ROLE OF HIGH FIRE FREQUENCY IN DESTRUCTION OF MIXED CHAPARRAL

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ABSTRACT

Postfire regeneration of *Adenostoma* and *Salvia* dominated chaparral was studied in adjacent sites burned by wildfire once, twice, or three times in the past six years, at intervals of 1, 4, and 6 yr prior to the study. The following combinations of burning were: 1 yr ago (previous burn was >20 yr); 1 and 6 yr ago; 1, 4, and 6 yr ago; 4 and 6 yr ago; and 6 yr ago. Marked changes in community composition occurred as fire frequency increased. On the site that burned only once in the past several decades the dominant shrubs *Adenostoma fasciculatum* and *Salvia mellifera* established abundant seedling populations in the first growing season after fire. Seedling establishment the first season after fire was 62% (*S. mellifera*) to 83% (*A. fasciculatum*) less on the site that had also burned 6 yr previously and zero on the site that had burned 1, 4, and 6 yr ago. The suffrutescent (chamaephyte) *Lotus scoparius*, likewise showed the lowest seedling establishment on the site burned the most frequently, however, it did best on the site burned 1 and 6 yr ago. Although *Adenostoma fasciculatum* resprouts after fire, there was some mortality after each fire and thus the number of resprouting shrubs diminished as fire frequency increased. Postfire annual species, in general, were abundant on all sites burned 1 yr ago, regardless of the prior fire frequency. Non-native species such as *Brassica nigra*, *Bromus* spp., and *Schismus barbatus* were poorly represented on the 1 yr old burn that had not been repeatedly burned in recent years. In general, as fire frequency increased, these non-native weeds increased dramatically. It is suggested that high fire frequency has played an important role in the establishment of these weeds and conversion from shrub-dominated to herbaceous-dominated ecosystems in the California landscape.

California chaparral is a "fire-type" vegetation that not only regenerates rapidly after wildfires, but many species are dependent upon such disturbance for regeneration (Horton and Kraebel 1955; Hanes 1971; Keeley and Keeley 1988). It seems reasonable, however, that different fire regimes may generate different patterns of postfire community composition, due largely to the fact that different regimes favor different plant species.

Gill (1973) distinguished three components of fire regime: fire frequency, fire intensity, and fire season. Fire frequency plays a dominant role in determining vegetation structure and vegetation structure largely determines fire intensity. In California chaparral, Zedler et al. (1983) described the impact of two fires only a year apart, on postfire regeneration of the woody vegetation at several mixed chaparral sites. The effect of this extreme event was to nearly eliminate

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one obligate-seeding *Ceanothus* species and greatly reduce the abundance of *Adenostoma fasciculatum.* Thus, it was shown that these two "fire-type" shrubs, which require fire for seedling recruitment, are negatively impacted by frequent fires.

The present study examines the impact of multiple fires on postfire regeneration of mixed "hard" and "soft" chaparral dominated by *Adenostoma fasciculatum* and *Salvia mellifera* in southern California. Here we extend the studies of Zedler et al. (1983) and others by following the concomitant changes in both woody and herbaceous elements. Our study takes advantage of a unique natural experiment in which adjacent sites were burned by wildfires at different intervals in the past 6 yr.

Study Sites and Methods

The study sites were on the north side of the Verdugo Mountains, which are considered to be an extension of the San Gabriel Mountain Range. The sites were west of Sheep Corral Canyon, T2N R13W sect. 30, 600 m elevation. The study was carried out in spring 1992 and sampling was done on adjacent sites burned at different intervals over the past 6 yr as described below. The precipitation records for the nearest station La Crescenta (5 km east and 125 m lower) for this period were: 1986–1987 = 292 mm, 1987–1988 = 556 mm, 1988–1989 = 583 mm, 1989–1990 = 338 mm, 1990–1991 = 545 mm, 1991–1992 = 894 mm (44 yr average = 586 mm) (NOAA 1986–1992).

A large portion of this area burned in 1986 (Keeley unpublished data). In 1988 approximately half of the 1986 burn-site burned again, and in 1991 approximately half of the 1988 burn-site burned a third time. Thus, the following combinations of burning frequency at the time of the study in spring 1992 were: 1 yr ago; 1 and 6 yr ago; 1, 4, and 6 yr ago; 4 and 6 yr ago; and 6 yr ago. Based on the size of *Adenostoma fasciculatum* shrubs in the portions of the site missed by all recent fires it appeared that the shrubs were >20 yr of age at the time of the 1986 burn.

Sites were sampled by random placement of 10 4-m-square quadrats within each site and recording the number of all shrub seedlings and resprouts. Nested within each quadrat a 1-m-square plot was sampled for herbaceous species. Sites were compared statistically with a one-way ANOVA and Duncan's multiple range test. Nomenclature follows Munz (1974).

Results

The dominant hard-chaparral shrub at the site, *Adenostoma fasciculatum,* re-established after fire from both resprouts and seedlings (Figs. 1 and 2). On the one yr site that burned only once in 6 yrs,

A. fasciculatum seedling density was 7.1 times greater than the prefire population size (based on total number of resprouting shrubs and dead shrub skeletons). Seedling establishment by *A. fasciculatum* was markedly reduced on sites that had burned more than once in the past 6 yr (Fig. 2) and this pattern was also seen for the dominant soft-chaparral shrub *Salvia mellifera* (Fig. 3). The suffrutescent *Lotus scoparius* likewise showed the lowest seedling establishment on the site burned the most frequently, however, it did best on the site burned 1 and 6 yr ago (Fig. 4). *Marah macrocarpus* is a resprouting herbaceous vine that was also absent on the most frequently burned site (Fig. 5) as was the native annual *Cryptantha* sp. (Fig. 6).

Postfire native annual species, which are typical of postfire burned sites, were abundant on all sites burned 1 yr ago, regardless of the prior fire frequency (Figs. 7–9).

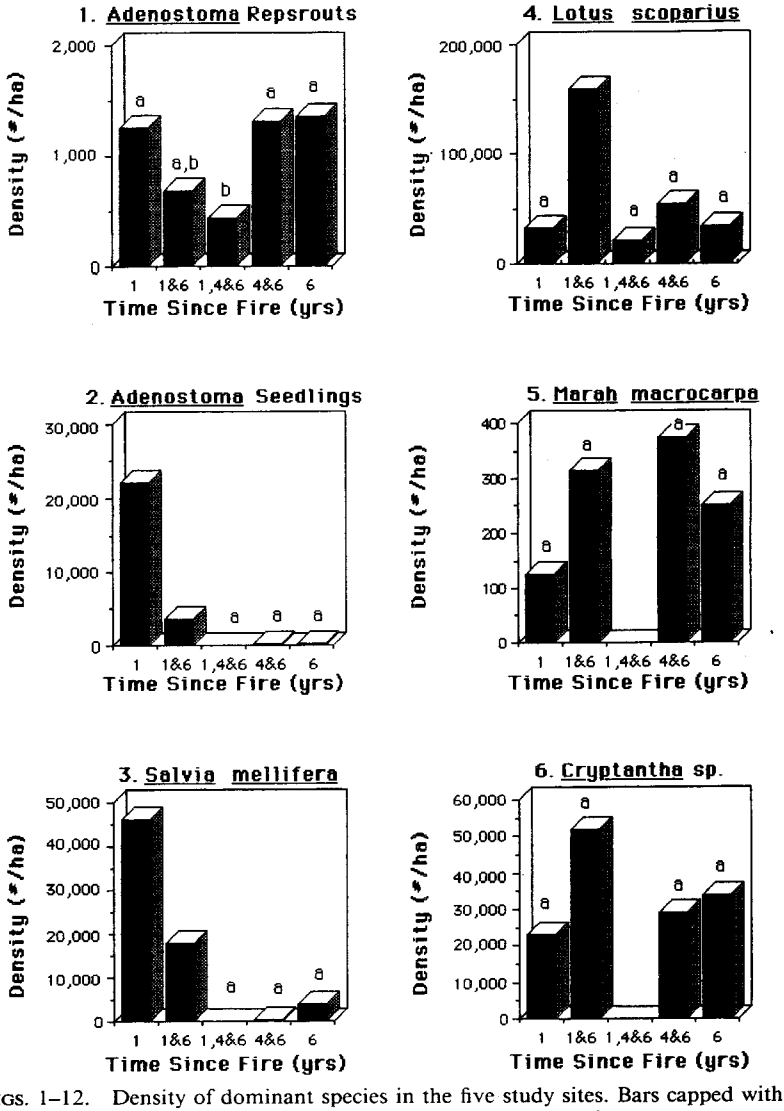
Non-native species such as *Brassica nigra, Bromus* spp., and *Schismus barbatus* were absent or poorly represented on the 1 yr old burn that had last burned more than 20 yr ago (Figs. 10–12). However, postfire recruitment of these aliens was substantially increased on sites that were repeatedly burned. *Brassica nigra* and *Bromus* spp. were particularly abundant on the most frequently burned site.

The composition of the community changed with increasing fire frequency. In general, as the number of fires increased the percentage of annuals increased (Fig. 13) and the percentage of non-native exotics increased (Fig. 14). Species richness was greatest on the site burned 1 and 6 yr ago (16 species) and lowest on the site burned 1, 4, and 6 yr ago (10 species).

Discussion

This study attempts to take advantage of a natural experiment that is not readily duplicated under controlled conditions. Of course the inherent weakness of utilizing such natural experiments is lack of replication. Therefore, it is prudent to clarify that conclusions about the role of fire frequency lack replication and we can not put statistical bounds around the possibility that observed patterns reflect site-to-site variability rather than reponses to fire frequency.

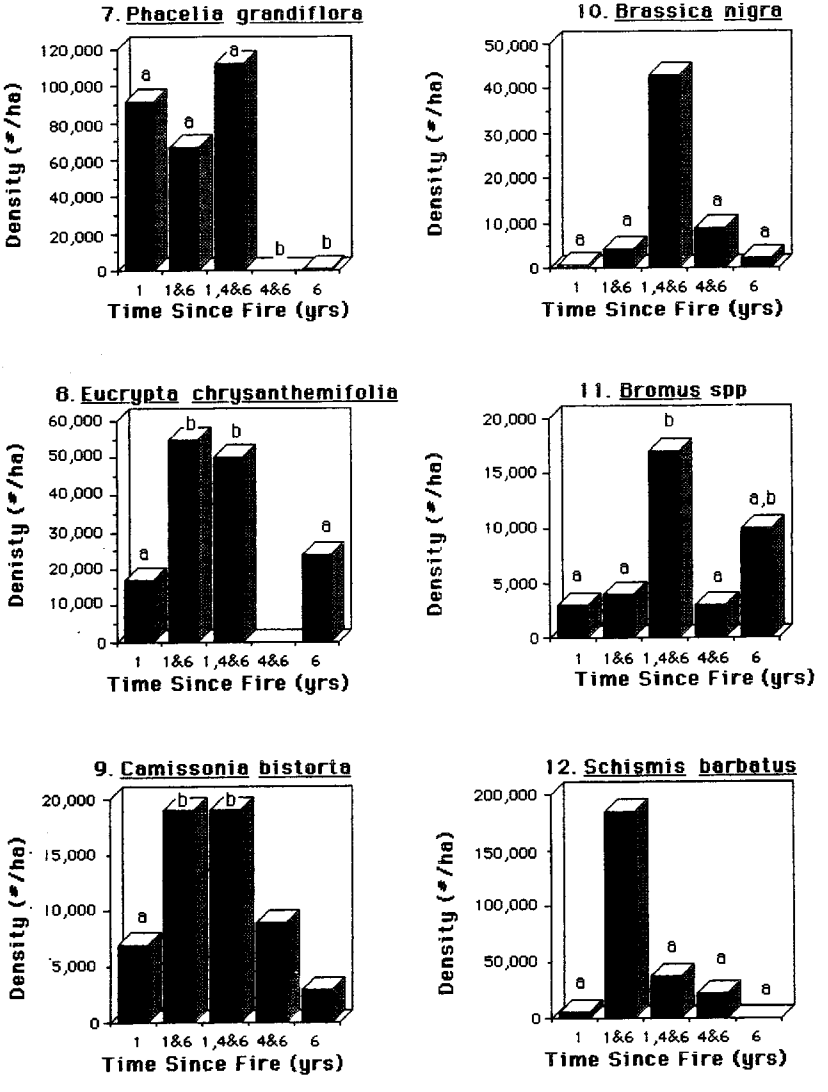
The results of this study, however, are consistent with the observation that fire-adapted chaparral species are not adapted to all fire regimes. As Zedler et al. (1983) noted, high fire frequency may have devastating impacts on shrub species that require a period of recovery before being resilient to further disturbance. At our sites, *Adenostoma fasciculatum* re-established well from both seedlings and resprouts after a single fire. This species requires a period of time after fire for development of a seed bank sufficient to insure adequate seedling recruitment after a repeat fire (Fig. 2). Addition-



FIGS. 1–12. Density of dominant species in the five study sites. Bars capped with the same letter are not significantly different at $P < 0.05$, $n = 10$.

ally, although this shrub is a resprouter, it is not immune to fires and there is significant attrition with each repeat fire (Fig. 1).

Others, such as the soft-chaparral/coastal sage shrub *Salvia mellifera,* follow a similar pattern (Fig. 3), in that repeat fires are destructive to their persistence on a site. The rapidly growing suffru-



FIGS. 1–12. Continued.

tescent, *Lotus scoparius*, although negatively affected by three fires in 6 yr, seems well adapted to fires at 5 yr intervals (Fig. 4). This suffrutescent is relatively short-lived and is a temporary postfire species. Apparently it is capable of developing sufficient seed banks during shorter fire-return intervals than other chaparral perennials.

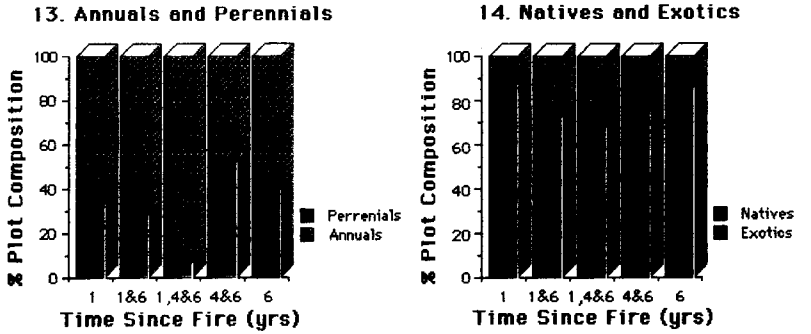


FIG. 13. Percentage of annuals and perennials in the five study sites. FIG. 14. Percentage of natives and exotics in the five study sites.

However, even this species has its limits and fares poorly when the fire frequency exceeds three times in 6 yr.

In general, annuals are well adapted to frequent fires. Natives and non-natives are separable in one important respect. The recent burn that occurred on a site not previously burned in several decades was dominated by natives such as *Phacelia grandiflora* and *Eucrypta chrysanthemifolia* (Figs. 7 and 8). In contrast, non-native annuals such as *Brassica nigra* and species of *Bromus* were poorly represented and were abundant only after the area burned repeatedly (Figs. 10–12).

The present study illustrates the potential role of high fire frequency in altering the California landscape from a shrub dominated ecosystem to an herbaceous dominated system. The apparent permanence of such changes is attested to by numerous studies that reveal the limited ability of coastal sage and chaparral shrubs to (re)invade sites dominated by non-native annual grasses and forbs (White 1966; Freudenberger et al. 1987; Hobbs 1983; Davis and Mooney 1985). Part of the explanation lies in the changes in soil water availability produced by the annual flora. Loss of native nitrogen-fixing species such as *Lotus scoparius* and *Ceanothus* spp. may result in additional changes in ecosystem properties that further limit the ability of shrubs to re-establish on these annual-dominated sites.

While it should not be surprising that repeated disturbance enhances the spread of non-natives, these results do call into question the conclusions of Westman (1979) that oxidant levels enhance the spread of non-natives. In Westman's study it was shown that levels of particular air pollutants were correlated with the percentage of non-natives (mostly annuals) in coastal sage scrub vegetation. Unfortunately, Westman (1979) did not investigate the correlation between fire frequency and non-native abundance. Although Westman (1979) appreciated the role of fire in structuring of coastal sage com-

munities, he lacked data on the frequency of fires at his sites. In his attempt to correlate the abundance of non-natives with site factors, he utilized the time-since-last-fire as a measure of fire history and sampled only sites that had not burned in 7 yr. Based on Westman's criteria, after 6 yr, all sites from the present study would be scored as having experienced the same fire history. It is little wonder that Westman (1979) found no correlation between non-native abundance and his surrogate measure of fire history. Westman's correlation between non-natives and air pollution may be spurious since oxidant levels are likely to be highly correlated with fire frequency. In other words, fire frequency, as well as oxidant level, increases in urban environments (Keeley 1982), and thus the correlation between oxidant level and non-natives should not necessarily be interpreted as representing a causative relationship.

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