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Fire frequency impacts non-sprouting chaparral shrubs in the Santa Monica Mountains of southern California

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ABSTRACT: Adult non-sprouting chaparral species are killed by fire, relying on the germination of refractory seeds for post-fire reestablishment. An increase in fire frequency (fire return intervals of <12 years) may prevent non-sprouting chaparral seedlings from reaching reproductive age, thus limiting recruitment prior to succeeding fires. A previous study found that a fire return interval of ≤6 years resulted in the localized extinction of the non-sprouting chaparral species *Ceanothus megacarpus* from a coastal site. We examined sites throughout the Santa Monica Mountains in southern California to determine if this pattern is generalized. We sampled 4 sites with fire return intervals of ≤6 years. Each site was matched to a nearby control site of similar slope aspect and elevation with a fire return interval of ≥12 years. We used a point-quarter sampling method for chaparral shrubs in tandem with a canopy-coverage sampling method for exotic weeds and grasses. Increased fire frequency reduced the frequency of non-sprouting chaparral shrubs, with shorter fire intervals having the greatest impact. Shorter fire intervals also increased gaps in the shrub matrix increasing the abundance of coastal sage scrub and non-native forbs and grasses.

1 INTRODUCTION

In our longitudinal studies of the regeneration of chaparral vegetation following fire, we have demonstrated that the recent increase in fire frequency at one coastal site in the Santa Monica Mountains has altered plant community structure. Non-sprouting species, which rely on post-fire regeneration from seed because adult shrubs are killed by wildfire, have decreased in number, and in one case (*Ceanothus megacarpus*) have undergone extinction locally. Two fire intervals of three and seven years did not allow chaparral seedlings to mature to reproductive age; therefore, seeds were not deposited in sufficient numbers to establish a soil seed bank before the arrival of succeeding fire. The few seedlings that did emerge had to compete with fast-growing, invasive annuals that thrive after a "cool burn." The cool burn was the result of a premature fire without adequate time to develop a fuel load that normally supports high fire temperatures. Only a few resprouting species, such as *Malosma laurina* and *Rhus ovata*, were able to maintain adult densities under frequent fire through vigorous resprout success. The overall decrease in mature shrub density increased the amount of light reaching the soil surface, further enhancing the germination and establishment of non-native invasive annuals. The cooler burn temperatures presumably allowed greater numbers of seeds from invasive forbs and grasses to survive. This increased the propagule pressure by the invasive species (Schultz et al. 1995, Holmes and Rice 1996), competitively excluding slow-growing chaparral seedlings and further shortening the fire cycle by providing a more flashy fuel.

These data are contradictory to the traditional view of chaparral vegetation that it has evolved to burn and that stands of chaparral will recover from wildfire and return to their natural pre-fire composition (Hanes 1971). Chaparral at the coastal site of the Santa Monica Mountains that was previously dominated by *M. laurina*, *C. megacarpus*, and *C. spinosus* is today dominated by *M. laurina*, *R. ovata*, and exotic annuals. The species of shrubs that rely exclusively upon recovery after fire by seed germination and establishment have been eliminated.

Although the data are clear for one study at a coastal site in the Santa Monica Mountains, we don't know whether the results can be extrapolated to other sites where fire intervals have been short. We predicted that we would find similar changes in native flora in sites with high fire frequency. Specifically we hypothesized that increased fire frequency would eliminate non-sprouting shrubs and create conditions favorable for the invasion of competing, non-native herbs and grasses (Zedler et al. 1983, Haidinger and Keeley 1993). Reestablishment of a natural community structure at these sites is unlikely because of a pre-requisite of long fire-free intervals (Keeley et al. 1999). In contrast, we predicted that the chaparral species that recruit from seed following wildfire would continue to recruit and dominate sites that have a lower fire frequency.

2 METHODS

We examined four sites that have experienced at least one short-burn interval (≤6 year fire return interval) between the years 1936 to 1996. We also examined four adjacent control sites with a fire return interval ≥12 years (Table 1). Sites with a short fire return interval were matched to nearby control sites of the same slope, aspect, and elevation.

We used GIS software to identify and locate possible study sites. We used vegetation data collected between 1930 and 1934 in the Santa Monica Mountains by the Wieslander survey (Wieslander 1930-4). These vegetation maps were subsequently digitalized by the National Park Service. This allowed us to locate areas historically dominated by non-sprouting chaparral species.

Table 1: Study sites in the Santa Monica Mountains near Los Angeles, CA are given by GPS coordinates. The dominant non-sprouting species (NS) historically found at each site is listed as *Ceanothus cuneatus* (Cc), *C. crassifolius* (Ccr), or *C. megacarpus* (Cm). Additionally, the years each site has experience fire beginning in 1930 to the present and the number of years of the shortest fire return interval is given for each site.

Site		GPS Coordinates	NS	Fire History	Shortest Fire Interval (yrs)
Pepperdine University	Control	N 34º02.38’ W 118º42.10’	Cm	1935, 1958, 1970, 1985	12
	Short Fire Return Interval	N 34º02.42’ W 118º42.06’		1935, 1958, 1970, 1985, 1993, 1996	3
Westlake	Control	N 34º07.79’ W 118º51.17’	Ccr	1984	N/A
	Short Fire Return Interval	N 34º07.90’ W 118º51.06’		1984, 1988	4
Paramount Ranch	Control	N 34º06.80’ W 118º45.52’	Cc	1978	N/A
	Short Fire Return Interval	N 34º06.86’ W 118º45.48’		1978, 1982	4
Saddlepeak	Control	N 34º04.94’ W 118º38.52’	Cm	1936, 1970, 1993	N/A
	Short Fire Return Interval	N 34º04.86’ W 118º38.54’		1936, 1942, 1970, 1993	6

We then employed fire maps that had also been digitized by the National Park Service to locate sites within those areas that have experienced short intervals between fires (≤6 years). We selected sites where the shortest interval between fires was ≤6 years and a control site (shortest interval between fires ≥12 years) were located within the same historic vegetation zone and showed similar slope, aspect, and elevation. Sites with a fire return interval of 1 year were excluded due to the possibility of multiple year entries by fire mapping agencies when fires occurred late in the year (Jim Woods, personal communication). Short fire interval sites in which the fire size was less that 800 m in width were excluded because the accuracy of the fire borders of the fire maps can range up to ±400 m for each fire boarder (Jim Woods, personal communication). We used a GPS unit (eTrex Vista, Garmin Ltd., Olathe, Kansas, USA) to record the longitude, latitude, and elevation of each site. A compass level (International Model, Brunton, Riverton, Wyoming, USA) was used to record the slope and aspect of each site.

Vegetation was sampled using two different methods at each site. For sampling shrubs, we ran three parallel transects through each site, approximately 10 m apart. Along each transect we sampled 6 haphazardly chosen points, spaced approximately 5 m apart. At each point, we used a point-quarter sampling method for the evergreen shrubs, measuring distance to each plant, basal diameter, crown diameter, and crown height. Calculated values included absolute density, relative density, importance values, mean crown diameter, mean basal diameter, mean height, and relative frequency (Cox 1985). In addition to the shrubs, we estimated the canopy coverage of grasses and forbs at each point using a 2x5 dm plot frame (Daubenmire 1988).

Control site and short fire interval sites were compared using unpaired student's t-tests (α = 0.05). Regression analyses and linear regression equations were generated using the assumptions of the least squares model for best linear fit (StatView, SAS Institute Inc., Cary, North Carolina and Minitab, v. 13.31, Minitab Inc., State College, Pennsylvania).

3 RESULTS

Sites that experienced a short fire interval (≤6 years) contained significantly fewer non-sprouting species and significantly more coastal sage scrub species than adjacent control sites ($p = 0.007$ for both; Fig. 1). The relative density of facultative or obligate sprouting species or non-native shrubs between sites that experienced a short fire interval and control sites were not different ($p > 0.05$; Fig. 1).

The percent canopy cover of native and non-native herbaceous species between sites that experienced a short fire interval and control sites were not different ($p > 0.05$; Fig. 2); however, there was a significant difference in total mean percent canopy cover between sites ($p = 0.043$, Fig. 3).

There was a strong correlation between the number of years of the shortest fire return interval and the percent loss in relative density of non-sprouting species relative to the control site (r^2 = 0.94, $p = 0.033$; Fig. 4).

4 DISCUSSION

Our data suggest that increased fire frequency negatively impacts non-sprouting shrubs in the Santa Monica Mountains of southern California. The Pepperdine University site that we sampled showed complete loss of the non-sprouting shrub, *C. megacarpus*, after a fire return interval of 3 years. This is consistent with what we previously found in a longitudinal study of chaparral regeneration post-fire at a coastal site in the Santa Monica Mountains (Davis unpublished data). For other sites with fire intervals of 4 to 6 years the non-sprouting species occurred at much lower relative densities compared to adjacent control sites. Thus, it appears that all three of the non-sprouting species included in our study are negatively affected by increased fire frequency.

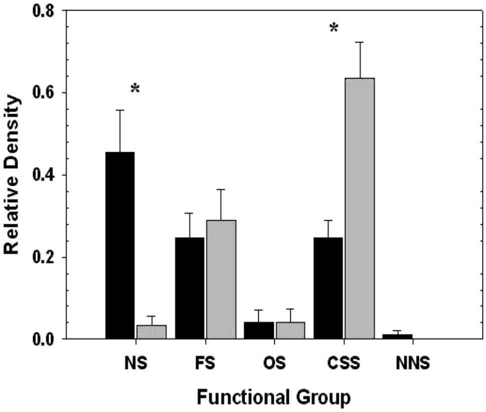

Figure 1. Relative density of evergreen shrubs displayed by functional group. The functional groups given include non-sprouting species (NS), facultative-sprouting species (FS), obligate-sprouting species (OS), coastal sage scrub species (CCS), and non-native shrub species (NNS). Black bars represent control sites (intervals between fires ≥12 years) and gray bars represent sites with short intervals between fires (≤6 years). Bars represent + 1 SE. An asterisk indicates significant difference between control sites and sites with short intervals between fires ($p < 0.05$).

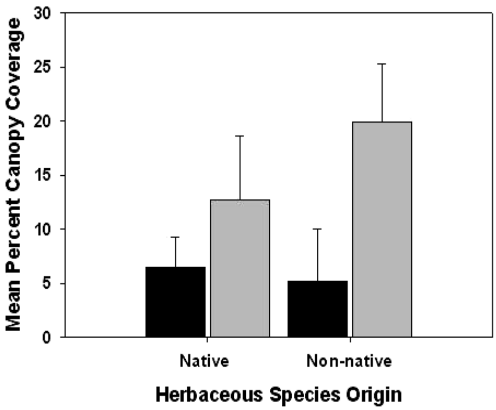

Figure 2. Mean percent canopy coverage of herbaceous species split by species origin. Black bars represent control sites (intervals between fires ≥12 years) and gray bars represent sites with short intervals between fires (≤6 years). Bars represent + 1 SE.

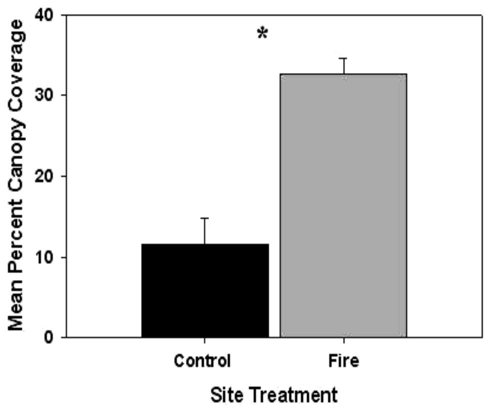

Figure 3. Mean percent canopy coverage of herbaceous species. Black bars represent control sites (intervals between fires ≥12 years) and gray bars represent sites with short intervals between fires (≤6 years). Bars represent + 1 SE. An asterisk indicates significant difference between control sites and sites with short intervals between fires ($p < 0.05$).

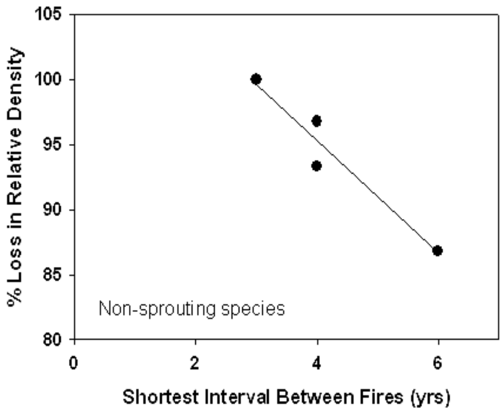

Figure 4. Shortest interval between fires versus the percent loss in relative density of non-sprouting species in frequent fire sites ($r^2 = 0.94$, $p = 0.033$).

The negative effects of short fire intervals appears to lessen as fire return interval lengthens (Fig. 4), however, even at a fire return interval of 6 years there remains an 86.8% loss in relative dominance of non-sprouting species. Further study is needed to determine the minimum fire return interval that non-sprouting species can withstand without experiencing a loss in dominance.

In sites that experience short fire return intervals it appears that coastal sage scrub species are able to fill the gaps created by the elimination of non-sprouting shrubs (Fig. 1). These gaps are also filled by increased coverage of both native and non-native herbaceous species (Fig. 3). Thus, what was previously a stand of closed-canopy chaparral is converted to an open-canopy mix of sprouting shrubs, coastal sage scrub species, and non-native forbs and grasses.

5 CONCLUSIONS

Our data have significant implications for the fire management of chaparral communities. Debate has continued in recent years over the relative benefits of fire suppression versus controlled burning. Our results show that frequent fires can be detrimental to the native chaparral ecosystem. Fire frequencies of ≤6 years significantly reduced the relative density of non-sprouting species, suggesting that the use of controlled burning needs to be sensitive to the age of chaparral stands in order to prevent the local extinction of species that recruit from seed following wildfire.

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