

Wildfire in Chaparral and Coastal Sage Scrub

An Annotated Bibliography

Prepared by

Bryant Baker, M.S.
Conservation Director
Los Padres ForestWatch



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You can also find most of the publications listed in this document at LPFW.org/fire-references.

Overview

Below are the primary research papers, books, and other literature that characterize natural wildfire conditions in chaparral and coastal sage scrub ecosystems as well as how human influence is changing those conditions. Some of these references also provide critical information for how communities can best protect themselves from the impacts of wildfire in and around these ecosystem types. While the references have been grouped into several categories, some publications may contain information pertinent to multiple categories.

There are five overarching findings across these publications:

1. Large, infrequent crown fires naturally occurred in chaparral and coastal sage scrub ecosystems along the Central and South Coasts once every 30 – 150 years, despite relatively small scale intentional burning by Native Americans before the arrival of Europeans and the spread of non-native, invasive plants.
2. Human activity has drastically increased fire frequency in our region due to sprawling development and an associated surge in fire ignitions, and fire suppression over the last century has been largely unsuccessful in limiting the consequential increase in burned area.
3. High fire frequency is resulting in chaparral and coastal sage scrub type conversion to non-native, invasive grasses and weeds that dry out earlier in the year, ignite more easily, and spread wildfire more quickly.
4. The past and present focus on vegetation management as the primary wildfire mitigation strategy is generally inadvisable due to its mixed to negligible success, especially in areas far away from communities and under extreme weather conditions expected to become more frequent with climate change.
5. Land management agencies and communities should focus on better land use planning (e.g. limiting development in fire-prone areas), fire-safe home construction and retrofitting, smart defensible space immediately around structures, and human-caused ignition prevention as primary strategies to reduce the impacts of inevitable wildfire on communities in and around the wildland-urban interface.



Natural Chaparral and Coastal Sage Scrub Fire Regimes

Halsey, R. W. and A.D. Syphard (2015) High-Severity Fire in Chaparral: Cognitive Dissonance in the Shrublands, pp. 177-209. In D. A. DellaSala and C.T. Hanson, Eds., *The Ecological Importance of Mixed-severity Fires: Nature's Phoenix*. Elsevier, Amsterdam.

Summary:

In this chapter of *The Ecological Importance of Mixed-Severity Fires: Nature's Phoenix*, experts from the California Chaparral Institute and Conservation Biology Institute explore the natural, high-severity fire regime in chaparral and public misconceptions surrounding it by reviewing key scientific studies over the past few decades.

Key Findings:

1. Fire suppression has not caused excessive amounts of chaparral to accumulate.
2. Fire suppression has played a critical role in protecting many chaparral stands from ecological damage resulting from excessive fire.
3. Infrequent, large, high-intensity crown fires are natural in chaparral.
4. There are few, if any, justifiable ecological/resource benefits in conducting prescribed burning or other vegetation treatments in chaparral.

Important Quotes:

"If chaparral does not have sufficient time to replenish the soil seed bank, accumulate the biomass necessary to produce fires hot enough to successfully germinate fire-cued seeds, or allow resprouting species time to restore starch supplies in underground lignotubers, a cascading series of events begins that can significantly change or completely eliminate the plant community." p. 181

"While fuel reduction projects can help fire suppression efforts and reduce fire intensity, they have been shown to be ineffective when it matters most: during extreme fire weather. During such conditions, the fire is not controllable because it will burn through, over, or around fuel treatments..." p. 201

Keeley, J. E. and C. J. Fotheringham (2006) Wildfire management on a human-dominated landscape: California chaparral wildfires, pp. 69–75. In G. Wuerthner, Ed., *Wildfire — A Century of Failed Forest Policy*. Island Press, Covelo, CA.

Summary:

Scientists at the U.S. Geological Survey and UCLA detail the patterns of wildfires in chaparral ecosystems in their chapter of *Wildfire — A Century of Failed Forest Policy*.

Key Findings:

1. Large, high-intensity wildfires are a natural feature of chaparral landscapes. They occurred prior to Euro-American settlement and will take place again in the future.
2. Twentieth-century fire management practices have been ineffective in preventing chaparral wildfires.
3. We need to view chaparral fires as we do other uncontrollable natural disasters and to focus on developing human infrastructure capable of minimizing their damage.
4. Chaparral species are not adapted to fire itself, but to a particular fire regime.
5. Fuel treatments are generally ineffective during extreme weather conditions.

Important Quotes:

“The extent to which landscape-level fuel treatments are effective in shrubland fire is mainly a function of weather conditions during the fire event. The evidence is overwhelming that under extreme fire weather conditions such as the autumn Santa Ana winds, young fuels, or even fuel breaks, will not act as barriers to fire spread.” p. 72

“For much of the past half-century, public agencies have held the false belief that how or where they allowed new developments to be built was irrelevant to fire safety—largely because of assurances that fire managers could prevent fires from burning across the wildland-urban interface. Undoubtedly there has been substantial pressure on fire managers to convey an overly confident image, and not to highlight their limitations.” p. 74

Keeley, J.E. and P.H. Zedler (2009) Large, high-intensity fire events in southern California shrublands: debunking the fine-grain age patch model. *Ecological Applications*, 19(1):69-94.

Summary:

Researchers with the U.S. Geological Survey and University of Wisconsin refute the fine-grain age patch model or “mosaic hypothesis” in Southern California chaparral, which states that fire suppression has allowed an unnatural amount of fuel to build up and for large wildfires to occur. The scientists use a

combination of scientific data, results of past studies, and historical evidence of large fires to make a case against the mosaic hypothesis. This is one of the key papers that essentially ended the debate about what type of fire regime is considered natural in chaparral and coastal sage scrub ecosystems.

Key Findings:

1. Large, high-intensity wildfires predate modern fire suppression policy.
2. Over the last 130 years, there has been no significant increase in the occurrence of large fires.
3. A review of empirical studies demonstrates that young chaparral and coastal sage scrub can still spread wildfire.
4. Attempts to create patches of young-aged vegetation will have no impact on large wildfire occurrence or spread.
5. Large fires are the result of extreme droughts, high temperatures, and high winds.

Important Quotes:

“Attempts to create a mythical fine-grain age mosaic are doomed to fail. Burning large areas on a 15–20 year rotation in small patches would require massive investments and a significant risk of damaging fire escapes that can cause expensive losses of property.” p. 90

“This analysis suggests that the greatest improvements in reducing community vulnerability to wildfires is not likely going to come from improved fuel treatments or fire suppression capabilities, but rather from changes in human infrastructure. The most significant advances are likely to come from improved fire prevention and careful analysis of land planning and zoning issues.” p. 90

Lombardo, K.J., T.W. Swetnam, C.H. Baisan, and M.I. Borchert (2009) Using bigcone Douglas-fir fire scars and tree rings to reconstruct interior chaparral fire history. *Fire Ecology*, 5(3):35-56.

Summary:

Scientists from the University of Arizona and U.S. Forest Service analyze bigcone Douglas-fir stands in the Ventura County backcountry to determine the historical and modern fire regime in the surrounding chaparral landscape. The researchers use fire scar and tree ring data collected from these stands to reconstruct fire history in an area within the Los Padres National Forest that has experienced major fires such as the 1932 Matilija Fire over the last century.

Key Findings:

1. Fire scar and tree ring analyses indicated that large, landscape-level wildfires have been occurring in the chaparral dominating the Transverse Ranges for centuries.

2. Large wildfires in these areas were likely driven by extreme winds and drought conditions both historically and in the modern era.
3. Smaller wildfires also occurred in these areas, but they did not affect the occurrence of larger fires over time.

Important Quotes:

"Lack of noticeable change in frequency of widespread events over the past 400 years, as evidenced in this study and Mensing et al. (1999), coupled with the fact that more than 90% of the fire scars in the tree-ring record were positioned in the latewood or dormant portion of each ring (K. Lombardo, University of Arizona, unpublished data), implies that landscape-scale fires have shaped the chaparral landscape for many centuries. As in recent decades, past widespread fires were likely driven by extreme winds and drought conditions." p. 52

"In light of our findings, we suggest that effort and costs may be better spent on wildland-urban interface management and updating zoning regulations to reflect the current scientific consensus. In the context of low fuel moisture levels and strong Santa Ana wind events, irregular spatial arrangement of fuels has been shown to be ineffective in controlling fire spread in chaparral landscapes...The historical and modern records both imply that large, landscape-scale fires are inevitable in chaparral landscapes." p. 53

Mensing, S.A., J. Michaelsen, and R. Byrne (1999) A 560-year record of Santa Ana fires reconstructed from charcoal deposited in the Santa Barbara Basin, California. *Quaternary Research*, 51:295-305.

Summary:

Researchers from UCSB, UC Berkeley, and the University of Nevada analyze the presence of charcoal and pollen deposits in marine sediments off the coast of Santa Barbara to trace the occurrence of large wildfires on the local landscape over the course of half millennium.

Key Findings:

1. Large charcoal particles in marine sediments off the coast can be correlated to major fires (> 50,000 acres) on the landscape that drains into the Santa Barbara Basin.
2. Major fires have occurred periodically for over 500 years, regardless of the various stages of human influence on the landscape (such as the modern fire suppression era, European colonization, and Chumash period).
3. There was no change in the number of major fires that occurred during these different eras, and the average time between major fires occurring somewhere on the landscape (though likely not in the same area) was similar for each era.

4. Neither small fires set by the Chumash nor modern fire suppression has changed the occurrence of major fires through time.
5. Climate exerts a significant influence on the occurrence of major wildfires, as they tended to occur at the end of wet periods and at the beginning of dry periods.

Important Quotes:

“Background levels of both large and small charcoal suggest that small fires are also common. Fires at this scale may have created a fine-grained vegetation mosaic in portions of the landscape, as suggested by Minnich (1983). However, there is no evidence that such a mosaic acted to prevent Santa Ana conflagrations.” p. 303

“Large fires occurred in every century. Neither the Chumash practice of setting fires nor the modern practice of suppressing fires appears to control the periodic occurrence of conflagrations in the region.” p. 303

“...the average length of time between large fires appears to be controlled to a large extent by precipitation trends....Oscillations between wet and dry phases over this period appear to contribute to large fires on a regular basis, regardless of changes in land use practices.” p. 304

Moritz, M.A., J.E. Keeley, E.A. Johnson, and A.A. Schaffner (2004) Testing a basic assumption of shrubland fire management: how important is fuel age? *Frontiers in Ecology and the Environment*, 2(2):67-72.

Summary:

Researchers from UCSB, UC Berkeley, the U.S. Geological Survey, UCLA, and elsewhere analyze the effect of chaparral and coastal sage scrub vegetation age on the probability of an area burning. These scientists use fire mapping data to develop a model determining whether the time since last fire is important to the probability that an area will burn.

Key Findings:

1. Shrubland vegetation age (or time since the last fire) is generally unimportant to whether an area burns. Wildfires can burn through both old and young chaparral and coastal sage scrub.
2. Only the Santa Barbara frontcountry (between Gaviota and Carpinteria) experienced a slight reduction in the probability of an area burning for the first several years after a fire, likely due to the enhanced fire suppression infrastructure already in place, topographic barriers to fire spread, and topographic barriers to extreme fire weather conditions.
3. Due to the lack of an age effect on fire potential, prescribed burning is likely to minimally reduce fire risk.

4. Large wildfires in these ecosystems are natural and inevitable.

Important Quotes:

“The lack of a strong age effect of fuels should have major implications for planning and management in many shrubland ecosystems. Our results contradict the widely held belief that large wildfires in California shrublands are the direct result of unnatural fuel accumulation due to fire suppression. Before modern suppression methods were introduced, extreme weather conditions could have infrequently generated large conflagrations that spread through all age classes of vegetation, just as they do now.”
p. 71

“Minimizing losses of life and property will ultimately require a science-based approach that integrates fireproofing of structures, intelligent landscaping, better evacuation preparation, and land use planning that constrains rapidly expanding urban–wildland interfaces.” p. 71

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

Summary:

Scientists with UC Berkeley, UCLA, and the NOAA Earth System Research Laboratory in Colorado examine where large fires are most likely to occur in the shrubland-dominated landscapes of southern California due to the location of extreme wind corridors. The researchers use several years of reconstructed weather data to identify Santa Ana wind events (the study did not examine other extreme wind types like sundowners near Santa Barbara) occurring in the most dangerous part of the fire season between 1995 and 2003. They then calculate the Fosberg Fire Weather Index (a measure of fire weather severity) during these time periods and model it across the landscape, using historical fire data to determine how well the models predict large fire probabilities.

Key Findings:

1. Fire weather severity associated with Santa Ana winds occur in specific areas, often associated with certain mountain passes, across southern California.
2. Large October wildfires consistently occur in locations experiencing higher fire weather severities.
3. Despite the importance of fire weather severity for fire growth, there are still factors such as human population and road densities that affect ignition probabilities and fire frequency.
4. Any fire-prone region is likely to see wildfires become large and difficult to suppress if ignitions occur where the wind conditions tend to be the most severe.

Important Quotes:

“Reducing future ignition sources and urban development in the most exposed regions could reduce the probability of large fire occurrence, which has recently led to repeated short-interval fires and losses of native shrubland species.” p. 71



Human Impacts on Chaparral and Coastal Sage Scrub Fire Regimes

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.

Summary:

Researchers from the Conservation Biology Institute and U.S. Geological Survey analyze trends in wildfire ignition sources throughout California using statewide datasets of fire locations and causes.

Key Findings:

1. Throughout California, human-caused ignitions increased throughout the mid-20th century before peaking in 1980. Such ignitions have been decreasing since. Even lightning ignitions (which were already lowest in the Los Padres National Forest compared to the rest of the state) have been decreasing since the mid-20th century, likely due to effects by climate change.
2. The decrease in human-caused ignitions over recent decades is likely due to cultural behavior changes, densification of urban areas and subsequent replacement of wildlands with non-flammable impervious surfaces (e.g. parking lots, roads, etc), and decreases in purposeful ignitions such as the mid-century push for converting chaparral into rangeland for economic reasons.
3. The only type of human-caused ignition that has not decreased since the 1980s is from powerline failures. These have continued to represent a significant source of ignitions and area burned.
4. Prevention efforts should be focused on addressing powerline ignitions, particularly in areas with known extreme wind patterns.

Important Quotes:

“Powerline distribution tends to follow roads and this may be part of the reason burning patterns are closely correlated with road distribution in southern California...Also, they burn larger areas than fires ignited by most other causes and are associated with more significant impacts on lives and property...”
p. 797

“Because these powerline failures typically occur in known extreme-wind corridors, it has been proposed that wiring these corridors with underground power could minimise the problem...However, utility companies have shown a reluctance to accept this solution...” p. 797

Safford, H.D. and K.M. 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. Research Paper PSW-RP-266, USDA, Forest Service. PSW Research Station.

Summary:

Researchers with the U.S. Forest Service examine the change in fire frequency over time throughout California.

Key Findings:

1. Fire frequency has dramatically increased in southern California chaparral, including in the counties surrounding the Los Padres National Forest.
2. Based on other studies, this increase in fire frequency is due to an increase in regional population and human-caused ignitions.

Important Quotes:

“Interactions between human populations and highly flammable vegetation types like coastal sage scrub and chaparral have led to major changes in fire regimes in and around southern California’s urban areas. The ecological subsections surrounding the San Diego, Los Angeles, and Santa Barbara metropolitan areas are among the most negatively departed [i.e. they have greater fire frequency than historically] in the state.” p. 34

“In these areas, extensive landscapes characterized originally by dense native shrublands have been converted to degraded, open stands of native shrubs and exotic annual grasses and forbs, which are easily reignited. These fire-mediated changes in vegetation lead to higher rates of erosion, increased exotic species invasion, and higher fire hazard as grass fuels replace shrubs.” p. 34

Syphard, A.D., V.C. Radeloff, J.E. Keeley, T.J. Hawbaker, M.K. Clayton, S.I. Stewart, and R.B. Hammer (2007) Human influence on California fire regimes. *Ecological Applications*, 17(5):1388-1402.

Summary:

Researchers from the University of Wisconsin, UCLA, Oregon State University, U.S. Geological Survey, and U.S. Forest Service explore the ways human development in and near wildlands have impacted wildfire patterns. They use large California datasets covering housing density, land cover, population density, road density, vegetation type, and ecoregion to determine whether any relationships exist between the variables.

Key Findings:

1. Approximately 95% of wildfires in southern California are started by humans either accidentally or intentionally (i.e. arson).
2. Population density and wildland-urban interface (WUI) development explained most of the variability in fire frequency.
3. Fire frequency and area burned were highest at intermediate levels of human activity but declined beyond certain thresholds (i.e. at a certain point, number of fires and area burned decrease once development removes ignition zones and flammable vegetation such as seen in heavily-urbanized areas like Los Angeles proper).
4. Fires occurred more frequently closer to developed WUI areas.
5. Land use planning should encourage compact development and the reduction of sprawling development.

Important Quotes:

“For number of fires, the proportion of intermix WUI explained more variation than any other variable except for population density, suggesting that the spatial pattern of housing development and fuel are important risk factors for fire starts.” p. 1396

“...fire frequency and area burned were greatest at short distances to WUI; and at longer distances, the trend lines leveled off. These distance relationships indicate that more fires would be expected in close proximity to settled areas where ignitions are likely to occur.” p. 1400

Syphard, A.D. and J.E. Keeley (2015) Location, timing and extent of wildfire vary by cause of ignition. *International Journal of Wildland Fire*, 24:37-47.

Summary:

Researchers from the Conservation Biology Institute and U.S. Geological Survey analyze the spatial and temporal distribution of wildfires in southern California based on ignition source.

Key Findings:

1. Most fires were started by the use of power equipment.
2. In the northern portion of the study area (within the Santa Monica Mountains), most of the area burned was due to wildfires started by arson and power lines. In the southern portion of the study area (San Diego County) most of the area burned was due to wildfires started by the use of power equipment and powerlines.

3. Throughout southern California, ignitions were more likely to occur close to roads and structures and this variable was the most important in explaining wildfire patterns.
4. Ignitions are likely to increase and spread throughout the WUI as these areas become increasingly developed due to the expansion of roads and highly flammable invasive plants.
5. Prevention efforts should be focused on reducing equipment-use ignitions and, if possible, addressing powerline ignitions.

Important Quotes:

“Because equipment use is such a common ignition source and is a potentially modifiable behaviour, this is one ignition source that should be a target for future prevention actions.” pp. 45-46

“Development of low density, exurban housing may also lead to more homes being destroyed by fire...Another consideration is that frequent fires and housing growth may lead to the expansion of highly flammable exotic grasses that can further increase the probability of ignitions...” p. 46



Causes and Impacts of Type Conversion and Invasive Plant Spread

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke (2004) Effects of invasive alien plants on fire regimes. *Bioscience*, 54(7):677-688.

Summary:

Scientists with the U.S. Geological Survey and other institutions around the world explore the impacts of non-native, invasive plants on natural fire regimes in chaparral and other ecosystems. The authors develop a model that describes the relationships between invasive plants and fire regimes with recommendations for how to restore ecosystems suffering from this cycle.

Key Findings:

1. Non-native plant invasions can completely alter the natural fire regime of an ecosystem and perpetuate a new fire regime. In chaparral, invasive grasses may result from increased fire frequency and they in turn increase fire frequency in a positive feedback loop.
2. The most effective way to prevent invasive plants from altering fire regimes is by preventing their initial introduction.
3. Invasive plants that have already become established should be targeted for eradication or reduction.
4. Land-use activities that promote the spread of invasive plants should be limited.
5. Management and restoration costs and rise dramatically after invasive plants become established and change the natural fire regime.

Important Quotes:

*"In perhaps most cases, plant invasions that change fire regimes do so by altering more than one fuel and fire regime property. For example, grass invasions of shrublands, such as the *B. tectorum* invasion described earlier, increase fire frequency by increasing the fuel surface-to-volume ratio, increasing horizontal fuel continuity, and creating a fuel packing ratio that facilitates ignition."* p. 979

"Thus, at each subsequent phase of the invasive plant–fire regime cycle, additional management considerations are added, costs increase, and the probability of successful management decreases..." p. 687

Keeley, J.E. (2003) Fire and invasive plants in California ecosystems. *Fire Management Today*, 63(2):18-19.

Summary:

Jon Keeley with the U.S. Geological Survey and UCLA details the spread of invasive plants throughout California ecosystems, including chaparral.

Key Findings:

1. Chaparral has been and is still being converted to non-native grass-dominated landscapes due to increased fire frequency.
2. Urban and suburban development has promoted the spread of invasive plants due to associated increases in ignitions.
3. Prescribed fire in ecosystems that have higher-than-natural fire frequencies also favors spread of invasive plants.
4. Fuel breaks can act as “invasive highways,” carrying non-native species into uninfested wildlands.

Important Quotes:

“Nonnative plants in turn increase the flammability of surface fuels, thereby promoting more frequent, lower intensity fires.” p. 18

“Fuel manipulation can contribute to invasion by exotic plants. For example, fuel breaks can act as invasive highways, carrying exotic species into uninfested wildlands. Normally destroyed by stand-replacing fires, exotic seed banks can survive the lower fire severities in fuel breaks, resulting in source populations poised to invade adjacent burned sites.” p. 19

Keeley, J.E. (2006) Fire management impacts on invasive plants in the western United States. *Conservation Biology*, 20(2):375-384.

Summary:

Jon Keeley with the U.S. Geological Survey and UCLA examines the impact of various fire management practices on non-native plant invasions in this review of past studies.

Key Findings:

1. Native Americans burned small areas of chaparral to favor native herbaceous cover for various reasons related to foraging and hunting. These practices allowed non-native plants to invade chaparral ecosystems when European settlers arrived.

2. Rangeland proponents pushed for widespread prescribed burning in chaparral to increase grazing, which led to invasion of various species of non-native, annual grasses and loss of chaparral.
3. Prescribed burning should be avoided in chaparral landscapes where fire frequency is already too high and causing type conversion.
4. Fuel breaks are often comprised of as much as 70% non-native plants and can act as conduits for non-native plant spread.

Important Quotes:

“Such type conversions not only affect biodiversity, but replacing slopes dominated by natural shrublands with grasslands also makes these landscapes highly vulnerable to major changes in hydrological processes. For example, experimental type conversions performed for fire hazard reduction have resulted in soil slips and other major geomorphological changes...” p. 379

“Consequently, following fires these fuel breaks represent a major source area for alien invasion of adjacent wildlands.” p. 380

Keeley, J.E. and T.J. Brennan (2012) Fire-driven alien invasion in a fire-adapted ecosystem. *Oecologia*, 169:1043-1052.

Summary:

Researchers from the U.S. Geological Survey study the effects of short fire return intervals on non-native plant invasion during post-fire recovery of chaparral. The scientists analyze plant diversity and growth on chaparral-dominated sites that burned multiple times in San Diego County within a relatively short period.

Key Findings:

1. Seedling recruitment and resprouting success in chamise were significantly reduced after fire that occurred in 3-year-old stands of chaparral compared to 24-year-old stands.
2. One species of ceanothus was extirpated after fire that occurred in 3-year-old stands of chaparral compared to successful population recovery in 24-year-old stands.
3. Invasive, flammable plants such as foxtail brome was dominant for at least the first five years after fire in 3-year-old chaparral stands.
4. Species diversity was significantly greater for five years following fire in 24-year-old chaparral stands compared to 3-year-old chaparral stands.
5. Short fire return intervals result in lower intensity fire (due to less vegetation build-up) that allows non-native plant seeds to survive and disallows native plant seed germination. Additionally,

short return intervals do not allow for many native species to reach maturity and replenish the seedbank or carbon stores in roots needed for resprouting.

Important Quotes:

“Early “range improvement” studies have shown that repeated burning is a highly effective means of type converting chaparral to alien-dominated annual grasslands.” p. 1050

“Annuals provide flashy fuels that are more likely to ignite under a wider range of weather conditions than native woody fuels, and alien grasses from the Mediterranean Basin dry very early in the growing season. The increase of alien grasses on a site has the effect of greatly expanding the fire season and the probability of a repeat fire.” p. 1050

Lucas, T.A., G. Johns, W. Jiang, and L. Yang (2013) A population model of chaparral vegetation response to frequent wildfires. *Bulletin of Mathematical Biology*, 75:2324-2345.

Summary:

Researchers from Pepperdine use data from a long-term study of response of chaparral species on a preserve in the Santa Monica Mountains to increased fire frequency to model the effects of varying fire return intervals on species survivorship.

Key Findings:

1. Nonsprouters such as *Ceanothus megacarpus* (bigpod ceanothus) was extirpated at the long-term study site following a 3-year fire return interval. Facultative sprouters (i.e. plants that can resprout or recruit seedlings following a fire) survivorship was also reduced under these conditions.
2. Facultative sprouters have better survivorship in short fire return intervals. Plants with high resprout success such as laurel sumac have the best survivorship in these areas as well.
3. Plants that rely on seedling recruitment after fire will be severely impacted by reductions in fire return intervals.

Important Quotes:

“The Ceanothus megacarpus simulations support the hypothesis that species survival is dependent on there being enough time between wildfires for seedlings to mature and build a seedbank, which is consistent with the field data...” p. 2340

“The simulations...suggest that the chaparral populations are threatened by the increase in incidence of wildfires. Specifically, species such as Ceanothus megacarpus and Ceanothus spinosus can be completely destroyed or significantly reduced by a rapid succession of wildfires. Differential species response to anthropogenic increases in fire events potentially causes shifts in plant community

structure. This can lead to invasion by exotic species which increases flammability and further exacerbates fire return intervals.” p. 2341

Lucas, T.A., R.A. Doña, W. Jiang, G.C. Johns, D.J. Mann, C.N. Seubert, N.B.C. Webster, C.H. Willens, and S.D. Davis (2017) An individual-based model of chaparral vegetation response to frequent wildfires. *Theoretical Ecology*, 10:217-233.

Summary:

Researchers at Pepperdine, USC, and Pomona College model the effects of fire frequency and drought on chaparral populations using data from a long-term study of chaparral on a preserve in the Santa Monica Mountains.

Key Findings:

1. Both facultative sprouter and nonsprouter species of *Ceanothus* can be eliminated by high frequency fire.
2. Successful sprouters such as laurel sumac or sugar bush can survive high frequency fire, but they will experience significant declines in canopy density due to decreased seedling recruitment during fire-free intervals (which is worsened by decreased canopy cover).
3. Drought, especially extreme long-term drought, can exacerbate these results.
4. High fire frequency combined with drought can result in type conversion from chaparral to invasive, highly flammable grasses and weeds.

Important Quotes:

“Our model predicts that if the current conditions of drought and increased fire frequency continue, there will be a reduction in vegetative cover and a loss of chaparral species diversity leading to vegetation-type conversion. The open spaces that were once occupied by chaparral are susceptible to invasion by exotic weeds and coastal sage shrub which will only further increase flammability, decrease fire return intervals and decrease slope stability.” p. 231

Syphard, A.D., J. Franklin, and J.E. Keeley (2006) Simulating the effects of frequent fire on southern California coastal shrublands. *Ecological Applications*, 16(5):1744-1756.

Summary:

Scientists from San Diego State University and the U.S. Geological Survey simulate the impacts of increased fire frequency on plant functional types (i.e. facultative sprouters, obligate sprouters, and nonsprouters) in southern California chaparral and coastal sage scrub.

Key Findings:

1. Nonsprouters (obligate seeders) were most susceptible to type conversion under short (15-year) fire return interval conditions. Facultative sprouters also experienced declines under these conditions.
2. Non-native, invasive grasses increased by taking place of chaparral when fire return intervals were short.
3. Coastal sage scrub experienced declines (conversion to grasses) in areas with the highest fire frequencies.

Important Quotes:

“Despite overwhelming evidence that fire frequency is continuing to increase in coastal southern California...the current fire- management program subscribes to the paradigm that fire suppression has led to fewer, fires, and that landscape-scale prescribed fire should be used to create a fine-scaled age mosaic. Considering the results of our simulations, we believe that adding more fire to the landscape through broad-scale prescribed burning may have negative ecological effects.” p. 1755

Syphard, A.D., T.J. Brennan, and J.E. Keeley (2018) Drivers of chaparral type conversion to herbaceous vegetation in coastal Southern California. *Diversity and Distributions*, 2018:1-12.

Summary:

Scientists from the Conservation Biology Institute and U.S. Geological Survey explore the primary causes of chaparral type conversion in southern California landscapes, specifically in the Santa Monica Mountains, using comparisons of historical and modern aerial imagery.

Key Findings:

1. Approximately 36% of the randomly-selected plots throughout the study area either completely converted or mostly converted to herbaceous cover between 1943 and 2014.
2. The mean number of years it took for a plot to transition from chaparral to grassland was approximately 50 years, indicating that type conversion may occur relatively slowly and thus may be occurring extensively in the region.
3. Short fire return intervals are a primary catalyst for type conversion in chaparral, but the success of herbaceous plants (typically non-native, invasive grasses) is highly dependent on characteristics of the site, particularly moisture availability (i.e. less moisture availability favors herbaceous spread).
4. Proximity to trails and roads can also increase the likelihood of an area of chaparral converting to herbaceous cover.

Important Quotes:

“Fires are so frequent now in Southern California that the region is burning far beyond what historical return intervals used to be...However, recent studies have documented lower cover and density of shrubs and higher cover and density of exotic herbaceous plants in areas treated for fire management...These results, and the strength of the relationship documented here, suggest that the negative ecological impact of these treatments may exceed whatever benefit they may provide in areas where they do not serve to benefit the protection of residential communities.” p. 9

“In conclusion, replacement of woody shrublands with annual herbaceous cover is becoming a widespread and serious concern in Southern California and other Mediterranean-climate and non-forested ecosystems...The model results here suggest that short-interval fire is a critical mechanism contributing to shrubland extirpation.” p. 10

Syphard, A.D., T.J. Brennan, and J.E. Keeley (2018) Chaparral landscape conversion in southern California, pp. 323-336. In E.C. Underwood, H. Safford, N. Molinari, and J. Keeley, Eds., *Valuing Chaparral: Ecological, Socio-Economic, and Management Perspectives*. Springer International Publishing.

Summary:

In this chapter of *Valuing Chaparral*, researchers from the Conservation Biology Institute and U.S. Geological Survey explore the issue of chaparral type conversion in southern California landscapes. The chapter includes a large-scale analysis of type conversion from San Luis Obispo County to San Diego County using historical aerial imagery comparisons.

Key Findings:

1. Low- and high-density development have fragmented and replaced large swaths of chaparral in southern California since the 1940s. This sprawling development has been the primary contributor, directly and indirectly, to loss of chaparral.
2. Low-density development and sprawl has resulted in higher fire frequency and expansion of highly flammable non-native annual grasses.
3. Increased fire frequency and expansion of non-native plants creates a feedback loop that exacerbates chaparral and coastal sage scrub conversion to grassland. This is likely to continue with increased development.
4. Chaparral conversion poses a threat to biodiversity, soil stability (which is associated with increased potential for debris flows), and carbon sequestration (due to loss of shrubs), an important component of mitigating the effects of climate change.
5. Land use planning should be aimed at lowering risk by arranging houses so they are less fire-prone, reducing human presence in flammable areas, and reducing disturbance corridors that expand non-native plants.

Important Quotes:

“In terms of fire frequency, the analysis showed highest mean fire frequencies in classes where either sage scrub or shrub converted to grass, or where shrub converted to sage scrub...” p. 333

“The sprawling development pattern in southern California has been the primary driver of contemporary chaparral conversion, both through the direct removal and fragmentation of habitat, but also through its indirect role in driving annual grass expansion associated with increased fire frequency.” p. 341

Syphard, A.D., T.J. Brennan, and J.E. Keeley (2019) Extent and drivers of vegetation type conversion in Southern California chaparral. *Ecosphere*, 10(7):e02796.

Summary:

Researchers with the Conservation Biology Institute, Sage Underwriters, UCLA, and U.S. Geological Survey analyze type conversion of chaparral to herbaceous cover in Southern California over a period of 63 years between 1953 and 2016 in San Diego County. They use historical and modern aerial images to determine the change in vegetation type.

Key Findings:

1. Only 46% of the 771 randomly-selected plots across the county retained the same type of cover between 1953 and 2016.
2. Approximately 59% of the 311 plots that had more than 75% woody cover in 1953 experienced a woody cover decline by 2016 (these plots loss 22.5% of their woody cover on average).
3. Approximately 28% of the plots that experienced woody cover decline over the 63-year study period fully type-converted to herbaceous vegetation.
4. The top drivers of chaparral conversion included minimum fire interval, total number of fires since 1898, actual evapotranspiration, and elevation. The most important factor for chaparral conversion or decline was whether the plot had experienced two fires less than 15 years apart.
5. Areas that are more susceptible to drought stress (such as steep slopes) are more prone to chaparral conversion or woody cover decline.

Important Quotes:

“...vegetation type change is a gradual process that cannot be fully captured, and in fact is underestimated, by classing vegetation into only two states.” p. 9

“...drought is of greatest importance in the post-fire environment, and thus, there could be serious implications if droughts were to increase under climate change. Drought interacts with fire to reduce post-fire recovery...and when fires are frequent under drought conditions, this can exacerbate the invasion of non-native grasses. p. 10

Zedler, P.H., C.R. Gautier, and G.S. McMaster (1983) Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal scrub. *Ecology*, 64(4):809-818.

Summary:

In this paper—which was one of the first to document chaparral type conversion—researchers from San Diego State University examine an area that reburned within one year of a fire and caused drastic, immediate type conversion through loss of dominant chaparral species.

Key Findings:

1. In the event of a 1-year fire return interval in San Diego County, the dominant chaparral vegetation such as *Ceanothus* spp. and chamise were either completely eliminated or reduced by up to 97%.
2. Loss of chaparral species is accompanied by an increase in non-native annual grasses.

Important Quotes:

“After the introduction of aggressive annual grasses, the probability of fire at short intervals increased. Unlike the majority of native annuals, which flush in the 1 st yr and fade quickly, grasses such as Bromus rubens persist indefinitely in open patches in the chaparral and create denser and more uniform cover better able to carry fire. They increase with grazing and other disturbances, so that a new vegetation type has emerged: degraded shrublands with an annual-grass understory.” p. 817

“Purposeful and accidental fires carried largely by grass have repeatedly burned some areas, and the cumulative effect has been recession of chaparral shrubs.” p. 817



Efficacy and Ecological Impacts of Fuel Treatments

Bradley, T., J. Gibson, and W. Bunn (2006) Fuels Management and Non-native Plant Species: an Evaluation of Fire and Fire Surrogate Treatments in a Chaparral Plant Community. *Final Report to the Joint Fire Science Program, Project Number: JFSP 01B-3-3-27.*

Summary:

Ecologists with the National Park Service examine the effects of different methods of vegetation clearance, including mastication and hand thinning, on mixed oak-shrublands and chaparral community recovery and invasive plant spread.

Key Findings:

1. In sites where understory vegetation is masticated and left on site, fire behavior indices actually increased in comparison to masticated fuelbeds under the tested parameters. The most effective way to prevent invasive plants from altering fire regimes is by preventing their initial introduction.
2. Low intensity spring burns can be used to reduce surface fuel loading in masticated fuels, but mortality to residual vegetation may be high.
3. Vegetation response to treatments is highly variable, and closely correlated with pre-existing condition.
4. Most exotic plant species are adapted to disturbances and will increase post treatment.
5. Treatments that retain greater levels of overstory shading and litter/surface cover greatly mitigate risk of increasing exotic plant cover.

Important Quotes:

“The reduction of overstory trees and shrubs through hand-thinning and prescribed burning increased the amount of direct sunlight and reduced the amount of litter on the soil surface, thus making conditions favorable for non-native plant species.” p. 27

“Fuels treatments often hasten the establishment and spread of exotic plant species. This exotic plant establishment may occur in a non-random pattern across the landscape and may not be visible during the early spring growing season.” p. 29

Brennan, T.J. and J.E. Keeley (2015) Effect of mastication and other mechanical treatments on fuel structure in chaparral. *International Journal of Wildland Fire*, 24(7):949-963.

Summary:

Scientists at the U.S. Geological Survey use field studies in treated and untreated stands of chaparral to examine the effects of mastication on fuel structure throughout the southern California national forests, including the Los Padres National Forest.

Key Findings:

1. Downed woody fuel increased significantly compared to untreated stands, with certain types of mechanical treatment resulting in more woody fuel than others (i.e. crushing vs mastication).
2. Herbaceous cover (often non-native, invasive plants) representing a finer fuel bed increased in all types of mechanical treatments.
3. Sites that were masticated more than once had the highest proportion of herbaceous cover and significantly reduced shrub recovery, indicating that they may be undergoing type conversion.
4. The increase in invasive, highly-flammable grasses, the increase in downed woody fuel, and the decrease in shading can all contribute to increased wildfire risk in mechanically-treated chaparral stands.

Important Quotes:

“When densely compacted fuel beds are subjected to longer duration combustion, heat energy can be re-directed to the underlying soil, potentially damaging underground plant structures...and depleting native plant seed banks...This in turn can lead to non-native plant establishment and vegetative community changes...Residual flaming and smouldering can also complicate fire behaviour, leading to fire control issues...and emission problems due to increased smouldering consumption...” p. 958

“A further complication of the widespread use of mechanical treatments is the increase in both native and non-native herbaceous fuels. Non-native species, and in particular non-native annual grasses, are highly flammable species that tend to cure earlier in the season than native plants and thereby shorten the length of time during which fuel moisture may inhibit fire ignition potential...” p. 959

Brennan, T.J. and J.E. Keeley (2017) Impacts of mastication fuel treatments on California, USA, chaparral vegetation structure and composition. *Fire Ecology*, 13(3):120-138.

Summary:

Scientists at the U.S. Geological Survey examine the effects of mastication on community structure, diversity, and composition as well as proportions of native and non-native species in chaparral throughout the southern California national forests, including the Los Padres National Forest.

Key Findings:

1. In untreated stands of chaparral, native plant species dominated 10:1 over non-natives.
2. Non-native species were present in 91% of masticated stands of chaparral, and they were generally the most abundant species in those stands overall.
3. Masticated stands of chaparral tended to favor regrowth of facultative seeding species, reducing obligate seeder species.
4. Non-native species persisted with no changes in abundance and density in masticated sites over the 8-year study period.

Important Quotes:

“Another concern about using masticated treatments is the layer of woody debris that is left on site. Decomposition in chaparral is very slow...and there is an increasingly high likelihood that these treatments will be subjected to a wildfire event before the fuel load from mastication has decomposed. The combustion of an excessive and abnormal woody fuel load on the soil surface in masticated treatments could result in prolonged heating, with temperatures capable of damaging plant structures and killing soil-stored seeds...Thus, if masticated treatments are burned in intense wildfires, the community is more likely to be put on a trajectory towards type conversion.” p. 135

“The primary focus of fuels management has often been the use of extensive mechanical fuel treatments; however, more may be gained by shifting that focus to changes that could be made in other areas including better land use planning, appropriate defensible space, building construction materials, urban vegetation, ignition control, and fire prevention education.” p. 135

Knapp, E.E., B.L. Estes, and C.N. Skinner (2009) Ecological Effects of Prescribed Fire Season: A Literature Review and Synthesis for Managers. General Technical Report PSW-GTR-224, USDA, Forest Service. PSW Research Station.

Summary:

Researchers at the U.S. Forest Service detail the effects of unseasonal prescribed fire on various ecosystems, including chaparral.

Key Findings:

1. Prescribed burns conducted outside of the natural fire season can reduce post-fire recovery (i.e. seed germination) due to either the conversion of soil moisture which is still high in the spring to steam (which may sterilize seed) or the lower intensity/temperature conditions that do not allow fire-cued seeds to germinate.
2. Prescribed burns conducted outside of the natural fire season can also limit the growing season and subsequent recovery.

Important Quotes:

“The bottom line is that the potential for shifts in the plant community exists when the heat generated by prescribed burning is dissimilar to what would have been experienced with the fire regime that species evolved with.” p. 24

Newman, E.A., J.B. Potts, M.W. Tingley, C. Vaughn, and S.L. Stephens (2018) Chaparral bird community responses to prescribed fire and shrub removal in three management seasons. *Journal of Applied Ecology*, 55:1615-1625.

Summary:

Researchers at UC Berkeley, the U.S. Forest Service, and other institutions detail the results of a large-scale field experiment involving prescribed fire and mastication’s impacts on bird communities in a chaparral ecosystem.

Key Findings:

1. Mastication of chaparral results in reduced bird species richness compared to untreated chaparral and even stands treated with prescribed fire (which reduces bird species richness in the short-term compared to untreated stands).
2. Compared to untreated stands, mastication reduced bird species richness by 25 - 67% depending on which season it was conducted.
3. Mastication significantly altered bird guild structure compared to untreated stands, particularly by reducing the presence of tree-nesting and foliage-gleaning birds.

Important Quotes:

“...prescribed fire is not necessary for the maintenance of chaparral biodiversity...” p. 1623

“All fuels management in chaparral has the potential to severely degrade habitat with repeated use. An ecologically conservative approach to lowering fire management impacts on wildlife communities would therefore be to (1) limit fire management to where there is a clear and demonstrated conflict with

human habitation (this will likely take the form of mastication for safety reasons), (2) plan development and manage risk to human habitation rather than managing natural areas...and (3) create a chaparral management inventory system to allow scientists and managers to assess changes to the vegetation community due to management.” p. 1623

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.

Summary:

Scientists with the Conservation Biology Institute, UCLA, and the U.S. Geological Survey compare the effectiveness of fuel breaks in wildfire suppression across the four national forests in southern California using a combination of fire and fuel break mapping as well as firefighter interviews.

Key Findings:

1. Fuel breaks played an important role in controlling large fires only when they facilitated fire management by providing access for firefighting activities.
2. Fire weather was an important driver of fuel break efficacy such that fuel breaks were generally not effective under extreme fire weather conditions (when fires are largest, spread the fastest, and cause the most structural damage).
3. Fuel breaks should be constructed in strategic locations closest to communities rather than in remote locations.

Important Quotes:

“The case studies from all four national forests demonstrate that fuel breaks will not stop fires without firefighter presence. Therefore, constructing fuel breaks in remote, backcountry locations will do little to save homes during a wildfire because most firefighters will be needed to protect the wildland–urban interface, and fires will not be stopped by those fuel breaks that are located farther away.” p. 2047

“Finally, because access to fuel breaks was consistently improved when vegetation structure was favorable, this study suggests that maintaining fuel breaks in strategic locations may be just as important as constructing new fuel breaks.” p. 2047

Syphard, A.D., J.E. Keeley, and T.J. Brennan (2011) Factors affecting fuel break effectiveness in the control of large fires on the Los Padres National Forest, California. *International Journal of Wildland Fire*, 206(6):764-775.

Summary:

Scientists with the Conservation Biology Institute, UCLA, and the U.S. Geological Survey examine the effectiveness of fuel breaks in wildfire suppression in the Los Padres National Forest over a 28-year period using similar methods to the study above.

Key Findings:

1. Most fires (79%) never intersected a fuel break.
2. A substantial proportion of fuel breaks did not encounter a fire, indicating that fuel breaks are often constructed in places where they will have little benefit.
3. Wildfires stopped at fuel breaks 46% of the time between 1980 and 2007, but only when firefighters were present.
4. Fuel break width was not important to whether the fire stopped at the fuel break.
5. Fuel breaks should be located closer to communities rather than in remote locations.

Important Quotes:

“Although fuel breaks surrounding communities clearly serve an important role in creating a safe space for firefighting activities, fuel breaks in remote areas and in areas that rarely or never intersect fires have a lower probability to serve a beneficial function.” p. 373

“It is also important to consider that many homes are not ignited owing to direct fire spread, but from firebrands...” p. 373



Indigenous Use of Fire in Chaparral and Coastal Sage Scrub

Anderson, M.K. and J.E. Keeley (2018) Native people's relationship to the California chaparral, pp. 79-122. In E.C. Underwood, H. Safford, N. Molinari, and J. Keeley, Eds., *Valuing Chaparral: Ecological, Socio-Economic, and Management Perspectives*. Springer International Publishing.

Summary:

In this chapter of *Valuing Chaparral*, researchers from the Natural Resource Conservation Service and U.S. Geological Survey detail the interactions Native Americans had with chaparral, including their use of intentional burning in this ecosystem.

Key Findings:

1. Native Americans intentionally set fires to open up small areas throughout southern California for a variety of reasons, including hunting and foraging.
2. Native Americans used high fire frequency to replace some chaparral with native herbaceous plants.
3. This type conversion was often conducted close to villages and along travel routes.
4. Restoring this practice to today's landscape would result in the widescale spread of non-native, invasive plants that were not present when Native Americans were employing prescribed fire before the arrival of European settlers.

Important Quotes:

"Southern California chaparral represents a very different situation and one in which restoring traditional fire practices on any significant scale would not improve fire hazard and instead would likely cause ecological damage. The primary reason is that indigenous burning in the region has been replaced by even more anthropogenic burning than Indians ever did." p. 113

"Repeated burning of chaparral is invaded by these non-native species, greatly diminishing the resource value, and is contrary to conservation goals of maintaining native vegetation. In addition, such type-conversion increases the highly flammable flashy fuels and results in increased ignitions and fire spread into more hazardous chaparral fuels..." p. 113

Keeley, J.E. (2002) Native American impacts on fire regimes of the California coastal ranges. *Journal of Biogeography*, 29:303-320.

Summary:

The perception that Native Americans were using prescribed fire for centuries is often used to justify prescribed fire in chaparral. In this key paper, Jon Keeley with the U.S. Geological Survey and UCLA examines why and how Native Americans were using prescribed fire in coastal chaparral.

Key Findings:

1. Evidence suggests that Native Americans were intentionally burning chaparral to cause type conversion for various reasons including (in order of relative importance): increasing edible herbaceous plants, increasing habitat for game, increasing surface water flow in local streams, reducing habitat for dangerous animals (e.g. grizzlies and rattlesnakes) immediately around settlements, and reducing fire hazard close to villages.
2. There is evidence that prescribed fires initiated by Native Americans often escaped.
3. Areas that were type converted by Native Americans are now dominated by non-native, invasive plants.

Important Quotes:

“However, I will argue that Native Americans greatly accelerated this natural fire frequency on shrubland dominated landscapes. As a consequence, shrublands were thinned-out or displaced and over a sizeable portion of the landscape, the physiognomy changed from shrubland to grassland.” p. 305



Wildland-Urban Interface Development

Alexandre, P.M., S.I. Steward, 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(7):2323-2338.

Summary:

Scientists from the University of Wisconsin, Conservation Biology Institute, U.S. Forest Service, and University of Haifa use pre- and post-fire satellite imagery to explore the factors that increase the chances of a building loss during wildfires in the United States.

Key Findings:

1. Vegetation-related variables were generally less important than other factors in explaining why homes burned.
2. Clusters of homes located at the tops of ridges, at higher elevations, and with greater road densities were more likely to burn in southern California.
3. Larger housing clusters with a greater number of buildings and more space between buildings were more likely to burn.
4. Topography and building arrangements most strongly affect which buildings are lost during a wildfire and therefore should be taken into account during land planning.

Important Quotes:

“Independent of the ecoregion’s characteristics, the location of the cluster in relation to other clusters and how far buildings were from other buildings had a clear association with building loss in case of wildfire.” p. 13

“Although vegetation may be the most obvious and manageable aspect of wildfire risk that managers can address, fuel treatments are only a partial and short-term solution, and insufficient to address the other sources of fire risk to buildings, as our models clearly show.” p. 14

“The challenge is that factors such as topography and building patterns cannot be changed after buildings are in place, and need to be accounted for when urban planners make community-wide planning, subdivision layout, or building siting decisions.” p. 14

Radeloff, V.C., D.P. Helmers, H.A. Kramer, et al (2018) Rapid growth of the US wildland-urban interface raises wildfire risk. *PNAS*, 115(13):3314-3319.

Summary:

Scientists from the University of Wisconsin, UC Berkeley, Conservation Biology Institute, and University of Haifa detail the rapid growth of WUI areas in the United States and the issues associated with this growth. While not specific to southern California chaparral, this paper is important in highlighting the growing problem of WUI development.

Key Findings:

1. More than 13 million new homes were built in the WUI between 1990 and 2010, a 41% increase.
2. The land area of the WUI grew by 33% during this time as well.
3. That vast majority (97%) of new WUI areas were the result of new housing.
4. Due to increases in wildfire ignitions associated with WUI expansion, this continuing growth will likely increase the incidence of wildfires.

Important Quotes:

“Homeowners can reduce their individual fire risk by removing vegetation directly adjacent to their house (i.e., the home ignition zone...), changing roofing and building materials, and following additional Firewise recommendations...” p. 3317

“Communities and local jurisdictions could anticipate wildfires and environmental impacts more explicitly when planning future land use to avoid housing expansion in high-risk wildfire areas and other environmentally sensitive areas....Agencies managing public lands could consider targeted purchases of private inholdings to limit future housing growth within the administrative boundaries of public lands, which has been particularly rapid...” p. 3317

Syphard, A.D., J.E. Keeley, A. Bar-Massada, T.J. Brennan, and V.C. Radeloff (2012) Housing arrangement and location determine the likelihood of housing loss due to wildfire. *PLoS ONE*, 7(3):e33954

Summary:

Researchers from the Conservation Biology Institute, U.S. Geological Survey, UCLA, and University of Wisconsin analyze house location datasets from the Santa Monica Mountains and San Diego County as well as fire location data to determine the impacts of housing arrangement and location on the probability of structure loss during wildfire in southern California.

Key Findings:

1. In the two study regions (Santa Monica Mountains and San Diego County), property loss was more likely in smaller, more isolated housing clusters with low- to intermediate-housing density and few roads.
2. Property loss was also significantly related to position on the landscape where homes closer to the coast in the Santa Monica Mountains and farther from the coast in San Diego County tended to burn.
3. The historical fire frequency of an area was the most important factor in determining the chances of a home burning in the Santa Monica Mountains, with more homes burning in areas with historically high fire frequency indicating that some places are more fire-prone than others.
4. Homes were more likely to burn in herbaceous vegetation types (generally grasses and weeds) in the Santa Monica Mountains.

Important Quotes:

“...new development would have a lower likelihood of burning if it were located away from fire-prone areas, such as wind corridors or steep slopes, and if new structures were arranged in intermediate-to high-density neighborhoods designed to minimize the amount of interface between homes and wildland vegetation.” p. 6

“... substantial property loss occurred when the primary surrounding fuel type was low fuel-volume grasslands. Although this result may seem counterintuitive, herbaceous fuels tend to have low fuel moisture, facilitate high wind speeds and fire spread, and have low heat requirements for ignition, thus promoting longer fire seasons and high fire frequency...Grasslands also tend to ignite quickly, then carry fires into shrublands or woodlands...These results suggest a need to reexamine the assumptions used in existing hazard maps and the management practice of converting shrublands to grasslands.” p. 6



Community Resilience to Wildfire

Anderson, S.E., R.R. Bart, M.C. Kennedy, A.J. MacDonald, M.A. Moritz, A.J. Plantinga, C.L. Tague, and M. Wibbenmeyer (2018) The dangers of disaster-driven responses to climate change. *Nature Climate Change*, 8:648-659.

Summary:

Researchers from UCSB and elsewhere discuss the importance of long-term solutions to issues such as wildfire and climate change rather than short-term, disaster-driven responses.

Key Findings:

1. Wildfires close to the WUI stimulate subsequent investment in fuel reduction projects such that WUI communities that experience a fire are 50-75% more likely to receive fuel management in the year the fire occurs compared to communities that did not experience a fire.
2. Focus on short-term, visible action such as fuel reduction may overshadow critical long-term solutions such as changes in land use planning.

Important Quotes:

“...immediately after a fire, when citizen attention is high, local officials might focus not on fuel treatments but on retrofitting of houses or zoning that reduces encroachment into the WUI, both of which would reduce vulnerability over the longer term. Or they might use a salient fire as the focus of an extended information campaign that emphasizes the importance of continued yearly maintenance of defensible space around homes.” p. 652

Halsey, R.W. (2008) *Fire, Chaparral, and Survival in Southern California*. 2nd Edition, Sunbelt Publications, San Diego.

Summary:

Researcher, educator, and director of the California Chaparral Institute, Richard Halsey, explores wildfires in chaparral and coastal sage scrub in southern California. Many of the chapters feature contributions from other researchers such as Jon Keeley, Max Moritz, Marti Witter, and others as well as experienced wildland firefighters.

Key Findings:

1. Southern California chaparral ecosystems are experiencing increased fire frequency, but fires are still primarily influenced by drought and extreme weather rather than fuel (or fuel reduction).
2. Emergency planning is increasingly important to resilience of fire-prone communities.
3. Scientific evidence suggests that the best approach to structure loss reduction is to focus on the structure and work outward from there since most structure loss is due to ember attack.
4. Building design and construction should incorporate fire-safe materials.
5. Vegetation reduction is most effective immediately adjacent to structures.
6. Local governments should address land-use regulations and building codes in fire-prone areas.

Important Quotes:

“We must also recognize fire will always be a part of the Californian experience, with or without chaparral. In a fire prone environment like ours, poorly designed structures can promote and spread devastating firestorms as well as uncut vegetation. Considering the inevitability of fire in southern California, it’s best to learn how to let fire burn around us instead of through us.” p. 29

“A deeper and more difficult transition is ahead of us because the “fire problem” is truly one of where we build, in addition to how it is done. There are lessons to be learned from other natural hazards, which have resulted in limited or specialized development in disaster-prone locations. Californians must engage our policy makers and urban planners to create safe and sustainable communities, so that fire can continue to play its inevitable and necessary role on whatever natural landscapes we manage to leave for future generations.” (Contribution by Dr. Max Moritz) p. 109

Kramer, H.A., M.H. Mockrin, P.M. Alexandre, S.I. Steward, 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.

Summary:

Researches from the University of Wisconsin, U.S. Forest Service, and the University of Lisbon examine nationwide wildfire-caused structure loss data to determine how their placement in or near the WUI or the availability of fire outreach programs affected their chance of ignition.

Key Findings:

1. Most threatened and destroyed buildings in the conterminous US were within the WUI (over 75% in California).

2. New building construction within recent fire perimeters occurred farther from existing fire outreach programs than buildings at the time of the fire.
3. Buildings near pre-existing Firewise community centroids had a lower rate of destruction than those farther away, but often the national outreach program was brought to the community after 76% of the buildings had been destroyed, indicating that fire outreach was more often reactive than proactive.

Important Quotes:

“As people continue to build new homes in the wildland, the WUI (as well as nearby non-WUI areas) will require increased fire outreach programs in addition to improvements in road, water and fire-fighting infrastructure.” p. 338

“Continuing efforts to change homeowner behavior in mitigating for fire on their own property and throughout the community is vital. Land-use planning, building regulations and zoning laws could also be used to encourage safer building practices...” p. 338

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 A.D. Syphard (2014) Learning to coexist with wildfire. *Nature*, 515:58-66.

Summary:

Scientists from UCSB and around the world lay out recommendations and strategies for society in fire-prone areas to learn to adapt to wildfire over the long-term.

Key Findings:

1. Southern California chaparral ecosystems are experiencing increased fire frequency, but fires are still primarily influenced by drought and extreme weather rather than fuel (or fuel reduction).
2. Emergency planning is increasingly important to resilience of fire-prone communities.
3. Scientific evidence suggests that the best approach to structure loss reduction is to focus on the structure and work outward from there since most structure loss is due to ember attack.
4. Building design and construction should incorporate fire-safe materials.
5. Vegetation reduction is most effective immediately adjacent to structures.
6. Local governments should address land-use regulations and building codes in fire-prone areas.

Important Quotes:

“...US studies show that most people living in high-fire-risk areas understand their exposure, but there is a tenuous link between understanding risk and taking action to mitigate it; whereas recognizing risk might be necessary to consider mitigation, perceived efficacy of mitigation and resource constraints can be more influential.” p. 62

“In some shrubland-dominated landscapes, the arrangement and location of homes have been the most important factors for explaining structure loss: landscape factors such as low housing density, isolated clusters of residential development and long distances to major roads are better predictors of house loss than local factors such as defensible space, fuel or terrain.” p. 64

Multihazard Mitigation Council (2017) Natural Hazard Mitigation Saves 2017 Interim Report: An Independent Study. K. Porter, Principal Investigator. National Institute of Building Sciences, Washington.

Summary:

The National Institute of Building Sciences is in the process of conducting a large-scale study of the cost-benefits of various mitigation measures for natural disasters, including wildfire. This interim report details their findings so far.

Key Findings:

1. Along the South Coast, up to \$6 in postfire damage costs can be saved for every \$1 spent on fire-safe home construction (compliant with the 2015 International WUI Code).

Important Quotes:

“Firebrands also cause ignitions: burning pieces of wood, carried aloft by hot gases, land on and ignite the roof, debris-filled gutters, or other parts of the building.” p. 144

“...requirements of the 2015 IWUIC depend on the fire hazard severity and may include: non-combustible roofing material; fire-rated cladding; automatic sprinklers; underfloor and underdeck fire-rated enclosure; fire-rated glazing and exterior doors; non-combustible or protected gutters; non-combustible or protected eaves and soffits; and a defensible space created within a fuel modification distance from the structure, in which one must remove or manage trees, bushes, litter, duff, accumulated dead natural fuels, firewood, and accumulated other combustible material and outbuildings.” p. 144

Schoennagel, T., J.K. Balch, H. Brenkert-Smith, P.E. Dennison, B.J. Harvey, M.A. Krawchuk, N. Mietkiewicz, et al (2017) Adapt to more wildfire in western North America forests as climate changes. *PNAS*, 114(18):4582-4590.

Summary:

Researchers from the University of Colorado, UC Berkeley, and other universities examine the need for communities to adapt to more wildfire in western North America.

Key Findings:

1. In California, more than 30% of burned areas were within the WUI between 2000-2016, with a greater proportion of WUI fires in southern California.
2. Communities should recognize that fuels reduction cannot alter regional wildfire trends.
3. Residential development should be planned and incentivized to withstand inevitable wildfire.
4. Fuels management for home and community protection will be most effective closest to homes.

Important Quotes:

“The majority of home building on fire-prone lands occurs in large part because incentives are misaligned, where risks are taken by homeowners and communities but others bear much of the cost if things go wrong. Therefore, getting incentives right is essential, with negative financial consequences for land-management decisions that increase risk and positive financial rewards for decisions that reduce risk.” p. 4587

“Providing incentives for counties, communities, and homeowners to plan fire-safe residential development for both existing and new homes and discouraging new development on fire-prone lands will make communities safer.” p. 4588

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.

Summary:

Researchers from the Conservation Biology Institute and U.S. Geological Survey study the effect of varying amounts and types of defensible space on the probability of structure loss during a wildfire in southern California. Through this analysis, they develop specific recommendations to maximize a structure’s chances of surviving a wildfire.

Key Findings:

1. The most effective defensible space treatments occur between 16-58 ft from the structure.

2. Removal of vegetation beyond 100 ft from a structure does not improve the odds of the structure surviving a wildfire.
3. The most effective actions include reducing woody vegetation by up to 40% immediately adjacent to structures and ensuring that vegetation does not overhang or touch the structure.
4. While the amount and type of defensible space is important for improving the odds of a structure surviving a wildfire, ultimately other factors such as housing density and distance to major roads are more important.
5. Long-term solutions should include improving defensible space awhile also focusing on building design, land use planning, and community education.

Important Quotes:

“The steepest overall decline in destroyed structures occurred when mean defensible space increased from 0–7 m (0–25 ft) to 8–15 m (26–50 ft). That, along with the multiple regression results showing the significance of vegetation touching or overhanging the structure, suggests it is most critical to modify vegetation immediately adjacent to the house, and to move outward from there.” p. 1172

“...the data in this study do not support defensible space beyond 30 m (100 ft), even for structures on steep slopes.” p. 1174

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.

Summary:

Researchers from the Conservation Biology Institute and U.S. Geological Survey examine the role of various types of building construction materials such as window panes, roofs, siding, and more in determining the probability of structure ignition during wildfire in southern California. The authors also compared the importance of these construction materials to other factors affecting the odds of a structure being lost to wildfire. The researchers conducted these comparative analyses at the local structure/property-scale and the landscape-scale (multiple homes, communities, etc). Thus, differences between results of each analysis could direct which steps to take as an individual homeowner in a specific location and as a community across a landscape of complex, variable terrain and other features.

Key Findings:

1. For individual homeowners, building construction materials are important, with the use of double paned windows specifically increasing the chance of structure survival more than other materials.

2. Defensible space immediately adjacent, touching, or overhanging structures was the most important component of defensible space regardless of analysis scale and is generally as important as fire-safe construction in reducing the probability of structure ignition.
3. Younger structures have a higher chance of survival in higher-density developments compared to younger structures in lower-density developments.
4. Generally, homes constructed in lower-density developments had a lower chance of survival during wildfire than higher-density developments, likely due to these types of developments being located farther from roads used by firefighters and being located in more complex terrain conducive for extreme wildfire behavior (though high-density developments have also been shown to facilitate home-to-home fire spread).
5. At the landscape-scale, housing location and development patterns may be more important than any other factor in reducing the chance of structure ignition, even compared to fire-safe construction and homeowner preparation.

Important Quotes:

“For residents living in existing, older developments, who need to prioritize which actions they can take to retrofit their homes, our analysis suggests that treating the windows should be among the first updates to consider.” p. 145

“What is different in this study, however, is the finding that housing location and pattern may be even more important than fire-safe construction and homeowner preparation. Clearly, local-scale factors are critically important, but the significant implication is that homeowners could do everything correctly to prepare their house for fire safety, but if the structure is located in a hazardous setting, none of these actions may be enough.” p. 146

“Even for the low-density structures, the threshold of percent clearance in the classification tree was 30%, meaning a homeowner could leave up to 70% of the woody vegetation on the property and still maintain adequate protection. The key is to do the clearance close to the structure.” p. 146

Syphard, A.D. and J.E. Keeley (2019) Factors Associated with Structure Loss in the 2013-2018 California Wildfires. *Fire*, 2(49):1-15.

Summary:

Researchers from Sage Insurance Holdings, LLC, the U.S. Geological Survey, and UCLA analyze building inspectors' reports documenting homeowner wildfire mitigation practices for over 40,000 structures exposed to wildfire between 2013 and 2018 to determine which mitigation efforts were most likely to decrease the probability that a home is destroyed.

Key Findings:

1. Defensible space was relatively unimportant for explaining the variation in structure loss statewide.
2. Defensive actions by firefighters or civilians significantly increased the odds that a home survived in the North-Interior region of the state, but it was less important in Southern California.
3. Home construction materials explained a significant amount of variation in housing losses across the state, with enclosed eaves responsible for the greatest risk reduction.
4. Having double pane windows reduced risk substantially compared to single pane windows in all regions.
5. Vent screens were almost as important as windowpanes for reducing risk in Southern California.

Important Quotes:

“The other surprising finding was that, of the structures that did have more than 30 m of defensible space, the vast majority were destroyed in these fires (Figures S1–S8). This of course reflects the large proportion of destroyed structures in the dataset, but it also suggests that structures with greater amounts of defensible space are often still vulnerable.” p. 10

“These results suggest that one of the potentially most effective methods of protecting homes from wildfire destruction would be to perform simple building retrofits, such as placing fine mesh screens over vents and coverings other openings in the structures, such as gaps in roofs, and enclosing structure eaves.” p. 11

“The likely explanation for why structure characteristics play a greater role than defensible space is that most homes burn by embers, which often come from long distances; and the impact of the ember cast is not likely affected by distance of defensible space. Whether or not the embers ignite is largely a function of structure.” p. 12