Why Large Wildfires in Southern California? Refuting the Fire Suppression Paradigm

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Abstract

This paper examines the common belief that past fire suppression and "unnatural" fuel build-up are responsible for large, high-intensity fires in southern California. This has been characterized as the fire suppression paradigm or the southern/Baja California fire mosaic hypothesis. While the belief is frequently repeated by the popular media and has been cited in land/fire management documents, support in the scientific community for the hypothesis has been generally restricted to the original author and his students. A significant number of scientists have raised serious questions about the hypothesis. These scientists offer substantial scientific evidence that the fire mosaic hypothesis should be rejected and that fire suppression has not had a significant impact on fire size, intensity, or frequency in shrubland dominated wildland fires in southern California. The management implications of this research are important because past fire suppression impacts have been used to justify fuel treatment projects on federal, state, and private lands for the purposes of fire risk reduction and the enhancement of wildlife habitat.

Keywords: mosaic, fire suppression, chaparral, southern California shrublands, Baja California, wildfire.

Introduction

Science reliably overturns our intuitions about how the natural world works.

Although it is possible for intuitions to be correct, intuition alone is not sufficient evidence that a testable claim is true. If this were not the case, we would still accept the intuition that the sun revolves around the earth or that the earth itself is flat. The southern/Baja California fire mosaic hypothesis, an attempt to explain wildland fire behavior, has gained traction in the fire management community because it is intuitively appealing and rational given that certain basic assumptions are true. However, in light of a growing body of empirical evidence, those basic assumptions are being called into question and critically analyzed. For instance, the claim that past fire suppression practices in shrublands bring about unnatural fire size and intensity is one that is not supported by research conducted since 1983. Just as further evidence in geology and astronomy led us to reject the flat earth and the geocentric universe hypotheses, so has further evidence in ecology led us to reject the southern/Baja California fire mosaic hypothesis.

The Fire Mosaic Hypothesis

The fire suppression paradigm or, more specifically, the southern California/Baja fire mosaic hypothesis can be summarized as follows:

Past fire suppression efforts in southern California shrubland ecosystems have caused an unnatural build-up of vegetation, leading to unnaturally large and intense wildfires. The hypothesis suggests that wildfires in Baja California are small because unsuppressed fires have created a mixed-aged mosaic of vegetation which naturally constrains fire spread. Commonly proposed options to eliminate the hypothesized "fuel" build-up in southern California include allowing fires to run without active suppression, conducting prescribed burns, and/or using mechanical methods (i.e. mastication).

Assumptions of the southern/Baja California fire mosaic hypothesis	Alternative explanations from other research
Large fires are unnatural and are the result of past fire management activities.	Infrequent, large fires are a natural part of the landscape. Fires are now unnaturally frequent due to human-caused ignitions.
Fire suppression has been successful in excluding fires on southern California landscapes and this has led to an unnatural accumulation of older shrubland vegetation.	Fire suppression has been successful at protecting urban environments, but has not excluded fire on the broader landscape. There is no evidence that the extent of older shrublands is above the historical range of variability.
Large fires can be prevented by creating mixed-aged vegetation mosaics across the landscape.	Large fires are wind-driven and are capable of burning through, over, or around mosaics of mixed-aged vegetation.
Baja can provide a model for how fire should be dealt with in southern California.	Baja is not comparable to southern California due to differences in weather, vegetation, and land use practices.
Fire spread is a function of fuel age. Chaparral stands less than 20-years-old will not burn.	Fires spread is determined by numerous variables (e.g. fuel type, fuel moisture, weather, and topography). Young stands burn.
Too frequent fires leading to type-conversion of native chaparral to non-native grasslands is not acknowledged as significant.	Significant type-conversion of all native shrubland ecosystems is occurring due to overly frequent fires.

Figure 1. Assumptions and alternative explanations for the southern/Baja California fire mosaic hypothesis.

Support in the scientific community for the hypothesis since it was published in 1983 has been generally restricted to the original author and his students. In contrast, a significant number of scientists from government agencies and academia have raised serious questions about the hypothesis (see attached bibliography). These scientists have reached their conclusions independently and have offered substantial scientific evidence that the fire mosaic hypothesis should be rejected.

This rejection is not a matter of opinion or "consensus," but rather based on an objective analysis of the data. Science does not work by consensus, it works by weighing the bulk of the evidence. In fact, government agencies, managers, and society at large rarely wait for a consensus in science before acting. Doing so would grind the wheels of intellectual progress to a halt.

A thorough analysis of the fire mosaic hypothesis is important because of its potential impact on land management decisions in southern California:

1. **Impacts on fire safety and finance.** By spending scarce funds to artificially create mixed-aged mosaics across the landscape, dollars will not be available to support efforts that have been shown to be more effective in reducing fire risk. Such efforts include community fire safe planning and zoning restrictions, creating defensible space zones around homes and communities, defensible space zone inspections, strategic fuel treatments near communities, design and maintenance actions to reduce structural ignitions, adequate funding of local fire departments, and public fire education.

   While a thorough cost/benefit analysis may not favor creating mixed-aged mosaics, *strategically placed* fuel treatments near communities have been shown to be an effective way to reduce fire risk when firefighters are present (Syphard et al. 2011). The location of such fuel treatments can be selected through a collaborative effort between fire scientists and the fire service to maximize their effectiveness and minimize their costs, both financially and ecologically.

2. **Ecological Impacts.** Adding more fire to the backcountry and protected wildlands in an effort to create mosaics may increase the threat of type-conversion, converting many of California’s native shrubland ecosystems to flammable, non-native, weedy grasslands. As a consequence, wildlife habitat will be negatively impacted.

We have provided the following analysis of the hypothesis and an extensive bibliography of the relevant papers so that others may examine the evidence and draw their own conclusions.

Examining the Fire Mosaic Hypothesis

The validity of a hypothesis rests on the ability of scientists to confirm that the methodology used, the data collected, and the predictions made in the original investigation were appropriate and unbiased.

The research demonstrates that the data, assumptions, and predictions behind the southern/Baja California fire mosaic hypothesis are flawed. It also shows that past fire suppression (fuel age), the sole variable in the hypothesis, cannot account for why there are large wildfires in southern California and small ones in Baja.

I. Data

The map in the original research paper (Minnich 1983) biases the comparison between Baja and southern California by including two very large fires north of the border that occurred outside the study period (1932 Matilija and the 1970 Laguna fires). This exaggerates the average size of fires north of the border during the time period in question.

In a follow-up paper (Minnich 1989), fire perimeter data south of the border were compiled in a completely different manner than north of the border. For Baja, three sets of aerial photographs separated by 16-18 years were used to estimate fire perimeters. There was no validation that fire perimeters could be accurately determined in this manner. North of the border, official state and federal records were used. This data set did not include smaller fires (below 40 acres). This is a critical error because between 1970 and 1979, a time period included in one of the aerial photo sets, 95% of the fires in San Diego County were less than 40 acres. This exclusion of important data further exaggerates fire size north of the border. To obtain comparable data sets, fire perimeters north of the border should have been estimated with aerial photographs as well. This would have helped reduce the potential for bias.

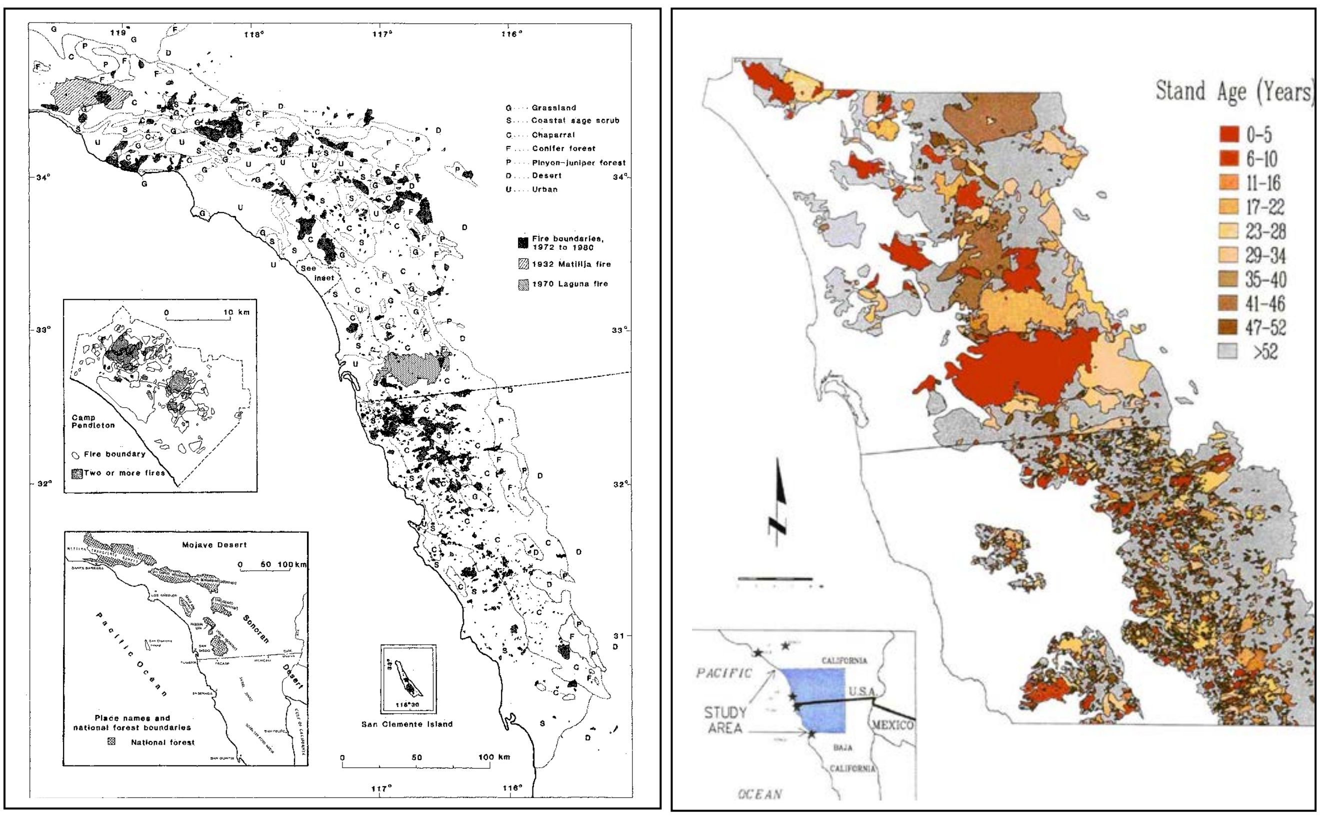

Figure 2. The Maps. Dark splotches in the left map (1983) represent fire scars as determined by analyzing satellite images. By inserting fires outside the study period (two grey splotches) the reader is left with the biased impression that fires north of the Southern California/Baja border are much larger than they actually were during the period in question. For the map on the right (1989), estimated fire perimeters in Baja were derived by subjectively analyzing aerial photos. Perimeters north of the border were determined by government investigators after the fire event. The different methodologies used raise serious questions about the validity of the maps.

Several assumptions supporting the hypothesis have been proven to be incorrect. The citations listed below reference the scientific studies which falsify these assumptions.

A. Large fires are new to southern California. Scientific research and historical documents have shown this to be false (Lombardo et al. 2009, Mensing et. al 1999, Keeley and Zedler 2009,).

B. Fire suppression has been effective in excluding fire from southern California shrubland ecosystems over the last century. Scientific research has shown that fire suppression in these ecosystems has not been successful in excluding fire (Keeley et. al 1999).

C. Baja and southern California are comparable. This has been shown to be false as there are a number of significant differences between the two regions. For example:

- There are significant land management differences north and south of the border. Baja has been subjected to hundreds of years of ranching and farming which has resulted in a significant alteration of the natural landscape (Henderson 1964, Dodge 1975).

- Weather patterns are different north and south of the border. The proportion of the area studied in Baja subject to strong Santa Ana winds is small when compared to southern California. Such wind events gradually diminish south of the border. Precipitation is greater in southern California when compared to Baja California (Henderson 1964, Mitchell 1969, Markham 1972).

- As a result of different climatic, topographical, and edaphic (soil) conditions, plant communities are distinctly different in many areas of Baja when compared to southern California (Keeley and Fotheringham 2001a).

III. Predictions

Mixed-aged vegetation mosaics alone have proven to be inadequate barriers to fire spread, especially during wind-driven events. Age of vegetation is not the only variable determining fire size as suggested by the hypothesis. Other variables are important in determining fire spread such as topography, fuel moistures, local weather conditions, and fire suppression efforts (Zedler and Seiger 2000, Moritz et. al 2004, Halsey 2006). Large fires occur in Baja California. More than 37,000 acres burned in Baja during the 2007 firestorm (Hernandez 2007).

The exclusive focus on fuel age as the sole variable to fire spread leads to the false assumption that all large wildfires are due to the "unnatural" build-up of vegetation. This was demonstrated in an article about the October 2008 fires in the San Fernando Valley in UCLA's newspaper, The Daily Bruin (10/13/08):

> "The cause of the fires is still unknown, though what caused it is irrelevant," said Richard A. Minnich, a professor of geography at UC Riverside.

> Fire suppression, Minnich said, has increased the severity of the wildfires. He said that since small fires which break out during the summer are typically extinguished, the vegetation which would normally be burned by the fires is still in abundance during the fall season. As a result, fires in the fall have much more fuel to burn, and are increased due to the strong Santa Ana winds. "Because we're putting fires out…we're making the role of the Santa Ana winds (larger)," Minnich said.

Two fires burned during the San Fernando Valley event in October: the 4,824 acre Marek Fire and the 14,703 acre Sesnon Fire. As shown in the map below, the larger Sesnon Fire burned within an area that had seen multiple fires over the past 27 years. The left one third of the fire scar (dark blue) burned in the 2003 Simi Fire. The right portion had last burned in 1988. The central portion had burned in 1981. Fire suppression has not been effective in excluding fire from these areas.

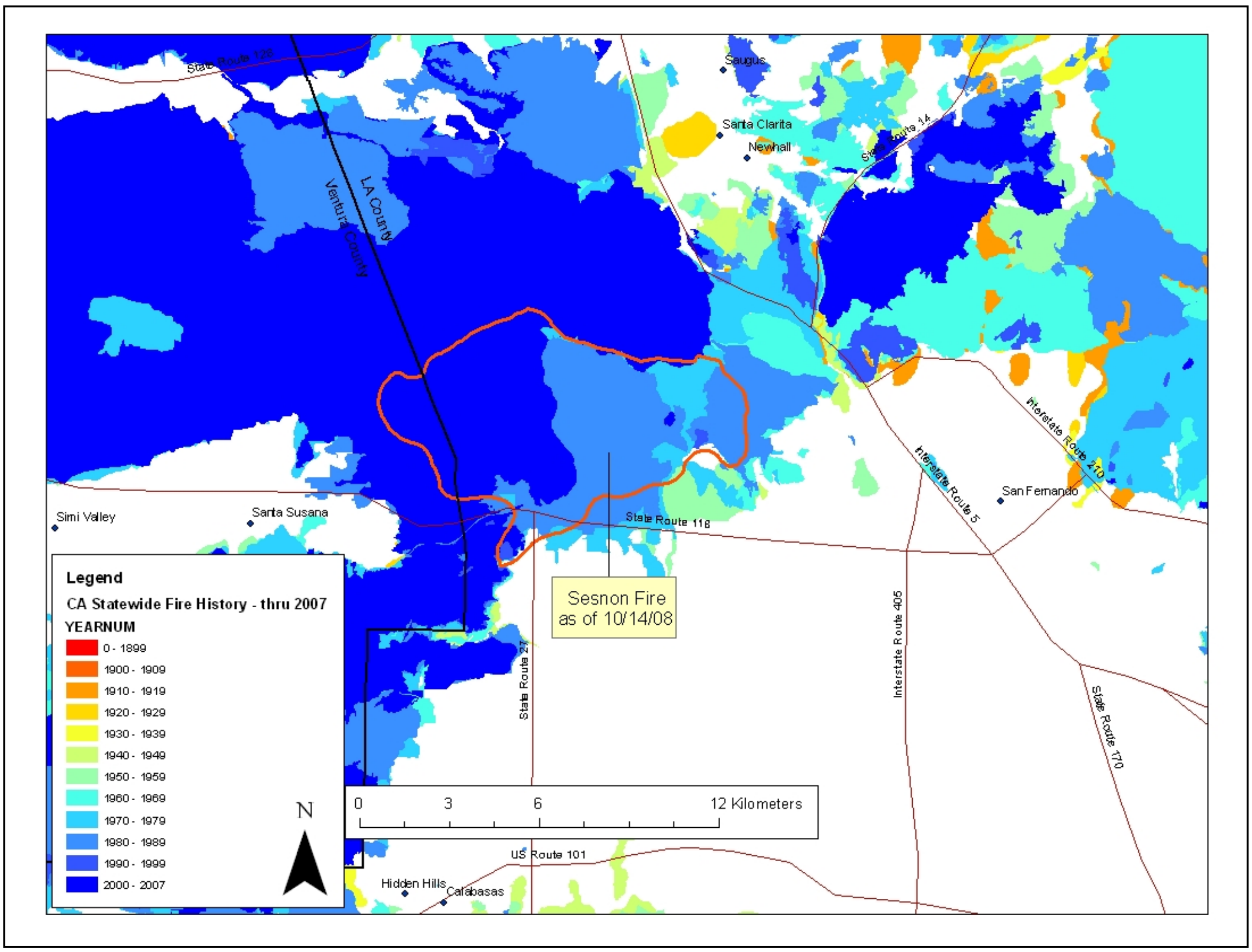

Figure 3. 2008 Sesnon fire (central outlined red perimeter) with fire history of the general area. Map by Anne Pfaff and Jon E. Keeley, USGS Western Ecological Research Center.

Natural, summertime lightning-caused fires at lower elevations are rare in southern California. Human activity has led to a significant deviation from the natural fire return interval by artificially increasing fire frequency. Such an artificial increase in fire frequency threatens native shrublands with type-conversion to highly flammable, non-native grasslands. Contrary to Minnich's quoted proposition, the cause, namely anthropogenic influence, is certainly relevant.

Management Implications

Numerous fire management plans in California have cited the presumed impact of past fire suppression to justify the creation of mixed-aged mosaics in native shrublands. For example:

> **1. San Diego County.** In 2013, a small prescribed burn in the San Felipe Wildlife Area in San Diego County was conducted in part to "improve habitat" by "*creating mosaic patterns* in moderately aged to decadent brush stands for improving deer grazing. The plan is to burn these blocks every 7-15 years."
>
> The fire escaped and proceeded to burn more than 2,700 acres of fragile habitat within the protected area. Much of it had previously burned in the 2002 Pines Fire. Re-burning a chaparral stand that had burned eleven years earlier has been proven to cause serious ecological damage. The targeted vegetation was the last remaining, healthy old-growth stand of desert chaparral in the entire San Felipe Valley Wildlife Area.
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> **2. Cal Fire.** One of the main goals of Cal Fire's proposed 2013 Vegetation Treatment Plan is to, "Improve wildlife habitat by spatially and temporally altering vegetation structure and composition, *creating a mosaic of successional stages* within various vegetation types." The rationale for this goal was that past fire suppression "had the effect of increasing the rate of spread as well as the annual acreage burned" in California wildlands. No effort was made to distinguish between ecosystem types.
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> **3. Santa Barbara County.** In 2008, the Santa Barbara County Game Commission advocated prescribed burning to clear chaparral in the backcountry because early Spanish explorers described, "abundant trees, grass, elk, deer, yearly running streams, burned areas, and other wildlife in these early reports, but little mention of brush." The burning proposal was eventually rejected.

There is a narrow window when prescribed burns can occur: in the cool season (late spring, just before summer). This is due to the fact that in the winter and early spring months, chaparral plants have too much moisture within their tissues so they won't carry a fire easily. In the summer and fall, the wildfire risk is too high due to low moisture levels. As a consequence, prescribed burns are conducted in the chaparral when it is the most vulnerable: the plants are growing, the soil is still moist, many animal species are breeding, and birds are using the ecosystem during their annual migrations.

The exact mechanisms are unknown, but cool season burns probably cause significant damage to plant growth tissues and destroy seeds in the soil due to soil moisture turning into steam. This can can lead to immediate type-conversion to a non-native grassland. Such an event occurred after a cool season burn in

Pinnacles National Park, California, in the late 1980's (Keeley 2006).

The following USFS document discusses the ecological risks of prescribed fire in chaparral and other plant communities:

Knapp, E.E., B.L. Estes, and C.N. Skinner. Ecological effects of prescribed fire season: A Literature Review and Synthesis for Managers. Gen. Tech. Report PSW-GTR-224. USDA, Forest Service. PSW Research Station. 80p.

The potential for ecological damage, as well as the lack of efficacy for mosaics to prevent fire spread, has led the National Park Service to stop prescribed burning in the Santa Monica Mountains Recreation Area. They explain,

> "In the last forty years fire managers have promoted the idea that prescribed fire is necessary to protect ecosystems and communities by restoring fire's natural role in the environment to thin forest stands and to reduce hazardous fuels. This is true for western forests where the natural fire regime was frequent, low intensity surface fires started by lightning, and for many other ecosystems like southern longleaf pine forests, Florida palmetto scrub, and the Great Plains tall grass prairies. However, this is not true for the shrubland dominated ecosystems of southern California and the Santa Monica Mountains."

Additional information is available on the Santa Monica Mountains National Recreation Area website.

In terms of creating mosaics to increase biodiversity, researchers from another Mediterranean-type climate, Australia, have concluded (Parr and Andersen 2006),

> "We identified serious shortcomings of PMB (patch mosaic burning): the ecological significance of different burning patterns remains unknown and details of desired fire mosaics remain unspecified. This has led to fire-management plans based on pyrodiversity rhetoric that lacks substance in terms of operational guidelines and capacity for meaningful evaluation. We also suggest that not all fire patterns are ecologically meaningful: this seems particularly true for the highly fire-prone savannas of Australia and South Africa. We argue that biodiversity-needs-pyrodiversity advocacy needs to be replaced with a more critical consideration of the levels of pyrodiversity needed for biodiversity and greater attention to operational guidelines for its implementation."

Parr, C.L. and A.N. Andersen. 2006. Patch mosaic burning for biodiversity conservation: a critique of the pyrodiversity paradigm. Conservation Biology 20: 1610-1619.

Considering the potential for significant ecological damage and the lack of efficacy in preventing fire spread, the creation of mixed-aged mosaics in native shrublands needs to be seriously re-evaluated.

The Research

The following three papers provide the basics of the southern/Baja California fire mosaic hypothesis (Minnich 2001) and a point by point explanation of its flaws (Keeley and Fotheringham 2001a,b):

Keeley, J. E., and C. J. Fotheringham. 2001a. Historic fire regime in Southern California shrublands. Conservation Biology 15:1536-1548.

Minnich, R. A. 2001. An integrated model of two fire regimes. Conservation Biology 15:1549-1553.

Keeley, J. E., and C. J. Fotheringham. 2001b. History and management of crown fire ecosystems: a summary and response. Conservation Biology 15: 1561-1567.

The Original Paper:

Minnich, R. A. 1983. Fire mosaics in southern California and northern Baja California. Science 219:1287-1294.

Main papers supporting the mosaic hypothesis (by date):

Minnich, R. A. 1989. Chaparral fire history in San Diego County and adjacent northern Baja California: an evaluation of natural fire regimes and effects of suppression management. In, The California Chaparral: Paradigms Reexamined (S. C. Keeley ed.). No. 34 Science Series. Natural History Museum of Los Angeles County.

Minnich, R. A., and R. J. Dezzani. 1991. Suppression, fire behavior, and fire magnitudes in Californian chaparral at the urban/wildland interface. Pages 67-83 in J. J. DeVries, editor. California watersheds at the urban interface, proceedings of the third biennial watershed conference. University of California, Davis, CA.

Minnich, R.A., and C.J. Bahre. 1995. Wildland fire and chaparral succession along the California-Baja California boundary. International Journal of Wildland Fire, *5*:13-24.

Minnich, R. A. and Y. H. Chou. 1997. Wildland fire patch dynamics in the chaparral of southern California and northern Baja California. International Journal of Wildland Fire 7:221-248.

Minnich, R. A., and E. Franco-Vizcaino. 1999. Prescribed mosaic burning in California chaparral. Pages 247-254 In A. Gonzalez-Caban, editor. Proceedings of the symposium on fire economics, planning, and policy: bottom lines. Pacific Southwest Research Station, Albany, CA.

Goforth, B. S., and R. A. Minnich. 2007. Evidence, exaggeration, and error in historical accounts of chaparral wildfires in California. Ecological Applications 17:779-790.

The six key research papers that support rejecting the mosaic hypothesis by testing its data set, assumptions, and/or predictions:

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: 69-94.

"A review of more than 100 19th-century newspaper reports reveals that large, high-intensity wildfires predate modern fire suppression policy, and extensive newspaper coverage plus first-hand accounts support the conclusion that the 1889 Santiago Canyon Fire was the largest fire in California history."

Lombardo, K.J., T.W. Swetnam, C.H. Baisan, M.I. Borchert. 2009. Using bigcone Douglas-fir fire scars and tree rings to reconstruct interior chaparral fire history. Fire Ecology 5: 32-53.

"*The historical and modern records both imply that large, landscape-scale fires are inevitable in chaparral landscapes."*

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 2:67-72.

"Fire frequency analysis of several hundred wildfires over a broad expanse of California shrublands reveals that there is generally not, as is commonly assumed, a strong relationship between fuel age and fire probabilities."

Zedler, P.H., Seiger, L.A. 2000. Age mosaics and fire size in chaparral: A simulation study. In 2nd Interface Between Ecology and Land Development in California. USGS Open-File Report 00-02, pp. 9-18.

" We conclude that age-based mosaics following the strict rules of the fuel/age paradigm are a transient phenomenon, and therefore we question if fine-grained age mosaics are characteristic of natural systems and whether they should be the objective of long-term landscape planning."

Keeley, J. E., C. J. Fotheringham, and M. Morais. 1999. Reexamining fire suppression impacts on brushland fire regimes. Science 284:1829-1832.

"In brush-covered landscapes of southern and central-coastal California, there is no evidence that fire suppression has altered the natural stand-replacing fire regime in the manner suggested by others (3, 5)."

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.

"The fuel and weather conditions necessary for large fires were present prior to fire suppression and are a natural part of chaparral ecology in a Mediterranean climate."

Two literature reviews that support rejecting the mosaic hypothesis:

Conard, S. G., and D. R. Weise. 1998. Management of fire regime, fuels, and fire effects in southern California chaparral: lessons from the past and thoughts for the future. In Teresa L. Pruden and Leonard A. Brennan (eds.). Fire in ecosystem management: shifting the paradigm from suppression to prescription: 1996 May 7-10; Boise, ID: Tall Timbers Fire Ecology Conference No. 20. Tallahassee, FL: Tall Timbers Research Station; 342-350.

"For these purposes, landscape mosaics are impractical, unnecessary, and probably not particularly effective. We basically recommend shifting the management focus away from pure mosaic burning toward development (and rejuvenation) of strategically placed fuel management zones."

Keeley, J.E.; Aplet, G.H.; Christensen, N.L.; Conard, S.C.; Johnson, E.A.; Omi, P.N.; Peterson, D.L.; Swetnam, T.W. 2009. Ecological foundations for fire management in North American forest and shrubland ecosystems. Gen. Tech. Rep. PNW-GTR-779. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 92 p.

"The fire regime in this region is dominated by human-caused ignitions, and fire suppression has played a critical role in preventing the ever increasing anthropogenic ignitions from driving the system wildly outside the historical fire return interval. Because the net result has been relatively little change in overall fire regimes, there has not been fuel accumulation in excess of the historical range of variability, and as a result, fuel accumulation or changes in fuel continuity do not explain wildfire patterns."

Other important research with findings inconsistent with the mosaic hypothesis:

Dodge, J.M. 1975. Vegetational changes associated with land use and fire history in San Diego County. Ph.D. dissertation. University of California, Riverside.

Dunn, A.T., and D. Piirto. 1987. The Wheeler Fire in retrospect: factors affecting fire spread and perimeter formation. Report on file at: U.S. Department of Agriculture, Forest Service, Forest Fire Laboratory, Riverside, CA.

Dunn, A.T. 1989. The effects of prescribed burning on fire hazard in the chaparral: toward a new conceptual synthesis. Pages 23-24 *in* N.H. Berg (technical coordinator). Proceedings of the symposium on fire and watershed management. General Technical Report PSW-109, U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

Halsey, R.W. 2006. Weather, fuels, and suppression during the 2003 Cedar fire: Which variables made the critical difference? In, 2003 Southern California Fires: Science Insights into the Fire Event and Recovery special session (J.E. Keeley, organizer). Proceedings, 3rd International Fire Ecology and Management Conference. Association for Fire Ecology. San Diego, CA.

Halsey, R.W., J.E. Keeley, K. Wilson. 2009. Fuel age and fire spread in southern California chaparral ecosystems: natural conditions vs. opportunities for fire suppression. Fire Management Today 69, #2: 22-28.

Henderson, D.A. 1964. Agriculture and livestock raising in the evolution of the economy and culture of the state of Baja California, Mexico. Ph.D. dissertation, University of California, Los Angeles.

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Mitchell, V.L. 1969. The regionalization of climate in montane areas. Ph.D. dissertation. University of Wisconsin, Madison.

Moritz, M. A. 1997. Analyzing extreme disturbance events: fire in the Los PadresNational Forest. Ecological Applications 7:1252-1262.

Moritz, M. A. 2003. Spatiotemporal analysis of controls on shrubland fire regimes: age dependency and fire hazard. Ecology 84:351-361.

Schoenberg F.P, R. Peng, Z. Huang and P. Rundel. 2003. Detection of nonlinearities in the dependence of burn area on fuel age and climatic variables. International Journal of Wildland Fire 12: 1–6.

Syphard, A.D., J.E. Keeley, T.J. Brennan. 2011. Comparing fuel breaks across southern California national forests. Forest Ecology and Management 261: 2038-2048.

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: 1388-1402.

Turner, M. G., and V. H. Dale. 1998. Comparing large, infrequent disturbances: what have we learned? Ecosystems 1:493-496.

Wells, M.L, J.F. O'Leary, J. Franklin, J. Michaelsen, and D.E. McKinsey. 2004. Variations in a regional fire regime related to vegetation type in San Diego County, California. Landscape Ecology 19: 139-152.

Witter, M., and Taylor. 2008. Preserving the future: a case study in fire management and conservation from the Santa Monica Mountains. In R.W. Halsey, Fire, Chaparral, and Survival in Southern California, 2nd edition. Sunbelt publications, pg. 109-115.

Zedler, P.H. 1995. Fire frequency in southern California shrublands: biological effects and management options. Brushfires in California Wildlands: Ecology and Resource Management. Ed. J.E. Keeley and T. Scott. International Association of Wildland Fire, Fairfield, WA.

Research discussing the negative ecological impacts of short fire return intervals in chaparral:

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

Diaz-Delgado, R., F. Lloret, X. Pons, and J. Terradas. Satellite evidence of decreasing resilience in Mediterranean plant communities after recurrent wildfires. 2002. Ecology 83: 2293-2303.

Franklin, J., A.D. Syphard, H.S. He, D.J. Mladenoff. 2005. Altered fire regimes affect landscape patterns of plant succession in the foothills and mountains of southern California. Ecosystems 8: 885-898.

Haidinger, T.L., and J.E. Keeley. 1993. Role of high fire frequency in destruction of mixed chaparral. Madrono 40: 141–147.

Jacobsen A.L., Fabritius S.L. and Davis S.D. 2004. Fire frequency impacts non-sprouting chaparral shrubs in the Santa Monica Mountains of southern California. In Ecology, Conservation and Management of Mediterranean Climate Ecosystems. Eds. Arianoutsou M and Papanastasis VP. Millpress, Rotterdam, Netherlands.

Keeley, J.E. 2005. Fire as a threat to biodiversity in fire-type shrublands, pp. 97-106. Proceedings of the Conference, Planning for Biodiversity: Bringing Research and Management Together. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-195.

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Lawson, D., H.M. Regan, P.H. Zedler, J. F. Franklin. 2008. Using Death Assemblages in Extant Stands of an Obligate Postfire Seeding Shrub Ceaonthus verrucosus, to Inform Fire Management. Unpublished study.

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Odion, D., and C. Tyler. 2002. Are long fire-free periods needed to maintain the endangered, fire-recruiting shrub *Arctostaphylos morroensis* (Ericiaceae)? Conservation Ecology6: 4.

Regelbrugge, J.C. 2000. Role of prescribed burning in the management of chaparral ecosystems in southern California. In J.E. Keeley, M.B. Keeley, and C.J. Fotheringham (eds.) 2nd Interface between Ecology and Land Development in California. Sacramento: US Geological Survey Open-File Rep. 00-02, p. 19 – 26.

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

van Wagtendonk, J. W.; Keeley, J. E.; Brooks, M. L.; Klinger, R. C. February 2007. Fire in California's Ecosystems. USGS Publication Brief.

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

Zedler, P.H., and T.A. Oberbauer. 1998. Comments on the Minnich and Franco-Vizcaino July 1997 article. Letters to the editor. Fremontia 26: 34-35.