Revisiting Spatial Patterns of Lightning Strikes and Fires in Yosemite National Park

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Introduction

In 2008, California experienced a dry lightning episode on June 21st that produced over 2,000 ignitions. During that time Yosemite National Park had only one start, which was suppressed. In early July, as California was experiencing smoke impacts from the June fires, Yosemite received 11 additional lightning ignitions over a five day period. Despite originating in the Fire Use Unit which would have allowed them to burn under prescribed conditions, all but two of the fires were suppressed due to air quality and resource availability concerns. Although the Sierra Nevada in California have an extensive history of lightning strikes and subsequent fires (van Wagtendonk et al. 2002; van Wagtendonk and Fites-Kaufman 2006), managers must consider factors other than ecology when deciding whether to suppress a fire. Yosemite National Park's extensive fire records (1930 to the present) have facilitated a study of the spatial distribution of lightning fire ignitions (van Wagtendonk 1994). Most of these fires were suppressed under the national fire policy of the time and could not be assessed in terms of fire size and area burned. In 1972, a Prescribed Natural Fire (PNF) program was established in Yosemite, allowing lightning ignited fires to burn under prescribed conditions (van Wagtendonk 2007). This paper revisits van Wagtendonk's (1994) analysis and updates it with fires from 1994 to 2007. Additionally, the distribution of the 2008 suppressed fires was compared to the results from this analysis. These fires were then modeled in FARSITE to determine potential fire size and acres burned had they not be suppressed.

Yosemite National Park covers 747,955 acres of the central Sierra Nevada in California and varies from 2,000 feet in elevation in the west, to 13,000 feet along the crest of the range. Along the elevation profile while travelling west to east, distinct vegetation communities can be seen. Lower montane forests occur between 2,000 and 6,000 feet, upper montane forests from 6,000 to 8,000 feet, and subalpine forests from 8,000 feet to tree line at 11,000 feet.

The Mediterranean climate of Yosemite is characterized by warm, dry summers, and cool, wet winters, with precipitation primarily occurring between November and April. However, a monsoonal flow from the south and southwest creates numerous thunderstorms, and is responsible for lightning and rain in the summer. At the lower elevations, where burnable vegetation is abundant, lightning is less frequent. The converse is true for the higher elevations: abundant lightning, sparse vegetation. The mid slope elevations are the confluence where lightning fire numbers and acres burned are maximized.

Methods

The same 1,000-foot elevation zones and 27 vegetation types grouped into eight categories by van Wagtendonk (1994) were used to determine the number of lightning ignitions and area burned, in elevation and vegetation categories. For the 2008 analysis, fire data from Yosemite National Park's fire history GIS spatial database were used. These data were updated each year at the completion of the fire season, dating back to 1930. Actual ignition point data were available for some fires, but where those data were not available, the center of each fire perimeter was calculated. These points were used for the spatial analysis of lightning ignition patterns. The 10-meter digital elevation model (DEM) was used to determine the elevation of the ignition, and the number of acres burned, in each of the eleven 1,000-foot elevation zones. The Yosemite 2004 Fire Management Plan/Environmental Impact Statement fire management units were used to determine how many fires could have been managed under the policy of Wildland Fire Use (WFU), which replaced PNF in 1998.

The ignition points for the 2008 fires were obtained from GPS points fire personnel assigned to those fires, while the elevation of each fire was determined using the 10-meter DEM. Nine of the 2008 ignitions were then modeled for growth using FARSITE (Fire Area Simulator, Finney 1998), three of which were modeled as a single ignition, point due to their timing and proximity, resulting in seven fires simulated. FARSITE is a fire modeling tool that uses spatial information on topography and fuels, along with weather and wind data, to simulate wildfire behavior. Due mainly to homogeneity in the fuel model inputs, FARSITE has a propensity to over-predict fire growth. To help compensate for this potential source of error, the model was only run when the Energy Release Component (ERC) was at or above the 90th percentile. The ERC is an index related to potential available energy that could be released by a fire, and is driven mainly by fuel model and fuel moistures. ERC was calculated from actual weather conditions gathered by the White Wolf remote automated weather station (RAWS). Based on advice from local fire managers, fire growth was simulated for eight hours per day when the ERC was at or above the 90th percentile and for a full 24 hours per day when the ERC was at or above the 97th percentile. The simulation was paused when the ERC dropped below the 90th percentile and resumed when ERC increased back to the 90th percentile. The vast majority of fire-growth occurs on these 'extreme' fire-weather days and will therefore be captured using these parameters. Simulations were terminated when the ERC dropped below the 90th percentile and didn't recover for the remainder of the fire season.

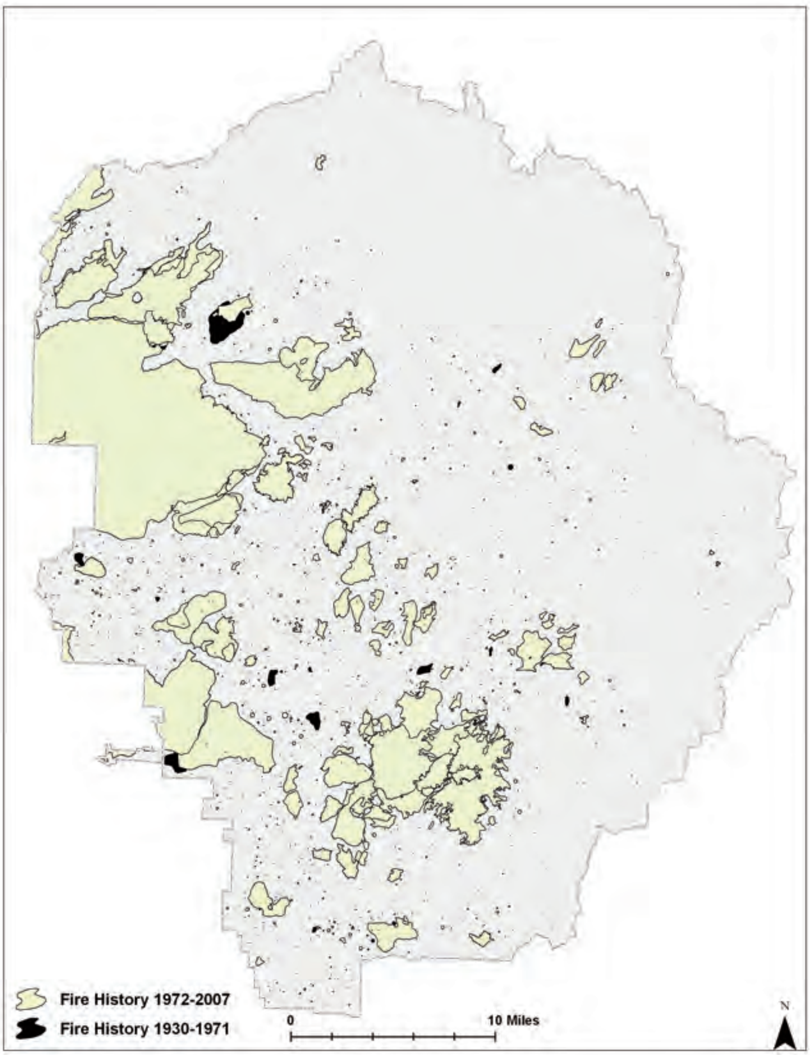
Results

Between 1930 and 1993, a total of 2,659 lightning fires burned in Yosemite National Park (van Wagtendonk 1994). The 7,000 to 8,000 foot elevation range had the most fires and acres burned in the park, with 744 fires burning 27,693 acres, accounting for one-third of the total area burned for that time period. After policy created the PNF zone in 1972, Yosemite recorded 1,095 fires in that zone. Of those fires, 908 were under ten acres, while the remaining 187 were ten acres or greater. The main reason for the large number of small fires was the fact that 633 fires were suppressed, despite originating in the PNF zone. Another reason is that many fires, especially in the PNF zone, were in areas of sparse vegetation and simply went out before reaching any significant size.

From 1993 through 2007, an additional 475 lighting ignitions were added to the data set, burning an additional 108,736 acres. This brought the total number of lightning fires since 1930 to 3,134, and the total number of acres burned to 181,278. Between 1930 and 1971 only 7,707 acres had burned due to lightning, but since 1972, 173,571 acres have burned (Figure 1). This is primarily due to the policy change that allowed the Park to manage fires for resource benefit, but also partly to the fuel accumulation from fire exclusion.

The total number of fires between 7,000 and 8,000 feet through 2007 increased to 888 fires that burned 46,498 acres, the largest numbers for any of the elevation zones (Figure 2). There is a normal distribution for fires by elevation and to a lesser degree for acres burned. However, there is a sharp decrease above 8,000 in acres burned, despite a large number of

Figure 1. Map of lightning fire history for Yosemite National Park. The dark areas show the 7,707 acres that burned from 1930 to 1971. The light areas represent the 173,571 acres burned from 1972 to 2007.



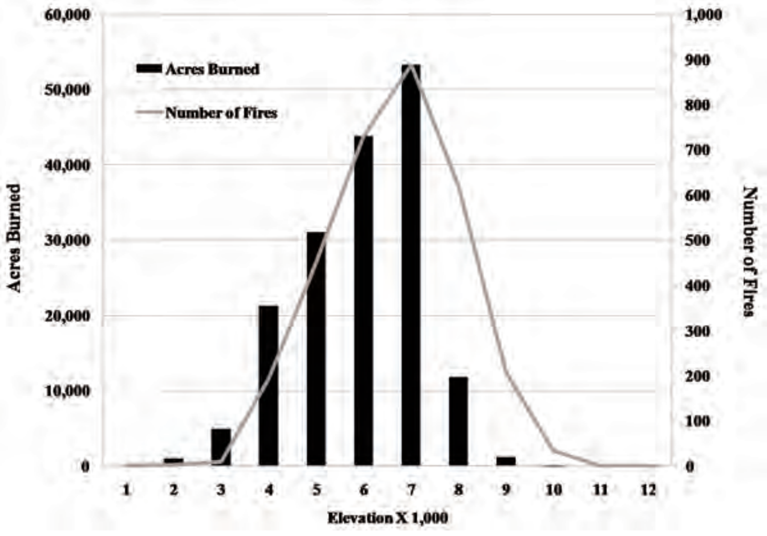


Figure 2. Distribution of lightning fires and acres burned by elevation. The left axis shows number of acres burned and corresponds to the dark bar graph. The right axis is for the light line showing the number of fires.

fires. These subalpine forests have a shorter growing season so are less productive than the vegetation communities lower in elevation, resulting in less available fuel and a shorter fire season. But just down slope, the upper montane vegetation community between 6,000 feet and 8,000 feet has the most lightning fires and acres burned in the park.

Between 1930 and 1971, Yosemite had 1,341 lightning ignited fires, while 1,793 occurred between 1972 and 2007. A total of 92% of these fires were less than ten acres in size. In this size class, between 1930 and 1971, there were 1,308 fires, and between 1972 and 2007 there were 1,594 fires. This increase, however, is much less than the increase of larger fires since 1972. For fires larger than 10 acres, there was an increase from 33, prior to 1972, to 199, as a result of the policy change that allowed for fire to return to the previously fire-excluded ecosystem (Figure 3). Based on the 2004 Fire Management Plan/Environmental Impact Statement fire management units, a total of 1,213 fires occurred within the WFU unit from 1972 through 2007. Out of all these fires, 48% were suppressed.

The FARSITE predictions for the seven fires occurring between July 8 and 13, 2008, did not initiate growth until August 1st, which was the first day since ignition that the ERC was at or above the 90th percentile. Some of the fires could have gone out between their ignition and August 1st. There were 29 days during the simulation where the ERC was above the 90th percentile, seven of which were above the 97th. As a result, FARSITE was 'burning' the landscape for eight hours per day for 22 days, and for 24 hours per day for seven days. On September 17th, the ERC fell below the 90th percentile and didn't recover before the end of the season, thus ending the simulation. Of the seven fires that were modeled (Figure 4), the Ten was the smallest, at 240 acres. The Cascade was predicted to grow to 4,767 acres, while the Flat, Hill, Cabin, Starr King, and PCF were predicted to grow together to

Size in Acres	1930-1971	1972-2007	1930-2007	Percent
0-0.25	942	1,011	1,953	62.32
0.26-9.9	366	583	949	30.28
10-99.9	23	82	105	3.35
100-299.9	5	48	53	1.69
300-999.9	3	32	35	1.12
1,000-4,999.9	2	30	32	1.02
5,000+	0	7	7	0.22
Total	1,341	1,793	3,134	100

Figure 3. Fire size class with respect to PNF policy: 3,134 lightning fires have been detected in Yosemite National Park between 1930 and 2007.

reach 36,550 acres, 22,730 acres of which burned in the WFU Unit.

Discussion

Fire history. In 2008, Yosemite had 12 lightning-ignited fires, 10 of which were suppressed despite originating in the WFU unit. The two fires that were managed as WFUs occurred above 9,700 and went out naturally. The ten fires that were suppressed ranged in elevation from 6,800 to 9,600 feet. Independent of recent fire history, weather, vegetation, smoke impacts, and fire resource availability, the data showed that the four fires above 8,000 feet could have been managed for resource benefit, because fires in the subalpine zone rarely grow to any significant size. The caveat, though, is whether red fir is part of the vegetation community, since it burns well and can be found above 8,000 feet. The other six fires occurred in the upper montane community, where the most fires and acres burned resulted.

Technology and policy. With the new 2009 fire policy, Yosemite will be able to manage a fire if it does move into the suppression unit and is not threatening values at risk. Fires could be managed for suppression near communities, and for resource benefit in areas that have had fire excluded for decades, yet pose no risk to anthropogenic features. With fire being treated as fire, thus eliminating the distinction between WFU and Suppression, Yosemite can more easily work towards its goal of acres treated by fire each year. Previously all lightning fires in the Suppression Unit could not be counted to achieve that goal. Now a fire can be managed for multiple objectives and, where applicable, acres treated can be counted even if part of that fire was being suppressed.

Additionally, technological tools like GIS and fire modeling that utilize a wide range of data can assist in determining how fires should be managed. Timely synthesis and presentation of this data in a meaningful manner is essential to making the right decision in fire management.

2008 California fires. 2008 was a challenging year for fire management in California, with many fires burning simultaneously throughout the state. This resulted in tremendous smoke emissions, and a drawdown of fire fighting

Name	Start Date	Elevation	Size
Old Tioga	6/21/2008	6,791	0.1
Pack	7/8/2008	6,921	0.1
Clark	7/8/2008	6,927	0.1
Fork	7/8/2008	6,931	0.1
Cabin/Arch	7/13/2008	7,334	6.0
Cascade	7/8/2008	7,580	0.1
Starr King	7/8/2008	8,006	0.1
Hill	7/10/2008	8,128	12
Flat	7/13/2008	8,131	0.1
Ten	7/13/2008	9,597	0.1
Sunrise	7/13/2008	9,738	0.1
Lewis	7/13/2008	10,371	0.1

Figure 4. 2008 fires. Fires are sorted by elevation. Start date and final size are also shown. The Old Tioga was not modeled in FARSITE, nor was the Sunrise or Lewis, which were managed for resource benefit, and self-extinguished. The Pack, Clark, and Fork fires were modeled as one fire.

resources. Yosemite, on the other hand, had a relatively quiet fire season, but did face smoke issues from the statewide fires, as well as the Telegraph Fire that burned near the park. Yosemite had many fires to choose from to manage for resource benefit, but managers understood the larger context in which they were operating, and chose to suppress all but two lightning fires. An interesting analysis that can be done in the future would be to calculate smoke emissions from the FARSITE modeled fires, and compare them to those calculated for the entire state. All major fires in the state were out by the time that FARSITE started modeling the Yosemite fires (August 1st).

Smoke levels measured at Yosemite Valley were in the good and moderate categories from the beginning of fire season until Yosemite started receiving smoke from the numerous fires in California. The Telegraph also impacted air quality in the park at the end of July. By August 1st, the air quality in Yosemite Valley returned to good and moderate with respect to human health impacts and remained so through the end of the fire season.

Decision support system. Yosemite has determined that a decision support system is needed to assist in how it manages fires. Data are being organized in a manner that will make its dissemination easier and more efficient. Included in this system would be the fire history analyses, Fire Return Interval Departure calculations, fuel succession models, FARSITE predictions, smoke emission models, historic weather records, topography, etc. Having an integrated approach can only help as the new fire policy is implemented in the face of global climate change.

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