

VOL. 47, NO.2

MARCH 2020

FREMONTIA

JOURNAL OF THE CALIFORNIA NATIVE PLANT SOCIETY

CALIFORNIA FIRES:
Challenges and
Proposed Solutions





CALIFORNIA NATIVE PLANT SOCIETY

Protecting California's native flora
since 1965

Our mission is to conserve California's
native plants and their natural habitats,
and increase understanding, appreciation,
and horticultural use of native plants.

Copyright ©2020
California Native Plant Society
ISSN 0092-1793 (print)
ISSN 2572-6870 (online)

The views expressed by the authors in this
issue do not necessarily represent policy
or procedure of CNPS.

2707 K Street, Suite 1
Sacramento, CA 95816-5130

Phone: 916-447-2677
Fax: 916-447-2727
www.cnps.org
Email: cnps@cnps.org

Executive Director
Dan Gluesenkamp

2020 Board of Directors
Cris Sarábia, *President*
Bill Waycott, *Vice President*
John Hunter, *Secretary*
Cari Porter, *Treasurer*
Cathy Capone, Lucy Ferneyhough,
Brett Hall, Dee Himes, David Pryor,
Vince Scheidt, Christina Toms

Chapter Council
Judy Fenerty, *Chair*

Editors
David Loeb, Emily Underwood

Fremontia Editorial Board
Jim Andre, Phyllis Faber, Holly Forbes,
Naomi Fraga, Brett Hall, Dan
Gluesenkamp, Nick Jensen, Gordon
Leppig, David Loeb, Pam Muick, Bart
O'Brien, Liv O'Keeffe, Teresa Sholars,
Greg Suba, Mike Vasey



Join CNPS!

Members receive many benefits,
including a free subscription to *Fremontia*
and *Flora*. For more information or to join,
please visit www.cnps.org/membership.

Vision

...when you can see the forest and the trees

Your love of native plants and landscapes
can be your legacy.

*Make a gift that costs nothing during your
lifetime by including California Native
Plant Society in your will or trust.*



CALIFORNIA
NATIVE PLANT SOCIETY

For more information, contact Christine Pieper, Development Director
legacy@cnps.org or 916.738.7622 or visit us at www.cnps.org/legacy

Photograph by Aaron Sims/CNPS

FREMONTIA

VOL. 47, NO. 2, MARCH 2020

FROM THE EDITORS

Perhaps you are one of thousands of California residents who have recently become intimately acquainted with Public Safety Power Shutoffs. Even those of us who haven't found ourselves in the path of recent wildfires have had to navigate dramatic interruptions to our daily lives, including smoke-filled air and increases in the cost of fire insurance (if we can still get it). It is becoming abundantly clear that living in California means living with wildfire.

Of course, fire has always been integral to California's diverse ecosystems. Many people choose to live here because of the state's natural beauty. But proximity to that natural beauty comes with the responsibility to respect and understand the forces that created it, including fire.

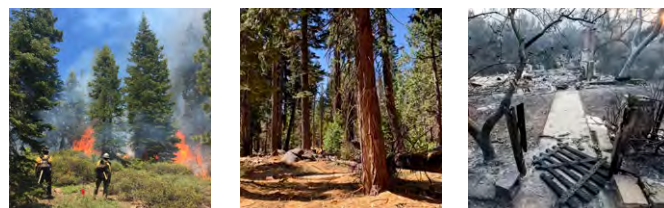
Over the past 20 years, a dramatic increase in large, deadly wildfires has transformed California's environmental politics, with unprecedented impacts on our communities. We're living through a time of remarkable change, and the need for solutions is urgent. Often missing in the midst of crisis, however, is a science-based, historical perspective which would help inform our search for effective responses to this "new normal."

The diversity of California's ecosystems means that we can't treat wildfire the same way throughout the state. Instead, we need rigorous science and regional expertise to inform how we deal with fire, from Sierra Nevada forests, to the chaparral of Southern California.

Providing such scientific expertise and local input is CNPS's role and the purpose of this special issue of *Fremontia*. In it, you'll find commentary from ecologists, foresters, sociologists, and others dedicated to understanding fire in California, as well as science-based recommendations for more fire-resilient homes, gardens, and communities.

Of course, even a special expanded issue of *Fremontia* is too small to contain all that must be said about fire in California. Native perspectives—and in particular, traditional practices developed by indigenous Californians over many centuries—are notably missing from this issue. For thousands of years, California's tribal communities have applied fire to steward landscapes and the critical resources they sustain. This tradition of caring for the land must be brought to the table as we seek more sustainable ways of living in this beautiful and diverse state. Generations of learning cannot be squeezed into a single article, and CNPS looks forward to devoting an upcoming issue to "Traditional Ecological Knowledge," encompassing (but not limited to) Native Californians' relationship with fire.

– Emily Underwood & David Loeb, *Guest Editors*



CONTENTS

REESTABLISHING BALANCE BETWEEN PEOPLE, PLANTS, AND FIRE IN CALIFORNIA 2

Greg Suba

NEXUS BETWEEN WILDFIRE, CLIMATE CHANGE, AND POPULATION GROWTH IN CALIFORNIA 4

Jon E. Keeley and Alexandra D. Syphard

WHY ARE SO MANY STRUCTURES BURNING IN CALIFORNIA? 14

Alexandra D. Syphard and Jon E. Keeley

WILDFIRES AND FOREST RESILIENCE: THE CASE FOR ECOLOGICAL FORESTRY IN THE SIERRA NEVADA 22

Rodd Kelsey

FIRE IN CALIFORNIA: THE LONG ROAD TO RECOVERY 32

Craig Thomas

DEVELOPING THE INFRASTRUCTURE NEEDED TO RESTORE FOREST HEALTH 36

Jonathan Kusel

LOOKING FOR MULTI-BENEFIT SOLUTIONS: AN INTERVIEW WITH CAITLIN CORNWALL 38

David Loeb

CNPS FELLOWS: CELEBRATING THOSE WHO SPEAK FOR NATIVE PLANTS 44

IN MEMORIAM:

Celia Kutcher: A Guiding Light in Orange County 60

Dan Songster

Watson McMillian "Mac" Laetsch 61

John Taylor

Steve McLaughlin 62

Stephen Ingram

Lester Bradford Rowntree 63

David Loeb



REESTABLISHING BALANCE BETWEEN PEOPLE, PLANTS, AND FIRE IN CALIFORNIA

Greg Suba

For millennia, fire has been a part of California. Our native flora evolved with fire and exists in part because of it. California's original people harnessed its forces to their advantage and continue to integrate fire successfully into their land management practices today. But over the last century, California's relationship with fire has changed.

While wildfire certainly brings great danger and tragedy to human communities, it remains fundamental to how California naturally functions. Nevertheless, most Californians have developed a misunderstanding of, and antagonism to, fire. This issue of *Fremontia* addresses how we got into our current wildfire situation, tracing the more than 100-year history of fire suppression in California. It describes how our penchant for harvesting the biggest trees has contributed to fire-starved, overgrown forests, and shows how an increasing population in chaparral and coastal sage scrub habitats is generating more problems with fire, suggesting that we must invest in more than vegetation management to develop resilience to wildfire.

The California Native Plant Society (CNPS) has long held a realistic view of the necessity of living with fire, communicated through policies, publications, and advocacy. We continue that dialog in this issue of *Fremontia*, which brings together a selection of research, personal stories, and expert opinion to explore our broken relationship with fire and what we can do to fix it.

Providing an historical perspective, Craig Thomas leads us along the path we've taken away from fire, describing the forest choices and actions that shape our current relationship with forest fire. Jon Keeley and Alexandra Syphard summarize research and data related to recent increases in wildfire extent, intensity, and damage. Caitlin

Above: The 2014 Happy Camp Complex Fire. [Photograph courtesy of U.S. Forest Service]

“The need for vigorous participation in the discourse underscores the fundamental importance of preserving a process whereby the public—all sides—can provide meaningful input that guides policy and action.”

Cornwall and Jason Mills provide examples of how one post-fire community is learning from their tragedy to balance rebuilding with conservation, keeping resilience in mind.

Many voices, including those of CNPS members, have long advocated that—rather than focus almost exclusively on vegetation management—California’s leaders should make a greater commitment to hardening homes against ember ignitions, maintaining defensible space, and favoring more fire-safe land use decisions. These are priorities reinforced by stories and findings presented by contributing authors in this issue.

Our members have advocated ardently and at length for appropriate vegetation management when and where it is needed. Rather than resist all vegetation management, CNPS has supported the thinning of some understory forest vegetation in order to restore greater forest structural heterogeneity, along with an increase in the pace and scale of prescribed and managed forest fire. At the same time, CNPS continues to dispel damaging misconceptions about the relationship between fire and chaparral and coastal sage scrub landscapes (see *Fremontia* Vol. 35, No. 4, Fall 2007 - Special Issue: Chaparral). In this issue, Rodd Kelsey makes the case for ecological thinning and increased burning in the Sierra Nevada’s mixed conifer forests. Achieving this presents social, economic, and ecological challenges as well as opportunities. Jonathan Kusel describes the potential for community-based biomass energy and alternative wood products to provide solutions to these obstacles.

Our imperative to build a fire-resilient California faces unprecedented opposing forces: rapidly changing climate, fire-prone landscapes, having to unlearn a century of wildfire bias, and a growing population of fire-starting humans. We’ve built ourselves into a problem. Solving it responsibly must include keeping lives and property safe without forsaking the beauty and wildlife (plants and animals) we experience today, nor our ability to pass it on to those who follow us.

Under these conditions, especially within our forested lands, the no-action alternative is hardly an option. The pace and scale of intervention on natural lands has begun to increase, spurring a concurrent increase in the scales of environmental decision making and management actions. Finding a sustainable path through this uncharted territory requires an all-lands, all-voices approach. Success will require using the best science, continued research, letting go of “No” at times, and acknowledging we’re going to make mistakes. Our ability to monitor our successes and failures effectively, to learn from them, and to improve on them will be all-important.

There will always be, and ought to be, tension around how much intervention is enough and how much is too much. Though frustrating at times, open debate is essential to successful natural lands management and conservation. The need for vigorous participation in the discourse underscores the fundamental importance of preserving a process whereby the public—all sides—can provide meaningful input that guides policy and action.

“The West is burning, but mostly not in the way it should be,” as Craig Thomas sums it up. This winter we sat in his home in the Sierra foothills, where he has lived since the 1970s, and I listened to him recount the years of effort he and many others have dedicated to reestablishing fire as an ecological tool in the Sierra Nevada. Their journey is a saga about people living through something new, and working together to establish a path forward. I find myself invested in a central theme of their story, one which I hope readers will take away from this issue: Challenges are neither always bad nor insurmountable.

—Greg Suba is Conservation Biologist for Sierra Forest Legacy. He served as CNPS Conservation Program Director from 2009-2019.



[Photograph by Cecilio Ricardo/U.S. Forest Service]



NEXUS BETWEEN WILDFIRE, CLIMATE CHANGE, AND POPULATION GROWTH IN CALIFORNIA

Jon E. Keeley and Alexandra D. Syphard

Since the year 2000 California has experienced a remarkable upsurge in wildfires. Over five million hectares have burned in the last 20 years, which is double the area burned in the previous two decades. Much of this increase has been driven by large fires of more than 50,000 hectares that cause catastrophic losses of lives and property (Keeley and Syphard 2019). This increased fire activity has been correlated with an increase in average temperature over this same period, leading many observers to assert that global climate change must be playing a major role. Climate models forecast continued warming and thus some have suggested these catastrophic fires are the “new normal” or the “new *abnormal*,” (Birnbaum 2018). In contrast, others have declared that these fires are the result of “forest mismanagement” (Cranley 2018) and this has stimulated renewed interest in fuel reduction (Office of Governor 2019). It’s almost as though these opinions aren’t even in reference to the same fires, and as described below, there is some validity to this assertion.

Sorting out the factors driving this rise in fire activity requires an appreciation for the diversity of landscapes and fire regimes in the state. After all, California has the largest latitudinal range of any western state, comparable to that from southern New Mexico to Wyoming, and the largest altitudinal range (containing both the lowest and highest points in the lower 48 states). California also is the most populous state in the union: One out of eight Americans live here. And most live within dense metropolitan areas juxtaposed with fire-prone wildlands, while a great many more live widely dispersed in rural settings.

A key to sorting out the factors behind increased fire activity is understanding that we are looking at two very different types of fires: fuel-dominated vs. wind-dominated fires. And each of these is controlled by different environmental and historical factors (Table 1). Understanding the differences between these two types of wildfires is helpful for navigating the confusing array of opinions expressed in the media as well as determining the appropriate management responses to reduce future fire impacts.

Above: Aerial retardant drop on a chaparral wildfire in coastal Southern California, taken July 5, 2008, in the foothills of the Los Padres National Forest. [Photograph by Dan Lindsay]

FUEL-DOMINATED FIRES

Many of the forest fires of the past two decades have grown out of control due to anomalous fuel loads resulting from 20th century management practices. In the early 1900s increasing state and federal interest in timber resources led to vigorous suppression of natural fires in forests that historically had burned at decadal frequency (McKelvey and Busse 1996) (Fig. 1). In the moderately productive mid-elevation conifer forests of the Sierra Nevada there is typically a vertical separation between dead branches and other litter on the ground and the living tree canopies above, and thus frequent lightning-ignited fires were commonly restricted to low intensity surface fires (Fig. 2). As a result such fires were relatively easy to extinguish and thus many forests in the western U.S. have experienced over a century of near total fire exclusion.

One consequence is that some of these forests have accumulated understory surface fuels that represent fuel loads an order of magnitude greater than historical levels (Keifer et al. 2006), made even worse by the massive ingrowth of new saplings that not only further increase the fuel load but also act as ladder fuels carrying fire from the surface to the canopy. A century without fire has made these forests susceptible to high-intensity crown fires, a fire pattern evident in many recent Sierra Nevada fires (Fig. 3). These types of fires are best described as fuel-dominated fires (Table 1).

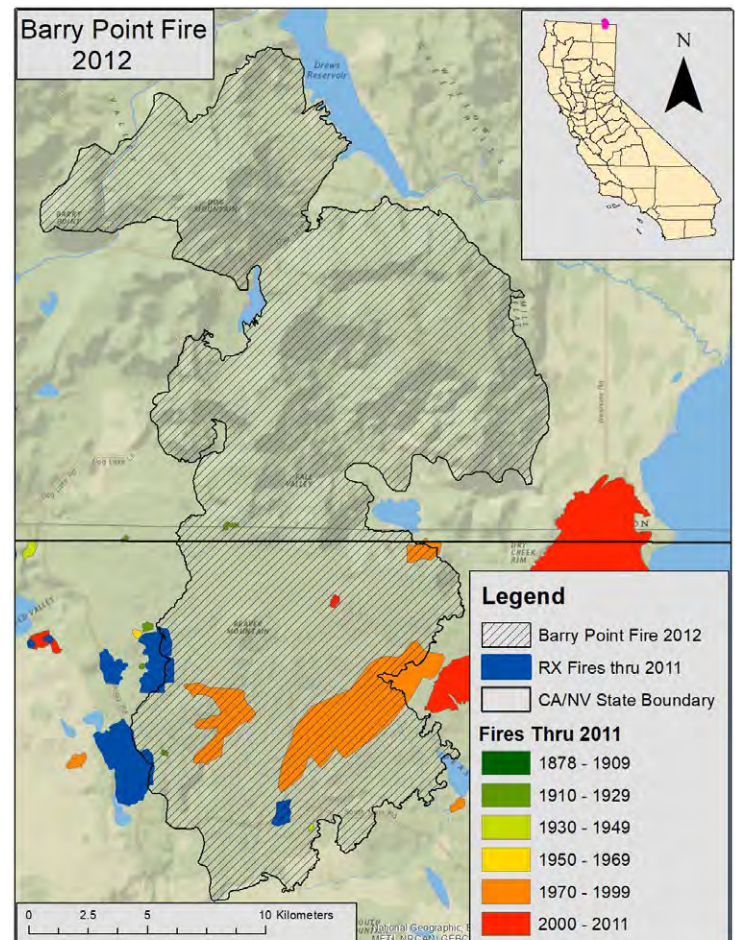
To be sure, some fuel-dominated fires can produce their own extreme winds (e.g., the 2010 Station Fire in Los Angeles County or the 2018 Carr Fire in Shasta County), resulting from the high-intensity burning of heavy fuel loads. The extreme heat produces pyrocumulonimbus clouds and are often described as plume-driven fires that can collapse, producing extreme wind events (Clements et al. 2018). However, such winds are internally generated, a phenomenon that could be altered by undertaking fuel treatments prior to fire events.



Figure 1. Cross section of ponderosa pine, upper edge is the outer bark, pith is toward the bottom. Dates indicate previous fires and none since active fire suppression in the early 1900s (Section from Bruce Kilgore, photograph by Jon Keeley, USGS)

Figure 2. Low intensity surface fire typical of historical fires in many western forests (Rim Fire burning in Yosemite National Park, photograph by Jon Keeley, USGS)

Figure 3. Fire perimeter for the 2012 Barry Point Fire. Hatched area indicates no previous recorded fire from 1910 to 2012, roughly 90% of area burned in 2012. Legend indicates other historical fire dates (Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, <https://frap.fire.ca.gov/mapping/gis-data/>; accessed Jan. 2020).



WIND-DOMINATED FIRES

On the other hand, wind-dominated fires are those controlled by external weather events. This is an important distinction, as we have no ability to alter such weather-driven wind events. Our most catastrophic fires of the past few decades have been just such wind-dominated fires. They typically occur in the western portions of California and burn over non-forested landscapes of shrubs, grasses, and woodlands. These fires grow rapidly due to extreme wind events and, as a result, pose severe challenges to fire suppression efforts. Readers will be familiar with several of these recent “firestorms,” including the 2017 Napa-Sonoma Wine Country fires and the 2018 Camp Fire driven by North winds in Northern California. (Historically this is the appropriate term; however, such winds are sometimes referred to as Diablo winds, a term spawned by a newspaper reporter who noted that the 1991 Oakland Hills Tunnel Fire was driven by winds coming from the direction of Mount Diablo; thus the term is less appropriate for wind-driven fires



Figure 4. Offshore dispersion of smoke from a) North Wind driven fires in northern California, 2017, and b) Santa Ana Wind driven fires in southern California, 2003.



throughout the region.) Other such “firestorms” include the 2017 Thomas Fire and the 2018 Woolsey Fire driven by Santa Ana winds in Southern California. While these winds may occur in both the spring and autumn (Fig.5a) they are most problematic in the autumn, following the three to six months of drought typical of our Mediterranean climate (Fig. 5b), leaving natural vegetation at its lowest moisture level. It is these autumn Santa Ana wind and North wind fires that account for the most catastrophic fires in the state (Table 1).

TABLE 1. Selected fires representing fuel-dominated and wind-dominated fires.

Year	Fire	County	Mon. (days)*	Hectares	Cause	Lives	Structures
Fuel-Dominated Fires:							
2007	Marble C	Monterey	July -	71,980	Lightning	0	0
2012	Barry Point	Modoc	Aug -	37,630	Lightning	0	3
2012	Rush	Lassen	Aug -	110,080	Lightning	0	1
2013	Rim	Stanislaus	Aug -	104,220	Campfire	0	112
2014	King	El Dorado	Sept -	39,260	Arson	0	80
2015	Rough	Fresno	July -	61,360	Lightning	0	4
Wind-Dominated Fires:							
1889	Santiago	Orange	Sept (3)	125,000	Campfire	0	0
1970	Laguna	San Diego	Sept (3)	70,500	Powerline	5	382
2003	Cedar	San Diego	Oct (3)	109,500	Flares	15	2,820
2007	Witch	San Diego	Oct (2)	80,200	Powerline	2	1,265
2017	Tubbs	Sonoma	Oct (2)	14,900	Powerline	22	5,643
2017	Thomas	Ventura	Dec (10)	114,080	Powerline	2	1,063
2018	Camp	Butte	Nov (2)	62,060	Powerline	88	18,804
2018	Woolsey	Ventura	Nov (3)	39,335	Powerline	3	1,643
2019	Kincade	Sonoma	Nov (5)	31,470	Powerline	0	374

*Indicates days of Santa Ana or North winds [Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, <https://frap.fire.ca.gov/mapping/gis-data/>; accessed Jan 2020].

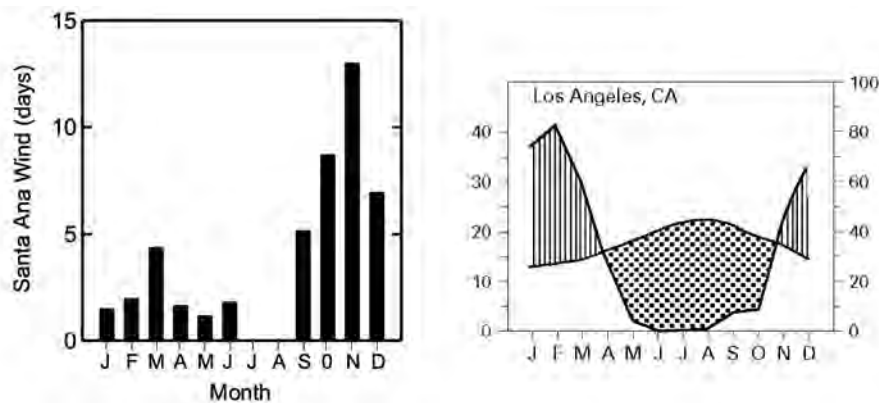


Figure 5. Days of Santa Ana winds (left) and (right) temperature and precipitation in Los Angeles illustrating typical Mediterranean climate of winter rains and summer droughts (from Keeley et al. 2012).

Historically these landscapes have not experienced the fire exclusion seen in many Sierra Nevada landscapes, despite being managed by the same fire suppression policy (Fig. 6). This is due to the fact that essentially all are caused by human ignitions, which are relatively common due to the high population density in the western portion of California (Keeley and Syphard 2018). As a consequence, there has not been any lack of fire and most large fire events burn across landscapes with an extensive fire history and no anomalous fuel accumulation. Indeed, some of these large fires—e.g., the Thomas Fire (Keeley and Syphard 2019)—have burned across areas where extensive prescription burning had occurred in recent years, pointing to the conclusion that prior fuel treatments are having limited effect on the spread of these fires. Even

landscapes not experiencing high fire frequencies, such as the San Francisco Bay Area, are not outside their range of natural fire frequencies and so fuels have not accumulated due to fire suppression (Keeley 2005). To be sure, some communities in this region have dangerous fuels but these are often the result of urban plantings of *Acacia*, *Eucalyptus* and *Pinus* and not so much due to accumulation of wildland fuels from elimination of natural fires.

Every year there are many Santa Ana wind events but most years we don't see major wind-driven fires because they are entirely dependent on a human ignition happening during an extreme wind event. Indeed, only about five percent of the Santa Ana wind days are accompanied by a large fire event (Rolinski et al. 2019). Some have suggested that these Santa Ana winds are increasing in frequency, duration, and intensity, but records do not show a change in the character of these winds since the mid-1900s (Williams et al. 2019). Rolinski et al. (2016) found that fires during extreme weather events are larger than ones in less extreme Santa Ana conditions, and some have interpreted this to mean that fires are becoming worse because Santa Ana winds are becoming more extreme. However, this study only considered Santa Ana winds after an ignition had occurred, thus ignition sources are critically important. It is important to recognize that Rolinski's Santa Ana Wind Threat Index is not an indication of when an extreme fire will occur but only

how bad the fire will be once ignited. What determines an extreme fire year is the untimely human ignition during an extreme wind event. This is illustrated by the fact that the frequency of these wind events is not correlated with area burned (Keeley and Syphard 2018) and our largest fire years occur in high- as well as low-Santa Ana wind intensity years

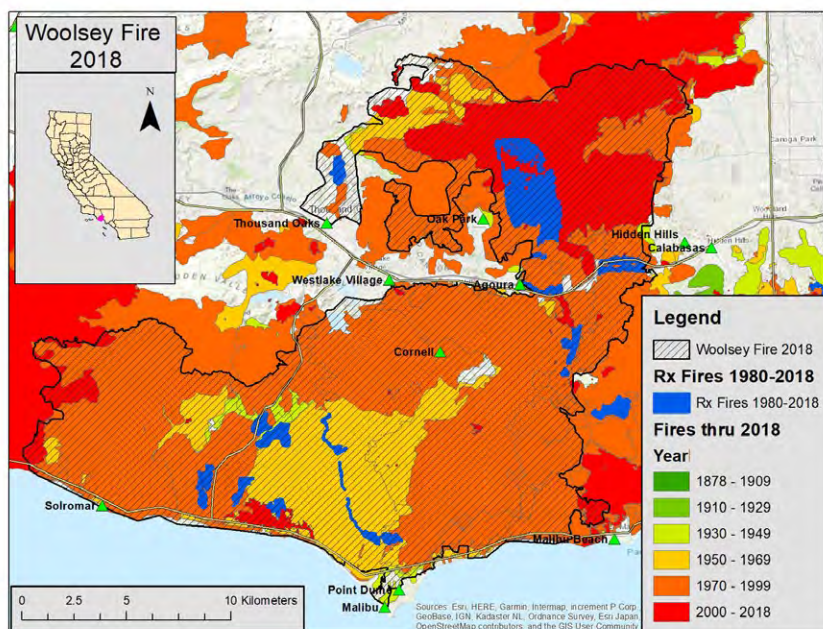


Figure 6. Fire history within the perimeter of the 2018 Woolsey Fire. Hatched area indicates less than 1% of the area unburned prior to 2018. Legend indicates other fire dates [Data from the State of California Fire and Resource Assessment Program, FRAP Fire History Database, <https://trap.fire.ca.gov/mapping/gis-data/>; accessed Jan. 2020].

(Fig. 7). Ultimately it is all determined by an untimely human ignition event. Of course climate is peripherally related as it has been found that these fires are less likely to occur when relative humidity is high (Jin et al. 2014) and this most certainly is tied to decreased probability of such fires after early autumn precipitation (Keeley and Syphard 2017).

Indeed, Santa Ana wind events occur multiple times every year, yet during most such wind events there is no human ignition and thus no fire (Keeley and Syphard 2017). There is little evidence that the increase in the number of catastrophic fires is the result of increased intensity of Santa Ana wind events. For example Guzman-Morales et al. (2016) mapped the annual intensity of Santa Ana wind events (Fig. 7) yet when we overlaid extreme fire years of over 100,000 hectares burned in Southern California (Fig. 7), we find that such extreme fire years are associated with low as well as high intensity Santa Ana wind years; e.g., the catastrophic 2003 Cedar Fire (Table 1) occurred during a year with low-intensity Santa Ana winds.

CHANGING IGNITION SOURCES

Lightning is a common ignition source in forests of the Sierra Nevada and northeastern California and thus accounts for many fuel-dominated fires (Table 1). However, lightning is relatively uncommon in coastal regions (Keeley and Syphard 2018) and does not occur under the synoptic conditions that create extreme Santa Ana and North wind events. Thus, these wind-dominated fires are ~ 100 percent human-ignited fires (either from intentional causes, such as arson, or accidental causes, such as sparks from equipment).

In the last decade, the majority of these large fires—including some of the biggest fires in 2017, 2018, and 2019—have been ignited by powerline failures during extreme wind events. Indeed, since the year 2000, over half a million acres have burned due to powerline failures, which is five times more than in the prior two decades (Keeley unpublished data). The increased impact of powerline-ignited fires is not the result of increased frequency or intensity of extreme wind events. There are two likely explanations for this increase in powerline-ignited fires: 1) expansion of the electrical grid due to increased development, which provides more opportunities for powerline ignited fires, and/or 2) deteriorating powerline equipment resulting from age and inadequate maintenance (one California regulator contends that electrical grid equipment is being run to the point of failure (Penn et al. 2019)).

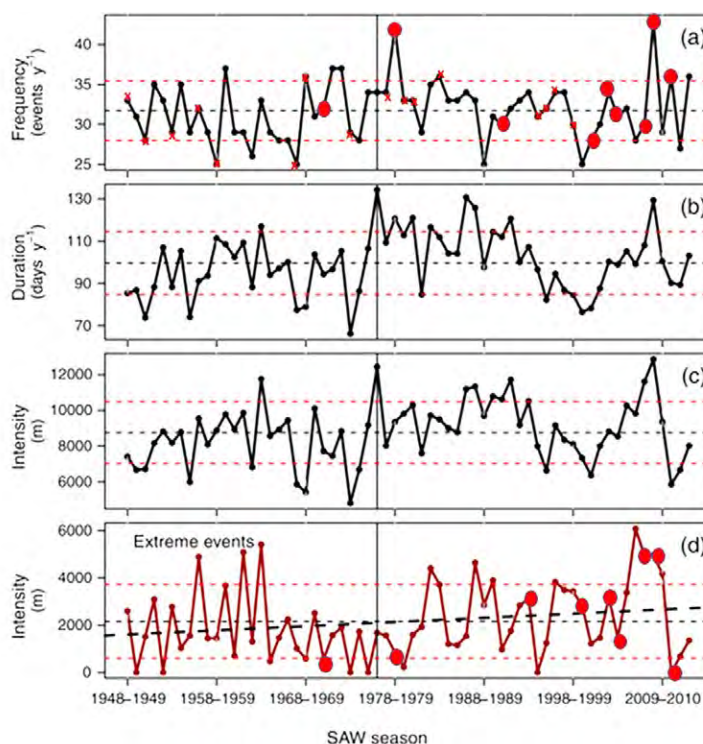


Figure 7. Pattern of Santa Ana wind (SAW) characteristics from Guzman-Morales et al. 2017 and with red dots indicating very high fire years exceeding a hundred thousand hectares burned [from Keeley and Syphard 2017]. Correlation analysis between frequency of Santa Ana wind events or the intensity of extreme Santa Ana wind events with area burned suggests there is no significant relationship in Southern California ($R^2=0.01$ and $R^2=0.00$, respectively).

GLOBAL CLIMATE CHANGE

Some forecasts of future fire regimes based on different climate change simulations predict huge increases in California wildfires (Westerling 2018). These models need to be viewed in light of the fact that they are driven by untested assumptions. They don't adequately account for the complexity of fire-driven changes in vegetation (Syphard et al. 2018b), and they don't consider changes in fire-climate relationships over time, as well as changes in human-ignition patterns.

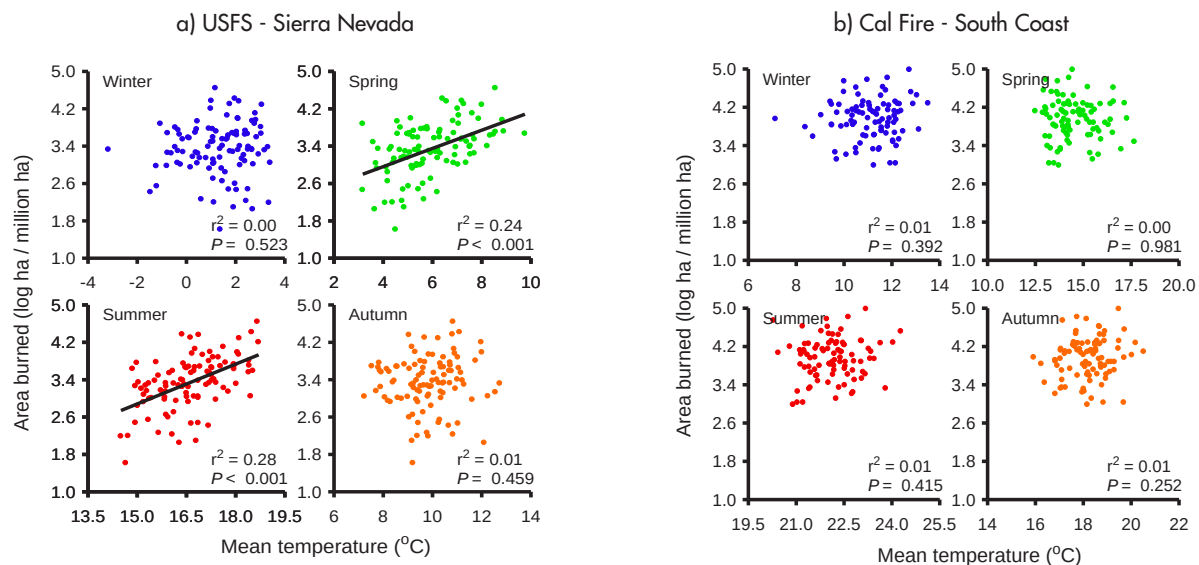
An alternative approach to future modeling is retrospective studies. Confucius stated, "If one wants to define the future, they must study the past" (Castro 2012). We recently conducted a study that took an empirical approach and asked how seasonal variation in temperature and precipitation has correlated with area burned, year to year, in the past. This investigation, which differs from those using algorithms of future fire-climate relationships, covered much of the last 100 years and separated out the effect of different seasonal temperatures (Keeley and Syphard 2017).

One interesting finding is that in no region of the state did winter temperature play a role in determining subsequent fire activity. This may be important since some climate models predict the greatest global warming to occur in the winter in the northern hemisphere. So perhaps this type of warming might not translate into changes in fire severity and frequency in California.

We can summarize our findings by contrasting U.S. Forest Service lands in the Sierra Nevada (Fig. 8a) with the lower elevation California Department of Forestry and Fire Protection (Cal Fire) responsibility lands in Southern California (Fig. 8b). In Sierra Nevada forests there is a significant relationship between higher spring and summer temperatures and area burned; indeed, in the last 50 years, the combination of these two climate variables (spring and summer temperature) could explain over 50 percent of the year-to-year variation in area burned (Keeley and Syphard 2017). This is consistent with claims that global warming has played a role in increased burning in western forests in recent decades (Abatzoglou and Williams 2016).

In contrast, on non-forested landscapes in Southern California we found little correlation between seasonal

temperatures and area burned (Fig. 8b), a pattern consistent with other recent studies (Williams et al. 2019). We surmise that this is likely due to the fact that in Southern California it is hot and dry enough every year to support large fires. (Note that maximum summer temperatures in the Sierra Nevada, when fires are most extensive, are similar to the lowest temperatures observed in Southern California in the summer, Fig. 8a&b). The lack of a strong annual climate relationship with fires in Southern California is due to climate being overridden by other factors, such as extreme wind events, increasing human ignitions during severe wind events, and long-term drought. Interestingly, while there has been an effect in the last 50 years of prior year precipitation on fires in Southern California, this effect is well known in grasslands and savannas throughout the southwest and is tied to elevated grass fuel loads following high rainfall years (Keeley and Syphard 2017). We believe this relationship showed up for Southern California in the last half of the long-term record (Fig. 8b) because of the well-documented increase in type conversion from shrublands to grasslands in the region (Syphard et al. 2018a).



Akaike IC regression models

Sierra Nevada (USFS) r^2			South Coast (Cal Fire) r^2		
1910 - 2013	0.39	Temp spr+Temp sum-Ppt spr	1919 - 2013	0.00	
1910 - 1959	0.42	- Ppt spr - Ppt win	1919 - 1959	0.00	
1960 - 2013	0.52	Temp spr + Temp sum	1960 - 2013	0.25	Prior ppt-Ppt aut -Ppt sum

Figure 8. a) Annual area burned from 1910–2013 for USFS lands in the Sierra Nevada plotted against winter, spring, summer, autumn temperatures and multiple regression models using all temperature and precipitation data for these four seasons, and b) annual area burned from 1919 – 2013 on Cal Fire lands in Southern California and multiple regression analysis (from Keeley and Syphard 2017).

One climate factor not considered when investigating annual climates is the impact of long-term droughts; i.e., those that last for multiple years. Recently California experienced an intense drought that began in 2012 and lasted for three years in the Sierra Nevada and eight years in Southern California (Jacobsen and Pratt 2018). It was accompanied by an immense dieback of trees in the Sierra Nevada (Stephens et al. 2018) and of shrublands in Southern California (Keeley and Syphard 2019). This creation of massive dead fuel loads represents a legacy on the landscape that may persist through subsequent years of higher rainfall. If drought-induced dieback proves to have been a critical factor in making the 2017 and 2018 fire years so extreme, it raises doubts as to whether these fire years represent a new normal for California, since although droughts are expected to be more severe under climate change, there is no evidence that such extreme droughts will be a normal feature going forward.

What can we conclude about how climate change may impact these coastal wind-driven fires? Global warming may reduce grass growth leading to reduced fire frequency in these grass-dominated landscapes. On the other hand, higher temperatures have the potential for increasing the intensity of plant stress during droughts, perhaps elevating dieback of woody plants that would exacerbate fire spread and intensity; a study by Williams et al. (2015) concluded that the last severe drought in the Sierra Nevada increased the stress by ~10-15 percent. A further likely impact of global warming is that it will alter postfire recovery of shrublands by changing the competitive balance to favor alien grasses, increasing type conversion to highly flammable herbaceous fuels, and leading perhaps to increased fire frequency (Syphard et al. 2018a, 2019, Park et al. 2018).

In summary, there is good reason to conclude that global warming is affecting Sierra Nevada forest fires. In montane forests with fuel-dominated fires, summer temperatures—although fluctuating greatly from year to year—have been on an upward trajectory for many decades and it is reasonable to assume a causal relationship between increased fire activity and global warming. However, over this same period there has been a steady increase in understory fuels. This raises an interesting question: Would the strength of the observed climate impact (Fig. 8a) have been as strong in the absence of this anomalous fuel accumulation due to fire suppression? In contrast, in the coastal regions there is limited evidence that climate change

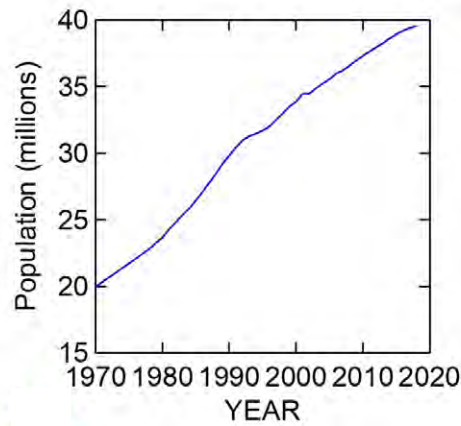


Figure 9. California population from Census Bureau (www.census.gov; accessed June 2019)

is impacting wind-dominated fires (Fig. 8b). However, global warming has the potential for a number of indirect impacts on vegetation that may alter fire regimes.

POPULATION GROWTH

Roger Kennedy, a former National Park Service director, was one of the first to bring attention to the role of population growth in raising the threat of wildfire (Kennedy 2006). It is true that since 2000 California has experienced a highly variable and subtle rise in temperature. However, less noticed is that there has also been a steep rise in population, adding about six million people (Fig. 9) over the last two decades. Since ~100 percent of the wind-dominated fires are ignited by humans or human infrastructure, there is likely a causal relationship between this population growth and the increased incidence of catastrophic wind-dominated wildfires.

Although local, state, and federal agencies have made significant progress in reducing the overall number of fires in the state over the last several decades (Keeley and Syphard 2018), there has been an increase in ignitions during extreme wind events. Thus, the real driver of wind-dominated fires is not the extreme wind events per se, but rather untimely human ignitions during such extreme wind events. And, of course, the addition of 300,000 more people every year in the state increases the probability of such an ignition event; moreover, urban sprawl into wildland areas increases the probability of losses of lives and property. An illustration of this is the 2017 Tubbs Fire that roared through sections of Santa Rosa, Sonoma County (Fig. 10b) causing the deaths of 22 people and destroying more than 5500 structures. Fifty years earlier the Hanly Fire had burned through much of the same landscape during a North wind event (Fig. 10a), yet no one died and only about

a) 1964 Hanly-Fire

b) 2017 Tubbs Fire

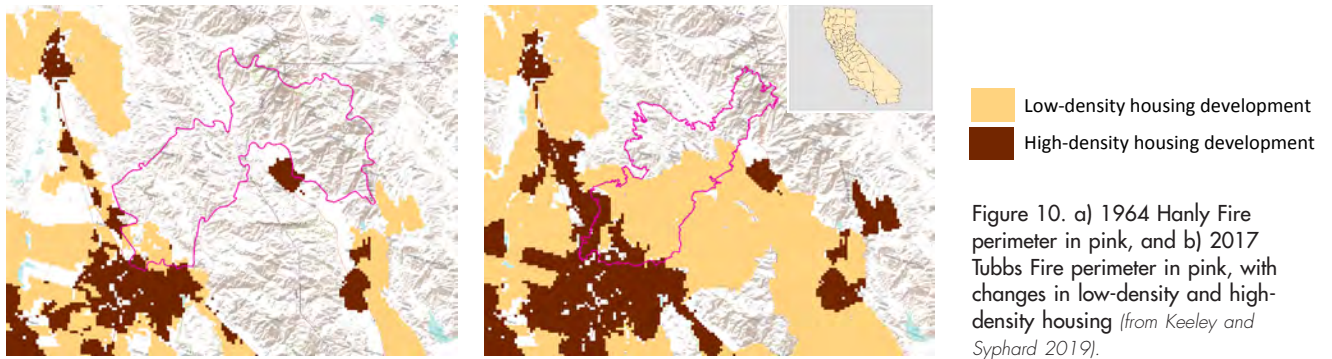


Figure 10. a) 1964 Hanly Fire perimeter in pink, and b) 2017 Tubbs Fire perimeter in pink, with changes in low-density and high-density housing (from Keeley and Syphard 2019).

100 structures were lost. Some researchers have discounted this comparison because the Hanly Fire burned over a longer period of time and therefore it is assumed it was not driven by severe winds. However, that fire burned for a longer duration because it was nearly three times the size of the Tubbs Fire and when it made its run toward Santa Rosa (overlapping with the perimeter of the much later Tubbs Fire) it was driven by extreme dry winds (*The Press Democrat*, September 26, 1964, front page), suggesting fire behavior similar to the 2017 Tubbs Fire. The difference in impact of these two fires is likely due to the fact that during this 50-year period Santa Rosa's population grew from 30,000 to 170,000 people and the urban footprint had expanded such that in 2017 development had expanded so that two-thirds of the area burned by the Tubbs Fire was low-density housing (Fig. 10b). This urban expansion was accompanied by expansion of the electric power grid, increasing the chances of a powerline failure during North wind events that drove both the Hanly and Tubbs fires.

MANAGEMENT CONSIDERATIONS

Fuel-dominated and wind-dominated fires exhibit important differences (Table 1) that inform how to manage these events. First, the fuel-dominated fires are largely forest fires in lightly populated regions such as the Sierra Nevada. In contrast, most wind-dominated fires occur in non-forested ecosystems in the western half of the state, though they may also occasionally occur in more interior sites, such as the 2018 Camp Fire that burned in Paradise. Wind-dominated fires occur in densely populated landscapes, and these fires are responsible for the greatest loss of lives and property.

MANAGEMENT CONSIDERATIONS—FUEL-DOMINATED FIRES

Montane forests have an anomalous accumulation of fuels due to more than a century of fire suppression and

logging and therefore require concerted efforts at reducing the present fuel load (North et al. 2012). In the late 1960s, staff at Sequoia National Park began prescription (Rx) burning and soon after the other national parks in the Sierra Nevada followed suit (Keeley and Syphard 2019). Over time these parks greatly exceeded the area burned by adjacent forests. In recent years the USFS lands have accelerated the amount of Rx burning. However, all Sierra Nevada lands are a long way from burning at a rate sufficient to restore natural historical fire frequencies. There are many limitations, including funding, air quality restrictions, diversion of personnel from Rx burns due to wildfires, among others.

MANAGEMENT CONSIDERATIONS—WIND-DOMINATED FIRES: THE 5 P'S

The distinction between fuel-dominated and wind-dominated fires is similar to the dichotomy between katabatic and non-katabatic wind-driven fires made by Kolden and Abatzoglou (2018). They point out that in Southern California there are summer “fuel-dominated fires” and autumn “wind-dominated fires.” While both types of fires occur in the region, it is the latter type that account for the vast amount of acreage burned, loss of lives and destruction of property. While management needs to be cognizant of both types of fire, it also needs to appreciate that summer fires are the least threatening fires and we should put our greatest effort toward autumn wind-dominated fires. Although all fires are a threat if fuels around homes have not been reduced, there are five points to consider with respect to the catastrophic wind-dominated fires:

- 1) **People:** On these landscapes, fire is more of a people problem than a fuel problem. More people translates into a greater probability of an ignition during a severe wind event, and more development in highly fire-prone landscapes inevitably results in greater losses of lives and homes.

- 2) **Prevention:** Rather than focusing on fuel treatments the scientific evidence clearly points to a need for a much greater emphasis on fire prevention. Although progress has been made in reducing the number of fires, the area burned has increased (Keeley and Syphard 2018). Powerline failures are a major cause of large fires and solutions to this increasing threat remain elusive. As widely reported in the media, three major utility companies in the state have implemented plans to monitor winds and shut down the power grid during extreme wind events. Such so-called Public Safety Power Shutoffs (PSPS) have the potential to decrease fire starts and limit damage (and, as a by-product, raise public awareness of fire threats). But there are many accompanying problems, as became evident during the recent Kincade Fire (Table 1) in October 2019, which was started by an electric failure, despite widespread power outages at the time. Such shutdowns impacted a multitude of vital services, including medical equipment, water pumps, traffic signals, communication equipment etc. One solution might be undergrounding the power lines in areas known to be corridors for extreme winds (Keeley et al. 2009). However, this would be much more expensive for the utilities to install and maintain. In addition, in areas where sensitive natural resources are present, overhead power lines may be less destructive. Nonetheless, San Diego Gas & Electric, which has led the way with responding to powerline-ignited wildfires, reports that 60 percent of its distribution lines are currently underground (Joe Vaccaro, Fire Mitigation & Climate Adaptation Manager, San Diego Gas & Electric Company, personal communication, 5 Dec 2019).
- 3) **Planning:** Community planning needs to devote similar attention and resources to fire as to other hazards. Since we have limited ability to control earthquakes and floods, some urban planners have utilized zoning restrictions to reduce impacts of these hazards. Yet, zoning restrictions are largely lacking when it comes to fire hazards, in large part because fires have been perceived as controllable. However it is increasingly obvious that this is not always the case and many communities are currently very vulnerable. Fire zoning (Kennedy 2006) needs to be given more consideration as well as urban planning that insures adequate ingress for fire fighters and egress for residents during extreme fire events. Perhaps replacing community planning with a more regional approach might contribute to these efforts.
- 4) **Protection:** High-intensity fires generally do not directly ignite homes when separated from vegetation by 30 meters (Cohen 2000). Home ignitions are usually the result of embers blown onto the structure, and this is particularly true under extreme wind conditions. Ember-cast firebrands often travel over a distance of half a mile or more. Embers ignite only under specific circumstances and this is most likely when they land on dead fuels (Zhou et al. 2019). Homeowners can diminish the probability of damage by addressing those factors that affect embers igniting their home, such as reducing plant litter on roofs and gutters, enclosing eaves so that vent orientation is less susceptible to ember entry, closing open eaves, placing fine-mesh screens on vents, and installing double-pane windows and appropriate siding (Syphard and Keeley 2019). Well-watered trees with significant foliage can provide protection from ember cast onto a home (Keeley and Syphard 2019). In fact, watered trees with green foliage may not be susceptible to ignitions by embers, but rather could serve to extinguish them and deprive them of dry fuels. While the notion of trees as “ember catchers” is appealing, it is a largely untested idea.
- 5) **Prediction:** There is an urgent need for improved meteorological and fire behavior models that can provide real-time prediction of wind patterns and

Rooftop sprinklers may provide an added measure of protection and may be justified by the observation that trees adjacent to destroyed homes often survive because their foliage is moist, whereas combustible materials in homes represent dead fuels that are likely at equilibrium with ambient relative humidity of 10 percent or less. However, such sprinklers would need to address a number of issues. For example, metropolitan water lines and water supplies are sometimes compromised during fire events and thus there would need to be a stand-alone water tank. Also, shutting down the power grid is happening more often and thus solar or other alternative power would need to be available to pump water. In addition, there is the need for further research on how to engineer such a system in order to prevent the water spray from being dissipated to the atmosphere due to the high winds. Incorporating a system like this would likely be a significant expenditure that may not be possible for many home owners.

Fuel treatment around homes is critical but needs to be focused on the “house out,” i.e., putting the greatest effort into the area nearest the home and less as one moves further into the wildlands. Reducing fuels within 30 meters of the house is generally sufficient and further clearance beyond that is of doubtful value (Syphard et al. 2012).

fire spread during these extreme events, coupled with improvements in communication systems for providing that information to agencies and homeowners.

Acknowledgments

We thank Marti Witter and David Loeb for very constructive suggestions on this manuscript and Anne Pfaff for preparing the fire history maps. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

—Jon E. Keeley, PhD. U.S. Geological Survey,
Western Ecological Research Center, Sequoia-Kings
Canyon Field Station; Department of Ecology and
Evolutionary Biology, University of California.
Email: jon_keeley@usgs.gov

—Alexandra D. Syphard, PhD. Sage Underwriters,
10423 Sierra Vista Avenue, La Mesa, CA 91941 USA;
Conservation Biology Institute,
136 SW Washington Ave, Corvallis, OR, 97333

REFERENCES

- Abatzoglou J. T., and A. P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proceedings of the National Academy of Sciences* 113: 11770-11775.
- Birnbaum, E. 2018. California governor on wildfires: 'This is the new abnormal.' The Hill 11/11/18, <https://thehill.com/homenews/state-watch/416167-california-governor-on-wildfires-this-is-the-new-abnormal>.
- Castro, J.A. 2012. What does 'Study the past if you define the future' mean? http://wiki.answers.com/Q/What_does_'Study_the_past_if_you_would_define_the_future'_mean
- Clements, C.B., N.P. Lareau, D.E. Kingsmill, C.L. Bowers, C.P. Camacho, R. Bagley, and B. Davis. 2018. The rapid deployments to wildfires experiment (RaDFIRE): Observations from the fire zone. *Bulletin of the American Meteorological Society* <https://doi.org/10.1175/BAMS-D-17-0230.1>.
- Cranley, E. 2018. Trump continues to blame fires on forest mismanagement even while traveling to California. *Business Insider* 11/17/18, <https://www.businessinsider.com/trump-continues-to-blame-wildfires-on-forest-mismanagement-2018-11>.
- Deser, C., A. Phillips, V. Bourdette, and H. Teng. 2012. Uncertainty in climate change projections: the role of internal variability. *Climate Dynamics* 38: 527-546.
- Jacobsen, A. L., and R. B. Pratt. 2018. Extensive drought-associated plant mortality as an agent of type-conversion in chaparral shrublands. *New Phytologist* 219: 498-504.
- Jin Y, J. T. Randerson, N. Faivre, S. Capps, A. Hall, and M. L. Goulden. 2014. Contrasting controls on wildland fires in Southern California during periods with and without Santa Ana winds. *Journal of Geophysical Research, Biogeosciences* 119: doi:10.1002/2013/JG002541.
- Keeley, J. E., H. Safford, C. J. Fotheringham, J. Franklin, and M. Moritz. 2009. The 2007 southern California wildfires: Lessons in complexity. *Journal of Forestry* 107: 287-296.
- Keeley, J. E., and A. D. Syphard. 2017. Different historical fire-climate relationships in California. *International Journal of Wildland Fire* 26: 253-268.
- Keeley, J. E., and A. D. Syphard. 2018. Historical patterns of wildfire ignition sources in California ecosystems. *International Journal of Wildland Fire* 27: 781-799.
- Keeley, J. E., and S. D. Syphard. 2019. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* 15: 24 doi.org/10.1186/s42408-019-0041-0.
- Keifer, M. B. 2006. Long-term surface fuel accumulation in burned and unburned mixed-conifer forests of the Central and Southern Sierra Nevada, CA (USA). *Fire Ecology* 2: 53-72.
- Kennedy, R. G. 2006. *Wildfire and Americans. How to save lives, property, and your tax dollars.* Hill and Wang, New York.
- Kolden, C. A., and J. T. Abatzoglou. 2018. Spatial distribution of wildfires ignited under katabatic versus non-katabatic winds in Mediterranean Southern California USA. *Fire* 1:19, doi: 10.3390/fire1020019.
- McKelvey, K.S. and K.K. Busse. 1996. Twentieth-century fire patterns on forest service lands. In *Sierra Nevada Ecosystem Project: Final report to Congress, vol II, Centers for Water and Wildland Resources, University of California, Davis*, pp1119-1138.
- North, M., B. M. Collins, and S. Stephens. 2012. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110: 392-401.
- Office of Governor 2019. Governor Newsom signs bills to enhance wildfire mitigation, preparedness and response efforts. 10/2/2019, <https://www.gov.ca.gov/2019/10/02/governor-newsom-signs-bills-to-enhance-wildfire-mitigation-preparedness-and-response-efforts/>
- Park, I. W., J. Hooper, J. M. Flegal, and G. D. Jenerette. 2018. Impacts of climate disturbance and topography on distribution of herbaceous cover in Southern California chaparral: insights from a remote-sensing method. *Diversity and Distributions* 24: 497-508.
- Penn, I., P. Eavis, and J. Glanz. 2019. How PG&E ignore fire risks in favor of profits. *New York Times* 03/18/2019, <https://www.nytimes.com/interactive/2019/03/18/business/pg-e-california-wildfires.html>
- Rolinski, T., S. B. Capps, R. G. Fovell, Y. Cao, B. J. D'Agostino, and S. Vanderburg. 2016. The Santa Ana wildfire threat index: Methodology and operational implementation. *Weather and Forecasting* 31: 1881-1897.
- Rolinski, T., S. B. Capps, and W. Zhuang. 2019. Santa Ana Winds: A descriptive climatology. *Weather and Forecasting* 34: 257-275.
- Stephens, S. L., B. M. Collins, C. J. Fettig, M. A. Finney, C. M. Hoffman, E. E. Knapp, M. P. North, H. Safford, and R. B. Wayman. 2018. Drought, tree mortality, and wildfire in forests adapted to frequent fire. *BioScience* 68: 77-88.
- Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2018a. Chaparral landscape conversion in Southern California, pp. 311-334. In E. C. Underwood, H. D. Safford, J. E. Keeley, N. Molinari, and J. J. Hooper (eds), *Valuing Chaparral. Ecological, Socio-Economic, and Management Perspectives*. Springer, New York.
- Syphard, A. D., T. Sheehan, H. Rustigian-Romsos, K. Ferschweiler. 2018b. Mapping future fire probability under climate change: Does vegetation matter? *PLOS ONE* 10.1371/journal.pone.0201680.
- Westerling, A. L. 2018. Wildfire simulations for California's fourth climate change assessment: projecting changes in extreme wildfire events with a warming climate. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CCCA4-CED-2018-014.
- Williams, A. P., R. Seager, J. T. Abatzoglou, B. I. Cook, J. E. Smardon, and E. R. Cook. 2015. Contribution of anthropogenic warming to California drought during 2012-2014. *Geophysical Research Letters* 10.1002/2015GL064924.
- Williams, A. P., J. T. Abatzoglou, A. Gershunov, J. Guzman-Morales, D. A. Bishop, J. K. Balch, and D. P. Lettenmaler. 2019. Observed impacts of anthropogenic climate change on wildfire in California. *Earth's Future* 7: 892-910.



WHY ARE SO MANY STRUCTURES BURNING IN CALIFORNIA?

Alexandra D. Syphard and Jon E. Keeley

California has earned a reputation for wildfires that inflict serious damage on human infrastructure, dating back to images of Richard Nixon hosing down the roof of his house in the 1961 Bel-Air fire, and of the famous “fireproof” home of grocery store entrepreneur Fred Roberts burning to the ground in 1982. In recent years, this notoriety has been transformed into public alarm, reflected in the apocalyptic headlines of recent newspaper articles suggesting the “end of California” (*New York Times*, 30 October 2019) and that “California is becoming unlivable” (*The Atlantic*, 30 October 2019). Now the phrase “the new normal” has worked its way into the lexicon, sustained by record-breaking structure loss numbers in 2017 and 2018 despite significantly lower structure losses in 2019.

It remains to be seen whether or not those two recent years were back-to-back, once in a century events, or if the trend has crossed some kind of tipping point,

but data does show a long-term trend of significant increase in structures lost to wildfires since the beginning of the 20th century (Fig. 1). What was an average of ~500 homes lost per year in Southern California from about 1950–2000 (Cal Fire 2000) has recently climbed to ~2700 structures per year statewide from 2000–2018 (Syphard and Keeley 2019). California is not alone in the U.S., or in the world, in suffering increasing impacts from wildfires (e.g., Blanchi et al. 2012, Haynes 2015, Viegas 2018). Impacts so far in the recent Australian bushfire season have been record-breaking, with several thousand structures lost, more than 25 fatalities, and unthinkable losses to wildlife. The question that follows, then, is why?

Although trends vary from region to region, one clear reason for increasing wildfire-related losses is

Above: A home burned by the Thomas Fire in 2017.
[Photograph by Master Sgt. Brian Ferguson/U.S. Air Force]

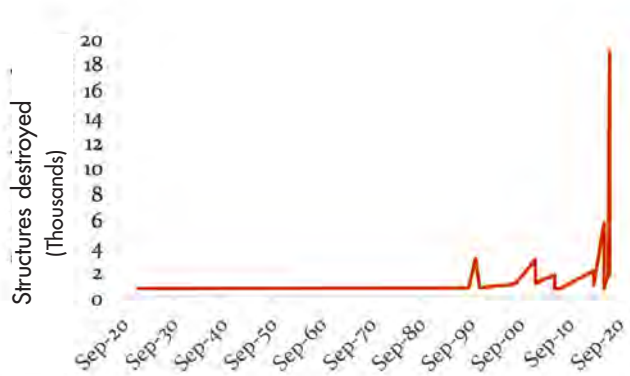


Figure 1. Annual number of structures destroyed in wildfires in California from 1920 to 2018. [Source: California Department of Forestry & Fire Protection]

the overall increase in wildfire activity. Although, counter to intuition, the number of wildfires has declined in the last several decades, area burned has either remained constant or increased, with substantially higher frequency of large wildfires (Keeley and Syphard 2018)(Discussed further in Keeley and Syphard, pg. 4 of this issue.) Perhaps an even stronger explanation for increased wildfire-related structure loss is the rapid development of the wildland–urban interface (WUI), which not only exposes more structures to wildland fire, but also increases the likelihood for more human-ignited fires (Radeloff et al. 2018). Despite these trends, however, not all fires result in structure loss, and not all structures are impacted by wildfires they are exposed to. Thus, it is essential to study the factors that are most strongly related to structure exposure and resilience to wildfire, which could then lead to better adaptation and coexistence with wildfire in this era of the “new normal.”

In response to this need, a growing number of scientists are conducting empirical research studies to answer the question of why some structures are lost in wildfires and others aren’t. Results so far show that the answer to that question is complicated. That is, structure loss results from the confluence of multiple interacting factors across different temporal and spatial scales, which all vary by ecosystem. Given this complexity, misunderstandings and disagreements have arisen over the cause and direction of trends in wildfire activity (Doerr and Santín 2016), fire risk and structure loss (McCaffrey et al. 2019), and thus, the most effective approach for prioritizing fire management decisions (Moritz et al. 2014). In fact, management techniques appropriate for one region are commonly applied inappropriately to other regions (Noss et al. 2006).

One way that this conflict over priorities can be reduced is through better information and under-

standing of the similarities and differences that contribute to structure loss among wildfire ecoregions. As data accumulate about the range of conditions under which losses occur, it will be increasingly possible to sort out which risk management techniques are most appropriate for different regions. Wildfire structure losses in the last several decades have already provided a wealth of data for studies comparing factors associated with structures that survived or were destroyed. Most of this work has been done in California (Maranghides and Mell 2009, Syphard et al. 2012a, 2014, 2017, 2019c, Miner 2014, Alexandre et al. 2015, Kramer et al. 2019, Syphard and Keeley 2019) and Australia (Leonard 2009, Blanchi et al. 2010, 2012, Gibbons et al. 2012, 2018, Price and Bradstock 2013, Penman et al. 2019); but some work has also been done in other parts of the continental United States (Alexandre et al. 2016, Kramer et al. 2019).

Combined, the results of this research show clear roles for both local, house-level factors (e.g., structural characteristics of a particular house and property-level landscaping) and broader, landscape-level factors (e.g., housing pattern and location, topography, fuel, and fire characteristics) in explaining why some structures survive wildfires and others don’t. This is consistent with the natural hazards literature that theoretically places vulnerability within the intersection of “exposure,” that is, potential contact with a hazard; and “sensitivity,” or the degree to which the hazard can cause harm (Birkmann 2006). Vulnerability to wildfire is a combination of exposure and sensitivity such that vulnerability results in loss when sensitive characteristics of structures are exposed to hazard events (e.g., the wildfire) (Cutter 1996, Schumann et al. 2019). Thus, exposure is the part of vulnerability related to characteristics of a location, and sensitivity is the risk of loss due to intrinsic physical or social characteristics.

EXPOSURE

Coincidence of fires and houses

A structure’s wildfire hazard exposure ultimately lies at the spatial intersection of a wildfire event and the location of the property. The probability of structure loss thus depends on the relative likelihood that a fire ignition results in a fire within the geographical range of structures in the WUI. In turn, this depends on the location and timing of a fire ignition, which varies depending on cause and biophysical characteristics (Syphard and Keeley 2015) relative to other determinants of fire size, including topographic con-



Most homes don't burn from direct contact with flame. Here, a wind-driven fire carried embers over cement and ice plant to the house, reinforcing the importance of reducing the flammability of the home—focusing fire risk reduction from the “house outward.” [Photograph by Rick Halsey]

ditions; fuel amount, moisture, and spatial continuity; and weather (Faivre et al. 2016). Large fires tend to be either primarily fuel-dominated or wind-dominated (Keeley and Syphard 2019), with most damage and economic loss occurring from wind-driven fire events (Jin et al. 2015, Keeley and Syphard this issue).

Large fire probability increases with the co-occurrence of human-caused ignitions and severe wind conditions (Abatzoglou et al. 2018). This means that, as population increases and development further encroaches into wildland vegetation, there is an increased risk that a human-caused ignition will coincide in place and time with hot, dry weather; flammable vegetation; and severe wind conditions. Data show that fires tend to be most frequent at low to intermediate housing and population densities (Syphard et al. 2009, Bistinas et al. 2013). Thus, the rapid increase in the spread of exurban development like that occurring now in California (Radeloff et al. 2018), has the potential to both increase the number of ignitions and decrease the overall distance between wildlands and housing.

As the distance between wildland vegetation and housing development decreases across a landscape, the overall exposure of houses to wildfire increases. This helps to explain research that shows the arrangement and location of housing development to be a top-ranked predictor of whether a structure survives or is destroyed by wildfire (e.g., Syphard et al. 2012b, Alexandre et al. 2016, Kramer et al. 2019). In terms of arrangement, data consistently shows that loss to wild-

fire is highest at relatively low housing density (Kramer et al. 2018, Syphard et al. 2019c) and at the interface between wildlands and development (Kramer et al. 2019), regardless of the geographic region in which a structure is located.

Other housing patterns, such as the way housing is dispersed, or the size of housing clusters, are also influential, although their relative importance in explaining structure loss varies from region to region (Alexandre et al. 2015, 2016). Topography is an additional exposure-related factor significantly related to structure loss, as fire tends to

spread quickly upslope, meaning that houses on ridgetops are particularly vulnerable. An important caveat to the relationship between low structure density and structure loss is that, once a fire reaches a development, structure-to-structure spread is possible if adjacent houses are highly flammable and spaced within at least 50 meters of one another (Price and Bradstock (2013). In these circumstances, high housing density can be a significant risk factor (Maranghides and Mell 2009).

Fire patterns, altered fire regimes, and vegetation management

In addition to housing arrangement, housing location affects the potential exposure of a structure to wildfire because some areas are inherently more fire-prone than others (Syphard et al. 2012b). Certain parts of the landscape tend to burn repeatedly while others do not, and this reflects the wide variation in fire regimes across California (Syphard and Keeley in press). During the last century, fire regimes in California have been altered due to a range of factors including climate change, land use change, and legacies of fire management. However, the cause of fire regime changes, and their relative effects, have been nearly opposite in the northern and southern coastal parts of the state (Safford and Water 2014). As described in Keeley and Syphard (this issue), a history of successful fire exclusion in dry, mixed-conifer forests contributed to an alteration of what had been a low-intensity surface fire regime that typically burned back the understory plants without reaching into the canopy and burning

the large trees. The subsequent increase in the density of surface litter and the unchecked ingrowth of young trees that serve as ladder fuels now facilitate uncharacteristically severe crown fires. In contrast, in the native shrublands of southern and central coastal California, increased human-caused ignitions have resulted in unnaturally high fire frequency, with increases in wildfire further promoted by ongoing conversion of shrublands to more flammable invasive grasses (Fusco et al. 2019, Syphard et al. 2019b, 2019a).

These differences in the two fire regimes, and how they have been altered, have led to substantial controversy regarding wildfire exposure and the effects and effectiveness of vegetation management (Keeley et al. 2009, Halsey and Syphard 2015). In both northern and southern California, changes in fire regimes could lead to more dangerous or frequent wildfires, thereby increasing structure exposure to hazard. Mechanical treatments and prescribed fire in dry, mixed-conifer forests that reduce the understory and decrease small diameter tree density may help return these forests to a more resilient condition, and thereby potentially reduce exposure of structures to high fire hazard (Knapp et al. 2017).

On the other hand, in the non-forested landscapes that dominate the coastal central and southern parts of the state, vegetation management is primarily focused on reducing the extent of woody vegetation. That is, mechanical treatments are typically designed to remove and reduce the cover of native shrublands and increase the cover of herbaceous vegetation. Prescribed fire in this region *increases* the amount of uncharacteristically frequent fire, putting additional stress on native chaparral and shrublands. Therefore, in non-forested ecosystems vegetation management is inconsistent with ecological integrity and, in addition, has minimal efficacy in the wind-driven fires that result in the most structure loss (Keeley and Syphard this issue).

Access as a risk factor

While vegetation management may control fire behavior by slowing wildfire spread, wildfires during extreme wind conditions typically generate embers and burning debris that can fly kilometers ahead of the fire front. Therefore, fuels management in remote

landscapes, even if it does alter fire behavior, has little possibility of preventing wind-driven fires from spreading and expanding if there are no firefighters present to control the fire. This is the likely explanation for why Penman et al. (2014) found that fire size and exposure of property to wildfire in Southern California are primarily controlled by fire weather and characteristics of the built environment, with fuel treatments or fuel load management having minimal influence. Fuel load is less likely to be limiting during wind-driven wildfires and reduction of fuel load in remote areas is unlikely to affect fire outcomes (Keeley et al. 2004, Schoennagel et al. 2004).

On the other hand, strategic placement of fuel breaks near communities may be more effective at reducing exposure because firefighters can use these for safe access to perform suppression activities (Syphard et al. 2011). In addition to strategically placed fuel breaks near communities, the road network surrounding a structure is also important for minimizing exposure from an access perspective. Wide roads and multiple access points can facilitate the transport of firefighting resources to properties within a community; in addition, a good road network provides faster and more efficient evacuation alternatives (Mangan 2000).

SENSITIVITY

Community sensitivity to wildfire, and the capacity to recover from wildfire losses, is related to the social and demographic characteristics of a region (Schumann et al. 2019). In terms of the physical nature of structure loss, however, the primary determinants of sensitivity include defensible space and home structure characteristics as well as firefighter accessibility.

Defensible space

There is certainly a degree of confusion regarding defensible space. A common sentiment is that the larger the defensible space, the better protected the home.

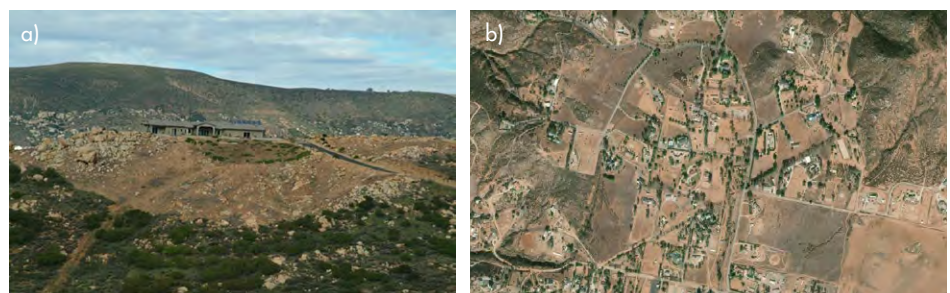


Figure 3. Local (a) and landscape-scale (b) examples of defensible space being performed beyond legal requirements or scientific evidence for protection. [Images courtesy of Alexandra Syphard]

Thus, clearance far in excess of legal requirements is increasingly being carried out (Fig. 3a), sometimes at a broad scale (Fig 3b). This is not necessarily helpful or effective. At the same time, many homeowners fail to create sufficient defensible space to improve structure survival.

What does the evidence show about the effectiveness of defensible space? The state of California requires homeowners in state-defined hazardous areas to provide 30 meters (100 feet) of defensible space around their home, which involves the maintenance of specific horizontal and vertical distances of spacing between patches of woody vegetation. Empirical studies in two Southern California areas found that defensible space of approximately 5-20 meters (16-66 feet) provided significant protection, with additional distance providing little or no significant benefit, even on steep slopes (Miner 2014, Syphard et al. 2014). Empirical research looking at structure loss in Australia also found that vegetation reduction and defensible space were most effective at close proximity to the structure (Gibbons et al. 2012, Penman et al. 2019), and that regular irrigation and proper spacing could be as just as effective as clearing woody vegetation (Gibbons et al. 2018).

The largest empirical study of home survival published to date, which included more than 40,000 structures subjected to wildfires over a five year period (Syphard and Keeley 2019), showed that defensible space distance explained little or none of the variance in structure survival. Instead, characteristics of the structure itself were far more significant (Fig. 4). These results should not be interpreted to mean defensible space is not important. But they do suggest that the

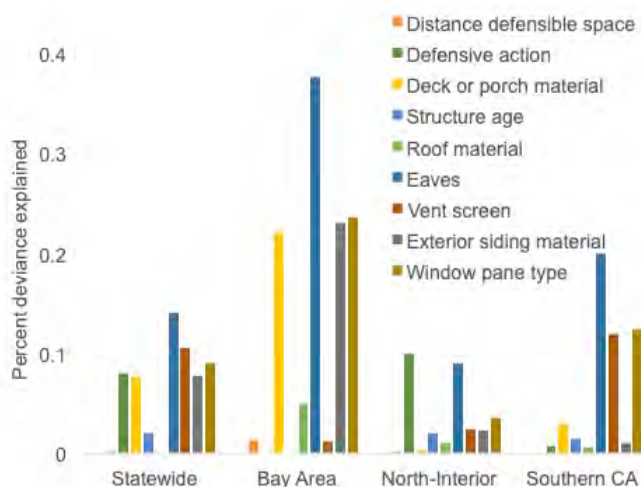


Figure 4. Relative importance (percent deviance explained) of defensible space distance and structural characteristics explaining structure loss to California wildfires from 2013–2018 for the entire state and broken into three broad regions. [Figure modified from Syphard and Keeley 2019]



Figure 5. Image of flammable debris on a roof that could ignite from wind-blown embers, reflecting how vegetation near or overhanging structures could increase the likelihood of structure loss.

most important component of defensible space may be the characteristics of vegetation closest to the house. For example, vegetation touching the structure and trees overhanging the roof were highly significant in the two empirical examples from Southern California.

Ember cast

It needs to be appreciated that, particularly during extreme wind-driven fires, most homes do not burn from direct flame contact, but rather from embers blown from the fire front, even from a kilometer or more away. Thus, the material that embers land on, be it vegetation or the structure itself, is key to whether the structure ignites or not. In some cases, the effect of overhanging trees or nearby vegetation is mostly related to the dead plant material or debris that is close to the structure (Fig.5). Likewise, many of the structural characteristics found to be most important in this recent study (Syphard and Keeley 2019) were related to the prevention of ember penetration, such as vent screens and eaves. Open eaves (Fig. 6a) are much more vulnerable to fires than closed eaves (Fig. 6b). Open eaves have vents that are arranged perpendicular to the ground and thus in direct line of oncoming wind-driven ember cast. Closed eaves have vents facing down towards the ground and perhaps less prone to embers entering the vents.

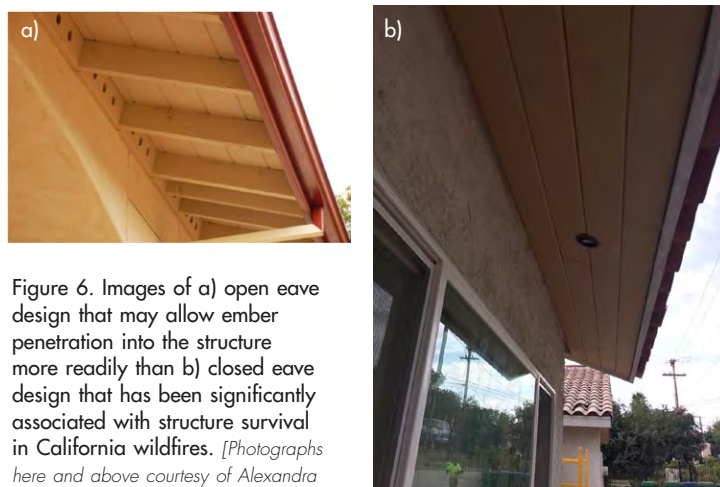


Figure 6. Images of a) open eave design that may allow ember penetration into the structure more readily than b) closed eave design that has been significantly associated with structure survival in California wildfires. [Photographs here and above courtesy of Alexandra Syphard and Jon Keeley]

CONCLUSION

The studies described above illustrate that some structures are destroyed in wildfires and others are not because of multiple, often interacting, factors that variably influence the exposure and sensitivity of a property to wildfire. In an ideal world, strategies to increase community resilience to wildfire would be ranked and prioritized according to their relative potential for success in preventing structure loss in any given ecosystem. Of course, an ideal world would also not have to account for factors such as cost, effort, and feasibility, which add to the complexity of decision-making in the real world.

While most empirical research on structure loss has so far focused on either exposure or sensitivity factors independently, an integrated analysis in Southern California provided a comparison of the relative importance of different exposure-related and sensitivity-related variables (Syphard et al. 2017, Fig. 7) in distinguishing destroyed from surviving structures. Study results suggested that exposure (when measured by structure density) was the most important factor overall that distinguished destroyed from surviving structures. The relative importance of different sensitivity variables (e.g., structure age or landscaping characteristics) varied depending upon whether the structure was highly exposed (i.e., at low housing density) or less exposed (i.e., at high housing density) (Fig. 7).

These results suggest that, in an ideal world, the most effective strategy at reducing future structure loss would focus on reducing the extent of low-density housing via careful land planning decisions. This conclusion is rather obvious given that reducing exposure reduces the chance that a wildfire could reach a structure in the first place. In the real world, regardless of land use planning decisions for future development, there is extensive existing development that may be exposed to future wildfires. Therefore, strategies like ignition prevention and strategic vegetation management could potentially reduce the exposure of these houses by focusing on the initiation or spread of the wildfire.

Once a fire reaches a property, structure sensitivity then becomes the key determinant for survival. In many areas, effective efforts to minimize sensitivity to wildfire include education and increased awareness of appropriate defensible space practices, development of Firewise Communities (Jakes et al. 2007), and improvement in building codes. Nonetheless, some communities underinvest in defensible space (Taylor

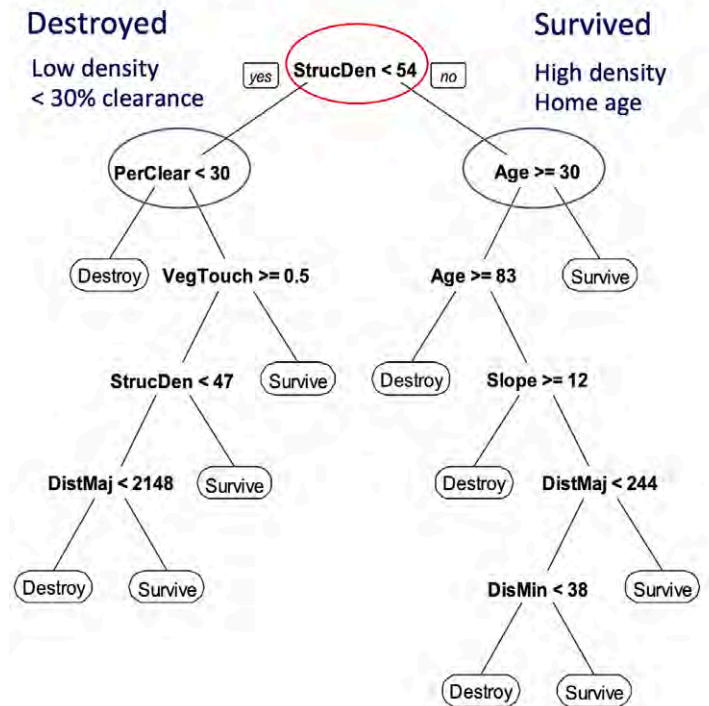


Figure 7. Classification tree showing the hierarchy of factors that best distinguished destroyed from survived structures in Southern California wildfires. Abbreviations are: StrucDen = structure density; PerClear = percentage woody vegetation clearance on property; Age = age of structure; VegTouch = number of sides of structure with vegetation touching; Slope = percentage slope on property; DistMaj = distance in meters to a major road; DisMin = distance in meters to a minor road. Modified from Syphard et al. 2017.

et al. 2019), while in others, homeowners create excessive clearance (Fig. 3) that may increase the extent of invasive grass on the property. Conversion of native woody vegetation into grass in the non-forested landscapes of Southern California, for example, could increase the flammability of the property (Fusco et al. 2019), particularly if the grass is not irrigated regularly (Gibbons et al. 2018).

Given the importance of structural characteristics in home survival in recent California wildfires (Syphard and Keeley 2019), the improvement of building codes has been a positive development overall. However, there is already extensive existing residential development in fire-prone areas that was built prior to the adoption of new building codes. Reducing the fire sensitivity of these homes generally entails retrofits and modifications, which can be expensive (Quarles and Pohl 2018). However, some of the most effective actions, such as eave coverings and vent screens, are generally less expensive than replacing roofing or exterior siding, although window replacement can also be expensive (Quarles and Pohl 2018).



The 2017 Thomas Fire. [Photograph courtesy of Stuart Palley/
U.S. Forest Service]

It would appear, given recent improvements in adapting structures to withstand fire, that the increase in the numbers of houses burned in wildfire is not a matter of increased sensitivity. Instead, the answer lies somewhere in the combination of factors that govern exposure, including changes to wildfire behavior and activity, as well as exurban development that places structures in the path of these wildfires. Climate and vegetation change may increase the probability of large wildfires in some regions, such as the northern parts of California (Syphard et al. 2019c); but in other regions, like Southern California, climate change is likely to manifest differently, most likely indirectly, via factors such as long-term drought and vegetation change.

While the effects of climate change on wildfire vary from region to region, housing pattern variables have consistently been the most important factors explaining structure loss across California and elsewhere. This suggests that much of the increase in structure loss in California may be attributable to increases in this type of exposure—and that planning decisions could have broad-scale benefits in the future. Also consistent across regions is the potential for homeowner mitigation measures to provide significant improvement in structure survival probability. Those measures that focus on reduction of ember impact and penetration are most important.

Despite these overall consistencies, there is variation in the nature and strength of relationships in all of these factors. Wildfire frequency and behavior, and fuel characteristics, vary widely by ecosystem; thus, vegetation management efforts differ greatly in effects and effectiveness and should be implemented appropriately. Regardless of regional variations, everyone, from the individual homeowner, to local planning and permitting officials, to state and federal government

authorities, will need to be involved in instituting preventive measures. Management appropriately informed by science and data analysis can reduce future structure losses and minimize ecological impacts to assure a more sustainable future. While these efforts may seem expensive in the present, it is much less expensive than paying for losses in the future.

—Alexandra D. Syphard, PhD. Sage Underwriters,
10423 Sierra Vista Avenue, La Mesa, CA 91941 USA;
Conservation Biology Institute, 136 SW Washington Ave,
Corvallis, OR, 97333

—Jon E. Keeley, PhD. U.S. Geological Survey, Western
Ecological Research Center, Sequoia-Kings Canyon Field
Station; Department of Ecology and Evolutionary Biology,
University of California. Email: jon_keeley@usgs.gov

REFERENCES

- Abatzoglou, J. T., J. K. Balch, B. A. Bradley, and C. A. Kolden. 2018. Human-related ignitions concurrent with high winds promote large wildfires across the USA. *International Journal of Wildland Fire* 27:377–386.
- Alexandre, P. M., S. I. Stewart, N. S. Keuler, M. K. Clayton, M. H. Mockrin, A. Bar-Massada, A. D. Syphard, and V. C. Radeloff. 2016. Factors related to building loss due to wildfires in the conterminous United States. *Ecological Applications* 26.
- Alexandre, P. M., S. I. Stewart, M. H. Mockrin, N. S. Keuler, A. D. Syphard, A. Bar-Massada, M. K. Clayton, and V. C. Radeloff. 2015. The relative impacts of vegetation, topography and spatial arrangement on building loss to wildfires in case studies of California and Colorado. *Landscape Ecology* 31:415–430.
- Birkmann, J. 2006. Measuring vulnerability to natural hazards: towards disaster resilient societies. United Nations University Press, Tokyo.
- Bistinas, I., D. Oom, A. C. L. Sá, S. P. Harrison, I. C. Prentice, and J. M. C. Pereira. 2013. Relationships between human population density and burned area at continental and global scales. *PLOS ONE* 8:e81188.
- Blanchi, R., J. Leonard, K. Haynes, K. Opie, M. James, M. Kilinc, F. D. De Oliveira, and R. Van den Honert. 2012. Life and house loss database description and analysis. CSIRO.
- Blanchi, R., C. Lucas, J. Leonard, and K. Finkel. 2010. Meteorological conditions and wildfire-related house loss in Australia. *International Journal of Wildland Fire* 19:914–926.
- Cal Fire. 2000. Wildland Fire Hazard Assessment. California Division of Forestry and Fire Protection, Sacramento, CA.
- Cutter, S. L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20:529–539.
- Doerr, S. H., and C. Santín. 2016. Global trends in wildfire and its impacts: Perceptions versus realities in a changing world. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371.
- Faivre, N. R., Y. Jin, M. L. Goulden, and J. T. Randerson. 2016. Spatial patterns and controls on burned area for two contrasting fire regimes in Southern California. *Ecosphere* 7:e01210.
- Fusco, E. J., J. T. Finn, J. K. Balch, R. C. Nagy, and B. A. Bradley. 2019. Invasive grasses increase fire occurrence and frequency across US ecoregions. *Proceedings of the National Academy of Sciences*: 1–6.
- Gibbons, P., L. van Bommel, A. Gill, G. J. Cary, D. A. Driscoll, R. A. Bradstock, E. Knight, M. A. Moritz, S. L. Stephens, and D. B. Lindenmayer. 2012. Land management practices associated with house loss in wildfires. *PLOS ONE* 7:e29212.

- Gibbons, P., A. M. Gill, N. Shore, M. A. Moritz, S. Dovers, and G. J. Cary. 2018. Options for reducing house-losses during wildfires without clearing trees and shrubs. *Landscape and urban planning* 174:10–17.
- Halsey, R. W., and A. D. Syphard. 2015. High-Severity Fire in Chaparral: Cognitive Dissonance in the Shrublands. The Ecological Importance of Mixed-Severity Fires: Nature's Phoenix.
- Haynes, H. J. G. 2015. *Fire loss in the United States during 2014*. National Fire Protection Association, Fire Analysis and Research Division.
- Jakes, P., L. Kruger, M. Monroe, K. Nelson, and V. Sturtevant. 2007. Improving wildfire preparedness: lessons from communities across the US. *Human Ecology Review*:188–197.
- Jin, Y., M. Goulden, S. Faivre, V. Veraverbeke, A. Hall, M. Hand, S. Hook, and J. Randerson. 2015. Identification of two distinct fire regimes in southern California: implications for economic impact and future change. *Environmental Research Letters* 10:094005.
- Keeley, J. E., C. J. Fotheringham, and M. A. Moritz. 2004. Lessons from the October 2003 Wildfires in Southern California. *Journal of Forestry* 102: 26–31.
- Keeley, J. E., H. D. Safford, C. J. Fotheringham, J. Franklin, and M. A. Moritz. 2009. The 2007 southern California wildfires: Lessons in complexity. *Journal of Forestry* 107:287–296.
- Keeley, J. E., and A. D. Syphard. 2018. Historical patterns of wildfire ignition sources in California ecosystems. *International Journal of Wildland Fire* 27:781–799.
- Keeley, J. E., and A. D. Syphard. 2019. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* 15:24.
- Knapp, E. E., J. M. Lydersen, M. P. North, and B. M. Collins. 2017. Efficacy of variable density thinning and prescribed fire for restoring forest heterogeneity to mixed-conifer forest in the central Sierra Nevada, CA. *Forest Ecology and Management* 406:228–241.
- Kramer, H. A., M. H. Mockrin, P. M. Alexandre, and V. C. Radeloff. 2019. High wildfire damage in interface communities in California. *International Journal of Wildland Fire* 28:641.
- Kramer, H. A., M. H. Mockrin, P. M. Alexandre, S. I. Stewart, and V. C. Radeloff. 2018. Where wildfires destroy buildings in the US relative to the wildland–urban interface and national fire outreach programs. *International Journal of Wildland Fire* 27:329–341.
- Leonard, J. 2009. Report to the 2009 Victorian Bushfires Royal Commission. Building performance in bushfires. Highett, Victoria, Australia: CSIRO Sustainable Ecosystems.
- Mangan, R. J. 2000. Improving firefighter safety in the wildland-urban intermix. USDA Forest Service, Technology and Development Program.
- Maranghides, A., and W. Mell. 2009. A Case Study of a Community Affected by the Witch and Guejito Fires.
- Mccaffrey, S. M., G. L. Duffner, and L. M. Decker. 2019. Chapter Twenty-Seven. Social Dynamics of Wildland Fire in California. *Fire in California's Ecosystems*: 507–516.
- Miner, A. 2014. Defensible space optimization for preventing wildfire Structure loss in the Santa Monica Mountains. Johns Hopkins University.
- Moritz, M. A., E. Batllori, R. A. Bradstock, A. M. Gill, J. Handmer, P. F. Hessburg, J. Leonard, S. McCaffrey, D. C. Odion, T. Schoennagel, and *Nature* 515 (6):58–66.
- Noss, R. F., J. F. Franklin, W. L. Baker, T. Schoennagel, and P. B. Moyle. 2006. Managing fire-prone forests in the western United States. *Frontiers In Ecology And The Environment* 4:481–487.
- Penman, S. H., O. F. Price, T. D. Penman, and R. A. Bradstock. 2019. The role of defensible space on the likelihood of house impact from wildfires in forested landscapes of south eastern Australia. *International Journal of Wildland Fire* 28:4–14.
- Penman, T. D., L. Collins, A. D. Syphard, J. E. Keeley, and R. A. Bradstock. 2014. Influence of fuels, weather and the built environment on the exposure of property to wildfire. *PLOS ONE* 9(10): e111414.
- Price, O., and R. Bradstock. 2013. Landscape scale influences of forest area and housing density on house loss in the 2009 Victorian bushfires. *PLOS ONE* 8:e73421.
- Quarles, S., and K. Pohl. 2018. Building a Wildfire-Resistant Home: Codes and Costs. Bozeman, MT.
- Radeloff, V. C., D. P. Helmers, H. Anu Kramer, M. H. Mockrin, P. M. Alexandre, A. Bar-Massada, V. Butsic, T. J. Hawbaker, S. Martinuzzi, A. D. Syphard, and S. I. Stewart. 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. *Proceedings of the National Academy of Sciences* 115:3314–3319.
- Safford, H., and K. Van de Water. 2014. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California.
- Schoennagel, T., T. T. Veblen, and W. H. Romme. 2004. The interaction of fire, fuels, and climate across rocky mountain forests. *Bioscience* 54:661–676.
- Schumann, R. L., M. Mockrin, A. D. Syphard, J. Whittaker, O. Price, C. Johnson, C. T. Emrich, and V. Butsic. 2019. International Journal of Disaster Risk Reduction Wildfire recovery as a “hot moment” for creating fire-adapted communities. *International Journal of Disaster Risk Reduction*: 101354.
- Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2014. The role of defensible space for residential structure protection during wildfires. *International Journal of Wildland Fire* 23:1165–1175.
- Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2017. The importance of building construction materials relative to other factors affecting structure survival during wildfire. *International Journal of Disaster Risk Reduction* 21:140–147.
- Syphard, A. D., T. J. Brennan, and J. E. Keeley. 2019a. Extent and drivers of vegetation type conversion in Southern California chaparral. *Ecosphere* 10:e02808.
- Syphard, A. D., T. J. Brennan, J. E. Keeley, and T. Vaclavik. 2019b. Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. *Diversity and Distributions* 10: 90–101.
- Syphard, A. D., and J. E. Keeley. 2015. Location, timing, and extent of wildfire varies by cause of ignition. *International Journal of Wildland Fire* 24:37–47.
- Syphard, A. D., and J. E. Keeley. 2019. Factors associated with structure loss in the 2013 - 2018 California wildfires. *Fire* 2:49.
- Syphard, A. D., J. E. Keeley, and T. J. Brennan. 2011. Comparing the role of fuel breaks across southern California national forests. *Forest Ecology and Management* 261:2038–2048.
- Syphard, A. D., J. E. Keeley, A. B. Massada, T. J. Brennan, and V. C. Radeloff. 2012a. Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLOS ONE* 14(2): e0211454.
- Syphard, A. D., J. E. Keeley, A. B. Massada, T. J. Brennan, and V. C. Radeloff. 2012b. Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLOS ONE* 7:1–13.
- Syphard, A. D., V. C. Radeloff, T. J. Hawbaker, and S. I. Stewart. 2009. Conservation Threats Due to Human-Caused Increases in Fire Frequency in Mediterranean-Climate Ecosystems. *Conservation Biology* 23:758–769.
- Syphard, A. D., H. Rustigian-Romsos, M. Mann, E. Conlisk, M. A. Moritz, and D. Ackerly. 2019c. The relative influence of climate and housing development on current and projected future fire patterns and structure loss across three California landscapes. *Global Environmental Change* 56:41–55.
- Taylor, M. H., L. Christman, and K. Rollins. 2019. Targeting policy to promote defensible space in the wildland-urban interface: evidence from homeowners in Nevada. *Land Economics* 95:531–556.
- Viegas, D. X. 2018. Wildfires in Portugal. *Fire Research*.



WILDFIRES AND FOREST RESILIENCE: THE CASE FOR ECOLOGICAL FORESTRY IN THE SIERRA NEVADA

Rodd Kelsey

INTRODUCTION

Forests of the Sierra Nevada and across the western U.S. are experiencing an unprecedented increase in the size and severity of wildfires,¹⁻⁶ along with widespread tree mortality due to drought and insect outbreaks.⁷⁻⁹ Over the last six years alone, five separate wildfires in the Sierra Nevada have burned 100,000 acres or more with unusually large patches of forest burned at high severity, with greater than 75 percent tree mortality.

Several of these fires behaved in ways unlike any experienced in recorded memory and were uncharacteristic of the way that the forests burned before Euro-American arrival in California. These developments

are detrimental to forest sustainability as the climate continues to warm,¹⁰⁻¹³ not only threatening lives and communities but seriously compromising forest health and resilience, degrading many of the important benefits forests provide to people.

The forested watersheds of the Sierra Nevada provide clean water for over 25 million people¹⁴, support rural economies and tourism¹⁵, and play a critical role in carbon storage and climate control.¹⁶⁻¹⁸ Healthy Sierra forests are also home to abundant and diverse wildlife, with over 500 vertebrate species (24 of which occur nowhere else) and 3,500 plant species (400 of which occur nowhere else).¹⁹

Above: Example of ecological thinning on lands owned by the American River Conservancy. [Photograph by David Edelson/
The Nature Conservancy]

This paper focuses on fire in the forests of the Sierra Nevada. Importantly, the causes and consequences of a changing fire regime vary among the different kinds of ecosystems in California. The now more frequent and devastating fires of coastal and inland shrub communities are driven by different factors and, thus, require different solutions.

We know how to manage forests so that they are less prone to megafires and drought and how to decrease the likelihood of large tree mortality events from insect and disease outbreaks.^{9,10,20,21} Through targeted ecological thinning, prescribed fire, and managed wildfire we can reduce high fuel loads, promote more resilient forests, reduce the risk of large, high-severity wildfires, and protect sensitive species. Unfortunately, the current pace and scale of these activities is inadequate given the widespread scope and long-term consequences of the problem.

An important obstacle to increasing the pace and scale of ecologically sound forest management in the Sierra Nevada is widespread misunderstanding among policy makers and the public of the two important approaches required to restore our forests: thinning trees to reduce fuels and using fire as a natural restorative process. In this article, we explain how our forests became overgrown and at risk from uncharacteristic, high-severity wildfire and tree mortality. Then, we make the scientific case for ecological forestry—a combination of strategic thinning, prescribed fire, and managed wildfire—as the best solution to the challenges our forests face.

A LEGACY OF LOGGING AND FIRE SUPPRESSION HAS CREATED FORESTS PRONE TO SEVERE WILDFIRES

Why do California's fires burn differently than they did 200 years ago? One critical factor is that, despite the large and destructive wildfires of recent years, many of the forests of the Sierra Nevada are fire-starved.

Prior to the 20th century, wildfires roamed over large areas in the Sierra Nevada every year.²²⁻²⁵ These were both naturally caused by lightning and intentionally set by Native Americans for the many benefits fire can create, like regenerating valuable food and textile plants. Prior to European settlement, 400,000 to 500,000 acres burned each year on what are now National Forest lands of the Sierra Nevada.^{3,26}

Most of these fires were of low or moderate severity. (Low severity generally means less than 25 percent tree mortality, while moderate severity refers to a mortality rate of 25-75 percent.) The majority of trees survived them, except for patches that created openings in the forest.^{13,23,27} This patchy mosaic created a wide array of forest conditions, including open, shrubby patches, pocket meadows, and shady stands of large, fire-resistant trees.²⁷⁻³² This maintained the health and resilience of the forest and the biota that depend on it. Frequent

low-to-moderate intensity fires also reduced the likelihood of megafires in some forests, by removing surface fuels and keeping the shrubs and understory trees that fuel intense fires in check.^{27,29-33} The fires also regenerated and increased the variety of understory plants.^{134,135} In contrast, today's high intensity fires tend to favor mostly shrubby species over uncharacteristically large patches, in some cases lowering diversity indefinitely.¹³⁶

California's lack of ecologically appropriate fire is the result of the aggressive elimination of fire, beginning in the mid-19th century when Native American burning was drastically reduced. Widespread fire suppression followed in the 20th century, based on the well-intentioned but now disproved assumption that all fire is bad.^{13,34-38}

Another important contributor, also beginning in the mid-1800s, was logging—specifically, timber management practices that removed most of the large, fire-resistant trees in old-growth forests and favored uniform “plantations” of trees of the same age and species. These practices removed trees that provide habitat for sensitive species like the California spotted owl and made many forests in the Sierra Nevada highly homogenous and—combined with fire suppression—overly dense with small trees and shrubs.

Today, many of California's forests are dominated by fire-intolerant species, like firs, where there were once mixed conifer forests. The resulting forests have few large fire-resistant trees, continuous canopy cover, and heavy understory fuel loading from litter and woody debris.^{13,31,36,37,39-43} Many private timberlands also have relatively homogenous, even-aged stands of trees. Overall, these uncharacteristically uniform, dense, young forests are more prone to high-severity fire.

As a consequence, while the overall frequency of fires remains lower than it once was, in recent decades we have experienced a rapid increase in the area burned by fires.^{5,44} There's also strong evidence for an increase in the severity of fires (as measured by trends in fire-driven tree mortality)^{1,3,11,34,45} and area burned at high severity.^{1,3,34,46} At high elevations, where fire was historically infrequent, the number of fires burning and the annual area burned also appear to be increasing.^{3,47} Of particular concern is the potential for more of the largest, most severe fires, like several experienced within the last five years.⁴⁸ One recent example of such a “megafire” is the 2014 King Fire, in which half of the 97,000 acres affected burned so severely that it formed a few very large contiguous patches of mostly dead trees. This reflects the change in forests over the



A California spotted owl parent and its chick, recently out of the nest. Most of the large, old trees that spotted owls need for nesting were removed by early logging efforts; those that remain are at risk from high-severity fires. [Photograph by Danny Hofstadter]

last hundred years.⁴⁹ Based on the best available evidence on historical fire regimes, in contrast to what we witnessed with the King Fire, high-severity burn areas would have been fewer and distributed across many smaller patches.^{2,3,27}

The King Fire also burned 30 spotted owl breeding territories where pairs nest and hunt. About half of each of these owl territories was severely burned, on average. In 14 of the territories, the high-severity burn area averaged 89 percent (Gavin Jones, personal communication). The result was a sevenfold higher incidence of abandonment of territories compared to that found in unburned and low-severity burned territories.⁵⁰

The intensity of the King Fire precipitated massive erosion events that caused millions of dollars in damage and maintenance costs for the Placer County Water Agency. It can take decades, if not hundreds of years, for large patches of severely burned forests to recover; some of the forests may be permanently converted to shrub fields if the high-severity patches are very large (like in the King Fire) or if they repeatedly burn during the warmest, driest periods of subsequent years.⁵¹⁻⁵⁴

Even more concerning are the observed and potential long-term effects of a warming climate. California is on track to exceed a 2°C increase in average temperature by 2050 and to experience more intense droughts.^{44,55,56} This may push many forests into a climate regime they have not experienced for millennia, or ever,⁵⁷ and intensify fire and tree mortality in

Sierra forests.^{10,12} Increasingly early snowmelt is likely to increase fire frequency and lengthen the fire season.⁵ Overall, burned area is expected to increase with a drier and warmer future: By the end of century, we can expect a roughly 50 percent increase in the frequency of extreme wildfires that burn more than 25,000 acres.^{58,59}

Dense and young forests are also more prone to the impacts of drought,^{60,61} including water stress, insect outbreaks, and some diseases.^{9,20,21,62-65} During the 2012-2016 drought, for example, an estimated 130 million trees died in the Sierra, including up to 50 percent of pines in lower and middle elevation watersheds in the central and southern Sierra.^{66,67} These conditions can lead to high-intensity fires that endanger human communities and forests.²¹

CURRENT FOREST CONDITIONS ARE BAD FOR PEOPLE AND NATURE

Not only do severe fires near communities threaten lives and properties, they can lead to erosion and mudslides that damage homes and water supplies.⁶⁸⁻⁷¹ The effects of severe wildfires also go well beyond the forest. Large, intense wildfires degrade air quality around the state and even across the country.⁷²⁻⁷⁴ This increases the duration of smoke exposure,⁷⁵ leading to acute and chronic human health impacts such as increased asthma-related hospital visits, respiratory disease, and cardiovascular disease.⁷⁶⁻⁷⁸

Forests are a significant source of carbon storage in terrestrial ecosystems, but the value of Sierra Nevada forests as a vital carbon sink is in jeopardy.^{12,16,18} Further, the many imperiled species that depend on older, closed-canopy forests and suffer from the legacy of past logging—including California spotted owls⁷⁹—are increasingly threatened by the impact severe fires can have on the little remaining old-growth forest they occupy.^{50,80-83}

Many more people live in the forest now than did a century ago. This has intensified the challenges of managing fire, especially at the wildland-urban interface.⁸⁴ But eliminating wildfire is not a practical, affordable, or ecologically desirable solution. As recent events have demonstrated, it is also impossible.

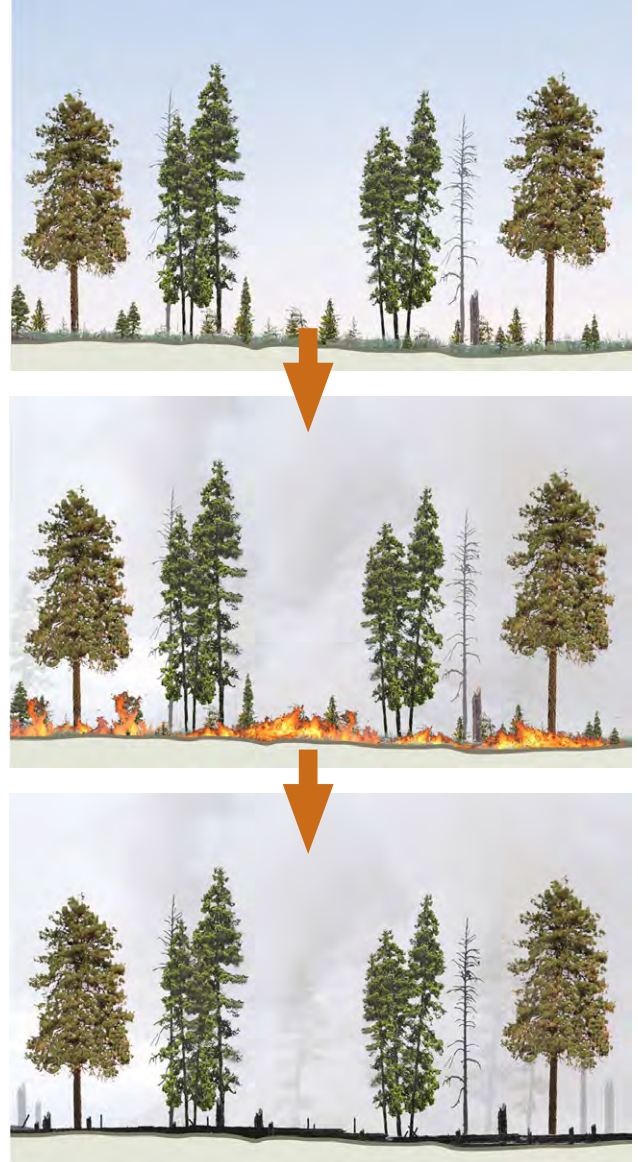
In sum, our fire-adapted forests need more of the right kind of fire, yet existing conditions and a warming climate make it unsafe for people and nature to allow all fires to burn under unmanaged conditions. So what is the solution?

Fire-suppressed forest



Fire-starved forests that have not experienced fire in many decades are prone to high-severity fires that burn very hot and kill 75% or more of trees, including large, fire-resistant trees.

Ecologically managed forest



By carefully thinning the understory of some forests to reduce fuel load, we can safely reintroduce fire as a restorative process.

[Graphics courtesy of The Nature Conservancy]

ECOLOGICAL FORESTRY

Forests are diverse and complex, as are the changes they have experienced. There is not a one-size-fits-all answer to restoring their resilience, diversity, and safety.⁸⁵⁻⁸⁸ The good news is that we largely know what needs to be done. There's robust science showing what the forests used to look like, and how to reduce high-severity fire risk while protecting forests in a changing climate.

Many low- and mid-elevation forests of the Sierra Nevada need to be restored to a more open, patchy,

and diverse structure, in order to make them more resilient to drought and a warming climate.^{87,89} This will require increasing the scale of ecological forestry: targeted thinning of smaller trees and shrubs where it is needed most combined with more frequent low- and moderate-severity fire. Reducing the impacts of fire on people will also require fire-hardening communities and reducing development in fire prone areas. All three measures will be necessary, and none of them will be sufficient on its own.



California spotted owl nesting and roosting habitat.
[Photograph by David Edelson/The Nature Conservancy]

Ecological forestry will also need to include proactive measures to ensure the resilience and adaptive capacity of the forests to a changing environment over the long term. This may include active replanting of seeds from drought tolerant populations or facilitating the expansion of tree and shrub genotypes that are better adapted to future climates and disturbance regimes.^{90,91}

ECOLOGICAL THINNING

As counter-intuitive as it may seem, given that historical logging created some of the challenges our forests face, cutting some trees is now a necessary part of the solution.^{28,92-96} Under current conditions, healthy fire cannot be safely reintroduced to some forested areas

without some preliminary fuel reduction. This is particularly important in areas that are closest to homes and communities and in areas that can transport high-intensity fire to the wildland-urban interface, as happened in the 2018 Camp Fire. Targeted and ecologically based thinning in accessible areas is needed to open up the forest where it is unnaturally dense. Done well, this kind of thinning can recreate a diverse forest structure that protects wildlife and plant diversity and facilitates the reintroduction of fire where it would currently be unsafe to do so.⁹⁵⁻⁹⁷

Ecological forestry has little in common with historical logging practices. Ecological thinning does not mean clearcutting, old-growth forest logging, or extensive salvage logging after fires. It is explicitly focused on protecting the oldest trees and creating a diverse mosaic of natural features that are essential for forest diversity and regeneration.^{96,98}

Intensive logging can negatively affect sensitive wildlife and the diversity and function of the forests, so this must be done carefully to balance the trade-offs between short-term impact and long-term benefits. That means prioritizing the removal of the surface and ladder fuels that contribute most to wildfire hazard⁹⁹, while minimizing ground disturbance and impacts to those trees and shrubs that will not be removed. It also means maintaining higher canopy cover in some locations and protecting stands of large trees in high quality habitat of sensitive species, such as the California spotted owl and Pacific fisher.

There remains some uncertainty about how sensitive species respond to severe wildfire compared to ecological thinning. For example, further research is needed to compare how ecological thinning affects spotted owls compared to varying amounts and severities of fire. However, it is clear that some thinning in strategic areas will be needed to reduce the risks that high-severity wildfire poses to these species.^{50,101} Otherwise, the benefits of avoiding near-term impacts from ecological thinning will be overwhelmed by the devastating loss of habitat due to high-severity wildfires.⁵⁰ Ongoing and future research will build on our understanding of how species respond to forest management and megafires, and we will be able to adapt our forest management strategies in response.

PRESCRIBED FIRE AND MANAGED WILDFIRE

Reintroducing fire to many of our forested watersheds is the second key ingredient in ecological forestry, and ultimately will be the most important contributor to restoring forest health and resilience. Both prescribed and managed wildfires will be important. Prescribed fires are intentionally planned, ignited, and managed fires targeted to specific places and often preceded by thinning of small trees and shrubs where needed. Managed wildfires are those that are unintentionally started by natural causes like lightning, but then allowed to burn where weather conditions permit and managed for resource benefits and human safety. Managed wildfires require advanced planning so that when fires start the appropriate measures can be taken to manage them.

Reestablishing more frequent fires of relatively low severity in places where this was once the natural regime will keep the most flammable fuels in check, protect the larger trees, and recycle nutrients in the forest to develop a healthier canopy and a less flammable and more diverse understory. It also means allowing and managing smaller patches of moderately and severely burned forest where safe and appropriate. Such patchiness moderates the intensity of future fires^{30,103-105} and is essential for supporting the full diversity of plants and wildlife that are unique to the Sierra Nevada, including those that are adapted to and benefit from severely burned forest patches.^{83,102,106-110}

There is now ample evidence that thinning, combined with prescribed fire, works best to restore Sierra Nevada forests. Areas treated with both approaches have more species diversity, and the reduction in potential fire severity lasts longer than if thinning or fire are implemented alone.^{11,26,28,89,113-117} In fact, following thinning with fire may be essential in many areas, because forests can grow back quickly after a single thinning treatment.^{99,116-119}

As a practical matter, given the many constraints on applying prescribed and managed wildfire, ecological thinning will be an important part of the solution, at least in the near to mid term. Management guidelines for federal and state lands often encourage wildfire suppression, regardless of the potential to safely manage them for resource benefits, and fewer than 1 percent of Forest Service lands are currently being managed with fire each year,²⁶ which likely reflects the scale across other federal and state lands. It will take years to build the capacity and social will to manage

fire for resource benefits at large scales, and some areas (e.g. near communities) may never be suitable for fire, even in the long term.

ECOLOGICAL FORESTRY WILL PROVIDE MANY BENEFITS

While it is a daunting challenge, implementing ecological forestry broadly across Sierra Nevada forests will help ensure that we are able to protect the natural diversity and beauty of California's fire-prone forests. Done thoughtfully, it will protect habitat for, and mitigate high-severity fire risks to, the imperiled species that have been pushed to the brink. It will also help to protect California's largest supply of clean water, the Sierra snowpack and runoff,¹²⁰⁻¹²⁵ and make forests more resilient to drought.^{10,60,126,127} Further, protecting our forests from the most extreme fire and tree mortality events will protect the forests against more extreme losses of carbon storage that would come with widespread and severe wildfires, as well as help stabilize carbon stores in these forests over the long term.^{44,128-132}

Taking a large scale, ecologically based approach to forest management is also important for human safety. Focusing California's forest management resources exclusively on defensible space around communities and fire hardening homes may not be enough. These defenses can be overwhelmed by an intense and fast-moving fire coming out of the forest, as recent fires like the 2018 Camp Fire have demonstrated. Late season fires of this intensity, fueled by large fuel loads, dry weather, and high winds, can quickly move out of the wildlands and send embers flying miles to land on homes in the middle of densely populated communities. Instances like these are becoming more frequent in California and forcing the state to rethink how it maps fire hazard zones.

There could also be important indirect benefits of ecological forestry to public health and the economy. Lower-severity fires (including prescribed fires and managed wildfires) can have lower emissions per fire event, and thus may reduce the potential human health impacts and costs over time compared to unplanned megafires.^{72,75}

California also has the opportunity to lead in the development of a forest restoration economy. At present, there are few innovative uses for the small wood material that will be removed and not enough facilities to process the material. There are also far too few trained personnel in ecological forestry and the application of prescribed fire. Those that are trained can

barely keep up with managing the dangerous wildfires that need to be contained. Ramping up investments and training in ecological forestry, bio-energy, and small diameter wood products (e.g. cross-laminated timber, a product made from gluing layers of lumber together) could create new jobs and revitalize struggling rural communities (see Kusel, page 36).¹³³

California's fire-prone forests are unhealthy and at serious risk of uncharacteristic, high-severity wildfire, drought, and insect outbreaks. There is compelling evidence that ecological forestry—ecological thinning, prescribed burning, and managed wildfire—can reduce these risks and promote healthier, more resilient forests. We urge policymakers to maintain and increase funding for ecological thinning and prescribed fire and to take steps to address the policy and practical barriers to implementing ecological forestry at a scale and pace appropriate to the challenge at hand.

Acknowledgements

This paper benefitted from thorough review, edits, and comments from the following experts: John Battles, PhD, Sue Britting, PhD, Dick Cameron, David Edelson, Matthew Hurteau, PhD, Gavin Jones, PhD, Jon Keeley, PhD, Pat Manley, PhD, Kerry Metlen, PhD, Malcolm North, PhD, Zach Peery, PhD, Hugh D. Safford, PhD, Edward Smith, MFS, and Scott L. Stephens, PhD.

—Rodd Kelsey, PhD, is lead scientist at The Nature Conservancy's California Chapter

REFERENCES

1. Miller, J. D., Safford, H. D., Crimmins, M. & Thode, A. E. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. *Ecosystems* 12, 16–32 (2009).
2. Miller, J. D. & Safford, H. Trends in wildfire severity: 1984–2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California USA. *Fire Ecology* 8, 41–57 (2012).
3. Mallek, C., Safford, H., Viers, J. & Miller, J. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. *Ecosphere* 4, art153 (2013).
4. Singleton, M. P., Thode, A. E., Sánchez Meador, A. J. & Iniguez, J. M. Increasing trends in high-severity fire in the southwestern USA from 1984 to 2015. *Forest Ecology and Management* 433, 709–719 (2019).
5. Westerling, A. L. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Philosophical Transactions of the Royal Society, London B* 371, 20150178 (2016).
6. Collins, B. M., Miller, J. D., Knapp, E. E. & Sapsis, D. B. A quantitative comparison of forest fires in central and northern California under early (1911–1924) and contemporary (2002–2015) fire suppression. *International Journal of Wildland Fire* (2019).
7. Marlon, J. R. et al. Long-term perspective on wildfires in the western USA. *Proceedings of the National Academy of Sciences* 109, E535–E543 (2012).
8. Preisler, H. K., Grulke, N. E., Heath, Z. & Smith, S. L. Analysis and out-year forecast of beetle, borer, and drought-induced tree mortality in California. *Forest Ecology and Management* 399, 166–178 (2017).
9. Kolb, T. E. et al. Observed and anticipated impacts of drought on forest insects and diseases in the United States. *Forest Ecology and Management* 380, 321–334 (2016).
10. Restaino, C. M. & Safford, H. D. *Fire and climate change, in Fire in California's Ecosystems* (eds. Van Wagtendonk, J. W. et al.) 493–505 (University of California Press, 2018).
11. Miller, J. D. & Safford, H. D. Corroborating evidence of a pre-Euro-American low- to moderate-severity fire regime in yellow pine-mixed conifer forests of the Sierra Nevada, California, USA. *Fire Ecology* 13, 58–90 (2017).
12. Dettinger, M. D. et al. Sierra Nevada summary report. California's Fourth Climate Change Assessment. (California Energy Commission/Natural Resources Agency, 2018).
13. Safford, H. D. & Stevens, J. T. Natural Range of Variation (NRV) for yellow pine and mixed conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. (USDA Forest Service, Pacific Southwest Region, 2017).
14. Klausmeyer, K. R. & Fitzgerald, K. Where Does California's Water Come From? Land conservation and the watersheds that provide California's drinking water. (The Nature Conservancy, 2012).
15. Case, D., Fowler, D., Morgan, H., Schwellenbach, S. & Culbertson, K. Moving to the Mountains: Amenity migration in the Sierra and southern Appalachian mountains, in *Political Economies of Landscape Change: Places of Integrative Power* (eds. Wescoat, J. L. & Johnston, D. M.) 77–88 (Springer Netherlands, 2008).
16. Gonzalez, P., Battles, J. J., Collins, B. M., Robards, T. & Saah, David, S. Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010. *Forest Ecology and Management* 348, 68–77 (2015).
17. Hurteau, M. D. & Brooks, M. L. Short- and long-term effects of fire on carbon in US dry temperate forest systems. *BioScience* 61, 139–146 (2011).
18. Hurteau, M. D., Bradford, J. B., Fulé, P. Z., Taylor, A. H. & Martin, K. L. Climate change, fire management, and ecological services in the southwestern US. *Forest Ecology and Management* 327, 280–289 (2014).
19. Manley, P. N. The Future of Biodiversity in the Sierra Nevada through the Lake Tahoe Basin Looking Glass 1, in *Proceedings of the Sierra Nevada Science Symposium*, October 7–10, 2002.
20. Guarín, A. & Taylor, A. H. Drought triggered tree mortality in mixed conifer forests in Yosemite National Park, California, USA. *Forest Ecology and Management* (2005).
21. Stephens, S. L. et al. Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire. *BioScience* (2018).
22. Agee, J. K. Fire ecology of Pacific Northwest forest. *International Journal of Wildland Fire* 4, 493 (1993).
23. McKelvey, K. S. et al. An Overview of Fire in the Sierra Nevada, in Sierra Nevada Ecosystem Project (SNEP)-Final Report to Congress (Vol. II): Assessments and scientific basis for management options 1033–1040 (University of California, Davis, Centers for Water and Wildland Resources, 1996).
24. Van De Water, K. M. & Safford, H. D. A summary of fire frequency estimates for California vegetation before Euro-American settlement. *Fire Ecology* 7, 26–58 (2011).
25. Safford, H. D. & Van De Water, K. M. Using fire return interval departure (FRID) analysis to map spatial and temporal changes in fire frequency on national forest lands in California. Research Paper PSW-RP-266. (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2014).

26. North, M. P., Collins, B. M. & Stephens, S. L. Using fire to increase the scale, benefits, and future maintenance of fuels treatments. *Journal of Forestry* 110, 392–401 (2012).
27. van Wageningen, J. W. *et al.* Fire in California's ecosystems. (University of California Press, 2018).
28. Hessburg, P. F. *et al.* Tamm Review: Management of mixed-severity fire regime forests in Oregon, Washington, and Northern California. *Forest Ecology and Management* 366, (2016).
29. Hessburg, P. F., Agee, J. K. & Franklin, J. F. Dry forests and wildland fires of the inland Northwest USA: Contrasting the landscape ecology of the pre-settlement and modern eras. *Forest Ecology and Management* 211, 117–139 (2005).
30. Perry, D. A. *et al.* The ecology of mixed severity fire regimes in Washington, Oregon, and Northern California. *Forest Ecology and Management* 262, 703–717 (2011).
31. Beaty, R. M. & Taylor, A. H. Fire history and the structure and dynamics of a mixed conifer forest landscape in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. *Forest Ecology and Management* 255, 707–719 (2008).
32. Beaty, R. M. & Taylor, A. H. Fire disturbance and forest structure in old-growth mixed conifer forests in the northern Sierra Nevada, California. *Journal of Vegetation Science* (2007).
33. Hessburg, P. F. & Agee, J. K. An environmental narrative of Inland Northwest United States forests, 1800–2000. *Forest Ecology and Management* 178, 23–59 (2003).
34. Steel, Z. L., Safford, H. D. & Viers, J. H. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* 6, art8 (2015).
35. Lydersen, J. M., North, M. P., Knapp, E. E. & Collins, B. M. Quantifying spatial patterns of tree groups and gaps in mixed-conifer forests: reference conditions and long-term changes following fire suppression and logging. *Forest Ecology and Management* 304, 370–382 (2013).
36. Parsons, D. J. & DeBenedetti, S. H. Impact of fire suppression on a mixed-conifer forest. *Forest Ecology and Management* 2, 21–33 (1979).
37. North, M., Hurteau, M. & Innes, J. Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. *Ecological Applications* 19, 1385–1396 (2009).
38. Calkin, D. E., Gebert, K. M., Jones, J. G. & Neilson, R. P. Forest Service large fire area burned and suppression. *Journal of Forestry* 103, 179–183 (2005).
39. Knapp, E. E., Skinner, C. N., North, M. P. & Estes, B. L. Long-term overstory and understory change following logging and fire exclusion in a Sierra Nevada mixed-conifer forest. *Forest Ecology and Management* 310, 903–914 (2013).
40. Lutz, J. A., van Wageningen, J. W. & Franklin, J. F. Twentieth-century decline of large-diameter trees in Yosemite National Park, California, USA. *Forest Ecology and Management* 257, 2296–2307 (2009).
41. Dolanc, C. R., Safford, H. D., Dobrowski, S. Z. & Thorne, J. H. Twentieth century shifts in abundance and composition of vegetation types of the Sierra Nevada, CA, US. *Appl. Veg. Sci.* 17, 442–455 (2014).
42. Bouldin, J. Twentieth-century changes in forests of the Sierra Nevada, California (Doctoral dissertation). (University of California, Davis, 1999).
43. Stephens, S. L., Lydersen, J. M., Collins, B. M., Fry, D. L. & Meyer, M. D. Historical and current landscape-scale ponderosa pine and mixed conifer forest structure in the Southern Sierra Nevada. *Ecosphere* 6, 1–63 (2015).
44. Bedsworth, L., Cayan, D., Franco, G., Fisher, L. & Ziaja, S. California's Fourth Climate Change Assessment: Statewide summary report. Publication number: SUM- CCCA4-2018-013. (2018).
45. Steel, Z. L., Koontz, M. J. & Safford, H. D. The changing landscape of wildfire: burn pattern trends and implications for California's yellow pine and mixed conifer forests. *Landscape Ecology* 33, 1159–1176 (2018).
46. Keyser, A. R. & Westerling, A. L. Predicting increasing high severity area burned for three forested regions in the western United States using extreme value theory. *Forest Ecology and Management* 432, 694–706 (2019).
47. Schwartz, M. W. *et al.* Increasing elevation of fire in the Sierra Nevada and implications for forest change. *Ecosphere* 6, 121 (2015).
48. Stephens, S. L. *et al.* Temperate and boreal forest mega-fires: characteristics and challenges. *Front. Ecol. Environ.* 12, 115–122 (2014).
49. Stephens, S. L., Stevens, J. T., Collins, B. M., York, R. A. & Lydersen, J. M. Historical and modern landscape forest structure in fir (Abies)-dominated mixed conifer forests in the northern Sierra Nevada, USA. *Fire Ecology* 14, (2018).
50. Jones, G. M. *et al.* Megafires: an emerging threat to old-forest species. *Frontiers in Ecology and Environment* 14, 300–306 (2016).
51. Stevens, J. T., Collins, B. M., Miller, J. D., North, M. P. & Stephens, S. L. Changing spatial patterns of stand-replacing fire in California conifer forests. *Forest Ecology and Management* 406, (2017).
52. Welch, K. R., Safford, H. D. & Young, T. P. Predicting conifer establishment post wildfire in mixed conifer forests of the North American Mediterranean-climate zone. *Ecosphere* 7, e01609 (2016).
53. Walker, R. B., Coop, J. D., Parks, S. A. & Trader, L. Fire regimes approaching historic norms reduce wildfire-facilitated conversion from forest to non-forest. *Ecosphere* 9, e02182 (2018).
54. Coppoletta, M., Merriam, K. E. & Collins, B. M. Post-fire vegetation and fuel development influences fire severity patterns in reburns. *Ecological Applications* 26, (2016).
55. He, M., Schwarz, A., Lynn, E. & Anderson, M. Projected Changes in Precipitation, Temperature, and Drought across California's Hydrologic Regions in the 21st Century. *Climate* 6, 31 (2018).
56. Diffenbaugh, N. S., Swain, D. L. & Touma, D. Anthropogenic warming has increased drought risk in California. *Proceedings of the National Academy of Sciences* 112, 3931–3936 (2015).
57. Thorne, J. H. *et al.* The impact of climate change uncertainty on California's vegetation and adaptation management. *Ecosphere* 8, (2017).
58. Westerling, A. L. *et al.* Climate change and growth scenarios for California wildfire. *Clim. Change* 109, 445–463 (2011).
59. Westerling, A. L. *Wildfire simulations for California's Fourth Climate Change Assessment: projecting changes in extreme wildfire events with a warming climate.* 57 (California Energy Commission, 2018).
60. Young, D. J. N. *et al.* Long-term climate and competition explain forest mortality patterns under extreme drought. *Ecol. Lett.* 20, 78–86 (2017).
61. Voelker, S. L. *et al.* Fire deficits have increased drought sensitivity in dry conifer forests: Fire frequency and tree-ring carbon isotope evidence from Central Oregon. *Global Change Biology* 00, 1–17 (2019).
62. Williams, A. P. *et al.* Temperature as a potent driver of regional forest drought stress and tree mortality. *Nature Climate Change* 3, 292–297 (2013).
63. Allen, C. D., Breshears, D. D. & McDowell, N. G. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere* 6, art129 (2015).

64. Allen, C. D. et al. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* 259, 660–684 (2010).
65. Carnicer, J. et al. Widespread crown condition decline, food web disruption, and amplified tree mortality with increased climate change-type drought. *Proceedings of the National Academy of Sciences* 108, 1474–1478 (2011).
66. Fettig, C. J., Mortenson, L. A., Bulaon, B. M. & Foulk, P. B. Tree mortality following drought in the central and southern Sierra Nevada, California, U.S. *Forest Ecology and Management* (2019).
67. Buluç, L., Fischer, C., Ko, J., Balachowski, J. & Ostoj, S. Drought and tree mortality in the Pacific Southwest Region: a synopsis of presentations and work group sessions from the science and management symposium - lessons learned from extreme drought and tree mortality in the Sierra Nevada. (U.S. Department of Agriculture, California Climate Hub, 2017).
68. Larsen, I. J. et al. Causes of Post-Fire Runoff and Erosion: Water Repellency, Cover, or Soil Sealing? *Soil Science Society of America Journal* 73, 1393–1407 (2009).
69. Moody, J. A. & Ebel, B. A. Hyper-dry conditions provide new insights into the cause of extreme floods after wildfire. *Catena* 93, 58–63 (2012).
70. Moody, J. A., Shakesby, R. A., Robichaud, P. R., Cannon, S. H. & Martin, D. A. Current research issues related to post-wildfire runoff and erosion processes. *Earth-Science Reviews* 122, 10–37 (2013).
71. Aha, N., Boorman, M., Leidman, S. & Perry, S. The Effect of sediment deposition on Sierra riverine ecosystems following high-intensity fires. (2014).
72. Schweizer, D. Fine particulate matter and wildland fire smoke: integrating air quality, fire management, and policy in the California Sierra Nevada. (University of California, Merced, 2016).
73. Preisler, H. K. et al. Estimating contribution of wildland fires to ambient ozone levels in National Parks in the Sierra Nevada, California. *Environmental Pollution* 158, 778–787 (2010).
74. Preisler, H. K. et al. A statistical model for determining impact of wildland fires on particulate matter (PM 2.5) in central California aided by satellite imagery of smoke. *Environmental Pollution* 205, 340–349 (2015).
75. Long, J. W., Tarnay, L. W. & North, M. P. Aligning smoke management with ecological and public health goals. *Journal of Forestry* 116, 76–86 (2017).
76. Reid, C. E. et al. Critical review of health impacts of wildfire smoke exposure. *Environmental Health Perspectives* (2016).
77. Reid, C. E., Jerrett, M., Tager, I. B., Petersen, M. L., Mann, J. K., Balmes J. R. Differential respiratory health effects from the 2008 northern California wildfires: A spatiotemporal approach. *Environmental Research* (2016).
78. Liu, J. C., Pereira, G., Uhl, S. A., Bravo, M. A. & Bell, M. L. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. *Environmental Research* (2015).
79. Jones, G. M., Keane, J. J., Gutiérrez, R. J. & Peery, M. Z. Declining old-forest species as a legacy of large trees lost. *Diversity and Distributions* 24, 341–351 (2017).
80. Jones, G. M., Gutiérrez, R. J., Tempel, D. J., Zuckerberg, B. and Peery, M. Z. Using dynamic occupancy model to inform climate change adaptation strategies for California spotted owls. *Journal of Applied Ecology* 53, 895–905 (2016).
81. Tempel, D. J. et al. Evaluating short- and long-term impacts of fuels treatments and simulated wildfire on an old-forest species. *Ecosphere* 6, 1–19 (2015).
82. Tempel, D. J. et al. Effects of forest management on California spotted owls: Implications for reducing wildfire risk in fire-prone forests. *Ecological Applications* 24, 2089–2106 (2014).
83. Miller, J. E. D., Root, H. T. & Safford, H. D. Altered fire regimes cause long-term lichen diversity losses. *Global Change Biology* 24, 4909–4918 (2018).
84. Dombeck, M. P., Williams, J. E. & Wood, C. A. Wildfire policy and public lands: integrating scientific understanding with social concerns across landscapes. *Conservation Biology* 18, 883–889 (2004).
85. Schoennagel, T., Veblen, T. T. & Romme, W. H. The Interaction of fire, fuels, and climate across Rocky Mountain forests. *BioScience* 54, 661–677 (2004).
86. Moritz, M. A. et al. Learning to coexist with fire. *Nature* 515, 58–66 (2014).
87. Schoennagel, T. et al. Adapt to more wildfire in western North American forests as climate changes. *Proceedings of the National Academy of Sciences* 114, (2017).
88. Stephens, S. L. et al. Managing Forests and Fire in Changing Climates. *Science* 342, 41–42 (2013).
89. Stevens, J. T., Safford, H. D. & Latimer, A. M. Wildfire-contingent effects of fuel treatments can promote ecological resilience in seasonally dry conifer forests. *Can. J. For. Res.* 44, 843–854 (2014).
90. North, M. P. et al. Tamm Review: Reforestation for resilience in dry western U.S. forests. *Forest Ecology and Management* 432, 209–224 (2019).
91. Stevens, J. T., Safford, H. D., Harrison, S. & Latimer, A. M. Forest disturbance accelerates thermophilization of understory plant communities. *J. Ecol.* 103, 1253–1263 (2015).
92. North, M. P. et al. Constraints on Mechanized Treatment Significantly Limit Mechanical Fuels Reduction Extent in the Sierra Nevada. *J. For.* 40–48 (2014). doi:http://dx.doi.org/10.5849/jof.14-058
93. Agee, J. K. & Skinner, C. N. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211, 83–96 (2005).
94. Noss, R. F., Franklin, J. F., Baker, W. L., Schoennagel, T. & Moyle, P. B. Managing fire-prone forests in the western United States In a nutshell : *Front. Ecol. Environ.* 4, 481–487 (2006).
95. Fulé, P. Z., Crouse, J. E., Roccaforte, J. P. & Kalies, E. L. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? *Forest Ecology and Management* 269, 68–81 (2012).
96. North, M. P., Stine, P., Hara, K. O., Zielinski, W. & Stephens, S. L. An ecosystem management strategy for Sierran mixed-conifer forests, Gen. Tech. Rep. PSW-GTR-220. (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2009).
97. Krofcheck, D. J., Hurteau, M. D., Scheller, R. M. & Loudermilk, E. L. Prioritizing forest fuels treatments based on the probability of high-severity fire restores adaptive capacity in Sierran forests. *Global Change Biology* 24, 729–737 (2018).
98. North, M. P. (ed). *Managing Sierra Nevada forests*. (U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2012).
99. Stephens, S. L. et al. Fire treatment effects on vegetation structure, fuels, and potential fire severity in western U.S. forests. *Ecological Applications* 19, 305–320 (2009).
100. Chiono, L. A., Fry, D. L., Collins, B. M., Chatfield, A. H. & Stephens, S. L. Landscape-scale fuel treatment and wildfire impacts on carbon stocks and fire hazard in California spotted owl habitat. *Ecosphere* 8, e01648 (2017).
101. Ganey, J. L., Wan, H. Y., Cushman, S. A. & Vojta, C. D. Conflicting perspectives on spotted owls, wildfire, and forest restoration. *Fire Ecology* 13, 1–20 (2017).

102. Stephens, S. L. et al. California spotted owl, songbird, and small mammal responses to landscape fuel treatments. *BioScience* 64, 893–906 (2014).
103. Finney, M. A. Design of Regular Landscape Fuel Treatment Patterns for Modifying Fire Growth and Behavior. *Forest Science* 47, (2001).
104. Ager, A. A., Vaillant, N. M. & Finney, M. A. A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. *Forest Ecology and Management* 259, 1556–1570 (2010).
105. Finney, M. A. et al. Simulation of long - term landscape - level fuel treatment effects on large wildfires. *Int. Journal of Wildland Fire* 16, 712–727 (2007).
106. Ponisio, L. C. et al. Pyrodiversity begets plant-pollinator community diversity. *Global Change Biology* 22, 1794–1808 (2016).
107. Tingley, M. W., Ruiz-Gutiérrez, V., Wilkerson, R. L., Howell, C. A. & Siegel, R. B. Pyrodiversity promotes avian diversity over the decade following forest fire. *Proceedings of the Royal Society of London, B* 283, 1–9 (2016).
108. Converse, S. J., White, G. C., Farris, K. L. & Zack, S. Small mammals and forest fuel reduction: national-scale responses to fire and fire surrogates. *Ecological Applications* 16, 1717–1729 (2006).
109. Meyer, M. D., North, M. P. & Kelt, D. A. Short-term effects of fire and forest thinning on truffle abundance and consumption by *Neotamias speciosus* in the Sierra Nevada of California. *Canadian Journal of Forest Research* 35, 1061–1070 (2005).
110. DellaSala, D. A. & Hanson, C. T. *The ecological importance of mixed-severity fires : nature's Phoenix*. (Elsevier, 2015).
111. Converse, S. J., White, G. C. & Block, W. M. Small mammal responses to thinning and wildfire in ponderosa pine-dominated forests of the southwestern United States. 70, 1711–1722 (2006).
112. DellaSala, D. A., Bond, M. L., Hanson, C. T., Hutto, R. L. & Odion, D. C. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? *Natural Areas Journal* 34, 310–324 (2014).
113. Graham, R. T., Harvey, A. E., Jain, T. B. & Tonn, J. R. Effects of thinning and similar stand treatments on fire behavior in western forests, General Technical Report, PNW-GTR463. (USDA Forest Service, Pacific Northwest Research Station, 1999).
114. Safford, H. D., Stevens, J. T., Merriam, K., Meyer, M. D. & Latimer, A. M. Fuel treatment effectiveness in California yellow pine and mixed conifer forests. *Forest Ecology and Management* 274, 17–28 (2012).
115. Clyatt, K. A., Keyes, C. R. & Hood, S. M. Long-term effects of fuel treatments on aboveground biomass accumulation in ponderosa pine forests of the northern Rocky Mountains. *Forest Ecology and Management* 400, 587–599 (2017).
116. Stephens, S. L., Collins, B. M. & Roller, G. Fuel treatment longevity in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management* 285, 204–212 (2012).
117. Stephens, S. L. et al. The effects of forest fuel-reduction treatments in the United States. *Bioscience* 62, 549–560 (2012).
118. Krofcheck, D. J., Hurteau, M. D., Scheller, R. M. & Loudermilk, E. L. Restoring surface fire stabilizes forest carbon under extreme fire weather in the Sierra Nevada. *Ecosphere* 8, e01663 (2017).
119. Stephens, S. L. & Moghaddas, J. J. Experimental fuel treatment impacts on forest structure , potential fire behavior , and predicted tree mortality in a California mixed conifer forest. *Forest Ecology and Management* 215, 21–36 (2005).
120. Boisramé, G., Thompson, S., Collins, B. & Stephens, S. Managed wildfire effects on forest resilience and water in the Sierra Nevada. *Ecosystems* 20, 717–732 (2017).
121. Smith, H. G., Sheridan, G. J., Lane, P. N. J., Nyman, P. & Haydon, S. Wildfire effects on water quality in forest catchments: a review with implications for water supply. *Journal of Hydrology* 396, 170–192 (2011).
122. Buckley, M. et al. Mokelumne watershed avoided cost analysis: why Sierra fuel treatments make economic sense: A report prepared for the Sierra Nevada Conservancy, The Nature Conservancy, and U.S. Department of Agriculture, Forest Service. (Sierra Nevada Conservancy, 2014).
123. Elliot, W. J., Miller, M. E. & Enstice, N. Targeting forest management through fire and erosion modelling. *International Journal of Wildland Fire* 25, 876–887 (2016).
124. Ellison, D. et al. Trees, forests and water: Cool insights for a hot world. *Global Environmental Change* 43, 51–61 (2017).
125. Ellis, C. R., Pomeroy, J. W., Link, T. E. & Rivers, M. Modeling increases in snowmelt yield and desynchronization resulting from forest gap-thinning treatments in a northern mountain headwater basin. *Water Resource Research* 49, 1–14 (2013).
126. D'amato, A. W., Bradford, J. B., Fraver, S. & Palik, B. J. Effects of thinning on drought vulnerability and climate response in north temperate forest ecosystems. *Ecological Applications* 23, 1735–1742 (2013).
127. Kerhoulas, L. P., Kolb, T. E., Hurteau, M. D. & Koch, G. W. Managing climate change adaptation in forests: a case study from the U.S. Southwest. *Journal of Applied Ecology* 50, 1311–1320 (2013).
128. Collins, B. M. et al. Beyond Reducing Fire Hazard. *Ecological Applications* 23, 515–522 (2013).
129. Hurteau, M. D. & North, M. Carbon recovery rates following different wildfire risk mitigation treatments. *Forest Ecology and Management* 260, 930–937 (2010).
130. Hurteau, M. D. Quantifying the carbon balance of forest restoration and wildfire under projected climate in the fire-prone southwestern U.S. *PLOS ONE* 12, e0169275 (2017).
131. Loudermilk, E. L., Scheller, R. M., Weisberg, P. J. & Kretchun, A. Bending the carbon curve: fire management for carbon resilience under climate change. *Landscape Ecology* (2017).
132. Liang, S., Hurteau, M. D. & Westerling, A. L. Large-scale restoration increases carbon stability under projected climate and wildfire regimes. *Frontiers in Ecology and Environment* 16, 207–212 (2018).
133. Wu, T., Kim, Y.-S. & Hurteau, M. D. Investing in natural capital: using economic incentives to overcome barriers to forest restoration. *Restoration Ecology* 19, 441–445 (2011).
134. Wayman, R. B., and M. North. 2007. Initial response of a mixed-conifer understory plant community to burning and thinning restoration treatments. *Forest Ecology and Management* 239:32–44.
135. Webster, K. M., and C. B. Halpern. 2010. Long-term vegetation responses to reintroduction and repeated use of fire in mixed-conifer forests of the Sierra Nevada. *Ecosphere* 1:1–27.
136. Richter, C., M. Rejmanek, J. E. D. Miller, K. R. Welch, J. Weeks, and H. Safford. 2019. The species diversity and fire severity relationship is hump-shaped in semiarid yellow pine and mixed conifer forests. *Ecosphere* 10(10):e02882. 10.1002/ecs2.2882
137. Lake, F.K., Giardina, C., Parrotta, J.A., and Davidson-Hunt, I. 2018. Considering diverse knowledge systems in forest landscape restoration-Chapter 3. In: *Forest Landscape Restoration: Integrated Approaches to Support Effective Implementation*. S. Mansourian and J. Parrotta (eds), Routledge Press:37-46, ISBN: 978-1-315-11187-2 (ebk).



FIRE IN CALIFORNIA: THE LONG ROAD TO RECOVERY

Craig Thomas

California has one of the most fire-prone climates on the planet, with mild, wet winters and long, dry summers. We share this adventure with only a handful of other places on Earth, among them Portugal, central Chile, and South Africa. We hear about these places regularly in the news, most recently, with the deadly bushfires in Australia.

There's nothing new about California's tendency to burn. Before the 1800s, wildfires ignited by lightning and deliberately set by Native Americans burned 4.5 million acres each year, according to research on early California fire patterns by UC Berkeley fire scientist Scott Stephens (Stephens et al. 2007). Fire scientists now call that early 1800s condition a "reference" condition that we can consider in many ways to be a reasonable landscape restoration goal for much (but not all) of California's remaining wildlands. Well-founded

science tells us what we must do to restore Sierra Nevada forest heterogeneity and health (see Kelsey, page 22 of this issue).

If fire is a constant in California, why is it taking so long for us to adapt to living with it? It has much to do with cultural history and misunderstanding of the landscape in which we live. In this article, I will lay out the history of our aversion to fire, and signs that we're moving toward a healthier relationship with the fires that sustain California's landscapes.

IN THE BEGINNING

A fundamental misunderstanding of our relationship with fire is deeply rooted in our culture. As a first step, with all due respect to the authors, we would do well

Above: Caples Creek prescribed fire, June 2018. [Photograph by Craig Thomas]

to reinterpret the marching orders “...fill the earth and subdue it. Rule over the fish in the sea and the birds in the sky and over every living creature that moves on the ground” (Genesis 1:28). Compared to other traditions that include more nature-centered worldviews, “ruling over” and “subduing” are taking a heavy toll on the Garden of Eden.

In California, trouble began during the Mission period in the late 1700s (Taylor 2016). The establishment and expansion of agrarian-based Spanish missions led to the removal of, and disease outbreaks in, the Native American population, putting an end to their frequent use of fire to increase food supplies and weaving materials.

In 1904, a program of active fire suppression on federal lands led to the lowest level of average fire activity in the past 400 years. Most of the lower montane forests of the Sierra Nevada have not burned in more than a century (Steel et al. 2015) because of effective early detection and initial attack efforts in this era.

Smokey Bear’s arrival on the scene 75 years ago fostered a new awareness of fire threat (for an historical perspective, read *The Big Burn* by Timothy Egan). In the 1970s, well-meaning environmental policies began to take hold in natural resource management decisions and carried an anti-fire bias into the current era.

In 1976 the U.S. Forest Service was governed by the National Forest Management Act (NMFA), a positive move forward that helped the agency improve its natural resource management planning process. This began an era of science-based consideration and management of multiple resources. Yet fire is mentioned only three times in the text of NFMA, and all in the context of a catastrophe. The goal was to grow lots of trees and put all fires out.

AN ERA OF SCIENCE-BASED MANAGEMENT

In the 1980s, the effectiveness of fire suppression began to unravel due to increased climate warming, extended fire seasons, and early snowmelt, along with higher levels of forest fuels due to the absence of natural fire. In recent years, fire science has been pushing fire policy into a new and deeper understanding of fire’s role in ecosystem resilience and diversity.

The 2009 Guidance for Implementation of Federal Wildfire Management Policy and the 2014 National Cohesive Wildland Fire Management Strategy supported management of planned and unplanned ignitions for multiple resource benefits, such as wildlife

habitat, fuels reduction, and watershed protection. These federal policies allow for the management of multiple objectives—which can change during a wildfire’s progression—and recognize the science and professionalism of the modern federal fire cadre, fostering a major step forward and bringing Smokey Bear in to the modern fire management arena.

CHANGING FIRE’S PUBLIC IMAGE

Fire is regenerative, reduces fuels, enhances biodiversity, and creates resilience. But it can also burn down entire towns when we mistakenly assume we can control nature and eliminate a natural ecological process.

In the past most Californians rarely saw fire in action, on the rare occasion when a wildfire made the evening news. But over the last 20 years the situation has changed dramatically in California, and increasingly large and severe wildfires have begun to dominate the news locally and nationally.

Our culture has evolved very different attitudes about fire and rain, though both are critically important ecological processes in our California landscape. Fire has gotten a century of bad press (Schweizer and Cisneros 2018) even though rainfall can be equally destructive. One need only recall recent floods and the eroded dam spillway in Oroville to be reminded of the high costs associated with rain, yet we tend to look forward to rain and fear fire. Many media outlets reinforce that attitude.

Beneficial aspects of fire, such as fire’s role in habitat enhancement, nutrient recycling, and soil health, as well as the lower smoke emissions outputs from strategically planned fire, are rarely part of the public discourse. Yet they need to be if we are to reestablish a positive relationship with fire and value its nurturing role in our landscapes. Efforts to change public attitudes took a major step forward in the California Legislature in 2018 with the signing of SB 1260 (Jackson 2018) at the end of the Brown Administration. Also positive were the 2017 California Biodiversity Initiative and the 2018 Little Hoover Commission Report, “Fire on the Mountain,” which pointed toward fire’s benefits in California. While prescribed fire is not a cure-all and can’t be guaranteed to halt all incoming wildfires, resilient landscapes that include frequent fire applications are a much better choice for our ecosystems, community protection, and public health.

Fire that benefits nature and humans has been operating alongside precipitation for tens of thousands of years. Scientists from California and throughout the

West have been calling for the reestablishment of fire as a critical ecological process for 30 years, and warning of some dire consequences if we don't heed their warning. It is now clear that those dire consequences have arrived. The West is burning, but mostly not in the way it should be.

GOING FORWARD

Have we reached a critical point in our shared cultural history to embrace a positive relationship with fire? The answer is yes. Our forests, watersheds, carbon sequestration goals, safety, and health all require that we embrace active fire use if we want to maintain a California landscape that is recognizable, productive, and resilient. While scientists warn of increasingly large, high-intensity fires, increased release of forest carbon into the atmosphere, and increased mega-emission events causing massive public health and economic impacts, there is one consistent recommendation stated in most of the published science pertaining to forest resilience, climate change and public health: to reestablish fire's role as a key part of natural resource management.

Multiple efforts are underway throughout the state to reintroduce fire into fire-excluded forests at appropriate scale, intensity, and timing. One example of a collaborative, landscape-level effort to restore natural fire in California is the expansion of prescribed burn programs across the Forest Service and National Park Service, such as the Fire MOU Partnership, and the State Forest Management Task Force and its Prescribed Fire Working Group.

With astronomical fire suppression costs, growing public health impacts and resource damage from mega-emission wildfires, and the state's forest carbon sequestration goals, these groups are forging a new path forward. Their recommendations are key to overcoming barriers to burning (Schultz et al. 2018) and restoring ecologically significant fire in California.

Calculate the avoided costs and co-benefits of a resilient California landscape

How do we balance what we take from our forests with what we restore, maintain, and rebuild, and how does achieving such balance pencil out economically? First and foremost, we must place real value in the avoided costs and co-benefits associated with a resilient and fire-restored California landscape. Real value means an honest accounting of the costs of restoring landscapes in the economic and political equation, including all major categories of avoided costs.

One example is the \$300 million estimate of the cost to remove the carcinogen benzene from the Paradise, Calif. water supply (Bizjak, Tony. "Rare toxic cocktail from Camp Fire is poisoning Paradise water," *The Sacramento Bee*, April 2019.) Another example is the carbon emissions from large fires that will eventually happen in the absence of treatment, and the health impacts and cost of hospital admissions from such events.

Also important to consider are co-benefits created when forest landscapes are maintained with ecologically appropriate fire. For example, fire reduces use of toxic herbicides on forest landscapes, which pollute our air, water supplies, forest workers, and native food sources. Another co-benefit occurs from stabilization or realignment of carbon stocks in larger, fire resilient trees, which is a more secure way to store forest carbon in our highly fire-associated landscapes.

Expand fire manager-air regulator collaborations throughout the state

Since the initiation of the California Clean Air Act in the 1970s, the state has made major improvements in air quality. After the act was passed, the state began to regulate emissions of six primary pollutants, including carbon monoxide (CO), lead (Pb), particulate matter (PM), ozone (O₃), nitrogen dioxide (NO₂), and sulphur dioxide (SO₂).

There is no question that we need the Clean Air Act statutes, nationally and in their strengthened form in California. But there is one enormous problem with the National Ambient Air Quality Standards (NAAQS) regulating pollution outputs in the state: They are too aggressive in limiting ecologically necessary fire. Fire has been interacting with vegetation as a regulating natural and critical ecological process for tens of thousands of years in California, along with rainfall, snow, wind, floods, and other natural disturbances. Unfortunately, when the new Clean Air Act regulations were drafted in the 1970s, much less was known about fire science or what a natural fire regime was, what it would mean to sustain aggressive fire suppression, or the mega-emissions that would result.

While the California Clean Air Act has made significant improvements in automobile and industrial pollution reductions since its inception, uncharacteristically frequent and intense wildfires and resulting smoke emissions have risen to hazardous levels in multiple events across the state. Recently, several air quality scientists, along with air quality regulators, medical doctors, and policy makers have taken a second look at

the harm to public health from denying fire its appropriate role in building resilience in California's forests and wildlands.

The California Air Resources Board, local air districts, the California Air Pollution Control Officers Association, federal air quality experts, and atmospheric scientists have also joined with fire managers in California (Forest Service, Bureau of Land Management, National Park Service, and the state fire agency, Cal Fire) to expand planned burning, and at the same time support the best smoke management and public health protection efforts in the country. This is a positive trend that needs to continue.

Capacity, capacity, capacity

If we had all the necessary plans and permits in place to increase prescribed and managed burning today, there still wouldn't be enough trained people to do the work. We must increase our prescribed fire workforce. Ideas on the table today include expanded prescribed fire training, support for multi-partner cross-jurisdictional burning, and increased logistical support of larger landscape burning. There is also discussion of setting up permanent, flexible wildfire crews capable of carrying out complicated burns across the state. Other issues include expanded burn windows for larger landscape fire restoration efforts, the need to resolve liability protection for prescription burning, and establishing Prescribed Burn Associations to bring private rural landowners into the restoration and maintenance fire culture.

Finally, it is critical to sustain public education and outreach regarding the need for fire restoration in California. Where there's fire, there's smoke, and we will all be affected by it. We need to include media, policy makers, and the public health community in conversations about fire and emissions tradeoffs, air quality monitoring, and fire prevention at the individual and collective scales.

The goal should be a state in which natural levels of smoke from science-based fire restoration efforts are considered normal background conditions (Schweizer and Cisneros 2016) and are exempted from regulatory limitations. Prescribed fire and smoke management collaboration efforts are expanding. When we reach meaningful ecological scales of fire restoration, we will have reached the best ecological and social outcome possible for our fire-prone landscape.

—Craig Thomas is co-founder of Sierra Forest Legacy and founder of the Fire Restoration Group.

REFERENCES

- Cisneros, R., Schweizer, D. 2018. The efficacy of news releases, news reports, and public nuisance complaints for determining smoke impacts to air quality from wildland fire *Air Quality, Atmosphere & Health*. 11(4):423–429.
- Egan, Timothy. *The Big Burn*. 2009.
- Fire MOU Partnership. Accessed Jan. 29, 2020. https://www.sierraforestlegacy.org/CF_ManagingFire/FireMOU.php
- Hurteau, M.D., Westerling, A.L., Wiedinmyer, C., Bryant, B.P. 2014. Projected Effects of Climate and Development on California Wildfire Emissions through 2100. *Environmental Science & Technology* 48 (4): 2298–2304
- Liu, X., et al. 2017. Airborne measurements of western U.S. wildfire emissions: Comparison with prescribed burning and air quality implications. *J. Geophys. Res. Atmos.* 122: 6108–6129.
- Long, J.W., Tarnay, L.W., North, M.P. 2018. Aligning Smoke Management with Ecological and Public Health Goals. *Journal of Forestry* 116 (1): 76–86.
- North, M., Collins, B.M., Stephens, S. 2012. Using Fire to Increase the Scale, Benefits, and Future Maintenance of Fuels Treatments. *Journal of Forestry* 110 (7): 392–401.
- Prescribed Fire Working Group. Accessed Jan. 2020: <https://fimt.fire.ca.gov/working-groups/prescribed-fire/>
- Schultz, C., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G., Moseley, C. 2018. Prescribed Fire Policy Barriers and Opportunities: A Diversity of Challenges and Strategies Across the West.
- Sally Jewell, Secretary of the Interior, Thomas J. Vilsack, Secretary of Agriculture. 2014: The National Strategy: The Final Phase of the Development of the National Cohesive Wildland Fire Management Strategy.
- Schweizer, D., Cisneros, R. 2017. Forest fire policy: Change conventional thinking of smoke management to prioritize long term air quality and public health. *Air Quality, Atmosphere & Health*. 10 (1): 33–36.
- Schweizer, D., Cisneros, R., Traina, S., Ghezzehei, T. A., Shaw, G. 2017. Using National Ambient Air Quality Standards for fine particulate matter to assess regional wildland fire smoke and air quality management. *Journal of Environmental Management* 201: 345–356.
- Steel, Z.L., Safford, H.D., Viers, J.H. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere* 6 (1): 1–23.
- Stephens, S. L., Martin, R. E., Clinton, N. E. 2007. Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands. *Forest Ecology and Management* 251: 205–216.
- Taylor, A.H., Trouet, V., Skinner, C.N., Stephens, S. 2016. Socioecological transitions trigger fire regime shifts and modulate fire-climate interactions in the Sierra Nevada, USA, 1600–2015 CE. *Proceedings of the National Academy of Sciences* 113 (48) 13684–13689.
- U.S. Dept of the Interior, U.S. Dept of Agriculture. *Guidance for Implementation of Federal Wildland Fire Management Policy*, 2009.



DEVELOPING THE INFRASTRUCTURE NEEDED TO RESTORE FOREST HEALTH: TURNING WOODY BIOMASS INTO ENERGY IN THE NORTHERN SIERRA

Jonathan Kusel

In September 2007, the Moonlight Fire burned 65,000 acres of forest land in the northern Sierra, emitting the annual carbon equivalent of 750,000 gasoline-powered cars. The fire also ravaged habitat for several sensitive species, including nesting habitat for spotted owls and goshawks. The U.S. Forest Service reported that 38,000 acres had burned at high severity.

Six years later, in 2013, an agency survey of the area found that shrubs now occupied 29 percent of the landscape, compared to only three percent before the fire. Sierra mixed conifer, true fir, and yellow pine forest types all gave way to the shrub encroachment (USDA Forest Service, 2013). Researchers from the University of California at Davis examined large fires that burned between 1999 and 2008, including the Moonlight Fire, and reported in the October 2019 issue of *Ecosphere* that high severity fires not only destroy forests but lead to reduced plant diversity. Other researchers have found that the shrub fields emerging five to ten years after high severity wildfires have more limited plant diversity than the forests that preceded them (Richter, 2019). What can be done to reduce this type of risk in our subalpine forests, where a legacy of fire suppression has led to dangerously high levels of forest biomass that contribute to the severity of these modern wildfires?

The nonprofit Sierra Institute for Community and Environment has been working for more than 10 years to improve forest and watershed health while also revitalizing rural economies and reducing the risk of catastrophic wildfire by increasing the utilization of low-value wood from forests of the Upper Feather River Watershed. In our rural Plumas County home in the northern Sierra, we are advancing community-scale wood utilization projects that create a market for woody biomass: the small diameter trees and other woody material that need to be removed from the forest to reduce fire risk and restore forest health.

To advance this vision, in 2018 the Institute completed installation of a small-scale, biomass-fired combined heat and power boiler system in Quincy, California. The system, one of the first of its kind in the state, generates both heat and electric power for the Plumas County Health and Human Services Center (HHSC), one of the largest buildings in the county, and one that has historically had high heating costs.

Wood chips derived from material removed as part of forest restoration projects fuel the boiler, which uses up to 400 tons a year of this fuel-reduction wood product (to produce 800 kW of heat). The boiler system burns the chips to heat water that is circulated throughout the building to provide heat. The heated

Above L-R: Biomass boiler burning inside the novel cross-laminated timber building; cross-laminated wood wall panels lowered into place; roof panel being lowered onto the structure. [Photos courtesy of the Sierra Institute for Community and Environment]

water is also used to heat an organic thermal oil to produce electricity through an Organic Rankine Cycle (ORC) power generator. The ORC generator converts thermal energy into mechanical power. As the thermal oil vaporizes, it creates pressure that spins a turbine that makes the power for electricity (up to 35 kW), which has the added advantage of being a closed system: As the organic fluid cools, it is condensed and reused. Another advantage is that, unlike water, the organic fluid does not corrode metal parts of the turbine. Together, the boiler and ORC unit are called a combined heat and power (CHP) system.

The boiler uses wood removed from nearby forest restoration projects, and in so doing creates value for this material that would otherwise be disposed of through burning. Compared to open pile burning in the woods, the most economical disposal method, burning forest biomass in a boiler results in a 98 to 99 percent reduction in emissions of fine particulate matter, carbon monoxide, non-methane organic compounds, methane, and black carbon, among other pollutants.

Like in many rural counties across California, inexpensive natural gas is unavailable in Plumas County, and most public facilities rely on expensive fossil fuels transported from afar for heating. Biomass fuel, on the other hand, is locally derived and relatively inexpensive, with prices more stable than those of fossil fuels. This helps counties avoid scrambling to meet costs when fossil fuel prices spike. Using biomass for heat and power can therefore reduce energy costs, fossil fuel use, and harmful emissions, at the same time that it supports essential fuels reduction work to lessen the risk of high severity wildfire and associated emissions. The biomass per boiler installed at the HHSC saves the county \$30,000 year in heating costs over a standard electric boiler for heat, and further reduces GHG emissions by securing fuel locally.

This project is also innovative in another way: The HHSC biomass system is housed in a full cross-laminated timber (CLT) building, the first of its kind in California. CLT is made out of multiple layers of solid lumber that are laid flat against one another, with each layer of lumber lying at 90 degrees to the layers above and below it. Layers are glued together, creating a strong, durable panel of wood. The walls of the HHSC boiler building are five layers thick and the roof is seven layers thick. Because CLT panels are multi-layered with no air space between layers, they have proven to be extremely fire resistant and seismically sound, as compared to the two-by-four lumber that is used in standard stud and fiberboard home construction. Use of CLT in buildings

Right: Moonlight Fire, 2007.

[Photograph courtesy of Wikimedia Commons]



also offers a tremendous opportunity to have carbon sequestered in a durable building product.

Construction of the CLT building was completed in two days. Use of local contractors for construction of the CLT building and biomass facility resulted in nearly \$1 million being pumped into the local economy. The project was made possible by a \$2.3 million California Energy Commission grant to fund development of the combined heat and power system; Plumas County contributed another \$400,000 for the building, with the remaining funds donated by the U.S. Forest Service, Sierra Nevada Conservancy, and the Barrett Foundation.

This biomass system and its CLT building at the HHSC are an example of how locally-sourced and abundant biomass material can be used to benefit both forests and local communities. Sierra Institute is working with the county school district and sheriff's department to install biomass boilers at a local high school and a new jail, respectively. A similar system based on the HHSC boiler is under development at a Lake Tahoe ski resort.

Of course, one or two or three such HHSC boilers can only make a limited dent in the abundant biomass that needs to be cleared from the currently overstocked forests of the northern Sierra. But as philosopher Lao Tzu said, "The journey of a thousand miles begins with one step." The HHSC biomass system in a CLT building is a first step and an important example of the wood utilization infrastructure needed to successfully reduce risks of catastrophic wildfire, restore forest health, and sustain the diversity of animal and plant species on which we depend, while also supporting rural communities.

—Jonathan Kusel, PhD, is the founder and executive director of the Sierra Institute for Community and Environment

REFERENCES

- Richter et al, 2019. The species diversity × fire severity relationship is hump-shaped in semiarid yellow pine and mixed conifer forests. *Ecosphere*. 10: 2150-8925
- USDA Forest Service, 2013. Moonlight Fire Restoration Strategy Forest Service, Plumas National Forest, Mt. Hough Ranger District.



LOOKING FOR MULTI-BENEFIT SOLUTIONS: RESPONDING TO FIRE IN THE SONOMA VALLEY CONVERSATION WITH CAITLIN CORNWALL OF THE SONOMA ECOLOGY CENTER

David Loeb

In October 2017, Sonoma and Napa counties were hit almost simultaneously by three separate wildfires (Tubbs, Nuns, and Atlas) that are collectively referred to as the Wine Country Fires. At the time, the Tubbs Fire was the most destructive wildfire in California history (a title it held for only a year, when it was surpassed by the November 2018 Camp Fire). These fires burned over 210,000 acres, claimed 44 lives, destroyed some 7,800 homes and other structures, and introduced a new narrative about the capacity of wind-driven wildland fires to cause significant damage in urbanized areas.

The Sonoma Ecology Center is a nonprofit organization that has been advocating for the environmental health of the land and people of the Sonoma Valley since 1990, and will celebrate its 30th anniversary on Earth Day, 2020. In response to the burning of more than one quarter of the landscape of the Sonoma Valley in the Nuns Fire, the Center's staff quickly rolled out a number of programs to help the community respond to the fire and heal from it. Soon thereafter, the work shifted to advocacy for initiatives and practices to make the valley's human and natural communities more resilient to future fires.

In October 2019, as the smoke from the Kincadee Fire in northern Sonoma County was still impacting air quality in the county, I traveled to the modest offices of the Sonoma Ecology Center in portable trailers along the banks of Sonoma Creek to talk to Caitlin Cornwall, who directs planning and partnerships for the Center, and Restoration Manager Jason Mills. We discussed the Center's perspectives on living with and responding to fire in Sonoma County.

DL – Your organization's website talks about a three-part response to the 2017 fires: education, active response, and prevention. Is that still a good way to frame your response to wildfire in Sonoma Valley?

CC – You know, I don't think these are the right categories now. The one that's not working for me is "prevention." There's no such thing as preventing fire in California. Collectively we could do a much better job

of preventing harm to people and their stuff from fire, but it would be impossible and counterproductive to try to prevent fire.

The categories that I thought you were going to ask about are the three that we use to talk to people about

Above: After the 2017 fires, the Sonoma Ecology Center led "fire recovery walks" through the burned areas of Sugarloaf Ridge State Park, to demonstrate the resilience of the native landscape.

[Photograph courtesy of Sonoma Ecology Center]

fire in its causes and appropriate responses. Those categories still ring true: One is the direct effects of fire on people. Second is how fire behaves in a healthy natural setting. And the third is what fire means in places that are already disturbed.

We devised those categories because what people should do is really different in those different categories. Impacts on people is all about emergency response, fire prevention, defensible space, fire-ready houses; land use, that is, where we put houses; electrical infrastructure; human caused ignitions; and social services.

The second category is wild places; that's where we talk about the incredibly extensive pattern of fire during Indian times, fire adaptations of all of the native flora and fauna, the potential benefits of prescribed fire (if it's done right), how fire rejuvenates plant communities (if it's on the right return interval). That's a huge topic.

And then the third category includes things like erosion, invasive plants, biodiversity, those parts of the landscape that need a lot of stewarding and active work that they aren't currently getting—invaded grasslands, areas near roads. By the way, there was a scientific study that came out the other day that showed how invasive plants have increased the risk of fire as much as climate change.

DL – Let's go back to the question of the Ecology Center's response to the October 2017 fires. What were some of the programs you developed to deal with the fires and their aftermath?

CC – One of the very first things we did right after the fire was respond to the crisis posed by the number of charred wrecks of houses with the rains coming on. These were essentially piles of toxic ash and debris. If you think about it, most of what's in a house, if it burns, is toxic. It was going to start raining soon, and all of this toxic stuff was going to wash into our creeks. And that was especially a problem here in the Sonoma Valley because we weren't going to be first on the EPA's list for containment work, because our population density here is much less than Santa Rosa's.

So we had no idea when they [EPA] would get here, they were so completely overwhelmed by the scale of the problem—the number of houses—that required containment. So we came up with this emergency program, with volunteer crews and emergency funding from the State Water Board, to map out the location of burned structures in Sonoma Valley, and where they were in relation to steelhead streams. Then we located



Caitlin Cornwall leading a spring hike at Van Hoesear Preserve, a privately protected grassland preserve in Sonoma Valley managed by the Sonoma Ecology Center. [Photograph by David Loeb]

nearby staging areas, and got truckloads of straw wattles and sand bags, and trained volunteers to install them. And more important than the materials was our experience in this area. We do a lot of erosion control in normal times, so we have the experience of thinking like water, putting the wattles in the right place, etc. So our restoration staff already had a background for this task. The hardest part about this project was reaching the residents [of the burned homes] to get permission to work on their properties. So many of them had left the area.

DL – What was the scale?

CC – Oh, hundreds of houses. And we just did it in Sonoma Valley.

DL – What other programs did you institute in response to the fires?

CC – Immediately following the fires we created pop-up day camps, to address the unbelievable level of chaos and disruption that happens when the schools are shut down. Children are so stressed out by the uncertainty; when they see that adults are uncertain about what's going to happen next, they can get really upset. When we do stuff with kids, we talk about the fires, about climate change, about why this is happening.

Then after the immediate emergency of the fires had passed, we took hundreds of people on fire recovery walks, primarily at Sugarloaf Ridge State Park, but other places around the Valley as well. We worked hard to craft the messages we wanted to get across. We wanted to address people's emotional trauma as well as educate them about the resilience of the landscape and the benefits of fire. No one on those walks had ever really touched these topics in this fashion. It felt really revelatory. Both to deliver this content and for people to receive it. It was pretty emotional. People were in a very ripped-open state emotionally, and we

wanted to be with them in that state, to acknowledge it, and at the same time let the vitality of the land help them be healed. And that's what happened. For most people, those topics were utterly novel, and we felt it was important to experientially convey to people—not just with words, but by walking and touching and smelling—that the land knows fire and was not harmed by it.

There were people on some of the earlier walks who work in the healing professions, who ended up bringing whole groups of their peers on later walks, because they needed the sort of metaphorical language of the land healing to help other people heal.



DL – And you also did other kinds of education about fire ecology?

CC – Yes, we integrated fire ecology into our existing environmental education curriculum that we do in all the schools in the Valley, including field trips. We do these programs for the 2nd, 4th, 5th, and 6th grades.

But beyond that, one of our biggest concerns was that people would take their fear of fire and use it to rationalize cutting down everything that grows on their property. For most people living in California now, fire is a new topic. Or at least it's newly relevant, and it's complicated. People usually get confused or overwhelmed or they apply a fact they've heard about fire to a situation that's not appropriate.

The biggest misapplication of fire facts that we see all over California is the belief that fire suppression is a major reason that we have these dangerous fires. That may be true in some plant communities, but it's not in others. Fire suppression in the forests in the Sierra, yes. But fire suppression in chaparral is not a reason we have lots of fire in chaparral. So when people misapply some of the facts, it can lead them to support problematic solutions.

So one of our projects was to produce a brochure putting out the message that your property can be

Left: Jason Mills doing post-fire transect monitoring at Upper Bidwell Park outside Chico as part of a study on the effects of prescribed burning on species composition in California grasslands. [Photograph by Ayla Joy Mills]

Jason Mills: Fire Resilience for Homeowners

Jason Mills is the Restoration Manager and Fire Ecologist for the Sonoma Ecology Center. One of his roles is to respond to requests for advice from local landowners who want to make their properties more fire resilient.

We have a program where we advise landowners in the Valley on what's happening on their properties and how to manage them to be more fire resilient. People don't have the time with their busy lives to understand this on their own. We go out and take a look at what's going on and provide an assessment. And I'll probably say that you don't want any vegetation within that first five feet from your house. Pathways, hardscaping, whatever it is, could be used, but you might have to sacrifice whatever you have growing there.

Then in the next 30 feet out, that's generally where people have their ornamental, irrigated, maintained landscape. That's a really sensitive subject, because these are the plants that people paid for, cared for, feel connected with. We don't get involved with clearing those plants, though we might point out that this is a woody plant full of oils that is more flammable than that plant. But we're not going to recommend decimating people's ornamental landscapes. And it's been shown that if these areas are receiving irrigation and are maintained and limbed and properly attended to, it lowers their flammability. Also, rather than take all the trees out, let's preserve them, so you can have shade and allow for herbaceous, rhizomatous, low-growing native plants to get established as ground cover. The more shade you have, the more you can do your irises, your blue-eyed grass, heuchera, carex, juncus, all of these low-growing natives. And that's going to be your best planting option within

made ready for fire *and* be wildlife friendly *and* water conserving. You don't have to choose. There are design and maintenance practices that can achieve all three objectives.

And now we're following up the brochure with workshops in neighborhoods that are at high risk of fire. The challenge for landowners is that they're receiving all these different messages that tend to be driven by just one issue at a time, and it's our job to integrate all of these admirable objectives—being ready for fire, being good wildlife habitat stewards, using less water, and being climate smart—into a unified set of practices.

Our society has a whole set of complicated problems right now in relation to the planet, and the right course of action isn't to try to solve these problems as if they are separate. That's just playing whack-a-mole. The right solution is to paint a picture of a better way of living on Planet Earth that addresses all these problems at once.

Yet it's important not to present all these problems as a horde of ten thousand, because that just paralyzes people. But it turns out that the solutions *do* reinforce each other and make for a better life overall. So if people can do their defensible space in a way that maintains their tree canopy and that focuses on long-lived native plants, they really will be conserving water, providing habitat, and making their house safer. Whereas if they do it in a scorched earth way, and open up their

yard to too much sun, and disturb the soil, they're going to invite in a whole crop of invasive, short-lived grasses, and make their property less safe. *And* require a ton of maintenance. *And* be ugly!

DL – I've heard you talk about the tension between the need to get people back into their homes as soon as possible, and the need to have those homes rebuilt in a more sustainable way.

CC – Unfortunately, land use policies and construction standards have not really changed. Polling shows that people think that housing should not be allowed in high fire risk areas, but they don't think that they themselves are in such an area. And of course, California *as a whole* is a high-risk area, so we can't eliminate all risks. But every new house in California is required to be built earthquake-ready, so why on earth don't we require houses to be fire-ready? And on the land use question, there are so many reasons to prioritize compact development and avoid isolated houses out in the woods. We're not the frontier anymore!

So the right community response to the belated realization that we live in a fire-prone place would be things like compact development, distributed power generation, renewable energy, electrification of things previously powered by combustion, microgrids. And having healthier land would help too, dealing with invasive plants, getting fire back to being a beneficial tool instead of a demon of chaos and destruction.

30 feet of the home. But if you cut everything down, and get all this sun in there, it's going to be harder to keep all of this wet and happy through the fire season.

Once you get outside that 30 feet, that's generally where you encounter wild vegetation. In that area, we advise and do active management to protect those resources. People really want to be proactive, anything that's burned they want it gone. Like, they want to take down burned trees, and yet that costs a lot. And when you bring in the tree companies, they may not be looking at this from an ecological perspective. So we're seeing a lot of damage being done to native trees that might have recovered if left alone. So when we come in, we can look at the trees for canopy damage, cambium damage, fungus and insect infestation. And come up with the likelihood of specific trees making it. UC Extension has a recent paper on recovery and mortality of burned oaks, and the US Forest Service has a paper on burned conifers, and those are great. But it would be really nice to have species-specific protocols for assessing post-fire tree mortality for hardwoods, such as madrone and buckeyes.

And then out there in the wildland, we prioritize removing the invasive weeds. Because the most aggressive plants are going to be your fuels. All this new growth in the spring is going to be flashy, flammable fuel in the peak fire season. And if you wait too long, until it starts turning brown, in late May, and the seeds are already forming, then you hire landscapers to go mow it all, and they're spreading the seed all around. But if you can get in there on those annuals in March, start mowing early, you could actually knock back the seed trajectory and start transforming the landscape back into an area that has more native beneficial habitat. And then if you shift to establishing native perennial grasses, they'll stay green longer going in to fire season.

DL – Is there funding for instituting any of these practices?

CC – There's funding for cutting down vegetation, which if done badly, is more of a harm than a benefit. Well, I shouldn't be so glib. The state as a whole is groping toward a long-term response to the problem. But just throwing money at people with chainsaws is not helpful.

There is a new initiative called Taking Action that's still in the discussion stage. It comes out of a realization that there are millions of acres of land in private hands that aren't being taken care of very well. People just don't have the knowledge or resources to do it right. This is everything from managing invasives to managing erosion; thinning forests where that's called for; etc. The basic concept of Taking Action is to create a self-financing mechanism for getting that work done. Not just for fire resilience, but for healthier lands overall. There are so many benefits that could come from this—water availability, biodiversity, jobs, etc., on top of reduced fire risk. So there ought to be a way to monetize these benefits of healthier wildlands. It would use science and mapping to figure out priority areas for which kinds of treatments; it would have its own equipment and crews, sort of like a utility. The way it is now, the agencies fund individual projects, but it's opportunistic instead of being systematic.

DL – What about the Sonoma Valley Wildlands Collaborative? Is that a step toward a regional response?

CC – It's a start. The collaborative is made up of six large conservation landowners—public and private—in the valley [California State Parks; Sonoma County Regional Parks; Sonoma Land Trust; Audubon Canyon Ranch (Bouverie Preserve); Sonoma County Ag & Open Space; Sonoma Mountain Ranch Preservation Foundation] who are banding together to develop permitted plans for vegetation management. The permits would come from Cal Fire. They're hoping that they can save time and money by doing it all as one entity, because their lands are almost contiguous. The Collaborative has been granted about \$1 million so far by Cal Fire, which basically just covers the cost of CEQA analysis for the work they want to do, not the work itself. But the work has already started on a small scale: County Parks has done some small prescribed burns; Bouverie did a burn. State Parks is by far the biggest player. The Ecology Center isn't officially part of the Collaborative because we don't own land, but we do work very closely with State Parks because we operate Sugarloaf Ridge State Park for them. We've already done some post-fire work for them on weed mapping there, and also mapping areas of burned Douglas fir forest, because they have Doug fir invasion issues—like many other landowners here—and the fire was actually positive on that front because it took out a lot of Doug fir, which had been part of their management plans even before the fire.

DL – Is it the objective of the Collaborative to make their conservation lands more fire resilient?

CC – There's some subtlety here. The money that was made available after the fires is coming from fire people, fire-fighting people. So that funding tends to be all about reducing fuels. But the mission of these landowners in the Collaborative is about biodiversity and conservation. So they want to use vegetation management as a tool for increasing the health of their lands. And of course that could also have the effect of reducing the risk of loss of life and property from fire. "Fuel reduction" can mean very different things. It can look like clear-cutting, or it can look like restoration. How much you cut, what you cut, when you cut, and how often you cut.



Sonoma Ecology Center staff and volunteers install fiber wattles to prevent toxic materials and erosion from burned homesites reaching local creeks.

[Photograph courtesy of the Sonoma Ecology Center]

DL – It seems that a lot of fire science and fire management practices have been developed around forests in the Sierra Nevada, or Southern California chaparral. But might we need a different set of practices here in the northern and central California coast ranges?

CC – Yes, as I said before, people can misapply facts from other parts of the state to areas where they're not relevant.

Unlike in the Sierra, there's very little natural lightning in coastal California, for example. So fires on the coast have mostly been caused by people, intentionally or not. And so the natural return interval of fire is different than it is in the lightning-prone mountains. And the concept that fires are now more severe due to fire suppression in the past, is not as relevant. Here, we have some plant communities that are vulnerable to too-frequent fires. Chaparral is a poster child for that; the natural fire return interval for chaparral is long, very long. We don't need to be doing prescribed fire in chaparral. If we do, we're in danger of losing it. While in other areas, prescribed burning is useful. In the coast ranges, we humans need to decide what we want these lands to support and then we need to work toward a fire regime that supports them.

DL – But it's my understanding that chaparral IS fire-adapted.

CC – Everything here is fire adapted, including oaks and redwoods; look at their bark. But fire in chaparral needs to be pretty rare. Otherwise, there's not enough time for it to regrow—chaparral grows really slowly.

DL – But in oak woodland, my understanding is that there was frequent low-intensity burning under Native Californian stewardship.

CC – Yes, that's right. But then you have to deal with the fact that many of our oak woodlands are completely infested with nonnative grasses, and when you burn them, these grasses do really well. So if I were designing a fire regime for oak woodland, I would design it around what's left of the native understory. Burn at the time of year that's good for those natives. The oaks are fine with a cool fire. But the timing and frequency can have a real impact on the understory plants. And so you want the timing to benefit those long-lived natives instead of the short-lived invasives.

DL – Do you think the response, both public and private, to this year's fires was improved by what was learned in 2017?



The Nuns Fire burns in the near distance in Sonoma Valley during the North Bay wildfires of October 2017. [Photograph courtesy of the Sonoma Ecology Center]

CC – Definitely. In 2017 we didn't have the content yet. Now we have this brochure. And we have developed workshops for both residents and agency personnel that focus on fire-wise, wildlife-friendly landscaping.

One thing going on now that wasn't happening in 2017 is that there are all these forces in the county working to get homeowners to implement defensible space. The county has an ordinance with inspectors going out; insurance companies are asking people to clear stuff. And PG&E is out clearing much more than it has before. And so our messaging, via the brochure and the workshops, is really important now that those programs are rolling. Because people are getting these messages to cut cut cut, but without a lot of nuance.

So it's very easy for people to believe that cutting more is going to make them safer. Some of the guidelines can be interpreted in problematic ways. For instance, there are horizontal and vertical spacing guidelines and nobody really knows where they came from. And if you followed all of them, you could do a lot of damage and make yourself less safe. So we're working actively with the county, with the fire chief, to make sure that we can be on the same page, that we figure out what people really need to know. They want to do a better job training their inspectors; they're really glad we're doing these workshops.

And again, problems arise when you look at the land through a single lens. The most fire-resistant thing you can have on your land is a paved parking lot and nothing else. So if you just pursue one objective, you won't get a desirable result. We all want to be safe, and to live in a beautiful place, in a functioning community. Generally people live here in Sonoma because they love the beauty of the land, they like being close to wildlife. So we're trying to help people see how then can have all of those values through multi-benefit solutions.



CNPS FELLOWS

CELEBRATING THOSE WHO SPEAK FOR NATIVE PLANTS

[Photograph by Catherine Traub]

Early in my tenure at CNPS, I was struck by a simple but profound statement I heard volunteers and staff repeat: ***“We are the voice for plants.”***

For those sensitive enough to hear, our native plants have something to say.

The people working to protect, study, and nurture California’s native plants are connected by the common understanding that native plants are the foundation of this place we call home. When we save these plants, we save everything else.

CNPS Fellow Ileene Anderson, the Center for Biological Diversity’s public desert lands director and former CNPS Southern California conservation botanist, once said, “If the bug has bitten you or the cactus has stuck you, and you’re hooked on plants, keep that alive! I do believe that the plants choose you.”

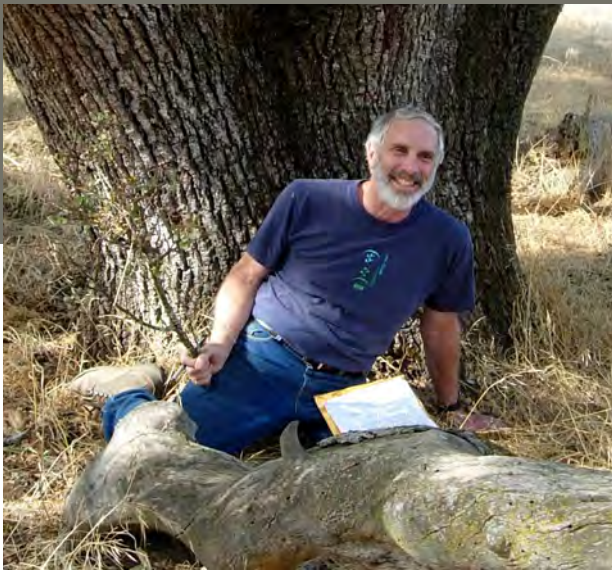
On the following pages, we celebrate an extraordinary group of people who heard that call of the green world and gave it voice—the 2016–2019 CNPS Fellows. To be named a CNPS Fellow is the highest honor given to members of the California Native Plant Society.

With this issue of *Fremontia*, we’ve got quite a few people to recognize. Please join us in thanking each of them for their service and contributions to California’s native plants.

In that same spirit of gratitude, we have four incredible lives to remember: Celia Kutcher, Les Rowntree, Steve McLaughlin, and Mac Laetsch, the first president of CNPS. While we mourn their loss, we celebrate their memories and their lasting contributions to California.

Together, these voices have made the voice for plants a cause for all Californians, and we are indebted.

~ Liv O’Keeffe is the CNPS senior director of communications and engagement



Michael Barbour is a national leader in vegetation conservation who guided the publication of the first CNPS *Manual of California Vegetation* in 1995. [Photograph by Jennifer Buck Diaz/CNPS]

To be respected in the scholarly world as well as the practical, boots-in-the-dirt plant world takes a special person. Michael Barbour is one of those rare individuals who moves freely between both realms, earning plaudits on all sides. A longtime leader for CNPS in vegetation conservation, he is also a widely published author and researcher, cherished educator, and a passionate spokesman for plants. As his Fellow nomination letter notes, he is one of California's most influential plant ecologists.

Michael graduated magna cum laude from Michigan State University, was a Fulbright Fellow in Australia, then received his doctorate in botany from Duke University in 1967. He then joined the faculty of the University of California, Davis, becoming a professor of botany and environmental horticulture. At Davis he earned a reputation for finely tuning his lectures for his audience, whether they were laypeople or graduate students. Since his retirement from UC Davis in 2008, he has remained actively involved in CNPS on many fronts, including his most recent publication through CNPS, the beautiful *California's Botanical Landscapes* (2016).

Michael has been the author or co-author of textbooks on botany, plant ecology, landscape ecology, and vegetation. He co-wrote one of the most widely used texts on plant ecology, *North American Terrestrial Vegetation*, with his major professor at Duke University, W.D. Billings. Along with his UC Davis friend and mentor Jack Major, Michael also edited and wrote portions of the first two editions of the extensive compendium on California vegetation ecology, the *Terrestrial*

CNPS FELLOW Michael Barbour

Vegetation of California, the second edition of which was published by CNPS in 1988. These books have set the stage for many developments in the study of Californian and western North American vegetation. His research work into plant ecology has taken him to many countries across the globe, including Argentina, Spain, Israel, Australia, and South Africa. He also welcomed European vegetation scientists to work with him on refining California's vegetation classification. He has published more than 50 books, book chapters, and papers, including several articles in *Fremontia*.

Michael has been involved in a number of conservation issues, demonstrating the power of conservation through scientifically defensible means. This includes the conservation and understanding of California's vernal pools. He and his co-authors developed a quantifiable approach to vernal pool classification that led to a means for putting metrics on vernal pool restoration by quantifying the deviance between created vernal pool communities and naturally occurring ones. The Environmental Protection Agency and other regulatory agencies have adopted this same methodology.

His efforts for CNPS have been as far-reaching as his academic work. In 1989 he was chosen to lead the new Plant Communities Committee, now known as the Vegetation Committee. He and his group established a sampling protocol for vegetation throughout the state, developed a database to contain collected vegetation transect and plot data, and trained many CNPS chapter members on the selection of rare communities and their sampling. Most important, his committee guided the development and writing of the first *Manual of California Vegetation* published by CNPS in 1995.

Michael not only has been a state leader in vegetation conservation, but also a national leader. He was the first chair of the Ecological Society of America's Vegetation Committee, which published the first U.S. National Vegetation Classification in 1998. And throughout his distinguished career, Michael has been a congenial, even-handed, and humorous member of the plant ecology community. As his nominators note, "CNPS and the conservation world has been extremely fortunate to have him in 'our corner.'"

—Kathy Morrison



Under Julie Evens' leadership, the CNPS Vegetation Program became an important partner for county, state, and national agencies. (Left) Julie with her children Leo and Daphne Cox at Carrizo Plain National Monument. [Photographs by Jeffrey Cox]

CNPS FELLOW Julie Evens

Being the first of anything can be tough, especially when expectations are high. That was the situation Julie Evens faced when she became the first full-time CNPS vegetation ecologist in 2001. Thanks to her efforts, the CNPS Vegetation Program has since grown in size and prominence, earning state and national respect as a leading force in ecosystem classification and conservation. CNPS recently recognized Julie Evens for her dedicated advocacy and support of the program with its highest honor, the title of Fellow.

Julie grew up in the Midwest and arrived in California to attend the University of California Santa Cruz (UCSC). As a horticulture intern at the UC Santa Cruz Arboretum, Julie assisted in the California collections, especially Channel Islands endemic plants. She graduated in 1995 with two BA degrees in environmental studies and biology/botany with honors.

Fresh out of college, Julie worked as a scientific aide with the Natural Diversity Database Natural Communities Program, where she helped inventory valley oak riparian forest in the Sacramento and San Joaquin valleys. She went on to be a field team leader in the joint State and Federal Mojave Desert Ecosystem Program, Central Mojave Vegetation Database Project. She and others collected more than 1,200 relevés throughout the central Mojave. This information formed the basis of the Mojave Desert Ecoregional vegetation classification, which was used to make a map of approximately 12 million acres of desert.

As a Humboldt State graduate student, Julie decided to explore the ecological intricacies of desert wash systems and spent two field seasons collecting relevé samples in the Sweeney Granite Mountains Reserve. Her master's thesis was an analysis and definition of the Eastern Mojave wash vegetation. It remains the authoritative work on the subject.

As a field team leader for two seasons in the Vegetation Classification project for Sequoia and Kings Canyon National Parks, Julie grew interested in CNPS' work. Allen Barnes had recently become the organization's first executive director, and CNPS was searching for its first full-time vegetation ecologist. Julie was selected for the position over stiff competition. Her goals for the Vegetation Program included increasing chapter involvement, and improving methods in data collection and description of vegetation. She also helped drive active conservation planning of natural communities through development of new vegetation information for key areas.

These goals took root in a project with the Santa Clara Valley Chapter, which resulted in a detailed report on the classification of Coyote Ridge, one of the premier serpentine grassland landscapes in California. To help raise awareness of vegetation conservation—a goal of the CNPS Vegetation Committee—Julie and her growing program delved into immensely detailed regional projects, such as the classification of the vegetation of Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP).

To accomplish these increasingly complex tasks, Julie became a diligent and creative grant writer and project manager. She received a competitive National Fish and Wildlife Foundation grant to test and develop efficiency and effectiveness of field data collection (Peoria Wildlife Area). Since then, she and her staff have won many contracts and grants with the California Division of Fish and Wildlife, NatureServe, National Parks Service, and others. Funding stability has allowed her program to address goals such as the writing of the second edition of the *Manual of California Vegetation*, and development of the online MCV and the MCV database.

On a more personal level, Julie has two young children and is active in the Sacramento Valley Chapter, showing off her native-plant-filled front yard during garden tours. Above all, as her Fellow nomination letter notes, "It has been Julie's strong sense of passion for her work, belief in the power of grass-roots involvement, and familial loyalty to her staff and her cooperators that has brought such statewide recognition to Vegetation Conservation."

—Kathy Morrison



Brett Hall and Tori Bauman with *Arctostaphylos montereyensis* in the Maritime Chaparral section of the California Conservation Gardens at UCSC Arboretum. [Photograph courtesy of Brett Hall]

Educator, advocate, enthusiast— all are characteristics that describe Brett Hall and his invaluable contributions to the California native plant community. As California Native Plant Program director of the UC Santa Cruz Arboretum, he has been deeply involved in teaching about and conserving native plants. Having served as president of the state CNPS board as well as the Santa Cruz and Tahoe chapters, he has spread the mission of CNPS and worked tirelessly on projects such as the new Important Plant Area (IPA) initiative. His botanical pursuits cover everything from plant sales to seed banks.

This dynamo of native plant advocacy was born in Carmel and grew up exploring the flora of the Santa Lucia Range. After working in his family's landscaping and garden design business, he enrolled in UC Santa Cruz and received a bachelor's in natural history and biology. Ken Norris and Ray Collett were among his instructors; their legendary Natural History Field Quarter courses launched many environmental careers. While at UCSC, Brett worked at the Arboretum, which was still in its early days, and his senior project was a study of the rare plants of Santa Cruz County.

In 1975, Brett became an official staff member of the Arboretum, and two years later was promoted to botanical garden manager. About this time, he joined the Santa Cruz Chapter of CNPS and became one of its great champions. His nominator, colleague and fellow CNPS member Dylan Neubauer, says, "Indeed, a more exemplary advocate for the organization would be hard to find."

CNPS FELLOW Brett Hall

The Santa Cruz Chapter, though small in those days, was able to preserve several special botanical areas in the county, including the Bonny Doon sandhills and the Glenwood grasslands, both home to federally and state-listed taxa. "Brett's earnest and hands-on style (never one to wear a suit to a meeting or hearing!) was invaluable during those early efforts as well as later ones," recalls botanist Laurie Kiguchi. "His trustworthiness and dedication were apparent, and he always came across as calm, thoughtful, and open."

Brett became director of horticulture at the UCSC Arboretum in 1985 and worked to expand its holdings, traveling and bringing in many ornamental plants that then were new to California horticulture but became popular in the nursery trade. He was director of collections and conservation in 2014-15 before assuming his current position as California Native Plant Program director. The Arboretum now is well known for its collections of Mediterranean-climate plants, including California natives. One of Brett's long-term projects, the California Conservation Garden, houses a large collection of rare manzanitas, a favorite genus of his.

Brett's passion for native plants is a common thread of his Arboretum work and his efforts for CNPS. For many years he served as coordinator of the semiannual CNPS plant sales, which were held alongside the spring and fall Arboretum sales. The venue for CNPS meetings for many years, the Arboretum also hosted chapter council meetings in 2009 and 2013 while Brett was chapter president. He joined the CNPS state board of directors in 2007, served as state president from 2009-13, then rejoined the board in 2016. He added numerous roles to his Santa Cruz Chapter activities, then helped revive the Tahoe Chapter in his "second home," becoming its president in 2014.

Brett has been deeply involved in the California Rare Plant (CaPR) initiative, seedbanking of rare and locally rare plants, and CNPS' Vegetation Program and new Important Plant Area initiative. His students benefit from his knowledge and enthusiasm for all these projects. As Neubauer notes in his nominating letter, "A true educator, Brett knows how to convey his expertise about California places and plants in a way that gets people turned on—for life."

—Kathy Morrison



CNPS FELLOW

Dave “Kim” Imper

Dave Imper, also known as “Mr. Lily,” has worked across government agencies to establish protections for rare plants.

[Photographs courtesy of Dave Imper]

David Kimberly Imper answers to both “Dave” and “Kim” but plant folks like to call him “Mr. Lily,” for his work with the endangered Western lily (*Lilium occidentale*). Now retired from his position as a U.S. Fish and Wildlife (USFWS) biologist, Imper is respected in the North Coast region for his academic and professional knowledge, as well as his willingness to stand up for the plants, even putting his job on the line when necessary.

Dave earned a BS degree in botany from Cal Poly San Luis Obispo and a master’s in botany and plant pathology from Oregon State. His professional career included time with the U.S. Forest Service, LACO Engineering Consultants, SHN Engineers & Geologists Inc., and finally USFWS, where the service hired three botanists to replace him after his retirement. His professional ethics always were foremost, say the writers of his Fellow nomination. They offer these examples:

“He reported a timber company to the Army Corps for illegally filling part of Crescent City Marsh. When Pacific Lumber Co. demanded that a section on obligate wetland plants be removed from a report on a timber harvest survey, Dave said, ‘Why don’t we call the Army Corps and see what they think?’ You can guess how that debate ended! He did wait until he retired to confront the Six Rivers National Forest on their lack of stewardship of the Lassics Lupine and then to proceed with the listing petition.”

Dave did not shy away from working with other agencies to protect rare plants. His partnerships

ranged from the Bureau of Land Management to the Humboldt County Roads Department, from the California Department of Fish and Wildlife to cannabis farmers. Through these efforts, projects such as the Two-Flower Pea Reserve became reality, and the Crescent City Marsh drainage issue was fixed for the benefit of the Western lily. Drivers along Highway 101 appreciate his work with Caltrans to establish a “botanical management area” where a large, gorgeous array of native Columbia lily (*Lilium columbianum*) blooms annually.

He also was an early and dedicated supporter of the concept that loss and alteration of natural ecological disturbance is as much a threat to rare plants and natural communities as the other more typical threats. Dave helped local conservationists understand that conservation is more than just roping off land and not touching it. Many rare plant populations need a certain fire, flooding, or grazing regime, or they will not persist.

As a botanist, Dave’s experience includes botanical surveys, protection measures, conservation and recovery plans, habitat restoration and purchase, monitoring, status reviews, listing petitions, genetic studies, publications, lectures, and field trips. So it’s no surprise he has been a cherished resource for the CNPS North Coast Chapter, which he joined in 1981. He has taken on many board roles, including chapter president in 1987. He has also led field trips, served as speaker at CNPS programs, written articles for *Darlingtonia*, and built an educational booth for use at fairs and other occasions. He was an important organizer of the 2002 Rare Plant Symposium, one of the chapter’s most ambitious projects, and developed an Adopt-a-Rare Plant program for the chapter. He was also the first recipient of the chapter’s highest award, the Gilded Darlingtonia.

For the last word on the invaluable contributions of Dave “Kim” Imper, here is James P. Smith, one of the founders of the North Coast Chapter: “Few indeed have been the combination of a person with such a strong professional background, active field experience, dedication to the cause of rare plant studies and conservation, and willingness to devote his time, knowledge, energy, and personal resources to the cause.”

—Kathy Morrison



Four taxa have been named in Dave Keil's honor, pictured here receiving his Fellow award. [Photograph by Melissa Mooney]

Was David Keil born with a plant key in his hand? At the very least, he carries one around in his head. Now retired from Cal Poly San Luis Obispo, where he taught for 37 years, Dave influenced generations of botany and biology students through his classes, field trips, and research. He continues to inspire and influence his fellow members of CNPS, and especially the San Luis Obispo Chapter, as a CNPS Fellow.

Dave attended Arizona State University, earning both a bachelor's and master's of science. In 1973, he completed his PhD at Ohio State University. He joined the faculty at California Polytechnic State University in 1976, and two years later was appointed director of the Robert F. Hoover Herbarium. Students have described his field botany course as both the hardest and best of their college careers. Not surprisingly, Dave is an avid plant collector; over the years, many of his more than 30,000 specimens became part of the herbarium's collection. He received the university's Distinguished Teaching Award in 1980.

Not long after his arrival in SLO, Dave joined the CNPS San Luis Obispo Chapter. In 1978, he served as the chapter president, and has since filled many other roles, including vice president. He has regularly presented chapter meeting programs and workshops that were fun and surprising, including new discoveries and unusual findings, members say.

CNPS FELLOW David Keil

CNPS members have also benefited from Dave's knowledge on chapter field trips, including for the chapter's annual Wildflower Weekend event; Sierra Madre and Mt. Pinos weekend ventures; trips to the Carrizo Plains; and trips focusing on coastal, riparian and serpentine endemic plants. Some trips were spur of the moment, such as an evening trip to the Irish Hills for grass identification, or a quick trip to West Cuesta Ridge.

Another example of Dave's dedication is related in his Fellow nomination letter: In 2009, he volunteered for a "quick" CNPS committee to develop a guide to common plants, for distribution by the city of San Luis Obispo, and the effort turned into a multi-month project. Dave later became editor of the 86-page guide, *Wildflowers of San Luis Obispo, California*, of which an expanded second edition was recently published. In recognition of his generous contributions to the SLO Chapter, Dave was given the 1989 Hoover Award, the chapter's greatest honor.

Dave also has been active and influential at the state level of CNPS, serving on numerous committees and boards, including the Rare Plant Scientific Advisory Committee and the *Fremonia* Editorial Advisory Board. He most recently sat on the 2019-20 Education Grants Committee, a roll he also volunteered for from 2014 through 2016. He also has conducted multiday workshops on California flora for the State Education Program.

Beyond CNPS, Dave has lent his expertise to the California botanical community through his contributions to *The Jepson Manual* Project. He wrote the "Key to California Plant Families" and served as the editor and primary author of the *Asteraceae* for both editions of *The Jepson Manual*. Key writing has always been one of his strengths, colleagues say, and it is a major part of his legacy. Fittingly, four taxa have been named in this plant expert's honor: Santa Ynez groundstar (*Ancistrocarphus keilii*); Keil's daisy (*Erigeron inornatus* var. *keilii*); *Wedelia keilii* B.L. Turner, and *Chrysanthellum keilii* B.L. Turner.

—Kathy Morrison

A NEW FELLOW REMEMBERED Celia Kutcher

(December 1938 – November 2019)



Members of the CNPS Orange County Chapter celebrate Celia's Fellow recognition last spring. Celia at center in green. [Photographs courtesy of the CNPS Orange County Chapter]



California native plants have lost one of their greatest champions. Last spring, CNPS awarded Celia Kutcher its highest honor of CNPS Fellow, recognizing Celia for four decades of native plant conservation advocacy and service to the organization. Now, we honor her passing.

In reviewing the nomination packet submitted by members of the CNPS Orange County Chapter, one is struck by one theme more than any other: the powerful example Celia set for others. Whether drafting meticulous comment letters in defense of endangered species, creating native gardens, or cleaning up after events, Celia did it all. Her nominators say the other chapter volunteers couldn't help "but follow her lead." Celia's example was an inspiration, and for so many reasons.

Celia is perhaps best known for her steadfast conservation work at the local level, where she served as the CNPS Orange County Conservation chair for 25 years, and statewide, as a member of the Conservation Program, Litigation, and Policy Committees. In 1997, she formed and chaired the Dana Point Headlands Action Coalition, taking on powerful interests to protect the last undeveloped headland in Orange County. The group's partial victory saved two federally endangered species and set aside a large Environmentally Sensitive Habitat Area for rare native plants.

Celia was an expert across many of California's most complex environmental issues, providing valuable input on behalf of her chapter and the statewide orga-

nization. "Whether on realistic fire/fuel management strategies, watershed issues, toll road proposals, legislative attacks on CEQA and many other CEQA-related issues, DEIR and EIR biological resources reviews, invasive plant topics, or NCCP actions, her detailed language is accurate and well supported, her tone is never strident or accusatory, always courteous and professional," said her nominators.

Celia held degrees in both botany and plant ecology and a master's in environmental studies from California State University Fullerton, where she served as the Fullerton Arboretum's curator of plant collections for 22 years. During that time, she directed the planting of Chaparral Hill, a native plant collection with trails and interpretive signage spanning more than an acre. She also designed the native landscape around the Oak Hall complex and organized CNPS Orange County Chapter members to install the garden. Both Fullerton landscapes were the first public native gardens in Orange County. Later, Celia organized a similar effort for the UC Irvine Arboretum, leading the chapter's creation of three California Gardens.

Celia directed her chapter's early efforts at controlling invasive weeds in county wildlands and served as an active member of the Orange County Chapter's award-winning Invasive Plant Program's Early Detection/Rapid Response Group. A founding member of the Orange County Chapter, Celia filled nearly every volunteer leadership role at one time or another, from vice president and historian to plant sales chair. Not surprisingly, her fellow volunteers awarded her the chapter's "Native Perennial Award" in 2008 and Board Member of the Year in 1999.

It is with much admiration and gratitude that we honor Celia Kutcher's contributions and life. A remembrance by her fellow Orange County Chapter member and friend Dan Songster appears on page 60.

—Liv O'Keeffe



CNPS FELLOW Dianne Lake

CNPS Fellow Dianne Lake was one of the first advocates for the concept of “locally rare” plants. She continues her work monitoring locally rare plants today and has authored a guide to help other chapters do the same.

[Photograph courtesy of CNPS East Bay Chapter]

Dianne Lake discovered botany during summers spent eating blackberries and caring for her grandmother’s garden in St. Charles, Illinois. These childhood pleasures formed an early stewardship ethic, which Dianne has enacted through decades of observation, advocacy, and leadership on behalf of California’s native flora.

A self-taught botanist, Dianne gained her knowledge of the flora of the East Bay by joining CNPS hikes, taking courses at Peralta and Merritt College, “pestering” the former director of the Tilden Botanic Garden, as she puts it, and hiking in the wilds of the East Bay with her kids.

While on East Bay Chapter outings in the 1980s, Dianne noticed that certain native plants were present all the time, while others could be found only occasionally, and some very rarely. She concluded that a list of East Bay plants with five or fewer known locations should be compiled. In this way, Dianne became an early advocate for the concept of “locally rare” plants that scientists consider sensitive or unique in a specific region.

Dianne’s observations kicked off a collaborative search for botanical information, including chapter and East Bay Regional Park District plant lists, conversations with other botanists, herbarium vouchers, field notes, and Environmental Impact Reports. The resulting list included 861 plants, and prompted Dianne to develop criteria for listing and ranking each plant.

In the years since, Dianne and her partners have produced eight hardcopy editions of the *Unusual and Significant Plants of Alameda and Contra Costa Counties*, which they converted to an online database in 2010. In all, they’ve tracked more than 1,000 plant taxa and compiled 18,000 observation records from 1,050 people. Dianne herself has personally reported 4,993 observations.

Dianne has been a member of CNPS for decades. She served on the board of the East Bay Chapter for approximately 28 years, continuing as a board member today. When Franklin Canyon in Contra Costa County was slated for development in 2004, Dianne went from door to door, collecting signatures to support the *Protect Franklin Canyon Area Initiative*.

Her efforts helped get the initiative on the ballot, ultimately saving Franklin Canyon and the nine locally rare plants that live there. In addition, Dianne participated in the efforts to get Richmond to include protection of locally rare plant species as a priority in its general plan.

Since Dianne started her work, many others have been inspired to develop lists for their chapters and counties—helped in no small part by Dianne’s how-to guide, *Establishing a Locally Rare Plants Program for Your Chapter*, which can be found online at cnps.org/locally-rare-chapter-program-guide.

Not one to slow down, Dianne continues her work alongside other chapter volunteers to continually monitor plants and update their knowledge of the East Bay flora. Dianne’s energy, conservation ethic, and steadfast study of the East Bay flora are an inspiration to all.

—Adapted by CNPS staff from text by Heath A. Bartosh

CNPS FELLOWS

Carol LeNeve and Brian LeNeve

Working both together and separately, Brian and Carol LeNeve have dedicated decades to California native plants and habitats, and to CNPS. Their story starts with Carol, “the glue that has held together the Monterey Bay Chapter,” as her Fellow nomination letter puts it. She joined the chapter in 1980 and quickly became involved in the annual plant sale. At that time the sale was held on the lawn of Carmel High School. By the late 1980s, Carol was in charge of the event, raising its profile so it became the primary fundraising source for the chapter.

The sale moved to the Monterey Peninsula College parking lot by the early 1990s, where high-quality plants chosen from local wholesalers drew a growing clientele of native plant gardening lovers. Carol developed sales aids, too, including cards for each species with color photographs and informative labels. The sale has since moved to the Hilton Bialek habitat area at Carmel Middle School, and Carol retired from sole management of the event in 2012, but she set the standard and helped establish stability for the Monterey Bay Chapter.

On the statewide level, Carol served as editor of the CNPS state bulletin from 1988 to 1994 and sat on the state book publication committee. She selected titles to be offered at the plant sale and chapter meetings. Proceeds from those book sales went into a special educational fund. In 1997 “a longtime goal was realized” with the publication of (Corky) Matthews’ *Illustrated Field Key to the Flowering Plants of Monterey County*, note Chris Hauser and Peggy Grier in their nominating letter. Corky Matthews “was the first to say that the project would not have succeeded without Carol’s management,” they add.

The book has subsequently been revised, each time with Carol’s careful oversight. In 2012, a revision of *The Jepson Manual* in turn required an update on Monterey flora. So in 2015 a new third edition was published, written by Michael Mitchell and retitled

Carol LaNeve has been a driving force behind seminal Monterey County botanical texts, including *The Plants of Monterey County*. [Photograph by Michael Mitchell]



The Plants of Monterey County. Carol again had a hand in the work: She enabled Mitchell to get started by taking on the huge project of creating a “crosswalk” database of old and new plant names.

Early on she joined the weekly day trips of Matthews, Vern Yadon, and Ron Branson, seeking out rare or unusual plants in the little-traveled areas of the county. (Interestingly, some of these trips wound up at the LeNeves’ ranch in Priest Valley, in the southeast corner of Monterey County.) She assisted Matthews and Yadon in the long-term project of updating the herbarium of the Pacific Grove Museum of Natural History, where Yadon was the director. She also compiled a display of the Ten Most Wanted (weeds) of Monterey County, which she toted to any and all meetings of environmental groups. Her dedication, knowledge, and attention to detail—not to mention her famous chocolate chip cookies—have made her an invaluable member of the chapter and the Monterey region plant community. At present she serves on the chapter board.

With Carol deeply involved in CNPS, it was bound to rub off on Brian. It took a while, but he became so interested in native plants and conservation that he’s now known as “Mr. Clarkia.” Brian grew up in the Carmel area, following in his father’s footsteps as a painting contractor. At first he was just an occasional driver on those plant-hunting drives around the county. As Carol took on more responsibility with the chapter plant sales, Brian became her go-to delivery man, banner installer, and general laborer. The couple



An expert in riparian habitat and clarkia, Brian LeNeve has been an adviser on the project to remove the San Clemente dam and redirect the headwaters of the Carmel River. [Photograph courtesy of CNPS]

developed a tight organization behind the scenes that became their trademark.

Brian eventually expanded his involvement to the Pacific Grove Wildflower Show, which Yadon and Beatrice Howitt founded at the Pacific Grove Museum. This annual event, now in its 59th year, requires a huge amount of legwork from CNPS members and other plant lovers. In his Fellow nomination letter, Grier and Hauser describe how Brian sets up tables and collection lists for the show, handles all coordination with museum staff, then oversees set-up day when the work crew transforms a sea of plant specimens in buckets in to a highly organized show that attracts many hundreds of plant lovers.”

A few years ago Brian finally was joined by a CNPS co-chairman to relieve him of some of the duties of the wildflower show. Since retiring from his painting business, he also has served three terms as president of the CNPS chapter, as well as serving on the state board of directors and the chapter council.

So how did he become Mr. Clarkia? About 15 years ago, Brian took on a year-long study of species occurring in a quadrant at the Church Creek divide, near Chews Ridge and China Camp, and later presented a program on the area at a chapter meeting. His long-term interest in clarkias took him to the Jepson Herbarium at UC Berkeley to review clarkia species across California, and he decided to track them all down, as well as species in neighboring states. Corky

Matthews, herself a CNPS Fellow, now calls him a leading authority on the genus.

The longtime hunter-fisherman also jumped into helping with the problems of steelhead in the Carmel River, eventually becoming president of the Steelhead Association. In the course of his steelhead involvement he developed expertise on riparian habitats, and now serves as consultant and adviser on the monster project of removing the San Clemente dam and redirecting the very headwaters of the Carmel River. (In winter months he takes time for multiple trips to fish the streams of Northern California.)

Brian’s newest role is chapter representative to the BLM monitoring of the Clear Creek area in the interior of Monterey County. The mission is protecting rare plant species in a serpentine area frequented by off-road vehicles, a mission with its share of risks. “Brian has been our chapter’s lead person in the filing of litigation against BLM, and the result has been to ensure enforcement of their management plans,” Grieg and Hauser note.

By the way, that ranch in Priest Valley, which the LeNeves bought originally so Brian could pursue his love of hunting, is now leased to neighbors for grazing. Carol and Brian have their own “plant preserve”—they are valuable stewards of the Monterey County flora and invaluable members of CNPS and the plant community.

—Kathy Morrison



CNPS FELLOW

Larry Levine

For more than four decades, Larry Levine has quietly helped lead CNPS efforts like the CNPS Phytophthora policy, chapter council, and technology innovation. [Photograph courtesy of CNPS North Coast Chapter]

CNPS is an organization dedicated to plants, but its success relies on tending to the human side of the operation. Not many people understand this more than North Coast Chapter member Larry Levine, whose peers named him a CNPS Fellow in 2018.

Larry balances his scientific savvy with social acumen, excelling not only in rare plant research but hospitality and communications. He has conducted research into rare plants like *Bensoniella oregona* and Howell's alkali grass (*Puccinellia howellii*), and was also the first in his chapter to point out the need to serve refreshments at chapter meetings.

He instituted accessible, two-hour plant walks for his community, organizing 18 consecutive walks in one year, and was also an early technology pioneer, advocating for putting the CNPS Rare Plant Inventory online in the early 1990s.

"Larry is a solid scientific thinker and an experienced, ace botanist who has both a deep and a broad knowledge of the California flora, natural history, and ecological principles," said North Coast chapter leaders Carol Ralph and Gordon Leppig in their nomination letter.

Larry also knows how to grow an organization and its mission. As co-organizer of the North Coast chapter's wildflower show, he developed a teacher's guide for the show, managed the database and species identification cards, and supervised the plant identification crew. In his respective roles as publicity chair and webmaster, he overhauled his chapter's website and provided website mentorship to other chapters. He also wrote, edited, and compiled hundreds of public service announcements, articles, and news releases.

Not limited to the chapter level, Larry's efforts extend to the entire organization. Over 30 years of service to CNPS, he served as CNPS chapter council vice chair for 10 years and, since 2003, has served as a chapter delegate.

As vice chair, he initiated the round table approach to facilitate discussion at meetings, and took an active role in developing and organizing CNPS policies across a wide range of complex issues. He was the Phytophthora Subcommittee chair and a major contributor to the development of the CNPS policy of preventing the spread of harmful pathogens via native plant nursery and plant sale stock.

"Larry always strives for thoughtful, effective engagement that focuses on active listening, finding common ground, seeking consensus, deescalating tensions, conflict resolution, facilitating creative solutions, and diminishing interpersonal issues while focusing instead on the substance of the issue," said Larry's nominators of his ability to bring people together—a much-needed gift in today's deeply polarized world.

—Liv O'Keeffe



Award-winning horticulturalist, author, and former *Fremontia* editor Bart O'Brien helped write the book(s) on native plant gardening. [Photograph by Ashika Narayan]

CNPS FELLOW Bart O'Brien

One of California's leading experts in native plant horticulture, Bart O'Brien's impact is felt statewide. A long time member and former president of the Santa Clara Valley Chapter of CNPS, he is the current director of the Regional Parks Botanic Garden in Tilden Regional Park in the Berkeley hills. Before that, from 1990 to 2013, he worked at the Rancho Santa Ana Botanic Garden in Southern California. In 2005, the Southern California Horticultural Society named him Horticulturist of the Year.

A fifth-generation California native from Hollister, Bart received his BA in Environmental Planning at U.C. Davis and then an MA in Landscape Architecture from the Harvard School of Design. In 1981, he returned to the Bay Area to pursue a career in landscape design, eventually becoming manager of Yerba Buena Nursery, the pioneering native plant nursery in the South Bay, from 1988–1990. He credits Gerda Isenberg, the visionary founder of the nursery, with stimulating his lifelong passion for native plants.

In 1982, Bart joined the Santa Clara Valley chapter of CNPS, becoming an active member right away. He served as chapter vice president in 1983–1984 and then as president in 1985–1986, increasing public awareness of native plants through field trips, lectures, and plant sales. In 1987, Bart became editor of the chapter newsletter, starting his career as a prolific writer about native plants. He also chaired the Edgewood Park Committee, which worked to keep this botanically important open space in San Mateo County from being developed as a golf course. This resulted in the permanent protection of important serpentine grasslands and the creation of Edgewood County Park and Natural Preserve in 1993.

In 1990, Bart was lured away from the South Bay to become director of horticulture at the Rancho Santa Ana Botanic Garden (RSABG). In his 24 years at this revered Southern California institution, he introduced generations of homeowners—and water agency officials—to the beauty of native plants adapted to the region's dry climate. His years of experience and knowledge in cultivating native plants for California gardens resulted in the authoritative *California Native Plants for the Garden* (Cachuma Press, 2005), which he co-authored with David Fross and Carol Bornstein, and which won the American Horticultural Society's annual Book Award.

Bart then shifted to the role of director of special projects, giving lectures on the benefits of native plant gardening and pursuing his research into the flora of Baja California. This latter area of interest has continued even after his subsequent move back north, as Bart continues to serve on the board of Terra Peninsular, a Mexican nonprofit dedicated to the preservation of the native flora of northern Baja.

One of Bart's greatest contributions to California horticulture has been his concentration on native cultivars, reflected in the new cultivar garden he created at RSABG and an accompanying guide. Bart also served CNPS as editor of *Fremontia* from 2006 through 2009, and he remains a member of the *Fremontia* Advisory Board. He has been active in the Education Committee's Horticultural Program and continues to serve on CNPS' Horticultural Experts Committee.

In 2013, Bart returned to Northern California when he was hired to take over the position of manager of the Regional Parks Botanic Garden from retiring longtime director Steve Edwards. There, at one of the most significant collections of California native plants in the world, he has continued as a leading advocate for the use of native plants in home gardens, while expanding the garden's dedicated community of volunteers and supporters. And he has worked to deepen the garden's partnership with California Plant Rescue, an ambitious effort to create a seed bank of all of California's native plants as a hedge against extinction.

—David Loeb



One of California's most influential botanists, Dieter Wilken managed the first edition of *The Jepson Manual*.
[Photograph courtesy of Santa Barbara Botanic Garden]

CNPS FELLOW Dieter Wilken

Dr. Dieter Wilken has been a pillar of California botany since he was a graduate student in the late 1960s, and has made tremendous contributions toward the appreciation and conservation of California Flora throughout his long career. His pioneering work in systematizing the identification and classification of rare native plants has set the gold standard in that field. As the lead manager of the first edition of *The Jepson Manual* (1993) and the lead editor of the second edition (2012), Dieter has provided resources of incalculable value to those working with native plants. He continues to serve the broad community of native plant adherents in his position as Director of Conservation at the Santa Barbara Botanic Garden (SBBG), an institution he has worked for since his return to California in 1993.

Like the plants that he knows so well, Dieter Wilken is himself a California native, born in East Los Angeles in 1944. Since graduating from UC Santa Barbara with his PhD in 1971, Dieter has worked tirelessly to support the understanding and conservation of native plants in western North America, including California. He is a broadly trained systematist and a world expert on several plant groups, including the charismatic California lilacs (*Ceanothus*, Rhamnaceae), showy *Ipomopsis* (Polemoniaceae), and the genus *Hulsea* (Asteraceae). Dieter was also a trailblazer in specimen digitization, and thanks to his guidance, the herbarium at SBBG is now nearly completely digitized.

Toward the end of his two decades teaching at Colorado State University, Dieter was hired to serve as Project Manager for the ambitious *Jepson Manual* project. At the time, the project was behind schedule, over budget, and at risk of total collapse. Dieter was able to right the ship, and the first edition of the *Manual* immediately became an invaluable resource for learning about and identifying California native plants. It

would later form the basis for *The Jepson Desert Manual* (2002) and the second edition of *The Jepson Manual* (2012), on both of which Dieter served as a primary editor. Dieter also published two other important books: *Ceanothus* (2006), and the complete flora of the plants of Santa Cruz Island (1995). He completed these important books while leading applied rare plant conservation on the Central Coast through SBBG and the California Native Plant Society.

Following publication of the *Manual*, Dieter returned to California to become Director of Research at SBBG. There, Dieter founded and ran all aspects of the Garden's rare plant program from 1993 to 2013. For the Central Coast and Channel Islands, there is no one more knowledgeable or passionate about regionally important rare plants; his work with many regional stakeholders has translated into direct conservation action on behalf of native plants and habitats in the region. In 2008, Dieter received the Center for Plant Conservation's Star Award for his work in protecting rare plants.

Dieter has also provided his expertise and knowledge as a contributor to the CNPS Rare Plant Forum, the primary vehicle for soliciting information from experts for decision making pertaining to the CNPS Rare Plant Inventory (e.g., listing and delisting of taxa). From 2008 until 2017, Dieter served as a founding member of the CNPS Rare Plant Program Committee. Through this committee, Dieter evaluated hundreds of plants for CNPS listing and worked with Jim Andre and other members to standardize and formally describe the process for listing a plant through CNPS. Andre describes Dieter as "our most experienced advisor on California's rare plants."

Finally, Dieter is a prolific contributor to CNPS's very active Facebook page, where he provides patient, thorough answers to posted queries from amateurs and professionals alike. In what other venue could one receive direct feedback from the Project Manager of the first edition of *The Jepson Manual* and one of the godfathers of specimen digitization?

—David Loeb



CNPS FELLOW Joe Willingham

As a landscaper, Joe Willingham was an early advocate for native plant landscaping back in the 1970s. He's since served his chapter in myriad ways, from conservation and rare plant advocacy to website development. [Photograph courtesy of CNPS East Bay Chapter]

Most people know Joe Willingham as the indefatigable editor of the *Bay Leaf* newsletter and the computer-savvy manager of the East Bay Chapter's website. Joe's decades of service to CNPS began in 1977, after he took a landscaping course at UC Extension on California native plants taught by the legendary David Bigham. Already employed as a landscaper, Joe quickly started using California natives on his clients' properties, and has continued to use them throughout his career.

Joe joined the East Bay Chapter board of directors in 1989. He has since held more than a dozen chapter board positions, including rare plant chair, chair of local conservation issues, and several years as chapter president and vice president.

As the rare plant chair, Joe participated in scouting expeditions, wrote monthly articles and led field trips. As local conservation issues chair, he kept abreast of the issues and wrote articles to keep the membership informed. He also served many years as one of the "plant experts" available to shoppers at the yearly plant sales at Merritt College and the chapter's Native Here Nursery.

In 2003, Joe became the editor of the East Bay Chapter newsletter, the *Bay Leaf*, learning the printing business from Phoebe Watts and Brett Boltz. Joe and his wife, Doris, hosted monthly mailing parties too numerous to count, and were always generous with wine and snacks.

In 2005, he created the chapter's website and later a website for the chapter's Native Here Nursery. Joe continues to work as *Bay Leaf* editor, coordinating capable proofreading by David Margolies, Holly Forbes, and Doris Willingham.

Joe served on the chapter council from 2004–2005, following state legislation. In that capacity, he played a key role in hiring now-retired CNPS lobbyist Vern Goering, serving as Vern's liaison to the CNPS board of directors. "Joe has indeed made so many outstanding contributions to our chapter and CNPS and continues to do so," say his nominators. Those of us fortunate enough to know him will agree that Joe Willingham deserves the Society's highest honor.

—Adapted by CNPS staff from text by Delia Taylor



See a listing of all CNPS
Fellows dating back to 1973
at cnps.org/fellows.

Photograph by Ger Ericson



Vern Yadon on the trail named after him in gratitude for his decades of service on behalf of Monterey County flora.

[Photograph by Lynn Bomberger]

The Monterey area, and particularly Pacific Grove, owes many of its nature traditions and resources to Vern Yadon, the “grand old man of the plant community,” as his nominators for Fellow dubbed him. Yadon was the first director and curator of the Pacific Grove Museum of Natural History and was instrumental in starting the Pacific Grove Wildflower Show, now in its 59th year. He also was a founding member of the Monterey Bay Chapter of CNPS in 1966.

“I can’t overestimate his value to our chapter,” says Brian LeNeve, chapter president and, like Vern, a CNPS Fellow. “He’s the go-to person for questions about local botany, and is well thought of in the state-wide botany community.”

Vern Yadon might be considered a well-adapted transplant. He grew up in the San Joaquin Valley, and went on to study biology at Oregon State University. Hired in 1957 at the Pacific Grove Museum, which has a history dating to the 1880s, he dove into establishing the museum’s plant collection. He assisted Beatrice Howitt and John Thomas Howell in gathering information for the original edition of *Vascular Plants of Monterey County, California* (1964).

In 1961, Yadon and Howitt founded the Pacific Grove Wildflower Show with about 100 species that he and a few others had collected. The show grew into an important tradition under the CNPS banner, and now includes 600-700 species on display over a three-day weekend.

CNPS FELLOW Vern Yadon

No corner of Monterey County has gone unexplored by Vern, who early in his career made it his business to learn all the plants in Howitt and Howell’s book. This plant bible became a detective story for the intrepid plant lover, who took weekly car trips on his day off to obscure sites such as Fort Hunter Liggett, Salmon Creek, Burro Creek and Clear Creek, and Fort Ord. Fellow plant fans Corky Matthews, Ron Branson, and Carol LeNeve (also a CNPS Fellow) often joined him; Branson estimates they put 20,000 miles on his VW bus.

Vern is at his most cheerful out in the field, friends say. He’s been known to smell a *Malacothamnus* 100 yards away. In the process of tracking down the known plants, he found new treasures: Several species are named for him, including Vern’s rein-orchid (*Piperia yadonii*), Santa Lucia horkelia (*Horkelia yadonii*) and Menzies’ wallflower (*Erysimum menziesii* ssp. *yadonii*). He always had his plant press with him, and his collections now grace the Pacific Grove Museum’s herbarium, which he refined and expanded. He retired from the museum in 1992 but still serves as curator emeritus.

Vern has shared his knowledge of the area’s botany with fellow Monterey Bay Chapter CNPS members, leading countless field trips. He trained and mentored several generations of local botanists, including Bruce Delgado of the Bureau of Land Management. “I learned so much so fast with Vern,” says Delgado, who is based at Fort Ord National Monument. In addition to serving as the CNPS chapter president, over the years Vern has been a Pacific Grove City Council member and a leader in the Sierra Club. He also was on the Del Monte Forest Open Space Advisory Committee. And he’s still always available to identify a mystery plant, no matter who’s asking.

Now 85, Vern Yadon is seen around town on regular walks with Farley, his Dalmatian. He’s also an artist, and his watercolors of local plants and animals have graced the walls of the Carmel Art Association for more than 40 years. His other areas of expertise include ornithology, carpentry, horticulture, and local Native American culture. Monterey County is richer for the myriad contributions of this renaissance man.

—Kathy Morrison



Native plant nursery expert Betty Young is a leader in phytophthora best management practices and Sonoma County Re-Oak efforts. [Photograph courtesy of Betty Young]

Betty Young's extensive knowledge of and experience in nursery management and native plant propagation have helped protect and beautify California landscapes throughout her career, most recently through two important CNPS initiatives: the Re-Oak California effort and the establishment of best management practices to prevent Phytophthora in CNPS chapter-sold plants.

After studying nursery management and plant science at UC Davis, Young went to work in 1985 at Filoli Garden, an historic estate in Woodside. The site is registered with the National Trust for Historic Preservation, and its extensive gardens change with the season. Young left Filoli in 1989 for a stint with the Peace Corps in Thailand, focusing on soil conservation. Returning to the U.S. in 1990, she moved to Sonoma County to work at Skylark, a wholesale nursery. Next she joined Circuit Riders, a revegetation nursery, where she gathered seeds of local natives and grew plants for use in Sonoma County revegetation projects.

In 1997, Young joined the staff of the Golden Gate National Recreation Area (GGNRA) as the director of native plant nurseries, managing six greenhouses and producing 175,000 plants annually for GGNRA revegetation efforts. While at the GGNRA, she was responsible for the recording and sharing of propagation information into a publicly available online database. She also presented on, and taught classes in, nursery management throughout California. Young worked at GGNRA until she retired in 2015, after which she moved back to Santa Rosa.

Young had joined the CNPS Milo Baker Chapter when she first lived in Sonoma County, serving as president from 1993-1997. The chapter at that time began

CNPS FELLOW Betty Young

managing Cunningham Marsh, a state Department of Fish and Game easement on private property. Young worked with the owners of the property that surrounded the marsh, winning a grant that paid for a local expert to draw up a plan for the active management of the rare plant on the property: the endangered Pitkin Marsh lily (*Lilium pardalinum* ssp. *pitkenense*). Continued maintenance of Cunningham Marsh remains an important chapter activity.

In her retirement, Young supported the CNPS Milo Baker Chapter as field trip chair, then chaired a group interested in organizing a garden tour. The chapter partnered with the Sonoma County Water Agency in its Eco-Friendly Garden Tour, held each spring.

A key initiative for Young, at both the state and local CNPS level, is putting in place best management practices (BMP) for plants grown for or sold at CNPS plant sales, to prevent the introduction and spread of *Phytophthora* root rot. This is a serious issue for nursery-grown plants, and Young has traveled around the state to assess nursery practices and help local chapters. Closer to home, she has been instrumental in getting the Milo Baker Chapter's nursery shade house built, in order for plants for its annual sale to be grown in a *Phytophthora*-free environment. In addition to working out all the details for the project, she was the main fundraiser, bringing in more than \$25,000 from grants and donations. The shade house, at the Laguna Foundation site in Santa Rosa, was completed in time for the 2019 sale.

Recently, Young has been the leader in the Re-Oak Sonoma effort, a CNPS-led initiative following the huge wine country fires in the fall of 2017. She organized volunteers to gather tens of thousands of acorns from all over the region, and taught members how to evaluate, clean, store, and germinate the oak seedlings. Her work inspired a similar, statewide CNPS effort for all of California's oak woodlands. In Sonoma County the young oak trees are now being used to revegetate burned areas on public and private lands. It's safe to say that Californians, and Sonoma County residents in particular, owe much to Betty Young's continuing efforts for native plants.

—Kathy Morrison

IN MEMORIAM CELIA KUTCHER A GUIDING LIGHT IN ORANGE COUNTY

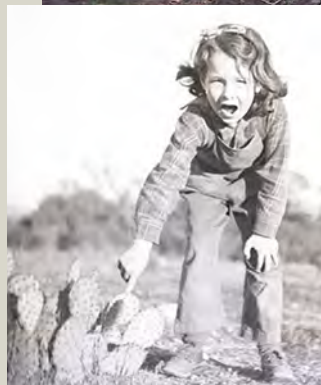
By Dan Songster

With great sadness we report the passing of Celia Kutcher, a vital and much loved member of the Orange County Chapter of CNPS since its founding. She was a mother, grandmother, and friend to many. She cherished her family and good company. Celia was a botanist, naturalist, and horticulturalist all rolled into one. She enjoyed the fragrance of coastal sage, the sound of its birds, the smell of winter rains, the shade of an oak woodland, and the discovery of a rare plant. She loved all of California's wildlands but Orange County was her home and we were lucky to have her. We will miss her in so many ways.

An environmental pioneer, Celia's passion for native plants and her growing awareness of conservation challenges emerged in the late 1960s and early 1970s. Even as she raised her two young sons, she resolved to return to school and pursue an education and career that would enable her to effectively work for the preservation of natural habitats. We can imagine her, having lived most of her life in Orange County, seeing the encroaching homes and roads fragmenting the lands she loved and resolving to do something about it.

It was only natural that Celia and CNPS would get together, but at the time there was no chapter here in Orange County. Celia was there in the late 1970s and early 1980s as the Chapter waxed and waned until 1982, when Celia and several other native plant lovers held a formal organizational meeting to assign roles and choose officers and in general ensure that meetings became more regular. Celia was in the heart of things then as she was throughout her life. And what a productive and fulfilling life.

She set a sterling example, serving enthusiastically and efficiently in nearly every chapter office and committee while attending almost every board and membership meeting for over 35 years. There were no "little" jobs for Celia, and her involvement extended from outreach events to chapter planning sessions and native habitat advocacy and so much more. Her practical advice on a broad range of chapter issues came with a seasoned historical perspective. Her steady commit-



Celia enjoying California's botanical wonders as a child and from the trail. [Photographs courtesy of the Kutcher family]

ment to the needs of the chapter, accompanied by a wry sense of humor, was inspirational to all of us who worked with her.

Above all else, Celia was the guiding light of our Conservation program, directing efforts to protect our county's wildlands. No matter the complexity of the situations or the applicable laws, Celia was always well prepared with a thorough understanding of the issues. Her comments, whether verbal or written, on behalf of CNPS were always succinct and clear, and in a tone that was always courteous and professional, never strident or accusatory. Celia is rightly known and applauded for her dedication over many decades to saving native habitat, rare plants, intact plant communities, and to upholding the laws that protect them. Her loss will be keenly felt for years to come in southern California conservation circles.

Her family requests that donations in Celia's honor be made to the California Native Plant Society, Orange County Chapter, with a note in the MEMO field indicating the gift is honor of Celia Kutcher. Please mail to: P.O. Box 54891, Irvine, CA 92619-4891.

IN MEMORIAM WATSON MCMILLIAN "MAC" LAETSCH

By John Taylor

Watson McMillan "Mac" Laetsch, a distinguished professor emeritus of plant biology and former vice chancellor of undergraduate affairs and development at the University of California at Berkeley, passed away at his home on January 5, 2020. He was 86.

Mac helped to found the California Native Plant Society and served as its first president. CNPS grew out of an ad hoc effort to save the Regional Parks Botanic Garden in Tilden Park in 1965. When the garden was saved, Mac asked, "Well, why don't we form a society to protect native plants?" Mary Wohlers, Helen-Mar Beard, and Leonora Strohmaier were also key players in starting CNPS, along with Jim Roof, then director of the Garden, and Jepson Herbarium staff members Remo Bacigalupi and Larry Heckard. The first meetings were in Mac's and Helen-Mar's homes, and the group persuaded Mac to become the first president.

Mac was born in Bellingham, Washington in 1933. His father was a Protestant minister and his mother an avid reader. Ministers and their families travel, so Mac spent his high school years in Indiana. He was an outstanding athlete and scholar in high school, earning multiple college offers, and ultimately chose to attend Wabash College, where he majored in botany, zoology, and history. At graduation, in 1956, he won a Fulbright scholarship to study in India, where he met his future wife, Sita Priyadarshini Capildeo. Sita was the daughter in a prominent Indian family in Trinidad and Tobago, and her parents had sent her to India to find a suitable Brahman husband. After a first kiss at the Taj Mahal, Mac and Sita eloped to Canada to get married.

Mac earned his PhD at Stanford in 1961, won a National Science Foundation Senior Fellowship to do postdoctoral studies at University College London, and taught briefly at SUNY Stony Brook before joining the botany department at UC Berkeley in 1963. Mac and Sita settled in Berkeley and raised a family there, while Mac became a lifelong member of the East Bay Chapter of CNPS.

As a scientist, Mac made seminal contributions to the understanding of C4 photosynthesis. His studies of leaf anatomy and chloroplast ultrastructure

Mac and Sita Priyadarshini (Capildeo) Laetsch, his wife of 61 years. [Photograph courtesy of the Laetsch family]



rounded out the biochemical studies of two Australian plant physiologists. In 1968 he wrote, "A hypothesis is presented stating that the unique morphological and biochemical characters of these plants represent adaptations for efficient and rapid carbon fixation in environments where water stress frequently limits photosynthesis." Mac's hypothesis was spot-on, and C4 grasses such as sorghum have since become the subjects of intense study owing to their ability to withstand drought.

Mac excelled as a leader, a rare quality at any university. He led the UC Botanical Garden and the Lawrence Hall of Science, and was vice chancellor for undergraduates and then vice chancellor for development. His colleague in botany, mycologist Ralph Emerson, wrote to a committee considering Mac's promotion that "Mac Laetsch walks with ease in the halls of wealth and power." Mac worked with Chancellor Ira Michael Heyman to lead the record-setting "Keeping the Promise" campaign, and later, as an emeritus professor, he worked with Heyman again to raise more than \$30 million to rebuild the Bancroft Library.

Mac is survived by his elder brother, Bruce Laetsch of Indianapolis, sons Krishen and John Laetsch, daughter-in-law Jenny Hanson, and his grandson Charlie Hanson. Mac's wife, Sita, preceded him in death in 2019, after 61 years of marriage.

Donations in the professor's name may be made to the Friends of the Bancroft Library or the UC Berkeley Botanical Garden.

Thanks to the CNPS East Bay Chapter for permission to reprint this article, which appeared in March 2020 issue of The Bay Leaf newsletter.

The scientific publication quoted above is: Laetsch, W. M. (1968). Chloroplast specialization in dicotyledons possessing the C4-dicarboxylic acid pathway of photosynthetic CO₂ fixation. *American Journal of Botany*, 55(8), 875-883.

IN MEMORIAM STEVE MCLAUGHLIN

By Stephen Ingram

Steve McLaughlin, former president of the Bristlecone Chapter of CNPS, died on December 29, 2019 at the age of 71 at his home in Santa Fe, New Mexico. Steve and his wife, author and botanist Janice Bowers, moved from Tucson to Birch Creek, southwest of Big Pine in the Eastern Sierra, in 2007 to enjoy their retirement.

Steve's knowledge of botany was broad and deep. He earned his PhD at the University of Arizona in 1978, where he taught courses in plant systematics, economic botany, and arid crops ecology. A professor of Arid Lands Resource Sciences and herbarium curator at UA, Steve studied the ecophysiology of arid lands crops, such as *Hesperaloe funifera* (giant hesperaloe) and *Grindelia camporum* (Great Valley gumweed). He also worked on the discovery and development of anti-cancer agents in plants, and on the analyses of floristic areas in the western U.S. He also named one new species, *Phacelia sonoitensis*, from southern Arizona.

In 2004 Steve received the Anson Ellis Thompson Career Service Award from the Association for the Advancement of Industrial Crops, and in 2006 was recognized by the Arizona Botanists Symposium with a Lifetime Achievement Award. Steve was sole author or co-author on more than a hundred scientific publications and presentations.

When Steve and Jan moved to the Eastern Sierra in 2007, it was inevitable that they would become involved with the Bristlecone Chapter of CNPS. Steve and Jan had joined our chapter back in 1999, but after moving here Steve wasted no time and became president within a year.

Steve was thoughtful, gentle, and generous. Michele Slaton, current vice president of the Bristlecone Chapter and an ecologist with the Inyo National Forest was asked by Steve to join the board in 2008. She says, "He made it clear this work was not about chores and busywork ... but that there is important progress to be made to protect our land and native plants. He was a real mentor, and helped me with botanical writing, with forest planning, and urged me to pursue tasks and skills that felt like a good match... I will truly miss him."

Steve strengthened ties between CNPS and other conservation organizations throughout the Eastern Sierra. He served on the Owens Lake Master Project Committee, where he was in many ways, the con-



Steve McLaughlin on a field trip to McGee Creek for Friends of the Inyo, June 2013. [Photograph by Maggie Wolfe Riley]

science of the working groups, according to Pete Pumphrey, Steve's friend and colleague with Eastern Sierra Audubon. Steve also contributed to the GLORIA (Global Observation Research Initiative in Alpine Environments) plant surveys in the White Mountains. Jim Bishop from the Mount Lassen Chapter recalls how Steve freely shared his expertise in the surveys: "He was always very helpful and an all-around nice guy."

Steve was a popular field trip leader, organizing trips for the Bristlecone Chapter, Friends of the Inyo, and the Mono Basin Bird Chautauqua. He always refused the honorarium offered to trip leaders, and had "the patience of a saint" when teaching others about plants, according to his friend and neighbor Sydney Quinn. Steve will be missed by everyone in the Eastern Sierra who cares about conservation, as well as those who value learning about plants and birds from a consummate teacher.

An excerpt from Steve's first President's Message from the January/February 2008 Bristlecone newsletter:

During my academic career I was fortunate to be able to travel and work many places on this earth, but I have never been anywhere as breathtaking and fascinating as the Eastern Sierra. There are many ways to enjoy and learn more about this great area in which we are privileged to live, and one important way is to take advantage of opportunities provided by the Bristlecone Chapter. I urge you all to come to our Wednesday evening programs and participate in our field trips. Enjoy exceptional places, beautiful plants, and interesting people.

IN MEMORIAM

LESTER BRADFORD ROWNTREE

By David Loeb

On August 30, 2019 the California Native Plant Society lost a good friend and California lost a dedicated teacher of environmental science. Dr. Lester B. Rowntree passed away at his home in the Berkeley hills after a protracted battle with cancer. Dr. Rowntree (or Les, as he preferred to be called) was a long-time professor for the pioneering Department of Environmental Studies at San Jose State University, which he joined in the early 1970s. He would eventually serve the department as program director and chair prior to his retirement in 2005.

Dr. Les was an integrative and open-minded scientist who sought to understand, and then educate others about, the elemental forces that shape the physical world. Nothing gave him greater pleasure than inspiring curious young students to become scientists dedicated to understanding the world and making it a better place.

In “retirement” Les dedicated himself to updating the widely-adopted environmental studies and geography course textbook, *Diversity Amid Globalization: World Regions, Environment, Development* (Pearson), of which he was the lead and coordinating author. Initially published in 2000, the textbook is now in its sixth edition.

If you were to visit Les’ website, the first words you’d encounter would be “Actually there are two of us.” Of course, he was referring to his more well-known grandmother, Lester Rowntree, née Gertrude Ellen Lester, the famous “California Native Plant Woman” who traveled around the state in a jerry-rigged station wagon to study the state’s native flora. She was the author of *Hardy Californians* (1935) and *The Flowering Shrubs of California* (1936), and lifetime honorary president of the California Native Plant Society at its founding in 1965. Grandson Les enjoyed being able to say that he was the “other Lester Rowntree.” But Les was a formidable contributor to our knowledge of California (and world) ecosystems in his own right.

Lester Bradford Rowntree was born and raised in Carmel. His interest in the natural world of California derived in part from the time he spent with his grandmother at her hillside home in Carmel Highlands. He always considered the rugged coastline of Big Sur to be his spiritual home, even after his immediate family moved to Berkeley in the late 1940s.



Lester Rowntree in Charleston Slough in the South Bay, in June 2004.
[Photograph by Allison Kidder]

I got to know Les through my work for *Bay Nature* magazine, accompanying him on a field trip to the Big Sur coast in April 2009 as he was researching an article on the 2008 wildfires there. It was the height of wildflower season, but to my surprise (and mild annoyance) he wasn’t able to help me identify the less common wildflowers we were seeing, and didn’t seem particularly interested in doing so. Instead, Les was a big picture, macro level scientist, attuned to how vegetation patterns had shifted in response to the fires. He was able to contrast what we were seeing with his prodigious memory of the area, developing a clearer picture of how fire had shaped—and continues to shape—this region.

Another of Les’s post retirement projects was the re-publication of his grandmother’s classic work, *Hardy Californians*, which includes additional chapters about his grandmother’s life and impact. The publication of this new edition in 2006 (University of California Press) gave Les the opportunity to travel up and down the state with a slide show reintroducing Lester—in all her idiosyncratic, convention-defying glory—to a new generation of native plant lovers.

In his talk, Les related a story from a day late in Lester’s life when she was in both physical and mental decline (she lived to be 100). He searched for her in the house to no avail, and finally found her lying under some bushes in the chaparral outside. “Leave me alone,” she said, “Can’t you see I’m trying to die.”

Les the grandson was considerably less prickly than his famous grandmother. But he was similarly clear-eyed about his approaching death. He chose to die at home, surrounded by his family, right next to an open door that looked out onto a backyard garden filled with some of his favorite California native plants.

FIRE MANAGEMENT



Helping you identify and implement the appropriate pre- and post-fire solution for long-term sustainability.



- Biological surveys and monitoring
- Archaeological surveys and monitoring
- Vegetation mapping
- Arboricultural surveys/tree inventories
- CEQA/NEPA compliance
- Expert witness testimony
- Fuel management including prescribed burns
- Invasive species control
- Habitat restoration
- Regulatory coordination and permitting

SAN DIEGO | ORANGE | RIVERSIDE | SACRAMENTO | PLACER

www.helixepi.com/fire

ENDANGERED PLANTS NEED YOUR HELP

PLEASE DONATE AT TAX TIME - LINE 403 - CALIFORNIA RETURN



Funds directly support efforts to prevent the extinction of imperiled plant species
Please spread the word - www.wildlife.ca.gov/conservation/plants



REGIONAL PARKS



BOTANIC GARDEN

Dedicated to conservation, education,
and horticulture in a beautiful landscape of
California native plants

Please join us for a free tour
Saturdays at 2 pm, Sundays at 11 am and 2 pm

For information about courses, lectures, plant sales,
and field trips, visit www.nativeplants.org

South Park Drive and Wildcat Canyon Road
in the Berkeley Hills



April Owens Design

California Landscapes

Biodiverse Resilient Sustainable Beautiful

AprilOwensDesign.com

NATIVE WILDFLOWER & GRASS
SEED BALLS
EXPAND THE CORRIDOR OF WILD PLACES!
www.wildjules.com



Photo: Dennis Mudd

Calscape.org

*The website that helps you restore nature
one garden at a time!*

- Discover which native plants grow in your exact location
- Create a personal plant list for your yard
- Search by water needs, pollinators, flower color, and more!
- Find nearby native plant nurseries
- New!** Discover host plants for local butterflies

Start your
free account
today!
Calscape.org



CALIFORNIA
NATIVE PLANT
SOCIETY

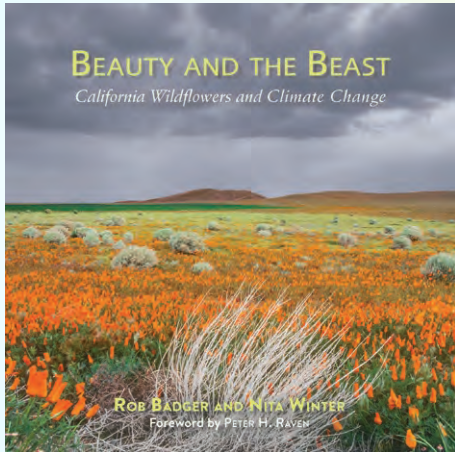


CALIFORNIA
NATIVE PLANT SOCIETY

2707 K Street, Suite 1
Sacramento, CA 95816-5130

Printed on sustainably harvested paper containing 50% recycled
and 10% post-consumer content, processed chlorine-free.

Nonprofit Org .
U.S. Postage
PAID
MLP



*Beauty and the Beast: California Wildflowers
and Climate Change*

Rob Badger and Nita Winter

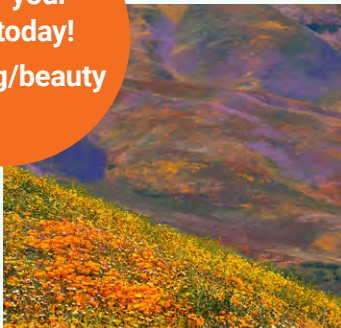
Hardcover \$60

ISBN: 978-1-7331044-0-1

WILDFLOWERS LIKE YOU'VE NEVER SEEN BEFORE

In a book that is both art and activism, award-winning conservation photographers Rob Badger and Nita Winter take readers on a stunning tour of California's wildflowers. From the super blooms of the Tehachapi Mountains to the monkeyflowers of Yosemite, the 12 x 12" coffee table book features 190 portrait and landscape images alongside 16 thought-provoking short stories. Authors include Jose Gonzalez of Latino Outdoors, Robin Wall Kimmerer (*Braiding Sweet Grass*), Mary Ellen Hannibal (*Citizen Science*), and other leading voices in today's environmental movement. Experience for yourself why Nina Simons, author and founder of Bioneers calls this book "potent medicine for our souls."

Order your
copy today!
cnps.org/beauty



In 1992, Rob Badger and Nita Winter discovered and fell in love with California's spectacular Wildflower blooms in the Mojave Desert's Antelope Valley California Poppy Preserve. This inspired a 27-year journey photographing wildflowers throughout the West, and, in 2011, their documentary art project, *Beauty and the Beast: Wildflowers and Climate Change*, a project sponsored by Blue Earth Alliance. In 2016, they created their first joint exhibit on California's wildflowers. The beautiful book, published in conjunction with the California Native Plant Society, is a companion to the traveling exhibit.



CALIFORNIA
NATIVE PLANT SOCIETY

Winter
Badger
Press