human modifications from very little or no Native American influence to fully human-created ecosystems. Vale (2002) concludes that the pre-European landscape in the American West was a mosaic of areas that were altered by native peoples and areas that were primarily affected by natural processes.

The Era of European and Asian Settlement

During the early settlement era, several widespread changes in the patterns of wildland fire took place. The changes were largely due to the removal of indigenous people (and their approach to the land) and replacement with newcomers who had a very different land-use philosophy and an array of tools to modify the landscape. In those ecosystems where Indian burning had been a regular practice—foothill woodland, montane meadow, and coastal prairie—the demographic change led to changes in species composition, invasion of non-native plants, and even type conversion of the vegetation. Mining and livestock, initially localized, also had widespread influence. An intensive pulse of sheep grazing during the late 1800s greatly changed fire in much of the western United States. Pyne et al. (1996) state, "More than any 'fire practice' per se, the wholesale introduction of domesticated animals reconfigured the fire regimes of the continent."

Fuel continuity in the herbaceous layer and ignition patterns controlled how and when fires occurred because it was in this layer that fire most commonly spread in many California ecosystems. In open forest and woodland ecosystems with herbaceous understory, the reduction and fragmentation of the herbaceous layer greatly reduced a fire's ability to spread. The result was a reduction in the number of days with conditions under which an area could burn, and a drastic reduction in the frequency of fire. This indirect fire exclusion also allowed vegetation to accumulate biomass, developing different fuel structures, changing species mixes, and shifting the geographic distributions of vegetation types.

The introduction of non-native, invasive plant species during this time had important impacts on fire patterns in many California ecosystems. In the grasslands and oak woodlands of the Central Valley, non-native species extended the late summer and fall fire season. In general, exotics have had a greater impact in mesic, lower elevations than in harsher habitats at high elevations, on unusual geologic substrates, or in arid deserts. Exotics can aggressively colonize following high-severity fires.

The impact of humans on fire frequency at this time can be deduced in several ways. As a general rule we have detailed records of recent fire patterns, but as we move back in time, this record becomes more fragmented and less specific. Current fire records are available through land management and fire fighting agency records and can be supplemented by remote sensing studies to very fine scales of detail. Written records often go back to the early 1900s, but they are very generalized and describe only unusually large and destructive fires in the early part of the century. Historic photographs, land survey records, and newspaper accounts from the 1800s can supplement fire records (Egan and Howell 2001). Tree-ring studies extend these records back several centuries (and in some cases for millennia in ecosystems containing long-lived species), but they cannot always reconstruct the details of fire intensity, severity, complexity, or area burned. Studies of charcoal deposits, phytoliths, and pollen in lake sediments allow fire history studies to be extended 10,000 years or more into the past, but the interpretations are more generalized and lack the resolution needed to provide the detailed information derived from other methods. Our knowledge of fire history and fire-related vegetation change is largely built on information developed from a combination of these methods.

The Fire-Suppression Era

The industrialization of America in the early to mid-1900s brought demands for the extraction of wildland resources. Protection of forests and rangelands from "the scourge of fire" was a central part of this era. A fire-protection philosophy, developed in Europe, was applied to most plant communities in North America (Wright and Bailey 1982). The primary focus of management in the early National Forest Reserves (1905–1910) was protecting the timber supplies and watersheds. Fire was seen as a potential threat to both, and a great deal of effort was committed to the removal of fire in America's forests.

Stephen Pyne (2001) states, "The great fires of 1910 shaped the American fire landscape more than any other fire in any other year throughout the twentieth century." Seventy-eight firefighters were killed and several million acres of national forest land burned. These fires instigated the creation of a national system of wildland fire protection that still dominates fire management.

During World War II, the firefighting effort was intensified in the interest of national defense and was paired with a public education campaign that included Smokey Bear. The public was now well shielded from the history of human–fire relationships and fighting fires had become "The moral equivalent of war" (Pyne 1997). After World War II, firefighting efforts were intensified. Science and technology allowed important strides to be made in understanding wildfire spread and its control. The study of fire at this time concentrated on fire physics, fire behavior, and the relationships between meteorology and fire. Subsequently, the focus broadened into fire's effects on ecosystems and a creation of the field we know today as fire ecology.

The Ecosystem Management Era

A number of factors are driving the continuing change of fire patterns in wildlands. A major factor is the increasing density and spread of humans on the landscape. A second factor is that the technology used for fire suppression continues to become more sophisticated, effective, and efficient. Third, the intentional use of fire as a tool for fuel management, natural resource management, and the protection of communities at the wildland–urban interface is increasing.

Starting in the 1960s and continuing today, the emphasis of fire study has become focused on natural resource values and the influence of fire as an ecosystem process. There has been widespread acceptance of the notion that fire is an important part of many ecosystems and that changes in the patterns of occurrence of fire have had many large-scale ecosystem effects. Fire ecology and fire management have become central issues in land management and there has been a greater recognition of the radiating impact of decisions about how to manage fire. Today, the practice of managing wildland fuels to modify future fire behavior has become an important land management activity. The wildland–urban interface has become the contentious focal point for application of fuel management to difficult situations.

In this book, we provide a great deal of information on the ecological role of fire and how our culture has evolved to recognize and appreciate fire as an ecological process. So are we mounting a massive effort to restore fire to all of our wildlands? No. Why? Because our culture also values other wildland attributes including clean air and water, species and habitats, and living in desirable locations without fire to threaten our health and quality of life.

Wildland fires produce smoke and other combustion byproducts and particulate matter that are potentially harmful to human health and welfare, and reduce visibility. These are natural byproducts of fire but are simply unpleasant to people. Uncontrolled wildfires are clearly responsible for the most widespread, prolonged, and severe periods of air quality degradation. The challenge in managing wildland fire is to understand the tradeoffs of balancing public interest objectives while sustaining ecological integrity. Minimizing the adverse effects of smoke on human health and welfare, while maximizing the effectiveness of using wildland fire, is an integrated and collaborative activity.

We also value clean water, and water quality is impacted by fire. California's watersheds include a diversity of intermittent, ephemeral, and perennial streams of various sizes that are shaped by the dynamics of water and sediment. The balance of water and sediment is continually influenced by fire and other physical and biological perturbations. A pulse of erosion due to removal of vegetation, surface cover, and the structural support that the root systems provide commonly follows wildfire. The scale and intensity of these erosion events is dependent on characteristics of the ecosystem and the pattern and severity of the fires and precipitation. Today, landscapes are highly altered with historic fire regimes greatly modified by human activities. Past and current management practices including water development, mining, road building, urbanization, fire suppression, timber harvest, and recreation influence watersheds. The largest erosion events typically follow very large, uniformly high-severity wildfires in steep erosive landscapes. Fire and its associated pulses of sedimentation, mass wasting, and flooding are natural processes that work within ecosystems and are part of the process that creates and maintains watershed. However, like air quality regulation, the focus of the watershed impact regulatory process is to minimize the impacts of discretionary managed fires. Until watershed managers and aquatic ecologists actively support and prescribe the restoration of fire regimes, fire regimes that benefit watersheds are unlikely.

Although fire is a natural process, the effects of fire are not always what they once were. One of the most significant impacts to California ecosystems is the effect of invasive species from other parts of the world that have been introduced since the earliest European contact. Fire can facilitate the expansion of non-native invasive species, and in other cases fire can be used to select against invasive species. In the grass–fire cycle, invasive grass species become established in an area dominated by woody vegetation. As the invasive grasses increase in abundance, a continuous layer of highly combustible fine fuel develops, resulting in increased rates of fire spread and fire frequency. Shrublands and forests composed of native species are converted to grasslands comprised mainly of non-native species. Invasive species are responsible for altering fire regimes in large areas in southern California chaparral, the Great Basin, the Central Valley, and the Mojave Desert. Using or excluding fire to manage invasive species is an important area of future work.

The Federal Endangered Species Act (1972) and the California Endangered Species Act (1986) were specifically enacted to protect native plants and animals that are threatened or endangered. In California, fire and fuel management and at-risk species conservation and protection have more often been in conflict than in accord with one another because addressing species and habitat needs takes additional planning, time, and resources, and restricts project implementation. Although there are difficulties, there are also potential opportunities for fire management to aid in the protection of at-risk species. The use of prescribed fire may provide the best opportunity for at-risk species where the absence of fire has degraded habitat or where fire is not likely to be allowed to return naturally. There are numerous examples across California where fire and fuel management activities, prescribed burning, fire suppression, or post-fire rehabilitation and restoration can be integrated while conserving and protecting at-risk species, their habitats, and ecological processes. Many at-risk species, and the ecological systems they depend on, cannot be sustained or recovered without the immediate and longer-term ecological functioning provided by fire.

The story of fire in California ecosystems is an epic adventure played out over millennia in a spectacular setting. This book sets the scenes, introduces the characters and situations, and provides you, the future of fire ecology, with the tools to write the next act.

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