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5

The 2003 and 2007 Wildfires in Southern California

JON E. KEELEY, ALEXANDRA D. SYPHARD AND C. J. FOTHERINGHAM

Although many residents of southern California have long recognised that wildfires in the region are an ongoing, constant risk to lives and property, the enormity of the regional fire hazard caught the world's attention during the southern California firestorms of 2003 (Figure 5.1). Beginning on 21 October, a series of fourteen wildfires broke out across the five-county region under severe Santa Ana winds, and within two weeks, more than 300,000 ha had burned (Keeley et al., 2004). The event was one of the costliest in the state's history, with more than 3,600 homes damaged or destroyed and twenty-four fatalities. Suppression costs for the 12,000 firefighters have been estimated at US$120 million, and the total response and damage cost has been estimated at more than US$3 billion (COES, 2004).

Just four years later, almost to the day, this event was repeated. Beginning on 22 October 2007, thirteen wildfires broke out across the same region, and under similar Santa Ana winds, consuming more than 175,000 ha, destroying more than 3,300 structures and killing seven people (Keeley et al., 2009). The 2003 and the 2007 wildfires were remarkably similar in their causes, impacts and the human responses they elicited. Particularly alarming is the observation that these fire events are not new to the region, as large fire events have occurred historically.

5.1 Prior Condition

Essentially every year, in all counties in the southern California region, there are fires that range in size from 1,000 to 10,000 ha (Keeley et al., 1999). This regional history of wildfires is largely a result of the Mediterranean-type climate, with winter rain growing conditions sufficient to produce dense vegetation and a long summer drought that converts this biomass into highly flammable fuels. Although these conditions occur periodically under other climatic regimes, the Mediterranean-type climate results in such conditions annually. Massive fires more than 50,000 ha, similar to the 2003 and 2007 fires, have occurred nine times since the earliest date for which we have records,

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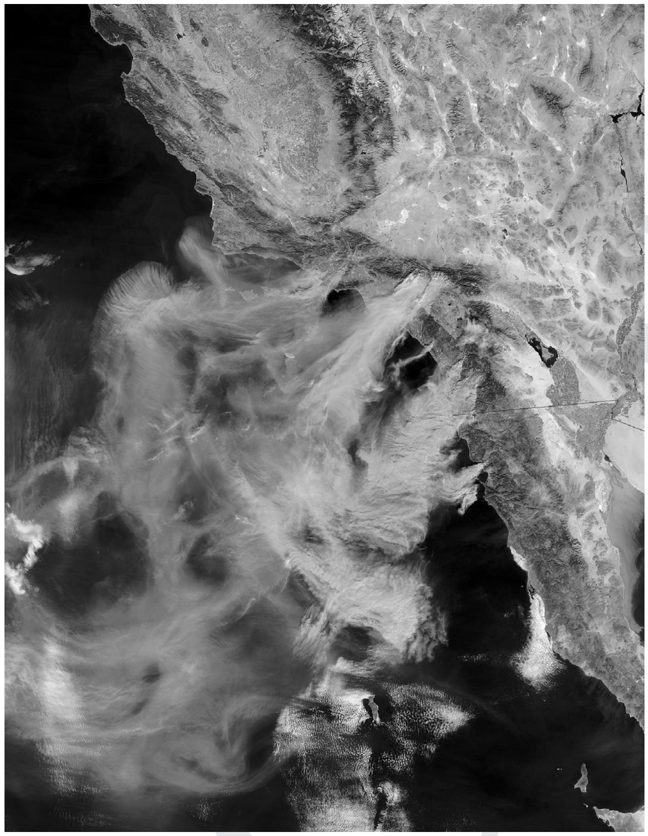

Figure 5.1 Smoke plumes blown by offshore Santa Ana winds during the 2003 firestorm in southern California, 24 October 2003. These winds occur every autumn after the summer drought with gusts >100 km hr^{-1} and relative humidity < 5%. Panel covers an area of ∼350 × 600 km; US–Mexico border indicated by thin line about mid-frame (http://earthobservatory.nasa.gov/).

beginning with the 24 to 28 September 1889 Santiago fire (Keeley and Zedler, 2009). These large fire events span the period from before active fire suppression to the present, when active fire suppression is practiced. This illustrates that large wildfires are a natural feature of this landscape and that, despite the best intentions, firefighters are unable to suppress all fires. Although firefighters often contain most fires at much smaller sizes than would be the case in the absence of fire suppression activities, the potential still persists for some fires to escape control, particularly under extreme weather conditions.

Although one major aspect of the prior condition is the regional propensity for large, high-intensity wildfires owing to the Mediterranean-type climate and regular Santa Ana wind conditions, the other major condition that contributed to the impact of the 2003 and 2007 wildfires is the distribution of human settlements relative to fire-prone wildland vegetation. The 1889 Santiago fire is estimated to have been the

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largest recorded fire in the region, yet no one died and no homes were destroyed. Since 1889, however, human population and the area of urban development have grown by orders of magnitude. In the last fifty years, the region has, on average, lost 500 homes a year to wildfires (Cal Fire, 2000). The massive losses of property and lives in recent fires are the result of human population growth and expansion into these fire-prone landscapes.

5.2 Vulnerability

In general, urban environments in southern California are particularly vulnerable to wildfires because of the hot Santa Ana winds, which last several days and have gusts exceeding 100 km/h and relative humidity under 5 per cent. These winds blow from the interior toward the coast, and there are one or more such events every year in the autumn (Raphael, 2003), when vegetation is at its driest. Although the 2003 and 2007 fires were driven by Santa Ana winds, these winds were not outside the normal range of variability in duration or intensity (Keeley et al., 2004; 2009), so it is apparent that winds alone cannot account for why these fires were particularly destructive.

One reason the southern California region was especially vulnerable to massive fire events in 2003 and 2007 is the extraordinarily long antecedent droughts. Annually, the region is subject to an intense summer drought of little or no rainfall for four to six months; however, prior to the 2007 fires, there had been seventeen months of drought with an average Palmer Drought Severity Index (PDSI) of –3.62, and prior to the 2003 fires, there were fifty-four months of drought (Keeley and Zedler, 2009).

Although drought typically affects fire behaviour by decreasing fuel moisture, this was not likely the main reason these droughts contributed to the extraordinary size of these fires. Nearly every autumn, there are Santa Ana wind-driven fires, and the fuel moisture of these shrublands is typically at the lowest level of physiological tolerance. At the time of the 2007 fires, live fuel moisture for the most common chaparral shrub, *Adenostoma fasciculatum*, was no different than in other years (Keeley and Zedler, 2009). It is hypothesised that the primary effect of the drought was to produce significant amounts of dieback in the vegetation, and this contributed to fire spread by increasing the incidence of spot-fires ahead of the fire front (Keeley and Zedler, 2009). This resulted in extraordinarily rapid fire spread that in many cases exceeded firefighters' capacity for defending homes.

5.3 Resilience

The resilience of urban communities to the wildfires of 2003 and 2007 was largely a function of their location and spatial arrangement, as well as the specific properties of home construction and landscaping. Santa Ana wind-driven fires follow specific topographic corridors (Moritz et al., 2010), and at a landscape scale, homes that burned

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in the 2003 and 2007 fires were distributed in areas that have been historically fire prone and in areas that were located farther inland, closer to the points of fire origin (Syphard et al., 2012). Homes at low to intermediate densities and in smaller, isolated neighbourhoods were also more likely to be burned (Syphard et al., 2012). This could be because of the spatial relationship between homes and wildland vegetation as well as the more limited accessibility of homes to firefighters, as neighbourhoods with fewer roads were also more likely to be burned. Those homes on the interior of developments or on the leeward side (i.e. southern and western perimeters) largely survived untouched (C. J. Fotheringham, US Geological Survey, Western Ecological Research Center, unpublished data).

Homes in the direct path of these fires were the most vulnerable, but housing construction also plays a role. Building ordinances have increased the resilience of homes to burning through structural changes that make homes more resistant to ignition, and as a result, new homes are often more resilient to burning (Quarles et al., 2010). However, another factor is that landscaping age affects the level of plant biomass in close proximity to the homes, and many of these landscaping choices pose significant threats as they age. In a study of 2003 and 2007 fires, the age of homes was significantly correlated with the total tree cover within a 22 m radius of the house ($r^2 = 0.244$, $p < 0.001$, $n = 310$; C. J. Fotheringham, unpublished data), and as discussed below, this may contribute to structural losses. Thus, it will require some work to parse out the relative role of improved construction techniques from increased landscaping fuels.

5.4 Physical Characteristics of the Event

There is evidence that most of the homes lost in these 2003 and 2007 fires ignited from embers blown from the wildland to the urban environment. An in-depth case study of a neighbourhood that experienced substantial home losses in 2007 showed that two out of every three homes were ignited either directly or indirectly from embers, as opposed to uninterrupted fire spread from the wildland to the structure (Maranghides and Mell, 2010). Another reflection of the importance of embers is the observation that for houses on the perimeter of developments, the amount of clearance around homes had no significant effect on whether a home burned (Table 5.1). These patterns fit a widely held generalisation that most homes are not destroyed by direct heating from the fire front but rather from embers that ignite fine fuels in, on or around the house (Cohen, 2000; Koo et al., 2010). Such embers or firebrands are often carried from fuels several kilometres away, and no reasonable amount of clearance around the home can protect against this threat. The extent to which embers create a hazard is a function of them landing on a suitable fine fuel on or adjacent to the home.

Urban landscaping played a significant role in property losses during the 2003 and 2007 fires (Table 5.1). Homes that burned had significantly greater ground surface

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Table 5.1. *Comparison of characteristics of burned and unburned houses in a portion of the 2003 and 2007 fires. Clearance is for a subset of homes on the periphery of urban development.* P *values for Mann-Whitney test (C. J Fotheringham and J. E. Keeley, unpublished data)*

	Burned		Unburned		
	Mean (S.E.)	N	Mean (S.E.)	N	*p*-value
Clearance width (m)	9.38 (1.27)	83	12.45 (1.41)	82	0.115
Tree canopy overlap (m)	10.79 (1.01)	150	5.37 (0.81)	160	0.00001
Tree ground surface cover (m^2)	146.74 (13.43)	150	97.75 (9.22)	160	0.021
Patio (m)	4.82 (0.45)	150	3.59 (0.35)	160	0.051
Deck windward side (m)	0.87 (0.20)	150	0.383 (0.10)	160	0.069

cover (GSC) of trees in the yard, and the amount of tree canopy that overlapped the house was greater than for unburned homes. It is hypothesised that tree canopies that shade homes drop highly flammable litter on and around the structure that contributes to ignitions from embers. Burned homes also had more patio and decking than unburned homes, and these too potentially contributed to ignition (Table 5.1).

Other landscaping choices that can affect structure loss are the planting of drought-tolerant species by home owners and landscape specialists. Many of these species come from other fire-prone regions and share characteristics with fire-prone native species, including retention of dead fuels in the canopy and increased flammability. In addition, it is commonly believed that ornamental vegetation is resistant to fire because of regular irrigation; however, no systematic studies have been conducted to determine the effects of the extreme Santa Ana conditions on ornamental plant moisture content.

5.5 Emergency Management

In 2007, roughly a half million residents were evacuated, with major disruptions in personal and professional lives. There are numerous ways to calculate the costs of such an event, and estimates range from hundreds of millions to billions of dollars. There are many indirect economic costs that are more difficult to estimate, for example, the displacement of the San Diego Chargers football game to Arizona because of occupation of their stadium by evacuees. Calculating the net economic impact is made even more complicated by the fact that there were huge offsets in the damage from wildfires by insurance payments that amounted to billions of additional dollars to the California economy (Hartwig, 2007).

The massive evacuation from homes in the path of the 2003 and 2007 fires would seem to have been the prudent thing to do, although, despite stern warnings from the

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media, most agencies involved in this evacuation contend that it was not mandatory. After the 2007 fires, it was advocated that one of the communities that suffered major home losses consider encouraging residents during the next fire to stay with their homes in order to assist firefighters (Paveglio et al., 2010). In southern California, this is referred to as 'shelter-in-place' and is fashioned after a program in Australia known as the 'go early or stay and defend' policy (Mutch et al., 2010). Key to this idea is that it requires pre-planning and decision making long before a fire incident occurs (see further discussion of this policy in Chapter 8).

5.6 Post–Event Adaptation

Understandably, after the enormous impact of the 2003 and 2007 fires, there has been strong public sentiment to try to prevent such losses from occurring again. For example, there was renewed interest in promoting community involvement in fire protection. The federal government has made large sums of money available to community groups such as Fire Safe Councils, whose objectives are to promote fire-safety education for homeowners and to encourage pre-fire management. One of the primary objectives of pre-fire management has been to increase efforts to reduce hazardous fuels. As a result, wildland fuel treatments in southern California U.S. Forest Service (USFS) forests have increased in the years following these 2003 and 2007 fires. In particular, the trend has been to broaden the areal extent of treatments beyond the traditional practice of creating long, linear breaks in vegetation to provide firefighter access for suppression.

Despite these efforts to reduce broad swaths of fuel across the landscape, recent research demonstrates that fuel breaks are most effective where they provide access for fire-fighting activities (Syphard et al., 2011a; 2011b). Therefore, some managers are also starting to recognise that strategically located fuel modification zones around the urban interface are likely to provide better community protection with fewer resource impacts to natural ecosystems (Witter and Taylor, 2005). In addition to strategically located fuel breaks, creating defensible space around homes is now widely embraced in the fire management, policy and scientific communities and strongly promoted in Fire Safe Councils. Defensible space is also likely to be more instrumental in community protection than remotely located fuel breaks.

Despite a legal mandate in California for 30 m clearance around homes, there has been increasing sentiment after the 2003 and 2007 fires that more clearance is always better (e.g. Figure 5.2). Therefore, in many communities, home owners are now requested to clear up to 90 m by the local fire department. In some cases, insurance companies require 120 m. It is increasingly evident from field inspections as well as from aerial imagery that many homeowners at the wildland-urban interface are clearing in excess of 30 m, and some in excess of 90 m.

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Figure 5.2 Clearance around a rural home in San Diego County, California, that exceeds state requirements (photo by J. E. Keeley).

A common misunderstanding regarding defensible space is that the words 'vegetation clearance' confuse people into thinking that they need to clear all fuel within the safety zone, that is, to bare ground (e.g. Figure 5.2), instead of simply reducing concentrated fuel around the home. Complete removal of fuel may actually create more problems than it solves; it encourages growth of highly combustible grasses, with a substantially longer fire season; it is aesthetically less pleasing (e.g. Figure 5.2); it degrades the water-holding capacity of the soil, promoting erosion; and it destroys important wildlife habitat essential to birds and small mammals that add to the rural lifestyle (Halsey, 2005).

The current lack of a clear science-based system for determining appropriate clearance size potentially has huge impacts on the landscape. In other words, although the mandate is to create 30 m of defensible space, empirical evidence is still lacking on whether more area will provide more protection. We conducted a rough experiment to estimate approximately how much vegetation removal would occur if defensible space guidelines were strictly adhered to, at both 30 m or increased to 90 m, by residential property owners in San Diego County that owned sufficient land to comply with these guidelines. Using a parcel boundary map and a digitised map of residential structures, we calculated the number of properties that were large enough to accommodate defensible space clearing requirements and multiplied these by the area of the

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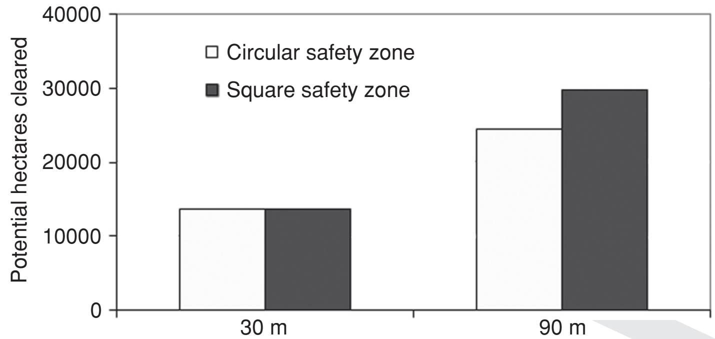

Figure 5.3 Potential area of vegetation clearance that would occur if San Diego County, California, property owners with large-enough properties adhered to 30 m vs. 90 m defensible space requirements. Circular and square safety zones refer to the shape of the clearance around all sides of an occupied structure.

circle that would account for defensible space around all sides of a house located in the centre of the property.

If all property owners on sufficiently sized parcels cleared a 30 m radius around their property, 13,722 ha of vegetation would be removed (Figure 5.3). If those property owners with parcels large enough, that is, a subset of the 30 m parcels, extended clearance to a 90 m radius, this would potentially bring the total vegetation loss to a figure equalling two-thirds the size of the region's largest habitat conservation area, the San Diego Multiple Species Conservation Plan. Of course, many of these parcels already have thinned the vegetation on their property, and not all properties are compliant or will be required to clear the full 90 m around their property. But the numbers do provide a perspective on the importance of understanding the benefits of increasing clearance from 30 to 90 m, which would represent a major loss of natural resources.

5.7 Climate Change Impacts on Southern California Fire Regimes

Southern California is recognised as one of the most fire-prone environments on earth because of its location, climate and vegetation. There is widespread concern that global warming will result in more frequent and more intense fires (Running, 2006). While some landscapes may experience more frequent fires and others more intense fires, it is of course unlikely both will occur in the same ecosystem since they are generally inversely related – that is, intensity is heavily dependent on duration of fuel accumulation.

It is our view that most of the published forecasts of climate change impacts on fire regimes are rather speculative at this point. Predictions are largely based on increasing temperatures affecting fire activity by reducing fuel moisture, which often is tied to increased probability of ignitions and fire spread. There are several considerations that

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need to be looked at before accepting this causal relationship. (1) Global warming is driven by increased partial pressure of CO_2, and there are direct effects of increased CO_2 on plant physiology that will act to produce opposite effects on fuel moisture. In short, as CO_2 goes up, water use efficiency goes up, and for chaparral, this has been estimated to be as much as 35 per cent with a doubling of CO_2 (Chang, 2003). (2) Fire regimes of different vegetation types will not likely respond the same to increased temperatures and increased CO_2, and since fire regime changes have the potential for type conversion of vegetation, predictions of future fire activity cannot be made without serious consideration of vegetation changes. (3) Climate change is only one of a multitude of global changes. In southern California, models predict a 3 to 5 per cent increase in temperature but more than a 50 per cent increase in population by 2040. Since humans are responsible for more than 95 per cent of all fire ignitions, and expansion of urban development into wildlands sets the stage for catastrophic wildfire outcomes, predictions about future fire impacts that fail to include human demographic changes are of questionable value for this region.

Changes in winds have the potential for substantial changes in future fire regimes, but we have even less certainty as to what to expect with winds. Some models of future changes in Santa Ana winds suggest a shift to later in the autumn, and Miller and Schlegel (2006) predict that this will result in increased area burned in coastal California. However, one could predict the opposite effect because later winds will increase the probability of Santa Ana winds being preceded by autumn rains, and historically, when winds have been preceded by precipitation, it has had a negative effect on area burned (Keeley, 2004). In a different modelling framework, Hughes, Hall and Kim (2009) predicted a dramatic drop in Santa Ana winds in the coming years, which of course would suggest we have a rosy future in terms of reduced fire hazard. In short, the models we have for predicting the future are often contradictory, which is to be expected because they are in a rudimentary stage of development. However, as a consequence, they are not presently useful for most of the decision making required to deal with future fire hazards in the region.

5.8 What Are the Lessons Learned?

The 2003 and 2007 wildfires remind us that large fire events are an inevitable and inescapable part of living in southern California. Despite decades of fuel break construction, improvements in fire-safe codes and building regulations and thousands of firefighters, homes continue to be lost nearly every year. The predominant viewpoint has been that government is responsible for protecting homes during fires; but as scattered patterns of development continue to extend into the most flammable parts of the landscape, it becomes more and more difficult for firefighters to defend every home. Thus, many victims blame government officials for not having cleared more fuel, or they accuse firefighters of not protecting their homes (Kumagai et al., 2004).

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Perhaps because most fire management has been focused on wildlands, there has been relatively little effort towards learning from other hazard sciences. For example, flood hazard science has made great strides in reducing losses through better land planning (Abt et al., 1989). The potential is immense for fire scientists and emergency mangers to learn from these hazard sciences, as altered land planning is very likely one of the more important avenues for reducing losses from wildfires as well. This is because the location and pattern of housing significantly influence where fires occur and, in turn, where fires are most likely to result in losses.

Earthquake science has never taken the approach of trying to eliminate the hazard but rather alters human infrastructure to make living in this environment much safer. Fire scientists are gradually coming around to the idea of infrastructure hardening, but most information on the types of construction and landscaping necessary to fire-proof a house are of an anecdotal nature, and there is an urgent need for science-based approaches. We suggest a change in perspective that acknowledges fire risk as an inevitable component of the landscape and that we prepare as we would for other hazards.

References

Abt, S. R., Witter, R. J., Taylor, A. and Love, D. J. (1989). Human stability in a high flood hazard zone. *Journal of the American Water Resources Association*, 25, 881–890.

Cal Fire (2000). *Wildland Fire Hazard Assessment. Final Report on FEMA 1005–47*. Sacramento: California Division of Forestry and Fire Protection.

Chang, Y. (2003). *Effects of Manipulated Atmospheric Carbon Dioxide Concentrations on Carbon Dioxide and Water Vapor Fluxes in Southern California Chaparral*. Unpublished PhD thesis. Davis: University of California, and San Diego: San Diego State University.

COES – California Office of Emergency Services (2004). *2003 Southern California Fires. After Action Report*. Sacramento: California Office of Emergency Services, Planning and Technological Assistance Branch.

Cohen, J. D. (2000). Preventing disaster: home ignitability in the wildland-urban interface. *Journal of Forestry*, 98, 15–21.

Halsey, R.W. (2005). *Fire, Chaparral, and Survival in Southern California*. San Diego, CA: Sunbelt Publications.

Hartwig, R. P. (2007). *The California Wildfire Season of 2007*. Washington, DC: Insurance Information Institute.

Hughes, M., Hall, A. and Kim, J. (2009). *Anthropogenic Reduction of Santa Ana Winds. CEC-500–2009–015-D*. Sacramento: California Climate Change Center.

Keeley, J. E. (2004). Impact of antecedent climate on fire regimes in coastal California. *International Journal of Wildland Fire*, 13,173–182.

Keeley, J. E., Fotheringham, C. J. and Morais, M. (1999). Reexamining fire suppression impacts on brushland fire regimes. *Science*, 284, 1829–1832.

Keeley, J. E., Fotheringham, C. J. and Moritz, M. A. (2004). Lessons from the 2003 wildfires in southern California. *Journal of Forestry*, 102, 26–31.

Keeley, J. E., Safford, H., Fotheringham, C. J., Franklin, J. and Moritz, M. (2009). The 2007 southern California wildfires: lessons in complexity. *Journal of Forestry*, 107, 287–96.

Keeley, J. E. and Zedler, P. H. (2009). Large, high intensity fire events in southern California shrublands: debunking the fine-grained age-patch model. *Ecological Applications*, 19, 69–94.

Koo, E., Pagni, P. J., Weise, D. R. and Woycheese, J. P. (2010). Firebrands and spotting ignition in large-scale fires. *International Journal of Wildland Fire*, 19, 818–843.

Kumagai, Y., Bliss, J. C., Daniels, S. E. and Carroll, M. S. (2004). Research on causal attribution of wildfire: an exploratory multiple-methods approach. *Society and Natural Resources*, 17, 113–127.

Maranghides, A. and Mell, W. (2010). A case study of a community affected by the Witch and Guejito wildland fires. *Fire Technology*, 47, 379–420.

Miller, N. L. and Schlegel, N. J. (2006). Climate change projected fire weather sensitivity: California Santa Ana wind occurrence. *Geophysical Research Letters*, 33, L15711, doi:10.1029/2006GL025808.

Moritz, M. A., Moody, T. J., Krawchuk, M. A., Hughes, M. and Hall, A. (2010). Spatial variation in extreme winds predicts large wildfire locations in chaparral ecosystems. *Geophysical Research Letters*, 37, L04801, doi:10.1029/2009GL041735.

Mutch, R. W., Rogers, M. J., Stephens, S. L. and Gill, A. M. (2010). Protecting lives and property in the wildland-urban interface: communities in Montana and Southern California adopt Australian paradigm. *Fire Technology*, 47, 357–377.

Paveglio, M., Carroll, S. and Jakes, P. J. (2010). Adoption and perceptions of shelter-in-place in California's Rancho Santa Fe fire protection district. *International Journal of Wildland Fire*, 19, 677–688.

Quarles, S. L., Valachovic, Y., Nakamura, G. M., Nader, G. A. and De LaSaux, M. J. (2010). *Home Survival in Wildfire-prone Areas: Building Materials and Design Considerations*. Richmond: University of California, Agriculture and Natural Resources.

Raphael, M. N. (2003). The Santa Ana winds of California. *Earth Interactions*, 7, 1–13.

Running, S. W. (2006). Is global warming causing more, larger wildfires? *Science*, 313, 827–928.

Syphard, A. D., Keeley, J. E. and Brennan, T. J. (2011a). Comparing the role of fuel breaks across southern California national forests. *Forest Ecology and Management*, 261, 2038–2048.

Syphard, A. D., Keeley, J. E. and Brennan, T. J. (2011b). Factors affecting fuel break effectiveness in the control of large fires in the Los Padres National Forest, California. *International Journal of Wildland Fire*, 20, 764–775.

Syphard, A. D., Keeley, J. E., Massada, A. V., Brennan, T. J. and Radeloff, V. C. (2012). Housing arrangement and location increase wildfire risk. *PLoS ONE*, 7(3), e33954, doi:10.1371/journal.pone.0033954.

Witter, M. and Taylor, R. (2005). Preserving the future: a case study in fire management and conservation from the Santa Monica Mountains. In *Fire, Chaparral, and Survival in Southern California*, ed. R. W. Halsey. San Diego, CA: Sunbelt Publications, pp. 109–15.