# Fire and Changes in Creosote Bush Scrub of the Western Sonoran Desert, California

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ABSTRACT: Seven years of above normal precipitation between 1976 and 1983 encouraged heavy growth of native annuals and exotic grasses in the western Sonoran Desert. Unprecedented fires in creosote bush scrub started mostly after 1978. Analysis of several burns near Palm Springs revealed that most shrubs, including *Larrrea tridentata, Ambrosia dumosa* and *Opuntia* spp., are poorly adapted to relatively low intensity fires as evidenced by limited sprouting and reproduction. These shrubs were replaced by open stands of *Encelia farinosa*, native ephemerals, and European exotics, mostly *Bromus rubens* and *Schismus barbatus*. The rapid selective thinning of creosote bush scrub species suggests that the modern biogeography of this ecosystem may be controlled, in part, by recurrent burning.

## INTRODUCTION

Fires are infrequent in the Sonoran Desert owing to limited biomass, wide spacing between shrubs and sparse ground cover (Humphrey, 1949, 1962). Recent studies in Arizona (Rogers and Steele, 1980) and California (Tratz and Vogl, 1977: Tratz, 1978; O'Leary and Minnich, 1981) indicate that many desert perennials are poorly adapted to burning. Successional studies in creosote bush scrub reveal postdisturbance recolonization by long-lived species is very slow initially and may require hundreds of years (Vasek, 1980, 1983). Thus rare fires may have long-term impact on the structure and composition of this community.

Heavy growth of native and exotic annual vegetation promoted by extraordinarily heavy precipitation between 1976 and 1983 resulted in unprecedented fires in creosote bush scrub vegetation along the western margins of the Mojave and Sonoran deserts of southern California. This study documents fire and early postfire succession in creosote bush scrub in several burns near Palm Springs, and it evaluates the stability and biogeography of this ecosystem in relation to recurrent fire.

## STUDY AREA

Four sites on Quaternary alluvial fans descending from the E scarp of the San Jacinto Mountains at the end of the Coachella Valley near Palm Springs, California, were chosen for study (Fig. 1). Coarse-textured soils are well-drained, moderately alkaline with a minimum of organic matter (Fraser, 1931; Proctor, 1968; Knecht, 1980).

The climate of the Coachella Valley is extremely arid owing to its subtropical latitude and to rain shadows of the San Jacinto Mountains (Bailey, 1966). Average annual rainfall at Palm Springs, mostly from winter cyclonic storms, is 138 mm (Table 1). Summers are hot and dry, although tropical moisture from the equatorial Pacific produce occasional thunderstorms, mostly over the nearby mountains.

## VEGETATION

Most of the Sonoran Desert is covered with creosote bush scrub consisting of scattered low shrubs less than 2 m. Representative growth forms include evergreen

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sclerophyllous and deciduous shrubs, subligneous subshrubs, leaf and stem succulents, and annual herbs (Johnson, 1974; Burk, 1977). Bajadas and adjacent mountainsides in the Coachella Valley are covered by *Larrea tridentata*, *Encelia farinosa*, *Hilaria rigida*, *Enchinocereus engelmannii*, and *Krameria grayi*. Vegetation on the plains and lower bajadas, including the study sites, is dominated by *L. tridentata*, *Ambrosia dumosa* and *E. farinosa*, which may form 60-100% of total vegetation cover (McHargue, 1973; Shreve and Wiggins, 1964). *Cercidium floridum*, *Olynea tesota*, *Dalea spinosa*, *Beloperone californica* and *Hyptis emoryi* are common along washes. Succulents such as *Ferocactus acanthodes*, *Echinocereus engelmannii*, *Opuntia basilaris*, *O. bigelovii* and *O. echinocarpa* reach maximum densities on sandy hillsides and bajadas with rocky, gravelly, or sandy substrates (McHargue, 1973).

## FIRE HISTORY

Until the last decade, burning was almost unknown in the area (Fig. 1). Two large fires in 1911 and 1945 burned chaparral and mixed evergreen forests above 1200 m. A 3600-ha fire on the N slope of Mt. San Jacinto in 1973 spread into a small area of creosote bush scrub (O'Leary and Minnich, 1981). Two rare Mexican west coast tropical storms (September 1976, August 1977), followed by abnormally stormy winters from 1977-1978 to 1979-1980 and 1982-1983, caused sustained above-normal precipitation

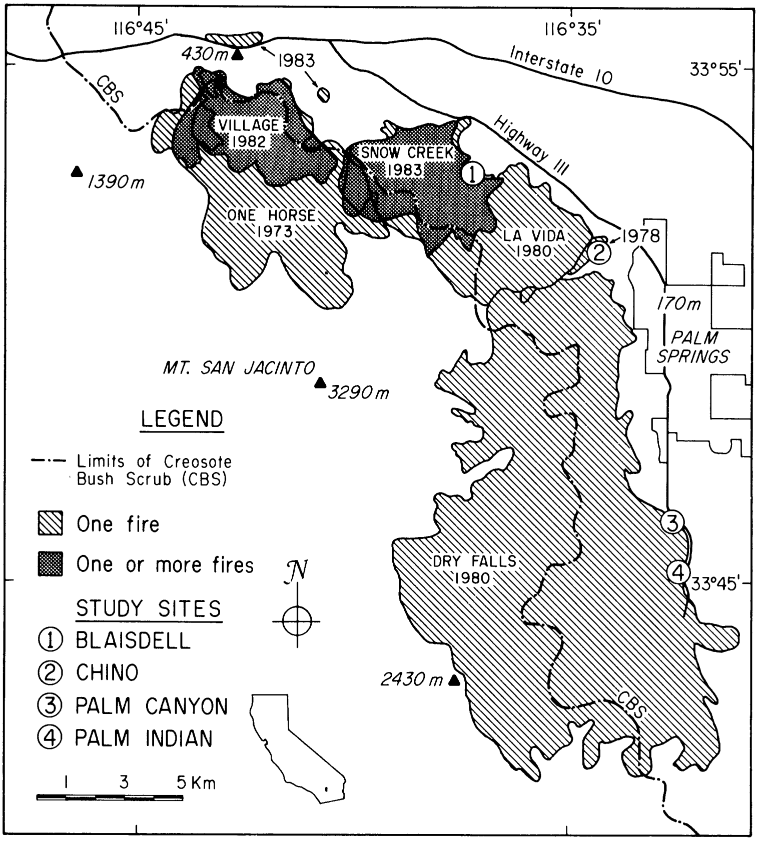


Fig. 1.—The study sites and fire perimeters. Limits of cresote bush scrub are interpreted from 1:30,000 scale aerial photography (1971) on file at the Department of Earth Sciences, University of California, Riverside

(Table 1) which encouraged heavy growth of shrubs and herbaceous understory. Beginning in 1978, a series of fires spread through dried herbaceous fuels into extensive areas of creosote bush scrub, including the Chino Canyon fan (500 ha, 1978), Blaisdell and Chino canyons (2800 ha, 1980), and the E scarp and alluvial fans below 1300 m from Chino Canyon S to Palm Canyon (6000 ha, 1980). A 1200-ha burn in 1982 overlapped large areas burned in 1973 near Snow Creek. In 1983, the first of three fires reburned portions of Snow Creek and Blaisdell Canyon. Two smaller fires also occurred along Snow Creek road and Interstate 10.

The fires in creosote bush scrub characteristically spread during periods when ambient temperatures averaged 35-40 C and relative humidity ranged from 10-25%. High winds (10-20 $ms^{-1}$) were caused by the typical spring and early summer gravity acceleration of descending coastal marine air spilling through San Gorgonio Pass. Upcanyon winds and nocturnal air drainage promoted fire spread on the eastern face of Mt. San Jacinto. The flames reduced the herb layer to a low stubble, indicative of fast-moving, low-intensity fires.

## SITE SELECTION AND METHODS

Four sites were located on relatively homogeneous terrain (*i.e.*, avoiding large washes or rock outcrops) at the fire boundaries on the Chino, Blaisdell and Palm Canyon alluvial fans in order to compare burned vegetation with adjacent unburned stands (Fig. 1). The areas were surveyed between 25 April and 27 May 1983, when desert annuals were declining and perennials were in full growth or flower.

Perennial and annual plants were analyzed separately, with major emphasis placed on perennial cover and density. In unburned transects, the vegetation sampled is assumed to represent the prefire state of burned areas. In each site, two 100-m parallel transects were employed in burned and unburned areas (200 m for each). Both belt and line methods of sampling were used along each 100-m transect (Mueller-Dombois, 1974). The line intercept method was used to obtain percent cover (intercept distance) and density of perennial species (*cf.* Canfield, 1942). Each plant along the intercept was measured, identified and counted. Seedlings on each intercept were counted as part of total perennial cover, and were also noted separately. Belt transects (100 m x 1 m) were used to determine seedling density. Seedlings were counted and time of establishment was assigned as first postfire growing season (older plants > 5 cm height) or later growing season (< 5 cm). A 1-m-sq area was located at the end point of each transect to estimate herbaceous cover and floristic composition.

In transects within the burns, surviving plants, sprouting behavior and mortality (fire-killed snags) were recorded. Fire damage was estimated by qualitatively ranking plants as burned, scorched or green. Burned plants showed pyrolysis of foliage and fine

TABLE 1.—Annual precipitation at Palm Springs (source: California 1984)

| Season | Total (mm) | Percent of normal |
|---|---|---|
| 1889-1983 Mean | 138 | |
| 1976-1977 | 174 | 126 |
| 1977-1978 | 289 | 209 |
| 1978-1979 | 188 | 136 |
| 1979-1980 | 412 | 299 |
| 1980-1981 | 64 | 46 |
| 1981-1982 | 98 | 71 |
| 1982-1983 | 222 | 161 |

stems, leaving a stump or main stems. Scorched plants retained all or most branches and dried foliage. Green plants retained living foliage or escaped fire entirely. In belt transects, plant snags were counted and ranked for fire damage and recovery. Seedlings were counted in each meter and assigned establishment dates as in unburned areas.

## RESULTS

The vegetation was sampled 3 growing seasons after burns at Blaisdell, Palm Canyon and Palm Indian sites and after 5-growing seasons at the Chino site. However, data for Chino were merged with other data because there was insufficient data from the single 1978 site to extrapolate small differences in succession from species composition which may be more related to site than temporal changes associated with age class. Nineteen perennial and 10 herb species were recorded.

### UNBURNED VEGETATION

Unburned perennial cover averaged 21% and was dominated by *Larrea tridentata*, *Ambrosia dumosa*, and *Encelia farinosa* (Table 2). Wash species (*Acacia greggii*, *Beloperone californica*, *Hyptis emoryi*) and cacti (*Opuntia acanthocarpa*, *O. bigelovii*) were occasional in all sites. Native herb cover (*Aristida adscensionis*, *Chaenactis fremontii* and *Chorizanthe brevicornu*) varied greatly while the European exotics, *Bromus rubens* and *Schismus barbatus*, were nearly everywhere (Fig. 2).

### BURNED VEGETATION

*Fire damage to perennials.*—Most perennials were scorched, although the majority of shrubs were locally burned in several sites, particularly the Blaisdell fan. The pattern of shrub damage was species-specific, suggesting that the combustion of shrubs was more influenced by individual species morphology and fuel properties than spatial variations in fire behavior (Table 3). *Larrea tridentata* was typically only scorched despite its resinous foliage and the dense herbaceous cover growing in organically rich eolian sedimentary mounds beneath. Most main stems were unburned and often contained green foliage. Flame heights from herbaceous fuels were apparently insufficient to burn *L. tridentata* canopies owing to limited herbaceous fuels, limited foliar dead fuel content, and spreading branch habit (low fuel continuity). *Encelia farinosa* was mostly scorched due to the morphology of pencil-thick branches which support an umbrella of leaves with few stems beneath. Only leaves and branches near the ground burned, leaving foliage on ultimate stems. *Ambrosia dumosa* regularly burned because the canopy comprises numerous small branches with a finely divided branching pattern close to herbaceous fuels which maximizes fuel continuity, surface to volume ratio and rapid pyrolysis.

The cacti, including *Opuntia acanthocarpa*, *O. bigelovii*, and *Ferocactus acanthodes*, were normally scorched. The dense spines of *O. bigelovii* tended to carry flames up the crown. *Beloperone californica* and *Hyptis emoryi* were usually less damaged than other shrubs, perhaps owing to higher fuel moisture content in wash habitats. *Hyptis emoryi* is characterized by an upward branching habit, and its upper stems extended above flames. Among infrequent shrubs (data not shown), *Acacia greggii* and *Dalea californica* rarely burned because of their arboreal and semideciduous growth habits. *Bebbia juncea*, *Ephedra californica* and *Krameria grayi* normally burned due to their low growth habits and compact crowns.

*Sprouting and mortality.* Sprouting of most perennials was limited and depended upon local fire intensity. At the heavily burned Blaisdell site, for example, most plants were reduced to ash and mortality was nearly universal; sprouting was intermittent among scorched shrubs at the other sites (Table 3).

Burned shrubs of most species sprouted less than scorched ones. *Larrea tridentata*, *Ambrosia dumosa* and *Encelia farinosa* rarely sprouted even among scorched individuals that retained full canopy foliage. Many *L. tridentata* shrubs with living foliage after burning died later, presumably as a result of basal cambium damage. Scattered resprouts of *Opuntia acanthocarpa*, *O. bigelovii*, *Echinocereus engelmannii* and *Ferocactus acanthodes*

TABLE 2.—Density (D) and cover (C) of established (unburned) and resprouting (burned) shrubs. Density is expressed in number of plants per 100 m², cover in percent ground covered

| Species | Blaisdell | | | | Chino | | | | Palm Canyon | | | | Palm Indian | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unburned | | Burned | | Unburned | | Burned | | Unburned | | Burned | | Unburned | | Burned | |
| | D | C | D | C | D | C | D | C | D | C | D | C | | C | D | C |
| *Larrea tridentata* | 2.5 | 3.1 | 0 | 0 | 3.5 | 3.4 | 0 | 0 | 3.0 | 4.2 | 0 | 0 | 8.0 | 13.4 | 0 | 0 |
| *Ambrosia dumosa* | 20.0 | 13.0 | 0 | 0 | 8.0 | 4.1 | 0 | 0 | 6.0 | 4.1 | 1.5 | 3.3 | 5.5 | 1.7 | .5 | .2 |
| *Encelia farinosa* | 1.0 | .9 | 0 | 0 | 11.5 | 9.2 | 1.5 | 2.0 | 13.0 | 10.6 | 2.0 | 2.6 | 3.0 | 1.4 | 2.5 | 3.5 |
| *Opuntia acanthocarpa* | 3.0 | 1.2 | 0 | 0 | | | | | 3.0 | 1.7 | 1.0 | .3 | 1.0 | .2 | 0 | 0 |
| *O. bigelovii* | | | | | | | | | | | | | 7.5 | 1.2 | 2.0 | .5 |
| *Hyptis emoryi* | | | | | 0 | 0 | 1.0 | .8 | 2.5 | 3.0 | 1.0 | .7 | 1.5 | 1.6 | 1.0 | .6 |
| *Krameria grayi* | 2.5 | 1.5 | 0 | 0 | .5 | .3 | 0 | 0 | | | | | | | | |
| *Dalea californica* | 1.0 | .4 | 0 | 0 | | | | | | | | | | | | |
| *Mirabilis bigelovii* | .5 | .3 | 0 | 0 | | | | | | | | | | | | |
| *Beloperone californica* | | | | | 3.5 | 2.0 | 7.0 | 3.7 | | | | | | | | |
| *Hilaria rigida* | | | | | 1.0 | .5 | 0 | 0 | | | | | | | | |
| *Ferocactus acanthodes* | | | | | .5 | .1 | 0 | 0 | | | | | | | | |
| *Acacia greggii* | | | | | | | | | 0 | 0 | .5 | 1.4 | | | | |
| *Bebbia juncea* | | | | | | | | | | | | | .5 | .9 | .5 | .6 |
| *Echinocereus engelmannii* | | | | | | | | | | | | | .5 | .1 | 0 | 0 |
| Total | 30.5 | 20.4 | 0 | 0 | 28.5 | 19.6 | 9.5 | 6.5 | 27.5 | 23.6 | 6.0 | 8.3 | 27.5 | 20.5 | 6.5 | 5.4 |

were surrounded by numerous skeletons of dead individuals. The wash species *Beloperone californica* and *Hyptis emoryi* exhibited well-developed stump and crown sprouting. *Acacia greggii* resprouted to former canopy cover within 3 years.

### SEEDLING ESTABLISHMENT

More shrub seedlings established on burned than on unburned sites, although the pattern of regeneration varied with species and annual precipitation (Table 4). *Encelia farinosa* accounted for most of the seedlings observed during the first growing season, especially in burns. Most reproduction during the first growing season was composed of *Encelia farinosa*, primarily in burns. *Hilaria rigida*, *Opuntia acanthocarpa* and *Trixis californica* seedlings were observed in burns only after the first growing season (1980-1981). *Mirabilis bigelovii*, *Sphaeralcea emoryi* and *Bebbia juncea* also reproduced in burns mostly during the first growing season, but establishment persisted into later growing seasons. *Ambrosia dumosa* and *Ditaxis lanceolata* establishment increased in later growing seasons. Most

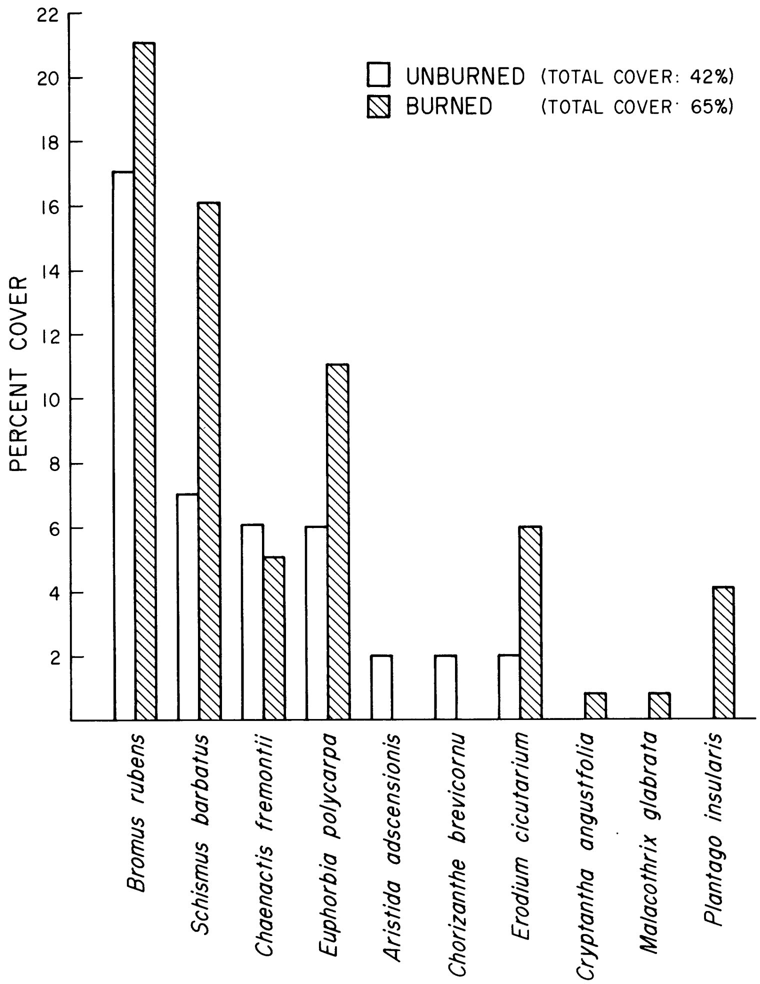


Fig. 2.—Herbaceous cover in burned and unburned sites

seedling reproduction in unburned sites was *E. farinosa* and *A. dumosa*. There was sporadic establishment of *Larrea tridentata* and *Hyptis emoryi*, mostly in unburned sites. The wet 1982-1983 season was followed by abundant reproduction of *E. farinosa* and lesser amounts of *A. dumosa* in both burned and unburned sites.

With the exception of *Encelia farinosa*, seedling densities were less than the density of established shrubs in unburned areas. Severely burned areas with few surviving perennials, such as the Blaisdell fan, had fewest seedlings (Table 2). Several infrequent perennials established no seedlings in the area, including *Acacia greggii*, *Dalea californica*, *Echinocereus engelmannii*, *Ephedra californica*, *Ferocactus acanthodes*, *Frameria grayi* and *Opuntia bigelovii* (removal of adults limited vegetative reproduction in the latter).

### CHANGES IN STAND COMPOSITION

The primary effect of recent burns was the reduction of perennial cover, owing to limited sprouting combined with scarce seedling establishment of most shrubs (Fig. 3). After 3-5 growing seasons, the total cover in burned sites was about half that of unburned sites and was composed mostly of *Encelia farinosa*. The largest change was the reduction of *Larrea tridentata* because it experienced almost no sexual or asexual reproduction or resprouting.

TABLE 3.—Shrub damage, sprouting and mortality (percent)

| Species | N | Burned | Resprouts | Scorched | Resprouts | Green | Resprouts | Mortality |
|---|---|---|---|---|---|---|---|---|
| *Encelia farinosa* | 122 | 20 | 0 | 78 | 5 | 2 | 2 | 93 |
| *Ambrosia dumosa* | 84 | 81 | 2 | 16 | 6 | 3 | 3 | 89 |
| *Opuntia bigelovii* | 49 | 4 | 0 | 94 | 6 | 2 | 2 | 92 |
| *O. acanthocarpa* | 36 | 11 | 0 | 89 | 8 | 0 | 0 | 92 |
| *Larrea tridentata* | 35 | 0 | 0 | 100 | 3 | 0 | 0 | 97 |
| *Hyptis emoryi* | 10 | 0 | 0 | 100 | 40 | 0 | 0 | 60 |
| *Beloperone californica* | 7 | 0 | 0 | 100 | 57 | 0 | 0 | 43 |

TABLE 4.—Seedling density in initial and subsequent growing seasons

| Species | Burned Area 1980-1981* growing season (number/ha) | Burned Area 1981-1983* growing seasons (number/ha) | Unburned Area 1980-1981* growing season (number/ha) | Unburned Area 1981-1983* growing seasons (number/ha) |
|---|---|---|---|---|
| *Encelia farinosa* | 1460 | 7010 | 90 | 5650 |
| *Hyptis Emoryi* | 90 | 50 | 10 | 30 |
| *Mirabilis bigelovii* | 90 | 40 | 0 | 0 |
| *Hilaria rigida* | 80 | 0 | 0 | 0 |
| *Ambrosia dumosa* | *60* | *160* | *30* | *200* |
| *Sphaeralcea emoryi* | 50 | 10 | 0 | 0 |
| *Bebbia juncea* | 50 | 30 | 0 | 0 |
| *Beloperone californica* | 40 | 40 | 0 | 0 |
| *Opuntia acanthocarpa* | 30 | 0 | 0 | 0 |
| *Ditaxis lanceolata* | 10 | 60 | 0 | 0 |
| *Trixis californica* | 10 | 0 | 0 | 0 |
| *Larrea tridentata* | 0 | 10 | 0 | 40 |

*At the Chino site, the first growing season was 1978-1979. Later growing seasons are 1979-1983

Postfire herb cover averaged 23% greater in burned than unburned stands. *Malacothrix glabrata*, *Cryptantha angustifolia* and *Plantago insularis* were found only in burned areas. Most cover was of exotic European annuals *Bromus rubens* and *Schismus barbatus* (Fig. 2).

## DISCUSSION

Fire mortality and postfire succession in creosote bush scrub at Palm Springs are similar to other studies in the Sonoran Desert (Rogers and Steele, 1980; O'Leary and Minnich, 1981). Sprouting behavior of *Larrea tridentata* in the Sonoran Desert was varia-

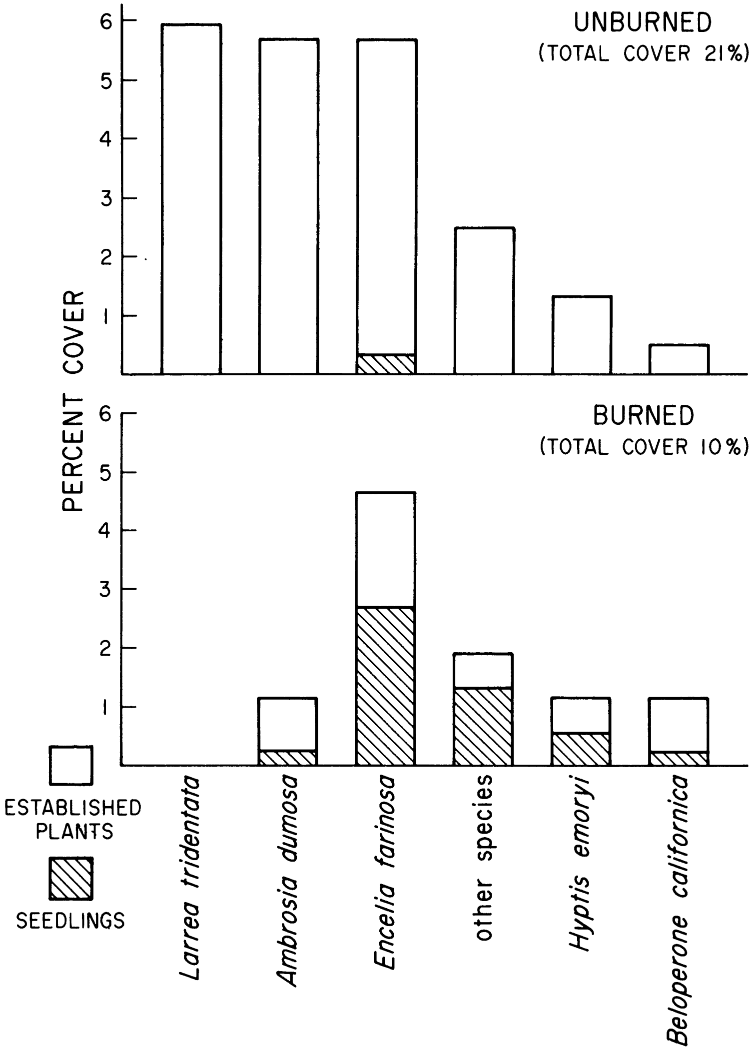


Fig. 3.—Perennial cover in burned and unburned sites (cover expressed in absolute percentages). "Other species" include *Acacia greggii*, *Bebbia juncea*, *Dalea californica*, *Echinocereous engelmannii*, *Ephedra californica*, *Ferocactus acanthodes*, *Hilaria rigida*, *Krameria grayi*, *Opuntia acanthocarpa* and *O. bigelovii*, *Ditaxis lanceolata*, *Mirabilis bigelovii*, *Spheralcea emoryi* and *trixis californica*

ble, depending primarily on fire intensity and season. Dalton (1962) found that slightly to moderately burned *L. tridentata* near Tucson, Arizona, experienced 60-70% mortality. Rogers and Steele (1980) observed minimal resprouting of *L. tridentata*. However, fire intensity and season were not reported. White (1968) found that *L. tridentata* mortality was related to season of burning, with highest mortality prior to the onset of the summer precipitation season. Increased fire intensity and duration also resulted in decreased sprout production.

At Palm Springs, sprouting of *Larrea tridentata* was highly variable in burns which occurred from June through September. O'Leary and Minnich (1981) found moderate sprouting following the July 1973 burn. We observed nearly 100% sprouting following a small burn near Snow Creek in June 1983, but heavy mortality in another burn 2 weeks later 10 km NW. The 1980 burns (July, August-September) caused heavy mortality. These trends indicate that sprouting rates are more related to fire intensity than season of burning.

Heavy *Encelia farinosa* and *Ambrosia dumosa* mortality at Palm Springs parallels findings in Arizona (*A. deltoides*: Rogers and Steele, 1980) and California coastal sage scrub (Malanson and O'Leary, 1982). The reduction of *Opuntia acanthocarpa*, and *O. bigelovii* is comparable to that in burns at Snow Creek (O'Leary and Minnich, 1981), the Borrego Desert (Tratz and Vogl, 1977), and Arizona (Rogers and Steele, 1980). The vigorous sprouting of wash species (*Hyptis emoryi*, *Beloperone californica*, and *Acacia greggii*) at Palm Springs was also observed in similar habitats in the Borrego Desert (*Chilopsis linearis*, *A. greggii*, Tratz and Vogl, 1977). Such sprouting behavior may be a generalized adaptation to flash flood disturbances (Tratz, 1978; Zedler, 1981).

Poor seedling establishment at Palm Springs is probably unrelated to seed availability since all species occur in adjacent unburned areas. Most are capable of long-range seed dispersal by wind (*Larrea tridentata*, *Ambrosia dumosa* and *Encelia farinosa*) or fauna (*Opuntia bigelovii* [vegetative reproduction], *O. acanthocarpa*, *Hyptis emoryi* and *Beloperone californica*) (Ridley, 1930). Scattered resprouts and unburned individuals throughout the burns provide local seed sources. Thus, postfire habitats were apparently unfavorable for establishment.

Reproduction may be encouraged by disturbance. In powerline and road construction disturbances in the Mojave Desert, seedling establishment was most prolific among short-lived species, primarily *Encelia frutescens*, while germination of most long-lived species, including *Larrea tridentata* was limited (Vasek, 1980). We found no evidence of abundant *L. tridentata* reproduction, as reported in Arizona burn sites (Dalton, 1962). In an investigation following severe flooding near Ocotillo, Calif., Zedler (1981) recorded abundant reproduction of *Ambrosia dumosa*, *E. farinosa*, *Larrea tridentata*, *Opuntia echinocarpa*, *Acacia greggii*, *Hyptis emoryi* and *Beloperone californica*. Since postfire establishment was limited in the Palm Springs sites, prolonged surface moisture from abundant rainfall or floodwaters may be required for comparable germination and establishment.

Season of rainfall may have inhibited establishment of several shrubs. In Joshua Tree National Monument (50 km NE), Went (1948) found that *Acacia greggii*, *Dalea* spp., *Hymenoclea salsola*, *Hyptis emoryi* and *Larrea tridentata* germinated only in summer. Beatley (1974) suggested that summer rainfall is a requirement for successful germination of *L. tridentata*. However, unusually heavy summer rains at Palm Springs in August 1979 (44 mm), and the two wettest summers of the century (1983, 1984) resulted in only sporadic establishment of these shrubs. Similarly, Vasek (1980) found only limited germination of long-lived shrubs and succulents, including *L. tridentata*, *Opuntia acanthocarpa*, *Krameria grayi*, *Hilaria rigida*, in the Mojave Desert, despite favorable climatic conditions. *Encelia farinosa* responded prolifically to heavy winter rains of 1982-1983, a trend consistent with its distribution in coastal sage scrub of coastal southern California where summer rain is nearly absent. Zedler (1981) also observed heavy summer germination of this scrub.

Vasek (1980) suggested that soil condition, primarily the accumulation of organic matter, is important for germination. Many perennials at Palm Springs established seedlings only in burns. *Encelia farinosa* and *Ambrosia dumosa* establishment was also initially stimulated in burns. However, both shrubs colonized both burned and unburned sites after the wet 1982-1983 winter.

Desert succession studies elsewhere in California (Vasek *et al.*, 1975a, b; Vasek, 1980, 1983) indicate that most long-lived shrubs (*Larrea tridentata, Ambrosia dumosa, Opuntia bigelovii, Echinocereus engelmannii, Acacia greggii* and *Krameria parvifolia*) are characterized by limited but continuous establishment and thus respond negatively to disturbance. The chronic disturbance of desert habitats by wind and water erosion permits suitable sites for both short- and long-lived perennials. Creosote bush scrub stands are reported to occur in various successional states indicating continuous establishment. Postdisturbance regeneration may take hundreds of years to complete, being very slow at first (Vasek, 1980). The scale of such disturbances, however, is much smaller than wildland fires which can remove plant cover over extensive areas and exacerbate reestablishment by long-range seed dispersal.

The limited period of succession considered here permits only speculation on the future postfire succession at Palm Springs. Long-lived species were nearly eliminated and replaced by short-lived shrubs, mostly *Encelia farinosa*, with wash species persisting locally through sprouting. To date, there is little evidence of continuous long-lived perennial replacement as reported by Vasek *et al.* (1975b), in spite of favorable conditions provided by abnormally heavy precipitation. Indeed, 1984 aerial photographs (1:24,000; Riverside County Flood Control) indicate that *Larrea tridentata* has been removed from extensive areas of the San Jacinto Mountains. An open *Encelia farinosa* community now covering the slopes may persist for decades.

## FIRE, CREOSOTE BUSH SCRUB STABILITY AND BIOGEOGRAPHY

In contrast with fire-prone chaparral and forest ecosystems covering the mountains of coastal California, many desert perennials appear unable to persist after burns by surviving fires, sprouting, fruit serotiny, long-term seed viability and immediate germination by scarification of soil seed (*see* reviews by Hanes, 1977; Wright, 1982; Reid and Oechel, 1984). Indeed, the rapid transformation of perennial cover and floristic composition of stands in the Palm Springs burns suggests that many creosote bush scrub taxa are poorly adapted to recurrent burning. Recurrent fire appears to select for short-lived desert shrubs, notably *Encelia farinosa* and *Ambrosia dumosa*, at the expense of long-lived species. At the Blaisdell site, the 1983 burn was carried entirely by herbs and eliminated the few shrubs which survived the 1980 burn. Field observations indicate that *Larrea tridentata* and *Opuntia echinocarpa* surviving a 1973 burn at Snow Creek were removed by the 1982 burn; the site is now covered by *Hymonoclea salsola* and annual grasses (*cf.*, O'Leary and Minnich, 1981).

The recent outbreak of fires, however, is clearly related to persistent above-normal precipitation and increases in native and exotic herb cover after 1976. It is important to ask whether recent burns are an aberration, and thus represent only an ephemeral event in creosote bush scrub ecology and biogeography.

Low mean annual precipitation and plant productivity at Palm Springs normally precludes short-term fire recurrences. Indeed, chaparral fires crossing the desert flanks of the San Jacinto Mountains earlier in the century stopped above desert scrub communities, owing apparently to limited fuel. Prehistoric burns doubtless extended into the desert margin on occasion when conditions were optimal. Disturbance intervals, however, were sufficiently long, perhaps centuries, to permit the establishment of long-lived desert perennials.

The western geographic limits of many taxa may thus be related to repeated, more intense burning associated with coastal sage scrub and chaparral. In southern California coastal sage scrub, burns are followed by rapid seedling establishment of *Eriogonum fasciculatum, Encelia farinosa, Salvia apiana, Salvia mellifera* and *Artemesia californica*, although resprouting is occasional (Malanson and O'Leary, 1982). Creosote bush scrub and coastal sage scrub are similar in that both ecosystems comprise mostly drought-deciduous mesophytic subshrubs. However, creosote bush scrub perennials, with the exception of *Salvia apiana* and *Encelia farinosa*, are poor colonizers following recurrent fire (Tratz, 1978). Indeed, recent burns have converted creosote bush scrub at Palm Springs to *Encelia farinosa* coastal sage scrub similar to stands covering semiarid interior valleys around Riverside, California.

Some desert taxa, including *Yucca schidigera*, *Simmondsia chinensis*, *Acacia greggii*, *Juniperus californica* and *Opuntia occidentalis*, extend westward into fire-prone areas of coastal southern California. These shrubs, however, are either vigorous sprouters (Tratz, 1978) or restricted to drier sites within the Pacific slope, such as at Aguanga and the Perris Plain in rain shadows of coastal ranges, and porous alluvial fans descending from the San Gabriel and San Bernardino mountains, where burning intervals are locally lengthened by low productivity (Axelrod, 1966; Smith, 1980).

*The role of European exotics.*—Recent burns, however, may have been encouraged by the profusion of European exotic grasses, especially *Bromus tectorum*, *B. rubens* and *Schismus barbatus*, during recent wet years. These species have continued to thrive during drier years since 1983. At Palm Springs, *B. rubens*, *Schismus barbatus* and other European grasses escape excessive summer heat through their winter annual habit. A minimum of cool-season precipitation (ca. 150 mm) appears sufficient to support these exotic grasses. In the dry interior, herbaceous cover resists decomposition resulting in accumulation of flammable fuels. Moreover, since exotic taxa may use desert habitats in ways distinct from indigenous taxa, consequent increases in herbaceous cover may thus increase fire frequencies and change the biogeography of creosote bush scrub without changes in climate.

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