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California Wildfires

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The social, economic, and ecological impacts of wildfire are an increasing concern in many areas of the world. In North America, the U.S. state of California stands out in terms of recent – 2017 and 2018 – high-loss fire events. California provides an interesting case study to examine the social, economic, and ecological conditions that influence and are affected by wildfire. California is the most populated U.S. state with an estimated 2018 population of over 39 million, or 12 percent of the total U.S. population. The California population is highly urbanized – 94 percent – with 1.8 million Californians distributed across rural areas. If California were an independent nation, it would rank as the world's fifth largest economy.[1] California has a range of fire-dependent ecosystems – landscapes that have evolved with varying frequency and intensity of wildfire – from Mediterranean chaparral, oak savanna, and conifer-dominated systems.[2] These ecosystems span differently managed geographies, including 100 federally recognized reservations or rancherias, seven other tribal areas, eight national parks, one national seashore, three districts of the Bureau of Land Management, and 18 national forests. Further, development patterns vary considerably from expansive suburban sprawl in southern and central coastal California to relatively rural isolated development in the forested northern portions of the state.

Historically, wildfires occurred throughout California from natural ignitions, such as lightning and extensive use of fire by indigenous people.[3] This fire history had a significant impact in defining the fire-adapted ecosystems of the state.[4] However, beginning in the early twentieth century, forest management largely eliminated the intentional use of fire and lightning-caused fires were suppressed to reduce potential wildfire losses to timber and human development, resulting in increased fuel loading and uncharacteristically dense forest and shrub conditions in many parts of the state.[5] Despite the near elimination of intentional fire use, human ignitions – both accidental and arson – are the predominant source of wildfire in the state.[6] Human-caused fires were positively correlated with population density for most of the twentieth century, with a peak around 1980, but the correlation between population density and wildfires reversed in recent decades, likely due in large part to increasing effectiveness of fire prevention programs.[7] However, increased population density can still exacerbate the overall wildfire problem, with increased probability of ignitions under the most extreme weather conditions, often from arson or by powerline failures.[8]

Anthropogenic climate change has increased the frequency and intensity of weather conditions under which extreme wildfire events can occur across most areas of the globe.[9] The impacts of increased wildfire potential can be mitigated or exacerbated by complex social (e.g., development patterns, wildfire management) and ecological (e.g., expansion of insect and disease in forested landscapes) processes.[10] Indeed, prior to the modern fire-suppression era, the amount of winter precipitation strongly and negatively correlated with the severity of the subsequent fire season. However, that relationship broke down as fire control efforts began to be successful in largely excluding fire under all but the most extreme fire weather conditions.[11]

Future climate scenarios for California include more wet-season moisture as rainfall and less from snow, followed by longer, hotter fire seasons. Thus, in contrast to historical scenarios in which wet winters decreased the likelihood of extreme fire years, such precursor conditions appear to have a diminished mitigating influence on fire season severity in current and future scenarios. Indeed, the 2017 and 2018 fire seasons and concomitant wildfire disasters both followed wet-winter extremes.[12] Moreover, because wet winters tend to increase the production of fine-flashy fuels – fuels that ignite readily and are consumed rapidly when dry – in grass-dominated ecosystems, including power-utility rights-of-way, they appear to increase the hazard from powerline fires.[13]

Emerging housing expansion into or adjacent to fire-dependent ecosystems creates the potential for wildfire disasters. This human expansion into what is termed the Wildland-Urban Interface (WUI) has been influenced by a range of factors, including increasingly expensive urban housing stock and a desire for environmental attributes associated with living near natural areas. WUI development has played a central role in the increased occurrence of wildfire disasters by both increasing the likelihood of accidental ignition or arson and increasing the potential consequences if a wildfire ignites. Although viewed primarily as a western U.S. phenomenon, the eastern United States is also experiencing increased wildfire risk. For example, the 2016 Chimney Tops 2 fire outside Gatlinburg, Tennessee killed 14 people and destroyed over 2000 structures.[14] Martinuzzi et al. estimates that 4.46 million housing units in California were located in the WUI as of 2010.[15] Haas et al. estimate that nine of the top 25 high wildfire risk (high burn probability and high development) counties in the coterminous United States are in California.[16] Wildfire disasters are currently impacting housing availability and affordability through increased building code requirement, restricted zoning, and increased insurance rates better reflective of relative structure risk. Given the devastating events of 2017 and 2018 (Table 7.1), these impacts appear only likely to worsen.

Wildfire Management

Wildfires are unique relative to other natural disasters such as hurricanes, floods, and tornados with respect to the role human activities and response have over these events. In many areas of the world, human-caused ignition – both arson and accidental – are the primary sources of wildfire.[17] Humans are currently the source of more than 80 percent of wildfire ignitions in the United States, but that figure varies by region.[18]

Table 7.1 Ten California Wildfires Included in Major Disaster Declarations of 2017 and 2018

Fire Year	Start Month	Disaster Declaration	Name	Cause	Area (ha) Burned	Structures Destroyed	Fatalities
2017	October	DR-4344	Atlas	Powerline	20,650	783	6
2017	October	DR-4344	Nuns[a]	Powerline	22,622	1,355	3
2017	October	DR-4344	Tubbs	Electrical equipment	14,723	5,636	22
2017	October	DR-4344	Redwood Valley	Powerline	14,609	546	9
2017	December	DR-4353	Thomas	Under investigation	112,757	1,063	23[b]
2018	July	DR-4382	Carr	Vehicle	91,860	1,604	8
2018	July	DR-4382	Ranch	Under investigation	164,081	280	1
2018	July	DR-4382	River	Under investigation	19,568	264	
2018	November	DR-4407	Camp	Under investigation	61,334	18,804	85
2018	November	DR-4407	Woolsey	Under investigation	38,780	1,643	3

Notes:
[a] Six fires that merged together
[b] Twenty-one fatalities were from post-fire debris flows

Source: The causes of five of the fires were still under investigation at press time, but they are believed to be human-caused and likely related to power transmission or related equipment use.

Federal Emergency Management Agency, Disaster declarations by year. Available at www.fema.gov/disasters/year; www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf

In the higher-elevation forested-mountain ecoregions of California (Figure 7.1) and the Intermountain West, for example, humans are only responsible for around 45 percent of ignitions, accounting for just 25 percent of burned area.[19] However, in the Mediterranean ecoregion of California with predominantly chaparral/brush fires (Figure 7.1), humans are the source of approximately 97 percent of the contemporary ignitions and 89 percent of the area burned.[20] Under most conditions when wildfires ignite, responders can extinguish them; however, under extreme fire weather conditions, such as high wind or aridity, wildfires are more likely to spread and cause significant damage.[21]

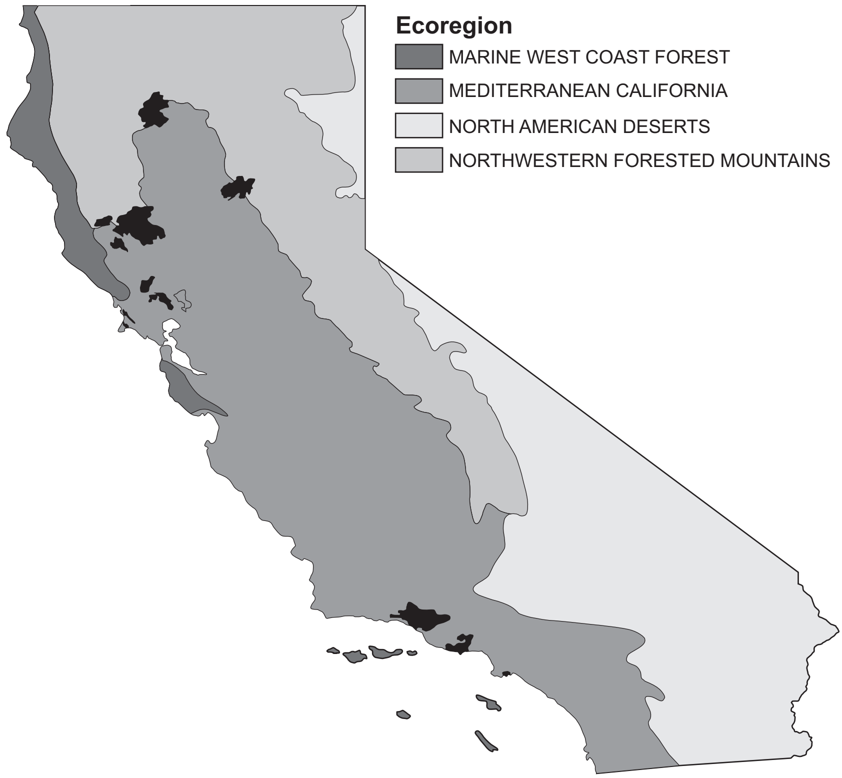

Figure 7.1 Ecoregions of California

Source: Authors. Map redrafted by Erika Pham, University of South Carolina

In response to the increasing damage over the last several decades, the state of California, local and county fire departments, and federal land management agencies including the U.S. Forest Service and Department of Interior have built up the largest coordinated wildfire response system in the world. Several studies have demonstrated that relative to wildfires in other U.S. states, wildfires in California are managed with significantly more suppression resources[22] and at higher cost[23] even after accounting for variation in fire size, environmental conditions, and values at risk. This increased response has had a major impact on governmental agencies charged with wildfire management. Within the California Department of Forestry, now known as Cal Fire to represent the agency's primary focus on wildfires, fire management costs have been continually increasing in response to fire response commitments. Emergency fund fire response expenditures in California reached $773 million in the fiscal year (FY) 2017–2018. Fire management costs for Forest Service Region 5 (California) are consistently higher than other regional expenditures and totaled over $600 million in both fiscal years 2017 and 2018. The rising cost of wildfire response on the Forest Service budget has had a major impact on the agency's ability to meet its core mission.[24] In 2018, Congress addressed the impacts of these rising costs on the Forest Service. Beginning in 2020, wildfire management costs in excess of the historical average will be covered through emergency funding similar to how other natural disaster relief is funded through FEMA.

Box 7.1 Wildland Fire Funding Fix

The FY 2018 Omnibus Spending Package included new budget authority for the United States Department of Agriculture (USDA) Forest Service and Department of the Interior (DOI) agencies to address the increasing scale and uncertainty of wildfire suppression spending. This budget authority begins in FY2020 and lasts through 2027. A total of $2.25 billion of new budget authority is available to USDA and DOI increasing by $100 million each year, ending at $2.95 billion in by FY2027. For the duration of the 8-year fix, the Forest Service suppression account will be funded at the FY 2015 President's Budget request of $1.0 billion. As a reference, in FY 2018, Forest Service wildfire suppression was budgeted at $1.6 billion but total spending was $2.6 billion.

Source: United States Department of Agriculture, *FY2020 Budget Justification*, March 2019, www.fs.fed.us/sites/default/files/media_wysiwyg/usfs-fy-2020-budget-justification.pdf

Humans have the ability to significantly alter the amount and arrangement of flammable vegetation through mechanical means (e.g. tree harvest), introduction of fire under controlled conditions (known as prescribed burning), and livestock grazing. Much of what we think of as historical landscapes (pre-Columbian in the United States) were largely shaped by indigenous peoples' use of fire.[25] Current fuel conditions in many areas are influenced by the decisions on how best to respond to emerging wildfires – either aggressively suppressing them when they are small or managing them in a manner to promote beneficial fire effects. Our ability to suppress wildfires when small played a major part in setting the stage for the current uncontrollable wildfire disasters being experienced in California and other parts of the globe. Essentially, the more effort that is put toward suppressing wildfires, the more likely that future fires will burn under conditions where suppression efforts do not work. Brown explained this "wildfire paradox" as being primarily driven by the accumulation of fuels that would have burned had fires not been suppressed.[26]

Beyond the physical accumulation of fuels, there is growing recognition that other systemic factors are leading to increasing suppression demands and associated costs.[27] Calkin et al. explored several additional factors driving the ever-increasing demands of wildfire suppression focusing on systemic feedbacks including public expectations, development subsidies, management agency budget influences, misalignment of fire manager incentives, and climate factors.[28] Collins et al. identified the tendency to underinvest in mitigation since it is difficult to clearly identify and take credit for actions when a disaster does not occur. Thus, the increasing cost of reactive suppression response can crowd out investment of preventive actions such as fuels reduction activities, resulting in the wildfire management organization caught in a "firefighting trap." This concept of a trap comes from business management literature and refers to conditions where a shortsighted focus on addressing immediate problems keeps organizations from addressing core problems that are at the root of these incidents. Further, this mentality of reactive response can become culturally ingrained in how we respond to wildfire that may be inconsistent with our societal goals and intentions.[29] Addressing core drivers of increasing wildfire loss will require an improved understanding of the structure and complexity of the existing fire management system and the role of suppression response as a limiting factor in addressing systemic change.[30] Fischer et al. describe this phenomenon as a socioecological pathology: "a nearly intractable problem . . . that is, a set of complex and problematic interactions among social and ecological systems across multiple spatial and temporal scales."[31]

Wildfire management is complicated as fire transitions from wildlands to areas of human development. Responding to wildfires in the WUI involves considerably more complexity, typically requiring coordination among local, state, and federal fire and emergency management responders. Not surprisingly, management costs for fires within the WUI are significantly greater than for wildfires burning in undeveloped lands.[32] WUI wildfire disasters, fires that destroy hundreds to thousands of homes, occur when wildfire in natural vegetation transitions to developed areas. These fire disasters share several common characteristics.[33] A landscape with high wildfire potential from the combination of burnable fuels and topography experiences an ignition under extreme fire weather conditions – particularly high winds – creating conditions for rapid fire spread. The wildfire then transitions into a community of homes susceptible to ignition, overwhelming both wildland and structure fire suppression efforts. In most WUI fire disasters, the majority of home loss occurs within several hours. Further, under mass-loss events, home-to-home ignition frequently plays a critical role (see, for example, the Coffey Park subdivision in Santa Rosa destroyed by the Tubbs fire). Despite the large geographic scale of recent WUI disasters such as the Camp and Tubbs fires (Table 7.1), home destruction is a localized phenomenon largely determined by what Cohen termed the Home Ignition Zone (HIZ).[34] The HIZ is defined as the characteristics of the home and the vegetation characteristics of the surrounding area only out to 100–150 feet. However, it is important to note that in most urban and suburban settings an individual homeowner may not have ownership of their HIZ.

Recent High-loss Events

Fire has been a pervasive natural disturbance in California's ecosystems for millennia. Ignited by lightning and Native Americans, wildland fires are estimated to have burned at least 1.8 million ha (4.5 percent of the land area) annually in California prior to nineteenth-century Anglo-European settlement.[35] As native populations dwindled and Anglo-European foresters embraced near-wholesale fire control (suppression) practices that became applied across the entire landscape well into the twentieth century, the area burned by wildfire fell to an average of around 100,000 ha per year – at least until recent decades.[36] Increased fuel loadings from long-standing fire-exclusion efforts, in conjunction with weather and climate conditions increasingly conducive to large fire-spread events, have set the stage for fires capable of burning over 100,000 ha – what was previously an average year's total burned area – in a single event.[37] Five such fires have occurred since 2003.[38] Wildfire area burned averaged approximately 265,000 ha per year between 2000 and 2018.[39] However, wildfires do not have to be extremely large to have massive impacts in terms of casualties and property loss. The Oakland Hills fire of 1991, which killed 25 people and destroyed 2,900 structures, grew to just 640 ha.[40]

First introduced in 1953, major disaster declarations have been issued for wildfires in 14 U.S. states.[41] However, they are most commonplace in California. Major wildfire disasters were declared in California during 16 of the 66 years from 1953 to 2018, while the other 13 affected states averaged only two disaster years each in the same 66-year period.[42] California's first major wildfire disaster was declared in 1956, in response to incendiary fires that burned 15,200 ha and spread into the community of Malibu, killing one person and destroying 120 structures.[43] Although brush and forest fires had threatened developed areas in California since Spanish mission days and burned into communities like Malibu repeatedly prior to the onset of formal disaster declarations, the events of 1956, including an earlier wildfire in San Diego County that killed 11 firefighters, brought national attention to the likelihood of even higher loss incidents.[44] The National Board of Fire Underwriters cautioned in the fires' aftermath that "with the encroachment into these areas [mountain brushfields] of more homes without a corresponding increase in the amount of quickly available fire protection, even greater losses are probable."[45]

Indeed, with fires continuing to burn into an increasingly populous Malibu on the average of two-and-a-half times per decade, additional wildfire disasters were inevitable.[46] The community's second major wildfire disaster was declared in 1970, when the 12,000-ha Wright fire consumed 403 structures and killed 10. A third occurred in 1993, when three lives and 350 structures were lost to two fires that burned 22,000 ha.[47] Then, in 2018, the 38,780 ha Woolsey fire prompted a fourth disaster declaration, with three fatalities, 1,643 structures destroyed, and nearly 300,000 people evacuated.[48]

Box 7.2 Disaster Declaration Types

When state and local emergency response resources are overwhelmed by a disaster or emergency, pending or realized, the governor may request aid from the federal government. The decision to provide federal assistance for such an incident is referred to as a "declaration." The Robert T. Stafford Disaster Relief and Emergency Assistance Act authorizes three types of declarations related to wildfires.

Major Disaster Declaration: A decision to provide federal assistance in response to an incident of such magnitude to cause severe damage, loss, suffering, or hardship. It can provide for a wide range of aid, including to individuals or households, state and local governments, and disaster relief organizations. Assistance can be provided for emergency work, temporary housing, crisis counseling, repair or replacement of damaged infrastructure, and other recovery programs. A major disaster declaration must be issued by the president.

Emergency Declaration: A decision to provide federal assistance to protect lives, property, and public health during or in anticipation of a catastrophic incident. Assistance is intended to supplement state and local emergency services (e.g., evacuation assistance, fire control resources) and does not extend to repair or replacement of affected facilities or infrastructure. An emergency declaration must be issued by the president.

Fire Management Assistance Grant (FMAG) Program Declaration (formerly Fire Suppression Authorization Declaration):

A FMAG declaration is intended to prevent a wildfire from developing into a major disaster. It authorizes federal assistance to state and local government entities for fire control and mitigation. It does not provide aid to individuals or households. A FMAG declaration can be issued by the President or a FEMA Regional Director.

Source: Bruce R. Lindsay and Francis X. McCarthy, *Stafford Act Declarations 1953–2014: Trends, Analyses, and Implications for Congress*, Congressional Research Service Report 7-5700 (Washington, DC: Congressional Research Service, 2015), available at https://fas.org/sgp/crs/homesec/R42702.pdf

In terms of structures destroyed, the Woolsey fire joined the Oakland Hills fire to rank among the top 20 most destructive California wildfires on record (Figure 7.2). Notably, 16 of those 20 occurred in the past two decades, with eight occurring in just the two most recent years, 2017 and 2018. All of those eight prompted major disaster declarations, as did the Ranch and River fires of northern California's Mendocino Complex in 2018 (Table 7.1). While not among the 20 most destructive in terms of structure loss, the Ranch fire became California's largest single fire on record, with a final size of 164,081 ha. Currently coming in second on the list of California's largest wildfires is the 2017 Thomas fire, which burned 112,757 ha and killed two people, with post-fire debris flows claiming another 21 lives.[49] California's deadliest and most destructive wildfire came in 2018 when the 61,334-ha Camp fire killed 85 people and destroyed 18,804 structures in the community of Paradise.[50]

Wildfire disasters and other high-loss fire events in California and elsewhere are generally the result of fires that spread rapidly into developed areas under extreme burning conditions that defy most suppression efforts.[51] Given an ignition, the resulting fire behavior, including spread rate and intensity, is a function of fuel conditions, weather, and topography. Unless recently burned or otherwise denuded, the shrublands and savannas of Mediterranean California and the state's forested mountains (Figure 7.1) generally provide ample fuel to carry fire under seasonally dry conditions, with higher fuel loadings leading to higher spread rates and

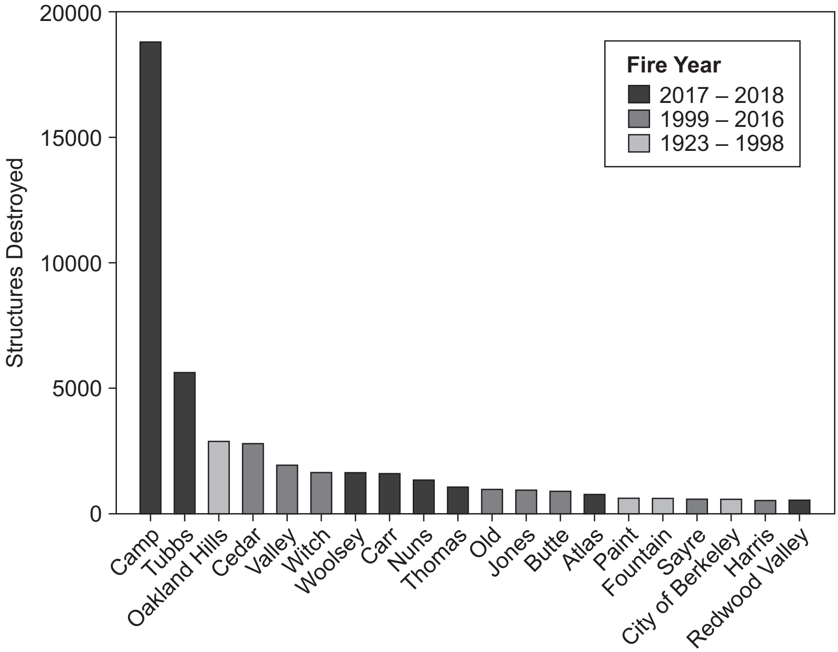

Figure 7.2 Twenty Most Destructive California Wildfires on Record

Source: www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf

intensities.[52] Moreover, seasonally dry conditions in the brushy Mediterranean ecoregion often co-occur with very strong easterly winds known – from south to north – as Santa Ana, Sundowner, or Diablo events. Any ignitions during those events can lead to intense, fast-spreading fires that can accelerate through rugged terrain (e.g., canyons). The vast majority – 97 percent – of wildfire ignitions in the Mediterranean region of California are human-caused, including from incendiarism (arson) and downed powerlines.[53] Arsonists have been known to set their fires during these high wind events, which rarely occur in conjunction with lightning, and the winds themselves can be sources of tree strikes to powerlines or other electrical equipment failures that start wildfires.[54] The typical proximity of such ignitions to developed areas increases the likelihood that even a relatively short-duration (e.g., 12 hour) high-speed wind event could spread fire into areas of concern.[55] Under high winds, this includes fire spread through ember transport far ahead of the flaming fire front. Lofted embers can ignite vegetation and structures well ahead of the main fire, even in areas with impediments to surface fire spread (e.g., roads, defensible space) that should be effective barriers under more moderate conditions.[56] As structures begin to burn, they become an additional source of heat and embers and in densely developed areas can result in home-to-home ignition, and, ultimately, urban conflagrations (e.g., in the 2017 Tubbs fire).[57]

California has seen these wildfire disaster and high-loss scenarios play out repeatedly in recent decades (see Figure 7.2),[58] with increasing impacts in terms of property destruction that culminated in 2017 and 2018, when insured losses reached $13 billion in back-to-back years.[59] According to the National Fire Protection Association, the only "fire" – wildland or urban – on record with higher property damage totals than the combined California wildfire events of either 2017 or 2018 was the terrorist attack on the World Trade Center in New York City on September 11, 2001.[60] Moreover, the $13 billion in California fire losses in 2017 was more than all U.S.–insured wildfire losses from the previous decade combined.[61]

The level of devastation from these recent events is largely associated with massive increases in development in and near California wildlands. The 2017 Tubbs fire, for example, burned similarly to and in much of the same footprint the 1964 Hanley fire.[62] However, limited suburban development at the time of the 1964 blaze precluded the level of home losses seen in the Tubbs fire, including those destroyed in the newer Santa Rosa neighborhood of Fountaingrove.

The worst WUI wildfire disaster to date was the 2018 Camp fire, when a wind-driven wildfire grew to 40,000 ha in its first two days, engulfing the forested town of Paradise, in Butte County, California.[63] Butte County's population has grown by 60 percent since 1980, with much expansion into the forested foothills of the Sierra Nevada Mountains, where large wildfires have been historically prevalent.[64] The town of Paradise was one of Butte's rapidly growing foothills communities, expanding from a population of about 8,000 in the 1960s to more than 26,000 at the time of the Camp fire.[65] Its transportation infrastructure had not kept up with the needs of its growing – and relatively older – population. With limited points of egress from the ridgetop town, the extremely fast-moving fire not only destroyed 80 percent of the town's buildings but also claimed 85 lives, many of whom were trapped in their vehicles as they tried to evacuate.[66]

Table 7.2 shows the disproportionately high percentages of persons over the age of 65 who died in the fires. The percentages of seniors ranged from 30.4 percent to 81.7 percent among the fire and post-fire event fatalities. Older age groups and other population groups – children, pregnant women, people with disabilities and chronic health conditions – may give rise to more access and functional needs (AFN) during emergency. Indeed, most of the young adults who perished in the mudslides following the Thomas fire were caregiving for young children or had an older spouse. Without comprehensive emergency planning and preparedness,

Table 7.2 Higher Proportion of Seniors in Fire-Related Fatalities Than Expected

Event	Counties	Percent Elderly Population (> 65 yrs.)	Percent Elderly Fatalities (> 65 yrs.)	No. treated for injury/ hospitalized
Camp	Butte	18.2 (n=229,294)	81.7[a] (n=85)	>60
North Bay	Napa, Lake, Sonoma, Mendocino, Butte, and Solano	17.9 (n=140,973)	70.5[b] (n-44)	>192
Thomas	Ventura, Santa Barbara	15.0 (n=1,302,373)	50.0[c] (n=2)	At least 2 firefighters
Montecito Mudslides	Santa Barbara	14.9 (n=448,150)	30.4 (n=23[d])	>163

Notes:

[a] Percentage is of identified Camp Fire victims (n =71) as of 1/31/2019, available at: www.kqed.org/news/11710884/list-of-those-who-died-in-butte-county-paradise-camp-fire.

[b] Percentage is of identified North Bay Fire victims (n =44) reported 11/28/2017, (accessed 3/13/2019 Identified victims reported here (11/28/2017), available at: www.kqed.org/news/11633757/october-fires-44th-victim-a-creative-globetrotting-engineer-with-the-kindest-heart).

[c] www.latimes.com/local/lanow/la-me-thomas-fire-contained-20180112-story.html.

[d] Number includes with the 21 identified bodies the two missing children whose bodies have not been recovered.

Source: Authors compiled based on U.S. Census Bureau County Population Estimates, 2017

AFNs cannot be adequately supported during an emergency when people may be performing complex evacuation activities for the first time or after a repeated number of times with "evacuation fatigue." Information for individuals hospitalized or injured was unavailable, but it is likely that persons with AFNs were disproportionately represented in these groups as well.

Reflections on the 2017 and 2018 Wildfire Seasons

Reflecting on the wildfire disasters of 2017 and 2018, key takeaways include the following: 1) large, destructive wildfires are not unprecedented and future disasters are to be expected; 2) the current fire management paradigm is not effective at preventing high-loss events; and 3) communities need to plan for wildfires and incorporate engineering solutions much the way that earthquakes and other natural disasters are planned for.[67] Furthermore, Keeley et al. emphasized that "fire management needs to do more to convey to the public their limitations in stopping massive Santa Ana[-type] wind-driven fires."[68] The Thomas fire, for example, grew more than 25,000 ha on two days, December 4–5 and December 9–10, 2018, when it had nearly 2,000 and over 5,000 firefighting personnel, respectively, working to suppress it. It continued to grow by 4,000 ha on eight separate days when there were as many as 8000 firefighting personnel assigned.[69] Fires burning under the types of extreme weather conditions witnessed during the Thomas fire and other high-loss events are typically "controlled" only after those conditions moderate, e.g., after winds subside, rains come, or both.[70] As argued by Calkin, et al. to lessen the inevitable impacts of future events, it is crucial to overcome "perceptions of WUI fire disasters as a wildfire control problem" when they are better framed as a "home ignition problem, determined by home [exposure and] ignition conditions."[71]

The back-to-back high loss years of 2017 and 2018 caused the insurance industry to reconsider wildfire risk as a serious peril in league with hurricanes, earthquakes, and floods.[72] Insurers are increasingly investing in development of fire behavior and catastrophe models that allow them to better plan for and reduce exposure to future high-loss events, including those potentially exacerbated by further climate change. Such mitigating actions can take place in the core business of underwriting, as well as in asset management. California, for example, is one of the few states in which insurers have given premium credits on policies for homes that comply with NFPA's Firewise USA® guidance.[73] However, Firewise status does not necessarily confer disaster resistance under extreme burning conditions. Referring to Fountaingrove's status as a Firewise USA® Community, the NFPA declared that the Tubbs fire – which caused the largest urban conflagration since the 1906 San Francisco Earthquake fire[74] – "could not have encountered a more prepared community."[75] In addition to insured property claims, industry exposure includes losses from business interruption claims associated with wildfire smoke, and impacts to power grids, communications networks, transportation systems, and supply chains.[76] The utility industry is also heavily impacted by wildfire disasters, which in many cases they are suspected or confirmed to have caused.

Many of the recent catastrophic wildfires in California including the Wine Country fires of 2017 and the 2018 Camp fire, appear to have been caused by failure of the power transmission grid. Conditions where electric transmission system failure due to extreme wind events – specifically electric arcing due to tree limbs or fatigue failure of transmission poles – frequently align with conditions conclusive to rapid wildfire growth.[77] Shutting off electricity on high fire risk days could obviously reduce likelihood of catastrophic home loss. However, temporarily shutting off power on high fire risk days could have significant impact to communication networks necessary for effective evacuation, could disrupt local water supply, and ultimately affect vulnerable community members. Prophetically, Collins et al. stated "if powerlines are found to be the ignition source of a destructive wildfire, then it is highly likely that network operators will face substantial claims for damages and compensation."[78] Mitigation actions such as burying cables underground or enhancing the structural integrity of poles and lines along with enhance inspection and maintenance are effective ways to reduce wildfire risk from the power transmission grid. However, the required investment to "fire-proof" the existing grid is likely to be quite expensive. Following the 2018 Camp fire, Pacific Gas and Electric Corporation (PG&E) submitted a wildfire safety plan to the California Public Utilities Commission outlining planned 2019 mitigation efforts totaling $2.3 billion.[79]

While the cause of the Camp fire is still under investigation, PG&E, California's largest power company, filed for bankruptcy in January 2019, asserting that insurance would not cover its costs if it was determined responsible for the Camp blaze. In 2019, the California state legislature grappled with the implications of the current liability statute and the potential impacts to electricity generation and home insurance affordability. Although the full implications of recent fire events have yet to play out, it is likely that not only will the cost of electricity and home insurance increase but also that housing markets and future development patterns will be profoundly affected.

Responding to the New Wildfire Reality

Over the last several decades, the impact of wildfire on human and ecological communities has increased around the globe. Mass-loss wildfire events are not isolated to the state of California; however, many of the most significant events in North America have occurred there in recent years. Record-breaking wildfires appear to be the new norm with 2018 breaking records for fire size – Mendocino Complex – and community destruction – Camp fire, which broke the previous record set by the Tubbs fire the prior year. Despite the massive increase in fire management response, it does not appear that the trajectory of losses will likely change unless we fundamentally change how we build and maintain our communities, manage the landscapes, and respond to fire.[80] The diversity of the geography, development, and economic drivers in California are mirrored in the diversity of wildfire behavior and impacts. Community safety and ecological health are challenging problems that will require a comprehensive solution involving land-use planning, fire-safe construction, property maintenance, active forest and rangeland management, promotion of naturally occurring wildfire where feasible, and effective suppression response when necessary.

Climatic and environmental changes are a major factor in the recent levels of loss. Riley et al. demonstrate how complex climatic, environmental, and human management drivers determine wildfire potential and over time these factors can flip from driving increased wildfire to reduced wildfire in different social-ecological systems.[81] Over the near term it is largely accepted that we are in a period of increasing wildfire activity in California and most of the western United States and that social and ecological consequences will continue to worsen.[82]

In 2009, Congress' Federal Land Assistance, Management, and Enhancement Act directed the Secretary of the Interior and the Secretary of Agriculture to submit a cohesive wildfire management strategy. From this directive, *the National Cohesive Wildfire Management Strategy* (NCWMS) was established. The strategy established a national vision for wildland fire management emphasizing collaborative work among stakeholders using best available science to achieve the following goals; 1) resilient landscapes; 2) fire adapted communities; and 3) safe and effective response.[83]

There is broad acceptance of the need for increased fuel reduction actions to improve ecological resilience to wildfire and reduce future wildfire risk. However, how fuel reduction goals are met is more contentious and the variety of ecotypes, land ownerships, and management objectives require a variety of management strategies. Increasing the pace of fuel reduction will require a combination of mechanical harvest, prescribed burning, and reduced suppression of wildfires that pose low risk to human development.[84] As argued by Keeley et al., fuel reduction efforts must be based on clearly defined objectives that do not rest on the expectation that even the largest practical fuel breaks will stop fast-moving, wind-driven fires.[85] But instead they may be strategically located, based on local or regional risk assessments, to provide defensible space for firefighting activities likely to mitigate those risks. Another challenge to address is our tendency to isolate the consideration of public land management, community mitigation, and wildfire management response; successful implementation of the NCWMS requires that we look at these goals using a systems approach that recognizes the interaction and feedback among wildlands, communities, and our response.[86] The transition between wildlands and communities defines the potential for WUI fire disasters. Coordinated management strategies in these areas is challenged by the multi-ownership nature of these areas, historic landscaping that has utilized highly flammable species such as Eucalyptus and Monterey Pine, the high cost of mechanical treatments, potential liability for prescribed burning and a lack of cross jurisdictional coordination. Recognizing these challenges, McBride and Kent make a call for implementation of regional commissions granted the authority to coordinate landscape planning, mitigation actions, and wildfire response coordination.[87]

Preparing at-risk communities for the eventuality of wildfire is a complex social and economic challenge. An integrated framework that recognizes wildfire as a necessary ecological process while addressing the vulnerability of communities is required.[88] However, severe wildland fire potential is a necessary but not sufficient condition for the occurrence of a WUI fire disaster. The condition of the structures and their immediate surrounding largely defines loss. Syphard et al. describe community wildfire safety as a complex, multi-variate problem requiring focus on home construction materials, home and landscape maintenance, and land use planning.[89] The state of California has implemented several land use planning and building material requirements to address home vulnerability to wildfire. In 2007 the state implemented the California Building Codes standards requiring the use of ignition resistant materials and design based on the classification system established in Fire Hazard Severity Zone mapping.[90] Additionally, California law requires the removal of all flammable vegetation within 30 feet with additional fire protection required up to 100 feet of all structures.[91] These efforts appear to influence structure loss as Syphard et al. demonstrated, finding that structure age and building material were particularly important in relatively high-density areas whereas defensible space was more critical for reducing home destruction in lower density areas.[92] Enforcement of existing WUI requirements is managed by the individual counties and therefore varies across jurisdiction.

A Shared Stewardship Vision for Future Wildfire Management

Although governmental agencies are currently playing a central role in wildfire risk mitigation and response it is likely that private industry will become an increasingly important actor. Potentially one of the biggest factors that could reverse the trajectory of increasing home loss is the insurance industry. As losses increase and our ability to predict the probability of a home burning due to wildfire improves, insurance rates may make development in high-risk areas unaffordable and require significant modifications of existing homes. Recent attempts to adjust federally subsidized flood insurance to better reflect new risk levels through modifications to the National Flood Insurance Program demonstrated the potential impacts of increasing natural disaster risk. However, unlike flood insurance, homeowner wildfire insurance is not subsidized and therefore potential actions by insurers and the re-insurance industry to fully account for wildfire risk may have a major influence on future development, the ability to rebuild burned structures after a wildfire, and the value and affordability of existing high-risk residence.

To date, the primary response to increased wildfire losses is an increased suppression response.[93] Wildfire suppression will remain a key component of any risk management strategy, with aggressive response to new wildfire starts the dominant response in areas near human development. Emerging research is helping to better understand how landscape conditions influence suppression opportunity to improve the effectiveness and efficiency of initial and large fire response.[94] Changing the way we respond to wildfires will require addressing systematic drivers of decision-maker behavior.[95] Improved understanding of suppression effectiveness that feed decision models to identify and address strategies to mitigate and respond to wildfire under critical conditions is necessary to achieve improved outcomes.[96] If communities in California and other areas with high wildfire potential adapt to become more resilient to wildfire there still will likely be wildfire disasters as the necessary transition occurs. The highest priority in fire response (wildfire and structural) is protection of human life.

More research is needed to understand wildfire impacts to communities. However, taking a whole community approach can help emergency managers learn from those who may be most sensitive to the impacts, and may have perspectives and solutions to integrate into emergency planning.[97] Local emergency management teams are coordinating with community organizations on these six whole community strategic themes: 1) understand community complexity; 2) recognize community capabilities and needs; 3) foster relationships with community leaders; 4) build and maintain partnerships; 5) empower local action; and 6) leverage and strengthen social infrastructure, networks, and assets. These strategies aim to address the disproportionately high rates of mortality and morbidity among certain population groups that not only define by geographic vulnerabilities (e.g., living in WUIs) as outlined previously, but also by a lack of representation and needed resources in emergency management.

As emergency managers take this approach, there is an increasing recognition that one in two community members falls into traditional "special needs population" categories.[98] Today, emergency managers no longer use these categories or the term "special populations" in planning; instead there is a growing focus on what access and functional needs a community might have during emergency preparedness, response, and recovery activities. With needs identified, resources and solutions are integrated into emergency plans with input from specific populations and community organizations.

In California's non-institutionalized population, 14 percent are over the age of 65, 6.3 percent are under the age of 5 years; 11 percent self-report disability (mobility, vision, hearing, cognitive, self-care, and/or independent living); 44 percent over age 5 speak a language other than English; and 17 percent live without broadband internet access.[99] California's institutionalized population includes people of all ages living in nursing homes, assisted living centers, large group homes, prisons, and other settings. Members of these populations are more likely to experience access and functional needs during wildfires; when involved in planning, stakeholders can help build governmental and certain private sector capabilities to perform emergency support functions (ESF) in ways that help the whole community. Planning for AFNs includes solutions in emergency management for evacuating and supporting persons living in poverty and with telecommunications and other communication problems; transportation challenges; caregivers and personal assistants; emotional support and service animals; and electricity for refrigerated medicines, air filters, and durable medical equipment. Community organizations affiliated with these populations usually can represent these needs and how they might be addressed in any scenario including wildfires. Such needs include early evacuation warnings and support to very young children and persons with mobility impairments and related disabilities; how to transport persons using wheelchairs; how to communicate with people who are deaf or blind; and how to make mass care shelters fully accessible to persons with disabilities and equipped for persons managing chronic conditions.

There are increasing occasions to broaden the partnership committed to mitigating the impacts of wildfire, post-fire events, and smoke. The challenges of coordinating across jurisdictions (federal, state, county, local, and tribal) and communicating strategies to reduce wildfire impacts to natural and human-made resources and human health impacts are extensive. Much more needs to be done to strengthen the partnerships between fire managers, emergency responders, and public health entities to plan for the inevitable future emergencies and increase the capacity of individuals and communities to weather these events. Taking a less-traditional approach of working with entities representing populations that are more vulnerable is one strategy consistent with emergency response traditions of worst case scenario planning. Data integration and use is one place to start with forging these partnerships in order to improve outcomes.[100]

Additional financial resources are being allocated at the federal and state level to address wildfire impacts. The NCWMS provides a structure under which cross-jurisdictional mitigation and response planning can achieve positive risk reduction goals. The power in the NCWMS comes from the recognition of the need for cross-jurisdictional coordination and the specific goals of resilient landscapes, fire adapted communities, and safe and effective response. The primary risk factors that are creating the increased wildfire losses we are experiencing vary across different communities and ecosystems. A uniform solution to address wildfire is unlikely to succeed and community wildfire preparation, risk mitigation, and event response will need to be tailored to the local reality. The additional attention and resources allocated to address wildfire are critical in achieving social and ecological resilience in the face of increasingly challenging wildfire conditions; however, new integrated strategies across ownership that identify and address dominant wildfire risk factors will be needed to achieving resilience. Success will be achieved by better learning to live with wildfire not by trying to win a fight with a natural and critical environmental process.

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