Postfire regeneration of chaparral in the first spring after the 2007 Witch Fire in northern San Diego County. In addition to shrub resprouts, it is remarkable how many annual species with seed banks that have been dormant for decades are stimulated to germinate by smoke and heat. All photographs by J. Keeley.

FIRE ON CALIFORNIA LANDSCAPES

by Jon E. Keeley

This volume comprises a fine collection of papers that introduces a diversity of issues pertaining to wildfires. They illustrate well the difficulty of balancing protection of natural resources with threats to urban environments. Critical to understanding these issues is the recognition that there are distinct ecoregional differences in the natural role of fire and consequently in appropriate management practices, and nowhere is this more evident than in the very diverse state of California with its sharp contrasts between forested and non-forested ecosystems.

The California flora is well known for its resilience to periodic fires, and many species are characterized as being "fire-adapted" or having "fire-adaptive traits," which means they have characteristics that are deemed critical to success in fire-prone environments. However, in recent decades we have come to recognize that no species is adapted to fire *per se*, but rather is adapted to particular fire regimes. For example, fire-adaptive traits are very different between forest species and shrubland species, and historical impacts on fire regimes and contemporary fire management needs are very different between these biomes (Keeley et al. 2009). In this issue the novel approach of Keeler-Wolf, Evens, and Sawyer in applying fire responses to community associations is a first attempt at providing a framework for understanding fire regime differences that may prove useful to fire managers.

A state as diverse as California has many fire regimes, but the concept can be illustrated by contrasting surface fire regimes in forests with crown fire regimes in shrublands. Forests with historical fire regimes of surface fires that largely burned understory litter, or in more open forest savannah sites burned

understory grasses, generally left most mature trees alive. The life history traits of the dominant mixed conifer trees reflect a strategy of outgrowing the surface fuels, maintaining the canopy well above the surface fuels, and evolving traits such as thick bark and self-pruning of dead branches as a means of providing separation between the fire and the live canopy. The trees in these forests depend on surviving, as they are the parent seed trees for subsequent recovery. Key to survival is the fuel load, and historically this was kept at a low level by frequent lightning-ignited fires. In these forest types, the landscape patterns of burning are critical to the speed of recovery, as seed dispersal is relatively localized and dependent on patches of seed trees surviving, interspersed with areas of high intensity burning that open gaps in the forest canopy.

Non-forested vegetation such as chaparral shrublands persist on more extreme sites where plant productivity is lower and the vegetation simply lacks the capacity to outgrow fire impacts. In these systems, crown fires periodically burn through entire canopies and leave very little above-ground living plants. On these landscapes lightning-ignited fires are far less frequent than in forested environments. Historically these shrublands burned perhaps once or twice a century, and fires profited from the massive landscape expanses of fuels. Most chaparral species recover endogenously (growing from within the site) by dormant seed banks and resprouting from basal burls or other below-ground vegetative structures. As a consequence of this endogenous regeneration system, fire size is seldom critical to vegetation recovery, although this is less true for the fauna.

This dichotomy of forest surface fire regimes and shrubland crown fire regimes of course only captures some extremes. In this issue, Lambert, D'Antonio, and Dudley describe Great Basin sage scrub, which experiences very frequent lightning-ignited fires, but due to the discontinuities in surface fuels, yields very patchy burn patterns. This is reflected in lack of resprouting and lack of dormant seed banks in many dominant shrubs (Keeley et al. 2009). The gaps are dependent on metapopulation dynamics, an ecological term that describes how landscapes recover by surviving populations recolonizing localized burned sites.

Disturbance of course is a concern to all botanists who appreciate natural landscapes and conservation of the native flora. Disturbance from a human perspective is not the same as disturbance from a plant's perspective. On fire-prone landscapes where fire is considered a natural ecosystem process, humans disturb ecosystems by altering fire regimes, usually by either reducing fire frequency through fire suppression, or increasing fire frequency by increasing fire ignitions as well as by changing the seasonal distribution of ignitions. These alterations in the natural fire regime represent the real disturbances in these ecosystems and can have negative impacts on plant survival.

The introduction in Jack Cohen's article describes well the impact of humans on forested ecosystems. It is the long-standing story of fire suppression allowing unnatural fuel loads to accumulate, thus changing fire regimes from frequent low intensity surface fires to infrequent high intensity crown fires. These high intensity fires can result in large portions of the forest landscape being type converted to early seral stages of native chaparral that may persist for many decades, if not longer. These shrubs develop from dormant seed banks that were produced following similar high intensity crown fires sometime in the past, but in some cases there is no native shrub seed bank and, as discussed in Lambert, D'Antonio, and Dudley's article, these are likely to be invaded by non-native grasses.

This however, represents only part of the California story. The majority of our landscape is not forested and humans have not reduced fire frequency, but rather have radically increased burning (Halsey 2004). In many places this has had the unfortunate impact of type con-

This community of chamise chaparral burned twice in three years and is now dominated by non-native species such as red brome (*Bromus madritensis* ssp. *rubens*).

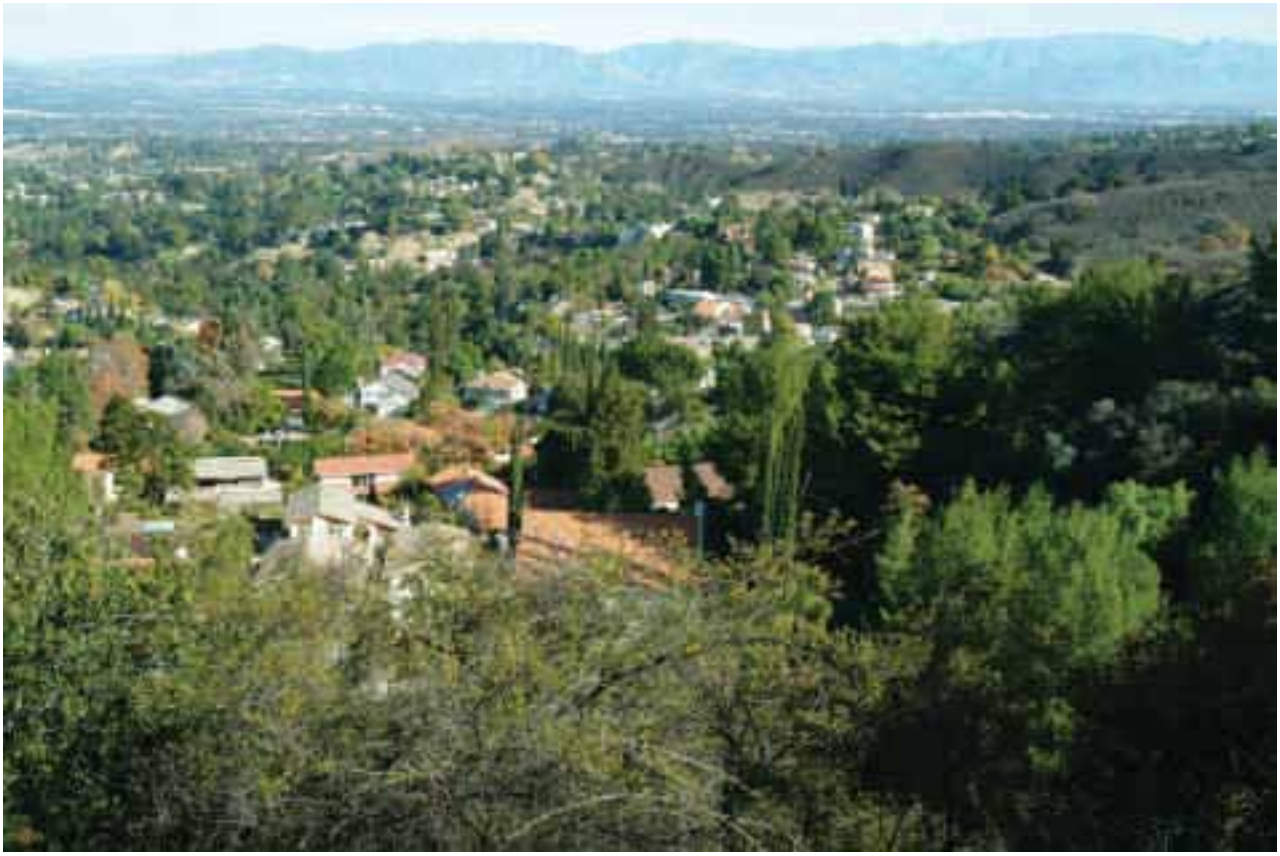
verting native shrublands to non-native grass and forb lands as outlined by Lambert, D'Antonio, and Dudley in this issue. As a member of the California Native Plant Society, this type conversion concerns me because of the loss of both native flora and fauna. As an ecologist this concerns me because of the change in functional types from deep-rooted shrubs that can hold soils on steep slopes, to shallow-rooted herbs. As a fire scientist this concerns me because of the change in fire season from about 6 months in shrublands to 12 months in annual grasslands, and lastly as a scientist this is of concern due to the loss in the capacity for carbon storage and potential impacts on climate.

These two fire regimes have different implications for how we manage these landscapes. Most forests in our region have evolved along with frequent low intensity surface fires. As a consequence, the use of frequent prescription burning to reduce hazardous fuels is compatible with much of the flora and fauna. In short, fire-hazard reduction and resource protection are compatible. In contrast, chaparral shrublands have evolved with infrequent high intensity burning and many of the species are at risk when fire frequency increases. Consequently, fire-hazard reduction and resource protection are oftentimes at odds with one another.

No one concerned with our native flora can ignore the demands humans place on ecosystems, most directly by habitat destruction. Looking down the road this is even more important, as there is currently no effort to curb population growth in California. According to the California Department of Finance, by 2050 the population is projected to reach almost 60 million—about a 41% increase. This will place demands not only on habitat availability, but also on wildland fire activities that will undoubtedly impact native plants and urban environments. Of all the potential global changes threatening our state, population growth has to rank at the top of our list.

Historically, communities have viewed fire as something that state and federal fire agencies will control and prevent from impacting the urban environment. This may be accomplished through a combination of fire suppression tactics and concerted efforts at reducing wildland fuels. On non-forested landscapes this latter approach has often been very controversial because, depending on the methods used, it may involve the sacrifice of native flora, the introduction of non-native species, and the disruption of natural ecosystem processes. These are problems CNPS has been keenly aware of as documented in the article by Betsey Landis in this issue. These costs in and of themselves do not constitute reasons for avoiding such treatments, but they do put an added burden of proof on the managers for demonstrating a positive benefit. Over the past 100 years, wildland fire-fighting agencies have made great progress in managing the fire risk, but it seems unlikely they will ever be able to eliminate the threat of fires crossing the wildland-urban interface.

Dense urban fuels create hazardous conditions when wildfires burn across the wildland-urban interface.



Excessive clearance of chaparral around new home (top center) in San Diego County. A growing body of evidence indicates vegetation thinning rather than denuding the site is sufficient to provide defensible space for fire protection.

Jack Cohen's article provides us with a new frontier for dealing with the fire problem. In short, divert attention away from trying to prevent fires from reaching the urban environment and instead focus on making homes fire-proof and thus immune to fire. His call for better home construction is one very important part of the solution to the wildland-urban interface problem. In his view we could reach a point where uncontrolled wildfires were of minimal threat to urban environments because of fire-proof construction.

However, home construction is only one of the ways to make the urban environment fire-safe. Landscaping around homes often determines which homes burn and which survive. The U.S. Geological Survey has been studying this problem and found that landscaping decisions frequently are critical to home survival in wildfires, particularly for those homes at the immediate wildland-urban interface (Fotheringham 2010). This work should ultimately contribute to the SAFE Landscapes program outlined by Sabrina Drill in her article. Suzanne Schettler's fire-resistant landscaping paper provides further insights into this issue.

"Clearance" is an issue of critical importance, not just for solving wildland-urban impacts, but also of importance to botanists like myself and other CNPS members who are concerned about the impacts on natural resources. The term refers to the fuel management zone around homes, and unfortunately the word "clearance" has been institutionalized in statutes. There is plenty of evidence to show that actual clearance of all vegetation is not the proper approach to fuel management, as outlined by Greg Rubin's article. What is needed is breaking up the continuity of fuels, both vertically and spatially, and reducing the proportion of dead to live wood. In other words—thinning the vegetation. Complete clearance can actually enhance fire spread by both increasing alien weeds that comprise flashy fuels, and by eliminating important "ember catchers" such as oak trees that can dampen the fire threat around homes.

As Jack Cohen has shown, 100 feet of fuel modification surrounding a home seems to be sufficient to prevent homes from being destroyed during wildfires, especially in forested areas. However, as Cohen

Most fires ignite in grasses and other herbaceous material and spread to shrublands, as illustrated by this fire spreading into chamise chaparral. Photograph courtesy of the National Park Service.

points out, most homes are not destroyed by the radiant heat from the fire front. Rather it is common for homes to burn from embers entering vents or igniting piles of dead leaves on roofs or gutters. Since embers can travel a mile or more, clearance zones are not likely to be highly effective in altering housing losses in many instances.

In recent years we have seen a demand by insurance companies and legislators for increasing the clearance zone to 300 feet or more. In a recent analysis for San Diego County it was found that if all homes at the wildland-urban interface that could clear this distance did so, it would represent a clearance of one-third of the natural areas of the county (Keeley and Syphard, in press). To those concerned with resource protection, this looms as an ominous threat to future sustainability of our native flora and fauna.

Current conversation would make it seem as if there are two approaches to solving the wildland-urban interface fire problem: 1) stop fires from encroaching the urban environment, or 2) prevent fires from destroying homes. What has been missing from the debate is a third option: why not alter where we put homes?

Changes in planning decisions may have some of the greatest potential for reducing home losses in the future. By analogy with other hazards such as flooding—where development is restricted to sites outside flood plains—fire hazard planning needs a much more thorough examination than it has traditionally received. Roger Kennedy, historian and former National Park Service Director, has coined the concept of "Fire Zone Planning." This approach has not been ignored by fire agencies; for example, it is part of the reason for Cal Fire's intensive effort at fire hazard mapping in the state. The guidance this provides to planners, however, is largely a function of scale. The California Department of Forestry and Fire Protection maps are based in part on assumptions about the importance of natural wildland fuel loads, and in this respect they do appear to point out the most hazardous regions in the state. However, at community scales they may not be adequate. In a recent empirical study of home losses over the past 10 years in Los Angeles, Ventura, and San Diego counties, fire hazard maps did not predict actual property loss. Rather, location of homes relative to historical fires was of far greater predictive value (Syphard et al. in review).

Of course future changes in land planning will not necessarily solve the wildfire problem for many existing communities, although keeping new development from extending into currently rural areas may prevent further increases in human-caused ignitions and thus, future fire losses in general. To this end communities currently at the wildland-urban interface will need to deal with the problems they face being positioned near watersheds of highly flammable fuels. The federally supported Fire Safe Councils have an important role to play in these cases as described by two articles, one by Yvonne Everett and one by Julie Rogers.

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